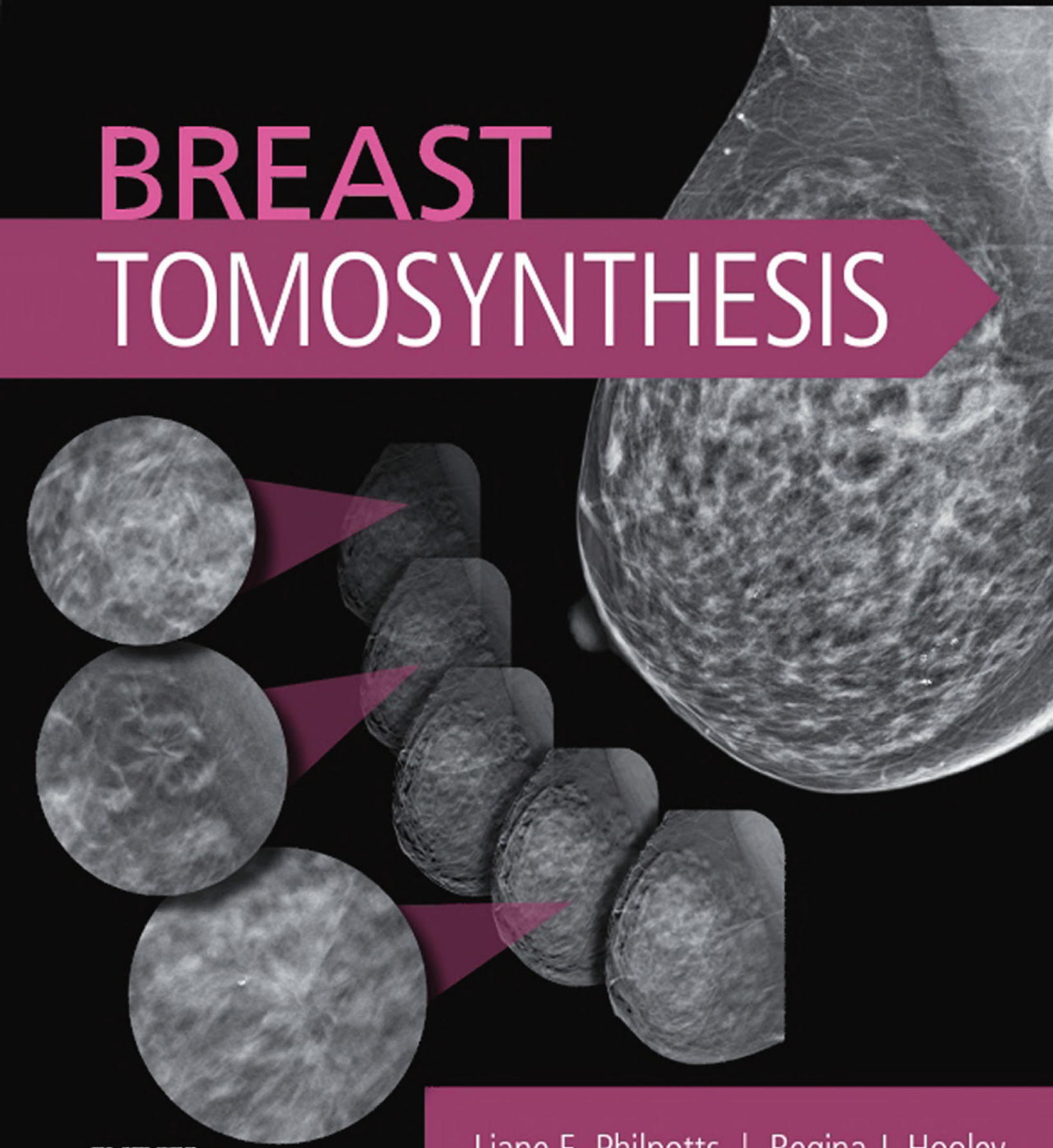
BREAST TOMOSYNTHESIS



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This book is dedicated to our families

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For your love, support, and encouragement

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Foreword

I very much appreciated Drs. Liane Philpotts and Regina Hooley asking me to write the Foreword to their excellent book, *Breast Tomosynthesis*. They have had considerable experience using digital breast tomosynthesis (DBT) and have put together a clear, concise text that covers all the important issues surrounding tomosynthesis applied to the breast, the introduction of its use to clinical care, and the issues involved in replacing two-dimensional (2D) mammography with DBT as the next advance in breast cancer screening. This will be the go-to work for those who want to improve their ability to detect more cancers at a curable size and stage and further decrease deaths from these cancers.

Mammography screening, which began in the United States in the mid-1980s, has been one of the major medical advances in women's health in the last 50 years. Before the introduction of mammography screening, the breast cancer death rate in the United States had remained unchanged dating back to 1940. However, in 1990, breast cancer deaths suddenly began to decline, and as more women participate in screening, the death rate continues to fall. There are now 35% fewer deaths each year from breast cancer, in large part due to screening. Therapy has improved, but in numerous observational analyses,[1-4] the decline in death rates among women who participate in screening is much greater than it is among those who do not.

In the United States, 40,000 women still die each year from breast cancer. In a study that my colleagues and I conducted in two of the Harvard teaching hospitals,[5] we found that more than 70% of the women who died from breast cancer were among the 20% of women who were not participating in screening, and it is likely that many of the 40,000 annual deaths from breast cancer are among women who were not being screened. Mammography has been an important tool in the fight against breast cancer, but we know that it is far from perfect and that it does not find every cancer early enough to permit a cure.

Although detractors of screening have claimed that mammography is an old and outdated technology, this could not be further from the truth. Once screening was shown to save lives, radiologists did not rest, and there have been significant advances in breast cancer detection over the decades. The plain film, high-dose technique of the 1960s, used in the first randomized controlled trial of screening, was replaced by xeroradiography, leading to a major improvement in cancer detection at a lower dose of radiation. In an effort to further reduce dose, film-screen combinations were developed and improved over time. Digital radiography was introduced for other organ systems under the U.S Food and Drug Administration (FDA) 510K process, but because of politics, digital mammography was delayed by the FDA, which required companies to pursue a more arduous and expensive premarket approval process. Full-field digital mammography (FFDM) was only slightly better than film-screen combinations in detecting cancers, but because of the logistical advantages of digital, it has almost completely replaced film-screen mammography. Although digital mammography did not substantially improve cancer detection, the development of digital detectors paved the way for a major advance in x-ray mammography—DBT.

After becoming the Head of the Breast Imaging Division at Massachusetts General Hospital (MGH) in 1978, I recognized what was obvious to all radiologists reading mammograms—the superimposition of normal tissue of the breast often blocked the visibility of breast cancers. I was struck by the obvious improved clarity with which lesions were seen on specimen radiographs after they had been surgically removed from the breast. My goal was to find ways to image cancers with similar clarity while they were still in the breast.

I was trained in the era of linear and polycycloidal tomography, when you could blur the planes above and below the plane of interest by moving the x-ray tube and film holder in opposite directions during a prolonged exposure. This worked well, for example with renal imaging, but it required a full dose exposure for each plane. In 1976 Bailar[6] had (incorrectly) written that radiation from mammography would cause more cancers than would be cured, so there was great concern about mammography and any x-ray exposure to the breast. Conventional tomography exposed the breast to far too much dose, so it was not a viable approach to breast evaluation. Although Chang and colleagues[7] made an important observation that breast cancers were enhanced on computed tomography (CT) scans following the intravenous administration of iodinated contrast, CT was still in its early development. CT required iodinated contrast, its spatial resolution was insufficient, and the dose was too high. Although a dedicated breast CT scanner had been built, the approach was dropped.

In 1978, while reading a series of old papers, I came across one by Miller and coworkers[8] that used the term *tomosynthesis* to describe the process of collecting a few projection images from multiple angles and utilizing them to synthesize an "infinite" number of planes through the structure being imaged. I became immediately convinced that tomosynthesis was the solution that I was looking for and that it could be a major improvement in finding breast cancers. Development was far more difficult than you might expect. It has been almost 50 years since I first decided to apply tomosynthesis to breast cancer screening.

It was clear to me that tomosynthesis for breast evaluation might allow us to detect cancers that were hidden by normal breast tissue. Unfortunately, my MGH colleagues and I needed digital images, and the kind of detector this required did not become available for digital breast imaging until 1992.

In that year, Rick Moore, my research director at MGH, Loren Niklason, PhD, who had become our division physicist in 1992, and I joined the Digital Mammography Development Group (later to become the International Digital Mammography Development Group [DMDG]). DMDG had been organized by Etta Pisano, MD, and consisted of Etta's group; my group at MGH; Stephen Feig, MD, from Thomas Jefferson University; Martin Yaffe, PhD; and Donald Plewes, PhD, from

Sunnybrook Hospital (Toronto, Canada), the Fisher Imaging company, and General Electric (GE). The goal of the DMDG was to aid companies in developing FFDM. I informed Rick and Loren that I wanted to apply the concept of tomosynthesis to the breast, and I gave them the article that I had on the topic. They advised me that GE had the detector that could do what I wanted, so we partnered with GE in the DMDG to gain access to their detector. Once we had the GE detector, we found that by moving the x-ray tube by hand over phantoms and mastectomy specimens, we could successfully perform tomosynthesis of the breast. The physics had been worked out by Loren and two other physicists, and we applied for and obtained a patent in 1999.

We also applied for and received a grant from the Department of Defense and paid GE to build the first tomosynthesis system that could image the entire breast. When no one stepped up to name the new approach in a contest that I held at MGH, I named it *digital breast tomosynthesis* because I felt that the acronym DBT was easy to say and remember.

Although MGH licensed the technology to GE, I thought that it was important to move it forward as quickly as possible for the benefit of women, so we worked with any company that was interested in our technology. Having convinced both Hologic and Siemens of the importance of the technology, we helped them develop their systems. It is both remarkable and unfortunate how long it took to move this technology from a prototype to a commercial device. However, DBT is now available, and this book provides excellent discussions of its benefits and clear examples and explanations of its use.

It has been interesting to watch the introduction of DBT into clinical practice. Although we developed DBT as a screening test, it has undergone a stepwise introduction to finally reach that point. As *Breast Tomosynthesis* clearly shows and as we recognized early in its development, DBT is the next step in improving screening for breast cancer. DBT increases the detection of small invasive cancers while reducing the recall rate according to most of the published studies.[9-15] The former is not surprising because small cancers are the most likely to be hidden on 2D mammography. However, usually when you increase the sensitivity (detection rate) of a test, you have to lower your thresholds for intervention and you find more of everything, increasing the false positive rate. DBT is an exception to this, making it a win-win technology. It detects more cancers (improved sensitivity) while reducing the recall rate (improved specificity). In our practice, 25% of recalls from screening with 2D mammography proved to be nothing more than superimposed normal tissues, called *summation shadows* by Sickles. DBT eliminates these summation shadows, which is one of the main reasons recall rates have been diminishing.

One final point. There are legitimate questions about the importance of finding ductal carcinoma in situ (DCIS). Although the detection and removal of DCIS is probably the reason the rate of invasive cancers is lower than expected, there are real concerns about detecting too many lesions that might never progress to invasive and lethal cancers. Mammography has been faulted because it is the main reason these lesions are now detected. However, DBT does not increase the detection of DCIS. The reason is that most DCIS is found by detecting clustered microcalcifications. Although Kopans and colleagues[16] showed several years ago that DBT characterizes calcifications more clearly than does 2D mammography, their very high contrast means that DBT does not increase our ability to detect them. They are found fairly easily using 2D mammography. Consequently, although DBT detects more small (curable) invasive cancers, it does not increase the detection of DCIS.

There is no question that having to review multiple planes for each screening case increases the time it takes to interpret screening studies, but DBT saves time by reducing recalls. In my experience, once radiologists use DBT, they are not interested in returning to only 2D mammography.

The initial FDA approval for DBT required a full exposure set of 2D screening images to accompany the DBT images. Many years ago Rick Moore at MGH was the first to put the planes back together to form a synthetic 2D "slab." This has now led to a full synthesis of the 2D mediolateral oblique and craniocaudal images from the DBT acquisition images. Although there is probably no risk from radiation to the breasts of women ages 40 years and older, the use of synthetic 2D mammography eliminates that extra dose, which was previously required.

Breast Tomosynthesis is an excellent guide for those seeking to adopt and use DBT for the first time, as well as for the experienced radiologist. Virtually every aspect of its use is covered in clear detail. I have no doubt that radiologists will embrace this important advancement in the quest to improve women's health. I expect ultrasound to be added to the DBT systems to permit the simultaneous acquisition of ultrasound and DBT, which will facilitate the detection of the small percentage of cancers that are not visible on DBT but can be found by ultrasound. We have looked at using DBT to inform on electrical impedance measurements, as well as optical imaging. I expect that DBT, with its quasi-3D information, will become the platform on which other technologies are added to help us detect more cancers at a time when cure is possible. Thanks to all the contributors to this excellent book.

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References

1. Swedish Organised Service Screening Evaluation Group. Reduction in breast cancer mortality from organized service screening with mammography: 1. Further confirmation with extended data. *Cancer Epidemiol Biomarkers Prev*. 2006;15:45–51.
2. Otto SJ, Fracheboud J, Looman CWN, et al. Initiation of population-based mammography screening in Dutch municipalities and effect on breast-cancer mortality: a systematic review. *Lancet*. 2003;361:411–417.
3. Hellquist BN, Duffy SW, Abdsaleh S, et al. Effectiveness of population-based service screening with mammography for women ages 40 to 49 years: evaluation of the Swedish Mammography Screening in Young Women (SCRY) cohort. *Cancer*. 2011;117(4):714–722.
4. Coldman A, Phillips N, Wilson C, et al. Pan-Canadian study of mammography screening and mortality from breast cancer. *J Natl Cancer Inst*. 2014;106(11).
5. Webb ML, Cady B, Michaelson JS, et al. A failure analysis of invasive breast cancer: most deaths from disease occur in women not regularly screened. *Cancer*. 2014;120(18):2839–2846.
6. Bailar JC. Mammography: a contrary view. *Ann Intern Med*. 1976;84:77–84.
7. Chang CHJ, Nesbit DE, Fisher DR, et al. Computed tomographic mammography using a conventional body scanner. *AJR Am J Roentgenol*. 1982;138:553–558.
8. Miller ER, McCurry EM, Hruska B. An infinite number of laminograms from a finite number of radiographs. *Radiology*. 1971;98:249–255.
9. Skaane P, Gullien R, Bjørndal H, et al. Digital breast tomosynthesis (DBT): initial experience in a clinical setting. *Acta Radiol*. 2012;53(5):524–529.
10. Skaane P, Bandos AI, Gullien R, et al. Comparison of digital mammography alone and digital mammography plus tomosynthesis in a population-based screening program. *Radiology*. 2013;267:47–56.
11. Ciatto S, Houssami N, Bernardi D, et al. Integration of 3D digital mammography with tomosynthesis for population breast-cancer screening (STORM): a prospective comparison study. *Lancet Oncol*. 2013;14:583–589.
12. Lång K, Andersson I, Rosso A, et al. Performance of one-view breast tomosynthesis as a stand-alone breast cancer screening modality: results from the Malmö Breast Tomosynthesis Screening Trial, a population-based study. *Eur Radiol*. 2015 May 1. [Epub ahead of print]
13. Haas BM, Kalra V, Geisel J, et al. Comparison of tomosynthesis plus digital mammography and digital mammography alone for breast cancer screening. *Radiology*. 2013;269(3):694–700.
14. Rose SL, Tidwell AL, Bujnoch LJ, et al. Implementation of breast tomosynthesis in a routine screening practice: an observational study. *AJR Am J Roentgenol*. 2013;200(6):1401–1408.
15. Friedewald SM, Rafferty EA, Rose SL, et al. Breast cancer screening using tomosynthesis in combination with digital mammography. *JAMA*. 2014;311(24):2499–2507.
16. Kopans DB, Gavenonis S, Halpern E, Moore RH. Calcifications in the breast and digital breast tomosynthesis. *Breast J*. 2011;17:638–644.

Preface

Tomosynthesis has revolutionized mammography. We are grateful to all the individuals who had the incredible vision and drive to develop this amazing mammography technology. Our practice was fortunate enough to be involved with tomosynthesis from an early stage—being one of the initial beta sites for development and one of the first clinical sites after approval by the U.S. Food and Drug Administration. Because we work with many talented breast imaging colleagues, we had the special opportunity to review challenging cases, ask each other questions, and learn together.

Tomosynthesis is truly a game changer, but at the same time, it has dramatically altered the practice of breast imaging. There is a learning curve when it comes to reading tomosynthesis studies. In addition, many of the conventional mammographic work-up techniques are no longer relevant. We felt that our experiences with this new technology and the knowledge that we gained as a result could prove quite valuable to other breast imaging specialist. That is why we wrote this book.

Writing a textbook about a three-dimensional (3D) imaging technology was, to say the least, a challenge! A textbook can only use two-dimensional images. We have tried to capture single slice tomosynthesis images that best depict a variety of findings. Additional 3D content, which better depicts the tomosynthesis findings encountered in clinical practice, is available on the web-based version.

We are extremely grateful to our colleagues at Yale who share our vision of the value of tomosynthesis. In particular, we would like to thank those individuals who were instrumental in supporting our early adoption of this new technology, specifically Jim Brink, MD; TR Goodman, MD; Cheryl Granucci; and Jacqueline Crenshaw. Our clinical work could not have been achieved without our dedicated hard-working and professional staff, including Sherry Delaventura, Fran Fanelli, Maria Gumkowski, Rhona Hall, Nicole Perez, Christine Puciato, Juliette Buccilli, and all of the many skilled breast imaging technologists of Yale-New Haven Hospital. Working together using tomosynthesis provides our patients with much better outcomes.

We are very thankful for the patience and support of our team at Elsevier, who guided us through this process, particularly Robin Carter, Janice Gaillard, Doug Turner, Nicole Beard, Catherine Jackson, and a host of others. Importantly, this book would not have been possible without the support and encouragement of our husbands and children, who thankfully spared us the time to pursue our passion. Finally, we are indebted to our patients who have entrusted our service to perform and interpret their mammograms year after year and have given us a precious gift—an invaluable source of information that we can now share so many others may also benefit.

Liane E. Philpotts, MD
Regina J. Hooley, MD

Contents

CHAPTER 1

Introduction

Liane E. Philpotts | Regina J. Hooley

We were fortunate that our breast imaging practice implemented the first tomosynthesis unit in our state of Connecticut during the summer of 2011. Soon thereafter we transitioned to offering tomosynthesis to nearly all of our patients at the Yale Smilow Cancer Hospital Breast Center and our surrounding satellite offices. From the beginning, Yale offered tomosynthesis to all of our screening and diagnostic patients regardless of breast density or risk. Our patients also were fortunate because we offered tomosynthesis at no extra charge. As a result we learned quickly how tomosynthesis could revolutionize our practice.

Such a seemingly simple transformation—from viewing two-dimensional (2D) mammography images to being able to view the tissue in thin layers—has had a dramatic effect on interpretation accuracy. The results include improved screening outcomes, diagnostic performance, lesion characterization, workflow, interventional procedures, and decreased health care costs. At a time when performance outcomes are increasingly scrutinized and often criticized, these changes are a welcome and necessary advancement to mammography. Mammography is the gold standard for screening for breast cancer, the second most common cancer in women and a major source of anxiety and financial resource allotment. However, despite the long-standing success of conventional 2D mammography, there are still many associated limitations.

Tomosynthesis overcomes many of these limitations in both obvious and subtle ways. By gaining the dual benefit of better cancer detection and reduction of false-positive findings, both screening and diagnostic mammography performance metrics are enhanced. Screening parameters, such as recall and cancer detection rates, are improved. Fewer women are recalled unnecessarily and fewer cancers, particularly lethal invasive cancers, are missed (Fig. 1.1). This greatly helps to shift the balance so that the harms of screening are decreased and the benefits are increased. These same benefits translate to diagnostic mammography; in addition, a dramatic improvement in diagnostic work-up patterns may be achieved. Because tomosynthesis permits both characterization and localization of lesions, many of the conventional diagnostic imaging views become unnecessary. This expedites work-ups, improves workflow, and reduces patient anxiety. Furthermore, improved lesion characterization leads to more precise biopsy recommendations, reduction of unnecessary (false-positive) biopsies and increased positive predictive values for biopsy. Moreover, when the detailed information from tomosynthesis studies is combined with information from other breast imaging modalities, including ultrasound and magnetic resonance imaging (MRI), the diagnostic accuracy is compounded. As breast imagers we can take our level of interpretation to a higher level.

In our current practice we use tomosynthesis in combination with 2D mammography or a synthesized mammogram. In this book we attempt to cover all of the practical aspects of tomosynthesis used in breast imaging and include a variety of contributions and wonderful perspectives from wonderful breast imaging colleagues from Yale and elsewhere. As an emerging technology the scientific literature is limited. Tomosynthesis technology and outcomes research are rapidly evolving, so capturing the clinical essentials and basic understanding of tomosynthesis in breast imaging is our goal, with the understanding that nuanced changes over time are inevitable. We expect that our knowledge and use of tomosynthesis will grow and change over time.

Many benefits of tomosynthesis are gleaned immediately, whereas others take more time as the radiologist gains experience and expertise. Many prominent themes will be found repeated throughout this book. Overlap of imaging findings and interpretation tips necessitates repeating important points among various chapters. Because we expect that readers will review individual sections and not read it cover-to-cover at one time, this repetition should reinforce important concepts.

In Chapter 2, an early pioneer in breast tomosynthesis explains the development of tomosynthesis and discusses the basic principles of this imaging modality. Developing the high-resolution imaging system necessary for mammography while maintaining a low radiation dose was a challenging feat. The key individuals and steps involved with that development are acknowledged. Understanding how tomosynthesis images are acquired and processed permits a better understanding of the variations in equipment and the inevitable developments that should occur over time. Varying angles, image acquisition methods (continuous or step-and-shoot), timing of acquisition, and radiation dose are some of the differences among vendors.

Providing tomosynthesis mammography is a collaborative effort between the radiologist, information technology (IT) personnel, and the technologist. Chapter 3 reviews technologist training and tips for performing a good-quality tomosynthesis exam. A variety of artifacts unique to tomosynthesis are also reviewed.

Implementing tomosynthesis into your practice may seem like a daunting task, especially when one considers the necessities of equipment procuring and installation, IT needs and support, training of staff, in combination with learning to interpret this new modality that will increase radiologists' interpretation times. Tips for those who are just adopting this new technique are discussed in Chapter 4. Advice spanning the spectrum from equipment and workstation choices, space and resource allotment, anticipation of workflow changes, marketing opportunities, referring physician and patient education, and other

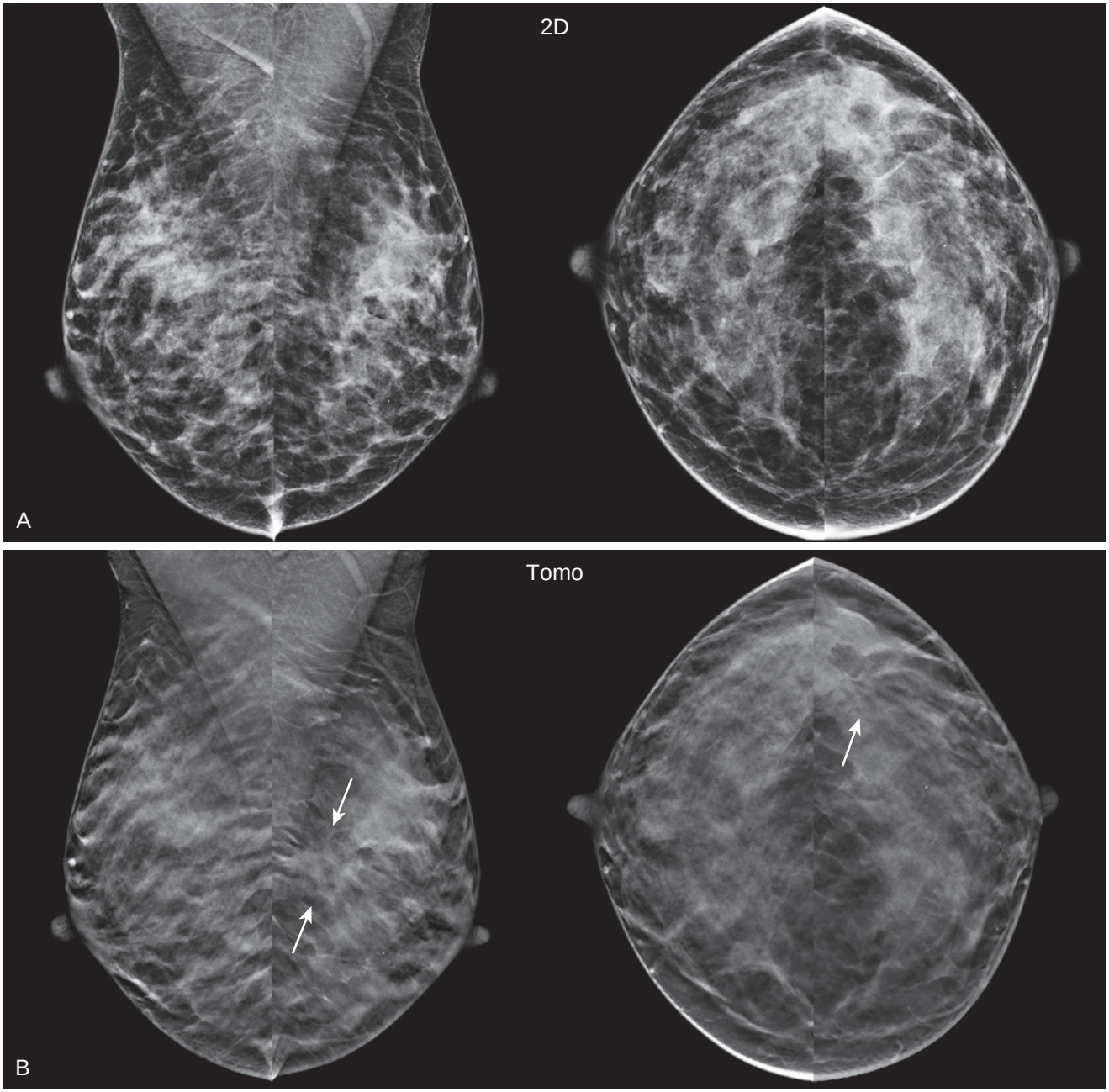


FIG. 1.1 Bilateral 2D **(A)** and tomosynthesis slice **(B)** images of a spiculated architectural distortion *(arrows)* representing an invasive ductal carcinoma. The malignant lesion is virtually impossible to appreciate on the 2D images, yet the tomosynthesis images demonstrate the lesion well. Tomosynthesis increases detection of invasive carcinoma, particularly in areas of dense fibroglandular tissue.

considerations in planning the transition are all discussed. We recognize that tomosynthesis implementation may differ slightly across practices, and this chapter includes perspectives from Dr. Stamatis Destounis, from the Elizabeth Wende Breast Center, at a large private practice, as well as our own large academic tertiary breast center. This provides invaluable insights and many important perspectives regarding differing experiences with tomosynthesis implementation.

Screening mammography is the fundamental breast imaging test, offering the best opportunity to find early cancers at a treatable stage. This vitally important function is vastly improved with the use of tomosynthesis. Tools used to interpret screening tomosynthesis exams are discussed in Chapter 5. Findings requiring recall with tomosynthesis differ from those found with 2D mammography. Asymmetries requiring 2D recall are very often due to superimposed tissue and are more accurately assessed as normal with tomosynthesis. In addition, calcifications may be approached differently, because subtle associated mass lesions not discernible on 2D may now be visible.

Diagnostic mammography work-up patterns change with tomosynthesis. Because mass margins and lesion location are often well characterized within the thin tomosynthesis slices, fewer problem-solving diagnostic views are needed for the radiologist to make a confident and accurate final assessment.

Chapter 6 reviews common mammographic findings seen in both asymptomatic and symptomatic patients, with a discussion of various strategies that can be used with tomosynthesis to increase efficiency and accuracy.

There is a learning curve to interpreting tomosynthesis exams, and some may adjust quicker and easier than others. However, very quickly, interpreting mammograms without tomosynthesis seems uncomfortable and incomplete. Such teaching points are covered in Chapter 7. Additional tips are found in every chapter throughout the book, with pertinent ones marked as "Tomo Tips!" Review of these should help to expedite the learning curve.

Although a greater number of cancers are detected on tomosynthesis than with 2D mammography, a larger number of benign lesions will also be found. Lesions that were normally hidden in superimposed fibroglandular tissue will be unmasked. Recognizing common benign findings is essential so that recall rates and biopsies are not unnecessarily increased. With the improved visualization of lesion shape and margins provided by tomosynthesis, we can potentially accurately classify more lesions as benign versus those that are suspicious. Such findings are discussed in Chapter 8. The well-established "multiple-bilateral rule" suggesting benign etiology is enhanced with tomosynthesis given that many additional masses not seen well on 2D imaging will be detected. Many benign masses, such as fibroadenomas, cysts, and hamartomas, are much better characterized on tomosynthesis, leading to a reduction in the need for diagnostic follow-up.

Tomosynthesis will often reveal suspicious mammographic findings more clearly than 2D images alone. Chapter 9 explores the tomosynthesis features of the various common breast malignancies. The initial diagnosis of multifocal, multicentric, and synchronous bilateral cancer will increase with tomosynthesis. Whereas malignant features often are obvious on tomosynthesis, they may also be quite subtle. The radiologists must be familiar with the spectrum of malignant findings to diagnose breast cancer and to best assess the remainder of the breast with tomosynthesis, which may be particularly useful if staging MRI is not performed.

Tomosynthesis will enhance detection of architectural distortion, which may present as a very obvious or very subtle finding. Management of architectural distortion can be difficult, particularly if only initially seen on tomosynthesis and not detected on ultrasound. Chapter 10 reviews the spectrum of imaging and pathologic findings typically encountered with architectural distortions discovered on tomosynthesis. Although some of these architectural distortions ultimately will be proven to be malignant, others may prove to be complex radial sclerosing lesions. The management of complex sclerosing lesions continues to evolve, because there is growing evidence that surgical excision may not always be necessary. Although further research is needed, we have included for guidance a management algorithm that our practice currently follows for architectural distortion initially seen only on tomosynthesis.

A major benefit of tomosynthesis is improved lesion characterization when combined with the information gleaned from other breast imaging modalities. Ultrasound is routinely used in the further assessment of all noncalcified and even some calcified lesions. Expert use of targeted ultrasound after tomosynthesis can enable lesion evaluations that are superior to that with 2D assessment. Lesion localization is more precise, and lesion features are more defined. Chapter 11 reviews how findings on tomosynthesis can be correlated with other imaging techniques, such as ultrasound and MRI, or conversely, how second-look tomosynthesis can aid in further assessing findings seen on screening whole breast ultrasound or MRI. This synthesizing of information results in the ability to refine biopsy recommendations and improve the positive predictive value of biopsy, resulting in the reduction of unnecessary biopsies for multiple imaging findings.

Many women undergoing screening or diagnostic mammography have undergone prior procedures, such as excisional biopsies, reduction mammoplasties, and lumpectomies. Just as tomosynthesis improves the detection of architectural distortion due to malignancy and radial sclerosing lesions, surgical scars can be exquisitely demonstrated by tomosynthesis. In Chapter 12, many of these common postoperative findings are reviewed. Differentiation of scar versus malignancy is a common concern among users of tomosynthesis. Careful history and marking of surface scars are important because scars within the breast tissue caused by remote surgeries are apparent that were never seen on 2D images. However, this improved visualization of scars with tomosynthesis can greatly facilitate detection of recurrences and differentiate common benign sequelae, such as fat necrosis, from more suspicious changes.

Men are routinely referred for breast imaging, usually due to symptoms and sometimes for high-risk screening. For the vast majority of men presenting with a palpable lump, gynecomastia will be the cause. This entity can sometimes be challenging to differentiate from breast cancer on 2D imaging. Tomosynthesis can help to better make this differentiation and it often reduces the need for other tests, such as ultrasound. In Chapter 13, tomosynthesis imaging of gynecomastia and other presenting benign and malignant findings in men are reviewed.

Percutaneous breast biopsy is an essential breast imaging tool. Just as there was a need to develop MRI breast biopsy devices for suspicious MRI detected lesions with no mammography or ultrasound correlate, tomosynthesis-guided biopsy devices have been developed for clinical use, enabling efficient and accurate evaluation for lesions seen only on tomosynthesis. This exciting new technique, along with tomosynthesis-guided wire localization, is reviewed in Chapter 14. Margarita Zuley, Ernestine Thomas, and colleagues from the University of Pittsburgh Medical Center were one of the first adopters of tomosynthesis-guided biopsy and share their experience in this chapter.

Any breast imaging textbook requires high-quality images that serve as an essential teaching tool. A picture is worth a thousand words! We hope to provide many excellent images of a wide variety of lesions representing a spectrum of benign and malignant findings. Tomosynthesis is not a static imaging modality. Viewing and interpreting these exams involves real-time review. Producing a 2D textbook about a three-dimensional imaging process is challenging. We have strived to capture optimal tomosynthesis still images to demonstrate various findings discussed. Recognizing that full appreciation of tomosynthesis exams is based in scrolling through a stack of images, we have included an atlas of cases that include tomosynthesis movie files at the end of the book, with the moving images found in the electronic, online version. A video icon indicates video content. Review of such cases is strongly encouraged.

We are living in a world of ever-increasing information and demands for improved and immediate outcomes. The imperfect and nebulous art of 2D mammography interpretation is something that is no longer sustainable. Tomosynthesis affords us the essential ability to raise our field to a higher level. Although studies investigating the cost effectiveness of tomosynthesis are currently limited, there is no doubt that tomosynthesis will ultimately reduce medical costs by decreasing many unnecessary follow-up tests and interventions. We need to adopt and further improve tomosynthesis technology to preserve breast cancer screening services that will benefit women and be valued by all. This powerful improvement in mammographic imaging is likely to have a profound effect on the whole practice of breast imaging—for the better!

CHAPTER 2

Physics and Development of Breast Tomosynthesis

Loren Niklason

Screening mammography has undergone many improvements since widespread screening began in the 1980s. These improvements have led to improved image quality, reduced radiation dose, and more accurate examinations. In the early 2000s there was a major shift in imaging technology, with the introduction of digital mammography. Although the transition to digital mammography systems took nearly a decade, there are now very few analog systems still in use. The transition to digital mammography also enabled the use of advanced imaging methods that were not practical with film mammography. Tomosynthesis is one of these advanced imaging methods that is rapidly being adopted for breast cancer screening in the United States. The adoption rate is much faster than that seen for digital mammography because the initial clinical results are far more compelling than those seen with the introduction of digital mammography.

Although digital mammography involves a different method for detecting mammography images, it is a two-dimensional (2D) image and suffers from superimposed tissue that may mask or mimic a breast cancer. Mammography sensitivity and specificity are inversely related to breast density. The structures that appear dense or white on a mammogram are composed of fibrous or glandular tissue. This fibroglandular tissue has nearly identical x-ray attenuation to that of breast cancer, and as a result it may hide breast cancer or superimposed tissue may appear suspicious for cancer. For this reason, as breast density increases, the ability to detect cancer decreases and the number of women recalled for additional testing increases. The limitations of conventional mammography for women with dense breasts have led many states to require women be notified if they have dense breasts, allowing them to discuss with their physicians supplemental screening methods.

Tomosynthesis is a three-dimensional (3D) imaging method that allows visualization of the tissue in a series of images spaced at 1-mm intervals through the breast. Instead of a single-projection image that is used for conventional digital mammography images, a series of 9 to 25 images are taken as the x-ray source moves in an arc above the breast (Fig. 2.1). These images are referred to as *projection images* and are obtained at 1- to 3-degree increments as the x-ray source moves in an arc above the breast. These images are reconstructed using methods similar to computed tomography (CT) reconstruction into a series of images with only structures in a small range of thickness in focus. In mammography the breast is typically compressed to a thickness of 40 to 70 mm, and this results in 40 to 70 tomosynthesis images for an average size breast.

A clinical tomosynthesis image is shown in Fig. 2.2 and demonstrates the marked reduction in complexity of the background in the reconstructed tomosynthesis images compared with the conventional mammogram. This reduction in superimposed tissue allows the detection of breast cancer that might otherwise be hidden by fibroglandular structures above or below the cancer and better differentiation of normal and abnormal breast structures; this results in a reduction of women recalled for additional imaging who do not have breast cancer.

Tomosynthesis systems are now available for imaging many parts of the body; however, only in breast imaging has widespread adoption occurred. This is likely due to some of the specific needs for breast imaging and the specific strengths of tomosynthesis imaging. Breast imaging requires extremely high spatial resolution, and the images must be obtained at very low dose. In addition, high contrast of small structures, such as calcifications, spiculations, and lesion margins, is critical and requires the use of low-energy x-rays. Tomosynthesis allows the use of low-energy x-rays, low dose, and high resolution needed for breast imaging while also reducing superimposed structures.

Development of Tomosynthesis

The initial work on breast tomosynthesis was performed at Massachusetts General Hospital (MGH), starting in 1995. Our group started with phantom imaging, then specimen imaging, and finally clinical imaging. Three medical physicists, including Bradley Christian, Laura Niklason, and myself, did the initial development work. The initial physics and specimen imaging work was supported by a grant from the Department of Defense Breast Cancer Research Program. Although our work was the first on breast tomosynthesis, there had been a lot of previous research on tomosynthesis for imaging other body parts.

The key technological breakthrough needed for the implementation of tomosynthesis was the development of a flat panel digital detector. A group at General Electric Corporate Research and Development provided the first detector that made breast tomosynthesis possible. This detector had the high resolution needed for mammography and the rapid image readout needed for tomosynthesis. The team at General Electric included Henri Rougeot, Beale Opshal-Ong, Cynthia Landberg, Donald Castleberry, Jeffrey Eberhard, and many others. The detector development was supported by a grant from Defense Advanced Research Projects Agency.

The clinical evaluation of tomosynthesis was led by Daniel Kopans at MGH. The first clinical unit was constructed by General Electric to support this research. The research was again funded by the Department of Defense Breast Cancer Research Program, and their support provided the funding to transition breast tomosynthesis into a clinical reality.

After the initial clinical work, there was a lag in development of tomosynthesis. General Electric, which had supported the early research, decided against commercialization at that time. In 2005 Hologic, Inc., decided to develop a clinical tomosynthesis unit, and I joined Hologic at that time. Hologic presented data for the US Food and Drug Administration (FDA) approval to a panel in 2010 and received approval in early 2011. Elizabeth Rafferty, MD, was the principal investigator for the FDA studies and presented the data at the FDA panel meeting.

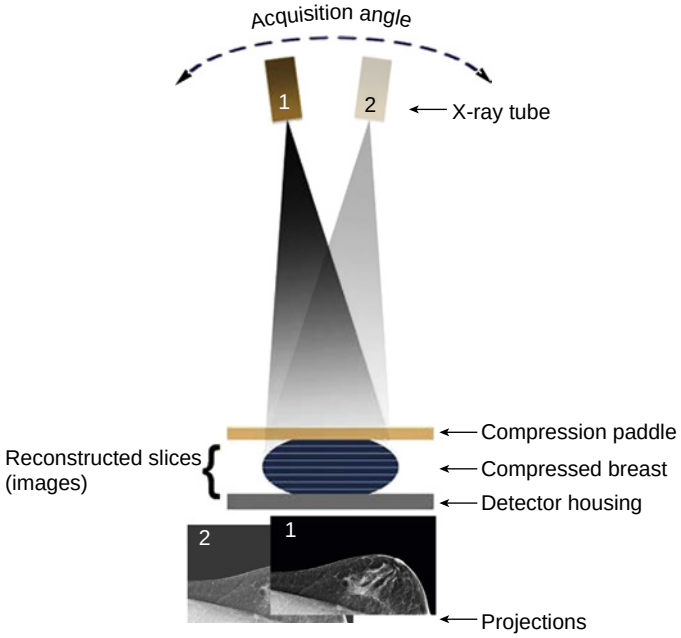


FIG. 2.1 Tomosynthesis image acquisition and reconstruction. Projection images are acquired as the x-ray tube moves in an arc above the breast. These images are reconstructed into the tomosynthesis images.

After just a few short years, tomosynthesis is now rapidly replacing conventional mammography for breast cancer screening. Looking back, there are several people who deserve special recognition for proving the clinical superiority of tomosynthesis and driving the commercial development. First, Elizabeth Rafferty, MD, from MGH led all of the Hologic reader studies investigating the best methods for using tomosynthesis and provided the clinical leadership for each study. In addition to publishing many of these results, she led the training effort and has trained many of the radiologists currently using tomosynthesis. Her training of the early adopters led to the superior clinical results from a wide range of practices, many of which have resulted in publications. Next, Per Skaane from Oslo, Norway, took on the challenge of performing the first large-scale, prospective screening trial of tomosynthesis. His team imaged 25,000 women over 2 years and doubled their workload by having each case read by four different radiologists. This research demonstrated the clinical efficacy of tomosynthesis for both the single reader method used in North America and the double reader method used in Europe. He also reported on the clinical performance of synthetic mammograms combined with tomosynthesis. David Gur from Magee Women's Hospital and the University of Pittsburgh Medical Center was a leader in evaluating tomosynthesis from the beginning and, along with Margarita Zuley and Jules Sumkin, provided much of the basic research demonstrating the clinical utility of tomosynthesis. David Gur was instrumental in working with Dr. Skaane and myself on study design for the Oslo study and brought together the group of 13 institutions in the United States that published the landmark study in the *Journal of the American Medical Association* evaluating tomosynthesis screening performance in 450,000 women.

Finally, on the commercial side, Jay Stein was the key person behind several decisions that made tomosynthesis a commercial

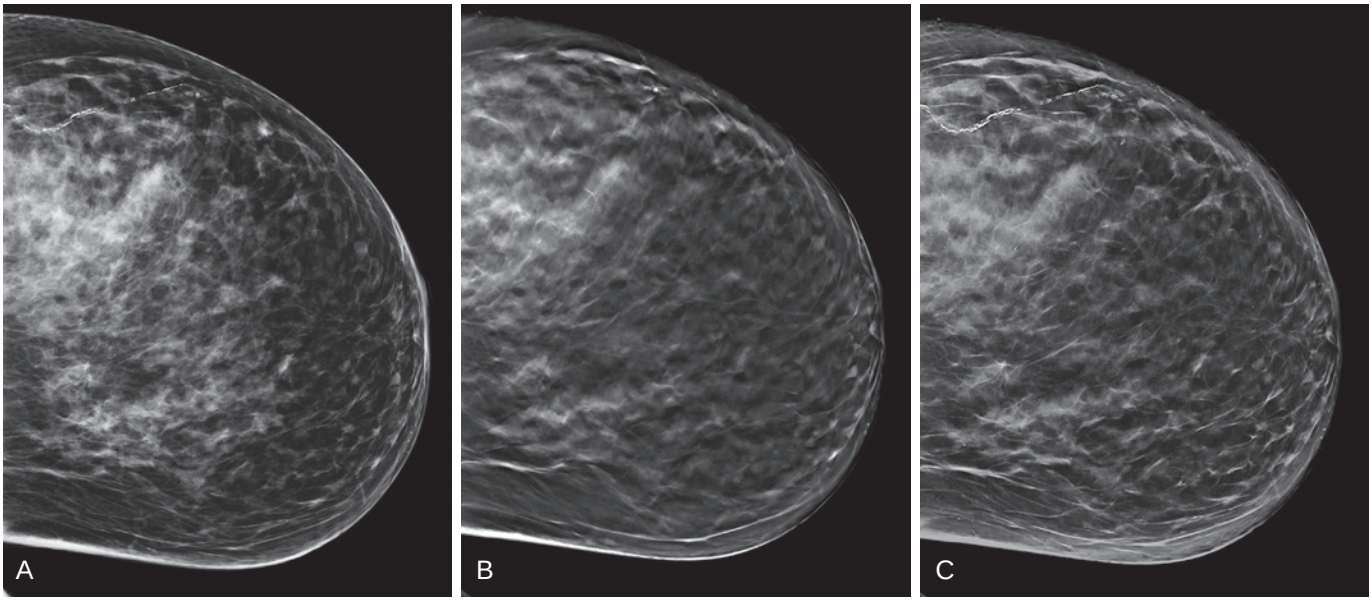


FIG. 2.2 Clinical example showing **(A)** the conventional mammogram, **(B)** a tomosynthesis image from middle of the breast, and **(C)** the synthetic mammogram. The tomosynthesis image demonstrates the reduction in anatomical or structured noise compared with the conventional mammogram.

success. First, the decision to add tomosynthesis to conventional mammography made clinical adoption much faster. Next, Jay Stein worked with Chris Ruth to develop the first synthesized mammograms. This development has been critical for widespread commercial adoption.

System Design

The design of tomosynthesis systems varies greatly among different manufacturers. Differences in design may have significant impact on clinical performance. In this section the key design parameters and their impact on image quality will be discussed.

Acquisition Angle

Tomosynthesis projection images are acquired over an angular range of 15 to 50 degrees. This angular range affects image quality in several ways. Wider angle acquisition reduces the amount of superimposed tissue that may be present in the reconstructed tomosynthesis images. If the tomosynthesis acquisition angle was increased to slightly greater than 180 degrees, a true CT image could be obtained, resulting in complete removal of superimposed tissue. Thus tomosynthesis images acquired at 50 degrees may have reduced superimposed tissue compared with those obtained at 15 degrees. However, there are benefits associated with narrow acquisition angles, including better depiction of calcifications.

Number of Projection Images

The number of projection images affects image artifacts. Current systems use between 9 and 25 projection images, and these images are then reconstructed into the tomosynthesis images. Artifacts are inversely related to the number of projection images. The artifacts from a limited number of projections are seen for highly attenuating objects, such as a highly attenuating calcification, and may be seen in planes above and below the plane that actually includes the calcification (Fig. 2.3). The number of artifacts seen is the same as the number of projections; for example, if 10 projections are obtained, there will be 10 out-of-plane artifacts of the calcification, and each will have about 1/10 the contrast of the actual calcification. This artifact is often referred to as the *slinky* artifact because the artifacts spread out the farther the images are from the plane containing the calcification and contract while scrolling toward the plane containing the calcification. If the tomosynthesis acquisition included 25 projection images, each artifact would have much lower contrast (1/25 of the original calcification) and in some cases may not even be visible. Therefore increasing the number of

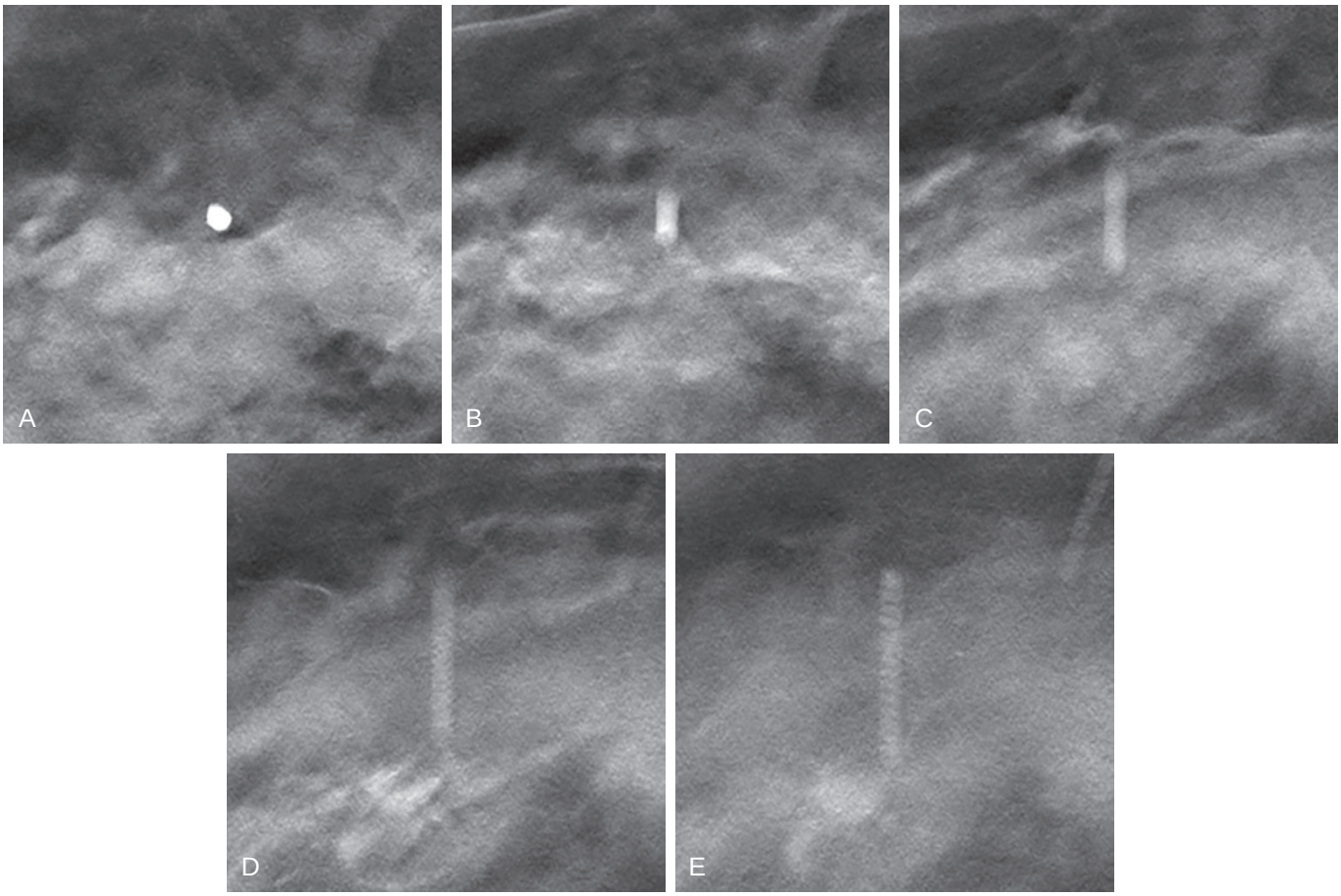


FIG. 2.3 Artifacts from limited number of projections. Image of a calcification at different planes (depth) in the breast. Image **(A)** shows a tomosynthesis image with the calcification in focus; the other images show the artifacts from the calcification at **(B)** 10 mm, **(C)** 20 mm, **(D)** 30 mm, and **(E)** 40 mm below the in-focus plane. Artifacts from a highly attenuating object may persist through the entire breast.

projections reduces the slinky artifact. There are also image-processing methods to reduce this artifact. As always, there are trade-offs that vendors must consider. In this case, more projections require more time to acquire the images.

X-Ray Source Motion

There are two types of x-ray source motion used for acquiring the projection images: continuous motion and step and expose. For systems using continuous motion, the x-ray source moves at a constant rate of speed and the x-rays are pulsed on and off at specific angles. The motion of the tube during image acquisition can lead to image blur. Vendors typically use very short pulses on the order of 50 milliseconds or less to minimize this source of image blur. This requires higher power x-ray sources to obtain these short pulses.

Step and expose motion is performed by physically stopping the x-ray source before each projection image is acquired and then moving to the next angle position after the exposure is complete. Motion from x-ray source motion can be eliminated using this method. Stopping the x-ray source for each projection image results in increased time required for each projection image acquisition. The vendors using this method acquire fewer projection images to compensate for the longer time needed for the acquisition of each projection image.

Acquisition Time

The total time required to acquire all tomosynthesis projection images varies widely, from 4 to 25 seconds. Imaging angle, the number of projection images, and the type of tube motion all affect the time required to acquire the projection images. Shorter times will result in less patient motion during image acquisition, and this may be a critical factor for visualization of small lesions, calcifications, and lesion margins.

Radiation Dose

Radiation dose from tomosynthesis is approximately the same as that from mammography. If both a conventional mammogram and a tomosynthesis image are acquired—something often referred to as *combo* imaging—then the dose for a screening exam would be 2 times that used for mammography alone. It is important to put this dose in perspective. The radiation dose from a mammogram is approximately equivalent to the amount of radiation from 1 month of background radiation. For comparison, a CT exam may be equivalent to several years of background radiation. If combo mode is used, the radiation dose is higher but still below the limits set by the FDA. The FDA has determined the benefit from tomosynthesis combined with mammography outweighs the increase in radiation dose. One manufacturer has FDA approval for a synthetic mammogram that is created from the tomosynthesis images so that it is no longer necessary to also obtain a conventional mammogram. If this method is used, the radiation dose for a tomosynthesis screening exam is similar to that used for a conventional mammogram. Synthetic mammograms are discussed in more detail later.

Breast Compression

In conventional mammography the breast is compressed to spread structures, improving the chances that a breast cancer will be visualized. Initially, tomosynthesis was primarily used in the combo mode. In this mode the conventional mammogram and tomosynthesis images are often acquired in the same compression, and therefore the same compression force is required as used for conventional mammography. As institutions move to tomosynthesis with a synthetic mammogram, some compression will still be needed to stabilize the breast; however, it is likely that less force will be required, resulting in less discomfort.

Imaging Views

A mammography screening exam includes two views of each breast, including mediolateral oblique (MLO) and craniocaudal (CC) views. Tomosynthesis systems vary in the number of recommended views. One manufacturer recommends tomosynthesis images in the MLO view and a 2D mammogram in the CC view. Other manufacturers recommend that tomosynthesis images be obtained in both the MLO and CC views. Because tomosynthesis is a 3D image, it might be assumed that a single view is all that is needed; however, there are several reasons that this is not the case. First, tomosynthesis does not eliminate superimposed tissue like a CT exam. For this reason, superimposed tissue in one view may reduce visibility of a lesion that may be seen in another view. Next, lesions are not isotropic and may have much higher contrast in one view versus another. Finally, two views may aid in deciding if a suspicious area is an actual lesion or superimposed tissue.

Synthetic Mammograms

The combination of a 2D mammogram and tomosynthesis offers a number of advantages. The 2D mammogram serves several functions in a tomosynthesis screening exam. First, it is used to compare with previous screening exams. Next, it provides an overview image that acts as a guide for searching through the large number of tomosynthesis images. Finally, it allows easy visualization of groups of calcification. The downside of using both a mammogram and tomosynthesis is that the radiation dose doubles compared with a mammogram alone. One solution for this is to create a synthetic mammogram from the tomosynthesis images. The synthetic mammogram combines the information from all tomosynthesis images into a single image. The algorithms used to create the synthetic mammogram can preserve the detail of some features, such as spiculations or calcifications, allowing these lesions to sometimes be better visualized on a synthetic mammogram than they are on a conventional mammogram. A synthetic mammogram, tomosynthesis slice, and conventional mammogram are shown in Fig. 2.2. The synthetic mammogram is very similar in appearance to the conventional mammogram. Because the synthetic mammogram is created from the tomosynthesis images, no additional radiation dose is needed beyond that used for the tomosynthesis images, and the radiation dose for a screening exam is similar to that used for conventional digital mammography. One vendor has approval for the use of tomosynthesis with a synthetic mammogram.

Summary

In this chapter, the physical basis for tomosynthesis imaging has been provided. The following chapters will explain the clinical implementation and use of tomosynthesis for breast cancer screening.

CHAPTER 3

The Technologist's Perspective

Regina J. Hooley | Amanda Albarella | Liane E. Philpotts

The introduction of tomosynthesis to an imaging facility is a positive experience for mammography technologists. Tomosynthesis improves the clinical workflow not only by allowing faster patient throughput but also by improving diagnostic accuracy, benefiting both the patients and breast imaging staff. Like most consumer-driven technology, tomosynthesis units are very user-friendly. Newly designed features that apply to both two-dimensional (2D) and tomosynthesis image acquisition such as fingerprint login, touch screen controls, flexible compression paddles, and better designed exposure buttons enable the technologist to perform a better and more efficient mammography exam.

Training

Technologists, like physicians, require an initial 8 hours of formal training before being certified to perform tomosynthesis exams. Typically the technologists are trained during a session with the manufacturer's applications specialist. A technologist who is trained and comfortable with the new tomosynthesis equipment can then successfully train other technologists. A useful tomosynthesis training tool for the technologist includes creation of a tomosynthesis checklist designed simply to list all the features of the tomosynthesis unit and to specifically differentiate applications that are unique to tomosynthesis, thereby facilitating technologist adaptation to the new equipment.

Radiation Exposure

Because tomosynthesis is based on x-ray technology, each tomosynthesis acquisition exposes the patient to radiation. In general the cumulative dose per tomosynthesis view is approximately the same or slightly more than a conventional 2D view, although this is variable depending on the manufacturer. For example, the dose of a combined tomosynthesis and 2D mammogram obtained by a commonly used tomosynthesis unit is approximately double the amount received during a conventional 2D mammogram. Despite the increased dose, it is important to understand that the dosage is still below Mammography Quality Standards Act (MQSA) limits. As per the American College of Radiology, 3 mGy is the upper limit for radiation dose of a single mammography exposure. This standard was established over 20 years ago for analog mammography. Since the development of digital mammography, the radiation dose for 2D mammography has decreased over time and is dependent on the equipment manufacturer. As per one vendor, the dose for 2D mammography is now approximately 1.2 mGy per average exposure, and for tomosynthesis, the dose is approximately 1.45 mGy; therefore a combination exam is approximately 2.65 mGy, less than the MQSA limit of 3 mGy.

Most patients do not understand dosage when described in units of mGy (radiation energy in a kilogram of matter) or mSv (biological effect of radiation energy in a kilogram of human tissue), so it can be useful to explain using comparisons with normal background radiation. Although a single exposure tomosynthesis combined with 2D mammography is slightly more than double the dose compared to conventional 2D mammography alone, the *combined* dose due to tomosynthesis is equivalent to only about 2 months of annual background radiation in the United States. Stated another way, the *combined* radiation dose of tomosynthesis is 50% less than the difference in annual background radiation dose in women living in the mountains of Colorado compared to the average background radiation dose for women living elsewhere in the United States.

Keep in mind that exact dosage for a tomosynthesis exam also varies among manufacturers and equipment. Because the tomosynthesis technique is different depending on the manufacturer of the unit, the dose per exposure and per bilateral exam is variable. For example, some manufacturers recommend performing simultaneous combination 2D plus tomosynthesis craniocaudal (CC) and mediolateral oblique (MLO) views for a routine screening exam. Other manufacturers recommend tomosynthesis only for the MLO views and 2D mammography for the CC views or vice versa. In an attempt to lower the dose of the tomosynthesis exam, some manufacturers offer or are developing a synthesized tomosynthesis mammogram. The synthesized mammogram acquires information from the tomosynthesis scan and reconstructs a 2D mammogram, eliminating the need for the conventional 2D mammogram. In addition, other manufacturers are hoping to develop an accurate tomosynthesis mammogram that would not require any additional 2D component. Technologists and radiologists should be aware of the extra radiation dosage for tomosynthesis, depending on the specific unit in use.

In addition to variations in dose and 2D/tomosynthesis image combinations, tomosynthesis equipment specifications also vary across different manufacturers. Detectors and filters, pixel size, scan angles, image time, and reconstruction algorithms are all vendor dependent, as shown in Table 3.1.

TOMO TIP ★ Because of differences in equipment specifications, the number and type of views obtained for a complete tomosynthesis exam may vary depending on the equipment manufacturer.

TABLE 3.1 Variables in Tomosynthesis Units Depending on Manufacturer

Detector	Reconstruction	Number of Projections	Pixels (mm)
Amorphous selenium Crystalline silicon Cesium iodide on amorphous silicon	Iterative Filtered back projection	9-25	50 × 50 70 × 70 85 × 85 100 × 100
Anode/Filter	**Scan Type**	**Scan Angle**	**Scan Time**
Molybdenum/rhodium Rhodium/rhodium Tungsten/aluminum Tungsten/silver Tungsten/rhodium	Continuous Step and shoot	15-50°	4-25 s

Performing the Tomosynthesis Mammogram

Performing a mammogram with tomosynthesis is similar to performing a conventional 2D digital mammogram with a few differences. The compression paddles and tube position are basically similar to conventional mammography units, with slight manufacturer dependent variations. Patient positioning is also similar. One important consideration is the importance of positioning of the CC view. Many technologists have a tendency to slightly laterally exaggerate the CC views, trying to include more of the tissue in the lateral, especially upper outer quadrant. This, however, can result in distortion of the tissues in the CC view (Fig. 3.1). When interpreting tomosynthesis images, radiologists find the CC view particularly useful, and consistency from year to year is therefore very important. For optimal positioning, the breasts should be pulled straight and the nipples centered.

TOMO TIP ★ As the CC view is more uniform from year to year compared with the MLO view, which can be variable in compression and angle, it is especially useful to make sure CC views are obtained with nipples centered to permit accurate comparisons.

The tomosynthesis acquisition time is typically around 5 seconds, but as noted in Table 3.1, some units may require a longer exposure time. Depending on the manufacturer, tomosynthesis may be performed as a single exam or in combination with the 2D mammogram. Some units only allow a single tomosynthesis acquisition without a 2D component. Other units allow conventional 2D only, tomosynthesis only, or a combination 2D/tomosynthesis exam to be obtained in any single view during a single compression. With the combined 2D plus tomosynthesis image acquisition, the exposure time may be 4 seconds longer than a conventional mammogram. Faster and more efficient image processing helps balance the extra exposure time of the tomosynthesis image acquisition. For example, one type of unit allows the technologist to take an image and continue onto the next image without waiting to accept or reject the previous.

During tomosynthesis, the tube rotates in an arc as the exposures are acquired. The angle of the arc is variable across manufacturers, typically ranging from 11 to 50 degrees. The motion across the arc may be continuous or a stepwise "stop and shoot" scan. A notable difference compared with standard mammography is the face guard on the tomosynthesis unit, which protects the patient's head while the tube is making its acquisition sweep. An important tip is to warn the patient that the tube will move. Although the compression paddle and receptor in which the breast is compressed is stationary, many patients may react by pulling back if they are not expecting the machine to move.

For combination 2D plus tomosynthesis exams, the total exposure time may be 10 seconds or more, with tomosynthesis exposures usually preceding the 2D exposure. Therefore attention to the patient's breath-holding technique is important to eliminate motion artifact. It is usually not possible for a woman to hold her breast during an entire 2D plus tomosynthesis combination acquisition. Technologists vary in their approach to coaxing the patient through the exam. Some technologists allow the patient to breathe normally throughout the entire exam. Others have the patient breathe normally during the initial tomosynthesis exposure and then hold their breath during the final 2D exposure. Both approaches are successful, and which technique is used depends on both the technologist and the specific patient.

Currently, the most common tomosynthesis technique used in the United States is the combination 2D plus tomosynthesis exam. For screening mammography, typically bilateral MLO and CC combined 2D and tomosynthesis views are obtained. However, women with large breasts requiring tiling/multiple images per view, as well as women with implants, are already receiving additional radiation from the standard extra views, and performing tomosynthesis could increase radiation beyond the MQSA limits. For these women, use of the synthesized 2D mammogram instead of the additional full-field digital mammography (FFDM) 2D view enables the patient to reap the benefits of tomosynthesis at the same dose as the conventional mammogram. On the other hand, a combination of FFDM and synthesized 2D plus tomosynthesis could also be obtained. For example, in women with implants, the standard CC and MLO views can be obtained using the conventional FFDM 2D technique, and the implant displacement CC and MLO views could be obtained using tomosynthesis plus the synthesized 2D tomosynthesis views.

Additional Views

Because attention to radiation exposure is important, repeat views for technical reasons should usually be done sparingly and preferably after consulting with the interpreting radiologist to determine if they are absolutely necessary and if they should be performed as 2D only, tomosynthesis only, or a combination exposure. A major advantage of tomosynthesis is that fewer technical repeats are required since common skin-related artifacts such as deodorant and small skin folds can be easily dismissed (Fig. 3.2). If a technical repeat image is required due

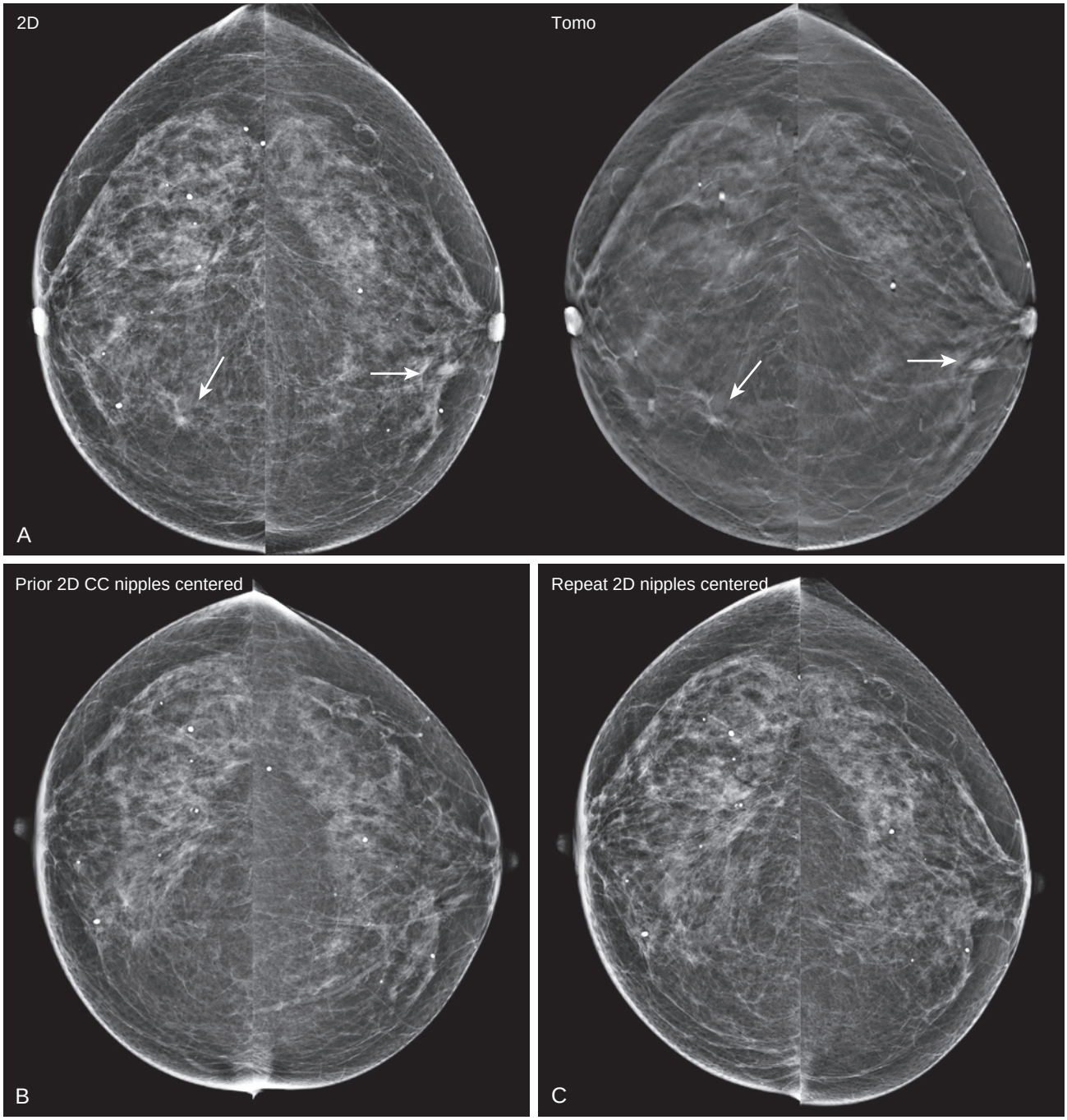


FIG. 3.1 The nipple should be centered for optimal CC positioning. (A) Screening mammogram in a 76-year-old woman with a history of remote right lumpectomy shows new asymmetries bilaterally on the CC 2D and tomosynthesis views *(arrows)*. The asymmetries appear to persist on tomosynthesis slice images and were not seen on the prior exam **(B)**. Note the nipples on prior CC view are centered, unlike the current CC views, which are slightly laterally exaggerated. **(C)** On (immediate) repeat 2D imaging with nipples centered, the asymmetries are not reproduced and are confidently assessed as BI-RADS 2, benign.

to poor positioning, a 2D or tomosynthesis-only view is usually sufficient.

With experience, it will become apparent to radiologists that many of the conventional additional views necessary in diagnostic mammography performed with 2D imaging are not necessary with tomosynthesis. For example, the tomosynthesis slice number can help determine the location of a lesion. Therefore triangulation, typically requiring a true lateral view for a lesion seen only on the MLO view, is rarely needed. Margins are often well characterized on tomosynthesis so that spot compression views are often unnecessary. Many patients with masses recalled from a screening mammogram can go directly to ultrasound. If an ultrasound correlate is found, then no additional views are needed, averting the time, cost, and radiation of a diagnostic mammogram.

Tomosynthesis cannot be performed with magnification. Therefore, conventional magnification views are still often required during the diagnostic workup of microcalcifications (see Chapter 6).

It is important to note that high-quality ultrasound is still necessary to further evaluate most soft-tissue lesions seen on tomosynthesis. Careful attention to technique, lesion margin, and location are essential while performing the targeted ultrasound, which can be performed by either an US-trained mammography technologist or a dedicated ultrasound technologist. The benefits of a single technologist performing both the ultrasound and any required mammographic views include improved lesion detection and characterization, more efficient workflow, and improved continuity of care for the patient.

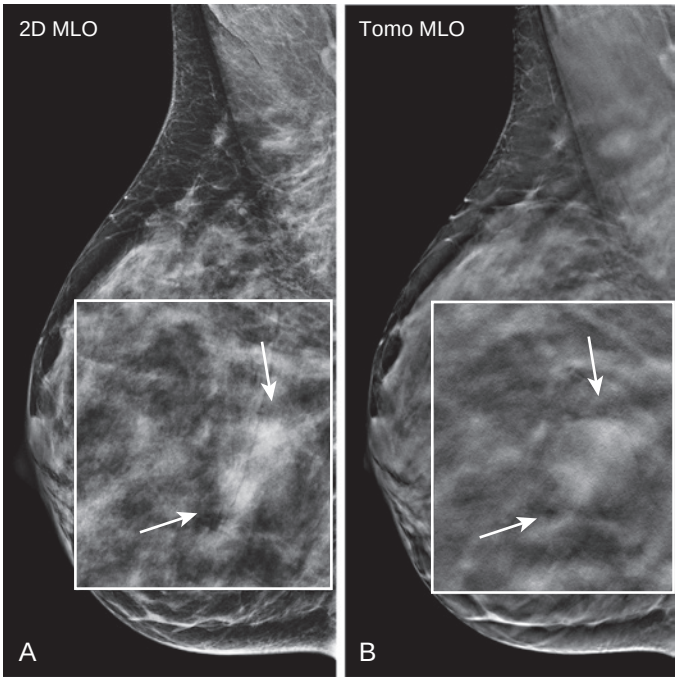


FIG. 3.2 Skin fold obvious on tomosynthesis and not requiring a technical repeat. Screening mammogram in a 42-year-old woman reveals heterogeneous dense breast tissue. **(A)** A skin fold and asymmetry are seen in the right posterior breast in the MLO view *(arrows)*. **(B)** Because the exam was performed in combination mode, tomosynthesis revealed the skin fold on the first slice and a well-circumscribed mass located on a medial slice *(arrows)*. Technical repeat mammography views were unnecessary. Targeted ultrasound *(not shown)* revealed a simple cyst.

Artifacts

Technologists should be familiar with technical artifacts unique to tomosynthesis. Some common artifacts such as dermal calcifications and skin folds can be easily dismissed, while other common artifacts, such as motion, appear differently on tomosynthesis.

TOMO TIP ★ Artifacts seen on 2D that are easily dismissed without additional work-up on tomosynthesis: skin lesions, dermal calcifications, deodorant, zinc lotions, talc, hair, skin fold, nipple out of profile.

Skin and Positioning Related Artifacts

Deodorant artifact and artifacts secondary to mineral-containing talc and zinc-containing lotions often mimic the appearance of microcalcifications. With 2D mammography, repeat imaging after wiping the skin with alcohol is often required. Likewise, dermal calcifications can sometimes be difficult to distinguish from suspicious microcalcifications within the breast. In these cases, tangential views are often necessary to prove the calcifications are located within the skin.

Artifacts associated with the dermal surface are easily recognized with tomosynthesis because location of the skin can be easily determined, appearing at either the beginning or the end of the tomosynthesis stack (Fig. 3.3). Because moles and other skin lesions are seen so well on tomosynthesis, mole markers are not routinely required and may be distracting due to associated tomosynthesis slinky artifact. Positioning artifacts such as skin folds, hair, or a nipple out of profile can almost always be easily dismissed as benign. For example, a nipple that is not

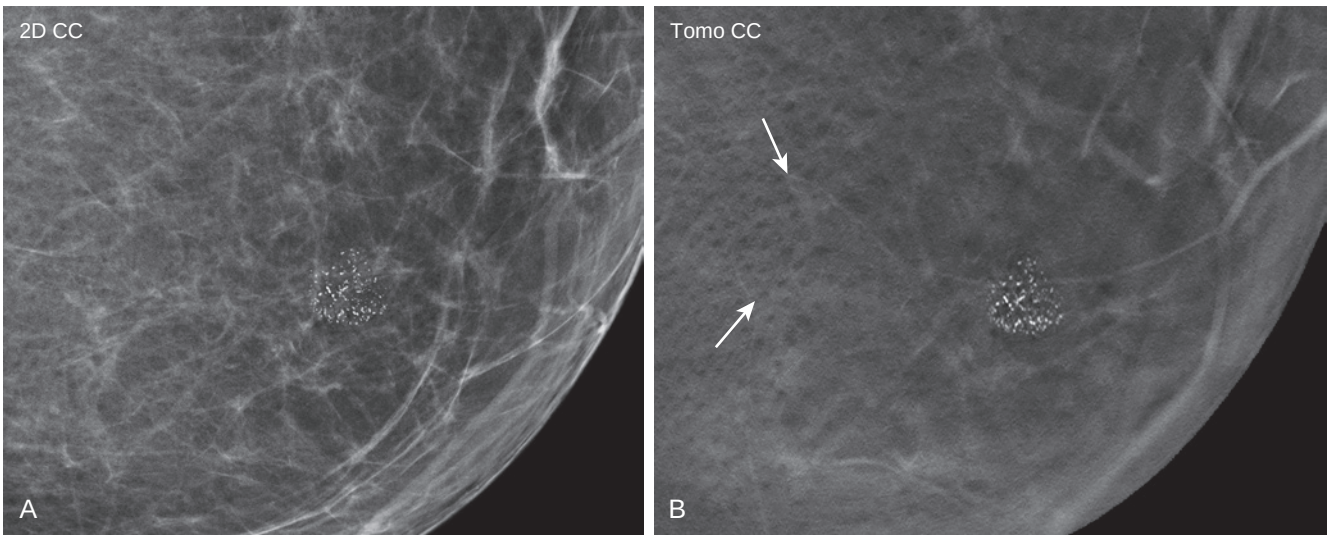


FIG. 3.3 Dermal calcifications easily identified on tomosynthesis. Screening mammogram in a 52-year-old woman. **(A)** Grouped heterogeneous calcifications are identified in the left medial breast seen on the 2D CC view. **(B)** These calcifications are located on the first tomosynthesis slice indicating a dermal location. Note the nearby skin pores *(arrows)*.

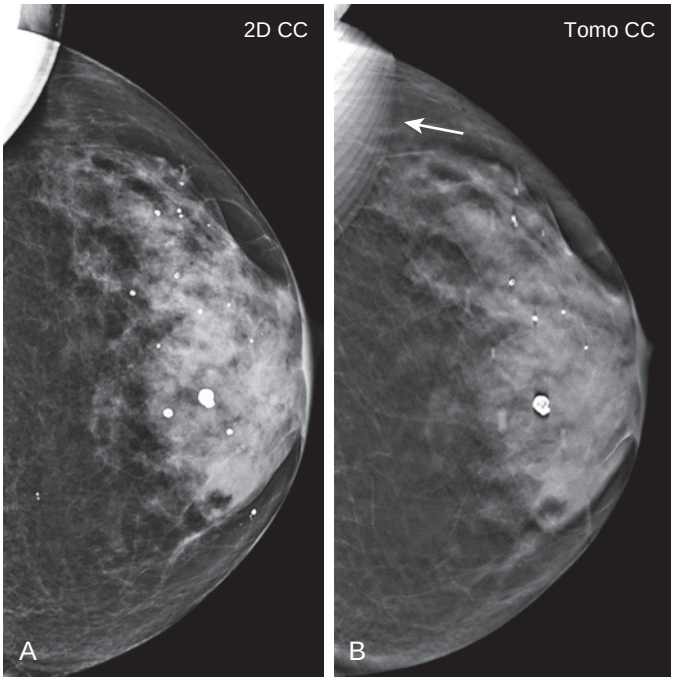


FIG. 3.4 Shoulder artifact. Screening mammogram in a 68-year-old woman. **(A)** Due to kyphosis, her left shoulder could not be optimally positioned and obscured the lateral posterior breast on the 2D image. **(B)** Tomosynthesis slice view, after scrolling beneath the superior region, allows a somewhat improved assessment of the underlying breast tissues. Note that on tomosynthesis, the shoulder produces a "staircase or terracing" artifact *(arrow)* caused by edges of sharp objects that are perpendicular to the scan direction.

in profile can easily be distinguished from a true breast mass with tomosynthesis, and repeat views are often not required since the nipple can easily be determined to be located at the skin surface and not within the breast. All of these positioning artifacts will be out of the plane of view when scrolling through the breast and therefore will not obscure visualization of underlying tissue. In some women with severe physical limitations, obstructing objects such as shoulders can markedly affect the 2D image interpretation. The tomosynthesis images may help salvage the study, as scrolling deep to the obstruction permits at least partial visualization of the underlying breast tissue (Fig. 3.4).

Slinky Artifact

The slinky artifact is associated with high attenuation objects such as skin markers, metallic clips, or calcifications. When out of plane of the tomosynthesis slice, these objects are blurred in the direction of tube. This out-of-plane artifact increases with the distance from the plane of the object, thus causing a stretching, coil-like, or slinky effect in the vertical direction. This artifact can be quite distracting in the presence of multiple biopsy clips or coarse calcifications (Fig. 3.5). Metallic reduction software algorithms decrease the slinky artifacts associated with biopsy clips, skin markers, BBs, and scar markers. This is especially important in synthesized 2D imaging, as the slinky artifact, present on all tomosynthesis images, will therefore be present in the reconstructed 2D synthesized mammogram. Use of the metal erase functionality will eliminate the artifact and render the synthesized 2D image optimal (Fig. 3.6).

Despite the occurrence of slinky artifacts, placement of skin markers, BBs, and scar markers may still be warranted at times. Special markers, designed specifically for tomosynthesis, are commercially available and can minimize these artifacts.

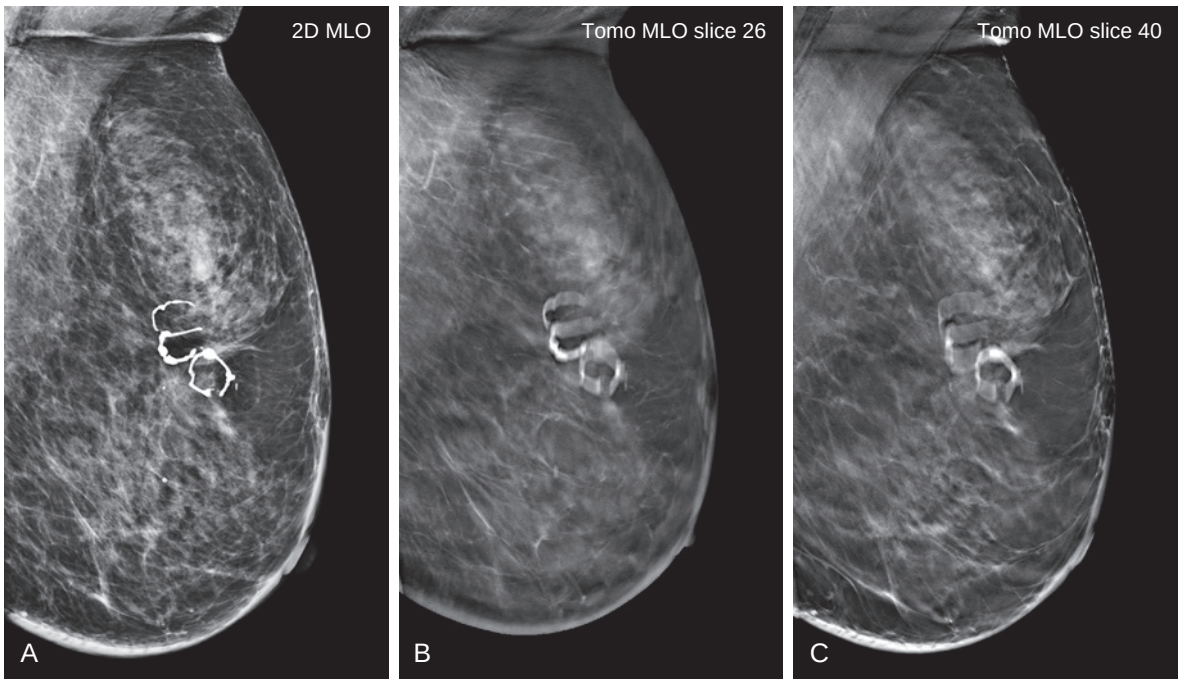


FIG. 3.5 Slinky artifact. Screening mammogram in a 70-year-old woman s/p remote lumpectomy. **(A)** Coarse suture calcifications in the left central breast. **(B and C)** Scrolling through the MLO tomosynthesis views demonstrates blurring of the calcifications with associated slinky artifact, which progressively increases with distance away from the calcified sutures.

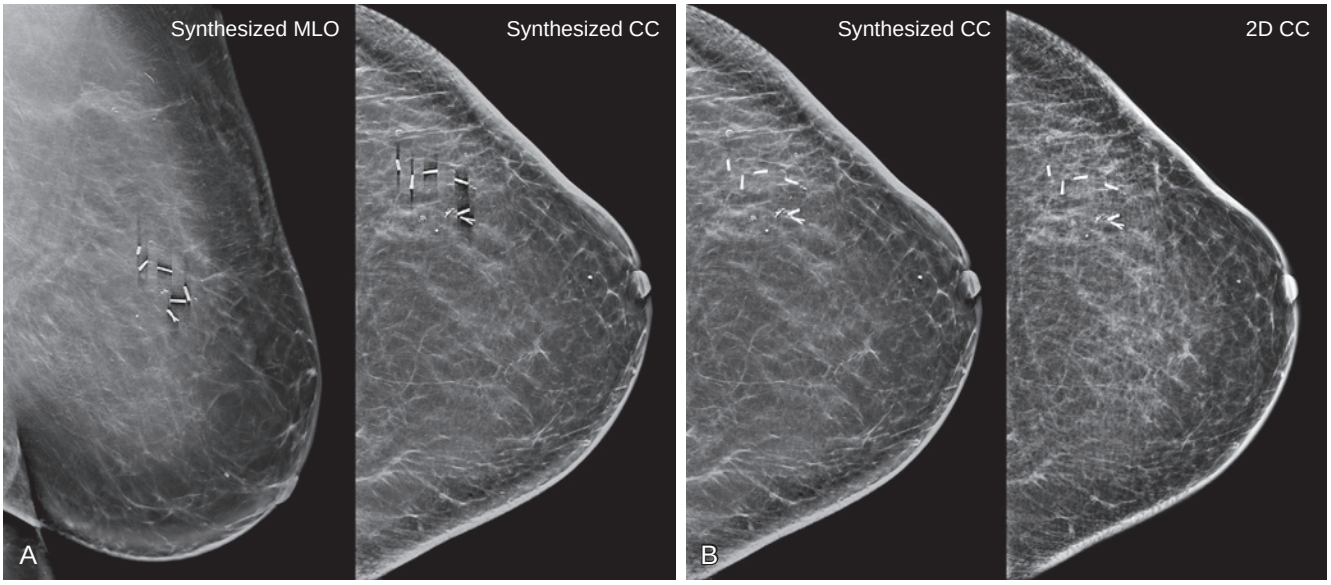


FIG. 3.6 Metal erase software with reduction of the streaking artifact. Diagnostic mammogram performed with synthesized 2D tomosynthesis in a 64-year-old woman with a history of left lumpectomy. **(A)** Multiple surgical clips are seen in the upper outer quadrant, causing streaking artifact and limiting assessment of the tissue at the lumpectomy site on tomosynthesis. **(B)** After the de-metal processing feature was applied, the artifact is eliminated and the image approximates the FFDM 2D image.

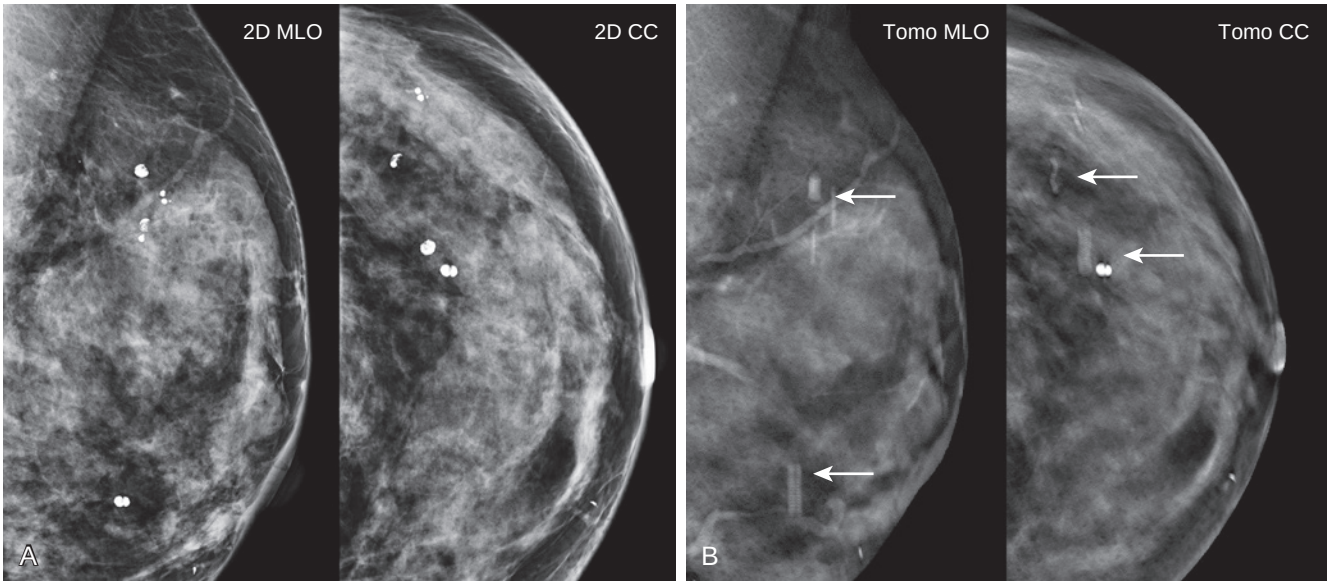


FIG. 3.7 Tomoynthesis motion artifact. Screening mammogram in a 57-year-old woman with dense tissue and multiple coarse calcifications. **(A)** MLO and CC 2D views show no motion artifact, with the calcifications in sharp focus. **(B)** Tomosynthesis slice images show the slinky appearance of the calcifications to be in a straight linear orientation on the MLO view *(arrows),* but serpentine on the CC view indicating motion on the CC tomosynthesis images *(arrows),* that was not present on the 2D CC image even though the 2D and tomo images were obtained during a single compression.

Motion Artifact

Motion artifact can sometimes be difficult to assess on tomosynthesis. All tomosynthesis images have inherent blurring appearance because out-of-plane objects are blurred due to of out of plane signals. Gross motion may be determined by viewing the projection images in cine mode, paying attention to the periphery of the breast, specifically the skin of the axilla or the inframammary fold on the MLO view or the cleavage area on the CC view. If motion occurred during the tomosynthesis exposure, the skin in these regions will appear to bounce or wiggle. Motion should also be suspected if a slinky artifact is not in a straight vertical direction and instead is curved or V shaped (Fig. 3.7). If motion is noted on the 2D component of the combination exam, the projection images should be checked for motion as well. Finally, motion should also be considered if a mass or microcalcification is not as sharp as expected when in plane on the tomosynthesis slice.

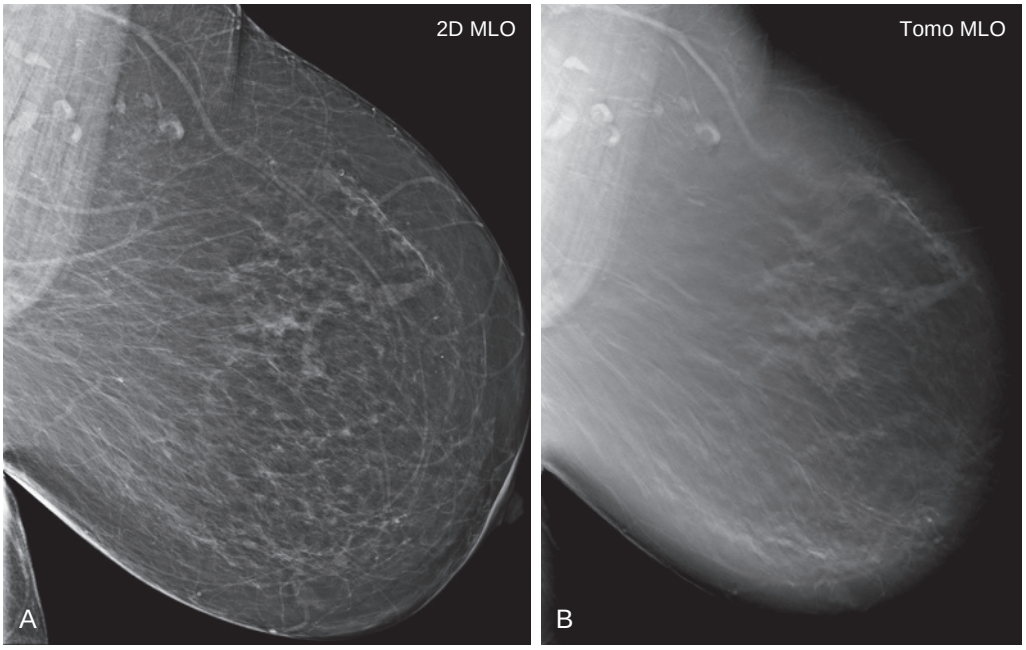


FIG. 3.8 Skin processing error. MLO views of a screening mammogram in a 48-year-old woman. **(A)** The 2D MLO appears normal. **(B)** The tomosynthesis MLO reveals a hazy appearance of the tomosynthesis view with poor visualization of the skin and superficial tissue. This is an exposure and reconstruction problem. For very large breasts that require more radiation dose, the detector may be saturated outside of the breast, making it difficult for the reconstruction software to identify and depict the skin line.

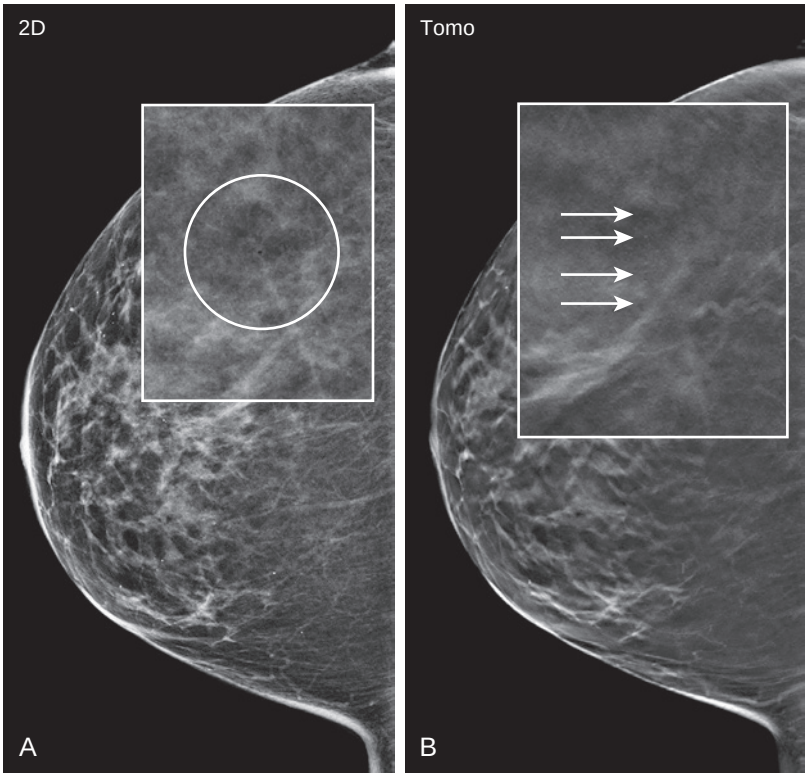


FIG. 3.9 Dead pixel artifact. (A) Close-up 2D CC tomosynthesis view shows a small black dot in the lateral breast *(circle)* due to a dead pixel(s) located on the detector. **(B)** On tomosynthesis, a very fine white slinky artifact is seen *(arrows)*. Although a dead pixel artifact is typically a white dot, occasionally it may appear as a black dot. This artifact can be seen on all images across different patients.

Additional Tomosynthesis Artifacts

It is important to recognize that there are a variety of other artifacts occasionally encountered on tomosynthesis. Tomosynthesis processing artifacts can result in variable appearances. For example, tomosynthesis processing error due to failure of the reconstruction algorithm can result in a horizontal linear artifact through the image. Skin processing reconstruction errors will make the superficial tissue and/or skin line difficult to visualize, resulting in an image with the appearance of an exposure problem (Fig. 3.8).

A dead pixel artifact will usually result in a small white dot on the 2D and on the first tomosynthesis image, since the dead pixel is located on the detector. Although typically a white dot, occasionally the dead pixel will appear as a black dot. Because the dead pixel is on the detector, this artifact will appear on every 2D view in the same location. On the tomosynthesis images, the dead pixel will appear as a very fine slinky artifact (Fig. 3.9).

Grid artifacts are more commonly encountered on 2D images. Some manufacturers use a retractable grid that slides

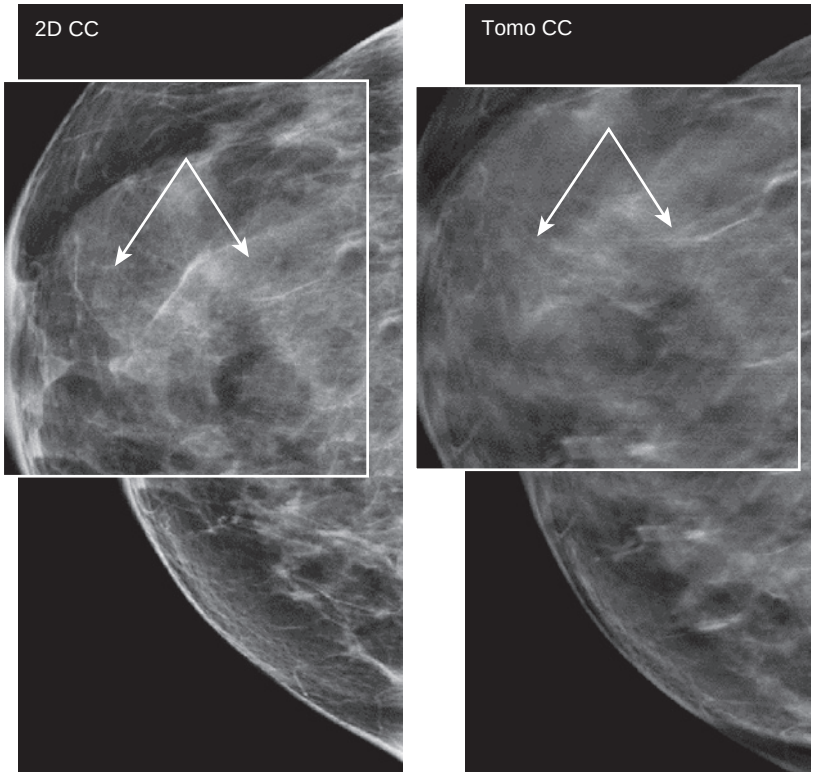


FIG. 3.10 Artifact due to power supply to array resembling grid lines. Screening mammogram in a 54-year-old woman shows very subtle artifact and multiple very fine striations in both the right breast 2D and tomosynthesis CC views, giving the appearance of grid lines *(arrows)*. As a grid is not used for tomosynthesis imaging, it was apparent the artifact was due to another etiology. At servicing, it was determined it was caused by a failed high voltage power supply to the array.

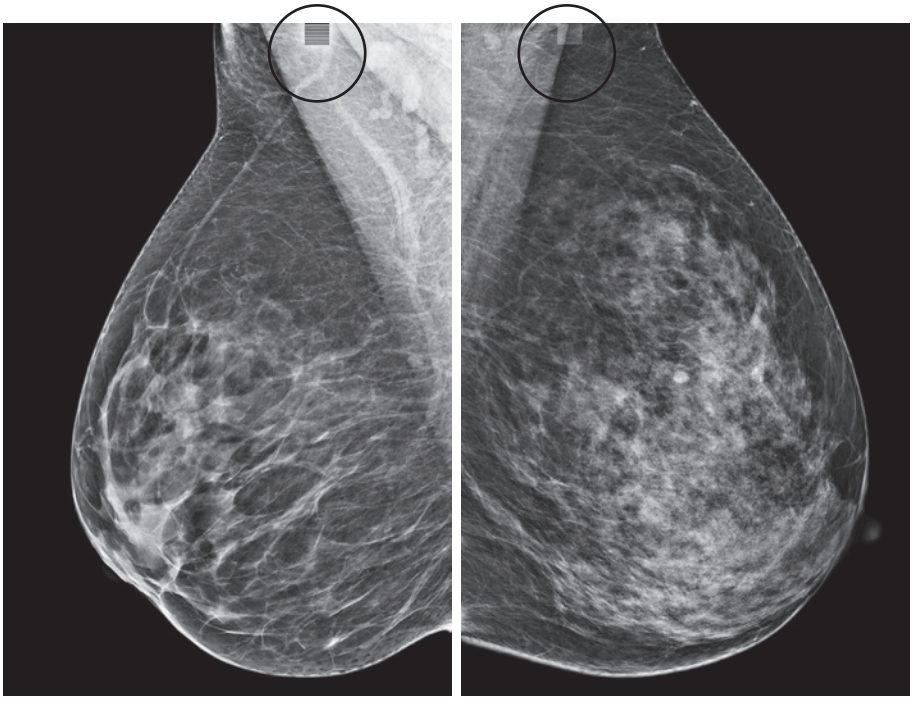


FIG. 3.11 Barcode artifact seen on the MLO views in two separate patients. This artifact is a detector readout error creating white and black lines near the edge of the detector. This is an uncommon artifact and is more of a problem with the 2D images. If seen on tomosynthesis, the barcode artifact would probably only be seen on 1 of 15 projection images and have minor impact on reconstructed images.

into place for the 2D images only. An artifact that resembles grid lines on tomosynthesis may be related to other issues, such as failure in the power supply to the array (Fig. 3.10).

Rarely, a linear artifact resembling a barcode will appear near the edge of the mammogram. The barcode artifact is a detector readout error that is typically obvious on the 2D images. On tomosynthesis, the barcode artifact may only appear on the projection images and have little effect on the reconstructed views (Fig. 3.11).

Tomosynthesis Quality Control

Tomosynthesis quality control (QC) involves calibration, phantom, and biannual QC functions. It is necessary to check with the specific manufacturer as to exactly what QC functions are required and how to perform them. Most tomosynthesis QC functions are similar to those performed for 2D and are done simultaneously (Fig. 3.12). Geometry calibration

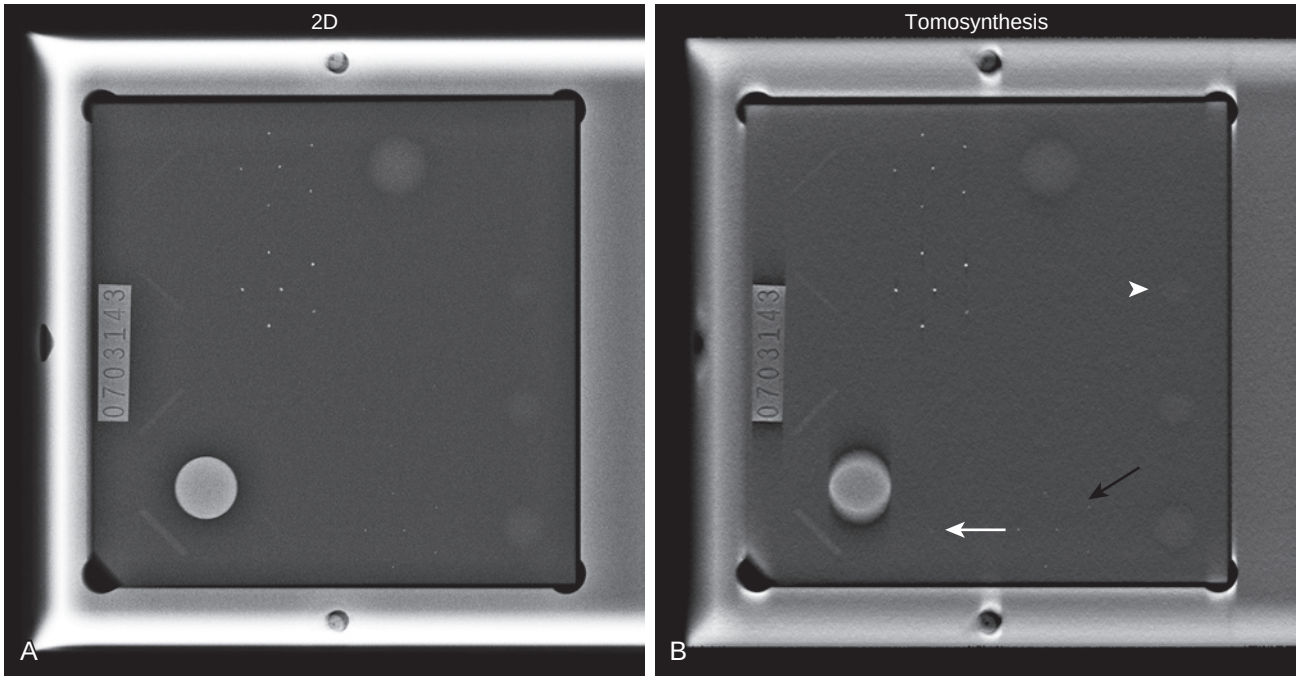


FIG. 3.12 Phantom QC. Mammography phantom 2D and tomosynthesis views. **(A)** 2D image shows the fibers, specks, and masses. **(B)** Tomosynthesis slice 36 of 50 images best depicts the findings *(white arrow, black arrow, and arrowhead,* respectively*)*.

is performed semiannually. Weekly calibration is performed, similar to 2D and the mAs and kVp charted. Artifact evaluation is done with rhodium, silver, and aluminum. Basic QC functions for tomosynthesis involve detector flat-field calibration (five additional exposures for tomosynthesis gain calibration with the aluminum filter), geometry calibration (one exposure), artifact evaluation (one additional tomosynthesis image), and phantom image (one additional tomosynthesis image). The phantom image is acquired as a combination (2D and tomosynthesis) exposure and charted separately. Masses, specks, and fibers are assessed on the tomosynthesis slice that best depicts the findings. It is essential that the calibration phantom is clean, as dirt or dust would be included in calibration and result in artifacts.

Conclusion

Tomosynthesis is beneficial for the patients, technologists, and interpreting radiologists. Fortunately for the technologists, the new technology associated with tomosynthesis is very user-friendly. Mammographic positioning is identical to 2D mammography, and advances in "knobology" of the equipment makes performing the mammogram straightforward. Common artifacts frequently encountered on conventional 2D mammography are easily recognized and dismissed on tomosynthesis. Nevertheless, the technologist should also be familiar with artifacts unique to tomosynthesis. Because patients require fewer images—fewer technical repeats and fewer diagnostic images—there is greater efficiency and increased patient satisfaction.

CHAPTER

4

Implementation of Digital Breast Tomosynthesis Into Clinical Practice

Stamatia Destounis | Andrea Arieno | Renee Morgan | Liane E. Philpotts

Introduction

The limitations of conventional digital mammography have been well established. Conventional mammography creates a two-dimensional (2D) image of a three-dimensional (3D) structure, which may result in superimposition of normal tissue and obscuration of lesions. This influences cancer detection and leads to high screening recall rates and false-positive findings. Conventional 2D mammography is particularly limited in dense breast tissue, and cancer detection is as low as 48% in women with extremely dense breast tissue.

Digital breast tomosynthesis is being increasingly adopted in breast imaging centers around the world, largely due to early clinical studies demonstrating this technology's ability to address many of the limitations of conventional mammography. Due to improved diagnostic performance, it is expected that tomosynthesis will eventually become the standard of care in breast imaging facilities, and thus every facility will ultimately be faced with the task of incorporating the technology into practice. This presents a challenge, as to date there is limited guidance regarding how to best implement the technology, nor are there standard guidelines for the clinical use of tomosynthesis. In this chapter, we will discuss experience with the adoption and implementation of the tomosynthesis technology into the clinical practice setting, with perspectives from both a large private practice and a tertiary academic hospital setting.

Tomosynthesis Equipment

As of this writing, three manufacturers have received US Food and Drug Administration (FDA) approval for tomosynthesis use in the United States: Hologic Selenia Dimensions (2011), GE SenoClaire Digital Breast Tomosynthesis (2014), and Siemens MAMMOMAT Inspiration with Tomosynthesis option (2015). These units all differ in their features, notably the angle of sweep, acquisition time, and receptor materials, as has been discussed in Chapters 2 and 3. Thorough investigation into the variations between manufacturers is advised prior to purchase of equipment to determine which unit best fits a facility's needs.

Early Research With Tomosynthesis

For the early adopters, experience with tomosynthesis began by participating in research. Through such participation and using prototype machines, a few select sites were able to get early experience with the technology prior and leading to FDA approval for clinical use. At the current stage where tomosynthesis has entered the commercial sphere, facilities will now benefit from the knowledge acquired from this early research. The medical literature reporting on clinical experience with tomosynthesis is growing exponentially. Published literature can inform potential adopters of the benefits of the technology; however, each site will need to determine the optimal workflow and protocol for adopting tomosynthesis into their own practice.

Implementation Considerations

There are many important factors to consider when planning the implementation of tomosynthesis into clinical practice. The following will discuss some of the issues many practices have encountered in the conversion process.

Preparation

Before implementing tomosynthesis, it is important to prepare financially. Adoption of the technology can be expensive and includes not only the cost of the unit(s) but also potential facility renovations, changes to the picture archiving and communication system (PACS), and information technology (IT) requirements. The cost of a tomosynthesis unit is more expensive than a 2D full-field digital mammography (FFDM) unit, by as much as 50%. For many facilities, the issue of conversion speed is a primary factor. Depending on budget considerations, some practices may be able to convert all at once, while others have to transition slowly, working in a hybrid setting of both tomosynthesis and FFDM as additional units are procured over time.

There are specific room size requirements to house a tomosynthesis unit, with a minimum of 12 × 12 feet required—larger than that required for an FFDM unit. This may mean that existing room space may need to be altered to install tomosynthesis units, which increases overall implementation costs.

It is important to recognize that the installation process requires a period of time during which imaging of patients will be limited. This downtime is approximately 3 days for removal of the previous unit, installation of the new unit, and physicist testing. In addition, once installed, FDA approval of the unit for use of tomosynthesis must be granted, which can take up to 10 business days. Until this approval is received, only FFDM imaging is permitted. Even if only upgrading a preexisting mammography unit to add tomosynthesis imaging capabilities, approximately the same amount of downtime will be required. These downtimes have to be considered, as they may mean adjusting patient schedules during the crossover period.

TABLE 4.1 Comparison of File Size

Modality	File Size	Compressed File Size
FFDM	200 MB	65 MB
Tomosynthesis	2 GB	200 MB

FFDM, Full-field digital mammography.

Information Technology, Picture Archiving, and Communication System and Workstation Requirements

IT support is critical for successful implementation of tomosynthesis. PACS storage requirements for tomosynthesis images are substantial, and there are many aspects to consider when investigating storage options based on the specific needs of a facility. Moreover, workstations requirements are different from those for 2D imaging.

Tomosynthesis datasets are large. A combination FFDM-tomosynthesis exam consists of three components: 2D FFDM, tomosynthesis source projection images, and reconstructed (1 mm) slice images (the number of which depends on breast thickness). This file size is about 10 times the size of FFDM (Table 4.1). Due to the larger file size, storage needs dramatically increase and must be budgeted accordingly. For example, in 1 year's time, at the Elizabeth Wende Breast Care, LLC, there were approximately 4 times as many 2D studies in comparison to tomosynthesis exams, yet tomosynthesis accounted for 40% of the storage (4.1 TB vs. 2.7 TB). An additional issue with large file size is how images will be stored. Storage with 4:1 loss-less compression is recommended such that images can be adequately retrieved without loss of information. Large image size is also important when considering transfer of images. For off-site satellite locations or multiple sites, transferred to and from a centralized location, adequate bandwidth is necessary. Adjustments may be needed to increase bandwidth to accommodate the large file size of tomosynthesis images. While increased image storage is an important consideration with tomosynthesis, storage capacities and options have greatly increased in recent years and are becoming less expensive over time, such that most facilities should be able to accommodate the increased demands without significant difficulties.

TOMO TIP ★ Tomosynthesis files are 10 times the size of FFDM images, so prepare adequately for your increased storage needs.

Workflow must also be considered: How many prior exams will generally be desired for comparison purposes? This choice affects the radiologist's hanging protocol as well as image retrieval prior to patient appointments and becomes a more significant consideration after multiple years of imaging with tomosynthesis have accrued. It is strongly recommended that all recent prior imaging, whether tomosynthesis or 2D, is available to the interpreting radiologist for subsequent years' comparisons. While it is not expected that all prior tomosynthesis studies will routinely be reviewed, they should be available if needed. The advantage of tomosynthesis to increase both sensitivity and specificity of mammography may depend on appreciating subtle changes compared to prior studies.

There are other factors to consider, such as having adequate random access memory (RAM) to workstations. Some monitors might be too old to adequately display tomosynthesis studies. If the display speed is not sufficient, it will result in "jumping" while scrolling through the tomosynthesis slices. Other considerations entail having updated server hardware (this should be discussed with the PACS vendor) and network considerations. All these vary by site (size of facility and volume of studies), and each facility has unique needs.

Ease of viewing of the tomosynthesis images is critically important, such that interpretation time is minimalized and accuracy is optimized. Proprietary workstations designed specifically for tomosynthesis viewing provide optimal user-friendly functionality. Initially, tomosynthesis studies could only be viewed on such proprietary workstations, and they are more costly than standard PACS mammography workstations. To not hinder workflow, an adequate number of tomosynthesis reading stations are required for a busy practice. This can add considerable costs to tomosynthesis implementation. There are now several PACS vendors who have well-designed tomosynthesis display and viewing capabilities. Others are still not able to display tomosynthesis optimally, in which case purchase of dedicated workstations will likely be the only option until the specific PACS vendor is able to offer suitable tomosynthesis display capabilities.

Hanging Protocols

The initiation of tomosynthesis in a practice requires the creation of new hanging protocols. It is important to have customized hanging protocols specific to radiologists' preferences. Many have found it helpful to maintain a hanging protocol similar to their standard 2D review; however, that reading flow will usually be altered for tomosynthesis. Many radiologists may prefer to review the 2D images in full resolution—and then the tomosynthesis images with the current 2D images or the stacked comparison images side by side. If synthesized 2D images are utilized, these can be inserted into the sequence at the preferred point. As always, CAD images are reviewed at the end of the hanging protocol. Most proprietary or PACS workstations will permit toggling between the 2D and tomosynthesis images with ease at any point during the course of image review. Single click functions and seamless toggling between 2D and tomosynthesis are of the utmost importance. Many variations of hanging protocols can be constructed, and the prime importance is finding a protocol that permits efficiency and accurate reading of all images.

TOMO TIP ★ Optimizing the hanging protocol is important for tomosynthesis reading efficiency and accuracy.

Radiologist and Technologist Considerations

As with any new modality, training is an important factor in the implementation process. Radiologists, technologists, and physicists are all required to undergo tomosynthesis-specific training. Radiologists are required by the Mammography Quality Standards Act (MQSA) to complete an 8-hour training session that includes test cases. There are many training seminars offered through continuing education courses, as well as through tomosynthesis vendors, that meet this 8-hour requirement. Technologists are also required to have 8 hours of training; this is most commonly obtained through applications training provided by the vendors.

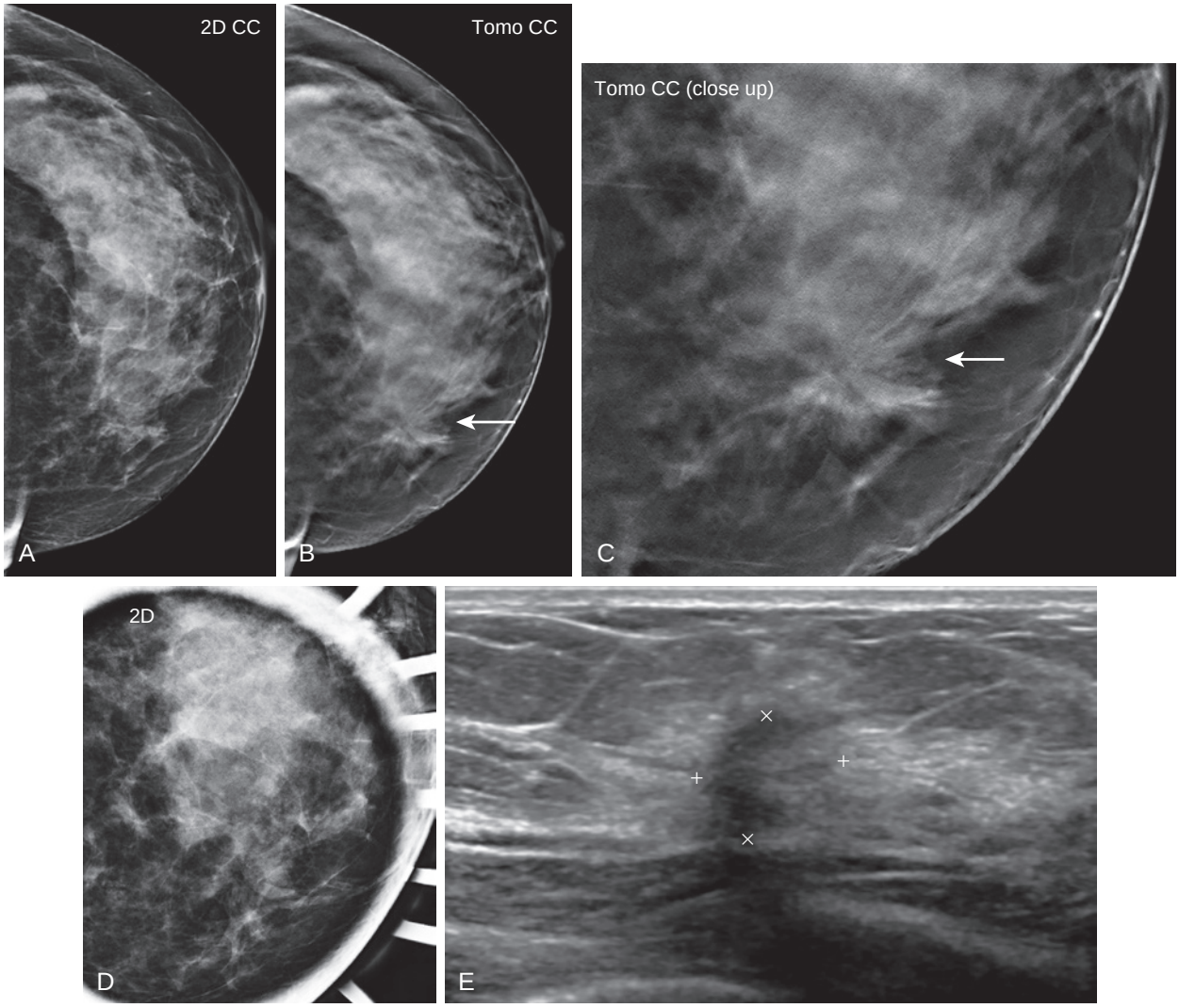


FIG. 4.1 Radial scar with DCIS. A 53-year-old patient presented for screening evaluation. An area of architectural distortion was identified in the left breast. The area was seen on the full-field digital mammography craniocaudal (CC) view **(A)**, but best demonstrated *(arrows)* on the CC tomosynthesis view **(B and C)**. **(D)** On the 2D spot compression CC view, the area of architectural distortion was less apparent. **(E)** Breast ultrasound identified an irregular hypoechoic mass. Ultrasound-guided core biopsy was performed, resulting in a diagnosis of radial scar. The patient was recommended to undergo surgical excision, at which time associated ductal carcinoma in situ was diagnosed.

Once all are trained, there is a learning curve associated with tomosynthesis. For radiologists, this primarily involves image interpretation. Radiologists will generally see a decrease in recall rates; however, some may experience a slight increase, at least initially, while getting used to seeing more detail on tomosynthesis. This may in part be due to the detection of subtle, "tomo-only" cancers and architectural distortions, as well as a multitude of benign findings that may be newly seen. Follow-up on the outcome of recalled lesions detected on tomosynthesis cases is extremely valuable. At larger practices with multiple breast imagers, sharing interesting cases and feedback among the group are encouraged and will help expedite the learning curve. Radiologists will need to find a new threshold for what they dismiss and what they call back. Most users have seen an increase in the detection of radial scars. Tomosynthesis is exceptional at depicting the architectural distortions caused by these high-risk lesions. At the Elizabeth Wende Breast Care, the detection rate of radial scars nearly tripled post-tomo implementation compared with pre-tomo implementation (Fig. 4.1). The management of tomosynthesis-detected radial scars and complex sclerosing lesions is challenging and still evolving.

Interpretation time of tomosynthesis studies is increased compared to that of 2D exams, due to the considerable number of images to be viewed. An average tomosynthesis mediolateral oblique (MLO) or CC view consists of 60 1-mm slices. Variable length of time for interpretation has been reported in the literature, with the majority of facilities reporting times that are approximately twice as long as FFDM alone. This may decrease slightly with experience, but will always remain longer due to the increased volume of images to review. It is important to recognize, however, that the increased time required to read individual cases is balanced by both the decreased number and markedly abbreviated diagnostic work-ups associated with tomosynthesis.

Tomosynthesis Biopsy Capabilities

Another important concern for users new to tomosynthesis is how to deal with tomo-only findings. For most, it will be inevitable that suspicious tomo-only findings, such as architectural

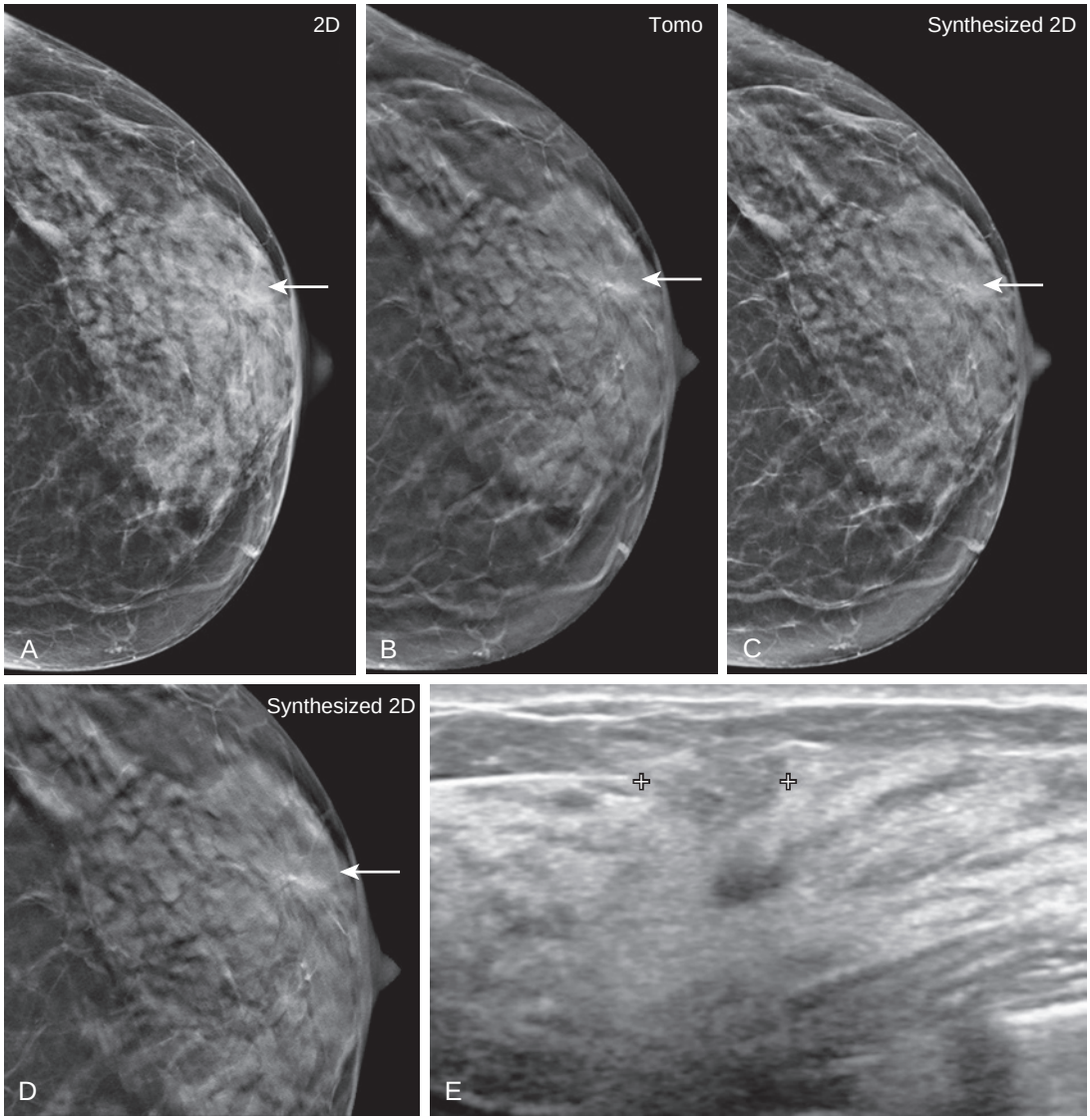


FIG. 4.2 Tomosynthesis imaging with synthesized mammography. A 46-year-old with dense breast tissue presented for screening mammography. Bilateral combination tomosynthesis was performed with synthesized mammography. An area of architectural distortion *(arrows)* was noted in the left breast, best demonstrated on the craniocaudal (CC) view. **(A)** The area was identified on the full-field digital mammography CC. The tomosynthesis slice **(B)** and corresponding synthesized mammography image **(C and D)** demonstrated the area with improved conspicuity. Breast ultrasound **(E)** demonstrates a mass corresponding to the area of architectural distortion. Ultrasound-guided core biopsy revealed invasive ductal carcinoma.

distortion, will be detected and require biopsy. Tomosynthesis stereotactic biopsy equipment is commercially available and designed specifically for those findings seen only on tomosynthesis, although this equipment can also be used to sample any suspicious lesion detected on mammography. Tomosynthesis stereotactic biopsy is discussed in detail in Chapter 14. Purchase of tomosynthesis stereotactic equipment will increase implementation costs. It is important to recognize that tomosynthesis-directed biopsy has not been widely incorporated into practice thus far, and many facilities have found other strategies to deal with such findings, including carefully directed ultrasound, magnetic resonance imaging or tomo-guided needle localization.

Dose Considerations

When used in combination with 2D imaging, the radiation dose with tomosynthesis imaging is approximately twice that of conventional digital mammography, though this varies depending on breast size and tissue composition. The radiation dose may influence decisions regarding which patients are to receive tomosynthesis, especially if resources are limited. For those patients with implants or very large breasts who require extra images beyond the standard views, tomosynthesis would further increase the radiation dose and probably should be avoided.

The clinical incorporation of the synthetic 2D mammogram, which generates the required 2D image from the tomosynthesis images alone, negates the need for the 2D FFDM acquisition, thereby reducing the total dose to half, similar to FFDM alone. With such imaging, all patients can benefit from tomosynthesis, without the extra radiation dose. Several studies have demonstrated that use of the reconstructed synthetic 2D views with tomosynthesis performed comparably to combined 2D FFDM plus tomosynthesis and thus is adequate for clinical use. Early experience with synthetic 2D imaging has shown lesion detection to be comparable to conventional 2D (Fig. 4.2).

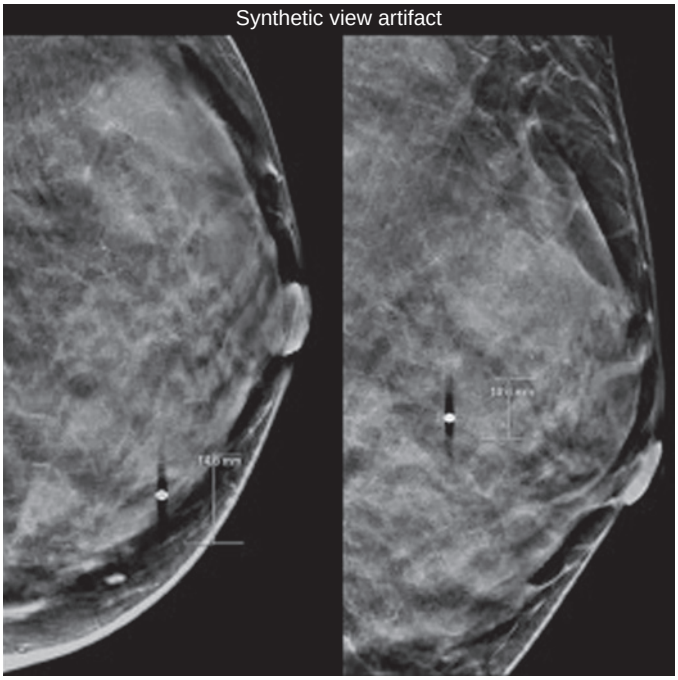


FIG. 4.3 Image artifact on synthesized mammography. This image demonstrates the substantial image artifact that was seen when utilizing a metallic BB.

There is a learning curve with the synthetic 2D view, however, as this has a different look compared with FFDM. Many sites continue to image in combination mode until comfort and confidence with the synthetic 2D images are established. Computer-aided detection (CAD) is available for the synthesized 2D images. For a facility that practices in a hybrid setting of FFDM and tomosynthesis, it is important to apply consistent care for all patients; thus if CAD is the standard of care, it should be utilized uniformly for all patients.

An issue unique to tomosynthesis imaging is the substantial streak artifacts that occur with the use of BBs or internal metallic objects, which is not present in 2D FFDM imaging (Fig. 4.3). De-metal software and use of tomosynthesis-specific skin markers that are plastic-based help to considerably reduce image artifact (Fig. 4.4).

Community Outreach

Marketing strategies and community education are key components to the implementation or expansion of a tomosynthesis program. Marketing to the community is important to ensure that the public is aware the facility now offers tomosynthesis. This can be done through press releases, patient brochures, and websites. Reaching out to referring physicians and other health care professionals in the community is also important. Radiologists can provide lectures to local medical or breast cancer groups, discussing the benefits of tomosynthesis. Such efforts generally yield enthusiastic support from patients and clinicians who are eager to embrace the benefits of tomosynthesis, including the reduction of false-positive exams and the increase in cancer detection.

Hybrid Conversion: Things to Consider

There are many facilities that cannot afford to convert to tomosynthesis all at once. Table 4.2 demonstrates the evolution of the specific experience with tomosynthesis at Elizabeth Wende Breast Care. The program has grown from 1 unit initially in 2011 to tomosynthesis imaging with 11 units at all facilities (out of a total of 15 mammography units). When a facility transitions slowly and operates in a hybrid setting, there are some factors to consider that are not relevant with complete conversion. Most important is identifying which patients will receive tomosynthesis imaging. Many facilities choose to perform tomosynthesis for screening patients because this centers on the key benefits of recall reduction and increased cancer detection, as well as being available to the greatest number of patients. But other facilities choose to use it in the diagnostic setting, where there will be fewer exams, and permit radiologist experience to be gained in a more controlled environment. Yet others preferentially target specific patient populations who will likely benefit most, such as women with personal history of breast cancer/postlumpectomy (Fig. 4.5), those with dense breast tissue (Fig. 4.6), women at high risk for breast cancer, and baseline screening patients.

If used in the screening environment, many diagnostic recalls will be avoided, and those that are recalled will require fewer or no additional views. Utilizing tomosynthesis in the diagnostic imaging of patients has been shown to potentially reduce,

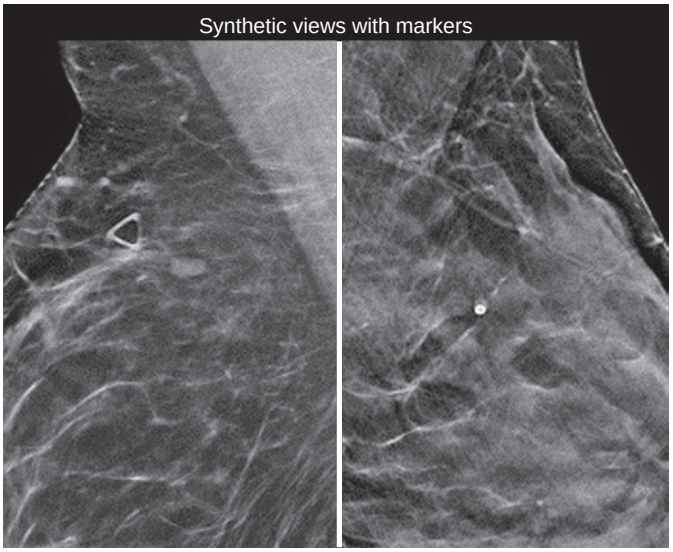


FIG. 4.4 Spot markers for use with tomosynthesis imaging. This image demonstrates markers designed specifically to reduce image artifact on tomosynthesis.

TABLE 4.2 Expansion of Tomosynthesis Program (Elizabeth Wende Breast Care)

Year	Number of Units	Screening Exams	Diagnostic Exams
2011	1	332	46
2012	2	3,962	1,026
2013	5	9,552	3,807
2014	7	15,121	2,012
2015	11	27,119	9,077

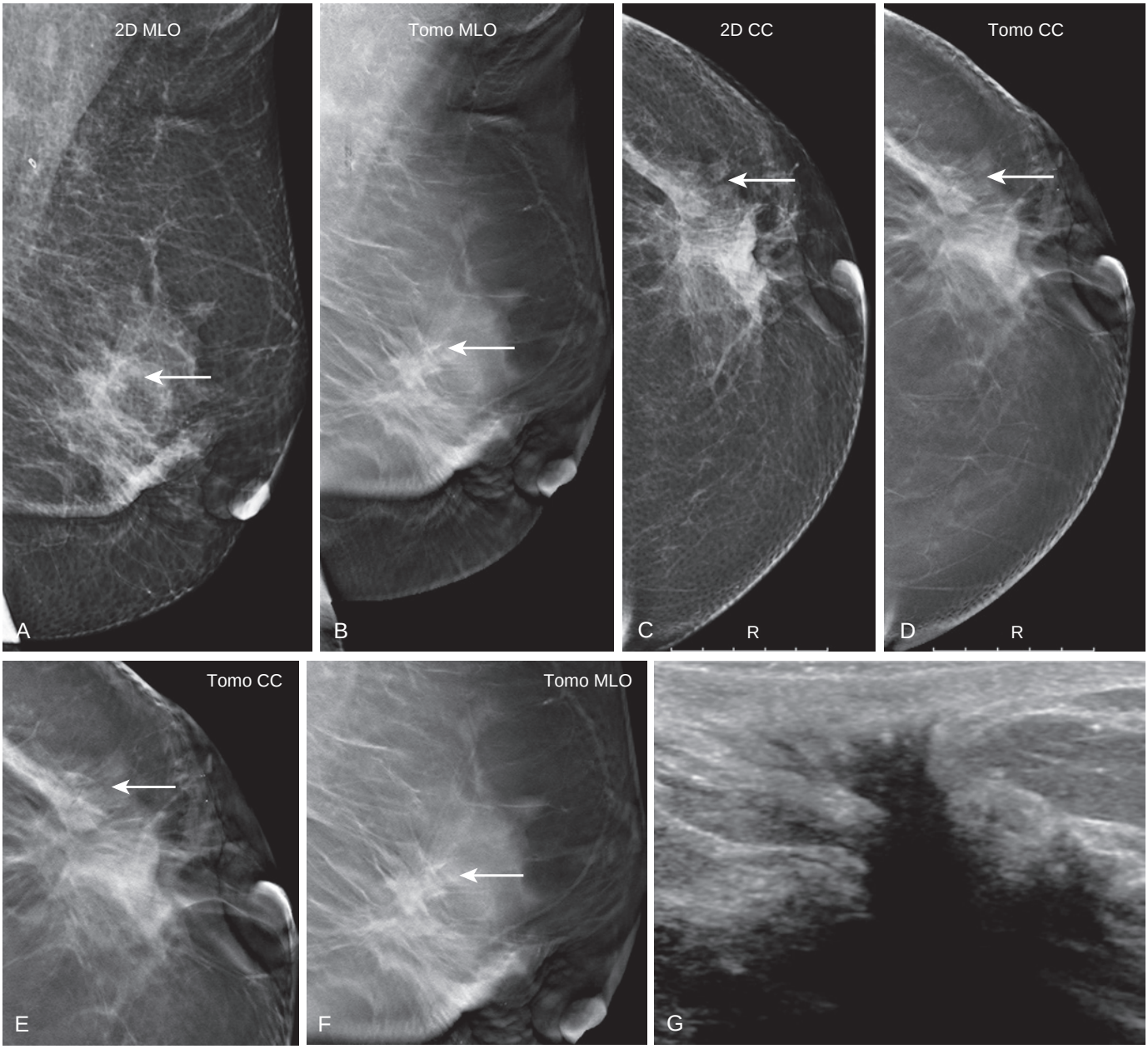


FIG. 4.5 Tomosynthesis imaging in a woman with a personal history of breast cancer. A 54-year-old patient with personal history of mammographically occult left breast invasive lobular carcinoma presented for mammographic evaluation. **(A-D)** A new suspicious area in lateral aspect of the scar was identified on full-field digital mammography and tomosynthesis *(arrows)* imaging. **(E and F)** Close-up views of the area on tomosynthesis demonstrate improved visualization of a mass *(arrows)*. **(G)** Ultrasound demonstrated an irregular mass corresponding to the mammographic finding, and ultrasound-guided core biopsy was performed resulting in diagnosis of recurrent invasive lobular carcinoma.

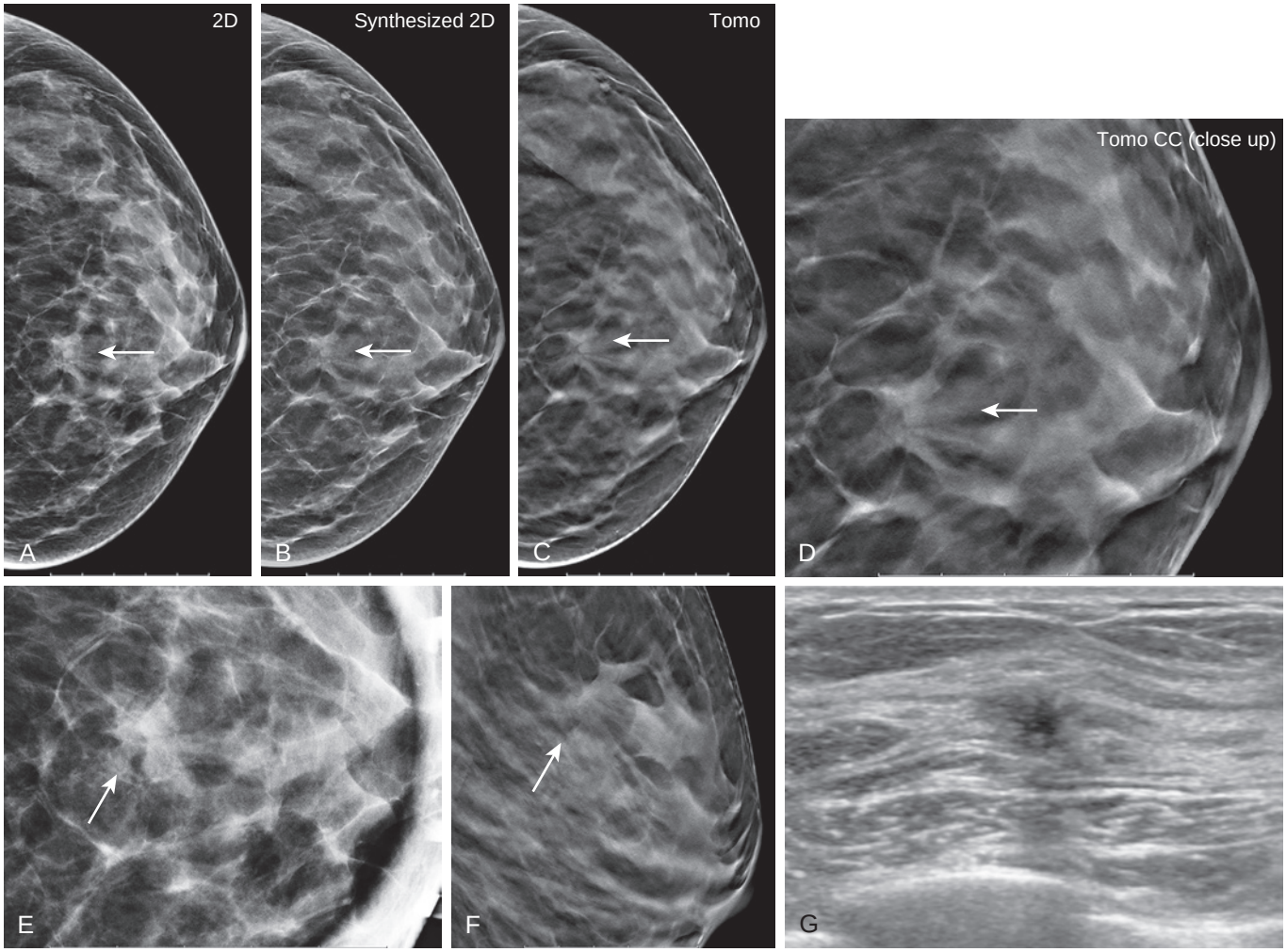


FIG. 4.6 Tomosynthesis imaging of a woman with dense breast tissue. (A to D) A 52-year-old patient with extremely dense breast tissue presented for routine screening mammography. Architectural distortion *(arrows)* was noted in the left breast at mid/posterior depth. This was best demonstrated on the CC tomosynthesis and synthesized mammography views. 2D spot compression view **(E)** was performed along with a lateral tomosynthesis view **(F)**, confirming the area of architectural distortion *(arrows)* better seen on tomosynthesis. **(G)** Breast ultrasound was performed and a 9-mm irregular, hypoechoic mass with architectural distortion was seen. US-guided core biopsy was performed, diagnosing a grade 2 invasive ductal carcinoma.

or even replace, most additional diagnostic mammographic views (such as spot, lateral, and rolled views). Several studies have shown similar or improved performance of tomosynthesis compared with conventional diagnostic mammography views. This benefits the patient, as it decreases both the dose and time required for the exam.

In early experience at Yale with a single tomosynthesis unit (and three additional FFDM units), an unexpected trend was discovered. Technologists clearly favored the tomosynthesis unit for several reasons, when used not only for screening but for diagnostic exams as well. Their patients commonly noted how much more comfortable the exam was (likely due to the flexible paddle). For screening exams, there were fewer technical repeats. Diagnostic exams were expedited, as far fewer additional diagnostic views were requested. This resulted in preferential performance of the majority of exams on that single tomosynthesis unit. The technologists preferred to wait for the tomosynthesis room to become available if possible, as the entire exam would still be quicker than immediately utilizing a conventional mammography unit. Over the first year, this resulted in 2.5 times the number of exams performed on the single tomosynthesis unit than any of the FFDM units before or after tomosynthesis implementation (Table 4.3).

TABLE 4.3 Exams Performed per Mammography Unit: Yale Early Experience

	2D Unit Pre-Tomo	Tomo Unit	Increase Utilization
Screening exams	3,154	7,913	2.5×
Diagnostic exams	1,537	3,594	2.5×
Total exams	4,691	11,507	2.5×

In addition, at Yale a continuous decrease in the number of diagnostic exams has been noted for each year since implementing tomosynthesis. With tomosynthesis, not only are there fewer recalls from screening mammography, a decrease in short-term

imaging follow-up recommendations (BI-RADS 3) has been noted, and many more patients are entering the screening pool who previously were considered diagnostic (eg, lumpectomy patients). Such improved throughput of patients and change in exam volumes are important and may be an unanticipated downstream effect of tomosynthesis use that should be taken into consideration when purchasing equipment. There is the potential that fewer tomosynthesis units than FFDM might be adequate. The goal of most sites is to ultimately convert to imaging all patients with tomosynthesis, and thus have a uniform workflow environment.

TOMO TIP ★ Improved throughput of patients and change in exam volumes is an important downstream effect of tomosynthesis use, and should be taken into consideration when budgeting for equipment.

Summary

Tomosynthesis is an exciting new technology in breast imaging that has been shown to improve upon many of the limitations inherent in 2D digital mammography technology. Research to date has been consistent in demonstrating that tomosynthesis can reduce recall rates while increasing cancer detection. The technology has been shown to be beneficial in many different patient populations, speaking to the promise the technology shows for eventually becoming the standard of care for breast cancer screening.

As with any new modality, there are concerns that need to be addressed when implementing tomosynthesis into clinical practice. Addressing these implementation concerns can aid in a successful transition. There is a learning curve for radiologists and technologists. Longer interpretation times will be an initial concern for the radiologists, although this will improve over time. Other members of the team will be involved in the implementation, as there are substantial PACS and IT requirements. An important aspect of successful implementation is outreach to the community by informing and educating patients and referring health care professionals of this technology. Continued research and collection of outcome data are vital, as breast imagers around the country, and the world, continue to implement and learn more about the technology.

Acknowledgments

The authors thank Diana Frillici and Annette Wiebeld for their valuable input.

CHAPTER 5

Tomosynthesis in Screening Mammography

Melissa Durand | Liane E. Philpotts

A successful screening program relies on the ability of radiologists to detect potential malignancies while maintaining an acceptably low recall rate. To do so requires rigorous adherence to quality controls for both personnel and equipment, as warranted by the US Food and Drug Administration (FDA) and the Mammography Quality Standards Act. The controversy that follows screening mammography has largely focused on patient anxiety and increased health care costs due to the number of false alarms and the additional work-up these cases entail.

The hallmark of tomosynthesis is the dual benefit of decreasing false positives while increasing cancer detection in screening mammography. Tomosynthesis allows radiologists to scroll through thin slices of breast tissue, reducing superimposed tissue and the structured noise that limits conventional two-dimensional (2D) mammography. This permits enhanced lesion detection and facilitates lesion margin analysis of both benign and malignant findings. In addition, overlapping tissue can be confidently assessed as normal, and unnecessary recalls can be obviated.

How to Read Screening Mammograms With Tomosynthesis

Batch reading of analog screening was a cost-effective method because labor and time to load and take down films on an alternator made it impractical to read screening cases online. Even for a few years during the transition to digital mammography, in which prior analog images were still needed for comparison, batch reading was still the most practical approach. However, when a practice achieves a state in which the current and recent prior images are all digital, reading online is feasible. Over time, due to tomosynthesis, practices may find that fewer patients are in the recall or follow-up diagnostic pool, and the radiologist has more time to read screening cases online. Thus, although individual tomosynthesis screening cases take more time to view and interpret, overall the caseload and workflow are improved.

Tips for interpreting tomosynthesis images are discussed in Chapter 7, but a few topics are worth repeating here. Reading any mammogram requires the undivided attention of the radiologist, but reading tomosynthesis cases requires even more concentration. Reading a large number of screening tomosynthesis exams consecutively can potentially be more tiring compared with 2D mammography interpretation. Distractions are common in busy practices, but attempts must be made to minimize them. Taking breaks frequently during the day between cases is also recommended to avoid excessive fatigue.

Much attention has been given to the increased time required to interpret tomosynthesis exams. Given the larger number of images and increased amount of information inherent in tomosynthesis screening, it is inevitable that the exams will take longer to read.

However, radiologists quickly become accustomed to the tomosynthesis hanging protocol, and conversely having only 2D images to interpret seems uncomfortably limited. In addition, it must be recognized that the increase in time required to read tomosynthesis screening exams is balanced by the reduction in time required for diagnostic studies.

A common concern is whether review of previous tomosynthesis images is necessary when assessing subsequent years' exams. Although individuals may have their own personal protocols, routine review of prior tomosynthesis exams is generally not necessary. Comparing the prior 2D images usually suffices; however, if questionable areas are noted on the current exam, scrolling through the prior tomosynthesis slices is greatly beneficial.

As with reading 2D mammograms, assessing subtle changes over time is essential for detection of early malignancies. Although many cancers will appear more obviously spiculated or distorted on tomosynthesis images compared with 2D images, not all malignancies will have this characteristic appearance. Some cancers will still be identified only as a very subtle focal asymmetry or mass. These findings require careful attention and recall for diagnostic evaluation.

The use of tomosynthesis in both the craniocaudal (CC) and mediolateral oblique (MLO) projections is very important in obtaining the full benefit of tomosynthesis. Although the MLO view may capture more of the breast tissue than the CC view, the CC view produces better compression and separation of tissue that is more uniform from year to year, making the reader's assessment of changing tissue patterns more confident. There is evidence that suspicious lesions are more frequently detected on the CC than the MLO view, making the CC view essential to mammographic assessment. The CC view also allows for more precise lesion localization information. The benefit of performing screening tomosynthesis in the MLO view only is the reduction of overall radiation exposure, although this may be offset by the loss of potentially vital information provided by the CC tomosynthesis view.

How Is Tomosynthesis Reducing Recall Rates?

The fifth edition of the American College of Radiology Breast Imaging Reporting and Data System (ACR BI-RADS) Atlas states that a recall rate of up to 12% is acceptable for screening mammography. In 2013, results from the Oslo Tomosynthesis Screening Trial were published comparing conventional digital mammography alone with digital mammography plus tomosynthesis. In this single-institution prospective study of 12,631

screening exams, a 15% reduction in false-positive recalls was seen with the use of tomosynthesis. In the United States in 2014, a multicenter retrospective study involving both academic and community-based practices reviewed nearly half a million screening exams and also found a 15% reduction in recall rates, solidly corroborating the Oslo findings. Additional single-institution studies have shown significant reductions in recall rates (15% to 30%) since implementing tomosynthesis.

Although reduced recall rates are noted across all patients, the rates are variable, depending on breast density and patient age. More significant reductions are noted in younger women and in those with dense tissue. In addition, in women undergoing baseline mammography, in which interpretation is more challenging due to lack of comparisons, tomosynthesis significantly reduces recall rates by up to 50%. For practices with limited resources, such findings are important to consider in triaging which patients preferentially receive tomosynthesis.

Technical Issues

In some situations, tomosynthesis imaging can prevent what otherwise would require additional imaging for technical reasons. On 2D mammography, artifacts from deodorant or radiopaque lotions preclude adequate assessment of the tissues beneath. Deodorant, talc, or skin lotion artifact can be readily identified on the skin surface with tomosynthesis. Upon scrolling a few slices beyond the dermal surface, the tissue deep to the skin will be seen with clarity, and the need for additional tangential views or repeat imaging is avoided (Fig. 5.1). Superimposed hair can also produce an artifact that may simulate a mass. Hair artifact may appear superimposed on the 2D image, but it does not appear on the tomosynthesis slices because it is above and not within the compression plates (Fig. 5.2).

Asymmetry

False positives in conventional 2D mammography are often the result of superimposed tissue and frequently recalled as asymmetries. With tomosynthesis, careful scrolling through areas of suspected asymmetry often reveals layers of fibroglandular tissue, overlapping at different planes, without evidence of an underlying mass. By virtue of its ability to separate overlapping tissue, tomosynthesis disperses deceptive 2D asymmetries and can resolve these potential false-positive findings as normal

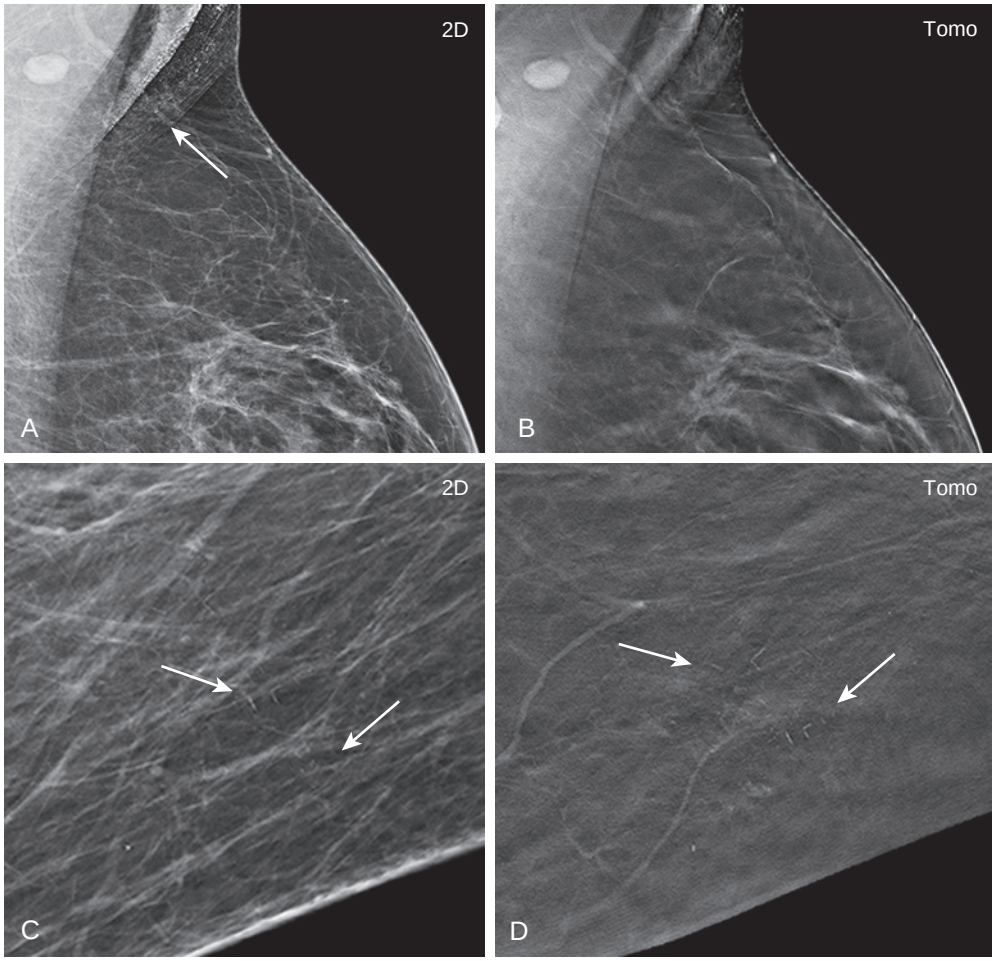


FIG. 5.1 Deodorant and talc artifact. (A) Abundant deodorant artifact is noted in the left axillary region on the two-dimensional image of a screening mammogram *(arrow)*. **(B)** Tomosynthesis slice images just internal to the skin, eliminates the finding, indicating the artifact was located in the skin and permits adequate assessment of the underlying tissues in the axillary area. **(C)** In another case talc in the inferior right breast has the appearance of fine pleomorphic calcifications *(arrows)*. **(D)** The finding is captured on the peripheral tomosynthesis slice *(arrows)*, indicating it is localized to the skin surface at the same level of multiple visible skin pores. Subsequent tomosynthesis slices deep to the skin showed no abnormality (not shown).

fibroglandular tissue or other benign entities, such as crossing Cooper ligaments or tortuous vessels. Lower recall rates are seen for all mammographic findings—asymmetries, calcifications, masses, and architectural distortion—with the most marked decline in the recall of asymmetries (Fig. 5.3).

Calcifications

The detection of calcifications on tomosynthesis has been controversial. Early prototype studies had data acquisition times of as long as 20 seconds, which introduced the possibility of motion artifacts potentially obscuring calcifications. In addition, calcifications can be spread across multiple tissue planes or exist in loose groups. This may limit the sensitivity of tomosynthesis when viewed in 1-mm intervals because the individual thin slices may not capture the entire group of calcifications if the group occupies more than a few mm of breast tissue. However, tomosynthesis units currently in clinical use can acquire images in as little as 4 seconds. In some cases, overlapping tissue can obscure fine calcifications or small groups of calcifications, and thus tomosynthesis can actually improve their detection and characterization. Importantly, tomosynthesis images are usually read in conjunction with a 2D image, whether conventional or synthesized, and this combined interpretation should permit identification of all calcifications at least equal to if not better than 2D mammography alone.

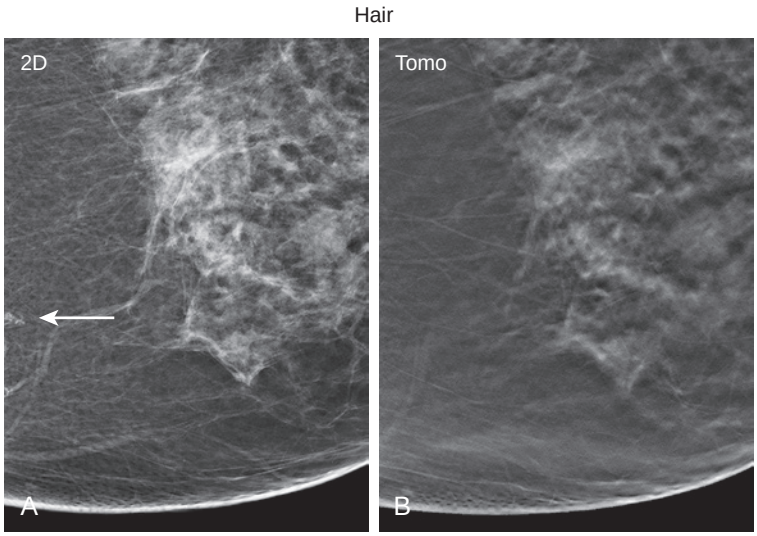


FIG. 5.2 Hair artifact. (A) Overlying hair is seen as an irregular shaped density *(arrow)* in the posterior medial left breast on this two-dimensional craniocaudal view of a screening mammogram in a 66-year-old woman. **(B)** The tomosynthesis slices show no such finding because the hair is usually located superior to the compression plate.

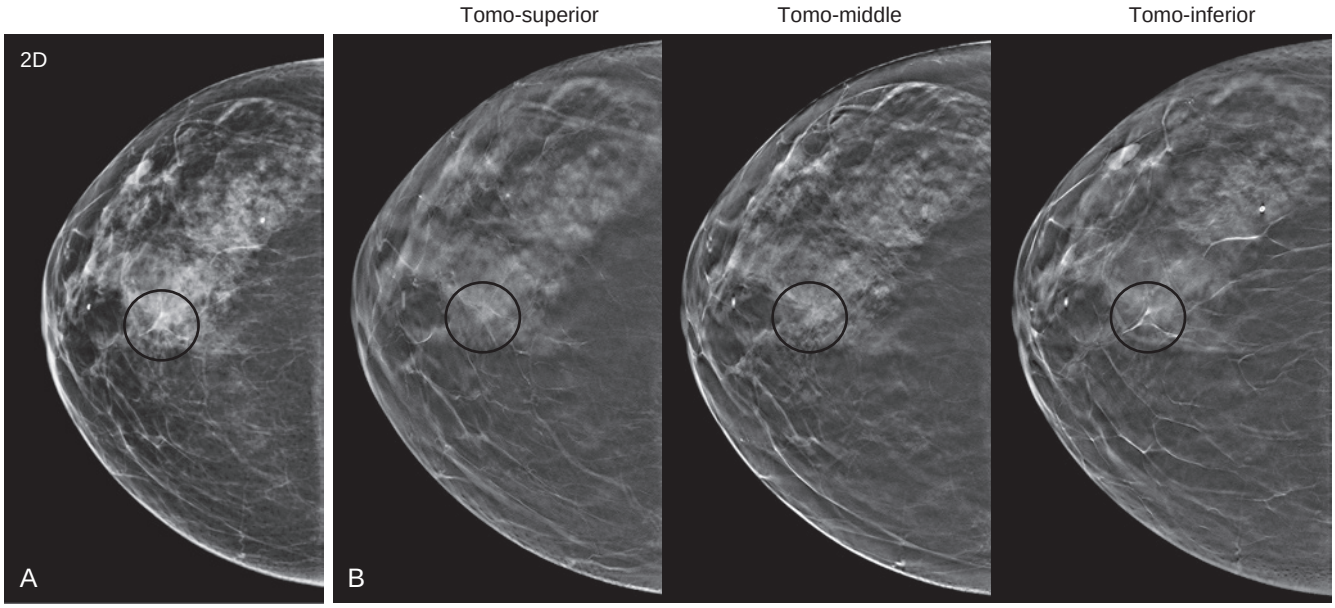


FIG. 5.3 Asymmetry. (A) Screening mammogram in a 72-year-old woman shows an irregular asymmetry *(circle)* centrally on the two-dimensional craniocaudal view. **(B)** Tomosynthesis slices in the superior, middle, and inferior regions demonstrate normal tissue with no underlying mass *(circles).* No recall was necessary.

The localization feature is fundamental to decreasing recalls for many dermal calcifications or deodorant artifacts. A quick glance at the localizer will definitively tell the radiologist where the calcifications are located. If the calcifications are at end slices of the dataset, then they are on the skin surface (Fig. 5.4). Importantly, only those skin surfaces in contact with the receptor or compression paddle will be visualized in those bookend slices. Some dermal calcifications may also be captured tangentially. A correlation between the MLO and CC tomosynthesis image series usually permits the confident characterization of most dermal calcifications. This ability to precisely localize some calcifications to the skin surface permits definitive benign assessments of these findings.

Other examples of typically benign calcifications that can be better characterized by tomosynthesis include vascular calcifications, milk of calcium, and fat necrosis. As overlapping tissue is cleared away, milk of calcium can be better visualized layering dependently within benign microcysts, averting recall for magnification views (Fig. 5.5). 2D views of linear vascular calcifications may also be difficult to discern from suspicious ductal calcifications; however, with tomosynthesis the vessel itself can appear and the reader can confidently see the calcifications associated with the vessel (Fig. 5.6). Fat necrosis may produce rim calcifications around lucent fat-containing masses. This may be better appreciated in the tomosynthesis slice images, in which the calcifications

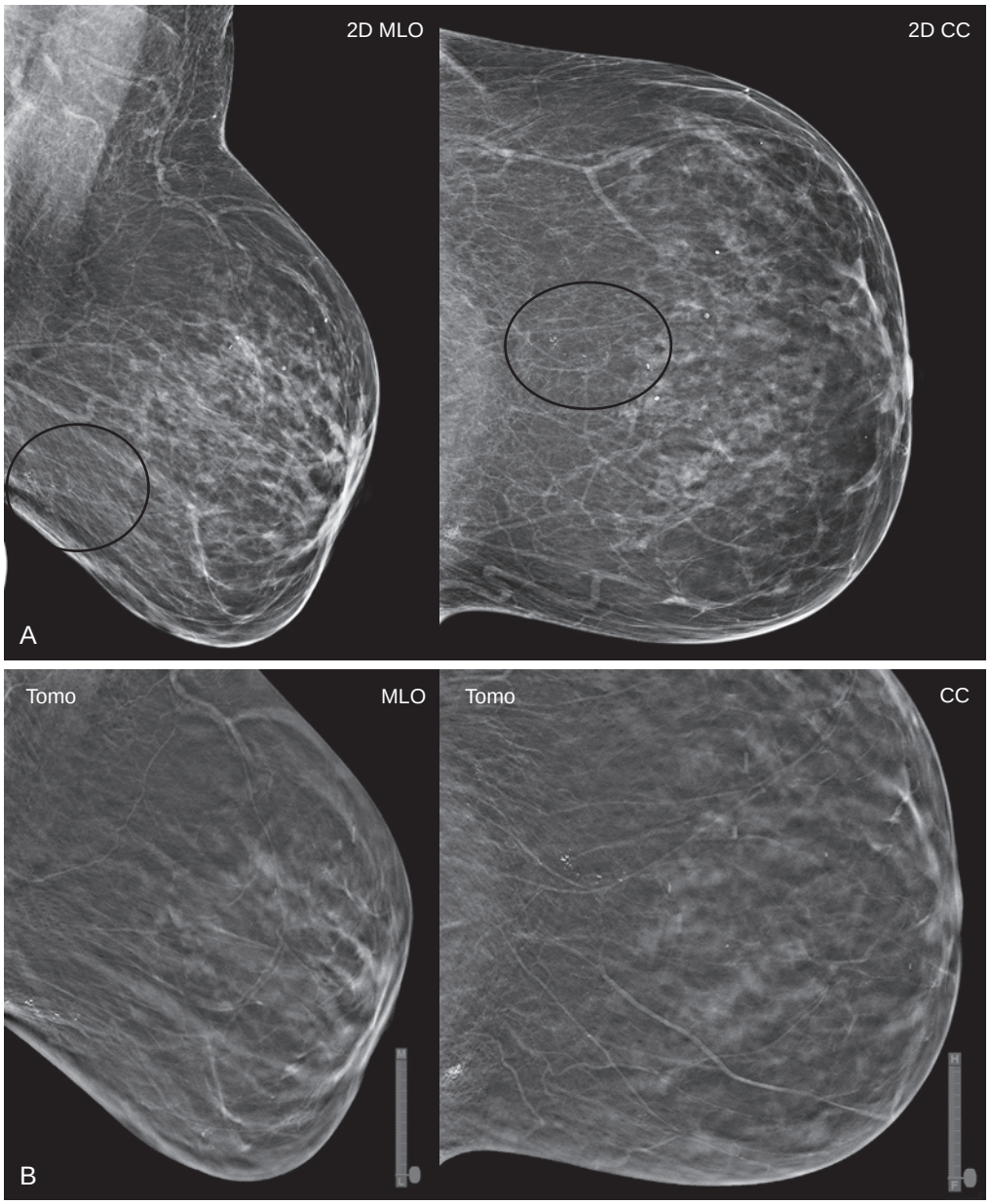


FIG. 5.4 Skin calcifications. (A) Screening mammogram in an 80-year-old woman shows what appear to be heterogeneous calcifications in a linear distribution in inferior central left breast on the two-dimensional images *(ovals)*. **(B)** Three-dimensional tomosynthesis images demonstrate the calcifications on the first slice of the study, correlating with the inferior skin surface. No recall was necessary.

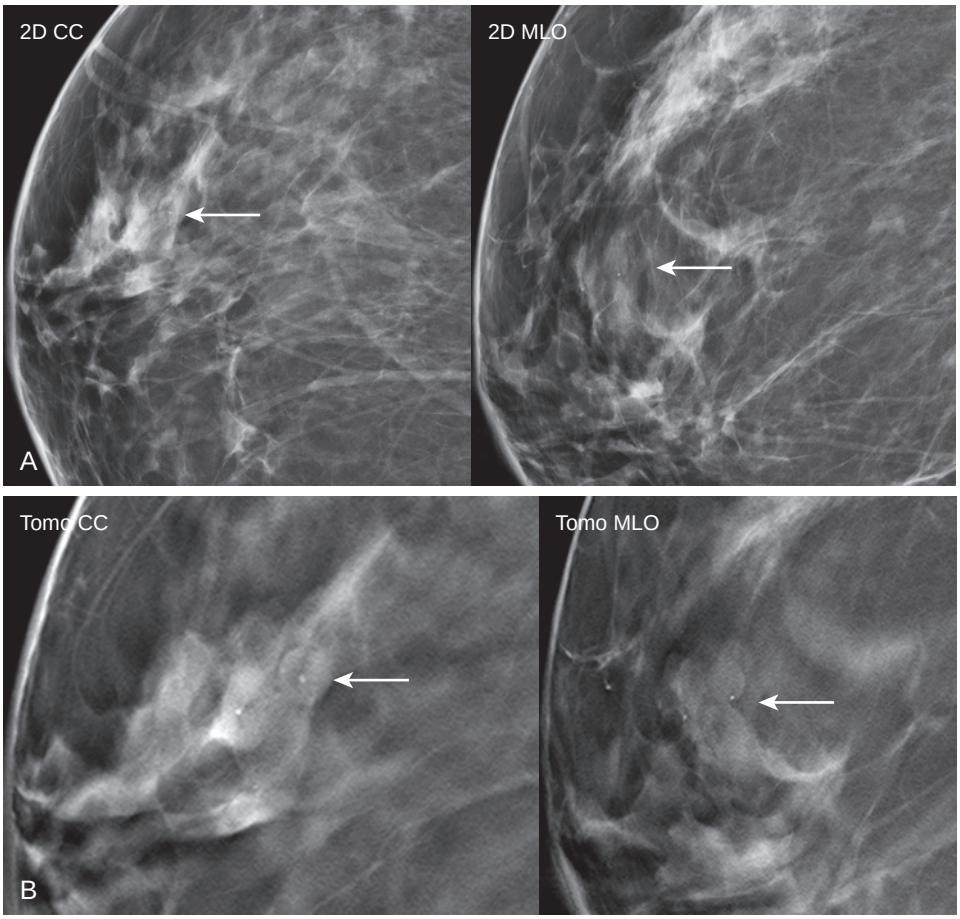


FIG. 5.5 Calcifications within a cyst. (A) Screening mammogram in a 54-year-old woman with scattered fibroglandular tissue demonstrates calcifications *(arrows)* in the retroareolar right breast on the 2D images. **(B)** Tomosynthesis images better demonstrate the punctate calcifications *(arrows)* on the craniocaudal view that are seen dependently on the MLO view at the periphery of a cluster of small masses (cysts).

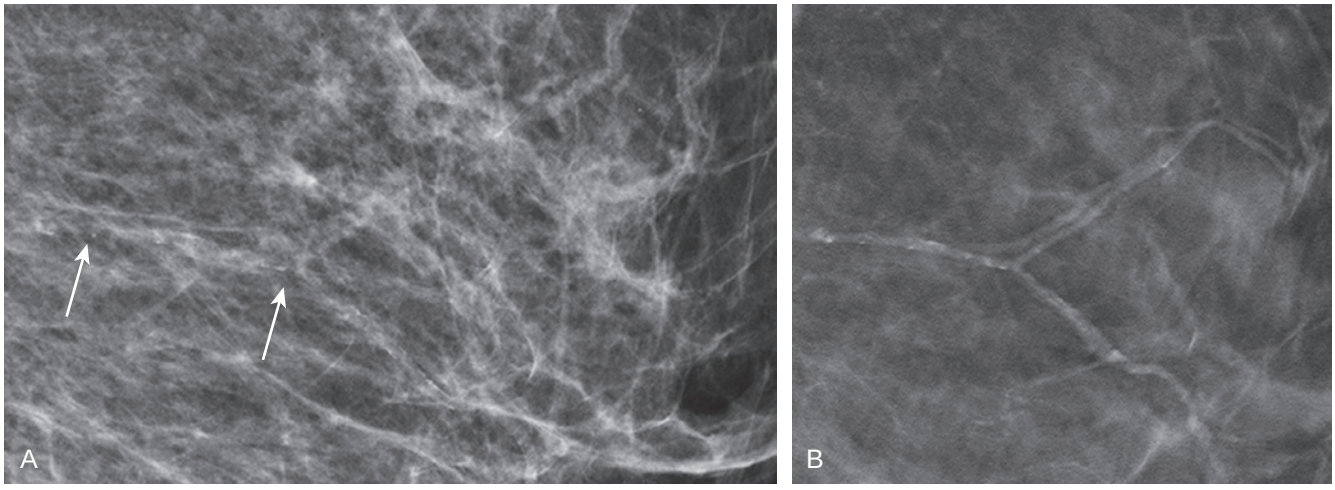


FIG. 5.6 Vascular calcifications. (A) Screening mammogram in a 57-year-old woman shows faint calcifications in a linear distribution on the two-dimensional images *(arrows)*. **(B)** Tomosynthesis image clearly depicts the calcifications along the walls of a vessel.

are noted to be associated peripherally with the fatty mass. Postoperative dystrophic calcifications are further discussed in Chapter 12.

Mass

The ability of tomosynthesis to dispel superimposed tissue can also improve the assessment of masses. For example, surrounding tissue may obscure the normal fatty hilum of a benign lymph node. However, with tomosynthesis these hila can often be seen with such clarity so as to render a recall unnecessary (Fig. 5.7). Other typically benign masses, such as lipomas and hamartomas, can be seen with more frequency and clarity on tomosynthesis imaging. In some cases the glandular density within or surrounding a hamartoma can appear irregular and raise concern. Tomosynthesis nicely demonstrates the mixed fatty and fibroglandular tissue surrounded by a pseudocapsule that cannot often be appreciated on 2D images (Fig. 5.8).

Multiple, bilateral, circumscribed masses may also be plainly visible after layers of breast tissue are scrolled away, and a benign assessment can be confidently made. Multiple cysts or fibroadenomas that were previously unrecognized without tomosynthesis are not uncommonly encountered. Such cases do not require recall unless a dominant or otherwise suspicious mass is present among the other benign-appearing masses. Overlapped, looped, or tortuous blood vessels may simulate a mass on conventional 2D imaging. The corkscrew nature of the looped vessel may be clearly seen when scrolling through tomosynthesis images, and a recall can be avoided (Fig. 5.9).

Just as dermal calcifications can be localized to the skin with tomosynthesis, dermal masses can be definitively identified as superficial and not within the breast tissue when visualized on the bookend images (Fig. 5.10).

How Is Tomosynthesis Increasing Cancer Detection?

An effective screening program must not only limit false positives; it must identify true positives. With tomosynthesis, large-scale studies have demonstrated increased rates of cancer detection by approximately 30%, with the addition of tomosynthesis to conventional mammography. Furthermore, these studies demonstrated increased detection of invasive cancer by approximately 40% with tomosynthesis. Critics of mammography often raise the argument of overdiagnosis. However, with tomosynthesis the increase in cancer detection is predominantly invasive cancers, those that have already grown beyond the ductal system, and are more likely to potentially be more lethal.

So what is being recalled? How are more invasive cancers being found? The same clarity that arises for benign cases after superimposed tissue is resolved can also be seen with lesions requiring a recall.

Architectural Distortion

The increased conspicuity provided by tomosynthesis can be seen most dramatically for architectural distortion, whether as a solitary finding or in association with a mass. In many cases the delicate lines of a distortion can be hidden behind layers of fibroglandular tissue on 2D imaging. However, after this tissue is scrolled away, distortions can emerge. In some cases the distortion is only visible on tomosynthesis images and cannot be discerned on 2D imaging (Fig. 5.11).

Similar to conventional imaging, it remains a challenge to differentiate between distortions caused by benign etiologies,

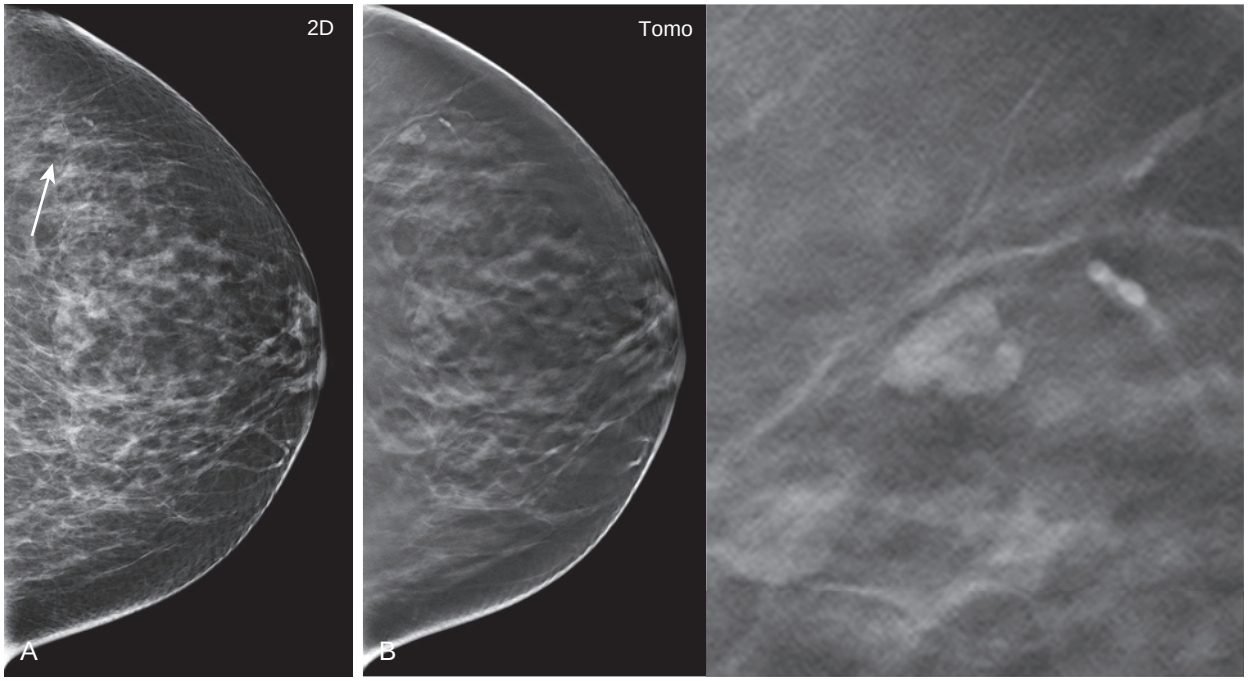


FIG. 5.7 Benign lymph node. (A) Screening mammogram in a 50-year-old woman with heterogeneously dense breasts demonstrates an oval mass *(arrow)* in the upper outer left breast on the 2D craniocaudal view. **(B)** Tomosynthesis image clearly demonstrates the normal fatty hilum of a benign lymph node, is not appreciable on the 2D images.

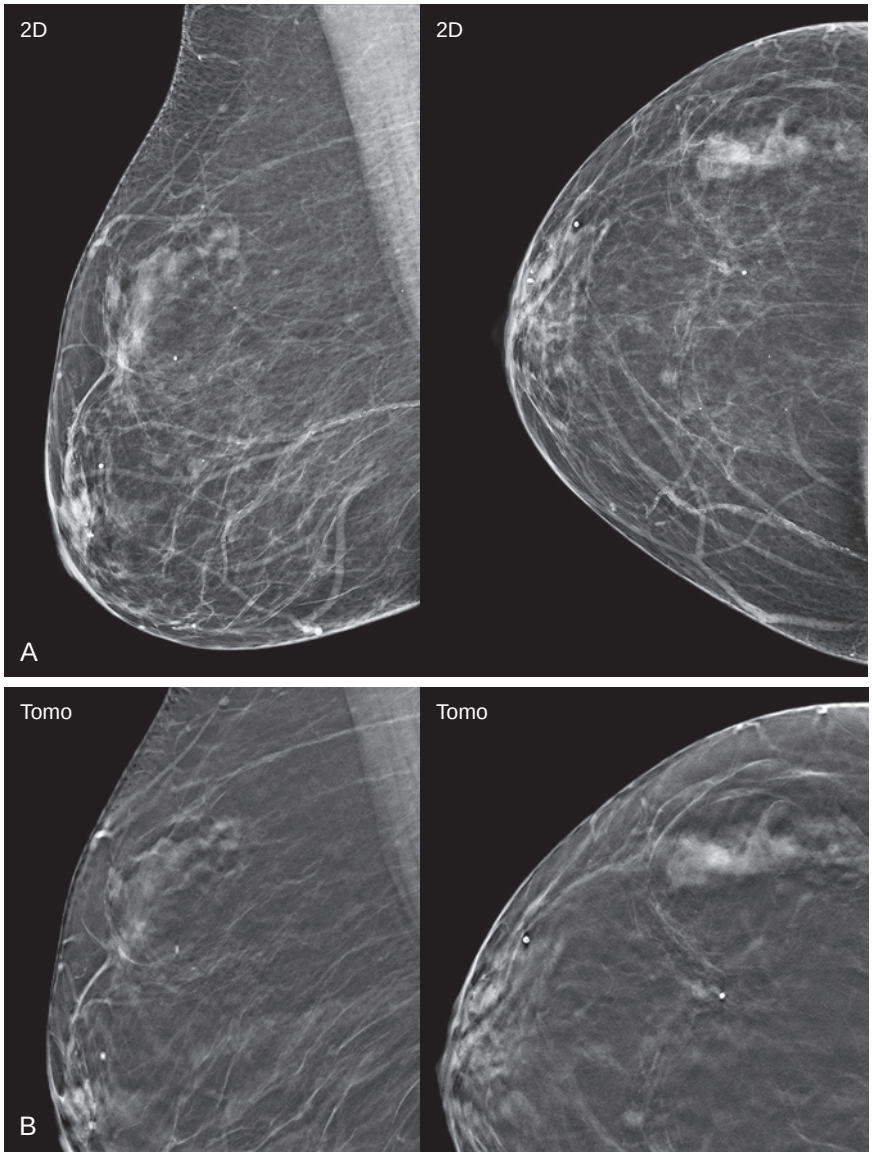


FIG. 5.8 Hamartoma. (A) Two-dimensional mediolateral oblique and craniocaudal images of the right breast show an irregular focal asymmetry in the upper outer quadrant. **(B)** Tomosynthesis slice images show the density to lie within a larger area of predominantly fatty tissue surrounded by a thin linear pseudocapsule, indicating the entire area is a hamartoma.

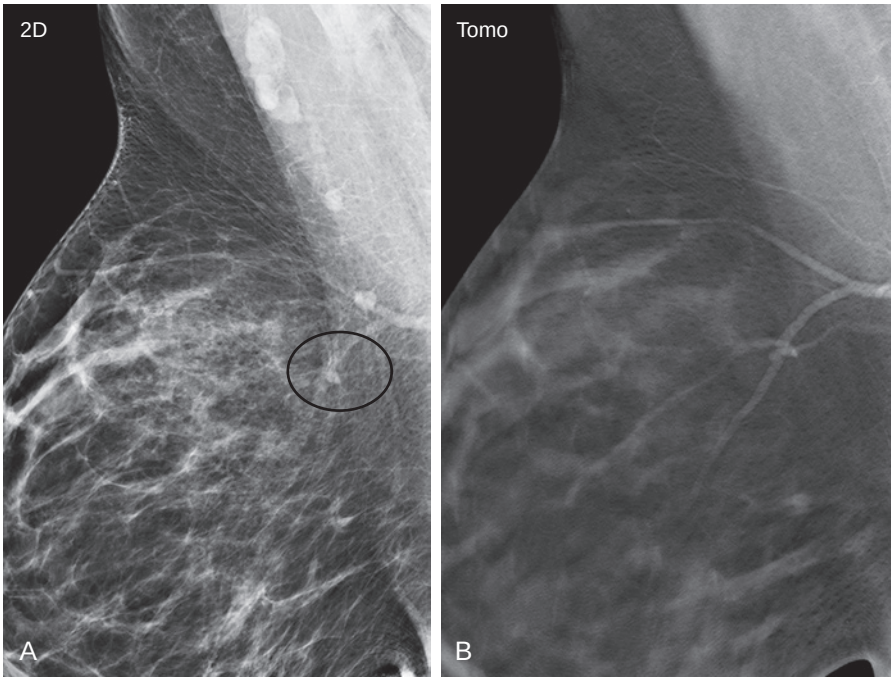


FIG. 5.9 Tortuous vessel. (A) Screening mammogram in a 49-year-old demonstrates a possible oval mass *(oval)* in superior right breast at posterior depth on the two-dimensional mediolateral oblique view. **(B)** Tomosynthesis image definitively depict a tortuous vessel at this location. No recall was necessary.

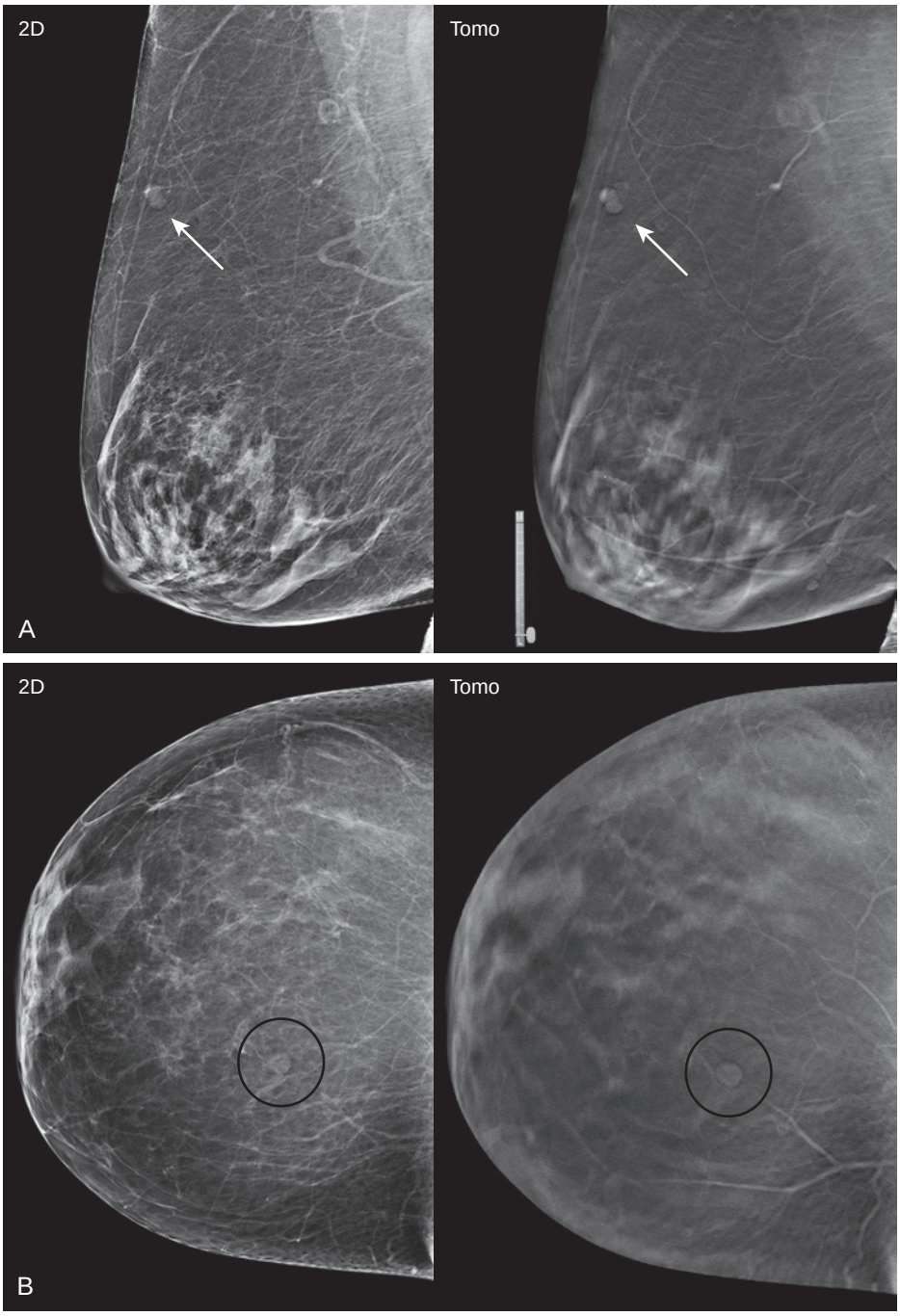


FIG. 5.10 Skin findings, mole. (A) Screening mammogram shows a lobulated mass *(arrows)* adjacent to a vessel on the two-dimensional right mediolateral oblique view. Tomosynthesis image shows the finding on the first slice of the set, indicating it is on the lateral skin surface. **(B)** In another case a round mass is noted on the right craniocaudal view. Tomosynthesis image shows it on the first slice, at the inferior skin surface and skin pores, consistent with a benign dermal lesion *(circles)*.

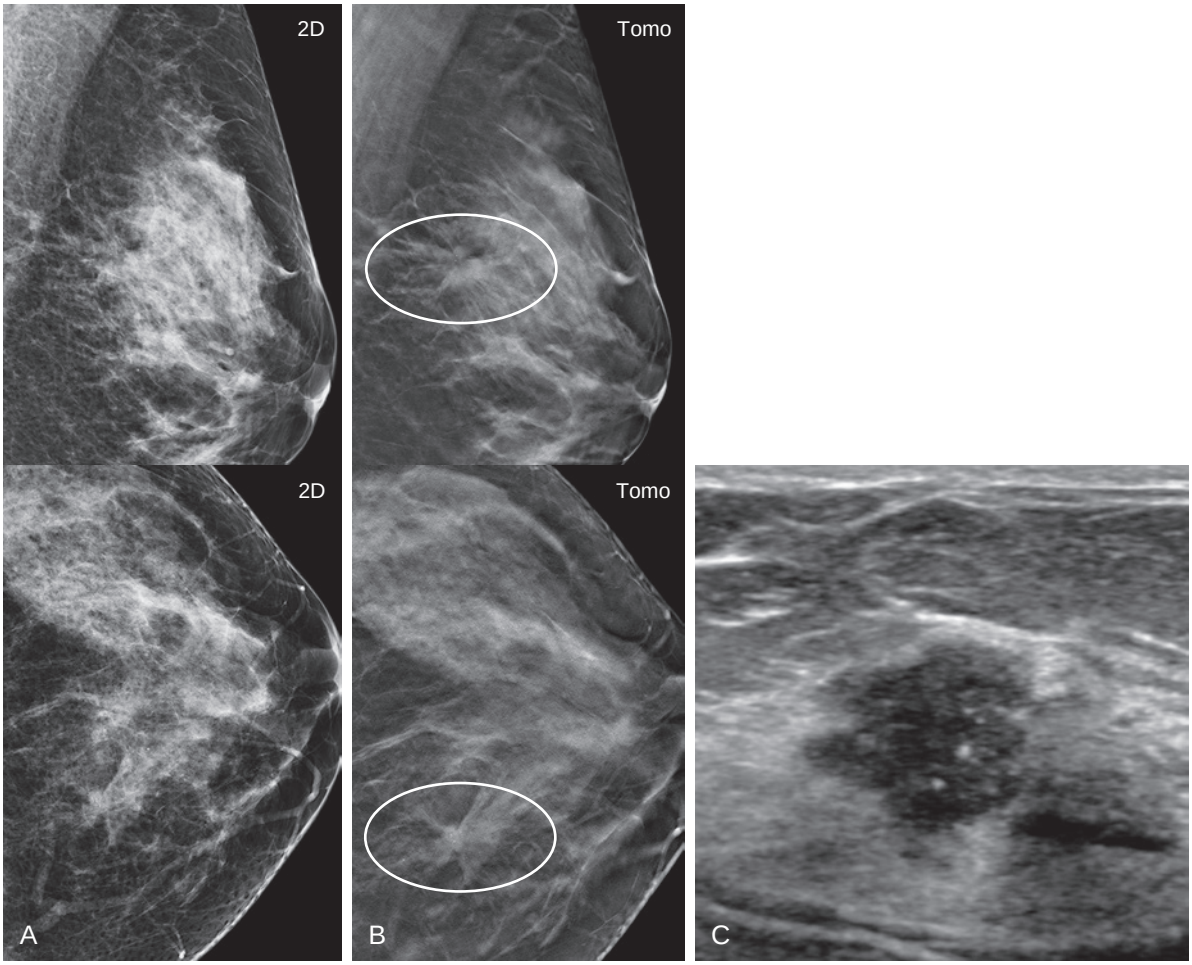


FIG. 5.11 Architectural distortion. (A) 46-year-old woman with heterogeneously dense breasts was recalled from screening for architectural distortion in the left breast at the 11-o'clock position, **(B)** more clearly shown on tomosynthesis images *(ovals)*. **(C)** Subsequent ultrasound correlate was found. Ultrasound-guided core needle biopsy and excision indicated invasive ductal carcinoma, T1cN0, ER/PR/Her2+.

such as radial scars, and those caused by cancers. However, there is evidence that many architectural distortions detected only on tomosynthesis imaging represent malignancy and emphasizes the importance of identifying these findings. After a distortion is detected with tomosynthesis, it can sometimes be discerned on careful inspection of current and prior 2D images. In the event that a distortion is detected on tomosynthesis screening, these cases should be recalled for additional evaluation. The management of architectural distortion is further discussed in Chapter 10.

Masses

Careful inspection of margins is essential to determine whether a mass is suspicious and requires further work-up. Just as tomosynthesis can clear a path to see distortions, it can help to resolve the true margins of a mass. If the margins remain irregular or indistinct after overlapping tissue is cleared, these masses should be recalled. In many cases a spiculated margin may only be seen on the tomosynthesis images, and it may be those spiculations that draw the reader's eye to the abnormality (Fig. 5.12).

In addition, if a lesion is seen initially in one projection, the localization feature on tomosynthesis images can help to pinpoint the finding on the orthogonal view. This can help to target the reader to a specific area and to sometimes identify a correlate. In this manner many asymmetries seen on only one conventional view may be more accurately defined as masses by using tomosynthesis.

Calcifications

Although many calcifications are readily visible on conventional mammography, in some cases superimposed tissue may obscure fine calcifications or result in underestimation of the true extent of the calcifications. In addition, as the reader scrolls through the layers of breast tissue around a suspected abnormality, intralesional calcifications can emerge, which can heighten the reader's suspicion and prompt a recall (Fig. 5.13).

Asymmetries

An asymmetry that does not resolve into normal fibroglandular tissue while scrolling through tomosynthesis images is one that should be considered for recall. With 2D screening, asymmetries have relatively low positive predictive values because many are suboptimally characterized and simply represent superimposed tissue. With tomosynthesis there are fewer one-view asymmetries because true lesions are better identified and characterized on multiple projections. Developing asymmetries,

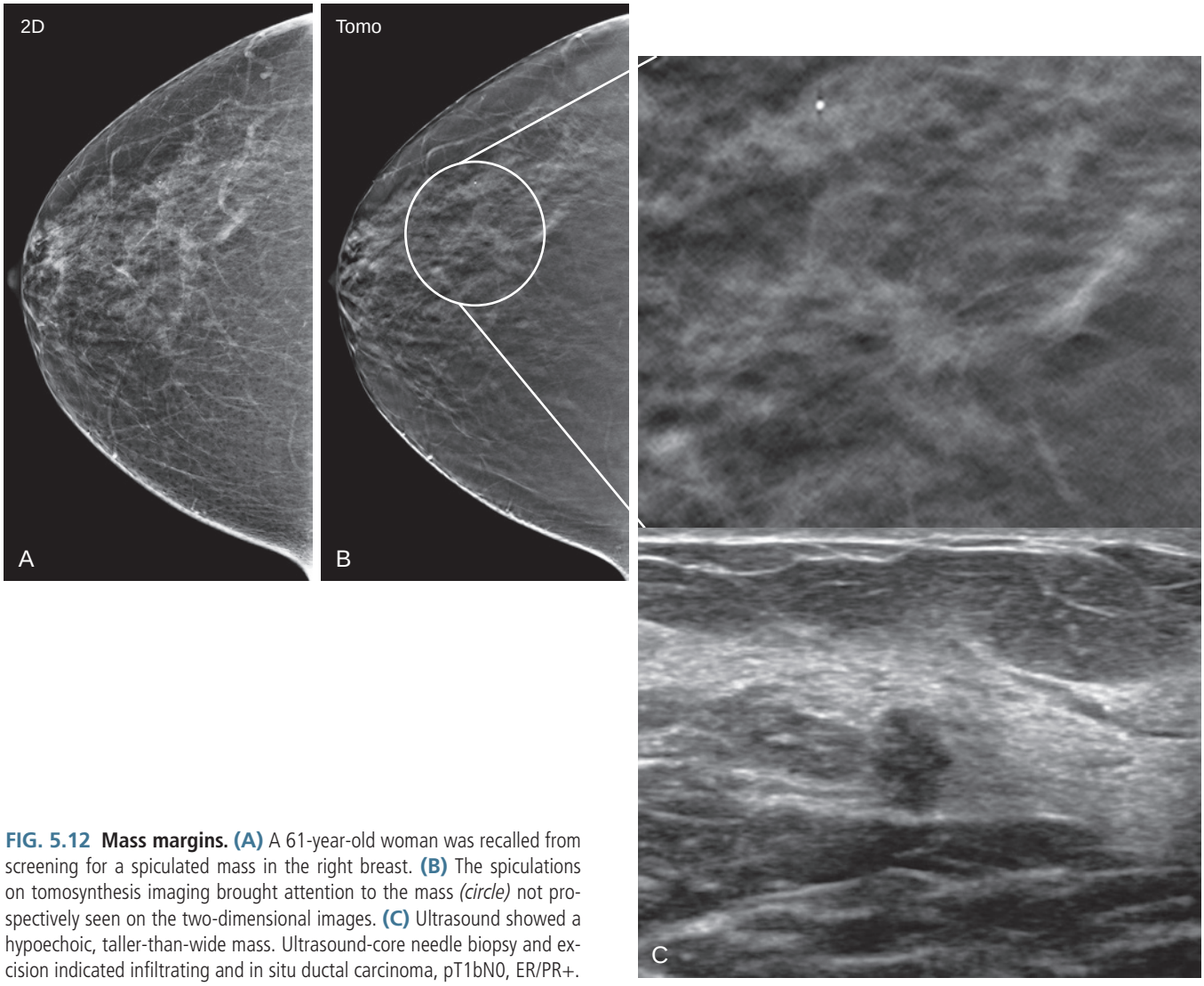


FIG. 5.12 Mass margins. (A) A 61-year-old woman was recalled from screening for a spiculated mass in the right breast. **(B)** The spiculations on tomosynthesis imaging brought attention to the mass *(circle)* not prospectively seen on the two-dimensional images. **(C)** Ultrasound showed a hypoechoic, taller-than-wide mass. Ultrasound-core needle biopsy and excision indicated infiltrating and in situ ductal carcinoma, pT1bN0, ER/PR+.

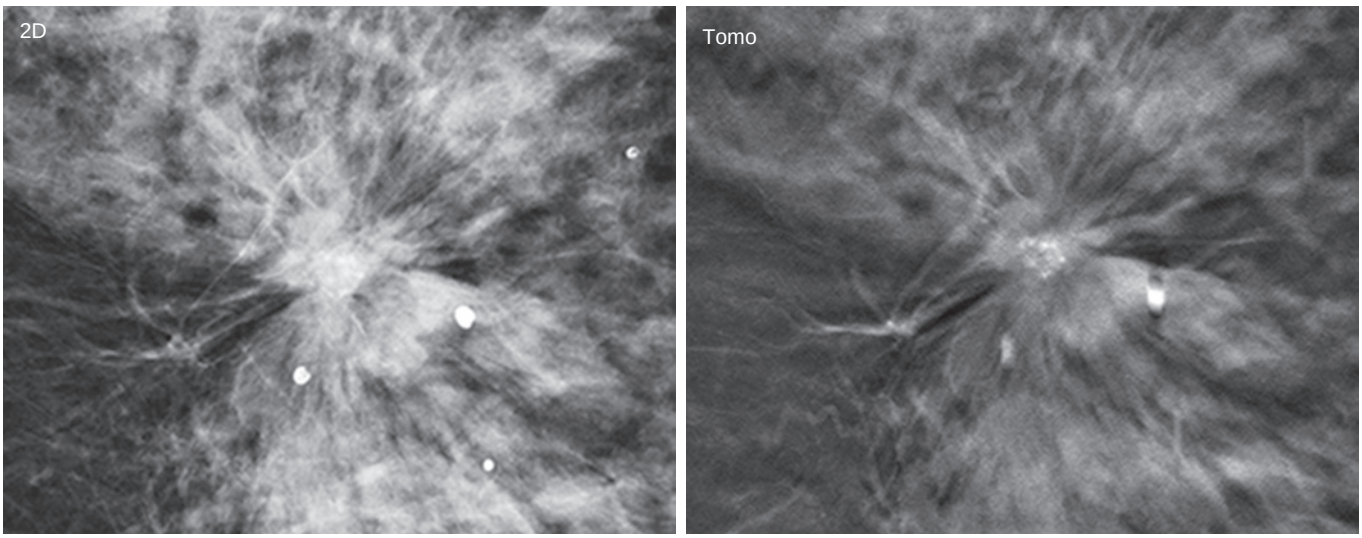


FIG. 5.13 Intralesional calcifications. Screening mammogram in a 57-year-old with heterogeneously dense breasts shows intralesional calcifications that are better seen within the spiculated mass on the tomosynthesis slice compared with the 2D image. Final pathology was invasive ductal carcinoma, T1cN0, ER/PR/Her2+.

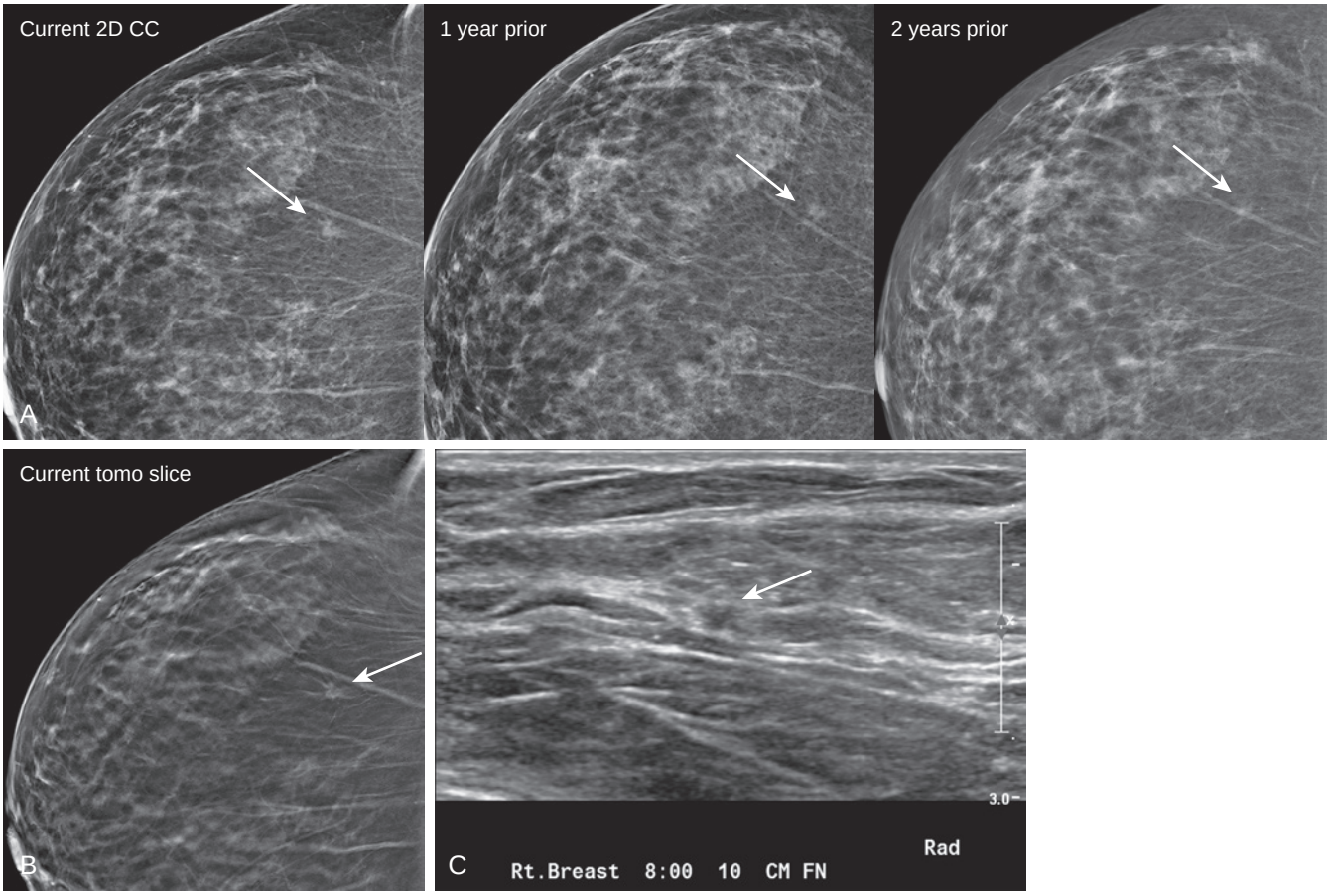


FIG. 5.14 Developing asymmetry. (A) Close-up of a screening mammogram in a 70-year-old woman shows a focal asymmetry *(arrows)* posterolaterally in the CC view, which is noted to be developing compared with the prior 2 years' exams. **(B)** Tomosynthesis slice views show a small mass with spiculated margins. **(C)** Ultrasound correlate is a vague, ill-defined hypoechoic mass *(arrow)*. Ultrasound-core needle biopsy and excision indicated well-differentiated invasive ductal carcinoma, with prominent tubular architecture; ER+, PR+, Her2–, pT1b N0.

as has been the practice in 2D mammography, should always be given careful consideration. Not all malignancies appear obvious on tomosynthesis because some still present as subtle findings (Fig. 5.14).

Using Synthesized (Two-Dimensional) Mammograms

FDA approval for tomosynthesis units in the United States requires its use in combination with 2D mammography. This is a reasonable requirement because comparing exams is difficult on tomosynthesis images alone. 2D images are useful to compare one breast to another or from one exam to another. They are also important in the detection and evaluation of calcifications. The 2D image supplies the *big picture* necessary to make those assessments. However, obtaining 2D and tomosynthesis images together increases the total radiation dose. Keeping radiation doses as low as possible in screening mammography is desirable. The synthesized 2D mammogram software constructs a 2D image from the tomosynthesis data, thereby yielding the necessary 2D image while reducing the radiation dose back to levels similar to 2D alone.

Synthesized mammograms have a different *look* than regular 2D digital mammograms. There is less contrast, making variations in tissue density and some masses more difficult to perceive. However, calcifications tend to have increased conspicuity, facilitating the perception and assessment in this finding which can be challenging on the tomosynthesis slice images alone. Architectural distortion is also enhanced with synthesized 2D imaging (Fig. 5.15). Patients with implants or large breasts are especially good candidates for synthesized 2D imaging because they already receive extra radiation from the additional exposures required to adequately image all tissues. Adding tomosynthesis to 2D mammography in such patients would further increase their radiation dose, whereas using synthesized 2D images permits these patients to receive the benefits of tomosynthesis without the additional radiation dose.

Challenges to Tomosynthesis Screening

Although there are many advantages to using tomosynthesis for screening, there are some challenges as well. Other than the increased interpretation time previously discussed,

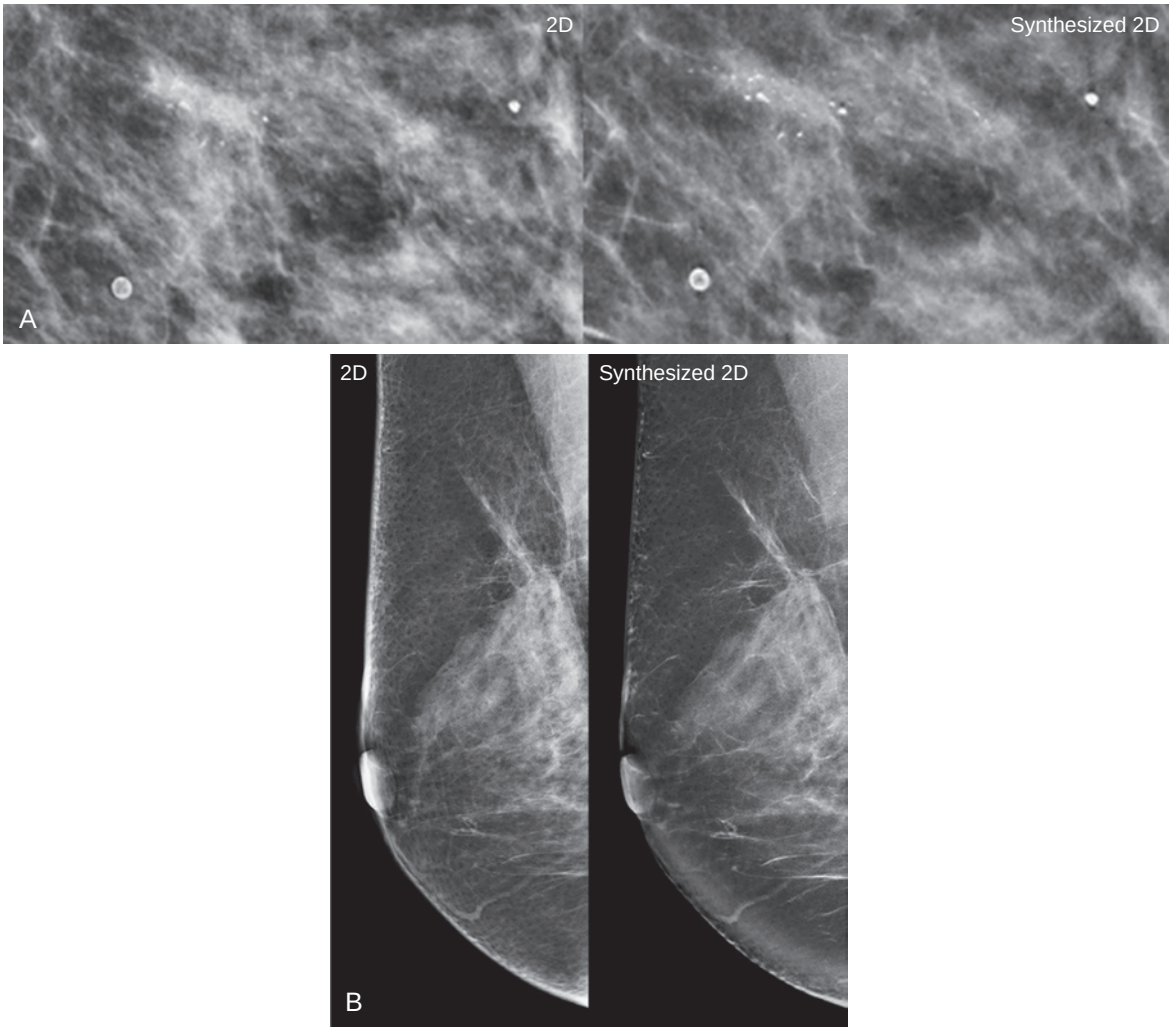


FIG. 5.15 Synthesized 2D mammograms. (A) Screening mammogram in a 54 year-old woman shows grouped calcifications in the left breast on the 2D and synthesized 2D images. The grouped pleomorphic calcifications are depicted clearly on the synthesized 2D image, better delineated from the surrounding tissue. Stereotactic biopsy revealed DCIS. **(B)** Screening mammogram in a 60-year-old woman shows architectural distortion in the upper right breast from a prior benign surgical biopsy. The radiating lines of the scar are better appreciated on the synthesized 2D images compared with the 2D image.

there is also a learning curve associated with tomosynthesis interpretation. Some radiologists may adapt to using the new technology quicker and easier than others will. Developing confidence in the modality involves reading many diverse cases. For practices recently adopting tomosynthesis or with limited resources, preferential use in screening over diagnostic mammography is recommended to maximize the number of cases that can be performed and interpreted. Following up on the outcome of recalled cases, with sonographic correlation when appropriate, is of great benefit.

The assessment of architectural distortion on screening tomosynthesis deserves special mention. Chapter 10 is devoted to this particular challenge in tomosynthesis; here are some highlights that bear repeating. Areas of true architectural distortion, due to prior surgery, may be found that were not apparent or were very subtle on 2D mammography. Careful documentation of patient history and annotation of scars on intake sheets or electronic reporting systems by the technologist is critically important. Given that architectural distortion detection is enhanced with tomosynthesis, there can be a tendency to overcall this finding when reading screening tomosynthesis exams. *Pseudo-distortions* can be questioned when intersecting or radiating lines are noted in adjacent tissue planes when scrolling through tissue, leading to an increase in false-positive recalls for this finding. However, architectural distortion must be given careful consideration due to its relatively high rate of malignancy. Using the basic rules of tomosynthesis interpretation—specifically, focused scrolling through the area on the predominant projection, localizing to a focused area, and assessment of that corresponding area on the orthogonal view—will usually help to either resolve or confirm the possibility of a true lesion.

As with conventional mammography interpretation, variations in individual radiologists' recall rates are similarly observed with tomosynthesis interpretation. Different radiologists have different thresholds for assessing a case as abnormal, resulting in variations in screening recall rates, cancer detection rates, and positive predictive values. Almost all radiologists experience some reduction in recall rates with tomosynthesis, but rates are variable. This may be due to the

individual's inherent confidence level, experience, and *trust* of tomosynthesis, and these recall rates may be observed to vary over time with experience. For example, some radiologists may still be uncomfortable not recalling a patient when a finding is prominent on the 2D image, even though it appears to resolve and not be localizable on the tomosynthesis images. Asymmetries may still be recalled despite the use of tomosynthesis. Particularly in dense tissues, assessing an area as normal remains challenging. As mentioned, close follow-up and review of recalled cases are instrumental in developing confidence and accuracy in tomosynthesis interpretation.

Computer-Aided Detection: To Use or Not To Use?

The value of computer-aided detection (CAD) in 2D mammography has been a source of debate since its inception. Although double reading of mammograms is not common in the United States, CAD can be a useful mechanism to reduce false-negative interpretation due to perception errors. However, its performance in 2D mammography is limited, with many false-positive marks due to superimposed tissue. Nonetheless, for some calcifications and mass lesions that might otherwise have been missed, CAD can improve the sensitivity of 2D mammography. However, it can also lead to more false-positive recalls and can even degrade some users' performance due to overdependence on the system.

The use of CAD in tomosynthesis has not been well studied because CAD systems specific for tomosynthesis are relatively new. With increasing demands on concentration required by radiologists when reading tomosynthesis cases, CAD may prove to be useful by reducing the rate of missed cancers due to fatigue and distraction. The marking of calcifications either on the 2D or synthetic 2D images or on individual tomosynthesis slices may be helpful as in 2D interpretation. With more areas on which to perform visual sweeps in tomosynthesis, the possibility of overlooking calcifications is relevant. The utility of marking mass lesions on tomosynthesis is more questionable. Flagging the 2D image has limited use, and markings on individual slices would generate a multiplicity of false positive and/or true marks, requiring a great deal of additional time and attention by the radiologist, likely limiting any potential benefit. Thus, there is much more to learn and consider as new technologies and strategies are developed in order to improve the tomosynthesis interpretation process so that the possibility of overlooking malignant lesions is minimized.

Downstream Effects of Tomosynthesis in Screening Mammography

The reduction of recalls in tomosynthesis screening will also result in a downstream effect of ultimately decreasing the diagnostic mammography patient pool. Moreover, superior diagnostic assessment translates into more definitive categorization of patients. Practices will likely see their positive predictive values for biopsy improve and more patients classified as BI-RADS 1 and 2 (negative/benign), with fewer patients requiring close mammographic follow-up. Certain populations needing closer attention but not specific follow-up, such as post lumpectomy patients, may be appropriately delegated to routine screening mammography.

As a result many more patients may be in the screening pool than before. Notably, given that routine CC and MLO tomosynthesis views are often adequate for thorough assessment of the breast tissue, a diagnostic exam begins to closely resemble a screening protocol. This results in speedier assessment of patients and greater throughput, which translates ultimately to cost savings.

Tomosynthesis Screening in Women With Dense Tissue

The reduced sensitivity of 2D mammography in women with dense breast tissue is well known. Attention to this limitation and interest in providing improved or supplemental imaging for women with dense tissue has raised the question of whether tomosynthesis provides sufficiently more accuracy in dense tissue. As mentioned above, tomosynthesis has been shown to be more useful in reducing recall rates in women with dense tissue than in women with fatty breast tissue. In addition, tomosynthesis increases the cancer detection rate over 2D mammography, largely due to uncovering cancers in areas of overlapping dense tissue that would otherwise be obscured. Despite this, detection of malignancy in dense tissue remains challenging, even with tomosynthesis.

There is evidence that the use of supplemental sonography screening can increase cancer detection in women with dense tissue; however, the additional cancer yield on such supplemental exams performed after tomosynthesis is less compared with after 2D mammography. There is no question that tomosynthesis increases the accuracy of mammography in women with dense tissue. Whether it will completely negate the need for other supplemental tests, such as breast sonography, remains to be determined.

Summary

Tomosynthesis has emerged as a superior form of screening mammography by virtue of its ability to increase cancer detection while decreasing recall rates. Both of these advantages are largely due to the reduction of masking effects of superimposed tissue. This allows true findings to be better visualized and characterized, and potential false-positive findings may be confidently assessed as benign. Reading screening tomosynthesis cases differs from reading 2D cases and involves a learning curve. The impact that tomosynthesis can have on screening depends on comprehensive understanding and use of this technology. Tomosynthesis has the potential to shift the benefits and harms of mammographic screening, such that many more women can benefit and both health care costs and lives will be saved.

CHAPTER 6

Tomosynthesis in Diagnostic Mammography

Reni Butler | Regina J. Hooley

Tomosynthesis will alter the clinical practice of diagnostic mammography. The standard diagnostic work-up of noncalcification lesions can be markedly abbreviated because fewer diagnostic views are required for lesion confirmation, characterization, and localization. Many patients, particularly those with masses, can proceed directly from routine tomosynthesis views to ultrasound, avoiding additional diagnostic mammographic views altogether. Although the value of tomosynthesis in the work-up of calcifications has not been well established, early clinical experience has shown tomosynthesis to be helpful in evaluating some types of calcifications. This is especially true for benign calcifications, such as early vascular, dermal, and dystrophic calcifications, in which tomosynthesis can reveal pathognomonic benign features that may be difficult to perceive on conventional two-dimensional (2D) mammographic views.

As in screening mammography, the improved visualization of lesion characteristics aids in achieving both greater sensitivity and specificity in the diagnostic setting. Both benign and malignant lesions can be assessed more accurately and with greater diagnostic confidence. For example, the subtle pseudocapsule of a hamartoma, which may be obscured by overlying dense breast tissue on 2D mammography, can be unveiled on tomosynthesis slices. Similarly, the spiculated margin or associated architectural distortion of a mass surrounded by dense breast tissue is often dramatically displayed on tomosynthesis, confirming a high probability of malignancy in a lesion that may otherwise be perceived as indeterminate. The exquisite sensitivity of tomosynthesis for fine detail can also reveal features within and surrounding breast cancers that could not be appreciated with conventional 2D mammography alone. For example, some breast cancers are shown to contain intralesional fat, which should not be misinterpreted as a sign of benignity.

Changes in Diagnostic Environment and Outcomes

Abbreviated Diagnostic Work-Up

In the conventional 2D diagnostic mammography environment, spot compression views are an essential diagnostic tool. By dispersing fibroglandular tissue within an area of interest, spot compression views are particularly useful in differentiating a mammographic density created by tissue overlap from a true lesion. Spot compression views help to characterize a true lesion by improving visualization of features, including mass margins. By reducing the masking effect of overlying breast tissue, tomosynthesis imaging precludes the need for many of the additional diagnostic views traditionally used in diagnostic mammography. Lesion features can often be assessed without obtaining spot compression or rolled, tangential, and other views (Fig. 6.1).

After implementing tomosynthesis, the number of diagnostic views required to reach a final assessment in screening recalls should be significantly reduced. Patients recalled from tomosynthesis screening typically require fewer additional views and more commonly proceed directly to ultrasound for an ultrasound-only work-up. This is particularly true for patients recalled for masses, in which standard craniocaudal (CC) and mediolateral oblique (MLO) tomosynthesis views often clearly reveal mass margins without the need for additional views. Despite the abbreviated diagnostic work-up, specificity can be maintained or even increased.

Among patients imaged in the diagnostic environment for reasons other than a screening recall, such as a clinical symptom or a Breast Imaging Reporting and Data System (BI-RADS) 3 follow-up, the number of additional views performed should also decrease. Diagnostic studies beginning with routine tomosynthesis MLO and CC views require fewer additional views, with the number of both spot compression views and even magnification views substantially reduced (Table 6.1).

Improved Accuracy and Shift in Use of BI-RADS Assessment Categories

The improved visualization of lesion features, such as mass shape and margins, facilitates a more accurate diagnostic assessment of the probability of malignancy. Cancers appearing mostly circumscribed or obscured on 2D images may be shown to have spiculated margins on tomosynthesis slices. Even small focal asymmetries may be revealed to represent suspicious masses on tomosynthesis (Fig. 6.2). The fine detail visible with tomosynthesis reduces the likelihood that a cancer would be missed or misinterpreted as a probably benign or benign finding.

Breast cancers are often more conspicuous on routine tomosynthesis CC and MLO views compared with 2D spot compression views, and some cancers are seen only on tomosynthesis. Indeed, in some cases, a 2D spot compression view may result in a false negative final interpretation. A cancer initially seen on tomosynthesis can appear to disperse on 2D spot compression, suggesting that the questioned lesion represented tissue overlap. In these cases, tomosynthesis shows the suspicious lesion more reliably than additional 2D views do and appropriately leads the work-up toward further evaluation and biopsy (Fig. 6.3).

Multiple authors have shown that diagnostic evaluation with routine tomosynthesis views could achieve equivalent or superior sensitivity and specificity compared with conventional 2D supplemental views. When combined with tomosynthesis,

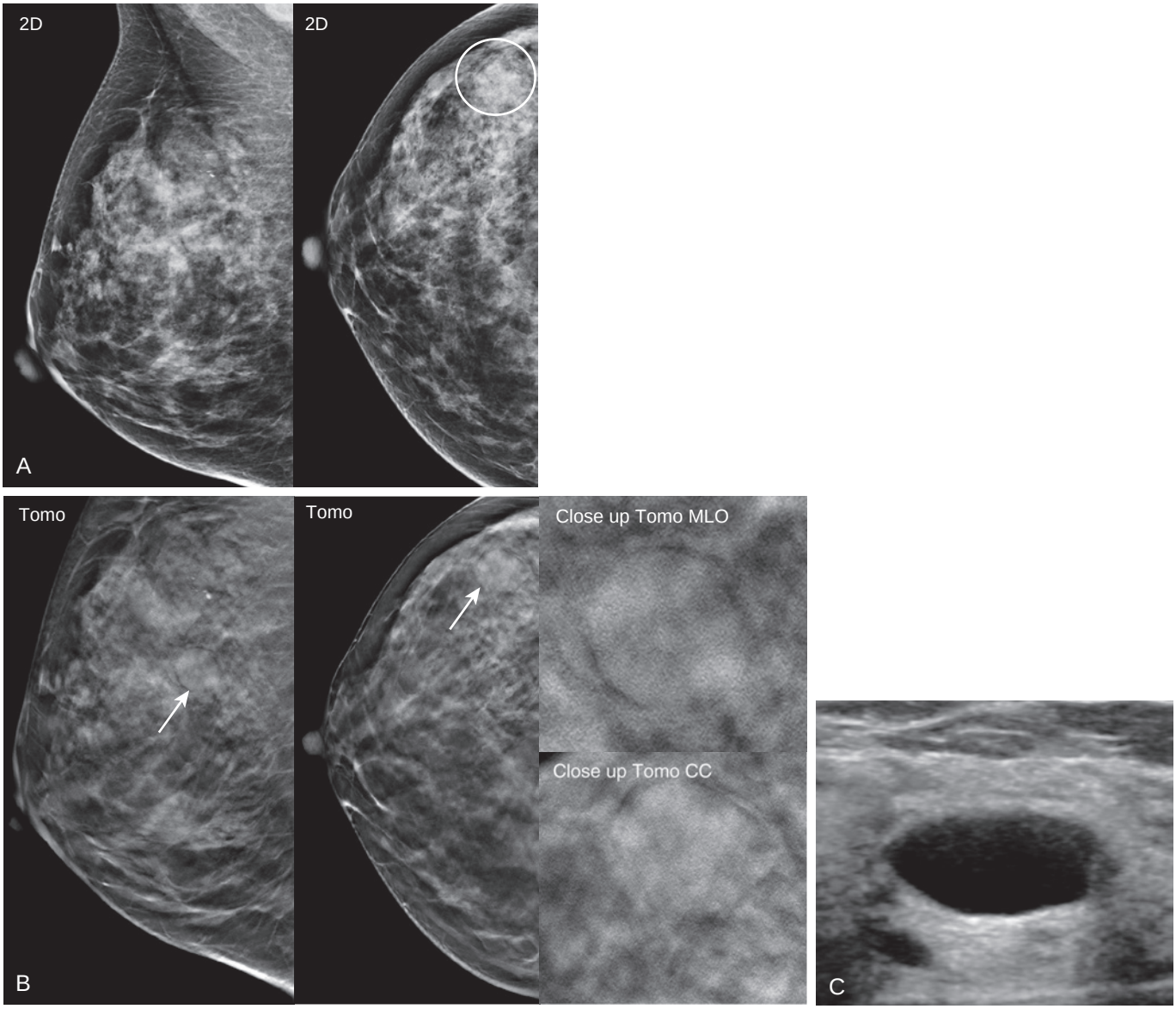


FIG. 6.1 Screening recall for mass requiring only ultrasound work-up (A) Annual screening right mammogram in a 43-year-old woman shows a new developing asymmetry *(circle)* in the right outer breast, seen only on the CC view. **(B)** Tomosynthesis reveals a circumscribed oval mass *(arrows)* at the 10-o'clock position in right breast. By demonstrating the features, including size, shape, and margins, as well as the precise location of this mass, additional diagnostic views are unnecessary, enabling the patient to proceed directly to ultrasound. **(C)** Ultrasound shows a simple cyst corresponding to the mammographic finding.

routine MLO and CC views may be sufficient in the diagnostic evaluation of the majority of abnormal findings, thereby replacing the conventional diagnostic work-up. Zuley et al. demonstrated that tomosynthesis CC and MLO views could not only replace supplemental diagnostic views but could actually improve diagnostic accuracy compared with a conventional diagnostic work-up of noncalcified abnormal lesions recalled from screening mammography. In this study there was a significant reduction of false-positive cases placed in the BI-RADS 4 and 5 categories, and a greater number of cancers placed in the BI-RADS 5 category when using tomosynthesis.

With more benign lesions placed in the BI-RADS 1 and 2 categories and more cancers placed in the BI-RADS 4 and 5 categories, a steady decline in BI-RADS 3 assessments, as well as an

TABLE 6.1 Additional Views Typically Required at Diagnostic Mammography

2D Mammography	2D Mammography Plus Tomosynthesis
Spot compression	Spot compression
Magnification	Magnification (for calcifications)
True lateral	
Exaggerated craniocaudal	
Rolled craniocaudal	
Step oblique	
Tangential	

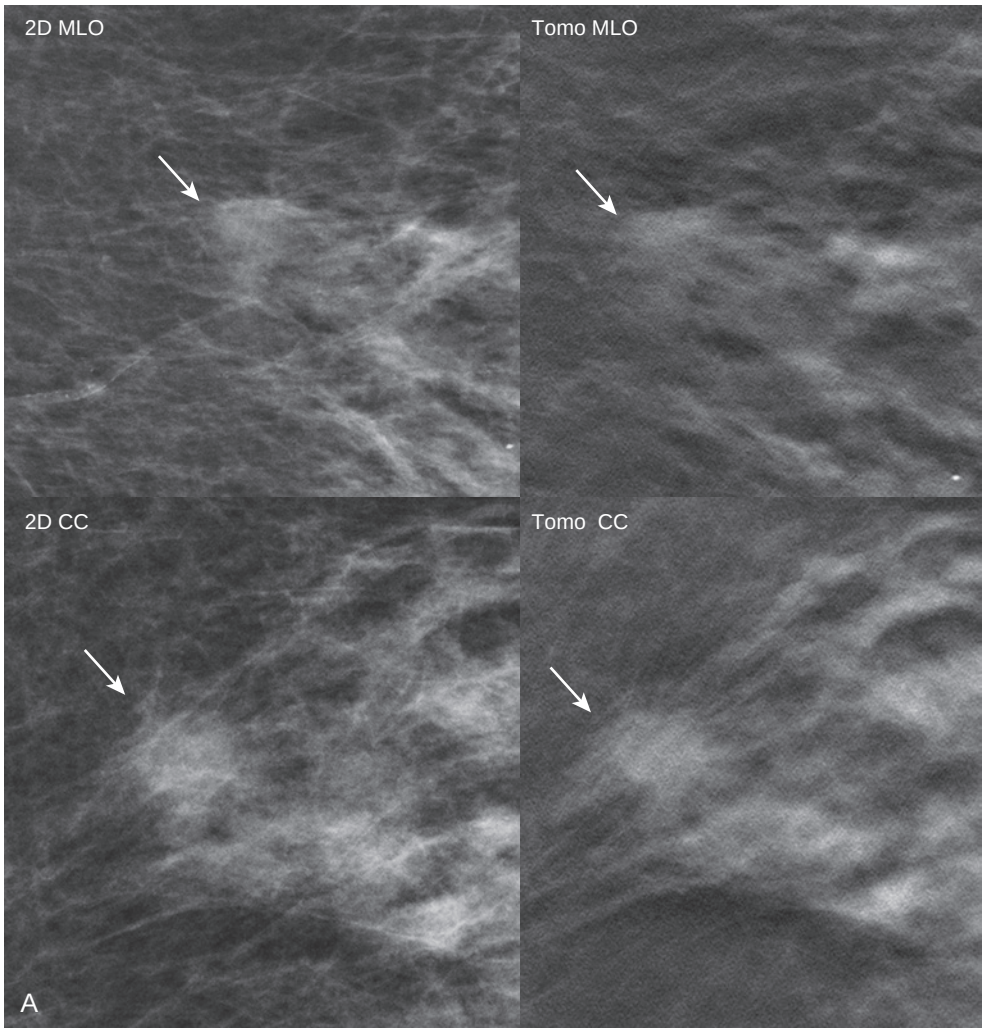


FIG. 6.2 Focal asymmetry with suspicious features revealed on tomosynthesis (A) On a screening mammogram in an 69-year-old woman, a round spiculated mass *(arrows)* resembles fibroglandular tissue on the standard two-dimensional view but is better seen on tomosynthesis, particularly on the craniocaudal view. Additional spot compression views were not necessary. **(B)** Targeted ultrasound demonstrates a corresponding oval hypoechoic mass with indistinct margins. Ultrasound-guided core needle biopsy and surgical excision showed invasive ductal carcinoma, grade 2, ER/PR+, Her–, 0/2 SLN.

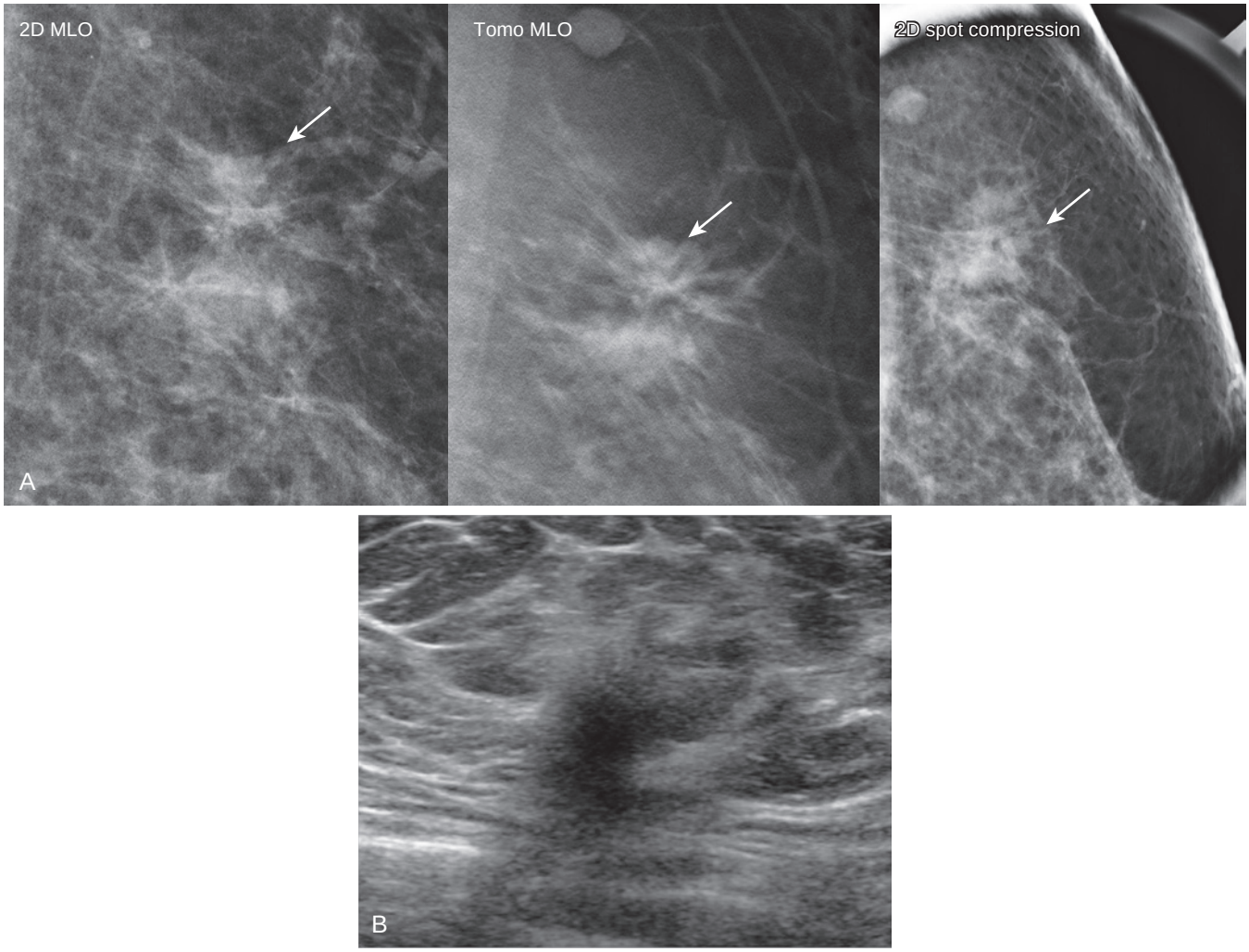


FIG. 6.3 Invasive ductal cancer best seen on tomosynthesis (A) Baseline screening mammogram in a 40-year-old woman shows a focal asymmetry *(arrows)* in the left superior lateral breast. The underlying mass and spiculated margins are well seen on tomosynthesis. On 2D spot compression the spiculations are not obvious and the underlying mass resembles fibroglandular tissue. **(B)** Targeted ultrasound demonstrates a corresponding irregular, taller-than-wide hypoechoic mass with angular and indistinct margins. Ultrasound-guided core needle biopsy and surgical excision revealed well-differentiated invasive ductal carcinoma, ER/PR+, Her2–, 0/1 SLN.

increase in the positive predictive value for biopsies (PPV3), may be seen with tomosynthesis. This improved accuracy in the assessment of benign and malignant lesions reflects both a higher sensitivity and specificity. For cases still assessed as BI-RADS 3 using tomosynthesis, the mammographic work-up at a 6-month follow-up may be abbreviated because fewer views are likely to suffice.

Diagnostic Work-Up Patterns

Noncalcification Lesions: Masses, Architectural Distortions, and Asymmetries: When Are Additional Views Necessary?

A mass, architectural distortion, or asymmetry may be obvious on both the 2D mammogram and tomosynthesis, may be subtle on the 2D mammogram but seen well on tomosynthesis, or may be difficult to perceive and characterize even on tomosynthesis. When the lesion is obvious, the diagnostic work-up can usually begin with targeted ultrasound. In such cases the routine views with tomosynthesis provide sufficient information regarding lesion location and features such that spot compression and 90-degree true lateral views are unnecessary (Fig. 6.4). When skipping the true lateral view and going straight to targeted ultrasound, it is important to remember that lesions located far medially or laterally will be located more superiorly or inferiorly, respectively, than depicted on the MLO view. When an ultrasound correlate is seen, the lesion can be determined to be benign, probably benign, or suspicious and is managed accordingly.

If a lesion is subtle on both 2D and tomosynthesis, a diagnostic work-up is helpful prior to targeted ultrasound. Unlike a conventional diagnostic work-up in which spot compression is often performed in two views, a single tomosynthesis spot compression view usually suffices to distinguish between tissue overlap versus a true lesion and, when a true lesion is present, to provide adequate margin detail. Occasionally a very subtle lesion will require tomosynthesis spot compression in two views. For such subtle lesions a small spot compression paddle may be helpful to optimize visualization.

If there is uncertainty that a sonographic finding definitively correlates with the mammographic finding, a metallic

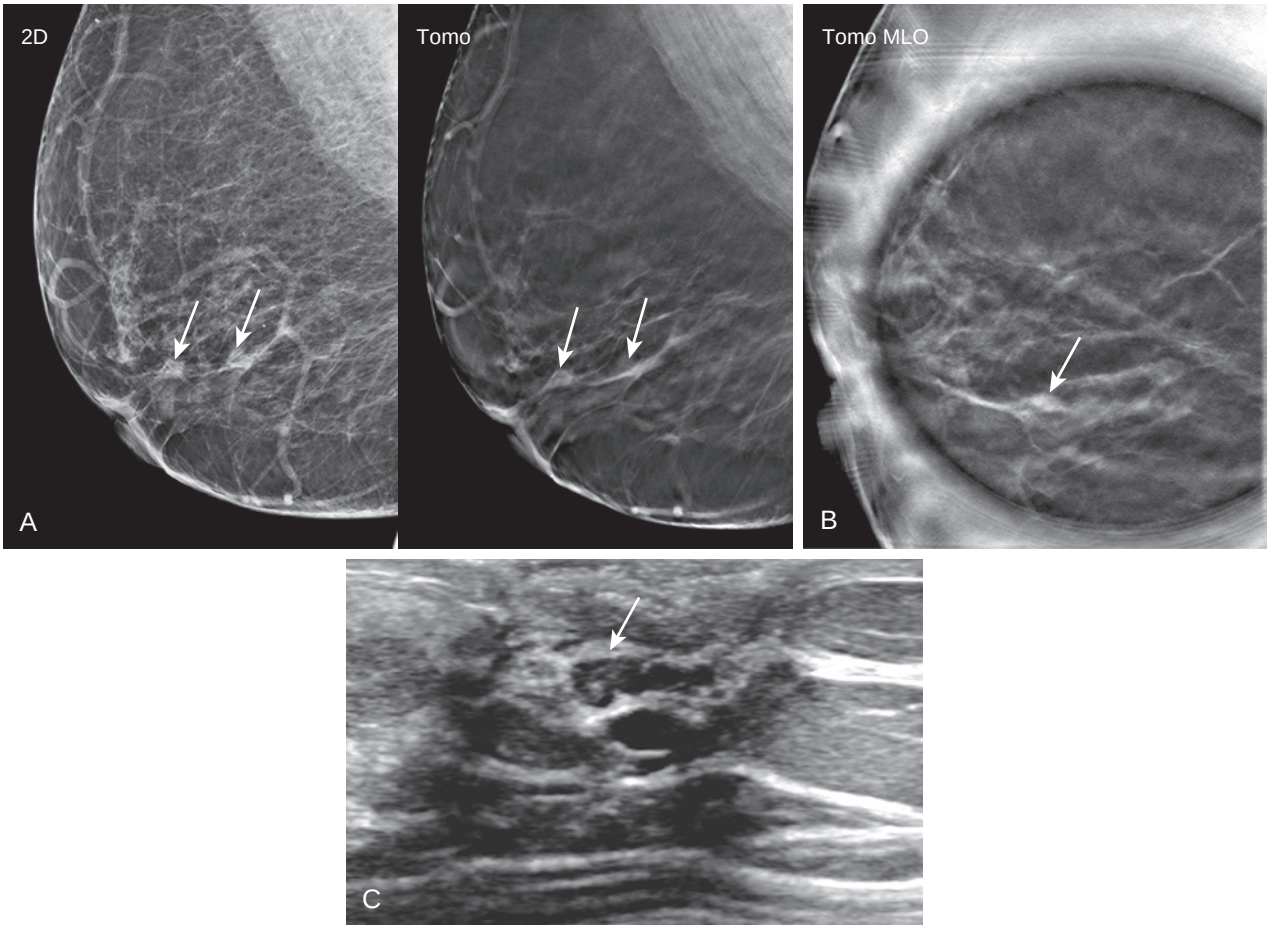


FIG. 6.4 Intraductal papillomas well seen on 2D mammography (A) Screening mammogram in a 58-year-old woman with two new asymmetries *(arrows)* in the right retroareolar breast, seen only on the mediolateral oblique view. The more posterior asymmetry did not persist on tomosynthesis. **(B)** Spot compression tomosynthesis view again demonstrates only the anterior asymmetry *(arrow)* and does not add any additional information. **(C)** Targeted ultrasound reveals a corresponding intraductal mass *(arrow)*. Ultrasound-guided core needle biopsy revealed benign papilloma, confirmed with surgical excision.

marker (BB) can be placed on the skin overlying the lesion during the ultrasound examination, and tomosynthesis spot compression views can be obtained. If the sonographic and mammographic findings are the same, the BB should be in the vicinity of the mammographic finding. Because the BB is placed on the skin and not directly on the lesion and the patient is positioned differently during mammography and ultrasound, the BB may not be directly overlying the mammographic finding. Caution must be exercised to ensure that the two lesions match not only in terms of location but also in terms of size, appearance, and level of suspicion. For suspicious ultrasound lesions that proceed to biopsy, placement of a biopsy clip and post-biopsy mammography with tomosynthesis are paramount to confirm correspondence of the biopsied ultrasound lesion with the original tomosynthesis finding.

When performing spot compression views with tomosynthesis, the question often arises whether to acquire only tomosynthesis or a combination of 2D imaging and tomosynthesis. When a lesion is best seen on tomosynthesis, a tomosynthesis-only spot compression view may suffice. However, a combination spot compression view using both 2D imaging and tomosynthesis is often beneficial because the 2D component allows better identification of nearby landmarks, ensuring that the appropriate region of the breast is included in the spot compression window. This may be particularly helpful in patients with large breasts. To reduce patient radiation exposure, synthesized 2D spot compression allows similar assessment of nearby landmarks and can replace the traditional 2D component of the combination spot compression. Importantly, a cancer may be visible only on tomosynthesis, and 2D spot compression views alone without tomosynthesis can be misleading. A suspicious finding seen on tomosynthesis should not be dismissed as benign if not reproduced on 2D spot compression views alone (Fig. 6.5).

TOMO TIP ★ If a subtle suspicious finding is seen on tomosynthesis and requires further evaluation, spot compression views with tomosynthesis are advised because some malignancies will not be reproduced on 2D spot compression alone.

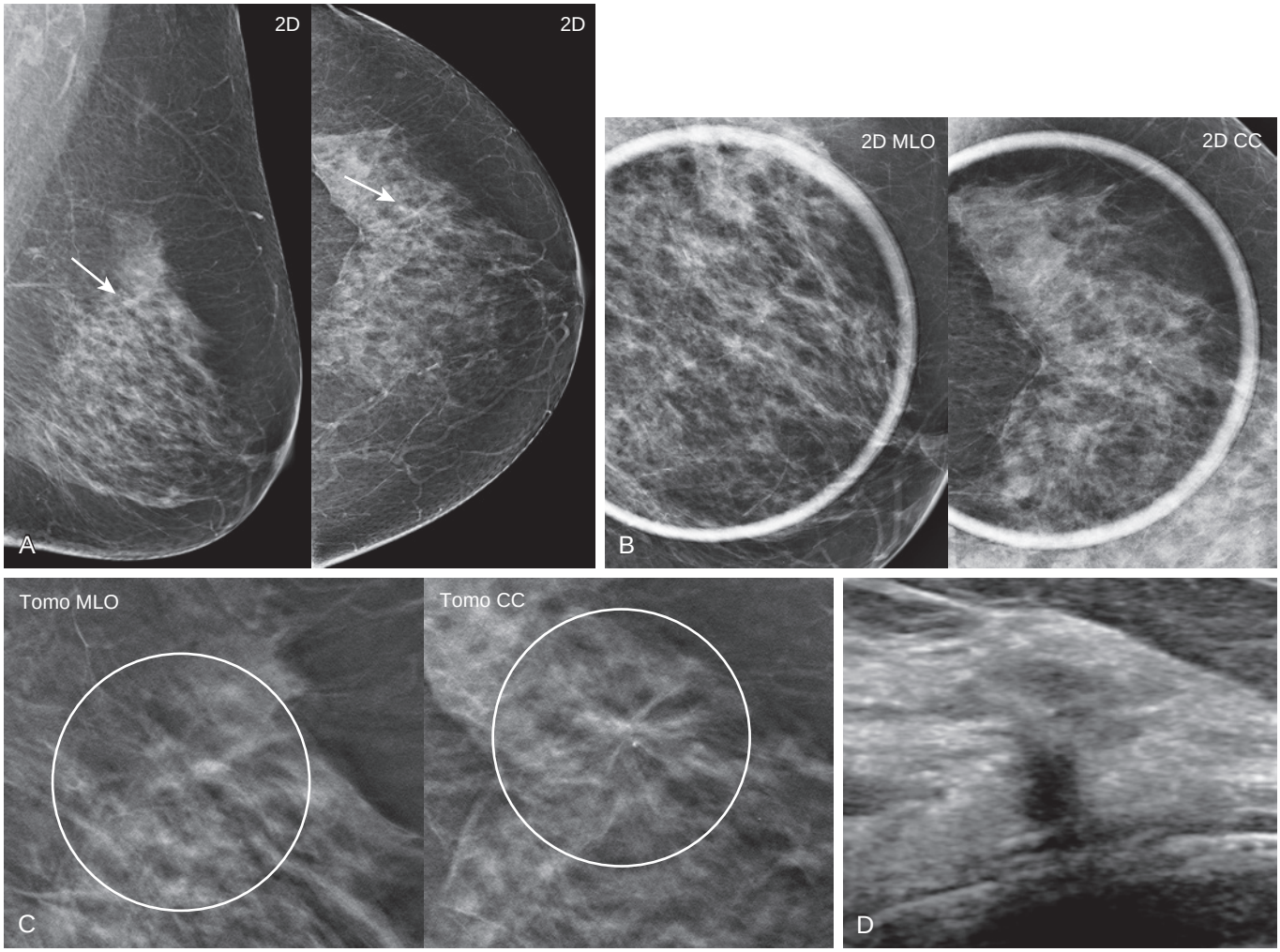


FIG. 6.5 Invasive ductal carcinoma not visualized on 2D spot compression **(A)** 2D MLO and CC views demonstrate possible subtle architectural distortion *(arrows)* in left superior lateral breast. **(B)** The architectural distortion is not reproduced on 2D spot compression views. **(C)** Close-up tomosynthesis slices of the standard MLO and CC projections confirm focal architectural distortion with associated microcalcifications *(circles)*. **(D)** Targeted ultrasound demonstrates a corresponding irregular hypoechoic mass. Ultrasound-guided core needle biopsy revealed well-differentiated invasive ductal carcinoma with tubulolobular features and grade 2 ductal carcinoma in situ, ER/PR(+), Her2(–), 0/2 SNL.

Single-View–Only Lesions

On 2D mammography, findings requiring additional evaluation may occasionally be seen in only one view. In these cases a number of additional diagnostic views are helpful in the diagnostic work-up. For example, when a possible lesion is initially seen only in the CC view, rolled CC views can be obtained to determine whether the lesion is located in the superior or inferior breast, thereby localizing it to a specific quadrant. Similarly, to triangulate a lesion initially seen only in the MLO view, true lateral or step oblique views can be performed to localize the lesion in the three-dimensional (3D) space. Precise lesion localization is important to exclude the possibility of summation artifact and to accurately direct targeted ultrasound. With the ability to localize a lesion within single, thin sections of breast tissue, tomosynthesis can eliminate the need for additional diagnostic work-up of lesions initially seen in only one view.

In the case of a lesion seen only in the CC view, scrolling through the breast from superior to inferior will identify the tomosynthesis slice(s) containing the lesion and pinpoint its location within the superoinferior dimension (Fig. 6.6). By knowing the location of the slice in the CC plane, the reader can determine the location of the lesion. Likewise, in the case of a lesion seen only in the MLO view, scrolling through the thickness of the breast from lateral to medial will identify the slice(s) where the lesion is best visualized. Thus even lesions seen in only one of the routine views can typically be localized in 3D space and accurately targeted by ultrasound without the need for additional views.

Two-Dimensional Screening Recall: Should the Study Be Repeated With Tomosynthesis?

The diagnostic work-up will differ depending on whether the patient originally underwent a 2D screening mammogram

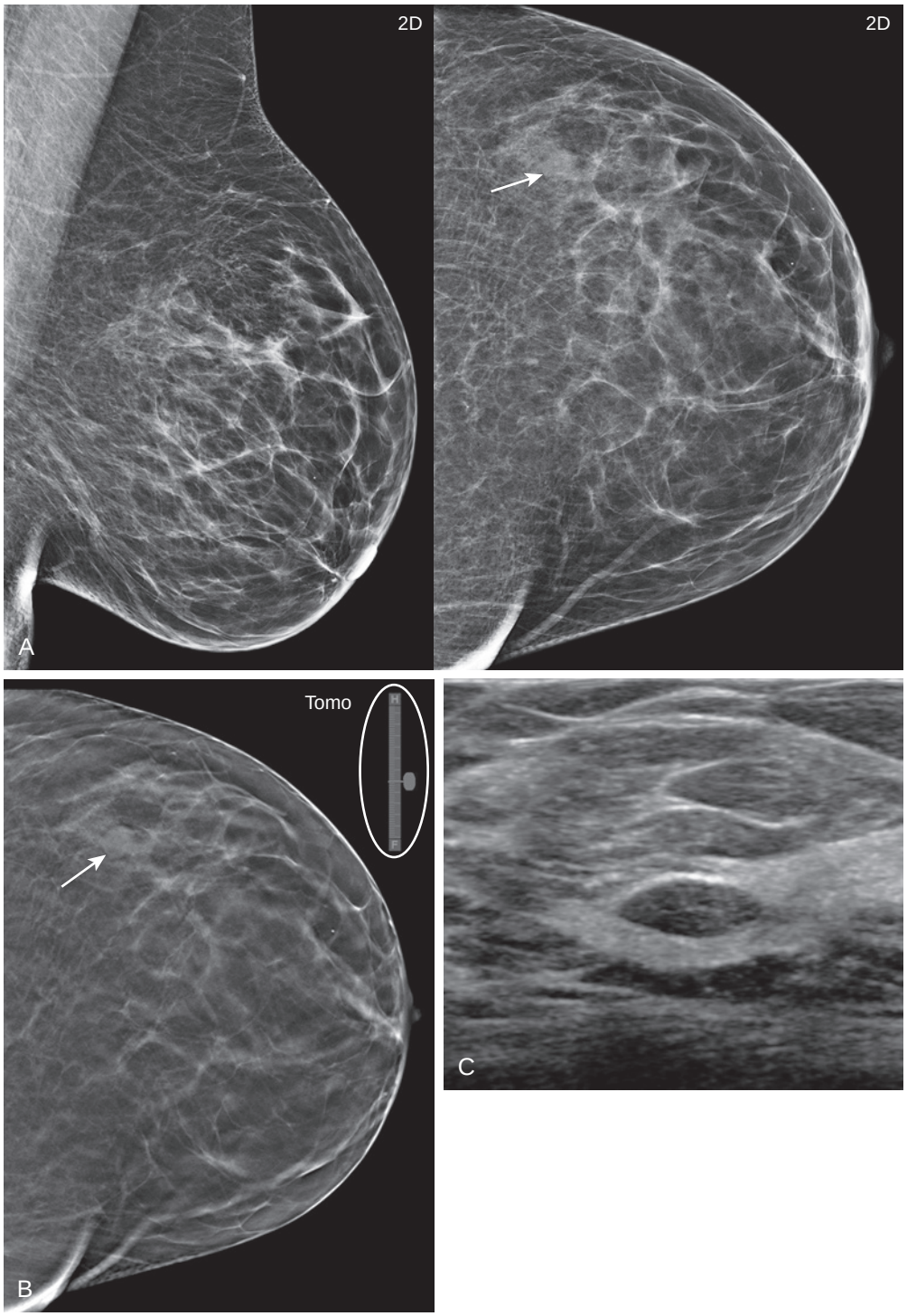


FIG. 6.6 Fibroadenoma only seen on CC view (A) Two-dimensional left MLO and CC views show subtle suggestion of a mass *(arrow)* in the lateral left breast in the CC view *(arrow)*, with no corresponding finding in the MLO view. **(B)** Tomosynthesis confirms a circumscribed mass in the lateral left breast on the CC view. No corresponding finding is seen in the MLO view even on tomosynthesis (not shown). However, the position of the CC tomosynthesis slice on the adjacent sliding scale *(circle)* shows the mass to be located in the mid-portion of the superior-inferior dimension. **(C)** Targeted ultrasound to the location indicated on tomosynthesis shows a corresponding oval circumscribed hypoechoic mass at the 2-o'clock position, likely representing a fibroadenoma; it was assessed as BI-RADS 3 and stable on follow-up.

versus a tomosynthesis screening study. When a mass or architectural distortion is well seen on a 2D screening mammogram, full MLO and CC tomosynthesis views may be sufficient to assess lesion margins and helpful to evaluate the remainder of the breast for any 2D occult lesions. Asymmetries recalled from a 2D screening mammogram can often be clarified by obtaining full combination 2D mammography and tomosynthesis in the same view(s) the asymmetry was initially seen. If the finding persists, further evaluation can be performed with ultrasound, obviating the need for spot compression views. Suspicious calcifications recalled from a 2D mammogram usually require standard magnification views. In these cases tomosynthesis can be helpful if an associated mass is suspected.

Second-Look Tomosynthesis

Second Look After Two-Dimensional Mammography or Ultrasound

When a suspicious lesion is initially identified with 2D mammography and/or ultrasound, tomosynthesis may help to evaluate the extent of disease. For example, tomosynthesis can reveal a larger region of involvement than initially suspected, such as a region of subtle architectural distortion associated with a suspicious mass. In other cases tomosynthesis may demonstrate multifocal or multicentric disease, which is occult on 2D mammography. For these reasons, patients with highly suspicious lesions or newly diagnosed breast cancer who have so far only undergone 2D mammographic imaging may benefit from tomosynthesis to help to define the extent of disease prior to surgery.

In assessing malignant masses, tumor size is an important consideration for clinical staging and surgical planning. Tomosynthesis may allow for a more accurate measurement of tumor size compared with 2D mammography. The spicules extending radially from spiculated cancers are revealed in exquisite detail, often appearing much longer on 3D slices compared with 2D views. In a study of 62 women with 73 breast cancers, Fornvik et al. showed that 3D mammography and ultrasound measurements correlate better with pathology (R = 0.86 and 0.85, respectively) than 2D mammography size (R = 0.71). Importantly, however, the spicules may not always contain proliferating tumor cells but rather be secondary to a fibrotic desmoplastic reaction. As such, tumor measurement on tomosynthesis should include the core of the mass with some average length spicules but generally not the longer spicules. In some cases, magnetic resonance imaging (MRI) may be a better predictor of pathologic tumor size based on enhancement (Fig. 6.7). However, MRI contrast enhancement is similarly not specific and may represent either tumor involvement or benign fibrosis. Histologic sampling is necessary to determine the extent of disease when suspicious areas of enhancement extend beyond a known primary cancer. Further studies are needed to define if and how much of associated spicules should be included when assessing tumor size.

Second Look After Magnetic Resonance Imaging

In the setting of a suspicious MRI-detected lesion, targeted ultrasound is often the next best second-look modality. A sonographic correlate is identified in approximately half of cases, being more likely to be seen for malignant lesions and/or for those presenting as a mass, rather than benign lesions and/or nonmass enhancement on MRI. It must be emphasized that, although malignancies are more likely to have a sonographic correlate, the absence of an ultrasound finding does not imply benignity. In this scenario an MRI-guided core needle biopsy or preoperative localization should be performed for histologic evaluation. However, with the advent of tomosynthesis, it may be possible to identify a mammographic correlate on tomosynthesis sections. A second-look tomosynthesis study may be helpful in patients with a suspicious MRI-detected lesion who have no sonographic correlate, particularly if initial imaging consisted only of 2D mammography.

Tomosynthesis-Detected Lesions With No Ultrasound Correlate

Most suspicious masses seen on tomosynthesis have an ultrasound correlate, allowing ultrasound-guided biopsy to be performed for histologic diagnosis. However, a suspicious architectural distortion or focal asymmetry will occasionally not have an ultrasound correlate, making the diagnostic work-up problematic if the lesion can only be seen with tomosynthesis. In these cases tissue sampling can be achieved with tomosynthesis-guided core needle biopsy or wire localization, which are both discussed in detail in Chapter 14. In some cases, MRI may be helpful. If a corresponding enhancing lesion is identified on MRI, tissue sampling with MRI-guided core needle biopsy can be performed (Fig. 6.8). It must be noted that, despite the high negative predictive value of MRI, there are currently little data to support imaging surveillance in lieu of tissue sampling of suspicious findings seen on tomosynthesis, which do not have an MRI correlate, particularly a worrisome architectural distortion. Until further data are available, histologic sampling of suspicious lesions seen only on tomosynthesis remains standard practice.

Lesion Assessment—Tomosynthesis-Specific Features

Benign and Malignant Masses

Tomosynthesis aids in the assessment of both benign and malignant masses. Typically, benign features may be obscured on 2D imaging but are frequently unveiled on tomosynthesis slices. For example, demonstration of a fatty hilum within a circumscribed mass confirms an intramammary lymph node. Visualization of a pseudocapsule surrounding a fat-containing mass supports the impression of a hamartoma. Identification of fat within a mass at the site of prior surgery or trauma increases the likelihood of benign fat necrosis. Confirmation of typically benign features increases diagnostic confidence in a benign assessment and improves the specificity of diagnostic mammography, reducing the number of benign follow-up examinations and biopsies and leading to a higher positive predictive value for biopsy (PPV3) for truly suspicious findings.

An essential note of caution is that tomosynthesis can sometimes reveal fat within cancers (Fig. 6.9). Histopathologic review of these cases suggests that cancers may engulf fat as they grow, resulting in the demonstration of intralesional fat on tomosynthesis slices. When overlapping breast

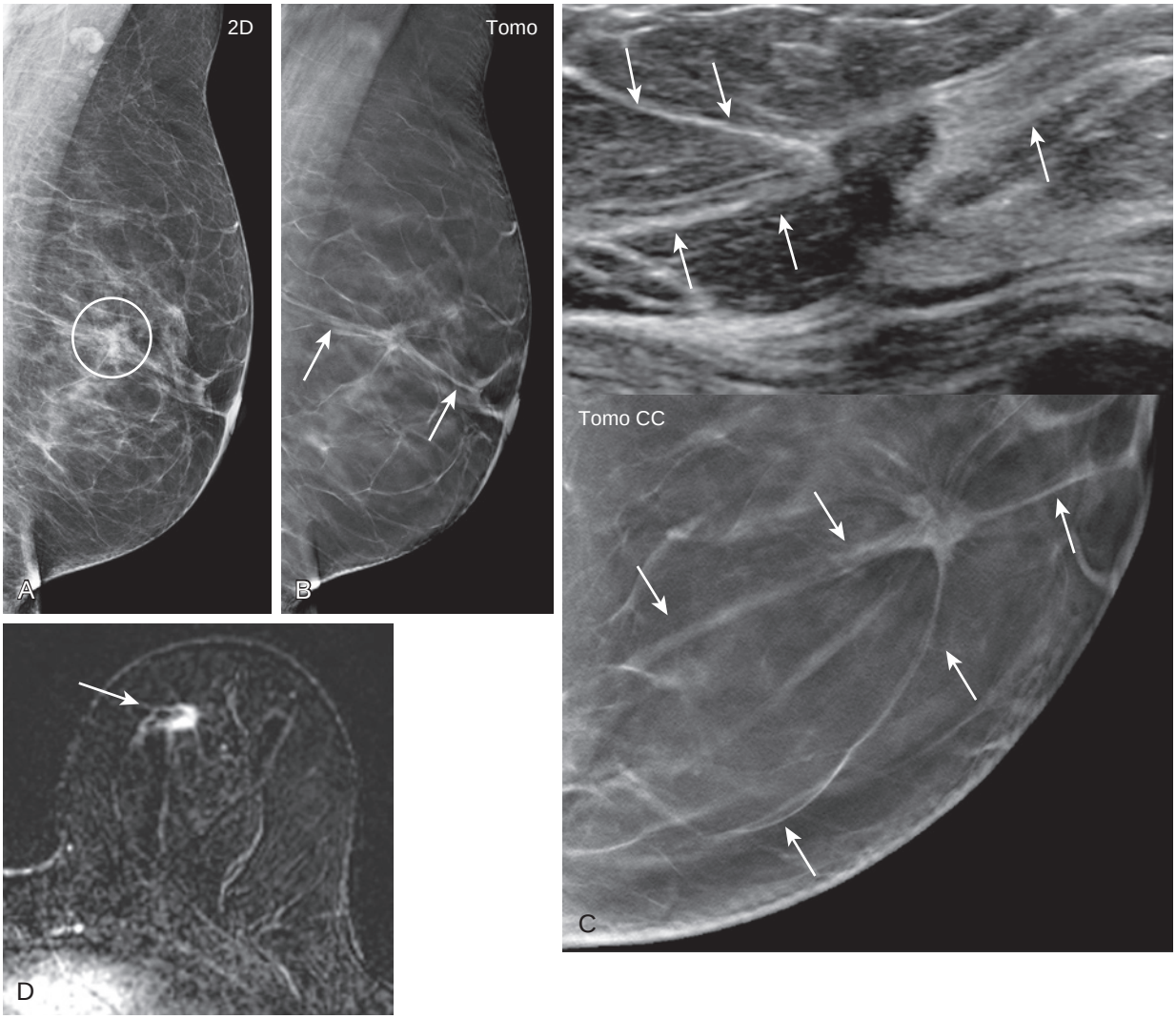


FIG. 6.7 Invasive ductal cancer with very prominent spicules on tomosynthesis (A) A 54-year-old woman with focal irregular asymmetry *(circle)* in the left superior medial breast on screening mammography, initially best seen on two-dimensional MLO view. **(B)** Tomosynthesis reveals a mass with extensive spicules *(arrows)* extending across the entire anteroposterior extent of the breast. **(C)** Targeted ultrasound demonstrates a 0.8-cm mass with straightening of the nearby Cooper ligaments *(arrows)*, mirroring the mammographic image. Ultrasound-guided core needle biopsy showed a grade 2 IDC. **(D)** Magnetic resonance imaging was performed to assess the tumor size preoperatively. A post-contrast, fat suppressed, and subtracted T1-weighted image shows a corresponding enhancing mass *(arrow)* without the associated long spicules seen mammographically. Surgical pathology showed grade 2 IDC, ER/PR+, Her2–, 0/3 SLN. Final pathologic tumor size was 1.2 cm and best correlated with MRI.

tissue is removed on tomosynthesis slices, cancers often appear less dense and may indeed contain lucent areas. For this reason it must be emphasized that low density is not a reliable feature of benignity, and the assessment of margins remains critical in evaluating the probability of malignancy. Correlation with clinical and biopsy history is also necessary because surgical and posttraumatic scars often contain fat. In the absence of a history of trauma or surgery a spiculated, fat-containing mass remains a highly suspicious finding.

TOMO TIP ★ Some cancers may appear less dense than expected on tomosynthesis. Although intralesional fat may not be the most prominent feature, it is a relatively common finding.

Architectural Distortion

The differential diagnosis of architectural distortion without a dominant central mass includes both benign and malignant etiologies. Malignant histologies most commonly presenting as architectural distortion include low- and intermediate-grade invasive ductal carcinoma, particularly tubular carcinoma, as well as invasive lobular carcinoma. Excluding known postsurgical scars, the most common benign etiology presenting with architectural distortion is radial scar or complex sclerosing lesion, the latter term generally reserved for lesions greater than 1 cm. Less commonly, sclerosing adenosis may produce architectural distortion (Fig. 6.10). Because sclerosing adenosis is a common incidental finding, caution must be taken before accepting this histology as concordant with the mammographic finding of distortion. However, when the

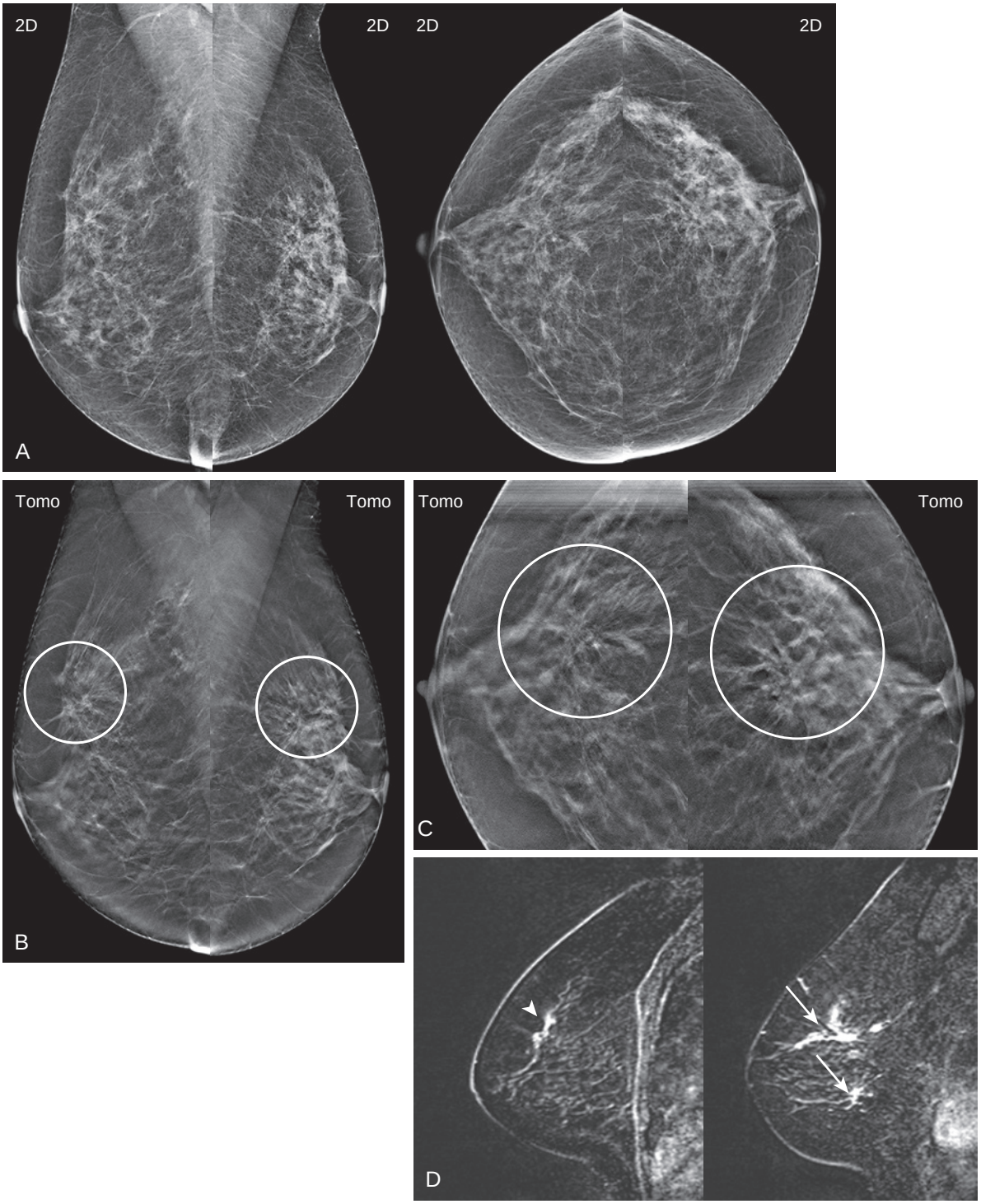


FIG. 6.8 Bilateral multicentric ductal carcinoma in situ not seen on two-dimensional mammography or ultrasound **(A)** Screening mammogram in a 60-year-old woman demonstrates scattered fibroglandular tissue with no suspicious findings and no change in comparison to her previous mammograms (not shown). **(B)** Tomosynthesis mediolateral oblique views demonstrate bilateral architectural distortions *(circles)*. **(C)** Spot compression craniocaudal and tomosynthesis views confirm the architectural distortions located at approximately the 12-o'clock position bilaterally *(circles)*. **(D)** No corresponding mass was seen on targeted ultrasound, and magnetic resonance imaging (MRI) was performed. T1-weighted, fat-suppressed, contrast-enhanced sagittal views demonstrate an area of nonmass enhancement in the right breast *(arrowhead)* and two abnormal areas of nonmass enhancement in the left breast *(arrows)*. MRI-guided core needle biopsy yielded ductal carcinoma in situ (DCIS), grade 2, ER/PR– at all three sites. The patient underwent a bilateral mastectomy, which revealed a 5.7-cm area of DCIS in the left breast and a 2.5-cm area of DCIS in the right breast.

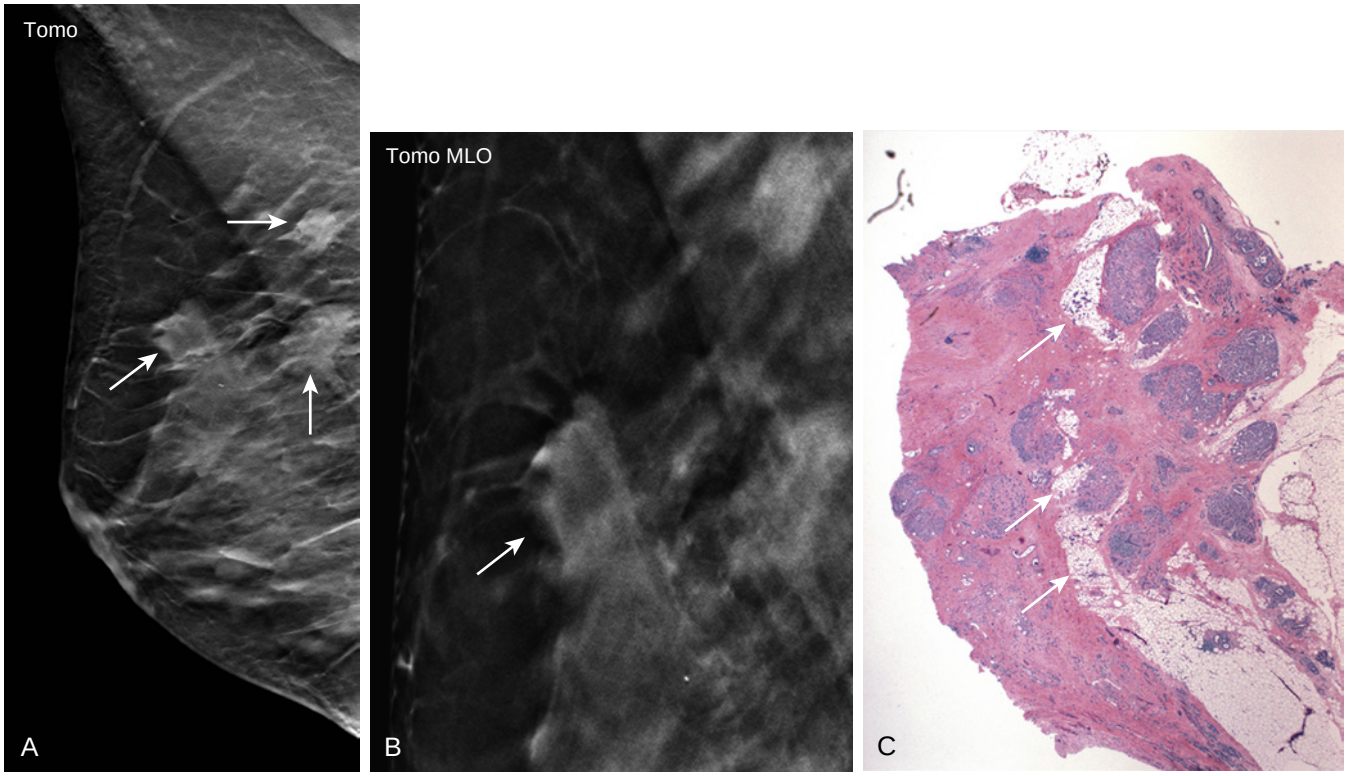


FIG. 6.9 Fat-containing infiltrating ductal carcinoma (A) Right MLO tomosynthesis view reveals three suspicious masses *(arrows)* seen in a 55-year-old woman on screening mammography. **(B)** Tomosynthesis slice through most anterior suspicious mass at the apex of breast on MLO view shows lucency *(arrow)*, indicating a substantial amount of fat contained within cancer. **(C)** Surgical pathology showed grade 2 infiltrating ductal carcinoma with tubulolobular features, ER/PR+, Her2+, 1/11 SLN. Fat cells engulfed by growing tumor *(arrows)* correspond to intralesional fat seen on tomosynthesis.

lesion has been adequately sampled and pathology shows exuberant sclerosing adenosis as the dominant histologic finding, it may be concordant. Discussion of the imaging-pathologic correlation with the interpreting pathologist in such cases is advisable. Architectural distortion is reviewed in detail in Chapter 10.

Focal Asymmetry

Focal asymmetry caused by tissue overlap can often be readily shown to represent benign breast tissue on tomosynthesis slices. Although an obvious lesion may not be present on tomosynthesis slices, an asymmetry may still represent a significant finding when it is a new or developing finding compared with prior studies or if it is palpable (Fig. 6.11). In such cases, ultrasound is critical in the diagnostic evaluation. In particular, invasive lobular carcinoma can present with mammographically subtle findings, such as a developing asymmetry. Ultrasound reveals suspicious findings, most commonly a shadowing mass, in the majority of these cases. In some cases of focal asymmetry, tomosynthesis can reveal associated architectural distortion not appreciated on 2D views. This finding increases the level of suspicion and should be further evaluated with ultrasound and biopsy.

Microcalcifications

Although spot compression can be obtained with tomosynthesis, magnification views can only be obtained with 2D techniques. When calcifications are recalled from screening mammography, magnification views are usually required. However, there are cases of benign calcifications in which tomosynthesis obviates the need for magnification views. One example is dermal calcifications lacking a typically benign appearance. If dermal calcifications are suspected, tomosynthesis views can easily determine the location in the skin without the need for dermal markers and tangential views. Tomosynthesis precludes the necessity of performing tangential views or "skin studies." It must be remembered that approximately five slices are added to the breast thickness on the side of the compression paddle (ie, medial on the MLO and superiorly on the CC) to ensure that the entire breast volume is reconstructed. Therefore, location within the dermis is easily determined by identifying the calcifications within the peripheral slices on either side of the breast. Similarly, the visualization of an associated vessel confirms the diagnosis of early vascular calcifications. The demonstration of a fat-containing mass with curvilinear calcifications may identify them as rim calcifications within the wall of an oil cyst. In these scenarios no further work-up is needed. With the exception of typically benign findings such as these, the standard work-up for calcifications remains 2D magnification views.

True lateral magnification views are often still required to clearly identify layering calcifications typical of benign milk of calcium. The morphology of indeterminate calcifications is still traditionally assessed with the aid of the increased

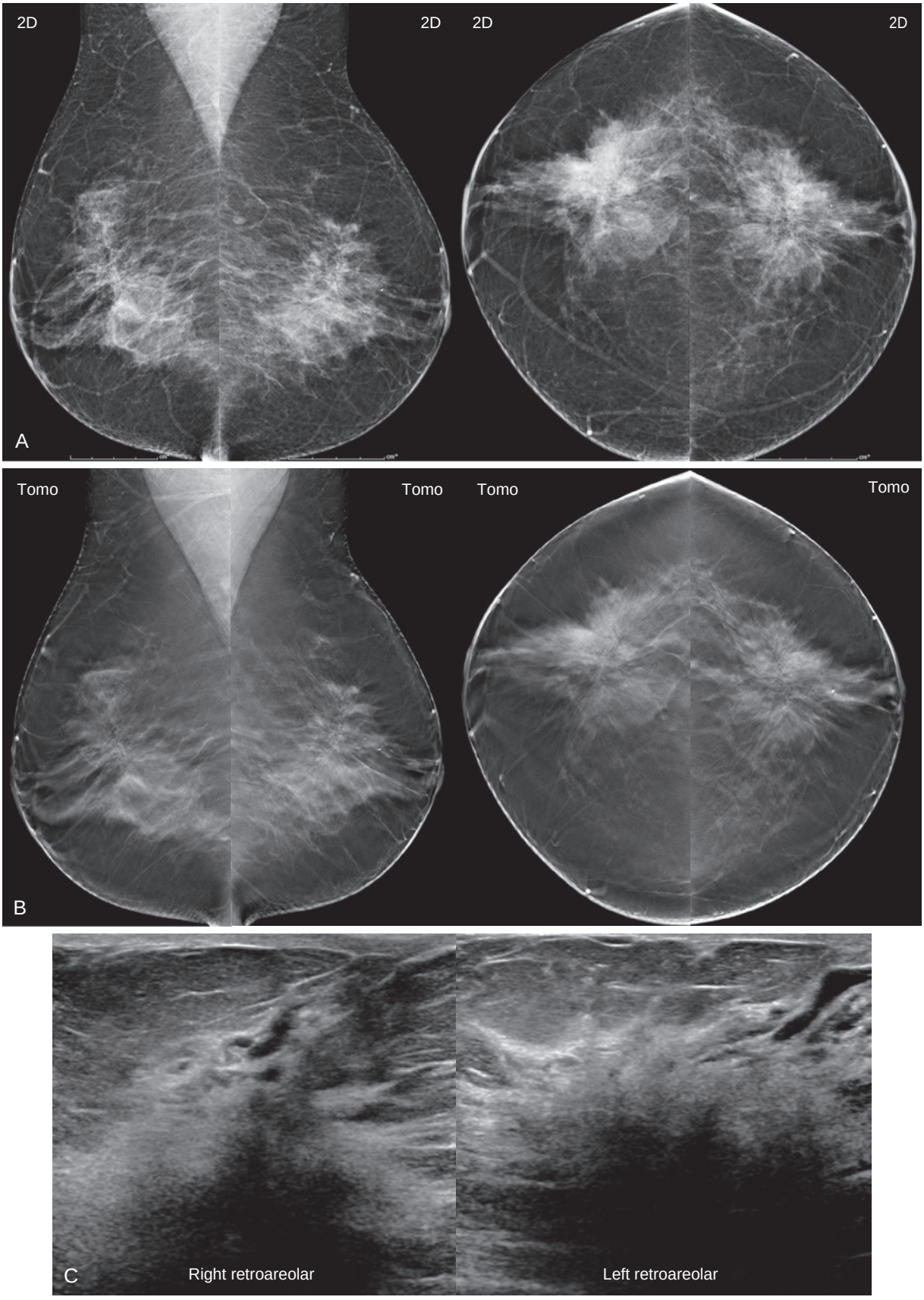


FIG. 6.10 Bilateral benign architectural distortion (A) Baseline screening mammogram in a 44-year-old woman demonstrates bilateral architectural distortion, seen better on the craniocaudal views. **(B)** The bilateral architectural distortion is even more conspicuous on tomosynthesis. **(C)** Ultrasound (US) reveals diffuse irregular shadowing regions bilaterally, most prominent in the retroareolar regions. US-guided core needle biopsy revealed bilateral exuberant sclerosing adenosis and ductal hyperplasia, which was considered concordant after careful imaging-pathology correlation with the interpreting pathologist. The lesions were stable on subsequent imaging follow-up.

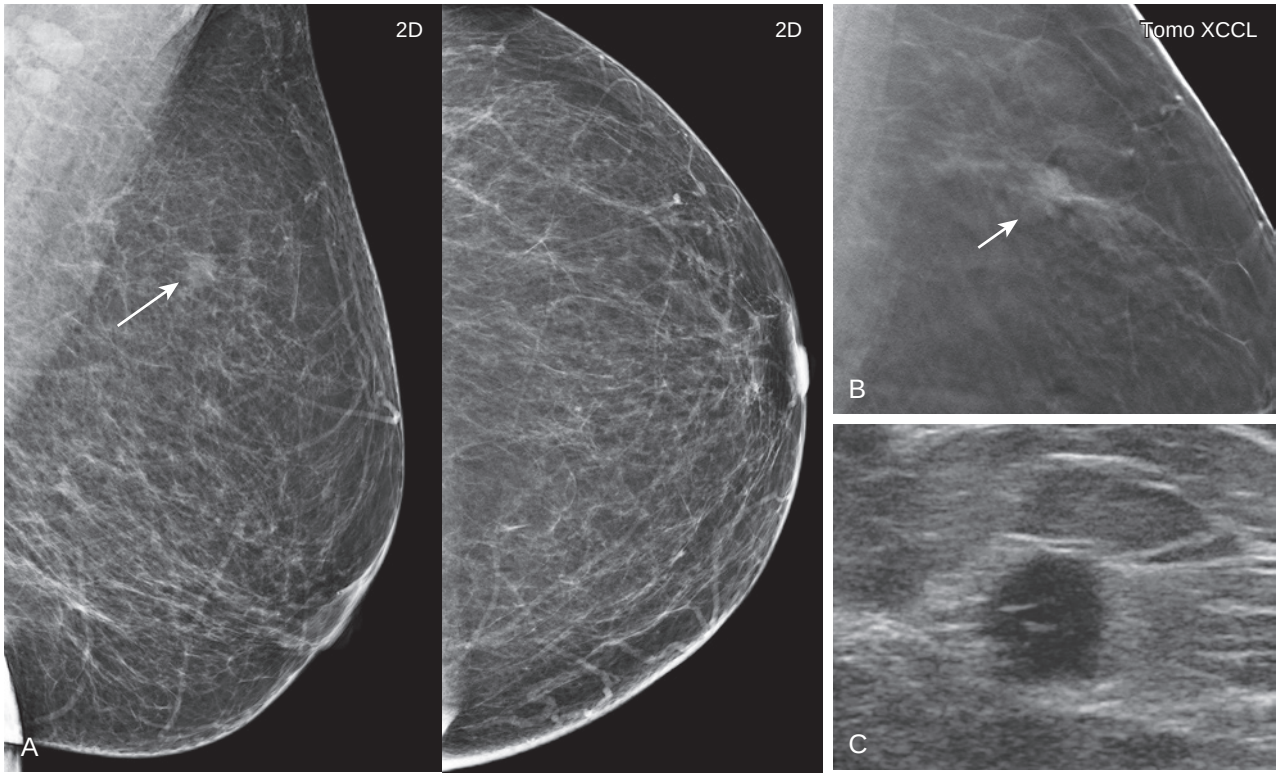


FIG. 6.11 Poorly differentiated invasive ductal carcinoma presenting as developing asymmetry (A) Two-dimensional screening mammogram in a 55-year-old woman shows a new asymmetry *(arrow)* seen only in the MLO view. **(B)** The lesion was determined to be located in the lateral breast based on the location of the finding on the mediolateral oblique tomosynthesis slice (not shown). The lesion *(arrow)* was identified on a laterally exaggerated craniocaudal (laterally) tomosynthesis image. **(C)** Ultrasound shows an irregular, taller-than-wide mass with microlobulated margins. Ultrasound-guided core needle biopsy and surgical excision showed poorly differentiated invasive ductal carcinoma, ER/PR+, Her-2–, 0/3 SLN.

geometric sharpness of magnification views. However, tomosynthesis may have a role in this setting. Microcalcifications are often more difficult to perceive as grouped on tomosynthesis images because the individual calcifications comprising the grouping are usually not located within the same slice (Fig. 6.12). However, once a microcalcification grouping is identified on 2D images, tomosynthesis slices may reveal the morphology of individual calcifications in greater detail, aiding in the assessment of their probability of malignancy. Occasionally, subtle grouped microcalcifications may be seen on a single view, and tomosynthesis may help to determine the location in the orthogonal view, thereby accurately directing the magnification views to the region of interest (Fig. 6.13).

Evaluation of the Symptomatic Patient

Palpable Abnormalities

In the conventional diagnostic environment, the work-up of a palpable mass includes spot compression views and/or tangential views of the palpable finding. By minimizing the masking effect of overlying breast tissue, tomosynthesis reduces the need for additional views. In many cases, patients presenting with palpable findings can proceed directly to ultrasound after routine 2D plus tomosynthesis MLO and CC views. Importantly, tomosynthesis does not replace ultrasound. A negative 2D plus tomosynthesis mammogram does not preclude the presence of malignancy. Although tomosynthesis improves the sensitivity of mammography, some cancers may still remain mammographically occult. Furthermore, posteriorly or peripherally located lesions may be excluded from the mammographic views even when the radiopaque skin marker placed on the palpable abnormality is included (Fig. 6.14). Finally, ultrasound can often demonstrate dermal lesions better, reassuring patients who present with palpable epidermal inclusion cysts or sebaceous cysts. For all of these reasons, ultrasound remains essential in the diagnostic evaluation of a palpable mass.

Conversely, tomosynthesis yields a more definitive diagnosis than ultrasound in certain clinical scenarios. In patients in whom a fat-containing lesion is suspected, tomosynthesis can confirm a benign lipoma, hamartoma, or fat necrosis. For example, symptomatic patients with prior mastectomy with or without reconstruction are typically imaged with ultrasound as the first-line diagnostic modality. Ultrasound may demonstrate a solid mass of mixed echogenicity with a differential diagnosis of fat necrosis versus recurrent carcinoma. In these cases, tomosynthesis can resolve the dilemma by demonstrating a radiolucent mass typical of fat necrosis, thus

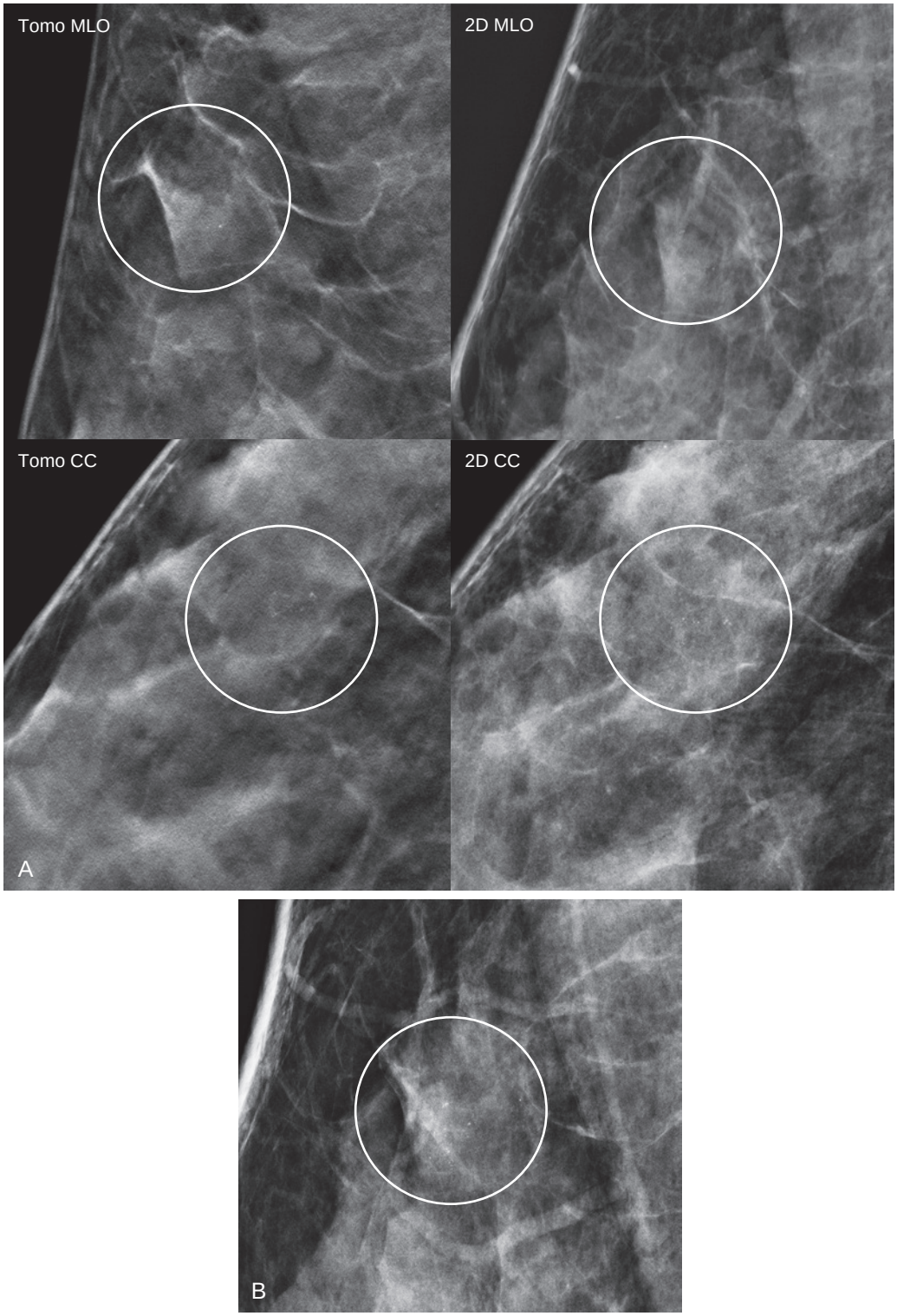


FIG. 6.12 Grouped calcifications better seen on 2D mammography (A) A 41-year-old woman presents for baseline screening mammogram. Fine grouped calcifications *(circles)* are seen better on 2D images compared with tomosynthesis sections, which show only a few of the calcifications within the cluster on any one slice. **(B)** These calcifications *(circle)* demonstrated layering in the ML (90-degree lateral) magnification view consistent with milk of calcium.

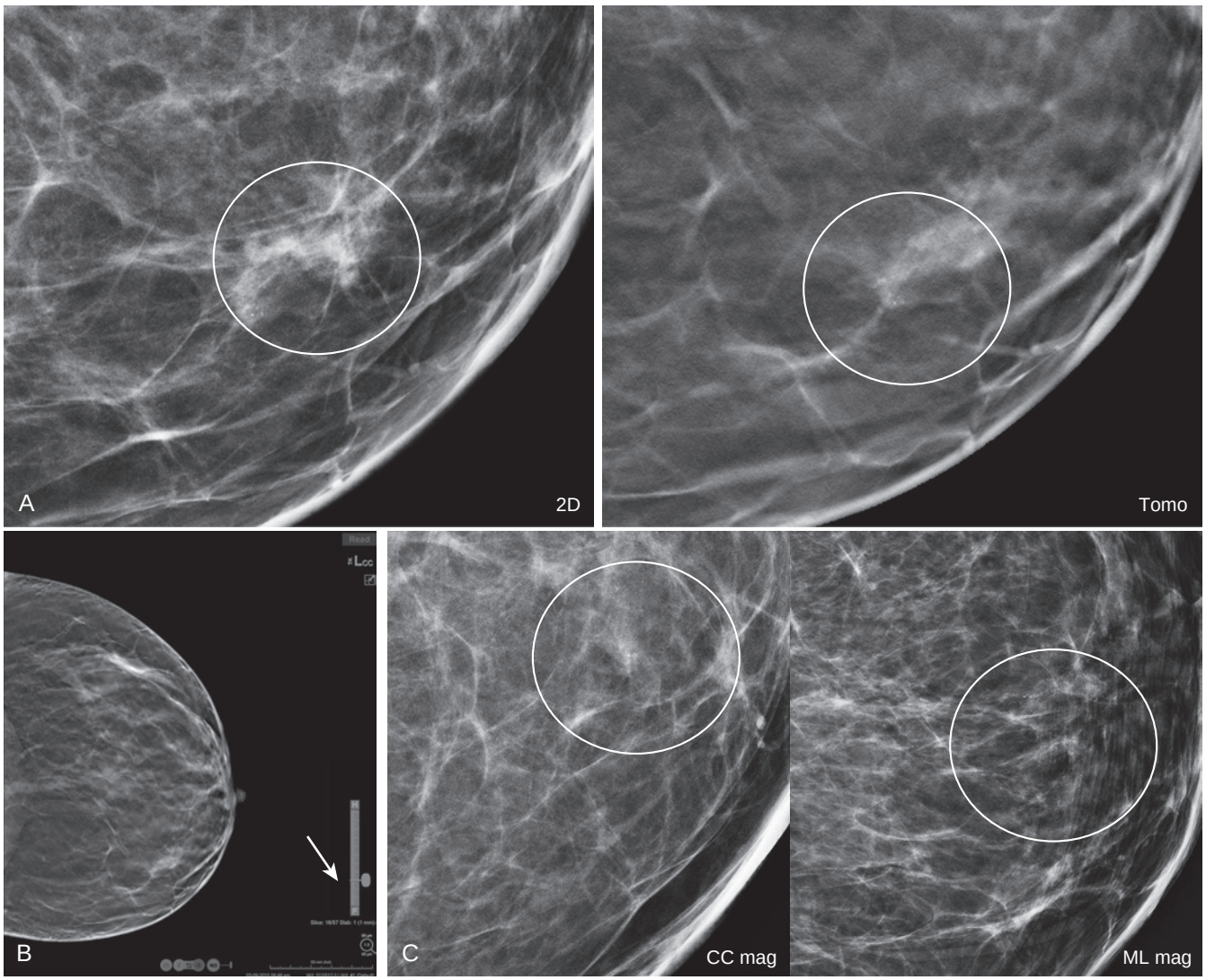


FIG. 6.13 Benign calcifications initially seen on only one view **(A)** Screening mammogram in a 53-year-old woman reveals a small group of subtle new amorphous calcifications *(circles)* in the right medial breast, seen only on the CC view. The calcifications are seen better on tomosynthesis. **(B)** Although the calcifications were only initially seen on the CC view, the location on the mediolateral oblique view could be determined by noting the location of the CC tomosynthesis slice containing the calcifications, using the tool bar locator. In this case, the calcifications were noted to lie in an inferiorly located slab *(arrow)*. **(C)** Magnification CC and ML (90-degree lateral) views confirm a subtle group of amorphous calcifications *(circles)*, BI-RADS 3.

TOMO TIP ★ In this case, tomosynthesis was useful in the work-up of new, subtle, grouped calcifications because the calcifications were initially better seen on tomosynthesis compared with standard 2D images and also allowed for efficient localization of the calcification on the orthogonal view.

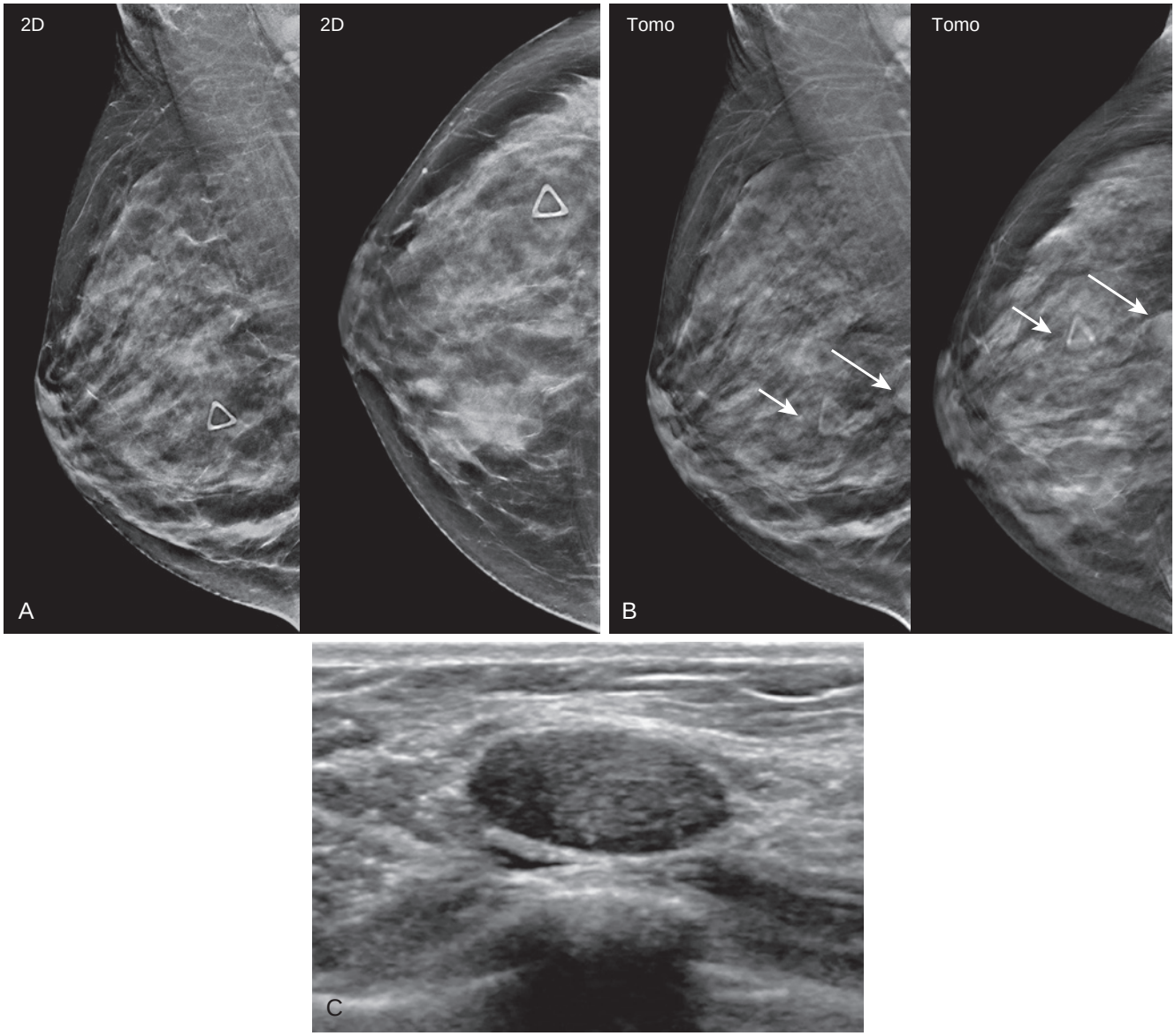


FIG. 6.14 Palpable fibroadenoma seen on tomosynthesis and ultrasound. (A) A 34-year-old woman presents with palpable mass in the right breast, denoted by a triangular radiopaque skin marker. Two-dimensional mediolateral oblique and craniocaudal views reveal dense breast tissue and no suspicious findings. **(B)** Tomosynthesis views demonstrate suggestion of partially visualized mass *(long arrows)* located posteriorly to skin marker *(short arrows)*. **(C)** Ultrasound reveals an oval circumscribed hypoechoic mass, likely representing a fibroadenoma, corresponding to the palpable abnormality, BI-RADS 3, stable on follow-up.

eliminating the need for unnecessary follow-up or biopsy (Fig. 6.15). Although this appearance may be appreciated on 2D images in some cases, it is often more definitively revealed on tomosynthesis slices.

Nipple Discharge

Tomosynthesis also facilitates the diagnostic work-up of nipple discharge. On routine 2D views the retroareolar region can be particularly challenging to evaluate due to an abundance of overlapping structures. Therefore, the work-up of nipple discharge is often supplemented with spot compression or magnification views. Tomosynthesis reduces the need for additional diagnostic views by improving visualization of the subareolar breast tissue. However, ultrasound should always be performed to image the interior of large ducts and search for intraductal lesions, such as papilloma or ductal carcinoma in situ (DCIS), which may explain the patient's nipple discharge. If ultrasound and tomosynthesis fail to reveal an underlying abnormality, ductography may still be required.

Breast Pain

In patients presenting with breast pain, routine 2D plus tomosynthesis views are generally sufficient. Because most breast pain, particularly in premenopausal women, is caused by hormonal changes, the mammographic evaluation is often

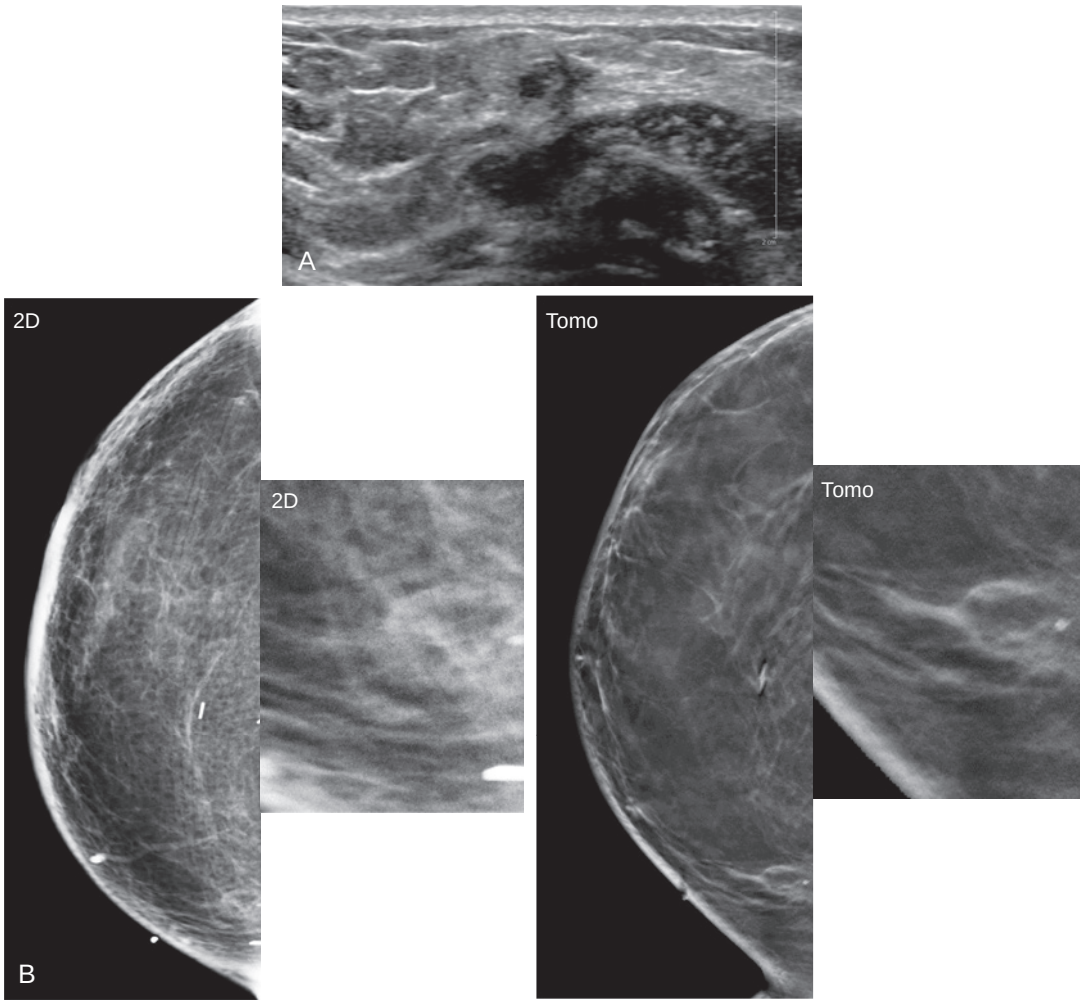


FIG. 6.15 Palpable fat necrosis (A) A 42-year-old woman with history of right mastectomy and deep inferior epigastric artery perforator flap reconstruction presents with palpable mass in medial reconstructed breast. Targeted ultrasound demonstrates a corresponding irregular mixed echogenic mass with indistinct margins. **(B)** Because the ultrasound findings were inconclusive, mammography was performed. 2D images reveal predominately fatty tissue and an asymmetry in the region of palpable concern, whereas tomosynthesis confirms the presence of a lucent mass consistent with fat necrosis, BI-RADS 2.

negative. Ultrasound completes the work-up by revealing common causes of focal breast pain, such as cysts, as well as relatively uncommon causes, such as superficial thrombophlebitis or Mondor disease.

With its improved sensitivity and specificity in the screening population, it may be expected that 2D plus tomosynthesis imaging would confer the same benefits on symptomatic patients. Nevertheless, further investigation is needed to define the advantages of tomosynthesis in this population.

Summary

Tomosynthesis improves the work-up of patients presenting for diagnostic mammography. Advantages include greater accuracy of diagnosis, stemming from both increased sensitivity and specificity, as well as improved efficiency with a marked reduction of additional mammographic views, benefiting both the patient and the breast imaging facility. Future studies and technologic advances will likely further establish tomosynthesis, together with ultrasound, as the primary tools used in the diagnostic setting.

CHAPTER 7

Tomosynthesis Interpretation Tips and Pitfalls

Liane E. Philpotts | Regina J. Hooley

Interpreting tomosynthesis screening exams differs from interpreting two-dimensional (2D) digital images. Just as switching from film-screen image interpretation using a view box with a magnifying glass to manipulating digital images on computer monitors, tomosynthesis similarly requires developing a different pattern of observation and assessment. Much more information is packed into a tomosynthesis exam compared with 2D full-field digital mammography, requiring more to observe and mentally assimilate by the radiologist. This process involves assessment of numerous individual images and requires scrolling back and forth multiple times to fully assess all parts of the breast and sometimes additionally through focal areas (targeted scrolling) in order to best evaluate potentially concerning abnormalities.

Increased time required to read tomosynthesis exams compared to 2D mammography has been shown by several studies. Batch reading of screening exams has been the most cost-effective method to read 2D analog exams mostly due to the labor and time required to load and take down analog films on an alternator, making it impractical to read screening cases online (ie, giving patients immediate results before leaving the breast imaging facility as is the usual practice following a diagnostic exam). Even in the early years during the transition from analog to digital mammography, batch reading was still very practical because prior analog images were still needed for comparison purposes. However, once a practice has achieved a state whereby the current and recent priors are all digital, reading online becomes feasible. With tomosynthesis mammography there are reduced screening recalls and fewer diagnostic mammograms requiring short interval follow-ups (Breast Imaging Reporting and Data System 3 [BI-RADS 3]). In addition, diagnostic work-ups with tomosynthesis are also greatly abbreviated, requiring fewer mammographic images. All of these factors combine so that over time breast imaging practices may find that radiologists actually have more time and can read screening cases online. Thus, although individual tomosynthesis exams may take a little more time to view and interpret, overall the caseload and workflow are improved and more efficient for both radiologists and patients.

Just as with the apprehension associated with the transition from film to digital mammography, once the process of reading tomosynthesis exams becomes familiar, the increased time and effort may be normalized to the point that interpreting cases without tomosynthesis views seems far too abbreviated and incomplete. While nothing can compare with the confidence associated with firsthand tomosynthesis interpretive experience, there are some tips that may expedite this process.

Interpretation Tips

Tomosynthesis Case Review

Reading any mammogram requires complete undivided attention, but reading tomosynthesis cases requires the brain to take in and process more information than it is used to. Reading a large number of consecutive screening tomosynthesis exams can potentially be more tiring than reading a similar number of 2D cases. Every mammogram belongs to a patient who has made time out of her daily life to come for the exam, as well as endured potentially uncomfortable positioning and radiation exposure. Women choose mammography because they want to have the best chance of detecting breast cancer early. Distractions are common in busy practices, but attempts must be made to minimize such diversions because important findings may otherwise be missed. When proceeding through the hanging protocol of any particular mammogram, try to avoid interruptions. Potentially concerning areas on the mammogram that the brain may be processing, consciously or subconsciously, will be lost if your attention is drawn away from the images. Ask your staff or colleagues to try not to interrupt you in the middle of a case. If interrupted, *start over*. Otherwise you'll risk missing something. While many mammograms may be read on any particular day, each mammogram is connected to a different individual and each one deserves the utmost careful consideration by the radiologist. If you are fatigued, step away and take a break.

Ease of viewing tomosynthesis exams is extremely important. Analogous to driving a car, it is best if you can keep your eyes on the images, and not look down at buttons, keyboards, and so on (Fig. 7.1). Having a well-designed keypad and hanging protocol that permits simple single button advancement of images and toggling between 2D and tomosynthesis not only makes the viewing process quicker and more streamlined, it also prevents losing track of findings being mentally processed. A hanging protocol can be developed such that a single button can advance through all images of a screening exam—including 2D, full resolution images, 3D with priors, and computer-aided detection—eliminating the need to take one's eyes off the monitor. Propriety workstations have such optimized keypads, but some picture archiving and communication system (PACS) vendors also supply these features. It is strongly recommended to establish such an optimal workstation configuration, ultimately saving time and potentially reducing errors.

Tomosynthesis interpretation obviously involves scrolling! Each mammographic view has many thin slices to analyze—the exact number depends on the breast thickness. To fully

FIG. 7.1 Tomosynthesis workstation setup. Comfortable viewing of tomosynthesis exams is key. Being able to review images and advance through the hanging protocol without having to look down at a keyboard is important to increase speed and reduce errors. Reduce excess arm and wrist movement, for example, by scrolling through images by depressing the mouse scroll wheel.

assess all slices within a particular view and not miss any part of the breast, it is necessary to scroll back and forth through the image multiple times. Develop a routine and consistent process of inspecting each section of the breast such that no part is missed. At a minimum, one must scroll through a normal-sized breast three times (eg, upper or outer, middle, and lower or inner). While the tomosynthesis slice images can be reviewed in automatic cine mode, it is better to be in control—similar to driving—such that when a potential lesion catches your eye, you can hover over it (targeted scrolling) to more closely evaluate the region. For many radiologists, the most simple and ergonomic method of scrolling is by depressing the scroll wheel on the mouse and slowly moving the entire mouse forward and backward. This requires no wrist or finger movement and only minimal elbow and shoulder motion. Make sure your workspace is not cluttered or cramped and you have ample space for excursion of the mouse.

An important tip with tomosynthesis interpretation is not to mentally assess too many findings simultaneously. For instance, calcifications should be assessed on the full resolution views, while soft tissues and architecture should be assessed separately particularly when scrolling through the tomosynthesis slices. Do not try to do both at once. Also, because there are more images on a tomosynthesis exam compared to conventional 2D mammography, one should be more cautious to avoid missing a lesion due to "satisfaction of search" (Fig. 7.2). If an obvious finding such as a cyst is seen, consciously disregard it at first and look at other areas before going back to more carefully assess the most obvious finding.

TOMO TIP ★ When analyzing multiple findings on tomosynthesis, do not try to evaluate them all at once. Each finding should be analyzed on its own, requiring scrolling through the tomosynthesis images multiple times.

When carefully looking for calcifications or scrolling through the stack of images in a tomosynthesis exam, focusing on the "close-up" imaging findings is easy to do. It is, however, very important to take an "arm's length" view, either at the beginning or end (or both) of the hanging protocol, comparing one breast to the other and each view to prior exams, to assess for more subtle findings such as developing asymmetries. Often such findings can be small and subtle, but even large areas can easily be overlooked when so much of the focus is on the improved detailed imaging tomosynthesis provides (Fig. 7.3). As with reading 2D mammograms, assessing for subtle changes over time is essential for detection of early malignancies. A developing asymmetry is one that appears as a focal area of tissue that is new, larger, or denser compared to prior exams. These findings are usually initially recognized on 2D mammography, and then further scrutinized on the tomosynthesis images. This finding should always be given careful consideration, particularly in postmenopausal women. While most cancers will appear more spiculated or distorted on tomosynthesis images than on 2D, some cancers will present only as a new subtle focal irregular asymmetry or mass even on tomosynthesis and still require recall for a diagnostic work-up. (Fig. 7.4). A negative ultrasound can reassure that a developing asymmetry likely represents an island of normal glandular tissue, and in these cases, routine imaging is usually appropriate, whereas a focal corresponding sonographic finding will help dictate further management such as short-term follow-up or biopsy.

TOMO TIP ★ Look for areas of developing asymmetries on the 2D images. Assessment of the big picture is necessary to detect subtle mammographic changes over time. Once a finding is questioned, scrutinize it more carefully by scrolling through the area on the tomosynthesis images to determine if it is real or simply superimposed tissue.

A common concern among new adopters of tomosynthesis is whether review of previous tomosynthesis images is necessary when comparing the current study to the prior year's exams. While individuals will develop their own personal protocols and preferences over time, generally routine review of prior tomosynthesis exams is not always necessary. Comparison of the prior 2D images usually suffices; however, if questionable areas are noted on the current exam, scrolling through the prior tomosynthesis images is greatly beneficial to either establish stability or recognize the finding as new or changing.

The source projection images should be available for review on the workstation. These are similar to a maximum intensity projection image in magnetic resonance imaging (MRI) and can provide a quick overview of the composition and arrangement of the breast tissue (Fig. 7.5). Most radiologists do not routinely review projection images. However, if there is a question of motion on a particular case, reviewing the projection images may show jumping of the images due to the patient's breathing or other movement during the tomosynthesis image acquisition. Additionally, if there is an area of questionable findings on the tomosynthesis slice images, review of the projection images—particularly by rotating back and forth—may sometimes help determine if a focal area represents normal fibroglandular tissue or a more concerning finding.

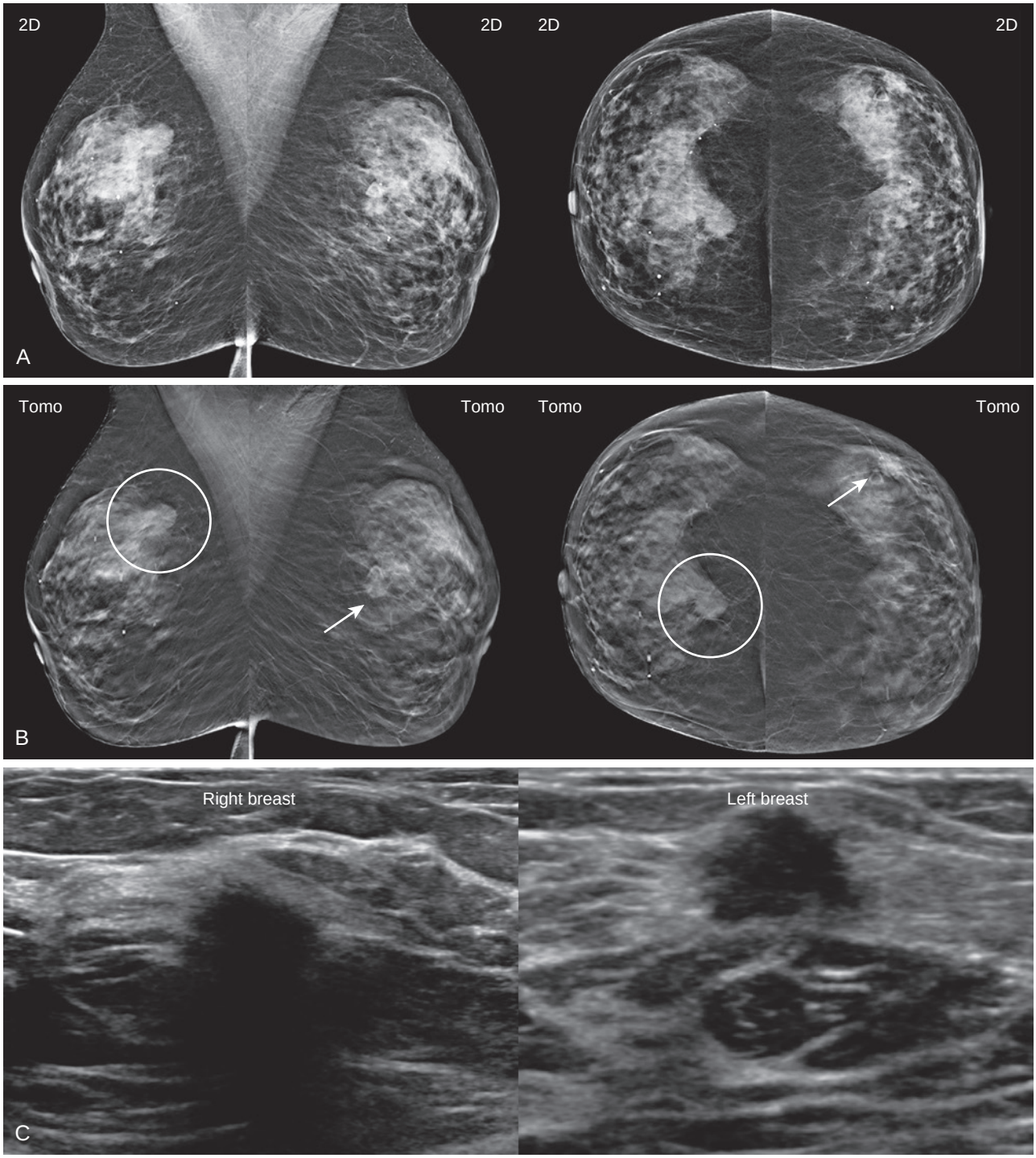


FIG. 7.2 Avoid satisfaction of search. (A) A 69-year-old woman with heterogeneously dense breasts presents with a palpable finding in the lateral left breast (indicated by triangular skin marker). **(B)** A mass with spiculated margins corresponding to the palpable lump *(arrows)* is depicted well on the tomosynthesis slice images. However, an even larger irregular mass with spiculated margins *(circles)* is seen in the right breast 12-o'clock region. **(C)** Ultrasound reveals corresponding hypoechoic irregular masses bilaterally. Core biopsy of both masses showed invasive ductal carcinoma. Final surgical excision of the right breast mass showed Stage 2A, poorly differentiated triple negative carcinoma and Stage 1A ER/PR+, Her2 equivocal cancer of the left breast. Obvious findings in one breast should never preclude careful assessment of all areas of both breasts.

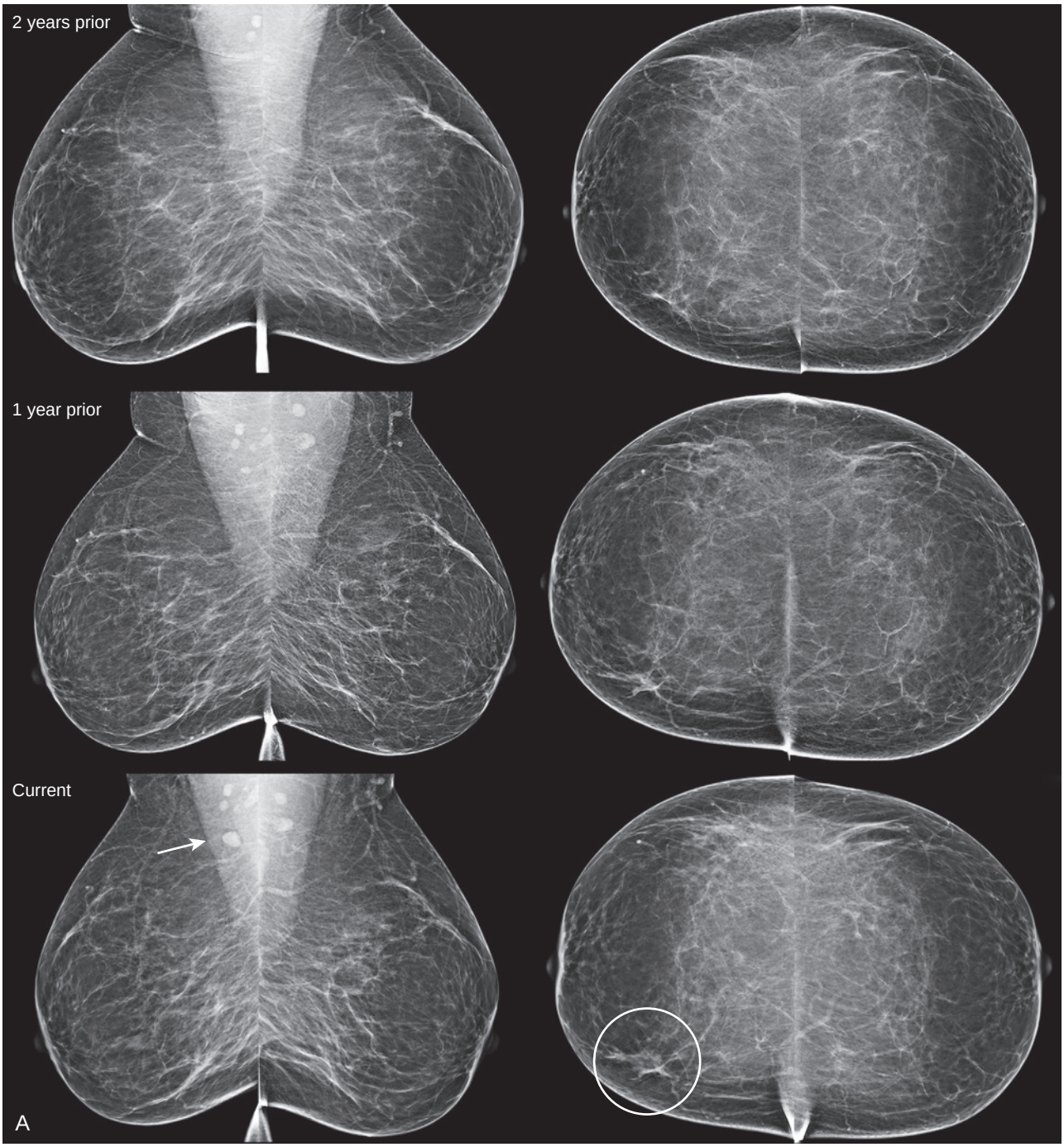


FIG. 7.3 Arm's length view. Screening mammograms of a 45-year-old woman. **(A)** 2D images demonstrate an asymmetry in the medial right breast *(circle)* more prominent compared to priors and an enlarged right axillary node *(arrow)*.

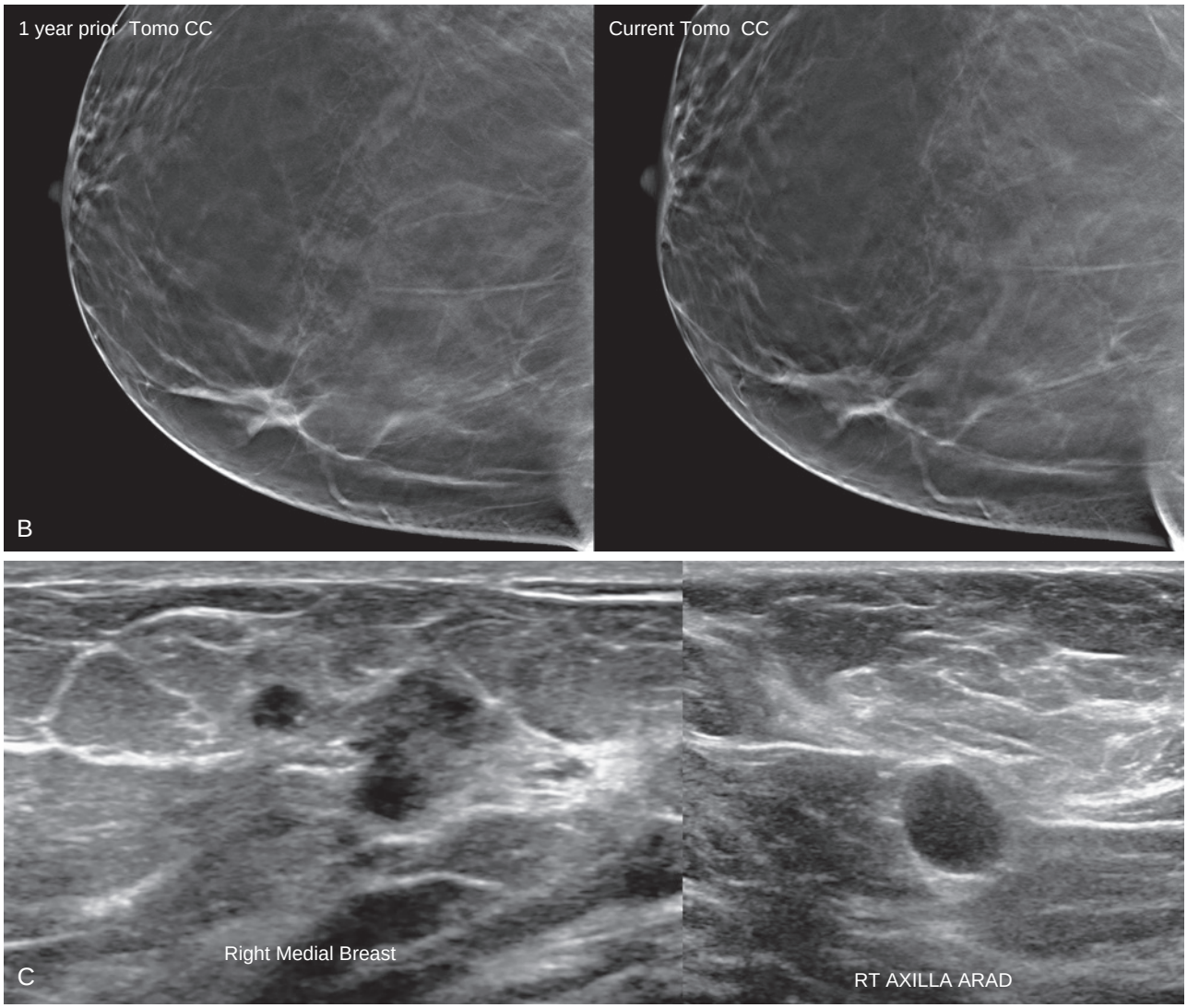


FIG. 7.3, cont'd (B) Closeup views of prior and current right CC tomosynthesis slice images demonstrate a medial low-density mass with spiculations extending at least 2 cm. The lesion was not seen 1 year prior and was not recognized as a developing density. **(C)** Ultrasound shows a corresponding irregular, hypoechoic mass, with satellite nodule and an enlarged node in the axilla. Biopsy revealed poorly differentiated IDC, lymphovascular invasion, and a positive axillary node. Recognizing developing densities is challenging and is best appreciated by taking an arm's length view of the images.

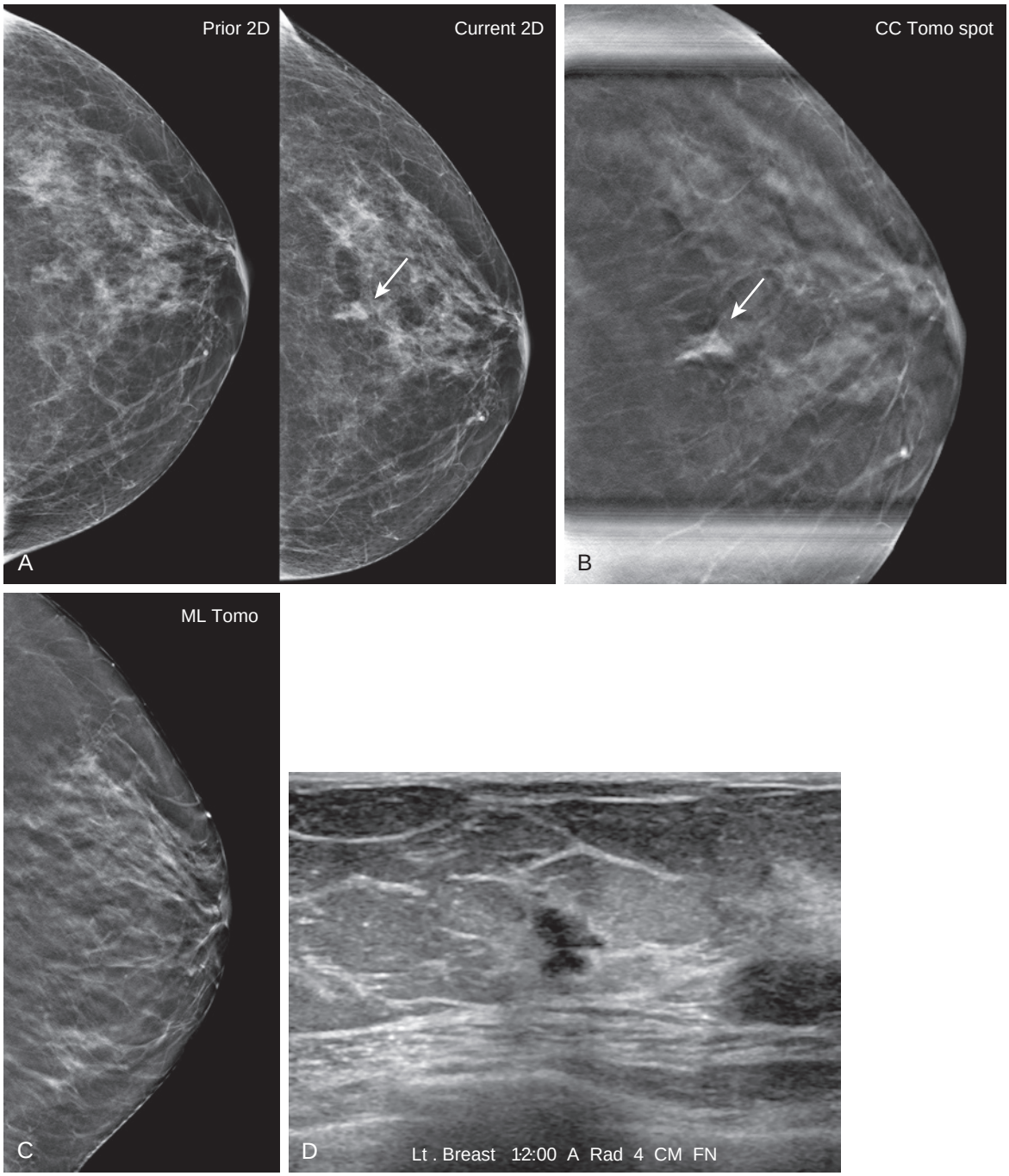


FIG. 7.4 Carcinoma presenting as a developing asymmetry. A 61-year-old woman was recalled from a screening tomosynthesis mammogram. **(A)** A developing asymmetry *(arrow)* was noted centrally on the CC view in 2D images, more prominent than the previous mammogram. **(B)** The tomosynthesis spot slice image also showed a focal asymmetry but without spiculated margins *(arrow)*, which located the lesion on the upper breast. **(C)** No definite mass could be seen on the ML (90-degree lateral) tomosynthesis views. **(D)** Ultrasound, however, showed a corresponding irregular taller-than-wide hypoechoic mass at the 12-o'clock region. Ultrasound-guided biopsy showed moderately differentiated invasive ductal carcinoma.

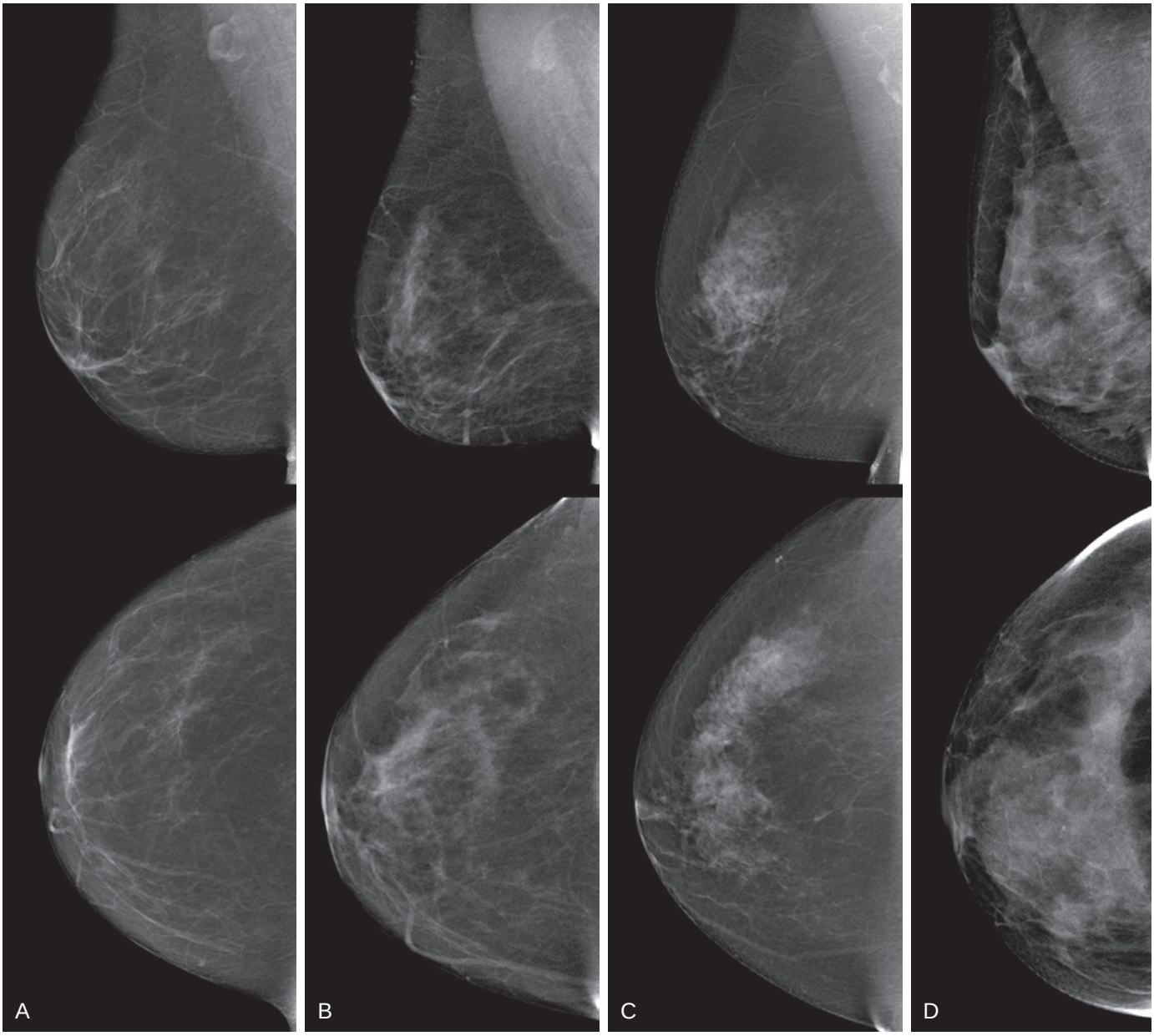


FIG. 7.5 Source projection images. Examples of source projection images in four different patients with varying density patterns: **(A)** predominantly fatty, **(B)** scattered fibroglandular, **(C)** heterogeneously dense, and **(D)** extremely dense. Such images yield a transparent view of the breast that can be helpful in assessing motion, tissue patterns, and focal findings. Source projection images are a proprietary image set that can be viewed in cine mode and contain the data used to create the tomosynthesis slice images. Typically there is a consistent number of source projection images acquired, regardless of the view or breast thickness.

Localization Tips

One key tomosynthesis tool is the localization feature. As the radiologist scrolls through the breast image, a localizer tab also moves indicating position within the breast. Additionally, the individual slices are numbered for ease of reviewing or reproducing findings (Fig. 7.6). For example, when scrolling through a craniocaudal (CC) view, the localizer tab moves from the inferior aspect to superior aspect and vice versa. If the radiologist were to stop at any point on the CC view, a look at the localizer tab will indicate that the potential finding lies in the inferior or superior breast, allowing a more targeted inspection of the mediolateral oblique (MLO) view. Assessing the orthogonal location of a lesion initially discovered on the MLO view is slightly more challenging than those initially seen on the CC view as the images proceed from lower outer through to upper inner quadrant, not strictly lateral to medial, as in a true 90-degree view. Furthermore, the angle of projection, while commonly 45 degrees, varies between patients and even within the same patient from year to year. Geometry and projection angle must be kept in mind to be able to mentally map findings in the MLO view to the correct portion of the breast. A visual reminder of MLO positioning demonstrates how some of the lower outer breast projects above the nipple on the early slices in the stack (ie, near the receptor) and tissue in the upper inner breast can project below the nipple on the slices near the compression paddle (Fig. 7.7).

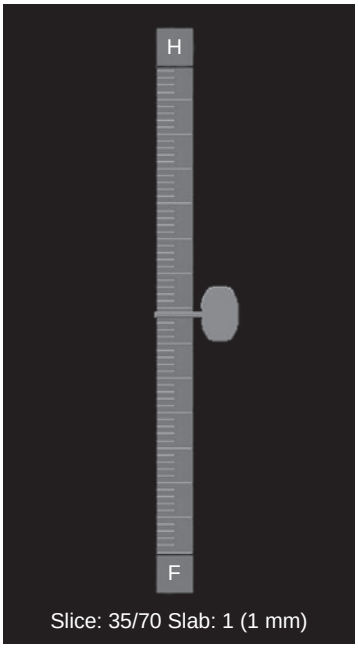


FIG. 7.6 Localizer tab. A localizer bar displayed with the tomosynthesis images on the workstation indicates where any particular slice occurs in the complete stack, which permits knowing the location of a finding in the breast (in this case, slice 35 out of 70, or midway through the breast).

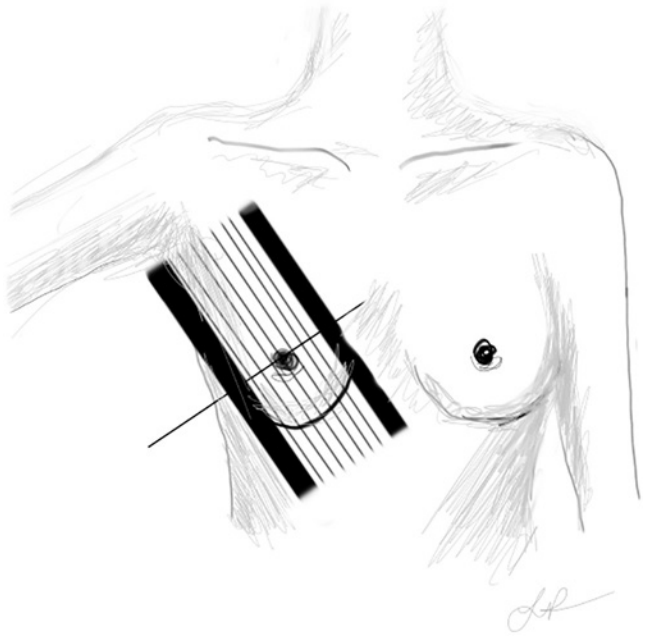


FIG. 7.7 Schematic drawing showing orientation of the MLO. Tomosynthesis slices from the receptor to compression paddle can be seen to include areas of the breast that project above or below the nipple, depending on the slice position. For example, some tissue in the upper inner quadrant can appear below the nipple level on the MLO view, and some tissue in the lower outer quadrant can appear above the nipple.

The accurate use of localization is a critical skill in tomosynthesis interpretation. Assessing potential lesions in both projections is much more comprehensive than on 2D mammography alone. The careful targeted scrolling through a new focal area in both projections helps determine whether a true lesion likely exists and requires further evaluation or is not real, therefore precluding recall. The greatest benefit in reducing unnecessary recalls is in the careful assessment of images in both projections and trusting the tomosynthesis images. Areas of focal density may stand out on the 2D images, yet the tomosynthesis slices show it is simply superimposed tissue with no focal correlate in the other projection. Radiologists have varying changes in their recall rates with tomosynthesis, depending on how well they integrate the information in the tomosynthesis images or whether they are still swayed by findings in 2D (Fig. 7.8). Review of diagnostic results of recalled tomosynthesis screening cases is strongly encouraged so that one can better gauge what represents true findings. This exercise can also help the radiologist achieve an appropriate threshold for recall.

The use of tomosynthesis in both the CC and MLO projections is important in order to reap the full benefit of tomosynthesis. While the MLO view may capture more of the breast tissue than the CC view, the CC view produces better separation of tissue and is more uniform from year to year, enabling a more accurate assessment of changing tissue patterns. The CC view also contributes more to precise lesion localization. There is evidence that a greater proportion of suspicious lesions are detected on the CC than the MLO view, making the CC view essential to tomosynthesis assessment. The benefit of performing tomosynthesis only in the MLO view is the reduction in overall radiation exposure; however, there is a risk of losing important diagnostic information.

Assessing Focal Findings

If there is a focal finding, can it be found in the orthogonal view? Often it can (Fig. 7.9). One-view asymmetries are far less common with tomosynthesis. The main reason why tomosynthesis has markedly reduced the screening recall rate is due to the reduction of the rate of recall of asymmetries. Many asymmetries seen on 2D mammography are not true lesions. 2D mammography is limited because it can be difficult to differentiate a true subtle or small mass from normal overlapping breast tissue without performing additional diagnostic views. On the other hand, with tomosynthesis, many asymmetries can be dismissed as benign on the routine views. Moreover, many findings that would be considered asymmetries on 2D mammography can often be identified on both tomosynthesis views and classified as a focal asymmetry or a mass. These findings can also be better characterized by assessing shape and margins on the tomosynthesis slices (Fig. 7.10). For these reasons, the frequency of recalled asymmetries is decreased with tomosynthesis.

The main determinant of a benign or malignant mass is shape and margin assessment. Most benign masses will have an oval or round shape and circumscribed margins. Conversely, most malignant lesions will be seen to have irregular shape and indistinct or spiculated margins. Tomosynthesis can distinguish margins better than 2D mammography. Obscured margins are less common with tomosynthesis, and most malignancies are not truly circumscribed. Margin assessment is a very important interpretive step because it helps to confidently characterize a lesion even before the patient proceeds to ultrasound.

To accurately correlate a subtle finding seen on tomosynthesis and ultrasound, placement of a BB on the skin surface

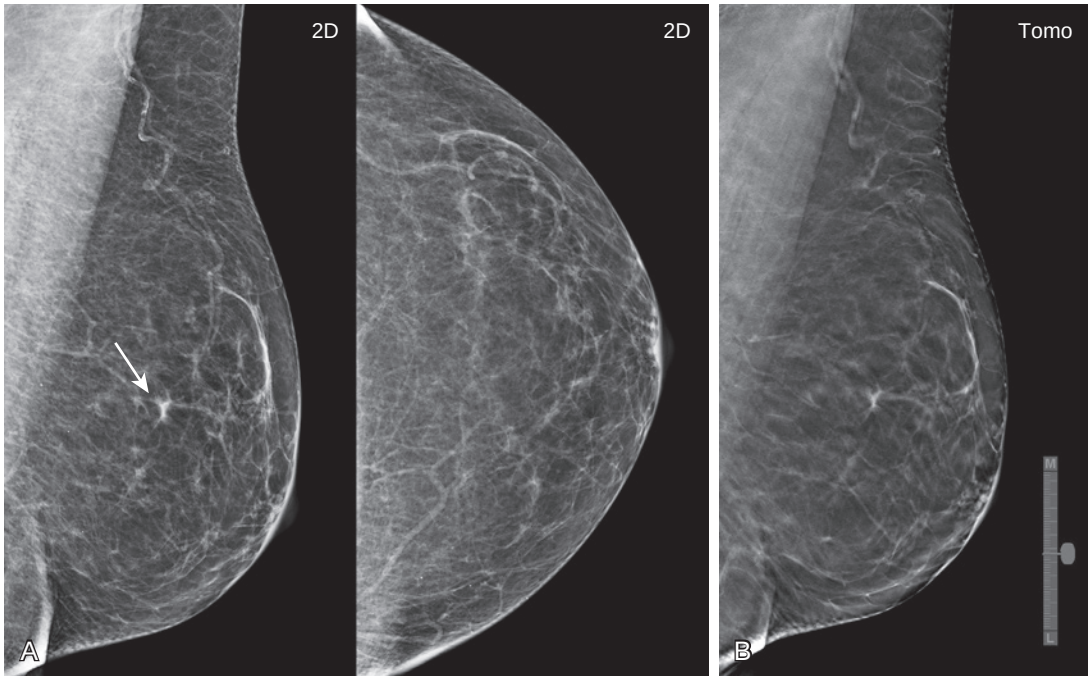


FIG. 7.8 Unnecessary recall. Tomosynthesis screening mammogram in a 65-year-old woman. **(A)** An asymmetry is noted in the central left breast on the MLO view only *(arrow)*. No corresponding mass was seen on the CC view. **(B)** The MLO tomosynthesis slice at the most prominent part maps the density to the central portion on the breast. Close inspection of the 2D and tomosynthesis CC view did not reveal a corresponding mass. This finding is consistent with overlapping fibroglandular tissue, and recall was not necessary.

overlying the sonographic finding and repeating the tomosynthesis views can be very helpful to confirm both lesions are the same (Fig. 7.11). This is particularly helpful for architectural distortions surrounded by dense tissue, such as radial scars, as well as small or subtle invasive ductal and lobular cancers.

For many cases, the use of tomosynthesis reduces the need for additional diagnostic imaging, resulting in a reduction in both radiation exposure and costs. The accurate assessment of the size and shape of a mass may preclude spot views and/or ultrasound, which are routinely necessary with 2D imaging (Fig. 7.12). This represents another example of how tomosynthesis improves workflow.

TOMO TIP ★ Steps in Assessment of Tomo Images

Review the CC and MLO projections carefully. If a finding is initially seen in one view, can it be identified in the other?
Is it likely real, or just convergent normal tissues?
If real, is it new or possibly stable?
Where is it located? Are the findings at similar locations in both images such that they may be the same?
Are the tomo features benign or suspicious?

Pitfalls

Pseudolesions

With 2D mammography, focal asymmetries often generate recall, particularly if a finding is seen on both CC and MLO views, which then require work-up to determine if a true underlying finding exists. With 2D mammography, this usually means additional diagnostic imaging including spot compression, lateral, or rolled CC views. With tomosynthesis, assessing such areas involves both scrolling through the tomosynthesis slices to ascertain whether a focal lesion exists and determining its approximate location on the orthogonal images. Frequently tomosynthesis may show that the focal asymmetry is a composite of Cooper's ligaments, vessels, and/or glandular tissue. Therefore, if no focal area seems apparent or localizable, then a recall may be avoided. Radiologists new to tomosynthesis may still recall a patient for a prominent 2D finding, even though the tomosynthesis imaging suggests no focal suspicious abnormality. However, this defeats the full benefits of tomosynthesis, and this practice can be avoided with reader experience.

In the case of an asymmetry initially seen on only one tomosynthesis view, the orthogonal view should be carefully examined for any suspicious corresponding findings. Lesions seen on one view only may in fact be "pseudolesions," produced by dense tissue interspersed with fat or other normal tissue elements. Pseudolesions can often be resolved by careful examination of the corresponding area in the orthogonal view. In contrast to 2D mammography, tomosynthesis provides the *added* benefit of being able to localize true lesions to a more precise quadrant or clock position based on its slice location, even when seen in only one projection. Beware that success in identifying a focal lesion in both projections is dependent on the density of the breast tissue. Even with tomosynthesis, findings in areas of dense tissue may not

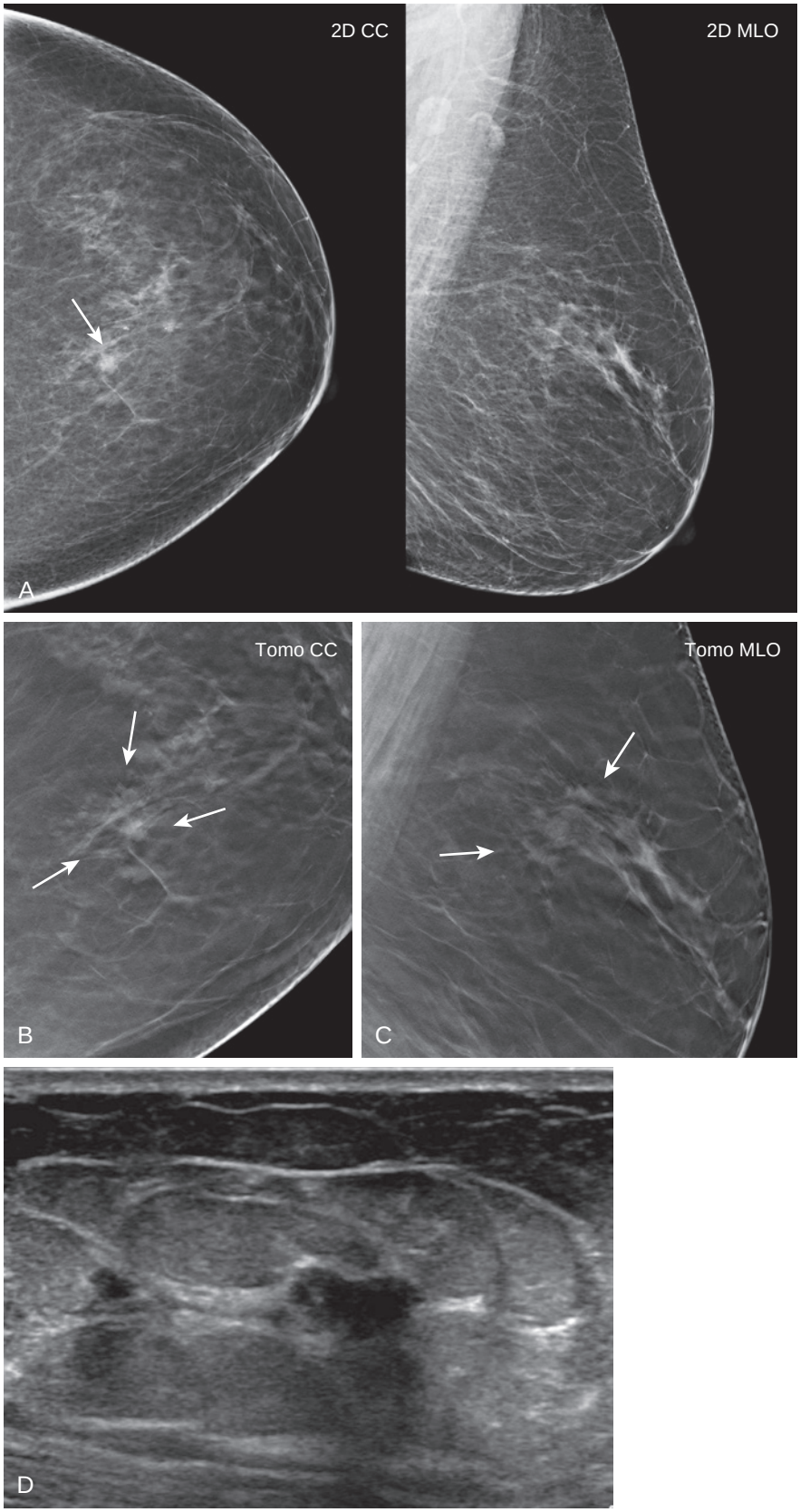


FIG. 7.9 Tomosynthesis permits better characterization of asymmetries. **(A)** A 55-year-old woman was recalled from a screening mammogram that showed a focal asymmetry *(arrow)* reported as being seen in the CC view only. **(B)** Careful review of tomosynthesis images actually shows it to be a mass with associated architectural distortion *(arrows)*, localized to the upper, slightly inner, breast. **(C)** Careful review of the MLO tomosynthesis images permits identification of the subtle lesion *(arrows)* in that view. **(D)** On recall, ultrasound shows a definite mass with associated extension in the surrounding tissue and a nearby small satellite lesion. Biopsy revealed poorly differentiated invasive ductal carcinoma, ER/PR–, Her2+.

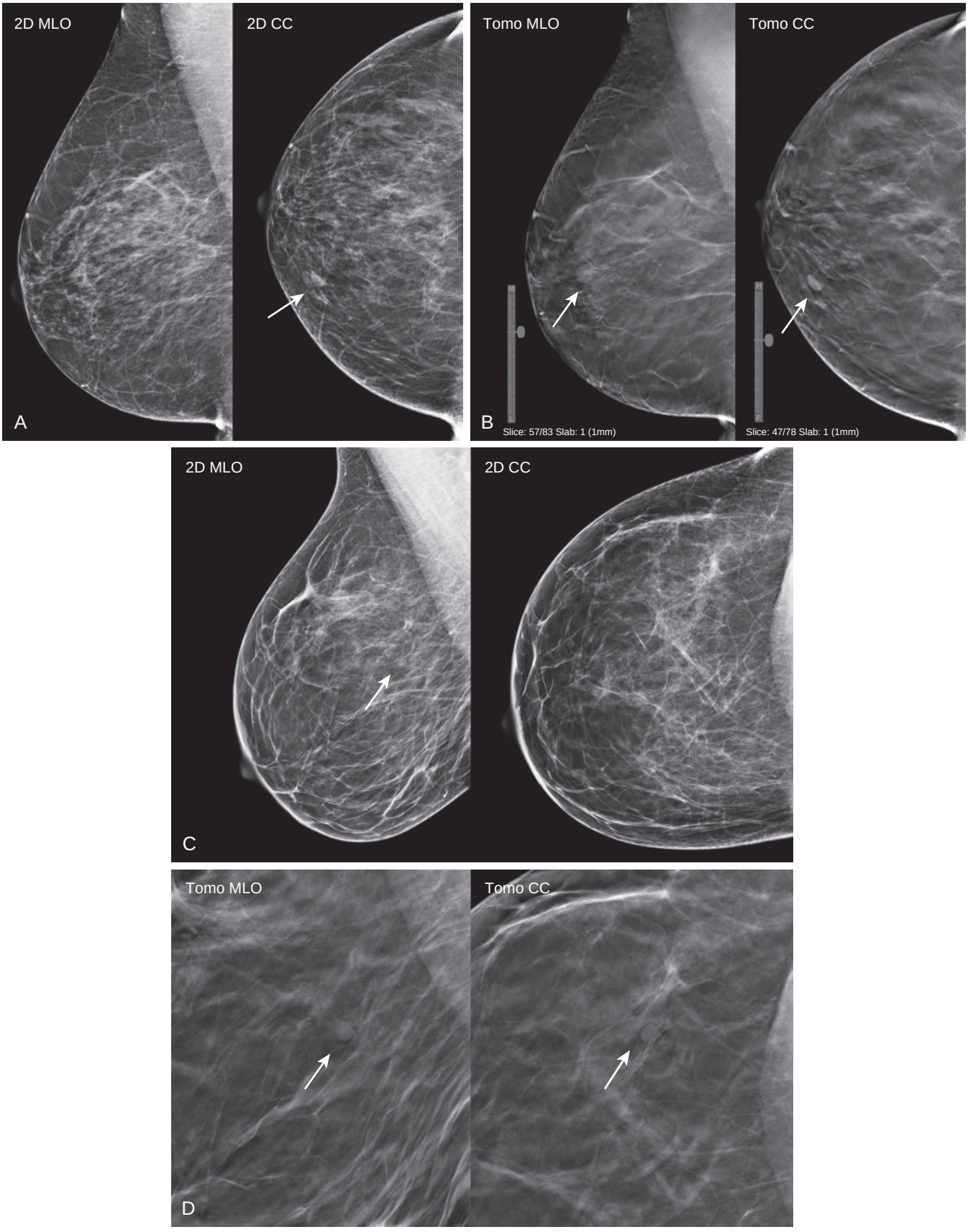


FIG. 7.10 One-view 2D findings seen in both views on tomosynthesis. (A) Screening mammogram in a 64-year-old woman shows a focal asymmetry in the right breast *(arrow)* evident on the 2D CC view only. **(B)** On tomosynthesis, 2D asymmetry corresponds to a mass *(arrows)* in both the CC and MLO views, permitting more complete assessment of the features and location. Ultrasound *(not shown)* showed a benign lymph node. **(C)** A 42-year-old woman presented for screening mammography. A small asymmetry *(arrow)* was seen in the right breast on the 2D MLO view only. **(D)** The close-up tomosynthesis images show the small benign-appearing oval low density mass *(arrows)* clearly in both projections, BI-RADS 2.

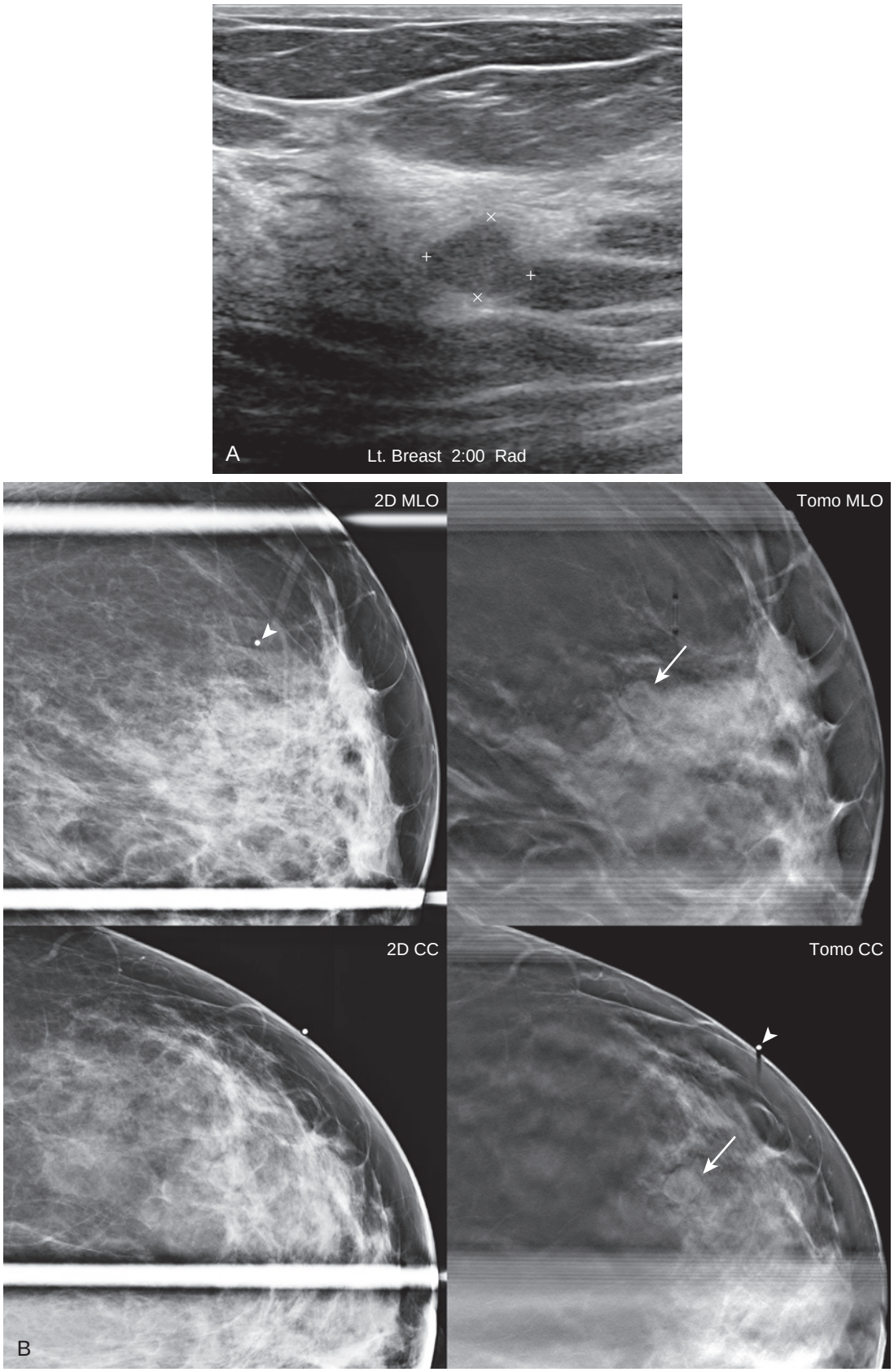


FIG. 7.11 Spot compression view after BB placement can help correlate ultrasound findings. A 53-year-old woman underwent screening mammography. Prior exams were unavailable. A small mass was noted in the left breast upper outer quadrant, best seen on tomosynthesis (not shown). **(A)** An ultrasound was performed, which showed a 1.2-cm solid mass with circumscribed margins in the left breast 2:00 region, likely representing a fibroadenoma. **(B)** A BB was placed on the overlying skin *(arrowheads)*, and tomo spot views were obtained showing the lesion *(arrows)*, correlated with the mammographic finding. Because there were no remote comparison studies, a BI-RADS 3 final assessment was given and the mass was stable at a 6-month follow-up ultrasound.

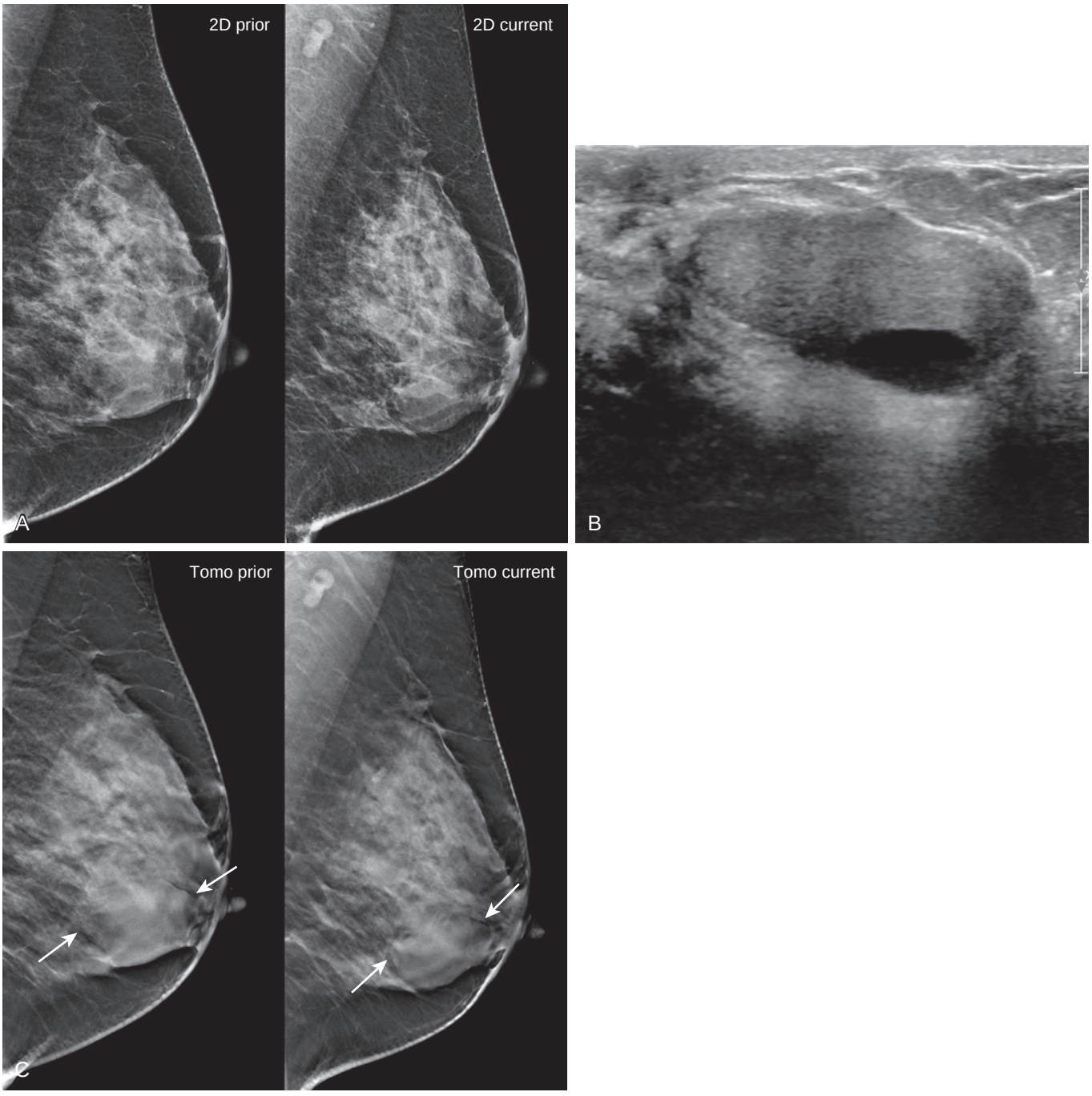


FIG. 7.12 Tomosynthesis reduces additional imaging and follow-up. Screening mammogram in a 49-year-old woman with dense breast tissue and a family history of breast cancer. **(A)** Left breast MLO 2D views from 1 year prior and current do not permit complete assessment of a large mass proven to be PASH (pseudoangiomatous stromal hyperplasia) on a previous biopsy. **(B)** Ultrasound performed 2 years prior shows the corresponding oval, hypoechoic, wider than tall mass. **(C)** The circumscribed margins and size *(arrows)* can be well seen on prior and current tomosynthesis images, which allow confident assessments of the mass as stable; repeat ultrasound was unnecessary.

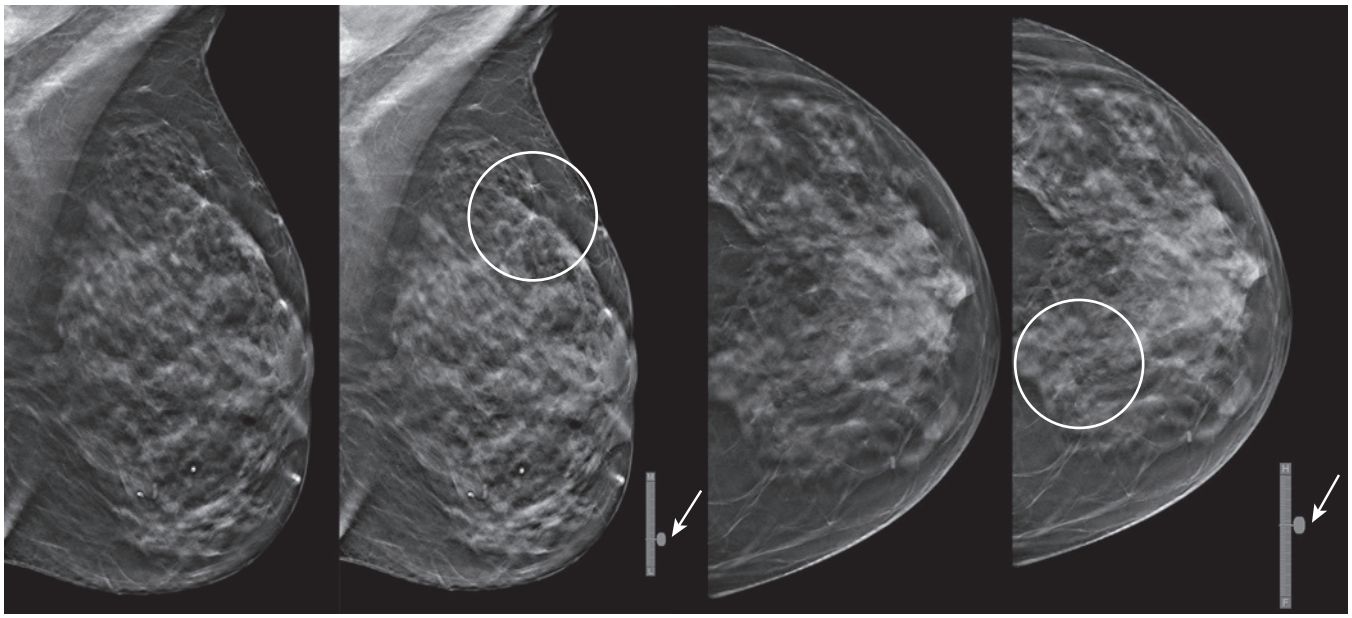


FIG. 7.13 Pseudoarchitectural distortion. A 64-year-old woman referred for further evaluation of a possible architectural distortion *(circles)* seen on tomosynthesis mammogram performed at an outside facility. From the localizer bars *(arrows)*, the lesion would be located in the *upper outer* part of the breast on the ML view (slice 18 of 51) and the *upper inner* area on the CC view (slice 33 of 57), and therefore clearly not representing the same lesion. Repeat tomosynthesis imaging was performed and no architectural distortion was reproduced. Whole breast ultrasound was also normal. BI-RADS 2.

always be thoroughly assessed. Ultrasound is often necessary to determine if the finding represents a true mass or simply normal tissues.

As mentioned previously, it is important to determine whether a finding represents the same area in both views. Incorrect interpretation of tomosynthesis findings can result in patients being recalled for areas of concern on the CC and MLO views that cannot realistically represent the same lesion (Fig 7.13). With 2D mammography, if an asymmetry is noted at a similar distance from the nipple in both views, it could possibly represent the same finding and require recall. With the ability to scroll and localizing using tomosynthesis, a more sophisticated assessment can be made. For example, if an area of concern in the CC view localizes to the lower outer breast, but that on the MLO view is in the upper inner, they cannot represent the same lesion, suggesting both findings may not be real.

Fat-Containing Lesions

It is critical to recognize that malignant lesions seen on tomosynthesis often contain fat. Historically, conventional teaching based on 2D mammography states that fat-containing lesions in the breast are benign, representing lymph nodes, lipomas, fat necrosis, galactoceles, and so on. However, fat is a frequent finding in many malignancies identified on tomosynthesis. In fact, some malignant lesions presenting as spiculated mass or architectural distortions can be very low density (Fig. 7.14). Malignancies can engulf surrounding tissue in the breast, leading to areas of fat entrapped within the mass. All nonencapsulated, fat-containing masses or distortions must be viewed with some suspicion, and further evaluation should be considered.

Tomo-Occult Cancers

A danger in working up suspected tomosynthesis findings is that some cancers may "spot away." Spot compression views are used commonly to work-up questioned findings with 2D mammography, yet it is known that some subtle malignant lesions may spot away. Similarly with tomosynthesis, some malignancies may not be reproduced on spot imaging (Fig. 7.15). If spot compression views are performed for work-up of a tomosynthesis finding, 2D spots alone are of limited use and combination (2D/3D) tomosynthesis spots are recommended. These views may be helpful if they confirm the presence of a lesion by further displacing adjacent tissue and enhancing lesion details, but if they do not reproduce a finding such as a subtle architectural distortion, one should not assume the original tomosynthesis finding is not real. *Beware of spot views!* Repeat full tomosynthesis views, in the original view, rolled CC views, or a true lateral view, may be preferable over spot tomosynthesis views. These may better determine if a true suspicious finding exists.

In some cases, a cancer may be overlooked on tomosynthesis but seen in retrospect. Some malignancies may be very subtle and difficult to detect, even when known to be present while others may be missed due to interpretation errors. Breast cancer presenting as subtle architectural distortions or spiculated masses is often associated with the straightening of tissue and Cooper's ligaments, with thin white lines visualized on tomosynthesis being the only clue to an underlying malignancy (Fig. 7.16).

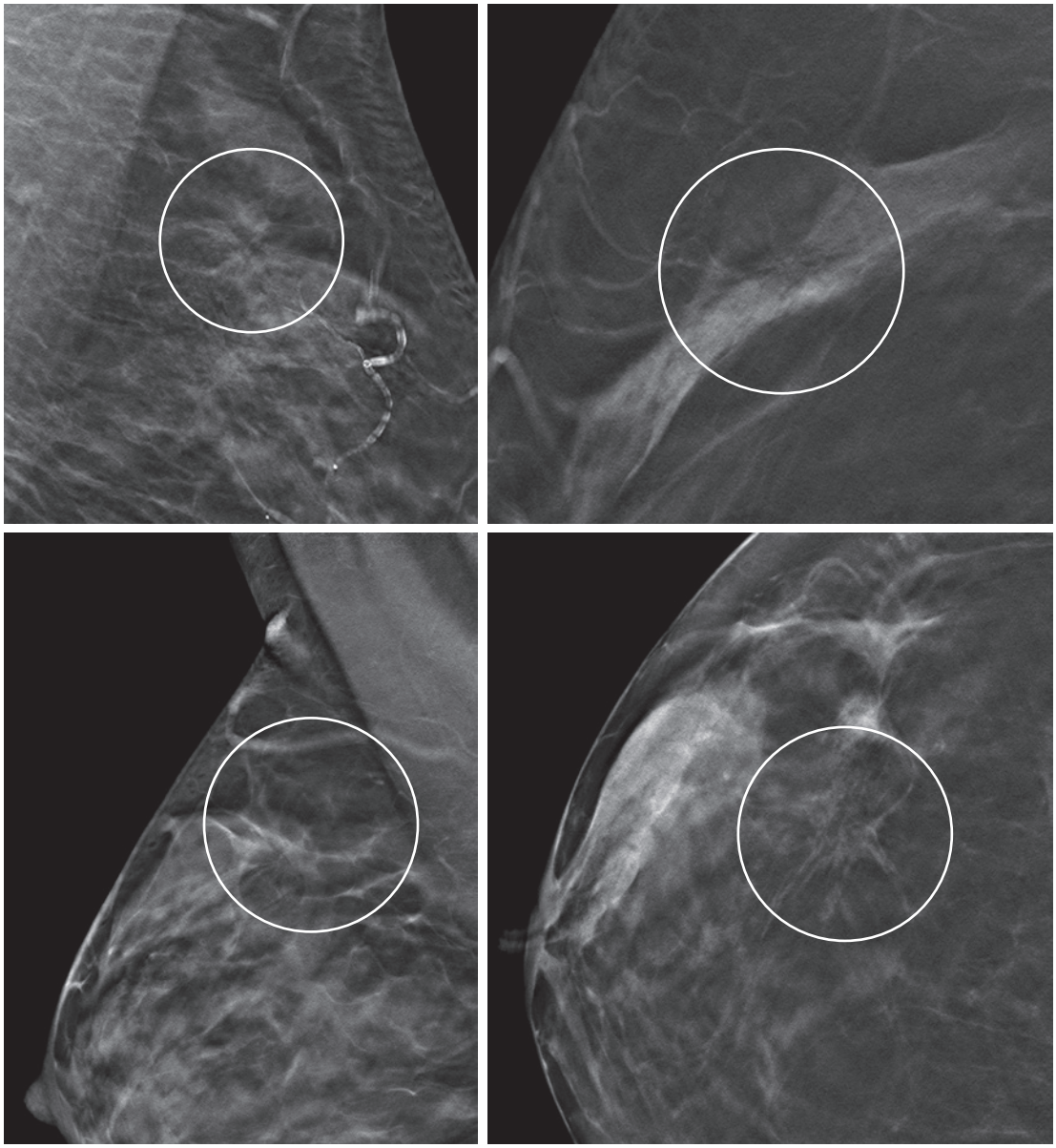
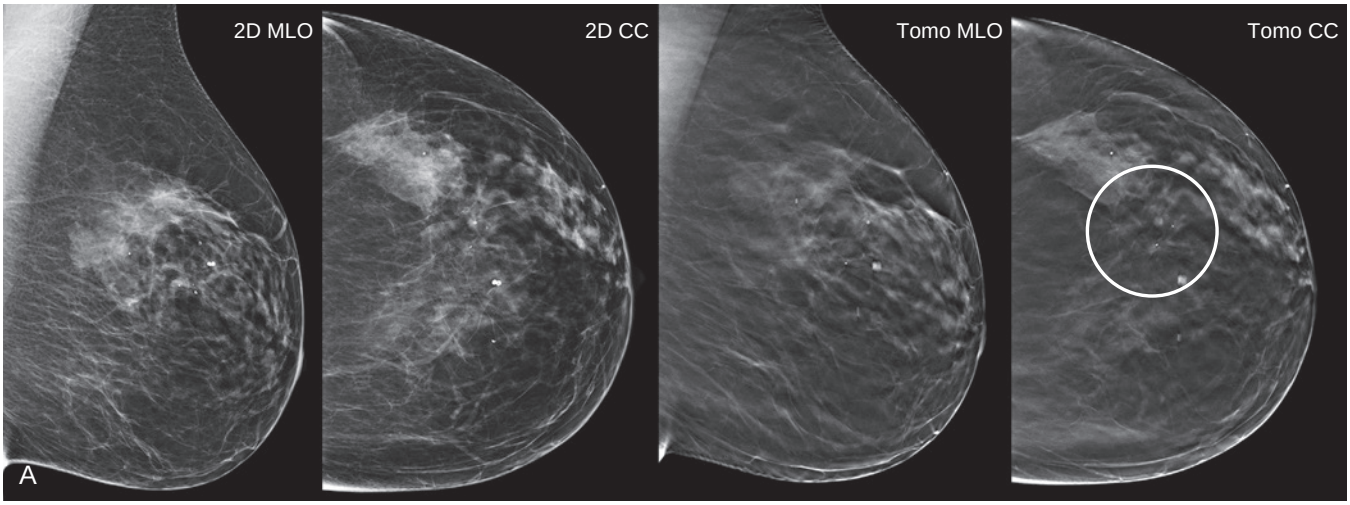
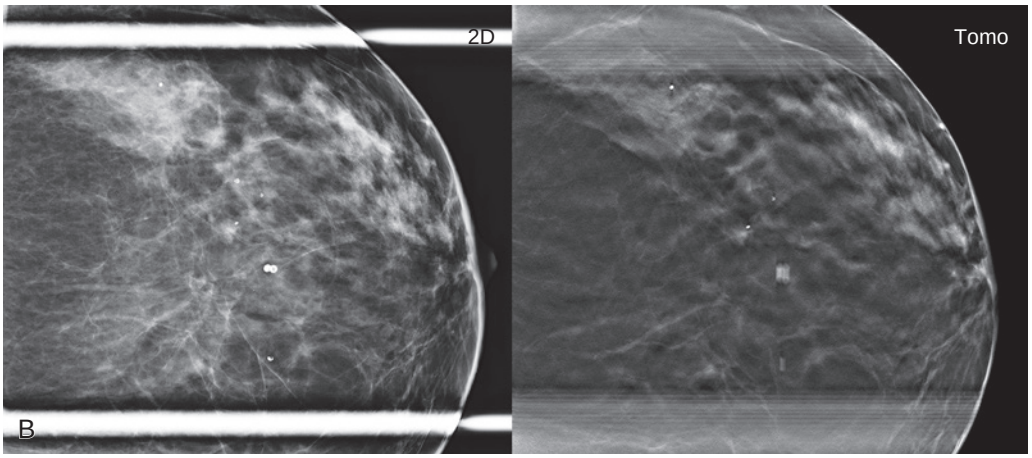


FIG. 7.14 Malignancies can contain fat and be low density on tomosynthesis. Four examples of subtle invasive cancers *(circles)* seen on tomosynthesis.

Another important consideration is that although tomosynthesis is superior to 2D mammographic imaging in detecting cancers, not all malignancies are detectable by tomosynthesis. Some may be very difficult to recognize, presenting as low-density focal asymmetries or distortions that cannot be readily differentiated from normal glandular tissue. And some, buried within dense tissue, will remain occult (Fig. 7.17). Supplemental screening ultrasound may still have a role in detecting important invasive cancers in women with dense tissue.

TOMO TIP ★ Not all carcinomas appear spiculated on tomosynthesis. Nonspecific developing asymmetries, especially in postmenopausal women, need to be carefully assessed.





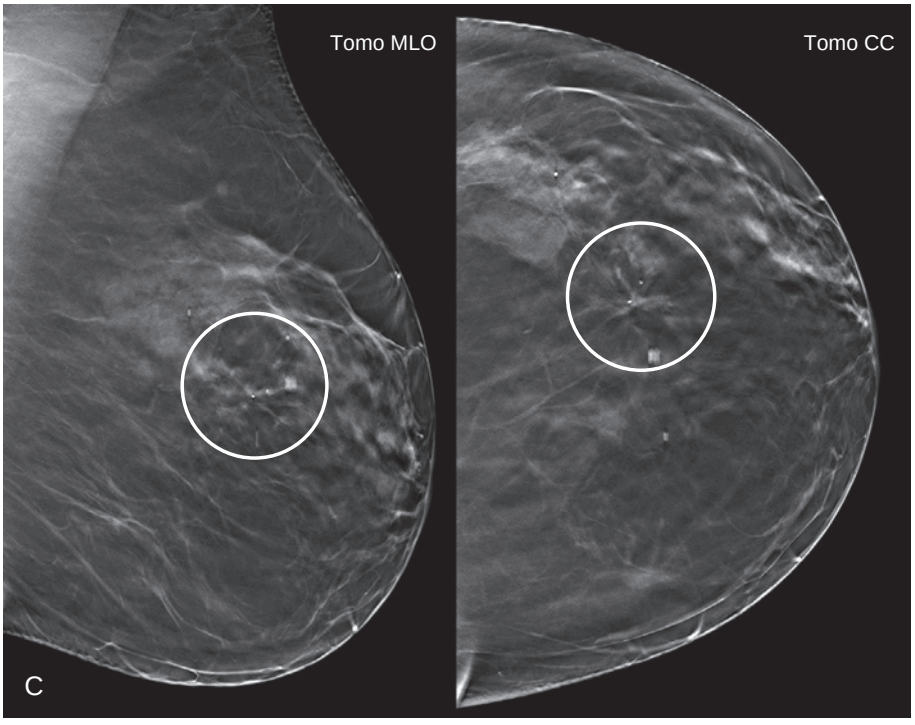


FIG. 7.15 Cancers can spot away even with tomosynthesis. (A) A screening mammogram in a 62-year-old woman questioned a subtle area of architectural distortion (AD) in the left breast *(circle)*, seen best on the tomosynthesis CC slice image. **(B)** Diagnostic mammogram with combination (2D + 3D) spot views failed to reproduce an abnormality. Ultrasound was performed but was negative. The AD was thought to not be real, and the patient was returned to screening. **(C)** Mammogram performed 1 year later again showed AD *(circles)*, now found in both MLO and CC tomosynthesis projections, and persisting on diagnostic spot views.

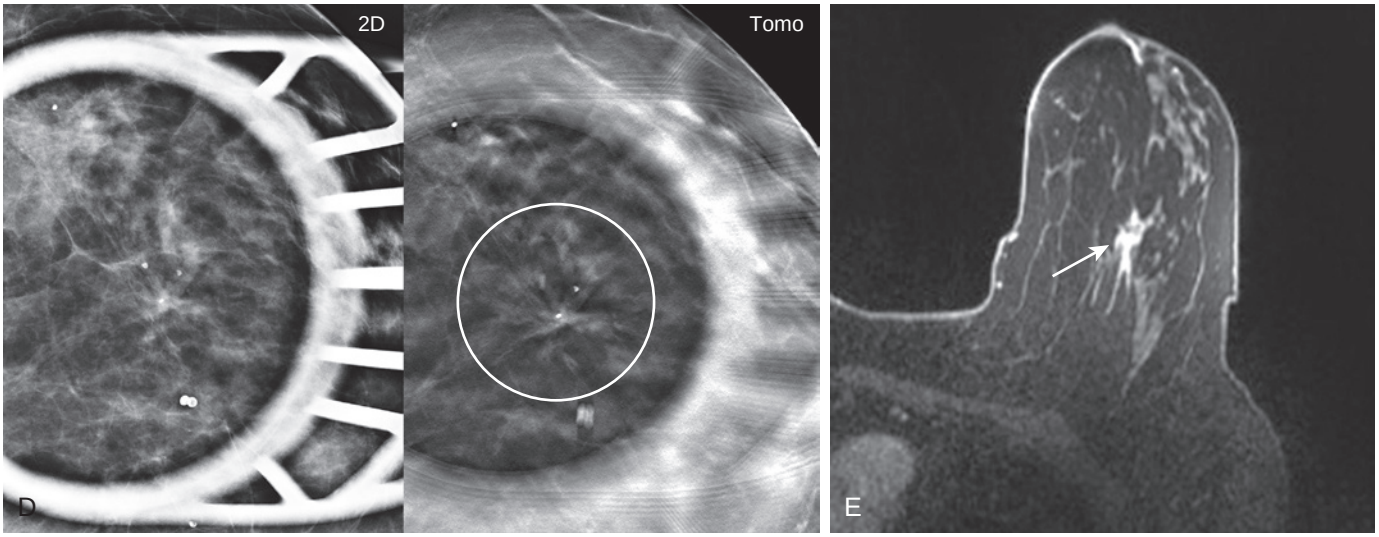


FIG. 7.15, cont'd (D) Again, ultrasound was negative. **(E)** The patient underwent MRI that showed a corresponding focal enhancing area *(arrow)* with washout kinetics. MR biopsy was performed revealing moderately differentiated infiltrating ductal carcinoma, ER/PR+, Her2−.

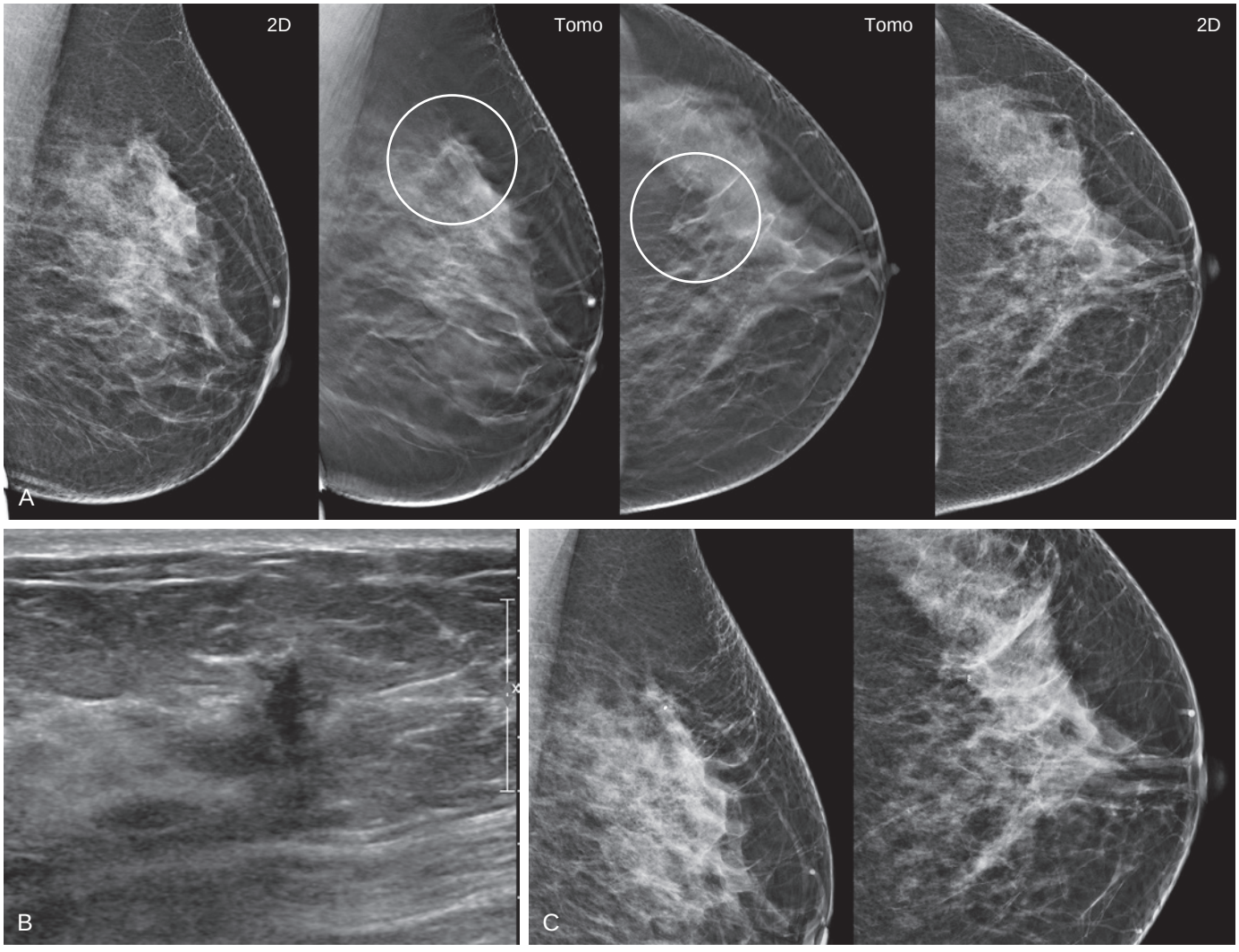


FIG. 7.16 Straightening of glandular tissue and Cooper's ligaments may be the best clue to detect a subtle malignancy. Screening mammogram in a 38-year-old woman with a strong family history of breast cancer. **(A)** A subtle architectural distortion is present in the left upper central breast *(circles)*, seen only on tomosynthesis. Note that straightening of the glandular tissue and Cooper's ligaments is the best clue that a true lesion exists. **(B)** Targeted ultrasound reveals a corresponding irregular hypoechoic mass with an antiparallel orientation. Ultrasound -guided CNB revealed an infiltrating ductal cancer, grade 2, ER/PR/Her(−). **(C)** Post-biopsy 2D mammogram shows the biopsy marker in the correct location.

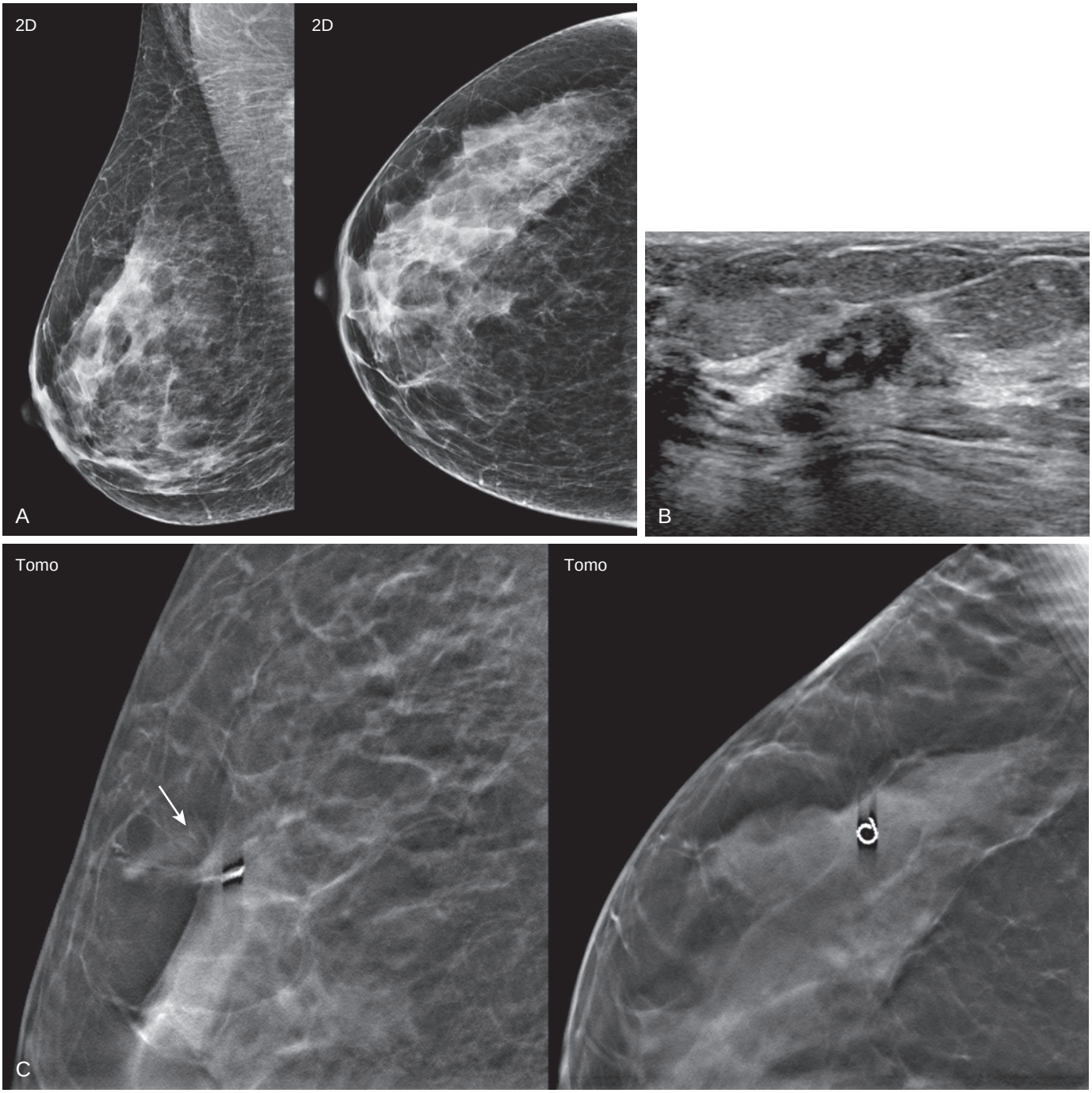


FIG. 7.17 Tomosynthesis occult cancer. (A) A 51-year-old woman had a normal tomosynthesis screening mammogram (right breast 2D images shown). **(B)** Screening ultrasound performed 1 month later revealed an irregular hypoechoic 1 cm mass in the upper outer quadrant. Ultrasound-guided biopsy revealed invasive ductal carcinoma, well-differentiated, ER/PR+, Her2–, 0 SLN. **(C)** Post-biopsy tomosynthesis spot views in MLO and CC show biopsy marker in an area of dense tissue with subtle spiculation *(arrow)*, not obvious prospectively, even on tomosynthesis.

Summary

Interpretation of tomosynthesis exams requires learning new skills and adopting new patterns of image review. Initial trepidation felt by some radiologists quickly leads to satisfaction and new confidence. Improved visualization of breast tissues prevents many false-positive screening recalls while missing fewer cancers. Learning to trust the tomosynthesis images requires experience. Skilled use of tomosynthesis involves careful assessment and correlation of potential findings in all views and accurate localization of lesions. Information provided by tomosynthesis can result in improved lesion characterization, with increased specificity and sensitivity. Increased diagnostic accuracy provided by tomosynthesis will result in continued reduction of false-positive screening recalls, diagnostic follow-ups, and biopsies. Once comfortable with reading tomosynthesis exams, radiologists will find there is no going back to 2D mammography alone.

CHAPTER

8

Benign Findings

Laura Sheiman | Liane E. Philpotts

Introduction

Benign findings in the breast are common. Most findings recalled from screening and even the majority of lesions that undergo biopsy are ultimately found to be benign. Findings that require additional imaging assessment and biopsy are stressful for patients and add costs to the health care system. These cases contribute to what is termed false positives—recalls or biopsies yielding clinically insignificant information—and are a commonly used metric to argue against mammographic screening. Of course, it is only retrospective analysis that defines these as false positives. Better prospective imaging to distinguish between benign and malignant lesions could reduce false-positive work-ups and patient anxiety.

Even after a thorough diagnostic evaluation including spot compression and/or magnification views, the complete assessment of a lesion with two-dimensional (2D) mammography can still remain limited. Overlapping tissue and obscured margins may limit the accuracy of the assessment. Although ultrasound is almost always used in conjunction with mammography for evaluation of masses or densities, it is the combined information from both modalities that ultimately leads to a recommendation to dismiss, follow, or biopsy a lesion. If any findings are concerning, a recommendation for tissue sampling will commonly be made. With improved visualization of lesion shape and margins provided by tomosynthesis, along with a better assessment of multiplicity of lesions and distribution of findings, one can potentially designate more lesions as benign versus those that are suspicious enough to require additional attention, reducing unnecessary imaging follow-ups or biopsies. Tomosynthesis provides the opportunity to reduce false positives and increase the positive predictive value of biopsy.

However, tomosynthesis can also present a challenge in that many more lesions previously undetected on 2D mammography may become more apparent. A benign mass potentially present for many years may be obvious on tomosynthesis, though not detected on prior 2D mammograms. Knowing how to manage a multitude of additional findings can be difficult at first. Close scrutiny of prior mammograms and breast ultrasound images may indeed suggest stability. Even if the margins were not discernable on prior mammograms, it may be possible that the tissue pattern suggests stability and therefore the *newly seen* finding on tomosynthesis can be safely followed. Certainly, increasing recalls for such additional benign findings is not desired. Analogous to *ditzels* or *UBOs* (unidentified bright objects) on magnetic resonance imaging (MRI) or small benign-appearing oval masses on screening ultrasound, many such benign-appearing lesions ultimately have to be disregarded. Learning over time to dismiss these benign findings seen only on tomosynthesis takes confidence and experience to achieve.

Many findings can be assessed thoroughly enough with the routine craniocaudal (CC) and mediolateral oblique (MLO) screening tomosynthesis views such that they do not require recall, including skin lesions or dermal calcifications, looped vessels, or other clearly benign findings on screening tomosynthesis exams. Such cases are discussed in Chapter 5. This chapter concentrates on additional benign findings, some of which may still require recall for more thorough assessment, and discusses their imaging characterization and management.

What Constitutes a Benign Appearance?

Like in all aspects of breast imaging, when a finding is encountered on tomosynthesis, Breast Imaging Reporting and Data System (BI-RADS) descriptors help to guide interpretation toward a benign, probably benign, or suspicious assessment. Oval shape and circumscribed margins are typical characteristics of benign masses. In many cases, screening mammography with tomosynthesis provides sufficient information on shape and margins that can be used in place of common diagnostic views.

Benign masses often have circumscribed margins. Although a small percentage of malignant masses are characterized as circumscribed on 2D imaging, tomosynthesis may depict subtle irregular or spiculated margins that were previously unrecognized. The complete assessment of margins of a mass requires evaluation of all tomosynthesis slices in which the mass is visualized. A circumscribed margin on a single 1-mm thick tomosynthesis image does not necessarily mean that the mass is circumscribed in its entirety and may lead to an inaccurate assessment. There will still be a small percentage of cancers that remain circumscribed-appearing, even on tomosynthesis. Use of all information, such as interval growth, dominant lesion, age of patient, and ultrasound appearance, needs to be taken into account before determining management. Nevertheless, the vast majority of lesions with circumscribed margins will be benign, and tomosynthesis will provide a better differentiation of benign and malignant masses compared with 2D imaging alone.

Multiplicity of bilateral similar findings is indicative of benign processes on 2D mammography and screening breast ultrasound. Multiple circumscribed masses can be regarded as likely representing cysts, fibroadenomas, or other benign etiology, and recall is unnecessary. Although tomosynthesis can initially present a challenge when additional masses are detected that were not seen on 2D imaging, it can also help in some cases to demonstrate multiplicity and bilaterality of findings that suggest benign etiology. Of course, in the case of multiple bilateral

findings, any lesion that is dominant or different in terms of shape, margin, or density should be considered for recall unless it has been demonstrated to be stable or previously shown to represent a benign finding, such as a cyst.

Asymmetries

The majority of mammographic asymmetries represent overlapping parenchymal tissue. After implementing tomosynthesis, asymmetries account for a smaller percentage of recalled abnormalities at screening mammography. Most asymmetries seen on 2D mammography can be dismissed after reviewing tomosynthesis images. Tomosynthesis most frequently shows that an asymmetry represents overlapping parenchymal tissue and may also reveal a benign cause of the asymmetry, such as a looped vessel or skin lesion. There are some asymmetries, particularly focal asymmetries, that may remain questionable on routine tomosynthesis images, especially if the asymmetry is new or more prominent than prior exams. Sometimes the 2D component is sufficiently concerning that even if tomosynthesis views do not demonstrate a definitive finding, a recall is still generated. Particularly in areas of dense tissue, even tomosynthesis cannot always definitively resolve whether or not a focal mass exists.

Cases of one-view asymmetries are far less common with tomosynthesis than with 2D mammography. Appropriate use of scrolling through the tomosynthesis images can usually determine if a true lesion exists or if the finding is more likely superimposed tissue. If real, one should be able to determine where in the breast it is located. Such findings can usually be located upon review of the corresponding area on the orthogonal tomosynthesis view and can help to further determine if the finding simply represents tissue, especially if the area is seen to be stable, versus a focal asymmetry or mass. Areas of questioned asymmetries in denser areas will be more difficult to assess and frequently require ultrasound for further assessment.

Diagnostic work-up for a patient recalled from screening may include spot compression views. Importantly, spot compression views can be performed as combination images (with both 2D and tomosynthesis image acquisition), as tomosynthesis-only images, or as conventional 2D image only. When performing spot compression views with tomosynthesis, the 2D component is helpful to assess if the appropriate location was "spotted" and if the asymmetry persists. These combined spot compression views are especially useful when first learning tomosynthesis interpretation because the familiar 2D images are obtained along with the tomosynthesis views. If available, synthesized mammography can be used to reduce the total radiation exposure. A word of warning: malignant lesions can efface. This has been observed with 2D mammography but can also happen with tomosynthesis. Spot compression views are helpful when they show a definitive lesion, allowing for better feature and location characterization; however, uncertainty can remain even with a "negative" spot compression view. Ultrasound may be used in the majority of diagnostic evaluations, even when a potentially suspicious finding appears to efface on spot compression views.

Ultrasound should be performed in most cases of a suspected asymmetry. If the tissue is not dense and the general location of the asymmetry is defined, this can be performed as a targeted exam. If the tissue is dense and/or the finding cannot be as precisely located, more extensive or even whole breast scanning may be necessary. If ultrasound is negative, the finding can usually be confidently assessed as benign and the patient can return to routine screening. The decision to designate a finding BI-RADS 3 (probably benign, for which short-term imaging follow-up is performed) is dependent on the level of confidence after fully assessing the area with tomosynthesis mammography and ultrasound imaging (Fig. 8.1). In the authors' practice, use

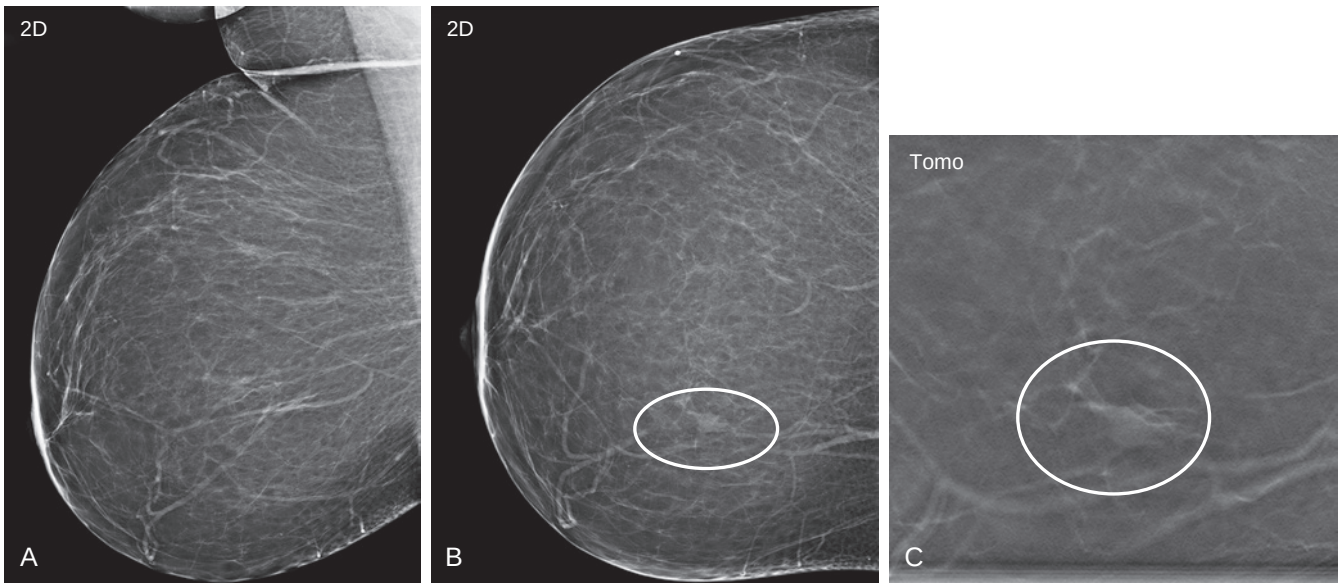


FIG. 8.1 Asymmetry representing normal tissue. A 41-year-old woman presented for baseline screening mammogram. **(A)** Right 2D mediolateral oblique view demonstrates no suspicious finding. **(B)** An asymmetry *(oval)* is seen in the medial right breast on craniocaudal view only on 2D image. **(C)** At the time of recall, a single-combination, 2D-tomosynthesis, spot compression view was performed that redemonstrates the asymmetry on tomosynthesis *(oval)*. Tomosynthesis images localized the finding in question to the upper inner breast, and targeted ultrasound was performed. No sonographic correlate was identified. The asymmetry was thought to represent fibroglandular tissue, and the finding was stable on a follow-up mammogram of the right breast in 6 months.

of tomosynthesis in diagnostic mammography has resulted in the percentage of asymmetries designated BI-RADS 3, probably benign lesions, to be substantially reduced.

Masses

Benign masses are commonly encountered on tomosynthesis in both the screening and diagnostic settings. Although tomosynthesis has been shown to reduce overall screening recall rates, some studies have shown a shift in the type of finding recalled. Although relatively more masses are recalled, this is offset by a decrease in the number of asymmetries recalled with tomosynthesis exams. By far the most common benign masses encountered are cysts, fibroadenomas, and lymph nodes.

In many instances, these findings may be confidently dismissed as BI-RADS 2 findings on screening exams based on clearly benign features, multiplicity, and/or stability. Some findings may still require recall for complete assessment. Of the recalled findings, many may be first evaluated with ultrasound because standard tomosynthesis views provide adequate information about lesion location and morphology compared with 2D mammography alone (Fig. 8.2).

TOMO TIP ★ Close inspection of prior 2D imaging may reveal that "new" masses seen on tomosynthesis were actually present previously.

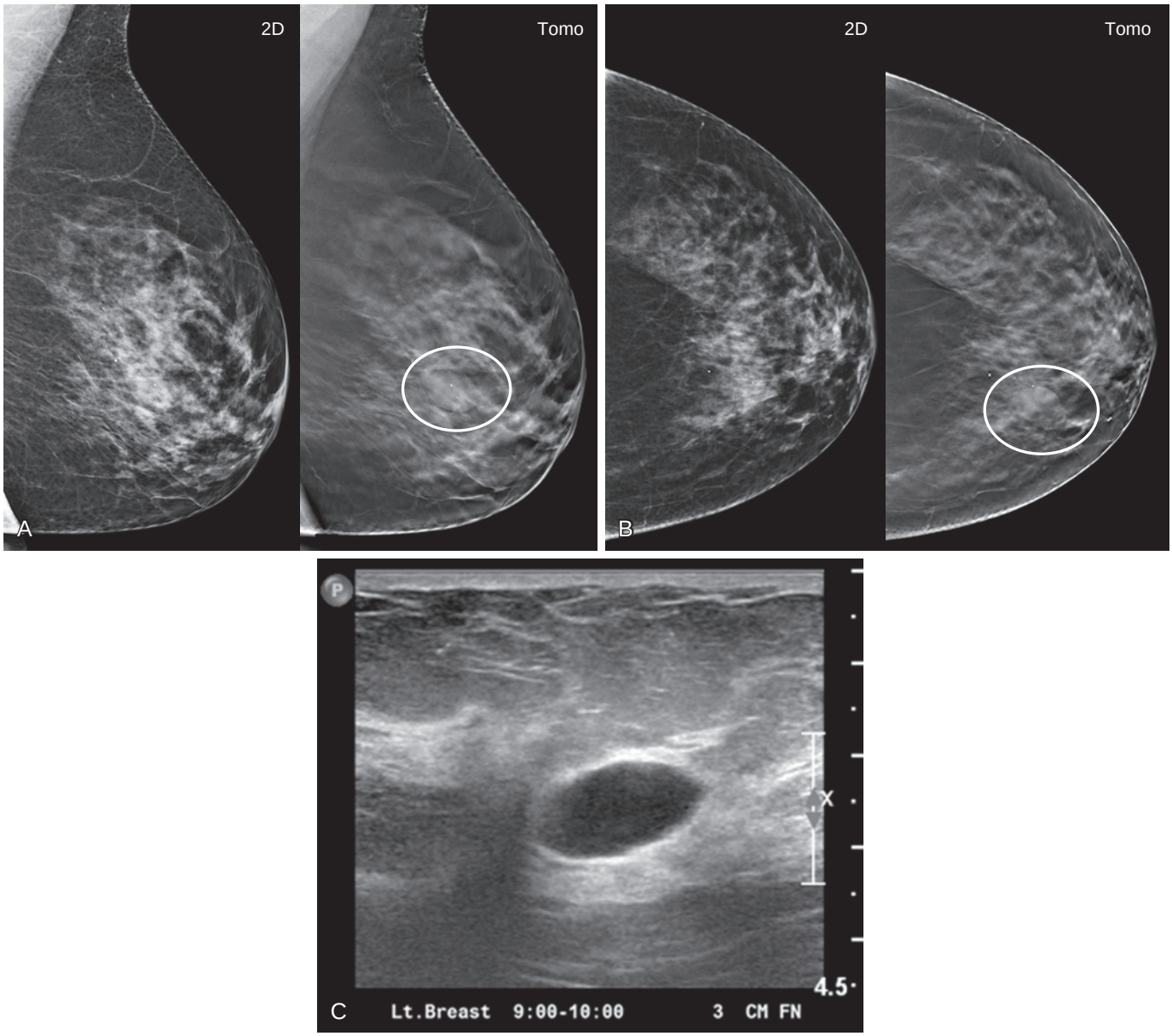


FIG. 8.2 Benign cyst. A 47-year-old woman was recalled for a mass in her left breast on her first tomosynthesis screening mammogram. Prior 2D-only mammograms had been negative. **(A)** Mediolateral oblique and **(B)** craniocaudal views in 2D mammogram and tomosynthesis show an oval, circumscribed mass *(ovals)* in the medial left breast best seen on the tomosynthesis images. **(C)** Targeted ultrasound demonstrates a simple cyst at the 9-o'clock position, corresponding to the mass on mammography. BI-RADS 2 (return to routine screening mammography) was recommended.

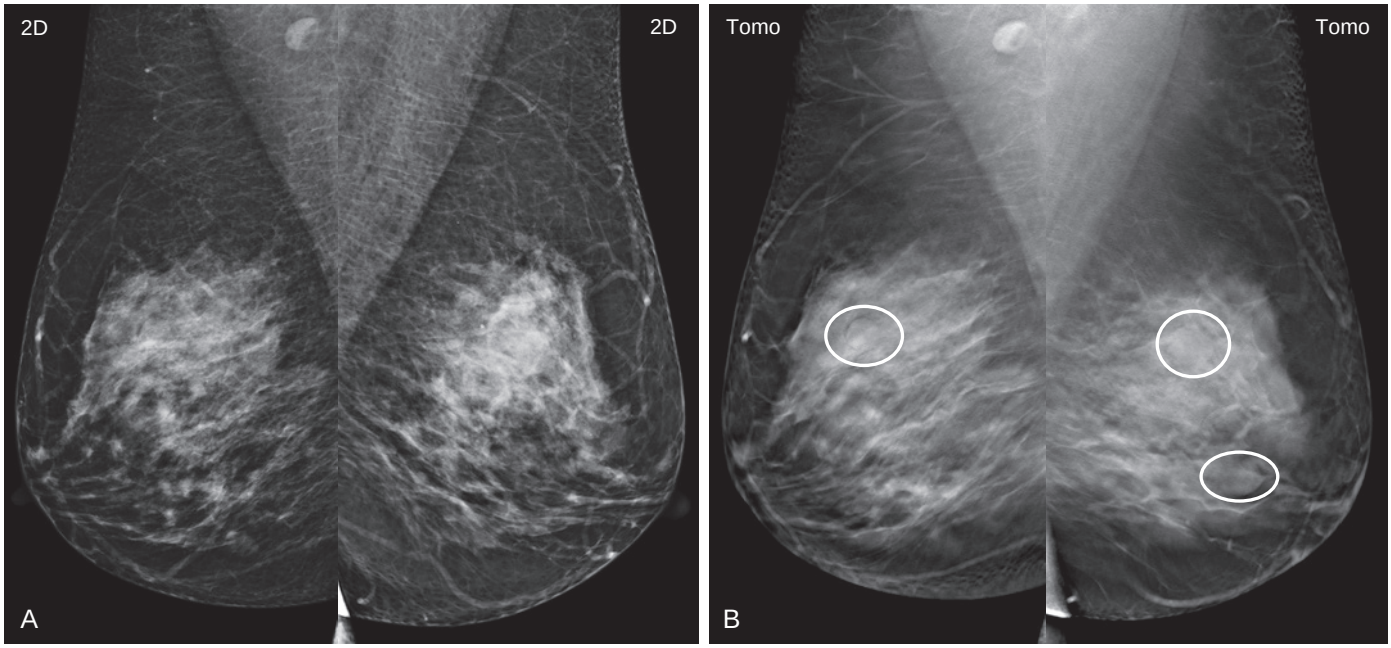


FIG. 8.3 Multiple bilateral cysts. A 58-year-old woman presented for screening. **(A)** 2D MLO views demonstrate extremely dense tissue. **(B)** Selected tomosynthesis images reveal multiple bilateral circumscribed masses *(ovals)*, which are not well delineated on 2D imaging alone. These benign-appearing masses on tomosynthesis were confirmed to be multiple benign cysts by ultrasound performed for dense breast screening ultrasound (not shown), BI-RADS 2.

Cysts

Cysts are commonly encountered in mammography in both the screening and diagnostic settings. Cysts are typically round or oval and have sharply defined margins. A solitary cyst may be encountered, but more commonly, cysts are multiple and the diagnosis is more easily established. Tomosynthesis accentuates the visibility of cysts. This is especially true in women with dense tissue (Fig. 8.3). If available, close review of prior images may demonstrate the characteristic waxing and waning pattern of these benign entities and prevent recall.

Cysts are a very common finding and may be seen at any age but peak in frequency during the perimenopausal years. Exogenous hormonal therapy can perpetuate fibrocystic changes in some women that might otherwise have subsided with menopause. Nevertheless, a new circumscribed mass in an older woman has to be viewed with suspicion. Careful assessment of the margins must always be performed, and ultrasound can be used for diagnostic evaluation. Beware—some malignant masses, such as medullary or mucinous cancers, metastases, and high-grade invasive cancers, can mimic cysts on mammography; however, ultrasound will generally show a corresponding solid mass.

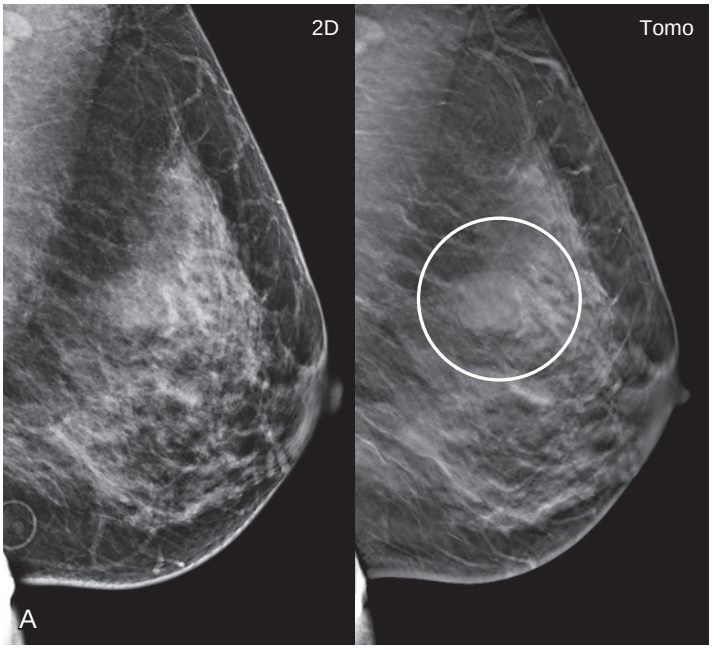
If a solitary, growing, dominant, or otherwise concerning mass is recalled, ultrasound is necessary to complement tomosynthesis and to further characterize the cystic or solid nature of the mass (Fig. 8.4). In cases of benign simple cysts, ultrasound will reveal an anechoic, oval, or round structure with sharply defined, thin walls, with posterior acoustic enhancement. Complicated cysts are common, particularly in the setting of multiple bilateral cysts. They appear similar to simple cysts except, rather than being anechoic, they have internal echoes. Clustered small cysts are also a common occurrence. Occasionally, calcifications seen on the 2D image will be seen to be within a cyst on tomosynthesis. When the calcifications demonstrate the typical layering "teacup" appearance within the cyst, further imaging evaluation is unnecessary.

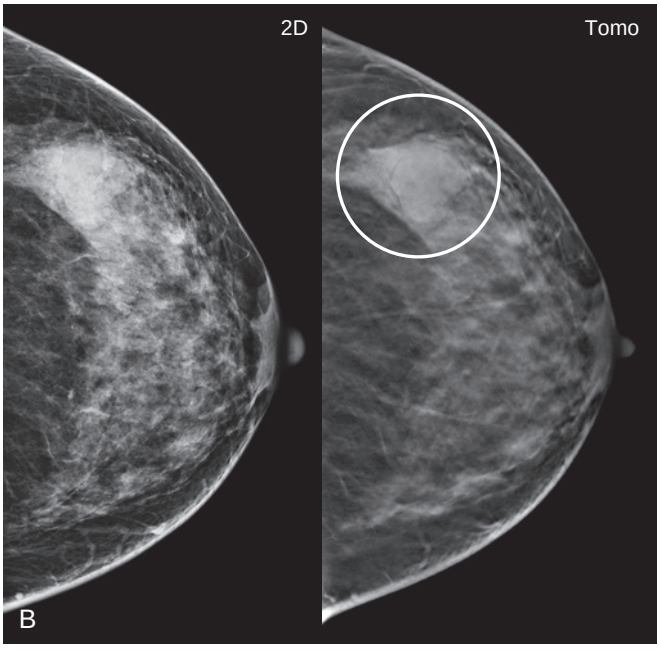
Fibroadenomas

Fibroadenomas are benign fibroepithelial tumors of the breast. They are the most common benign solid tumors of the breast in women of all ages and can be solitary or multiple and bilateral. Fibroadenomas may be indistinguishable from cysts on tomosynthesis, most frequently demonstrating an oval shape and circumscribed margins (Fig. 8.5). Some fibroadenomas may have been considered to be part of the patient's parenchymal pattern on 2D mammography. When "newly" discovered on tomosynthesis, some of these fibroadenomas can be shown to be stable after careful review of patients' prior mammograms and ultrasound images. Detailed characterization of such common benign masses afforded by tomosynthesis imaging may preclude additional diagnostic work-up, ultrasound, and short interval follow-up in many patients (Fig. 8.6).

Phyllodes Tumor

Phyllodes tumors are rare masses that may be indistinguishable from fibroadenomas on tomosynthesis and sonography. Phyllodes tumors are classified as low, intermediate, and high grade. Even on core biopsy, fibroadenomas and phyllodes tumors may be difficult to differentiate pathologically and may require surgical excision for definite diagnosis





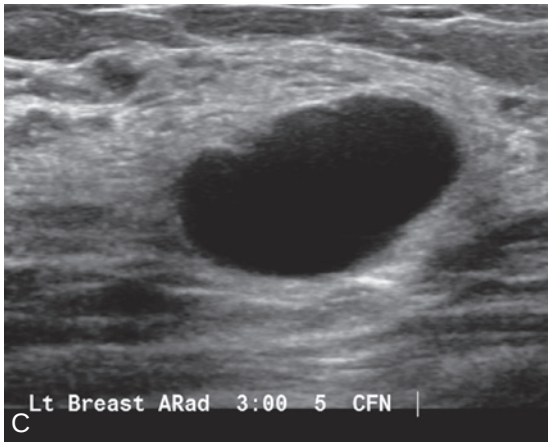


FIG. 8.4 Cyst presenting as dominant mass. Baseline screening mammogram performed in a woman at age 40 demonstrates heterogeneously dense breast tissue. Mediolateral oblique **(A)** and craniocaudal **(B)** views in 2D imaging and tomosynthesis reveal a large mass *(circles)* in the left breast at the 3-o'clock position, best seen on tomosynthesis images. The patient was recalled for ultrasound, and no additional mammographic views were required. **(C)** Ultrasound demonstrates a simple cyst corresponding to the mass in question on screening mammography. BI-RADS 2.

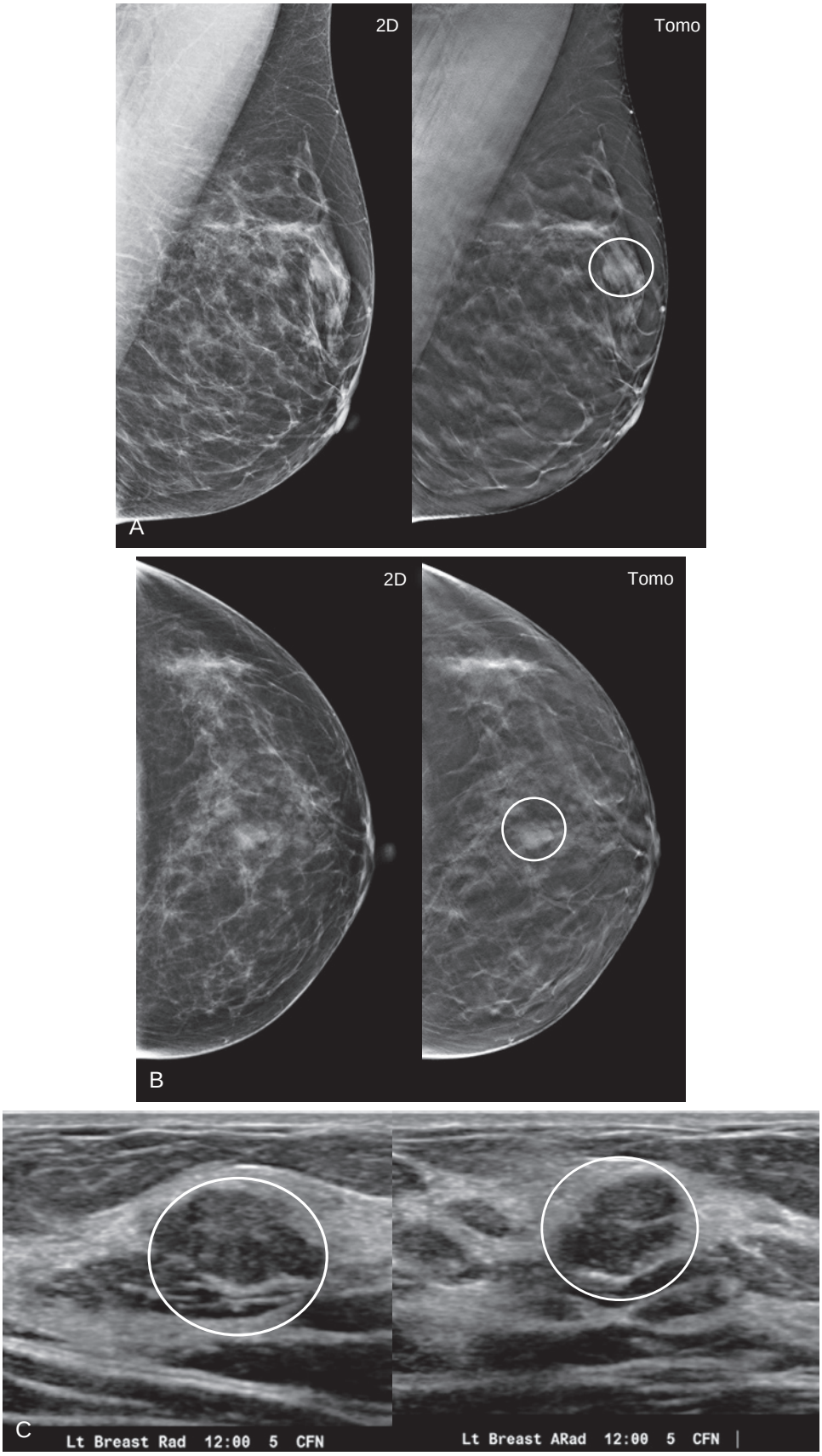


FIG. 8.5 Benign mass. Baseline mammogram in a 40-year-old woman. **(A)** Mediolateral oblique and **(B)** craniocaudal views in 2D imaging and tomosynthesis demonstrate a mass in the left breast at the 12-o'clock position *(circled)*. **(C)** Targeted ultrasound images demonstrate a corresponding hypoechoic mass *(circles)*. The mass was unchanged at 1-year follow-up and presumably represents a fibroadenoma.

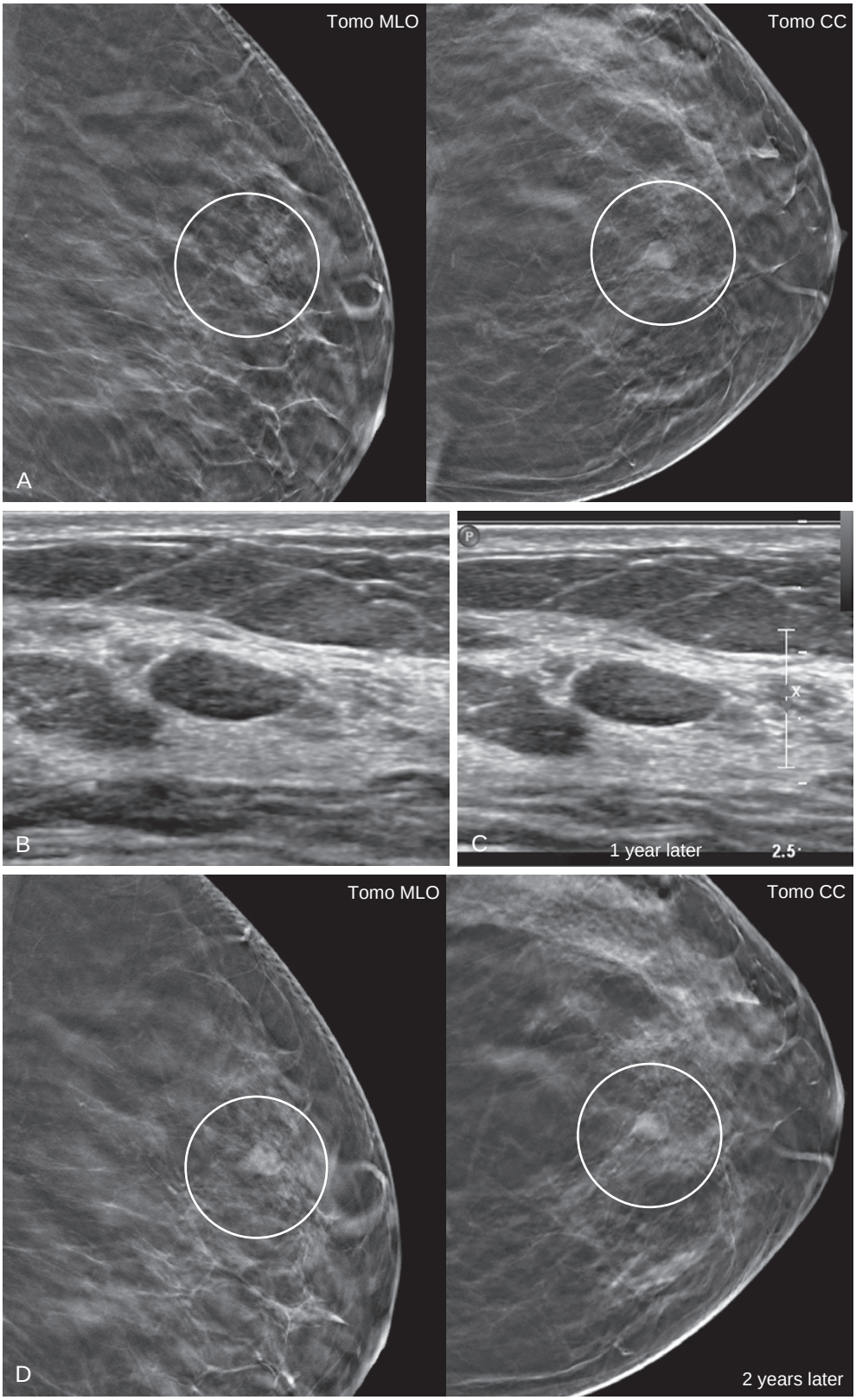


FIG. 8.6 Stable fibroadenoma. (A) A 43-year-old woman was found to have a benign-appearing, oval, circumscribed mass in the left breast seen on mediolateral oblique and craniocaudal tomosynthesis images *(circles)* and **(B)** ultrasound. **(C)** An ultrasound 1 year later was stable. **(D)** On annual mammography, 2 years later, the mass *(circles)* is seen to be completely unchanged on tomosynthesis images, precluding the need to repeat ultrasound. Benign mass shape, size, and margins can be better assessed on tomosynthesis imaging, reducing the need for extended follow-up.

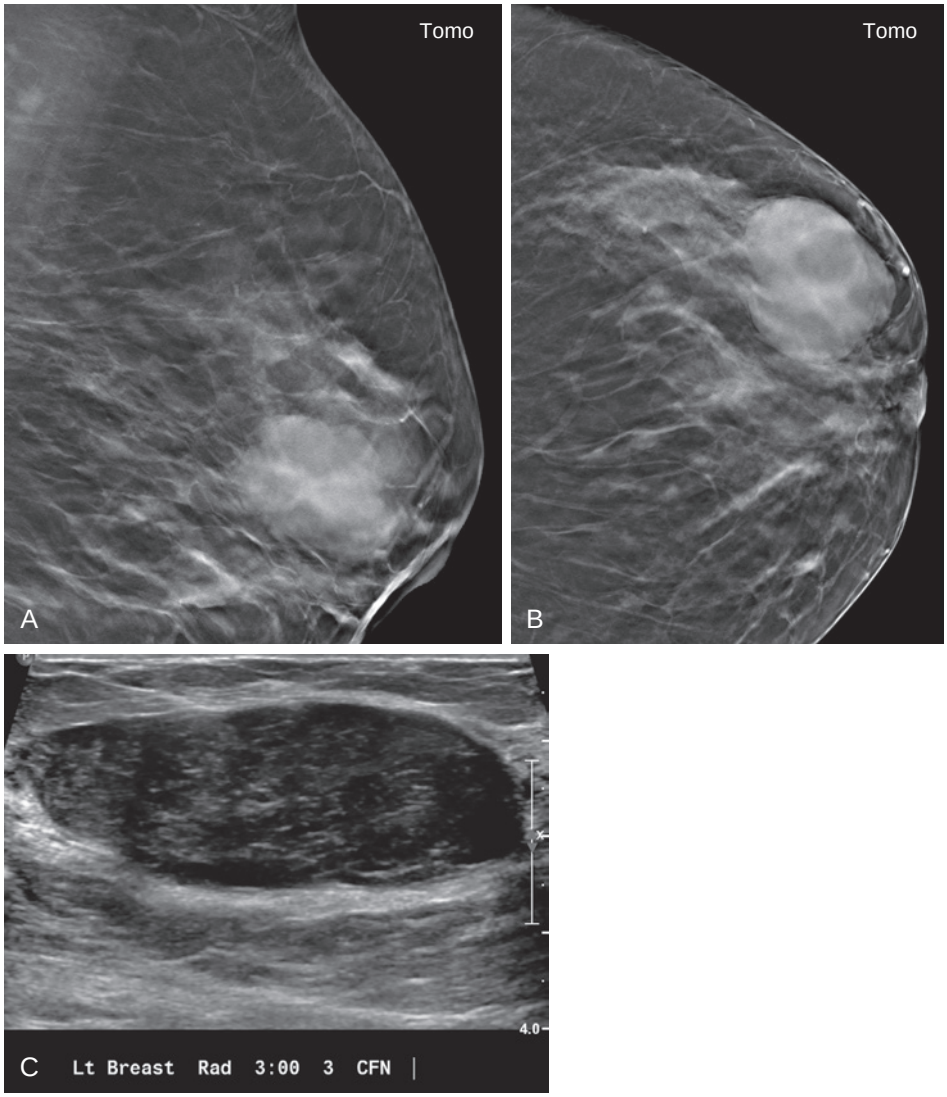


FIG. 8.7 Phyllodes tumor. A 54-year-old woman presented for screening mammography. Tomosynthesis images in mediolateral oblique **(A)** and craniocaudal **(B)** projection show a 5.4-cm mass in the left breast at the 3-o'clock position, which was new since the prior mammogram performed 16 months earlier. **(C)** Targeted ultrasound reveals a corresponding circumscribed, oval, hypoechoic mass. The patient ultimately had the mass surgically excised, yielding a benign phyllodes tumor.

(Fig. 8.7). The ultrasound appearance of a phyllodes tumor may be more heterogeneous than a fibroadenoma, with anechoic cystic (leaflike) spaces in a predominantly hypoechoic, lobulated mass. Marked growth or change in appearance of a lesion previously thought to represent a fibroadenoma, even if previously biopsied, should prompt consideration of a phyllodes tumor because these masses typically grow rapidly.

Fat-Containing Lesions

Traditional teaching is that most fat-containing lesions are considered benign. However, with the improved detail of tomosynthesis, many cancers will be seen to have fat within them on tomosynthesis images. Fat appears lucent or low density on mammography. Cancers may engulf the fatty tissue and therefore contain areas of low density. This appearance should not be confused with a benign fat-containing mass. To be classified as benign, fat-containing lesions should be encapsulated or pseudo-encapsulated. Other fat-containing lesions should be cautiously assessed with diagnostic evaluation.

TOMO TIP ★ To be classified as benign, fat-containing lesions should be encapsulated or pseudo-encapsulated because many malignant lesions are seen to have fat within them on tomosynthesis.

Lymph Nodes

Benign lymph nodes are commonly seen on mammography. Lymph nodes may be located within the breast (intramammary) or in the axilla. Normal lymph nodes are reniform or oval in shape and exhibit characteristic low central density on mammography due to the fatty hilum. The pathognomonic

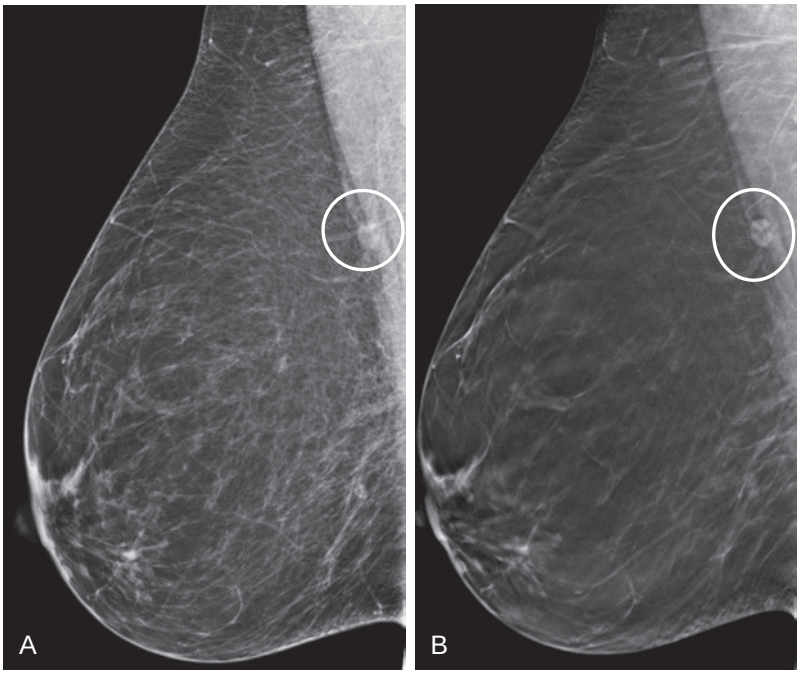


FIG. 8.8 Benign lymph node. (A) A small lobulated mass *(circle)* is seen in the left breast on the two-dimensional MLO view. Tomo-synthesis in the MLO projection **(B)** demonstrates low density within this mass *(circle)*, consistent with a fatty hilum of a benign lymph node. BI-RADS2.

reniform shape and fatty notch may be better visualized on tomosynthesis compared with 2D mammography (Fig. 8.8). Similar to cysts, intramammary lymph nodes are frequently obscured by superimposed tissue and therefore may only be visible on tomosynthesis. Such findings are so common, but fortunately, because tomosynthesis can clearly depict the reniform shape, circumscribed margins, and central hilar fat, most newly seen lymph nodes can be easily dismissed as benign.

For dominant, new, or growing lesions presumed to be lymph nodes, additional imaging may be required. Ultrasound is most frequently used for further assessment. For an intramammary or axillary lymph node to be classified as a benign finding, it should have a thin, uniform hypoechoic cortex with minimal vascularity and a fatty (echogenic) hilum. Suspicious lymph nodes may demonstrate a diffuse or focally thickened cortex, as well as increased peripheral vascularity and/or a small or absent fatty hilum. Upon identification of such nodes, the remainder of the breast should be carefully examined for any suspicious breast masses that could be the primary source of malignant adenopathy. Ultrasound-guided biopsy can provide additional information about the etiology of suspicious lymphadenopathy if a suspicious associated mass is not found or to help to document disease extent.

Lipomas and Hamartomas

Tomosynthesis nicely illustrates the encapsulated appearance of lipomas. These masses may have been considered to be part of a patient's parenchymal pattern on 2D mammography alone rather than a discrete mass. The improved detection of lipomas and hamartomas with tomosynthesis is particularly helpful when these benign masses correspond to a palpable lump. Likewise, if a lipoma or hamartoma is initially detected by ultrasound, because these may be occult by 2D mammography, tomosynthesis can more clearly depict the corresponding mammographic correlate (Fig. 8.9).

Hamartomas, or fibroadenolipomas, are a pseudo-encapsulated collection of normal breast tissue components. They may present on 2D mamography as an asymmetry because the fine pseudocapsule at the periphery cannot always be easily visualized. Sometimes such lesions, when large, actually cause displacement of the adjacent surrounding tissue, resulting in asymmetric tissue that may be questioned on 2D mammography, only to result in no discrete mammographic or sonographic finding found after further work-up. In such a case tomosynthesis may reveal previously unsuspected hamartomas (Fig. 8.10). Correctly recognizing tissue findings as hamartomas thus precludes unnecessary work-up or follow-up.

Galactocele and Lactational Changes

A galactocele is a benign milk-filled cyst that is seen in women around the time of lactation. The classic presentation is a breastfeeding woman with a palpable mass. Mammography typically demonstrates a fat-fluid level within a mass on the true lateral view. The fat-fluid level will be more likely to be appreciated on tomosynthesis than 2D imaging when it lies within dense tissue (Fig. 8.11).

Lactational changes on tomosynthesis are similar to those on 2D mammography with a characteristic diffuse increase in breast parenchymal density and breast enlargement.

Other Benign Lesions

Duct Ectasia

The retroareolar region has enhanced visualization on tomosynthesis compared with 2D mammography. Unilateral or

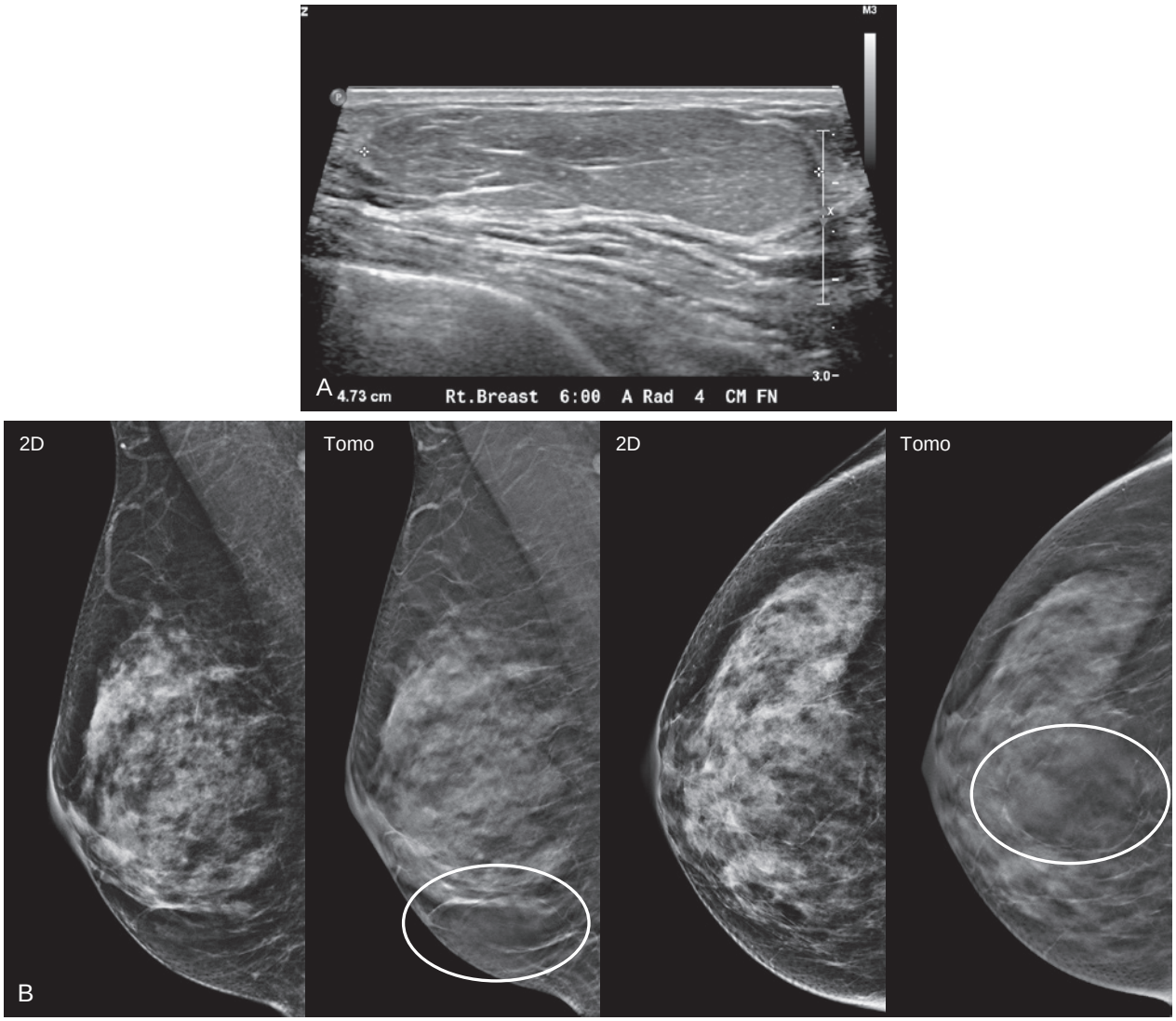


FIG. 8.9 Lipoma. (A) A 58-year-old woman presents for screening breast ultrasound, which demonstrates a benign-appearing isoechoic mass in the right breast at the 6-o'clock position. **(B)** A corresponding fat-containing mass with a thin capsule *(circles)* is best seen on tomosynthesis images of her preceding screening mammogram, consistent with benign lipoma. BI-RADS 2.

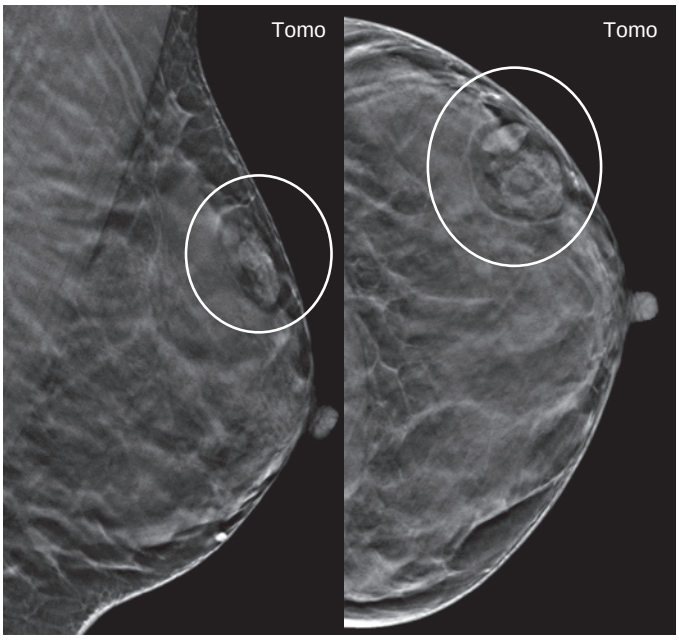


FIG. 8.10 Hamartoma. A 42-year-old woman presents for screening. Mediolateral oblique *(left)* and craniocaudal *(right)* tomosynthesis views nicely demonstrate a hamartoma in the upper outer left breast within extremely dense tissue. The characteristic pseudocapsule is well seen on tomosynthesis, and the mass demonstrates the classic *breast within a breast* appearance.

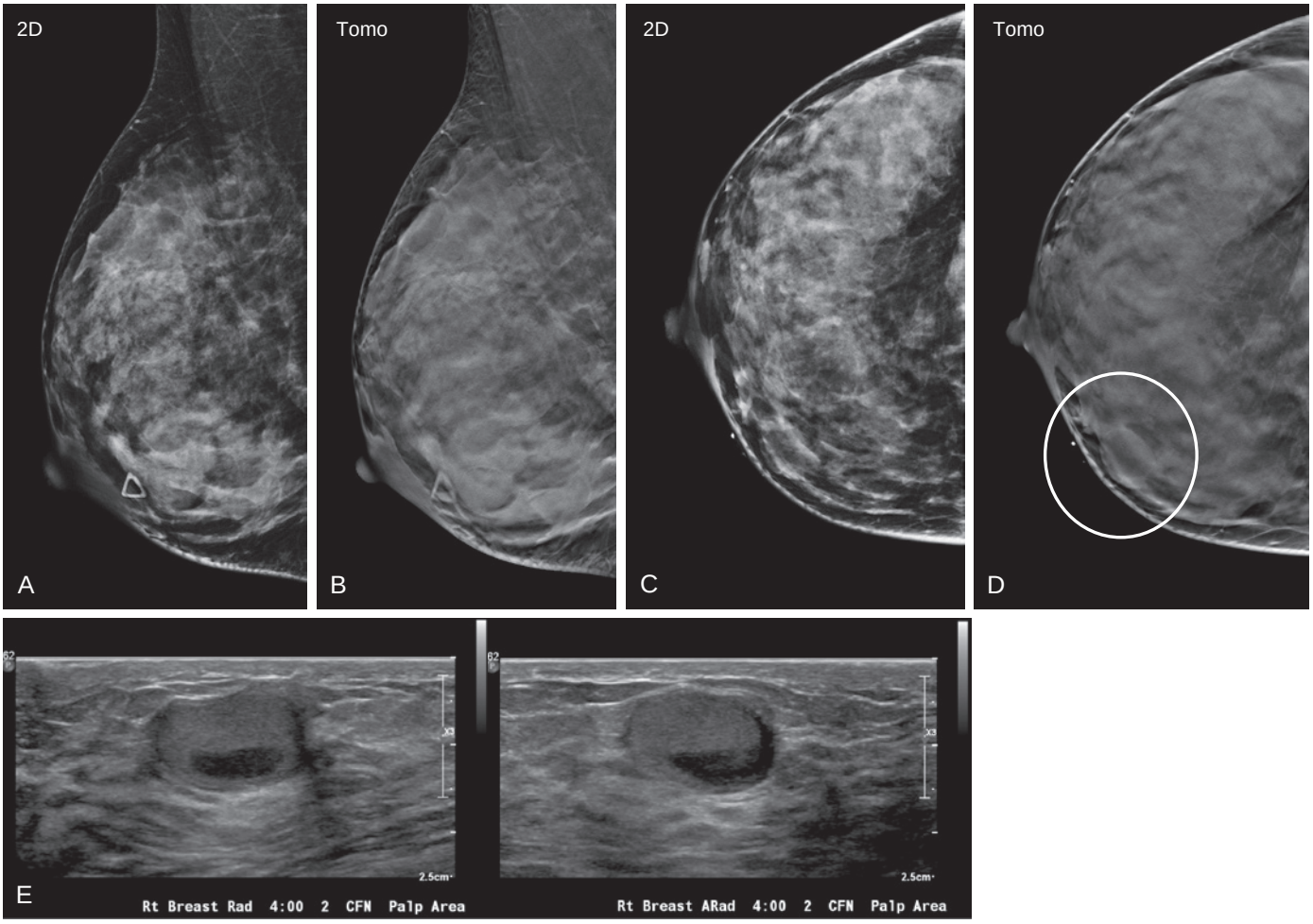


FIG. 8.11 Galactocele. A 37-year-old woman, 3 months postpartum and recently breast-feeding, presents with a palpable lump in her right breast. Mediolateral oblique views in two-dimensional (2D) imaging **(A)** and tomosynthesis **(B)** and craniocaudal views in 2D imaging **(C)** and tomosynthesis **(D)** demonstrate extremely dense breast tissue. A mass is seen in the right breast at the 4-o'clock position, corresponding to the area of palpable concern. Tomosynthesis images more clearly demonstrate lucency within the mass *(circle)*. **(E)** Ultrasound demonstrates a fat-fluid level within the mass, compatible with a galactocele. The patient opted for ultrasound-guided aspiration, which yielded milky fluid and complete resolution of the mass.

new duct ectasia in symptomatic or asymptomatic patients should be evaluated with targeted ultrasound for any associated masses or intraductal lesions. In the absence of other associated signs of malignancy, such as clear or bloody nipple discharge, suspicious mass, suspicious calcifications, or architectural distortion, duct ectasia is usually due to benign causes (Fig. 8.12).

Abscess

Abscesses can be indistinguishable from a solid breast mass on 2D mammography or tomosynthesis. They may demonstrate indistinct or spiculated margins, contain air, and have associated skin and trabecular thickening. Although patients frequently have symptoms that clinically suggest infection, an ultrasound is usually recommended for additional evaluation to exclude a suspicious solid mass, define the extent of the fluid collection, and to potentially plan for ultrasound-guided abscess drainage (Fig. 8.13).

Seromas and Hematomas

Seromas and hematomas are frequently observed at lumpectomy sites. These fluid-filled masses tend to contract with time, although seromas can remain stable for years. These lesions rarely present imaging difficulties when stable and at the expected surgical site. However, some seromas and hematomas can be worrisome for the patient, particularly if presenting as a new palpable mass. Although most cases are managed clinically, imaging is sometimes requested to differentiate a postoperative fluid collection from a palpable malignancy. Tomosynthesis can demonstrate these lesions with better definition than 2D imaging. Given that seromas and hematomas are frequently within an area of postoperative change, a variable amount of tissue distortion, increased density, and spiculation can be expected. Sonographic evaluation, in conjunction with tomosynthesis, is helpful to exclude a solid mass. Additional discussion of postoperative collections can be found in Chapter 12.

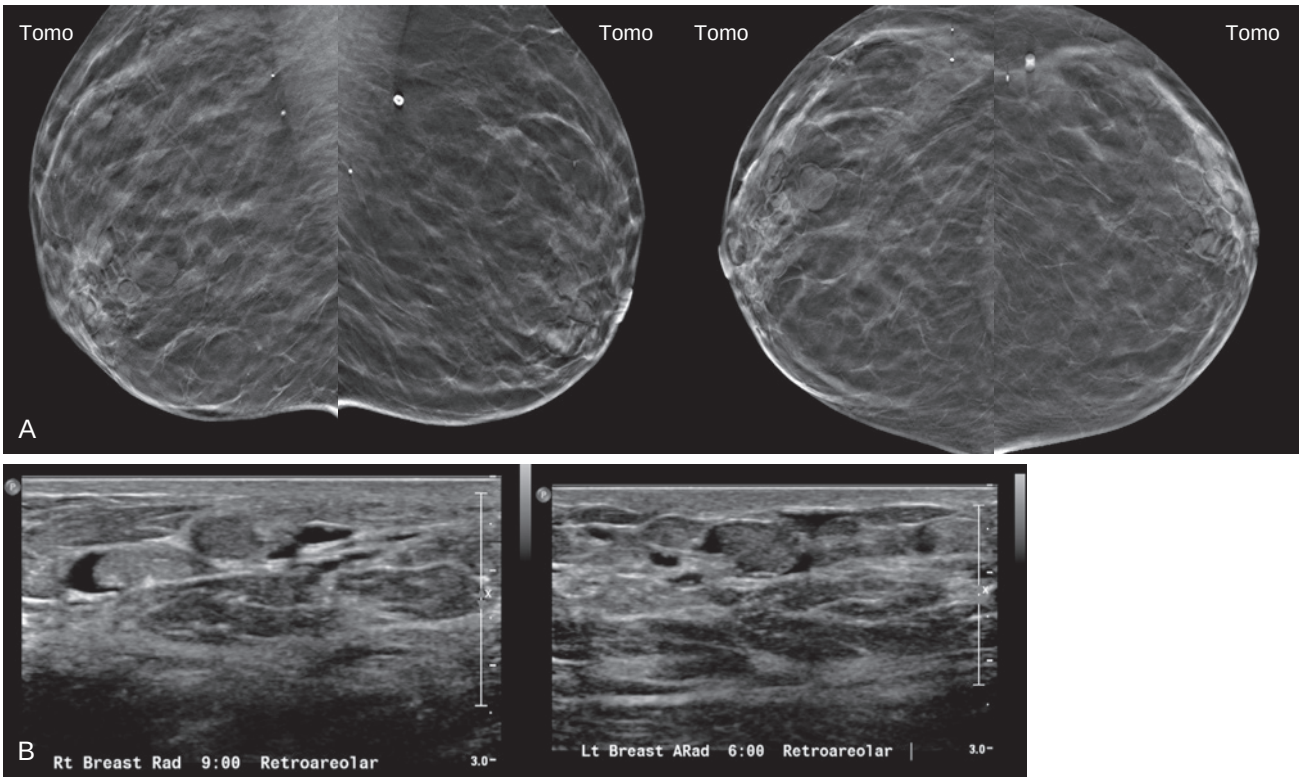


FIG. 8.12 Duct ectasia. A 45-year-old woman with heterogeneously dense breast tissue presented for routine screening. **(A)** Tomosynthesis views demonstrate multiple dilated ducts and associated intraductal densities bilaterally, which were not appreciated on two-dimensional imaging. Screening ultrasound performed concurrently demonstrates multiple dilated ducts containing echogenic debris without associated internal vascularity. In this asymptomatic patient, continued routine screening was recommended.

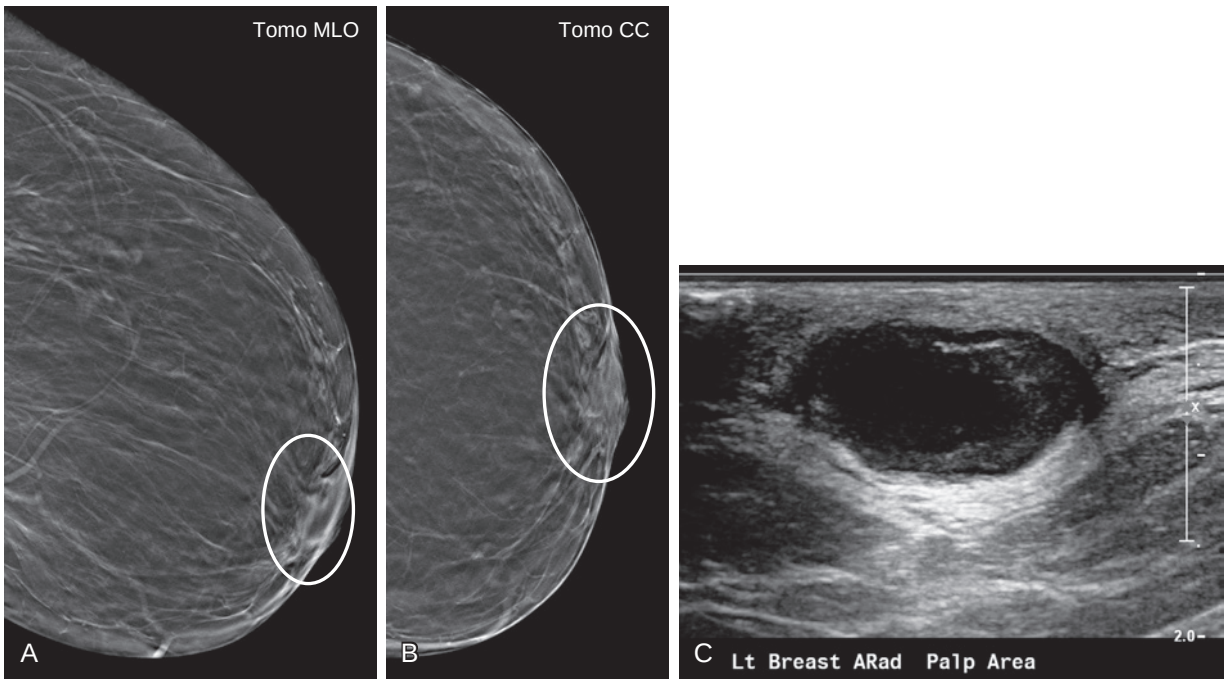


FIG. 8.13 Breast abscess. A 64-year-old female smoker presented with left breast pain and a history of left breast infection 1 year prior. A mass with indistinct margins is seen in the left retroareolar region on tomosynthesis *(ovals)* in mediolateral oblique **(A)** and craniocaudal **(B)** projections. **(C)** Targeted ultrasound demonstrates a fluid collection of mixed echogenicity. The patient underwent ultrasound-guided aspiration, which showed gram-positive cocci in pairs on Gram stain.

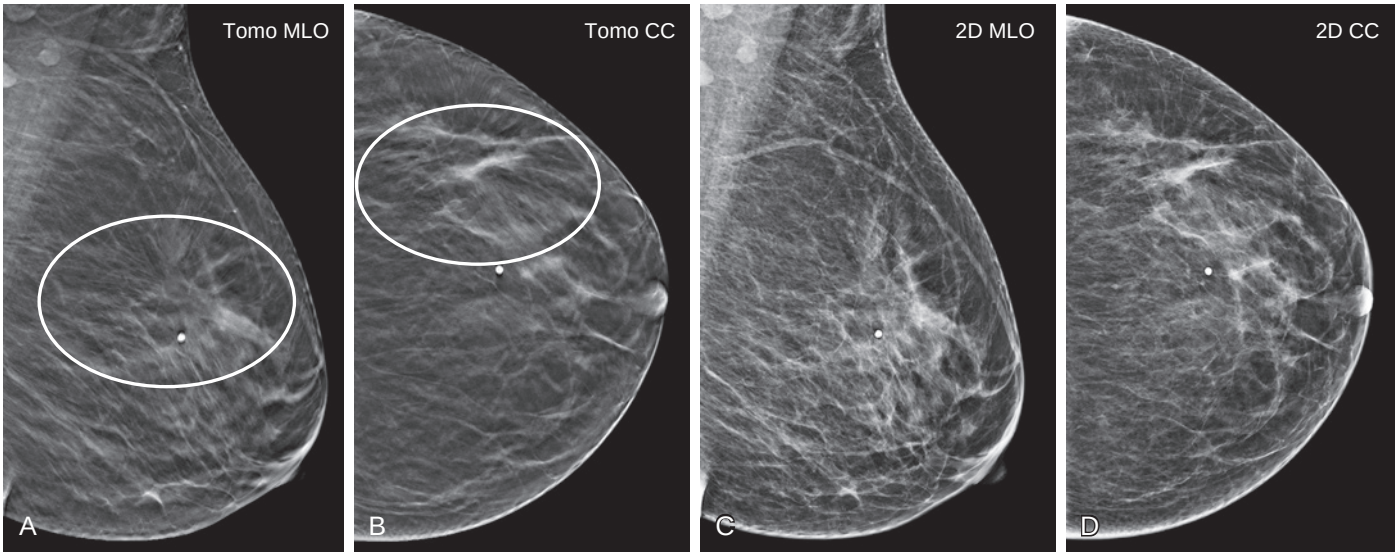


FIG. 8.14 Excisional biopsy scar. Tomosynthesis images in mediolateral oblique **(A)** and craniocaudal **(B)** projection demonstrate architectural distortion in the upper-outer left breast on the patient's first screening mammogram performed with tomosynthesis. The patient was given a Breast Imaging Reporting and Data System (BI-RADS) of 0. When the patient returned for diagnostic mammography, she reported that she had a remote history of a benign excisional biopsy. A faint scar was noted on the left breast after she reported this history. 2D mediolateral oblique **(C)** and craniocaudal **(D)** views were stable compared with prior exams. BI-RADS 2.

Architectural Distortion

Architectural distortion is commonly encountered on tomosynthesis, more so than on 2D mammography alone. Most architectural distortions detected on tomosynthesis are secondary to postsurgical scarring related to excisional biopsy, reduction mammoplasty, or lumpectomy and can be dismissed as benign. Because architectural distortion can also be due to malignancy, thorough correlation and assessment are necessary. It is important to obtain a history of any prior breast biopsies or surgeries at the time of mammography and to have the technologist note any scars (Fig. 8.14). Scar markers are generally not required on the breast when performing tomosynthesis if the location of scars is noted on the patient history form. Scar markers can cause ghosting artifacts on out-of-plane tomosynthesis slices, which can be distracting. Further discussion of postoperative scars can be found in Chapter 12.

Other benign causes of architectural distortion on tomosynthesis also include radial scars or complex sclerosing lesions. Architectural distortions are better visualized with tomosynthesis compared with 2D mammography, and increased detection of these distortions may present challenges, particularly if only seen on tomosynthesis and not identified on targeted ultrasound. Although many of these lesions are benign, an association of radial sclerosing lesions with malignancy has been reported in the past, which makes management more complicated. A complete discussion of benign and malignant architectural distortion is presented in Chapter 10.

Calcifications

Tomosynthesis is a useful tool in the evaluation of many breast calcifications. Skin calcifications or simulated calcifications due to deodorant artifact are easily localized to the skin with tomosynthesis. Other benign calcifications may be more confidently assessed with tomosynthesis as well. Tomosynthesis may help characterize calcifications secondary to fat necrosis earlier than on 2D mammography alone. Tomosynthesis images may depict a central, round, low-density structure representing the oil cyst. Associated calcifications will be seen outlining this low-density area, suggesting that they are due to fat necrosis or a developing oil cyst (Fig. 8.15). This can be especially helpful for patients with a history of prior surgery or trauma to the breast because these patients are most prone to developing calcifications related to fat necrosis. In the correct setting, these calcifications may be assessed as BI-RADS 2 or 3.

Linear calcifications may be secretory or vascular in etiology. Although the smooth rodlike calcifications characteristic of secretory calcifications are relatively easy to diagnose on 2D mammography, early vascular calcifications may be better characterized on tomosynthesis when the underlying vessel is seen in association with the calcifications in question.

Characterizing Benign Findings by Multimodality Work-Up

Many patients undergo screening breast ultrasound due to dense breast tissue on mammograms. At the time of ultrasound, a mass may be discovered that was not previously noted mammographically. Close scrutiny of the tomosynthesis images in the area of sonographic concern may reveal a mammographic correlate that in retrospect is stable, thereby eliminating the need for possible biopsy or follow-up. Likewise, in a patient with findings on MRI, it is frequently helpful to include a diagnostic mammogram with tomosynthesis along with ultrasound as part of the *second-look* evaluation. Such evaluations are further discussed in Chapter 11.

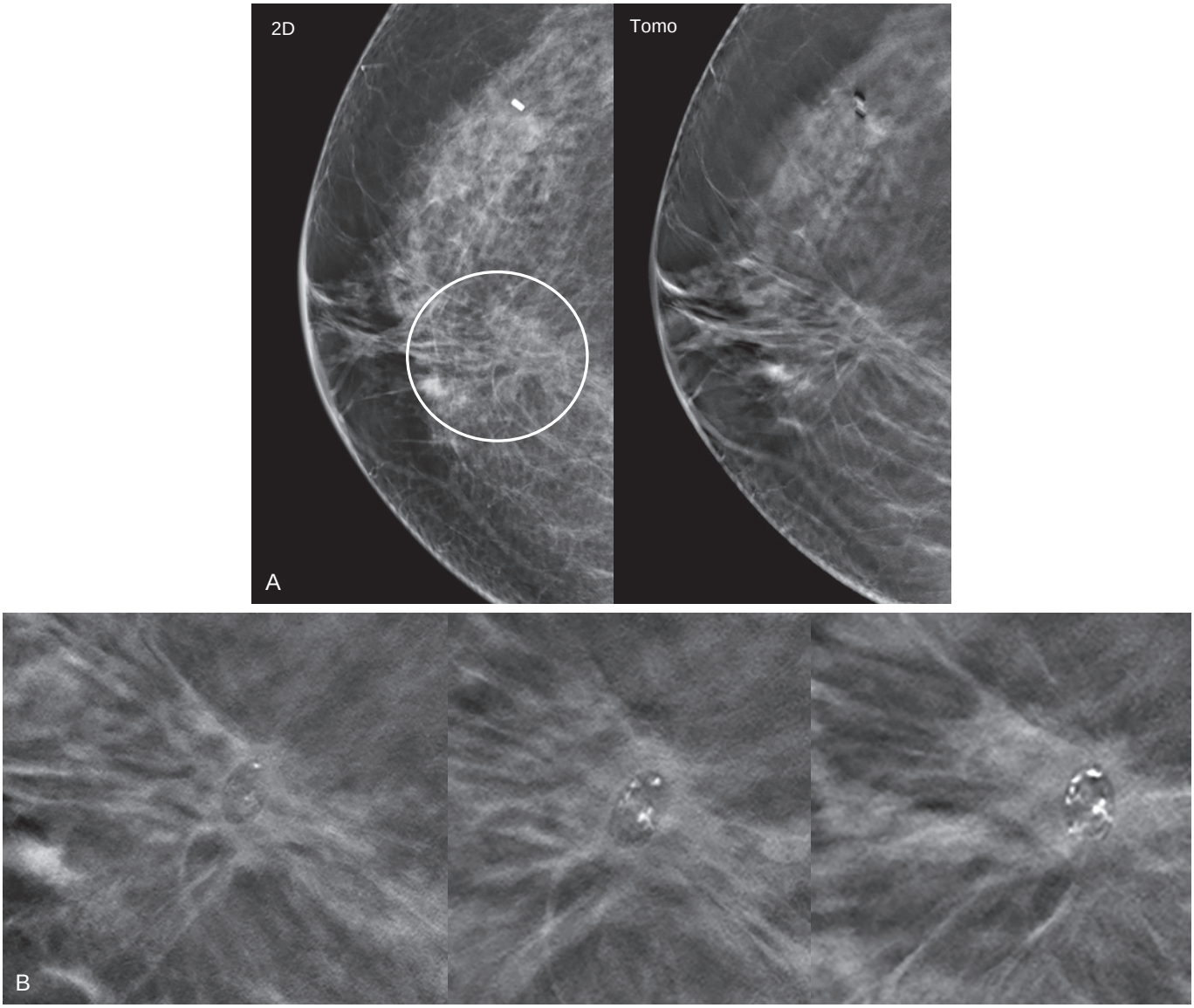


FIG. 8.15 Evolving fat necrosis. (A) Craniocaudal (CC) views in 2D imaging *(left)* and tomosynthesis *(right)* demonstrate fat necrosis in the lumpectomy bed *(circle)* in this woman with a history of invasive lobular carcinoma 3 years prior. **(B)** Three subsequent annual tomosynthesis images in CC projection demonstrate increasing calcifications in the lumpectomy bed, compatible with evolving fat necrosis.

Summary

Benign findings, including asymmetries, masses, calcifications, and architectural distortion, are often better visualized and more frequently encountered on tomosynthesis. Asymmetries, especially one-view asymmetries, can frequently be attributed to superimposed breast tissue with the use of tomosynthesis. Benign masses, such as intramammary nodes or cysts with layering milk of calcium, may show a classic benign appearance, best characterized on tomosynthesis views. In other cases, such as postoperative scars, a correlation with patient history is essential. Some patients who ultimately have benign findings on mammography may still require recall for diagnostic evaluation. In these cases ultrasound is useful for further characterization either alone or in conjunction with tomosynthesis. With experience, the radiologist will become more comfortable in assessing benign findings by tomosynthesis, resulting in decreased recall rates and use of fewer mammographic views in the diagnostic setting while maintaining sensitivity and cancer detection.

CHAPTER

9

Malignant Findings

Paul H. Levesque | Regina J. Hooley

The ultimate goal of any new breast imaging modality is to decrease mortality from breast cancer by improving breast cancer detection and diagnosis. Worldwide there are more than 1.5 million new cases of invasive breast cancer diagnosed each year. Among women in the United States an estimated 231,840 new cases are expected to be diagnosed each year and more than 40,000 women are expected to die of the disease. In addition, an estimated 50,000 new cases of ductal carcinoma in situ (DCIS) are also expected to be diagnosed. Early detection and diagnosis of both invasive breast cancer and DCIS increase less aggressive treatment options and save lives.

Despite all the many advantages that two-dimensional (2D) full-field digital mammography (FFDM) provides, the problem of breast density and heterogeneous complex breast parenchymal patterns masking underlying breast cancer has remained a persistent limitation of mammography due to both false-positive and false-negative results. Tomosynthesis is another significant leap forward, providing an imaging technology that can overcome the limitations of overlapping dense breast tissue, helping to uncover and detect more breast cancers.

Ductal Carcinoma In Situ

DCIS is confined to the breast ducts without invasion of the basement membrane and accounts for 25% to 33% of all screen-detected malignancies. The classic mammographic appearance of DCIS includes fine branching, heterogeneous, and/or pleomorphic calcifications in a grouped, segmental, or linear distribution, typically conforming to the path of the branching breast ducts. However, up to 20% of DCIS may also present as a focal mass with or without associated microcalcifications (Figs. 9.1 and 9.2). Moreover, in cases of DCIS presenting primarily as microcalcifications, tomosynthesis may identify a subtle associated mass representing the invasive component otherwise occult on conventional 2D mammography alone. Occasionally DCIS may present as a subtle architectural distortion, which may only be seen on tomosynthesis (Fig. 9.3).

Magnification views cannot be performed with tomosynthesis and in most cases of suspicious calcifications will still be required. However, some microcalcifications associated with DCIS may be better or equally well seen on tomosynthesis compared with 2D mammography. This is especially

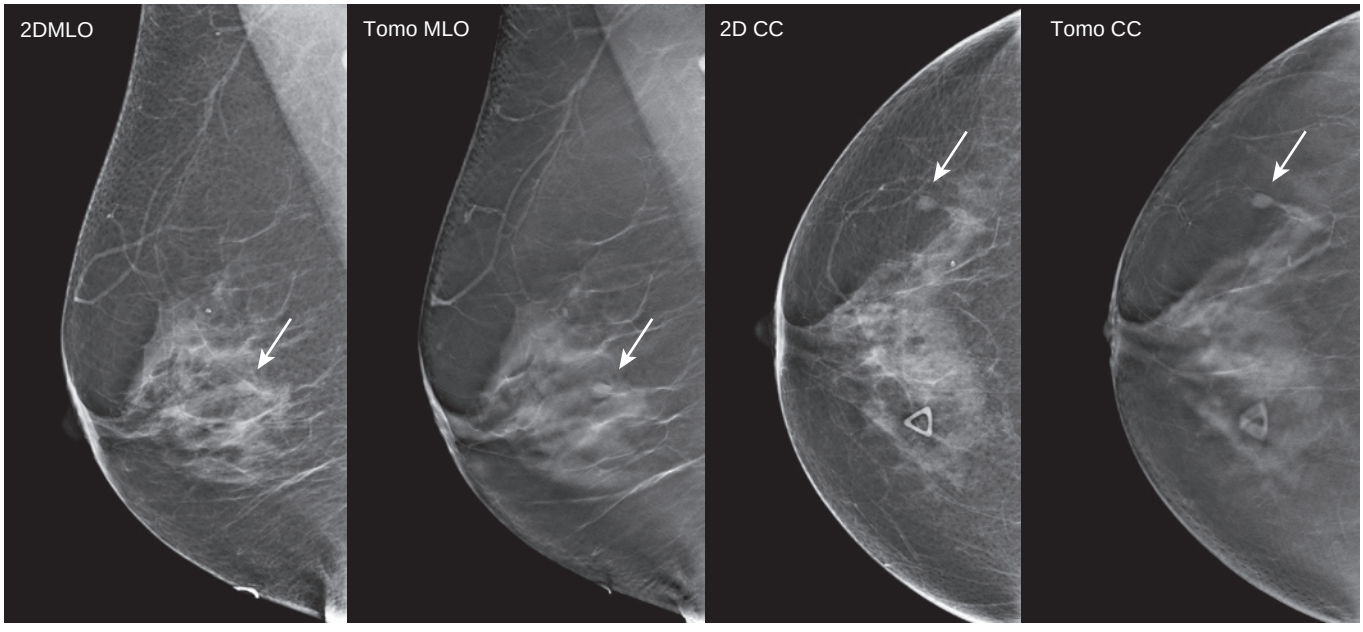


FIG. 9.1 DCIS presenting as a focal mass. A 53-year-old woman presents with a palpable mass in the right inferior breast. Diagnostic mammography reveals no corresponding mass in the region of palpable concern; however, an oval mass is seen in the right lateral breast at the 9-o'clock position on both 2D imaging and tomosynthesis *(arrows)*.

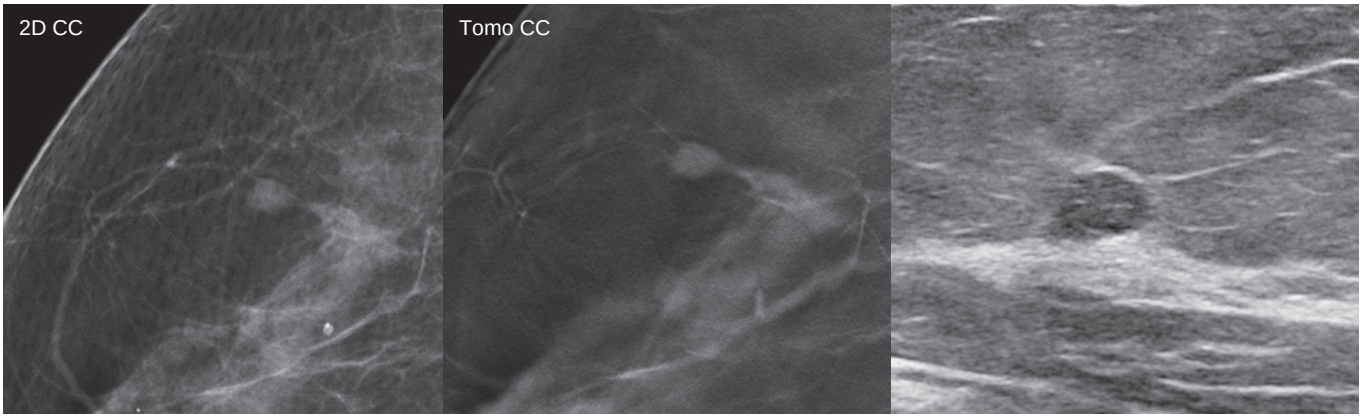


FIG. 9.2 In the same patient from Fig. 9.1, close-up views of standard craniocaudal 2D and tomosynthesis views show circumscribed margins better defined on tomosynthesis. Targeted ultrasound confirms an oval circumscribed mass. Ultrasound-guided core needle biopsy yielded intraductal papilloma with atypical ductal hyperplasia, upgraded at surgery to grade 1 to 2 DCIS, ER/PR+.

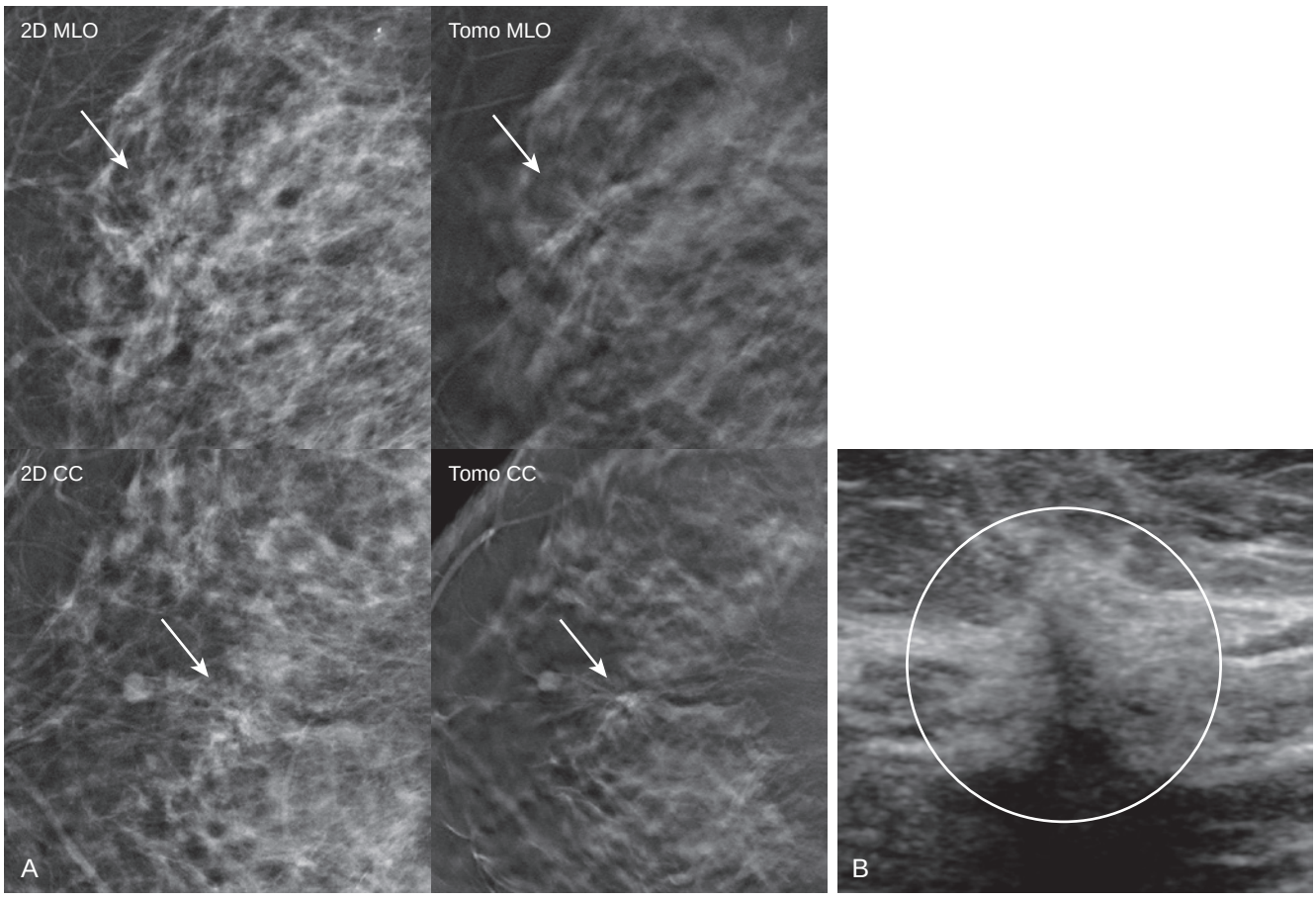


FIG. 9.3 DCIS presenting as architectural distortion. (A) Diagnostic mammogram in a 67-year-old woman with a palpable mass in the left breast. Tomosynthesis reveals a subtle architectural distortion in the right breast at the 12-o'clock position, not seen on two-dimensional images *(arrows)*. There were no other mammographic findings. **(B)** Targeted ultrasound reveals a corresponding subtle hypoechoic mass with indistinct margins and an antiparallel orientation *(circle)*, BI-RADS 4C. Ultrasound-guided core needle biopsy and surgical excision yielded DCIS, grade 2 to 3 with necrosis, ER+/PR–.

true if coarse and heterogeneous calcifications are predominately located within the same plane as the tomosynthesis slice (Fig. 9.4). However, more often, microcalcifications are distributed beyond a single tomosynthesis slice, and it can be challenging to see the whole picture across the multiple slices. Out-of-plane coarse calcifications may also produce a distracting "ghosting" artifact on tomosynthesis. Finally, subtle and fine microcalcifications may be seen on 2D mammography alone and not seen at all on tomosynthesis. As a result, magnification views are still often helpful for complete evaluation to capture the entire group on a single 2D image and also to detect additional subtle calcifications not readily appreciated on the original 2D or tomosynthesis mammogram (Fig. 9.5).

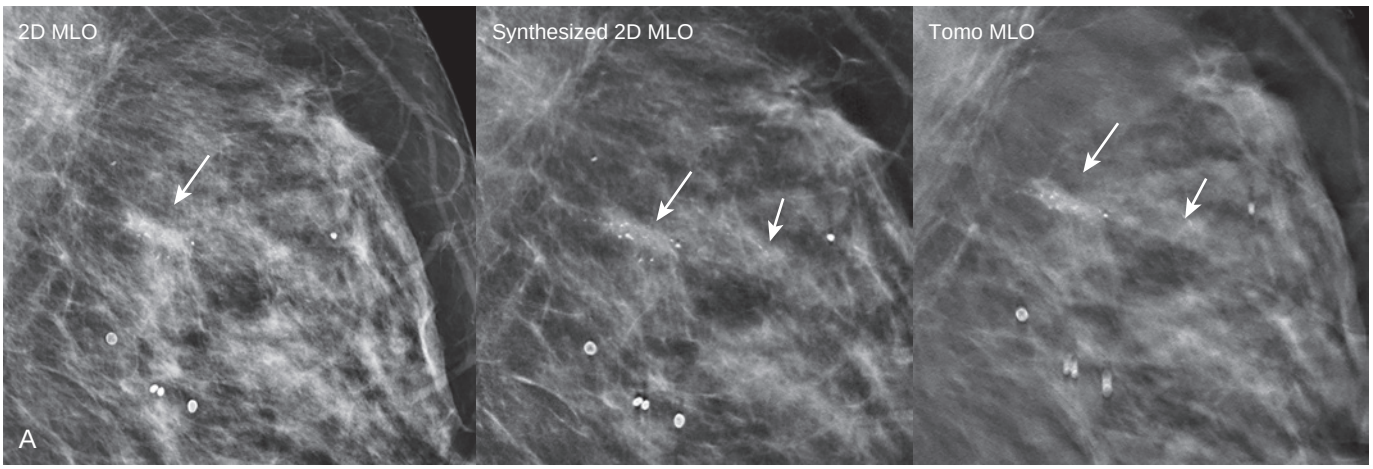
Some of the limitations of tomosynthesis in evaluation of microcalcifications can potentially be overcome by using the "slabbing" technique, in which the reconstructed slice thickness is increased using the tomosynthesis slider bar or by combining multiple tomosynthesis slices on the projection image (Fig. 9.6). Synthesized tomosynthesis may allow for improved visualization of some malignant calcifications, although more studies are needed to determine the future utility of synthesized tomosynthesis images in lieu of 2D magnification. Currently, whether microcalcifications are clustered, segmental, or regionally distributed, magnification views are easy to obtain and can provide the diagnostic confidence required when searching for fine or subtle suspicious microcalcifications and determining the final Breast Imaging Reporting and Data System (BI-RADS) assessment.

Invasive Carcinoma

Invasive Ductal and Lobular Carcinoma

Approximately 80% of all breast cancer is infiltrating ductal carcinoma, and 10% of invasive breast cancer is lobular. Although both invasive ductal and lobular carcinoma commonly present as a hyperdense or isodense mass with irregular shape and spiculated and/or indistinct margins, invasive lobular cancer is more likely than invasive ductal cancer to present as an architectural distortion or a developing asymmetry. Both invasive ductal and lobular carcinoma may also present with suspicious calcifications, with or without an associated mass.

Tomosynthesis can more easily detect invasive tumors compared with 2D mammography, including tumors that are occult on 2D mammography alone. Standard tomosynthesis craniocaudal (CC) and mediolateral oblique (MLO) views also provide exquisite visualization of mass margins, obviating the need for spot compression views. This is particularly



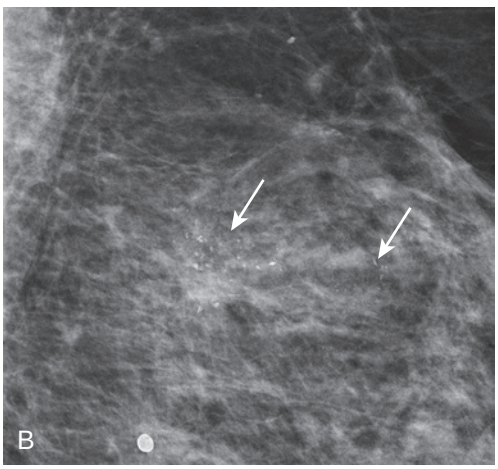


FIG. 9.4 Malignant microcalcifications on 2D and tomosynthesis. (A) Screening mammogram in a 55-year-old woman shows new suspicious heterogeneous calcifications in a segmental distribution in the left upper-outer quadrant *(arrow)*. The calcifications, including anterior fine calcifications *(short arrow)*, are better seen on both the synthesized tomosynthesis view and single tomosynthesis slice compared with the 2D mammogram. **(B)** The microcalcifications are also seen on the 2D magnification view *(arrows)*, although in this case the added information did not change management. Stereotactic core needle biopsy and surgical excision yielded ductal carcinoma in situ with microinvasion, grade 2 to 3, ER/PR+.

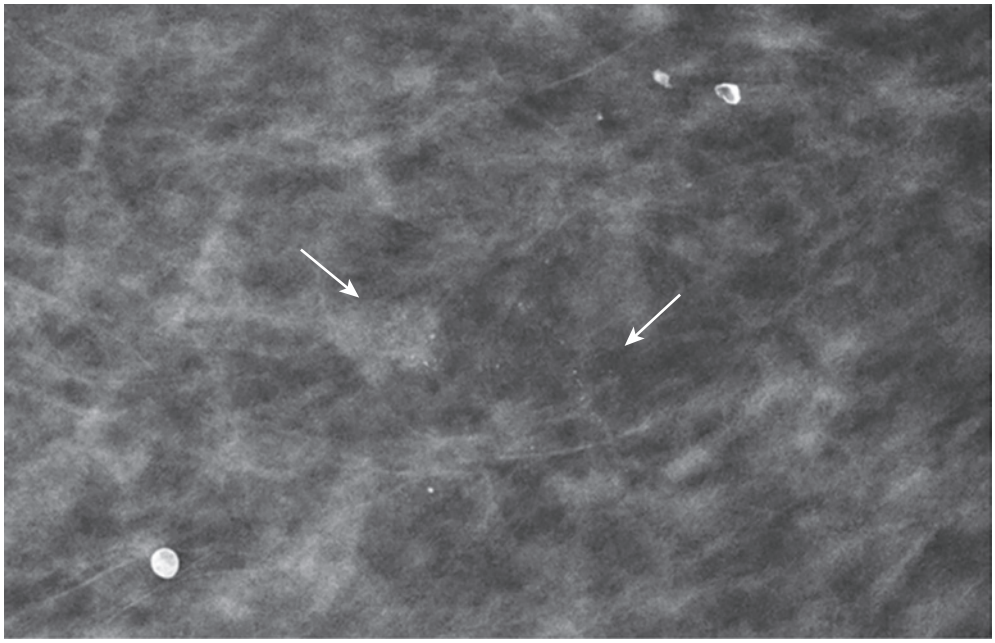


FIG. 9.5 Fine malignant microcalcifications seen only on 2D mammography. Screening mammography in a 70-year-old woman reveals a small subtle group of new calcifications seen on 2D imaging and not tomosynthesis (not shown). Spot magnification reveals predominately fine, round microcalcifications *(arrows)*. Stereotactic core needle biopsy and surgical excision yielded ductal carcinoma in situ, grade 1 to 2, ER/PR+.

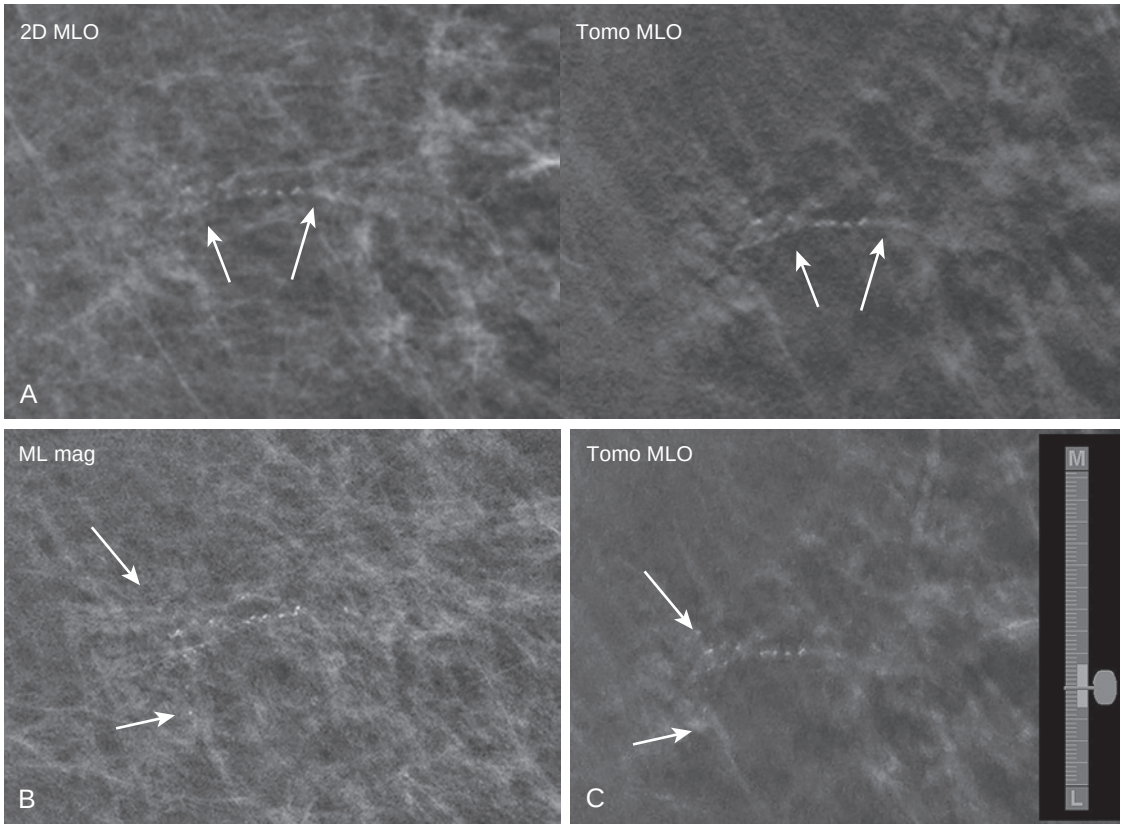


FIG. 9.6 Better visualization of malignant calcifications on tomosynthesis using the *slabbing technique*. (A) Suspicious heterogeneous microcalcifications in a linear distribution seen on screening mammography in a 70-year-old woman. The calcifications are slightly better seen on tomosynthesis *(arrows)*. **(B)** 2D 90-degree lateral (ML) magnification reveals additional fine inferior and posterior calcifications *(arrows)*. **(C)** By applying the slabbing technique to the original tomosynthesis image and widening the slice thickness to 10 mm using the slider bar, the additional microcalcifications are also visualized *(arrows)*.

true in women with scattered fibroglandular, heterogeneously dense, or extremely dense breast tissue (Fig. 9.7). The margins of a lesion surrounded by fatty breast tissue are often well seen on 2D mammography, and the added value of tomosynthesis in margin analysis is more limited but may still be useful (Fig. 9.8). Invasive cancers frequently present with spiculated margins, and these spicules can be very pronounced and elongated on tomosynthesis regardless of breast density. Although some spiculations may include tumor cells, they can also be secondary to fibrosis. Therefore, including long spicules in the overall tumor measurement often leads to an overestimation in size.

TOMO TIP ★ Malignant spiculations may be secondary to tumor cells or fibrosis. Including the full extent of the radiating fine spicules in the mammographic tumor measurement usually results in significant size overestimation of the tumor extent and should be avoided.

If a lesion is surrounded by dense breast tissue, the margins may still be partially or completely obscured despite viewing in thin tomosynthesis slices. In these cases the cancer may be very subtle even on tomosynthesis. It is important to be meticulous and methodical while interpreting the mammogram and look carefully at each tomosynthesis slice because some cancers—even large ones—with irregular margins may blend into the surrounding tissue and as a result may only be identified on a single tomosynthesis slice. In these cases the border of a mass may not be evident; however, it is important to look very carefully for associated signs of the presence of a malignancy, most often architectural distortion. This may manifest as very subtle fine spiculations at the site of the malignancy, with longer fine spiculations radiating out into the adjacent parenchyma.

Despite the ability of tomosynthesis to increase lesion conspicuity, some breast cancers can still be occult or very subtle on tomosynthesis. These tomosynthesis-occult cancers usually are associated with dense breast tissue but may also occur in mammograms with scattered fibroglandular tissue. Why is it that a mass surrounded by dense breast tissue can be imperceptible even with the advantages of tomosynthesis imaging? If a mass is completely surrounded by breast tissue, no matter how thin the tissue slices are on tomosynthesis, the contrast between the mass and adjacent tissue may not be sufficiently different to clearly define a perceptible border. This can render the lesion occult even on tomosynthesis (Fig. 9.9).

TOMO TIP ★ In patients with dense fibroglandular tissue, the malignant mass may blend in with adjacent tissues. If there is an absence of architectural distortion and a lack of sufficient contrast to define the mass margins, a malignant lesion may be occult to tomosynthesis imaging.

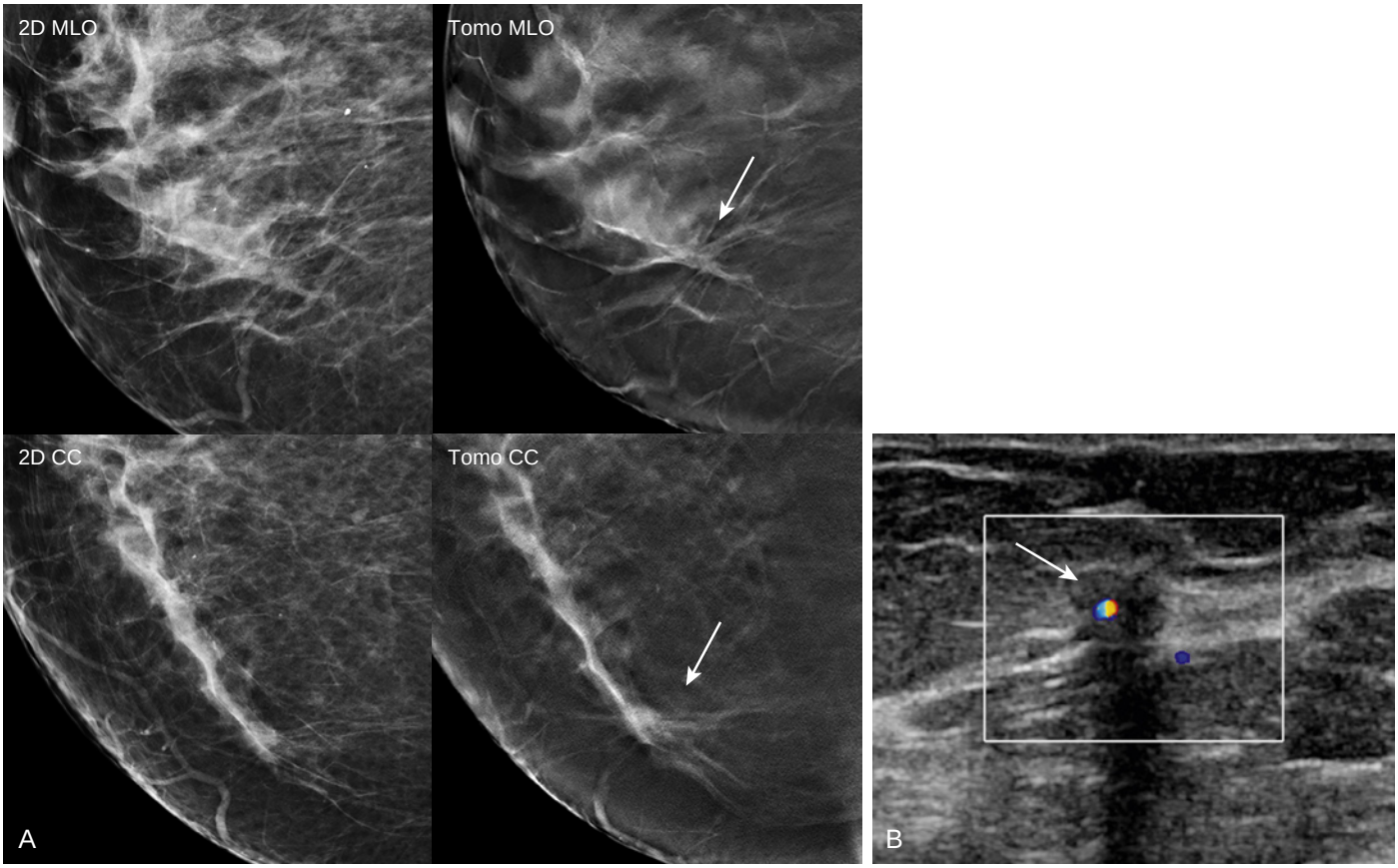


FIG. 9.7 2D occult infiltrating ductal cancer in scattered fibroglandular breast tissue. (A) Close-up views of a screening mammogram in a 57-year-old woman demonstrates a small spiculated mass in the right lower-inner quadrant that is obvious on tomosynthesis *(arrows)* but very subtle on the 2D images. **(B)** Targeted ultrasound demonstrates a corresponding hypoechoic mass with indistinct borders, posterior acoustic shadowing, and internal vascularity *(arrow)*. Ultrasound-guided core needle biopsy and surgical excision yielded infiltrating ductal carcinoma, grade 1, ER/PR+, Her2–.

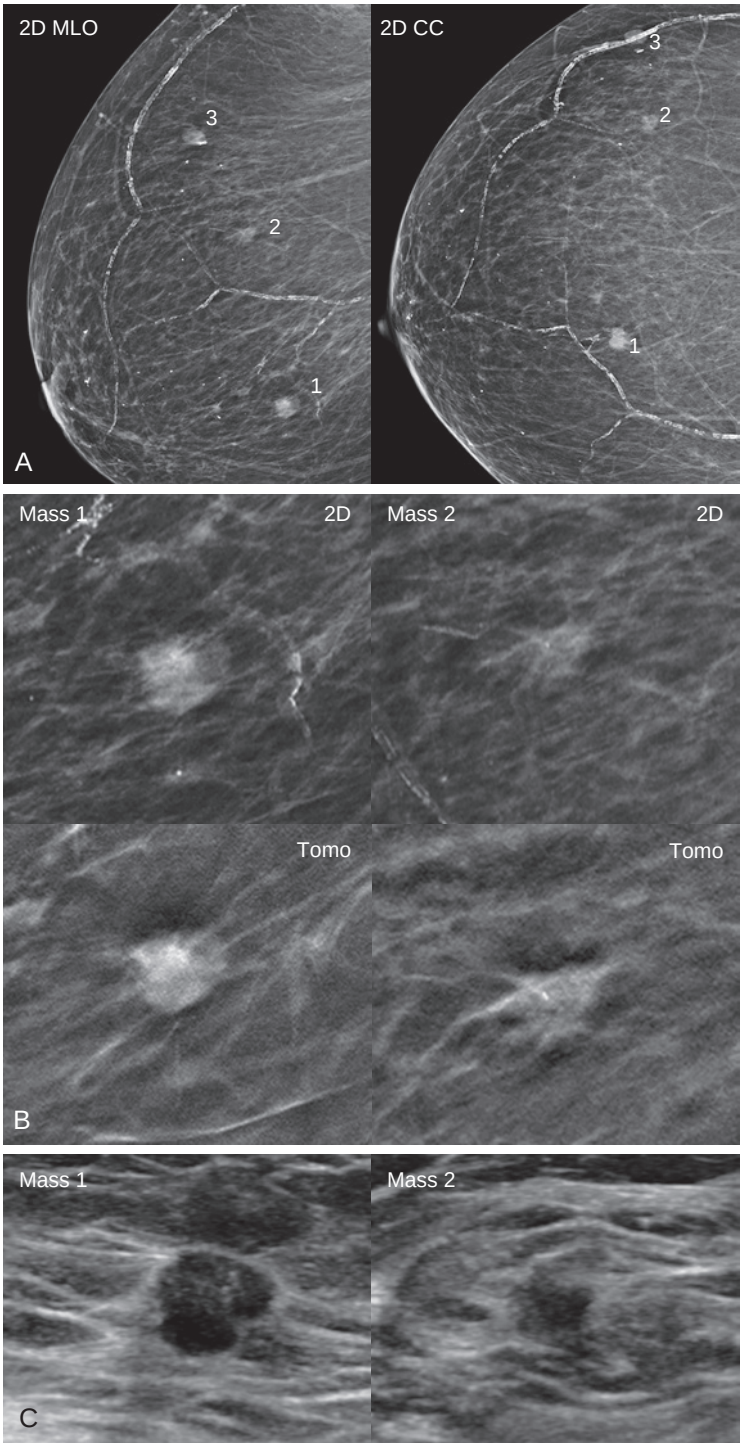


FIG. 9.8 Multicentric infiltrating ductal cancer in fatty breast tissue better seen with tomosynthesis. (A) 2D mammogram in a 79-year-old woman shows three distinct masses in the right breast *(numbered)*. Mass 3 is associated with a biopsy marker clip and is benign. **(B)** Comparison of close-up 2D and tomosynthesis MLO views show the subtle spiculated margins associated with masses 1 and 2 are much more obvious on tomosynthesis. In this case additional spot compression views were unnecessary. **(C)** Targeted ultrasound reveals corresponding suspicious solid hypoechoic masses. Mass 1 is oval with angular and indistinct margins, whereas mass 2 is irregularly shaped with indistinct margins. Ultrasound-guided core needle biopsy at both sites yielded infiltrating ductal carcinoma, grade 2, ER/PR+, Her2–, Ki67 = 5%. The patient underwent right partial mastectomy.

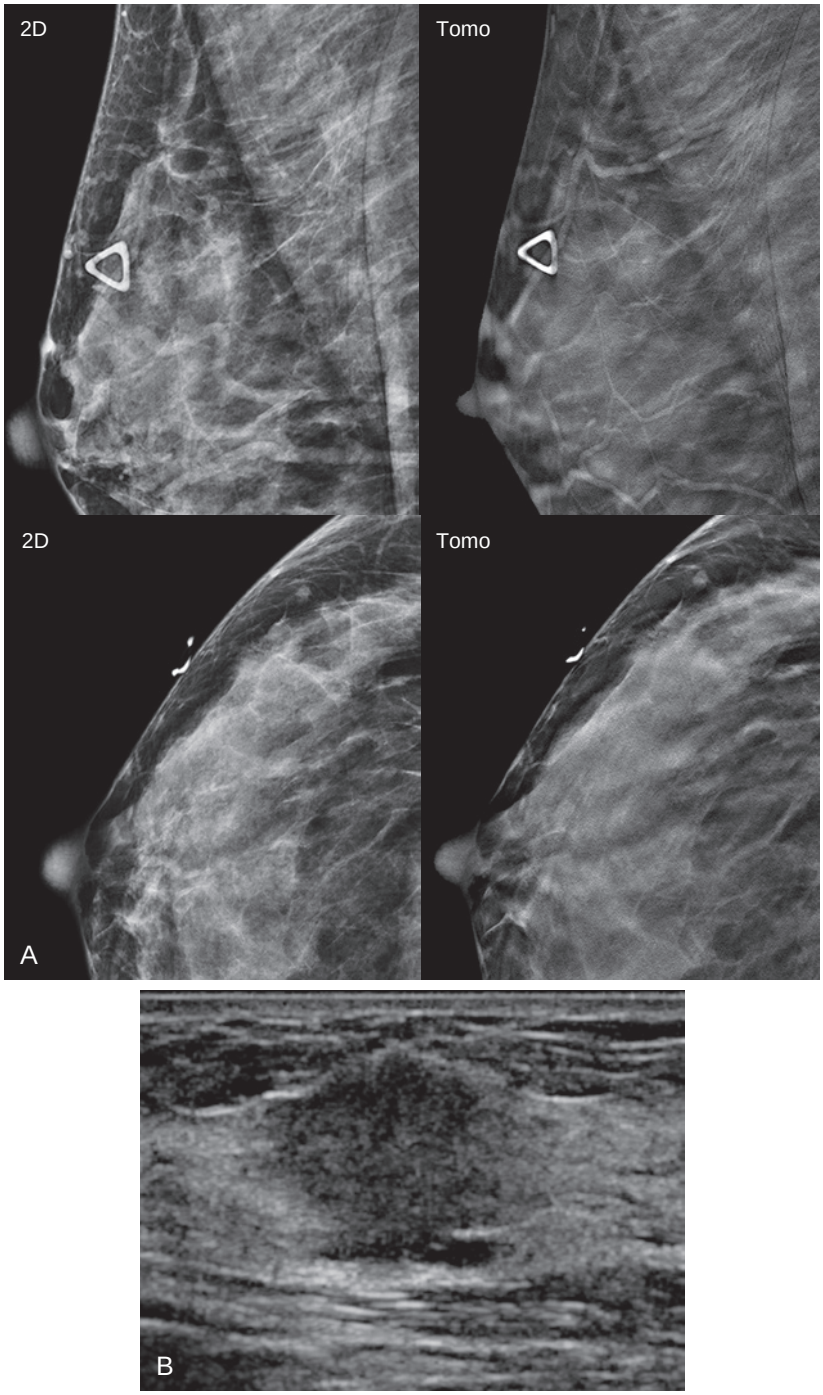


FIG. 9.9 Tomosynthesis occult cancer. (A) Baseline mammogram in a 42-year-old woman with a new palpable mass in the right upper-outer breast shows dense breast tissue without evidence of any abnormality. **(B)** Targeted ultrasound in the region of palpable concern reveals a highly suspicious isoechoic mass with indistinct borders. Ultrasound-guided core needle biopsy and surgical excision yielded infiltrating ductal carcinoma, grade 2, ER/PR+, Her2–, 1+/4 SLN.

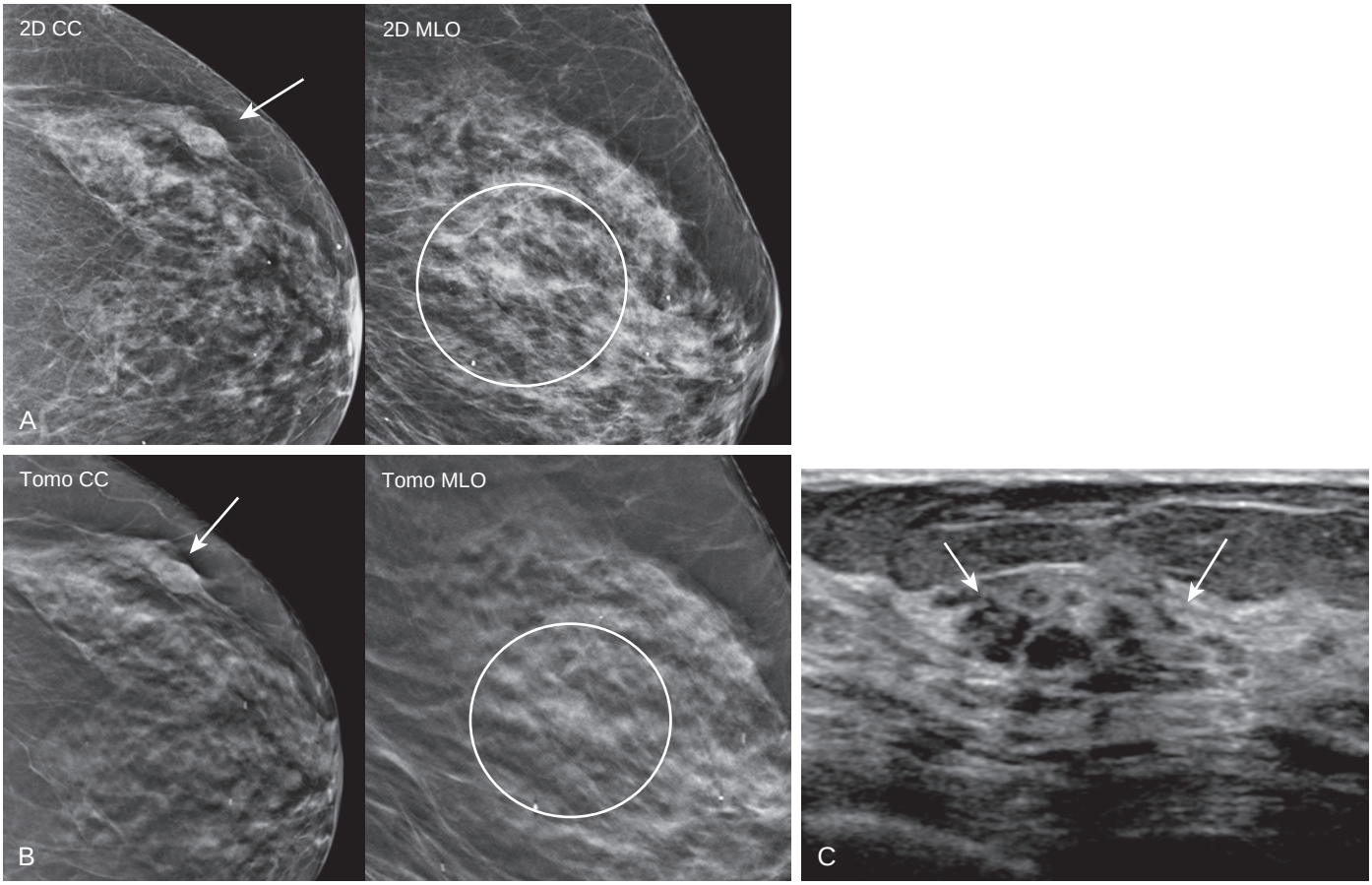


FIG. 9.10 Circumscribed mucinous cancer. (A) Oval mass *(arrow)* in the left lateral breast seen best on the 2D CC view in an 80-year-old woman. Although not clearly identified on the MLO view, it is located centrally *(circle)*. **(B)** Tomosynthesis demonstrates predominately circumscribed margins *(arrow)* on the CC view, best seen on a centrally located slice. The mass is located in the central breast on the MLO view *(circle)*, although the margins are obscured even on tomosynthesis. **(C)** Targeted ultrasound reveals an oval, mixed echogenic complex mass with cystic components *(arrows)*, BI-RADS 4B. Ultrasound-guided core needle biopsy yielded mucinous infiltrating ductal carcinoma, grade 1, ER/PR+, Her2−, 0/1 SLN.

Occasionally an invasive cancer may appear predominately circumscribed on mammography. The classic appearance of the well-differentiated subtypes of invasive ductal cancers, including mucinous, medullary, and papillary cancers, is a round or oval mass with circumscribed or indistinct margins, often mimicking the appearance of a benign fibroadenoma or complicated cyst on both mammography and ultrasound (Fig. 9.10). Although invasive ductal carcinoma (IDC), not otherwise specified (NOS) most commonly presents as an irregular mass with indistinct or spiculated margins, it can occasionally also appear as a partially circumscribed mass, particularly the more aggressive types that produce pushing borders. This is especially important to remember because compared with low-grade invasive cancers and cancers detected in average-risk women, high-grade IDC and cancers in very high-risk women will more frequently present as an apparent circumscribed mass on mammography (Fig. 9.11).

If a malignant mass appears to be circumscribed on 2D mammography, tomosynthesis will often reveal a subtle spiculation or partially indistinct or lobulated margin that is not apparent on 2D imaging. Careful assessment of all margins of a mass in both standard projections is important to fully characterize it. True circumscribed margins are much less common with tomosynthesis. Nevertheless, the appearance of circumscribed margins even on tomosynthesis should not be misinterpreted as benign, or probably benign, until the mass has been fully worked up and characterized, usually with ultrasound. Furthermore, some high-grade circumscribed cancers may also appear cystic with posterior acoustic enhancement and few internal echoes on ultrasound, so careful scanning including color Doppler interrogation is necessary to ensure a cancer is not dismissed as benign.

Architectural distortion is more easily recognized on tomosynthesis than 2D mammography and can have a variable presentation. Malignant architectural distortion may be occult on 2D mammography and be very obvious or very subtle on tomosynthesis (Fig. 9.12). Etiologies include IDC (NOS), well-differentiated tubular carcinoma, invasive lobular carcinoma, or DCIS, although benign pathology including radial scar, postoperative scar, and fibrosis may also have a similar appearance.

Although many invasive breast cancers present as a high-density or isodense solid mass, they may also present as a low-density, fat-containing lesion on tomosynthesis. Because of the thin slices and less tissue overlap, intralesional fat is much more obvious on tomosynthesis compared with conventional 2D mammography. Although some cancers with intralesional

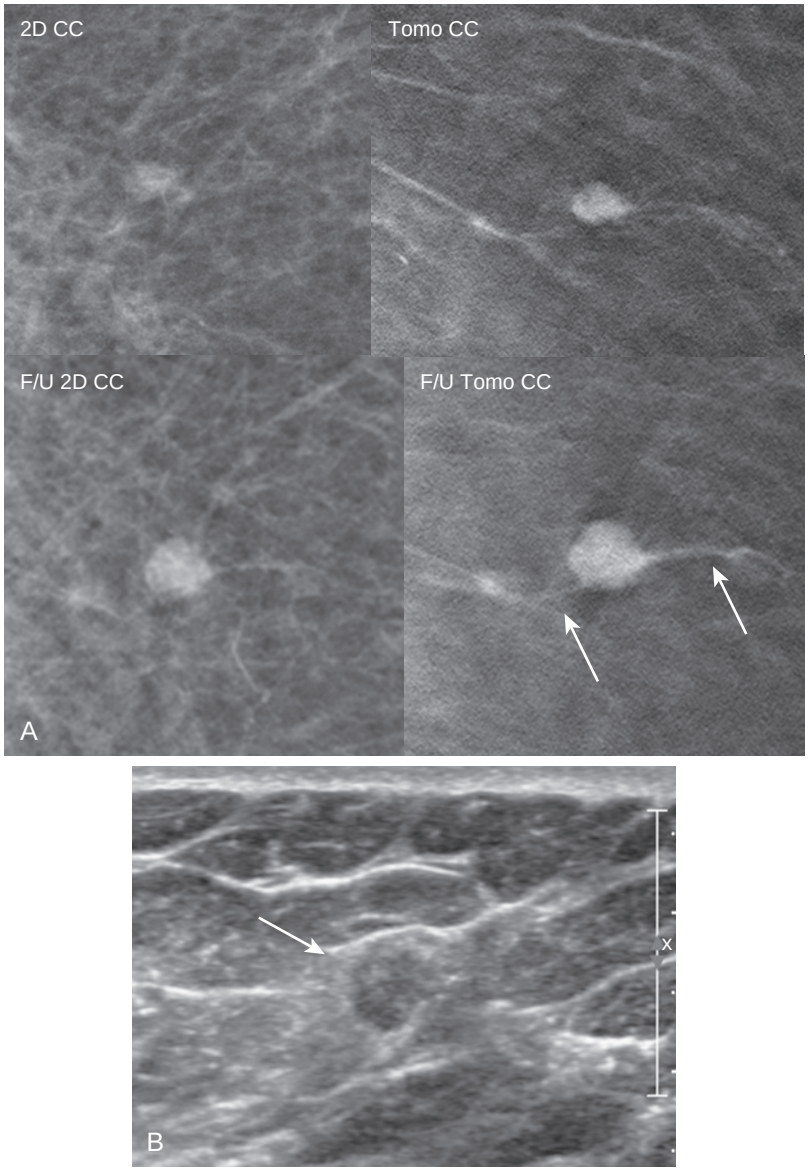


FIG. 9.11 Circumscribed high-grade invasive ductal cancer. (A) Screening mammogram in a 56-year-old woman demonstrates an oval, 5-mm mass in the left breast, with circumscribed margins on tomosynthesis and assessed as BI-RADS 3, probably benign. The mass appeared more prominent and slightly larger at a 6-month follow-up, with subtle lobulated margins and two spiculations *(arrows)*. **(B)** Targeted ultrasound shows a corresponding isoechoic vertically oriented mass *(arrow)* with indistinct margins. Ultrasound-guided core needle biopsy and surgical excision yielded invasive ductal carcinoma, grade 3, ER/PR+, Her2–, 0/1SLN.

fat may still maintain overall high mammographic density, some cancers with intralesional fat will appear much less dense than typically encountered on conventional 2D mammography. Low-grade cancers may be more likely to contain more entrapped fat compared with high-grade cancers. Therefore the presence of fat within a lesion, even if the lesion itself is not dense, should not be interpreted as a definitive indication of benignancy. Most benign, encapsulated, fat-containing lesions (lipoma, hamartoma, galactocele, lipid cysts) are usually readily recognized by their imaging characteristics. Fat necrosis, often associated with prior surgery, trauma, or arising spontaneously, can exhibit widely variable appearance on breast imaging and can mimic a malignant mass. It is critical to be aware of patient history. Breast cancer can incorporate fat that is well seen on tomosynthesis, and fat-containing masses should be thoroughly evaluated before being dismissed as probably benign or even benign.

Multifocal and Multicentric Cancer

After a suspicious lesion is found on mammography and needle biopsy is planned, it is always important to thoroughly review the remainder of both breasts for any additional subtle lesions. The frequency of synchronous contralateral breast cancer is 2% based on conventional 2D mammography plus clinical breast exam and up to 6% on magnetic resonance imaging (MRI). Likewise, multiple studies also demonstrate that MRI can also identify additional disease in the ipsilateral breast in up to 16% of newly diagnosed cancer patients. However, despite this

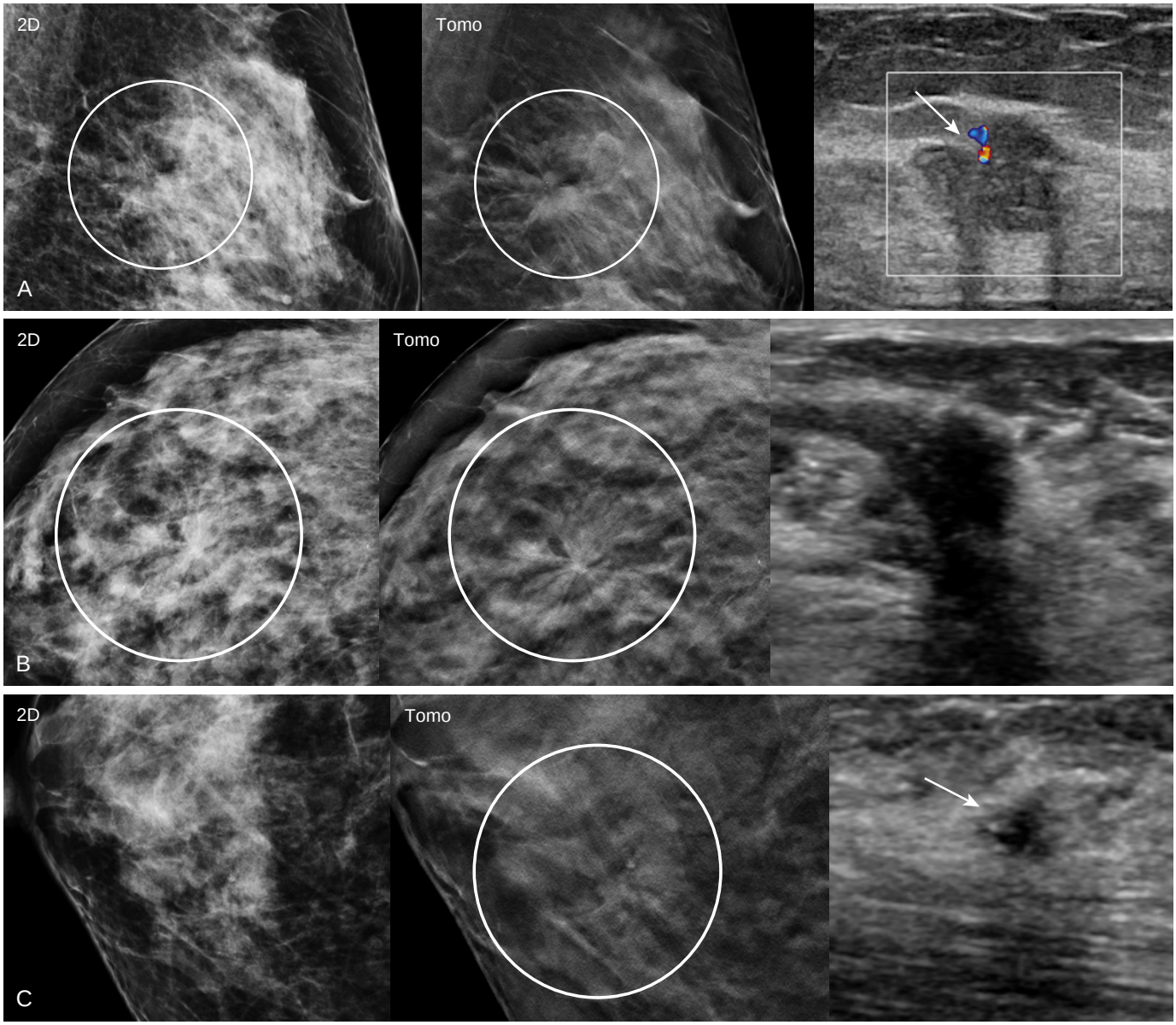


FIG. 9.12 Variable appearance of malignant architectural distortion on tomosynthesis. (A) Architectural distortion *(circles)* associated with a small mass and round microcalcifications seen only on tomosynthesis. Ultrasound demonstrates an isoechoic mass with angular margins internal vascularity *(arrow)* and posterior acoustic enhancement. Pathology at ultrasound-guided CNB and excision yielded infiltrating ductal carcinoma, grade 3, ER/PR+, Her2–, 0/2 SLN. **(B)** A subtle screening detected architectural distortion initially seen on the 2D CC view and very obvious on tomosynthesis *(circles)*. Targeted ultrasound shows a corresponding hypoechoic mass with an antiparallel orientation, indistinct margins, and posterior acoustic shadowing. Ultrasound-guided CNB and excision yielded invasive tubular carcinoma, grade 1, ER/PR+. Her2–, 0/1 SLN. **(C)** Subtle screening detected architectural distortion not clearly evident on CC 2D images is seen on a single CC tomosynthesis slice *(circle)* in the right medial breast. A corresponding hypoechoic mass with an antiparallel orientation and indistinct margins is found on targeted ultrasound *(arrow)*. Ultrasound-guided CNB yielded infiltrating lobular carcinoma, grade 2, ER/PR+, Her2–, Ki67 = 5%, 1+/7 SLN.

proven increased cancer yield, performing MRI to evaluate the extent of disease in newly diagnosed breast cancer patients is controversial and practice-dependent, mostly due to concerns regarding overall benefit in regard to reexcision rates, recurrence, and long-term survival. In addition, false-positive MRI results can delay definitive surgery and treatment, resulting in increased patient anxiety.

Tomosynthesis is probably not as sensitive as MRI in the detection of multifocal, multicentric, and/or contralateral disease. However, early studies show that in comparison with 2D FFDM alone, tomosynthesis can increase the detection of additional cancers in women with newly diagnosed breast cancer by 10% (Fig. 9.13). Tomosynthesis is efficient in this clinical setting as it can be performed at the same time as the diagnostic mammogram, requires little additional time and cost, and does not require intravenous contrast injection. By increasing the ability to detect multifocal and multicentric, and/or synchronous bilateral tumors, tomosynthesis can enhance surgical planning and staging particularly in centers that do not routinely perform staging MRI. In addition, contrast-enhanced tomosynthesis is also a potential tool that may be comparable with MRI in assessment of disease extent, but further study is needed.

Tomosynthesis can also be useful in women with newly diagnosed breast cancer initially detected with 2D mammography and/or ultrasound who also undergo staging MRI. When a suspicious lesion is detected on MRI, ultrasound is often performed to identify the lesion and guide biopsy. In a study by Mariscotti et al. 64% of MRI-suspicious lesions not identified on MRI-directed ultrasound were found on tomosynthesis. Furthermore, the clinical utility of tomosynthesis added to 2D mammography and whole breast ultrasound in the preoperative assessment of newly diagnosed breast cancer patients may be comparable to MRI. The benefit of tomosynthesis in this clinical setting is evolving and more studies are needed to compare the detection rate of additional synchronous cancers on tomosynthesis compared with conventional 2D mammography, ultrasound, and MRI.

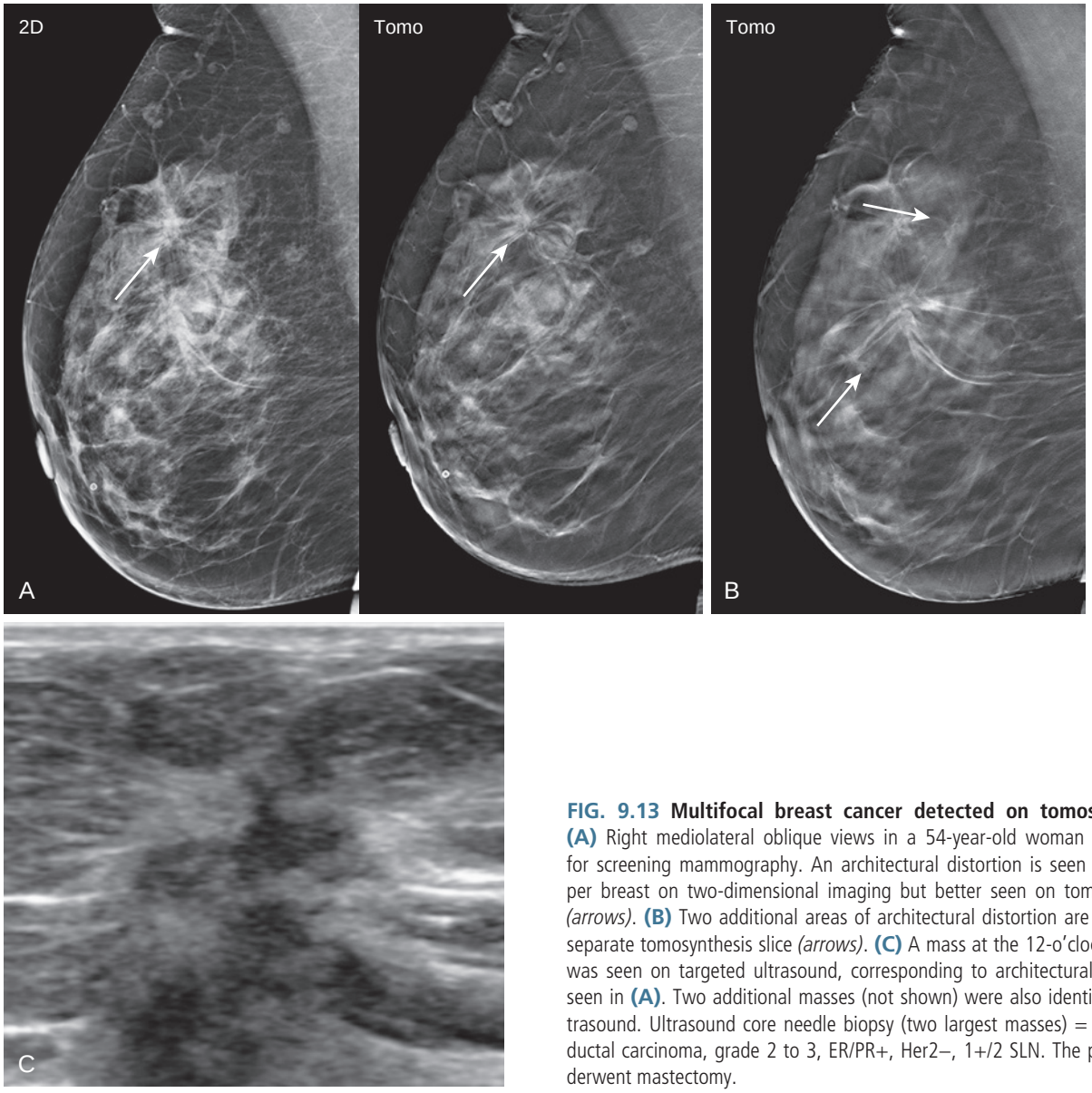


FIG. 9.13 Multifocal breast cancer detected on tomosynthesis. **(A)** Right mediolateral oblique views in a 54-year-old woman presenting for screening mammography. An architectural distortion is seen in the upper breast on two-dimensional imaging but better seen on tomosynthesis *(arrows)*. **(B)** Two additional areas of architectural distortion are seen on a separate tomosynthesis slice *(arrows)*. **(C)** A mass at the 12-o'clock position was seen on targeted ultrasound, corresponding to architectural distortion seen in **(A)**. Two additional masses (not shown) were also identified on ultrasound. Ultrasound core needle biopsy (two largest masses) = infiltrating ductal carcinoma, grade 2 to 3, ER/PR+, Her2–, 1+/2 SLN. The patient underwent mastectomy.

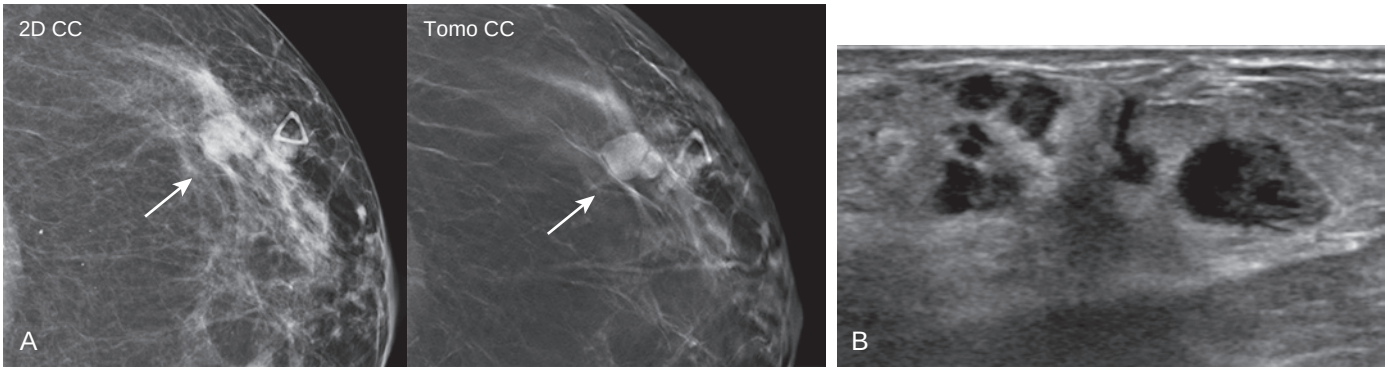


FIG. 9.14 Metastatic disease to the breast. A 61-year-old woman with normal mammogram 2 months previously. She noted a new lump and spontaneous large bruise on her left breast. **(A)** Craniocaudal two-dimensional and tomosynthesis views demonstrate a lobulated mass corresponding to the clinical findings *(arrows)*. **(B)** Ultrasound demonstrates a corresponding complex solid, multicystic mass with several adjacent additional hypoechoic lesions. Ultrasound core needle bopsy yielded metastatic melanoma.

Advanced Breast Cancer

Women with either locally advanced breast cancer (LABC) or inflammatory breast cancer may present with skin thickening, nipple changes, and axillary lymph adenopathy. These clinical findings may mimic an infectious process, such as mastitis and abscess. In most cases of LABC the underlying malignant mass is obvious on 2D mammography and ultrasound. However, in cases of inflammatory breast cancer the underlying mass may be occult on 2D mammography. The added value of tomosynthesis is to potentially find the subtle associated cancer and/or additional lesions and to direct the targeted ultrasound, as well as to facilitate core needle biopsy, thereby also facilitating accurate diagnosis. Despite the increased sensitivity of tomosynthesis, breast MRI is still usually necessary in patients with a diagnosis of inflammatory breast cancer. Not only is a mammographically occult index lesion usually identified on MRI, but also the extent of disease can be most accurately assessed particularly if neoadjuvant chemotherapy is planned prior to breast-conserving therapy or mastectomy.

Metastases

Metastases to the breast are not common but can occur in patients with advanced melanoma, ovarian, or lung cancer. These masses usually present as a solitary mass, which may appear circumscribed and benign, even on tomosynthesis. Clinical history is always important, and any new benign-appearing mass in patients with a history of other cancer—even if cystic on ultrasound—should be considered suspicious (Fig. 9.14).

Metastatic adenopathy in an abnormal axillary or intramammary lymph node is an uncommon presentation of malignancy on mammography in women without a history of lymphoma or leukemia. Adenocarcinoma from sites other than breast rarely present as isolated unilateral axillary metastases, and usually the primary is a mammographically occult breast carcinoma. Regardless of etiology, ultrasound evaluation of the abnormal lymph node can aid lymph node assessment and guide biopsy. When lymph node biopsy reveals a breast cancer that is occult on 2D mammography and ultrasound, MRI is typically performed to help identify the primary breast cancer. Tomosynthesis may also detect the occult malignancy, although the accuracy of tomosynthesis compared with MRI in this clinical setting is not yet established. The overall sensitivity of MRI is 50% to 86%, and similar to cases of mammographic and ultrasound occult inflammatory breast cancer, MRI is indicated if no suspicious mass is seen on the initial tomosynthesis work-up.

In patients presenting with metastatic breast cancer beyond the axilla, mammography is often ordered to identify an otherwise occult breast cancer. Women with metastatic but undiagnosed breast cancer most often present with bone, lung, liver, ovarian, and brain metastases. Mammography is usually performed as part of the metastatic work-up, and in the case of an invasive primary breast cancer, tomosynthesis may improve both detection and lesion characterization compared with 2D FFDM alone.

Summary

Tomosynthesis can significantly improve cancer detection and increase specificity of mammography by eliminating the masking effect of overlying tissue summation and also allowing superior visualization of mass margins. Currently, tomosynthesis may not provide a substantial benefit in the evaluation of microcalcifications compared with magnification views and conventional 2D mammography. Future technical advances will likely result in improvements in the visualization and characterization of malignant microcalcifications using tomosynthesis.

When a cancer is discovered, tomosynthesis can also help to reveal additional synchronous disease. Compared with 2D mammography, malignant findings are often better seen on tomosynthesis. The presence of a mass, features of the borders of a mass, presence of suspicious calcifications, and very importantly presence of associated architectural distortion with spiculation may be more clearly revealed. It is also very important to recognize the limitations of tomosynthesis. The borders of a mass may exhibit predominately benign features, or the abnormality may be occult to tomosynthesis imaging. It is always paramount to consider all of the presenting findings, patient history, and risk factors in interpreting mammography with tomosynthesis so that the appropriate interpretive and management decisions are made, which will ultimately lead to improved overall diagnostic performance of mammography and better outcomes for women.

CHAPTER
10

Architectural Distortion

Madhavi Raghu | Regina J. Hooley

With its inherent ability to decrease the masking effect of overlying fibroglandular tissue, tomosynthesis allows improved visualization of architectural distortion (AD). While most breast cancers present on mammography as a suspicious mass and/or microcalcifications, the third most common mammographic presentation of nonpalpable breast cancer is AD. It is an important mammographic finding; AD has been shown to be a frequent cause of false-negative mammograms, accounting for 12% to 45% of all missed breast cancers on two-dimensional (2D) mammography.

Similar to 2D mammography, the conspicuity of AD is quite variable on tomosynthesis. AD may be a very obvious finding seen in both mammographic projections and easily identified on ultrasound, or AD may be a very subtle finding on only a single tomosynthesis view, not identified on the 2D mammogram—even in retrospect—and not seen on targeted ultrasound. Overall, tomosynthesis allows for increased sensitivity in identification of subtle AD, and it is essential to recognize that tomosynthesis-detected AD not seen on 2D mammography can represent malignancy, with a positive predictive value (PPV) for biopsy of 44% across several studies; thus it is a finding that should be given careful consideration.

This chapter will address the practical applications of tomosynthesis in the evaluation of AD, including the management of these lesions seen only on tomosynthesis and potential imaging dilemmas that may arise.

Tomosynthesis Features of Architectural Distortion

AD is defined as distorted parenchyma, often with spicules or tethered Cooper ligaments radiating from a common point with no obvious associated mass (Fig. 10.1). AD can be

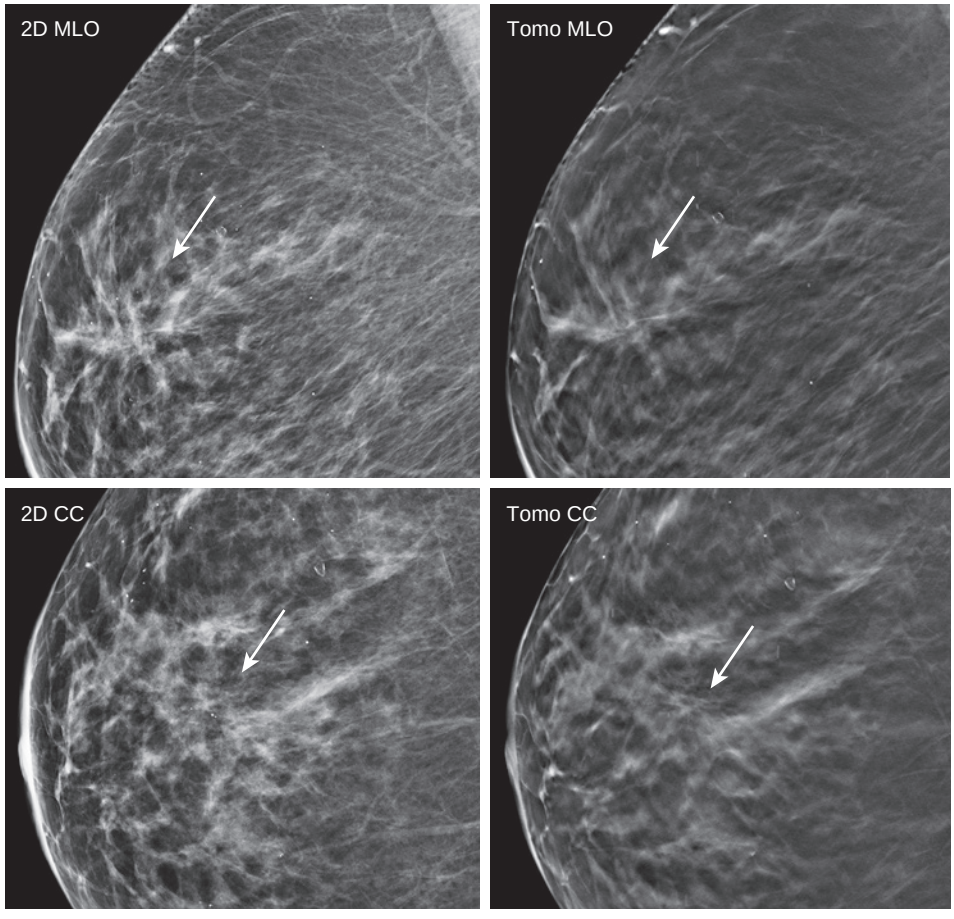


FIG. 10.1 Benign architectural distortion due to postoperative scar. Screening mammogram in an 83-year-old woman with a remote history of benign surgical excision in the right upper breast with a corresponding postoperative AD *(arrows)*. Note the fine spicules radiating from a central point, best seen on the MLO views.

associated with an asymmetry and/or microcalcifications. It is important to recognize that our understanding of AD to date has largely been based on 2D mammography, where complete assessment of lesions is more limited. With tomosynthesis, AD may be found to be associated with a subtle, low-density mass. Classic clues used to identify a subtle AD include focal retraction, distortion, and/or straightening of the tissue along the fat and parenchymal borders. These findings are usually more conspicuous on tomosynthesis, thereby increasing mammographic sensitivity and improving lesion characterization (Fig. 10.2).

AD is usually isodense to fibroglandular breast tissue and can be difficult to recognize on 2D mammography in both dense and nondense breast tissue. Tomosynthesis can more clearly depict the radiating spicules, allowing for improved mammographic sensitivity and specificity in all breast densities (Fig. 10.3).

When analyzing the tomosynthesis mammogram, it is essential to scroll slowly through the tomosynthesis stack, focusing only on a single area of the breast, as the AD may be best seen on a single view and only be apparent on one or two image slices. Once the potential AD is identified, scrolling back and forth just through the level of the suspected AD can help confirm that a true lesion exists. By determining the location of the tomosynthesis slice best demonstrating the AD, the orthogonal view can be carefully scrutinized in order to increase the likelihood of identifying a subtle AD on both the craniocaudal (CC) and mediolateral oblique (MLO) projections (Fig. 10.4). In these cases, identification of nearby landmarks can also assist in locating a subtle AD on the orthogonal view.

Pathology of Architectural Distortion

When AD is identified, one must always first correlate the finding with the patient's surgical history, as the most common cause of AD is previous surgery, secondary to either benign or malignant disease. If no surgical history is found, AD is considered a suspicious finding and malignancy must be excluded.

Malignant etiologies include invasive ductal (IDC) or lobular cancer (ILC). Given that IDC is more common, most

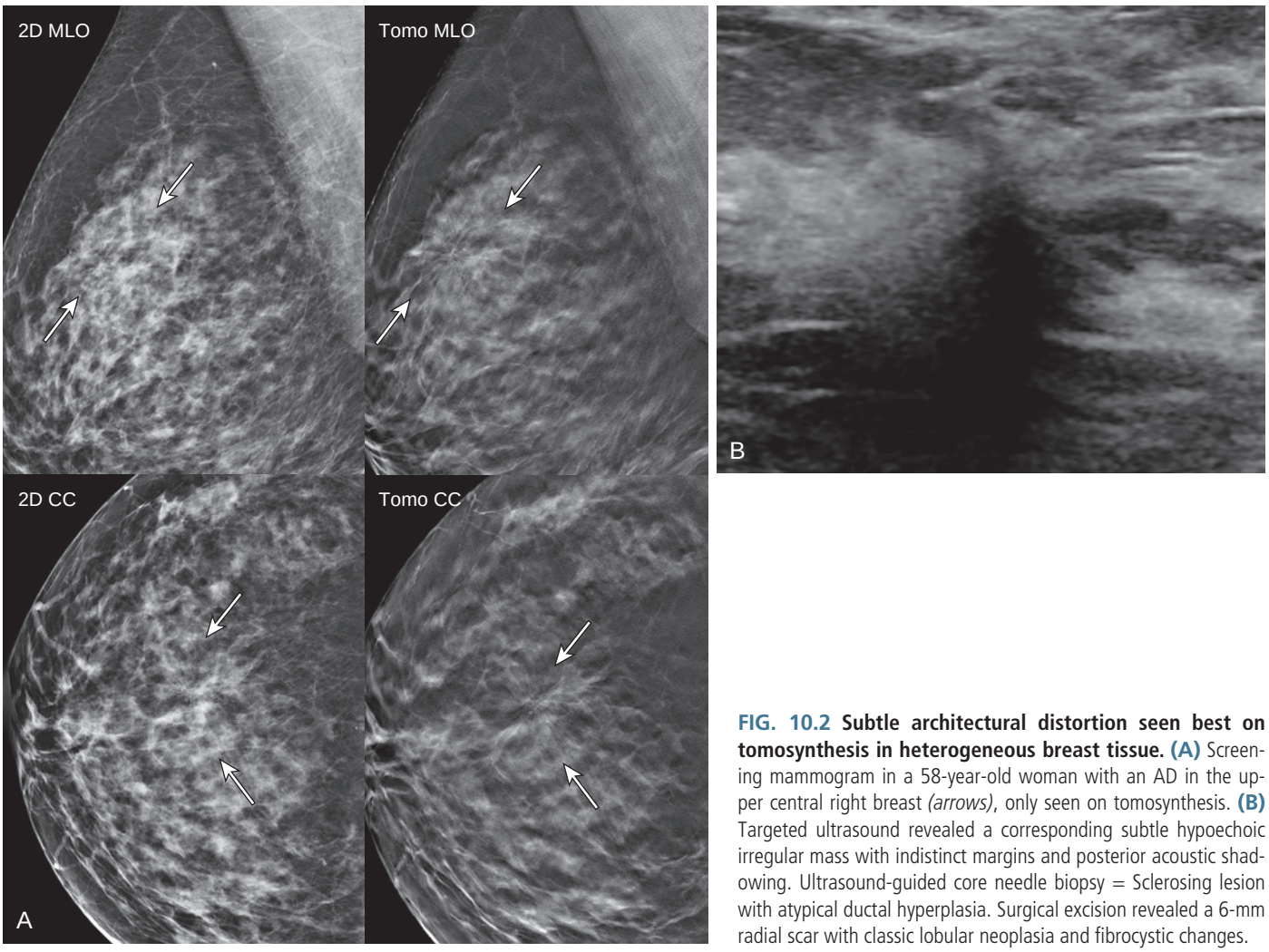
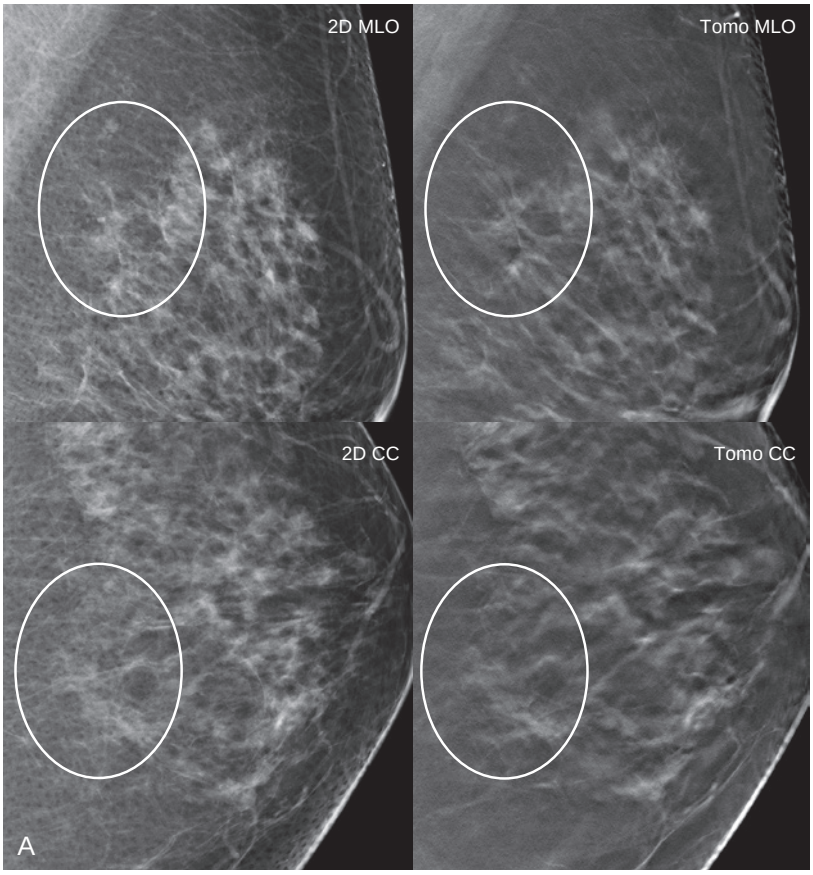
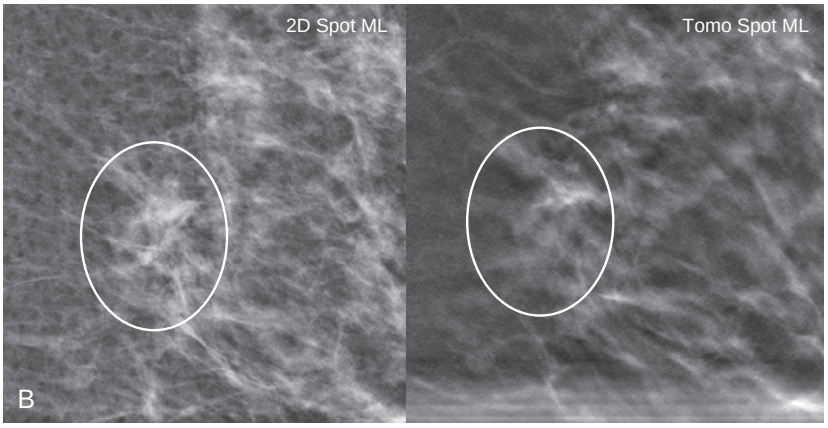
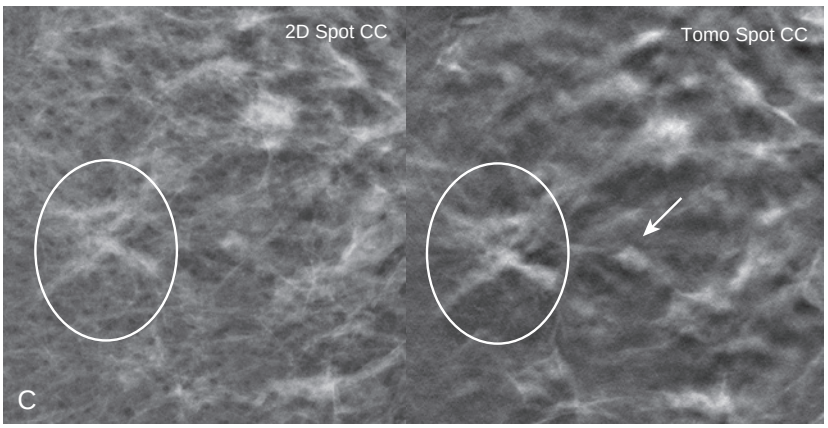


FIG. 10.2 Subtle architectural distortion seen best on tomosynthesis in heterogeneous breast tissue. (A) Screening mammogram in a 58-year-old woman with an AD in the upper central right breast *(arrows)*, only seen on tomosynthesis. **(B)** Targeted ultrasound revealed a corresponding subtle hypoechoic irregular mass with indistinct margins and posterior acoustic shadowing. Ultrasound-guided core needle biopsy = Sclerosing lesion with atypical ductal hyperplasia. Surgical excision revealed a 6-mm radial scar with classic lobular neoplasia and fibrocystic changes.







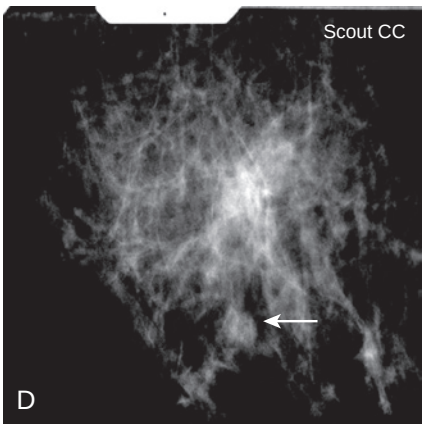


FIG. 10.3 Architectural distortion initially much better visualized on tomosynthesis. (A) Screening mammogram in a 62-year-old woman with scattered fibroglandular tissue reveals a subtle AD seen only the tomosynthesis MLO view *(circle)*. On the 2D MLO view, only a corresponding asymmetry is seen, which could easily be dismissed as normal fibroglandular tissue. **(B and C)** Combination 2D and tomosynthesis spot compression views were obtained, which demonstrated that the distortion *(circles)* was most obvious in the CC view with tomosynthesis. **(D)** No ultrasound correlate was found and stereotactic core needle biopsy was performed in the CC projection utilizing a nearby probable cyst *(arrow)* as a guiding landmark. Stereotactic core needle biopsy and excision = 6 mm grade 1 tubular IDC, ER+, PR–, Her2–, 0/2 SLN.

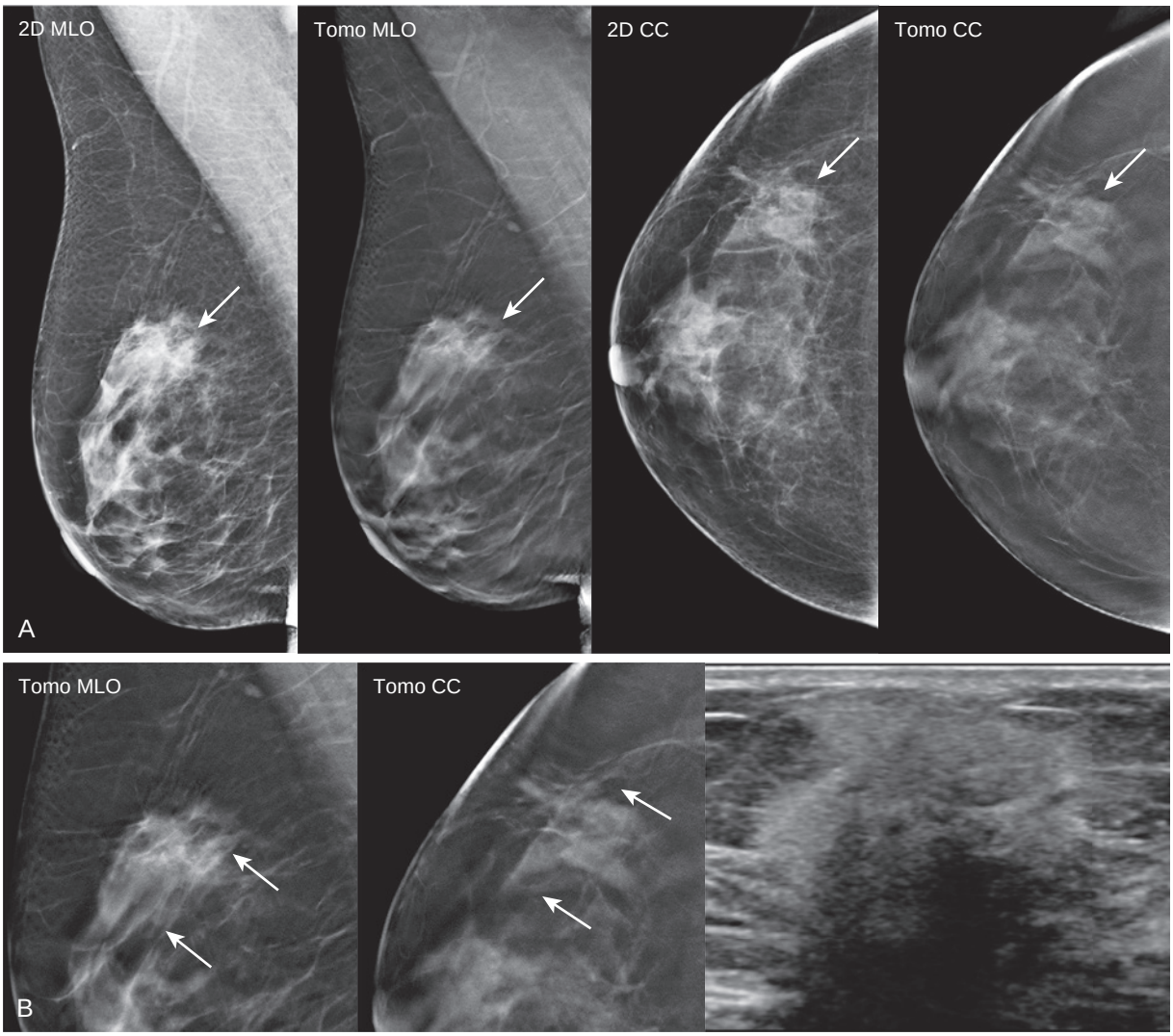


FIG. 10.4 Architectural distortion seen on only one CC slice. (A) Screening mammogram in a 56-year-old woman reveals a developing asymmetry in the right upper outer quadrant *(arrows)*. **(B)** Close-up tomosynthesis views reveal an associated AD. Although the spicules are obvious on the MLO view, they are more subtle on the CC view and only seen on a single tomosynthesis slice *(arrows)*. Targeted ultrasound shows a corresponding mixed echogenic irregular 2.5 cm mass with posterior acoustic shadowing. Ultrasound-guided core needle biopsy and excision = IDC, moderately differentiated, ER/PR+. Her2−, 1/2SLN.

malignant AD will represent IDC, including NOS (not otherwise specified) or well-differentiated invasive tubular carcinoma. ILC traditionally accounts for 5% to 10% of all invasive breast cancers and can be extremely subtle or occult on 2D mammography. Early studies indicate that the rate of ILC may be higher among suspicious AD seen only on tomosynthesis, thus potentially improving the rate of detection of this invasive subtype.

Although infrequent, ductal carcinoma in situ (DCIS) may also present as AD seen only on tomosynthesis. DCIS typically presents as suspicious linear, branching, and/or pleomorphic microcalcifications, but has been reported to present as AD on 2D mammography in 2% to 10% of DCIS cases. On tomosynthesis, DCIS may present as a subtle AD with variable density, with or without associated suspicious microcalcifications (Fig. 10.5).

In addition to postoperative scars and invasive and/or in situ cancers, other histologies presenting as AD include high-risk radial sclerosing lesions, atypical ductal hyperplasia (ADH), atypical lobular hyperplasia (ALH), and lobular carcinoma in situ (LCIS). Stromal fibrosis, sclerosing adenosis, and rarely granular cell tumor or breast fibromatosis may also present as an AD seen only on tomosynthesis. Radial sclerosing lesions, composed of both radial scars and complex sclerosing lesions, may also present as AD on tomosynthesis and are indistinguishable from carcinoma (Fig. 10.6). These lesions are histologically similar and are unrelated to trauma or prior surgery and may be secondary to a localized inflammatory reaction and chronic ischemia. Complex sclerosing lesions are distinguished from a radial scar by being more complex histologically and generally greater than 1 cm. Radial sclerosing lesions have been reported to be associated with atypia and/or malignancy, although the

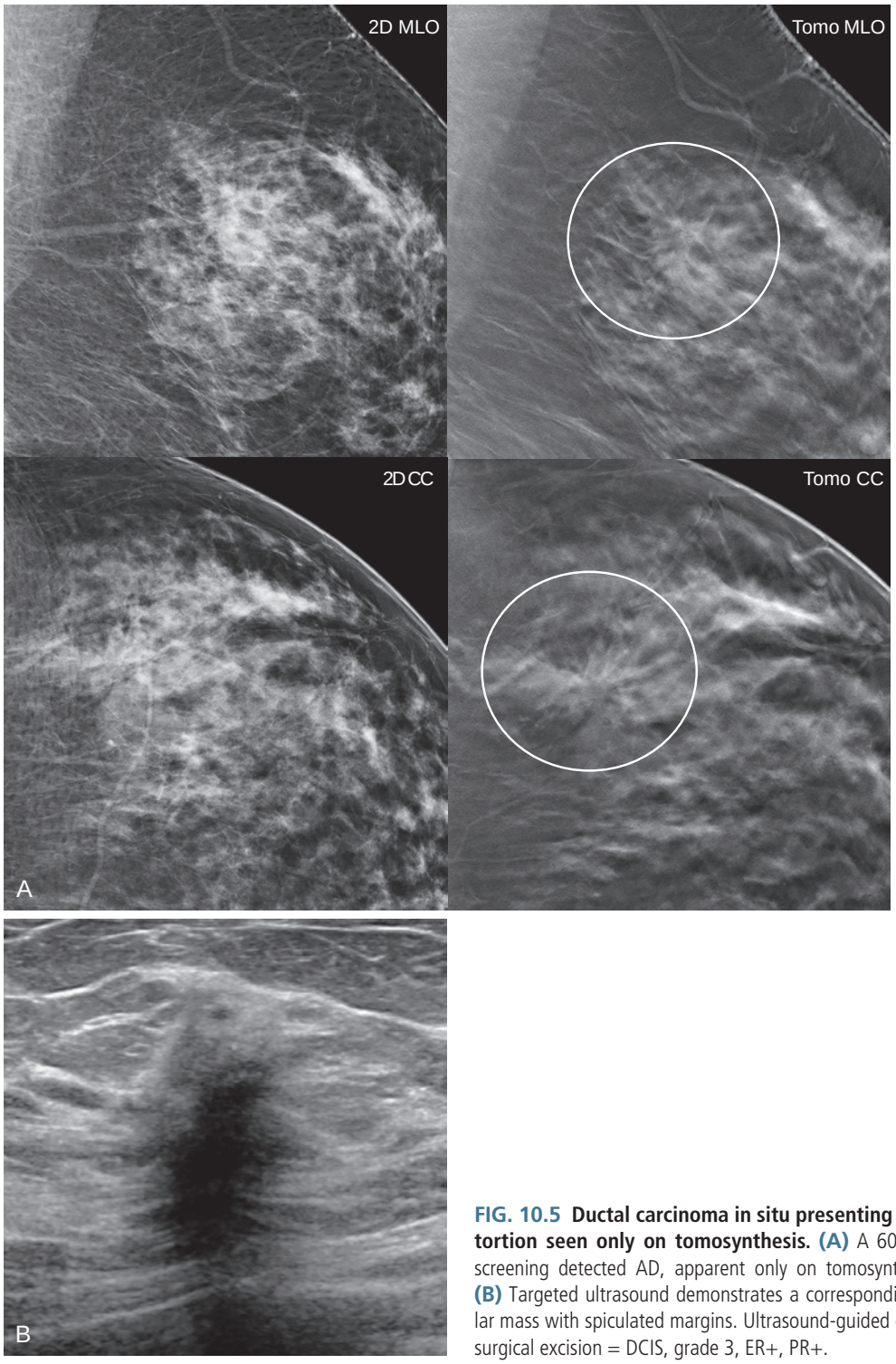


FIG. 10.5 Ductal carcinoma in situ presenting as architectural distortion seen only on tomosynthesis. (A) A 60-year-old woman with screening detected AD, apparent only on tomosynthesis images *(circles)*. **(B)** Targeted ultrasound demonstrates a corresponding hypoechoic, irregular mass with spiculated margins. Ultrasound-guided core needle biopsy and surgical excision = DCIS, grade 3, ER+, PR+.

data has been primarily based on 2D mammography. The understanding of the association of malignancy with radial sclerosing lesions found on tomosynthesis is still evolving.

TOMO TIP ★ Compared to 2D mammography, tomosynthesis can better identify AD, but cannot distinguish between benign and malignant AD.

Diagnostic Work-up of Architectural Distortion

In many cases, a suspected AD initially seen on mammography will represent benign postoperative scar or overlapping fibroglandular tissue. Postoperative scars typically are more pronounced on one view compared to the orthogonal view and do not require additional work-up if there is a correlative biopsy history (Fig. 10.7).

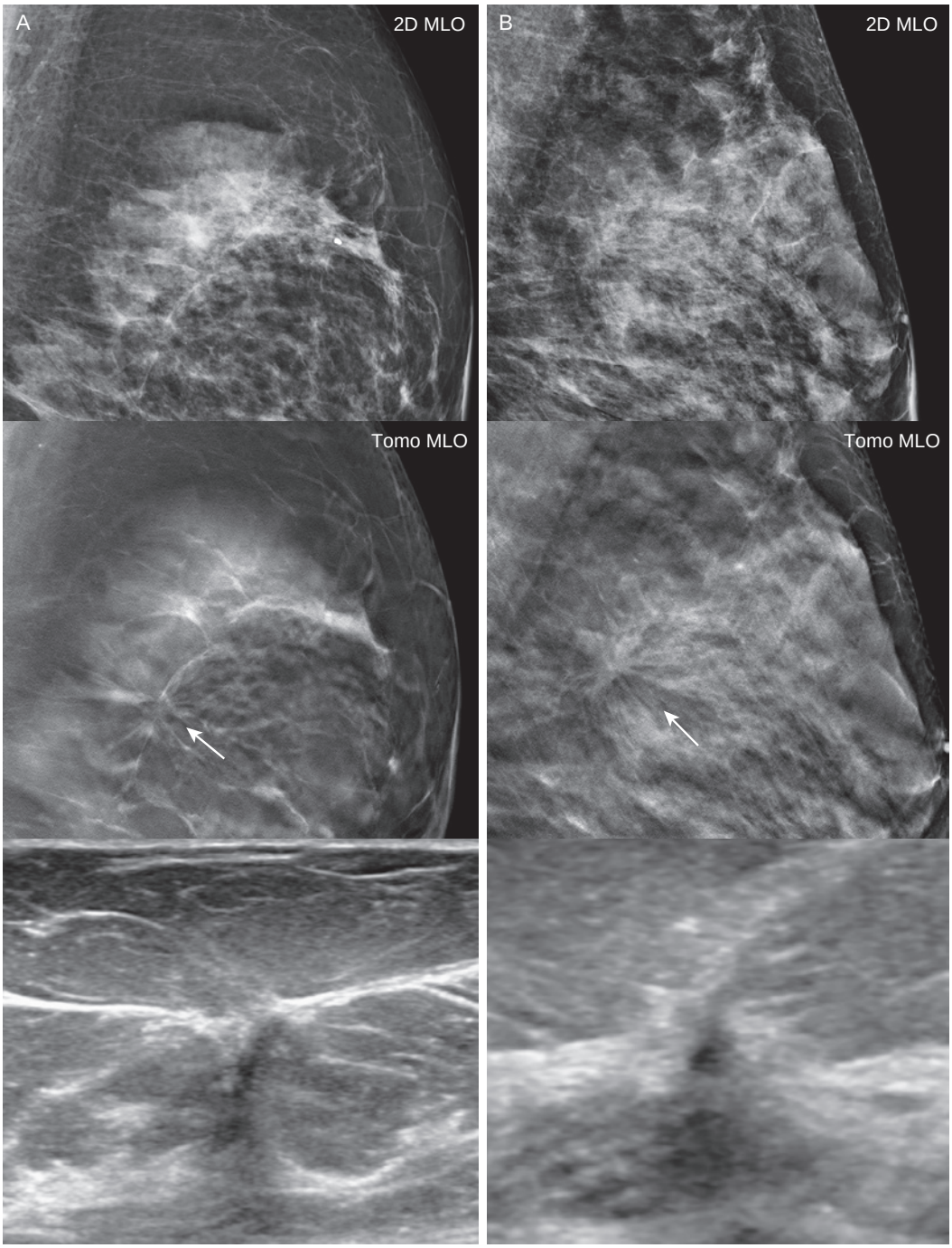


FIG. 10.6 Benign and malignant architectural distortion may look identical on tomosynthesis and ultrasound. (A and B) MLO views in two separate patients show a subtle AD seen only on tomosynthesis *(arrows)*. In both cases, targeted ultrasound reveals a corresponding irregular hypoechoic mass. Ultrasound-guided core needle biopsy = Patient A: 1.8 cm IDC, grade 1, ER/PR+, Her2+, Ki67 = 3%, 0/1 SLN. Patient B: Complex sclerosing lesion, confirmed with excision.

Assuming the possibility of postoperative scars being excluded, a suspected AD seen on conventional screening 2D mammography requires additional diagnostic work-up, including—but not limited to—spot compression views and lateral and/or rolled views. However, when performing the 2D mammogram in combination with tomosynthesis, the tomosynthesis images often show that an initially suspected AD is simply overlapping fibroglandular tissue, thereby eliminating the need for conventional diagnostic views and avoiding false-positive screening recalls (Fig. 10.8). Of course, in other cases,

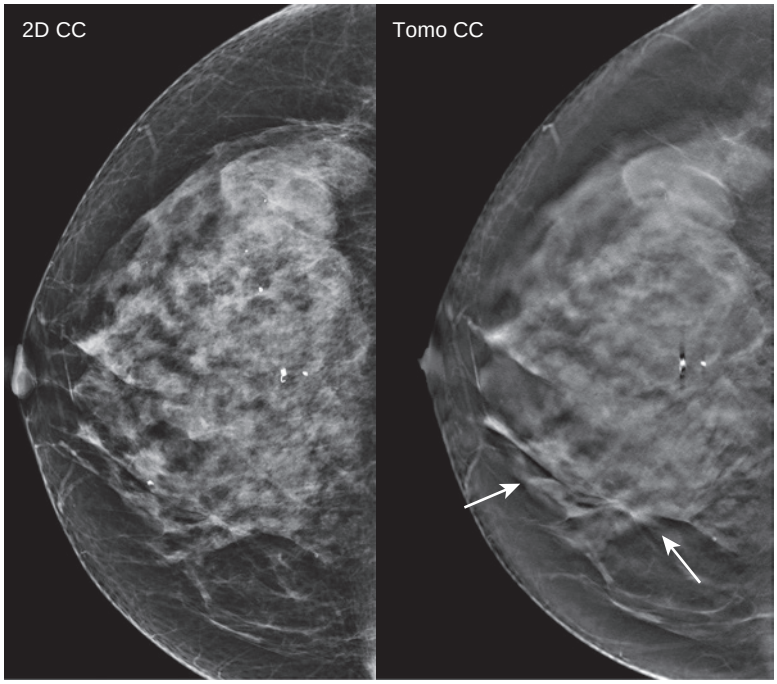


FIG. 10.7 Postoperative scar seen only on tomosynthesis mimicking malignancy. Screening mammogram in a 67-year-old woman reveals an AD seen only on the CC tomosynthesis view in the inner right breast *(arrows)*, best seen on a superiorly located tomosynthesis slice. This was a "new" mammographic finding, and recall was considered. Fortunately the screening mammogram was read online before the patient left the department. While the technologist was performing screening dense breast ultrasound, she noticed a corresponding very faint remote biopsy scar on the skin in the upper inner quadrant and no underlying sonographic abnormality. The patient had not previously reported this surgical history, and because the 2D mammogram was stable for many years, the AD and exam was interpreted as BI-RADS 2 and a diagnostic work-up was averted.

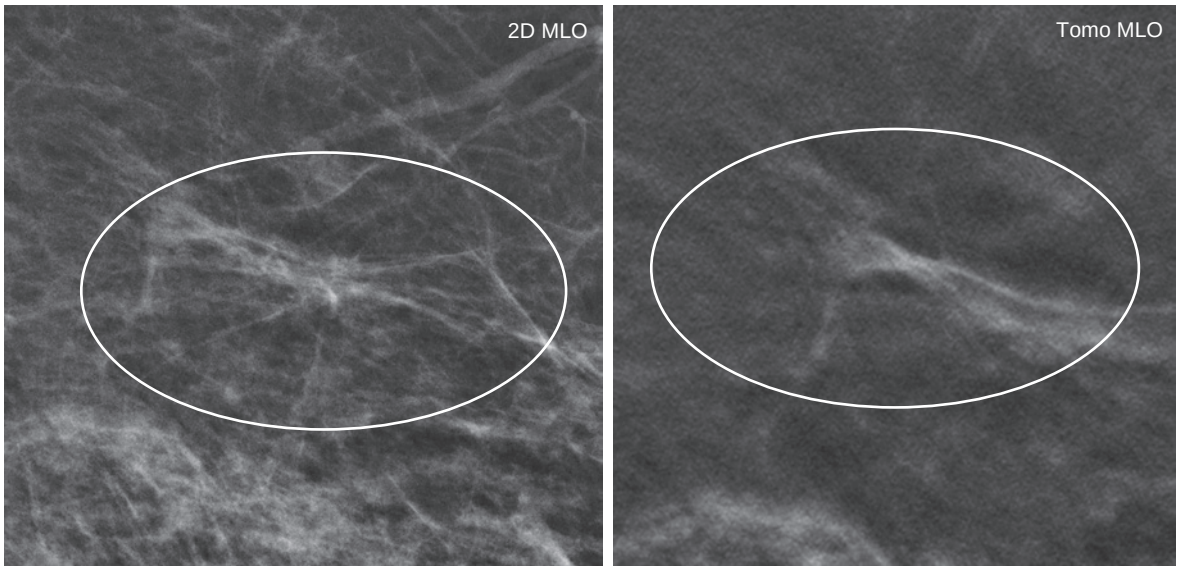


FIG. 10.8 Normal overlapping tissue mimicking architectural distortion. Close-up of a screening mammogram in a 72-year-old woman reveals a possible area of distortion in the upper breast on the 2D MLO *(circle)*. However, the corresponding tomosynthesis reveals normal fibroglandular tissue and overlying Cooper ligaments and no evidence of fine spicules *(circle)*, BI-RADS 2. This finding was stable on subsequent yearly follow-up.

tomosynthesis will reveal a true and suspicious malignant AD that will require biopsy.

When an AD distortion is identified on tomosynthesis, how should we work it up? Are spot compression views always necessary? If an AD is initially seen in both 2D and tomosynthesis images, typically the patient can go straight to ultrasound and skip the spot compression views (Fig. 10.9). If an AD is initially only seen on tomosynthesis, especially if

only in one projection, combination (2D+3D) spot compression views may help determine if the finding is real or not and where it is located. 2D spots alone are not recommended. In a study by Partyka et al., there were no cases in which suspicious AD was seen better on diagnostic 2D spot compression views, compared to standard tomosynthesis views, or seen only on the diagnostic 2D spot compression views and not seen at all on tomosynthesis. But done as combination spots, the 2D component can help ascertain that the correct area of the breast is imaged, and identification on 2D mammography can also be useful if tomosynthesis-guided biopsy is not available and routine stereotactic biopsy or needle localization is to be attempted.

Tomosynthesis spot compression views may be useful for very subtle AD seen only on tomosynthesis, especially if the AD is initially seen on a single view. In these cases, overlapping tissue can mimic an AD or obscure an AD, even on the tomosynthesis views. The added benefit of increased focal compression to disperse surrounding tissue in combination with tomosynthesis may provide the clarity necessary to differentiate overlapping fibroglandular tissue from a true AD. It is also important to recognize that it is possible that subtle malignant AD may not be reproduced even on tomosynthesis spot compression, similar to the occasional cancer that "spots away" on 2D spot compression (Fig. 10.10). In many cases, full-view tomosynthesis rolled CC views or true lateral views may be more helpful than spot views in further characterizing AD seen on tomosynthesis.

TOMO TIP ★ Beware of using spot views for work-up of AD seen on tomosynthesis. Just as in 2D mammography, malignant AD may not be reproduced on spot compression views. Full tomosynthesis views and careful targeted sonography can be more beneficial in determining if a suspicious finding exists.

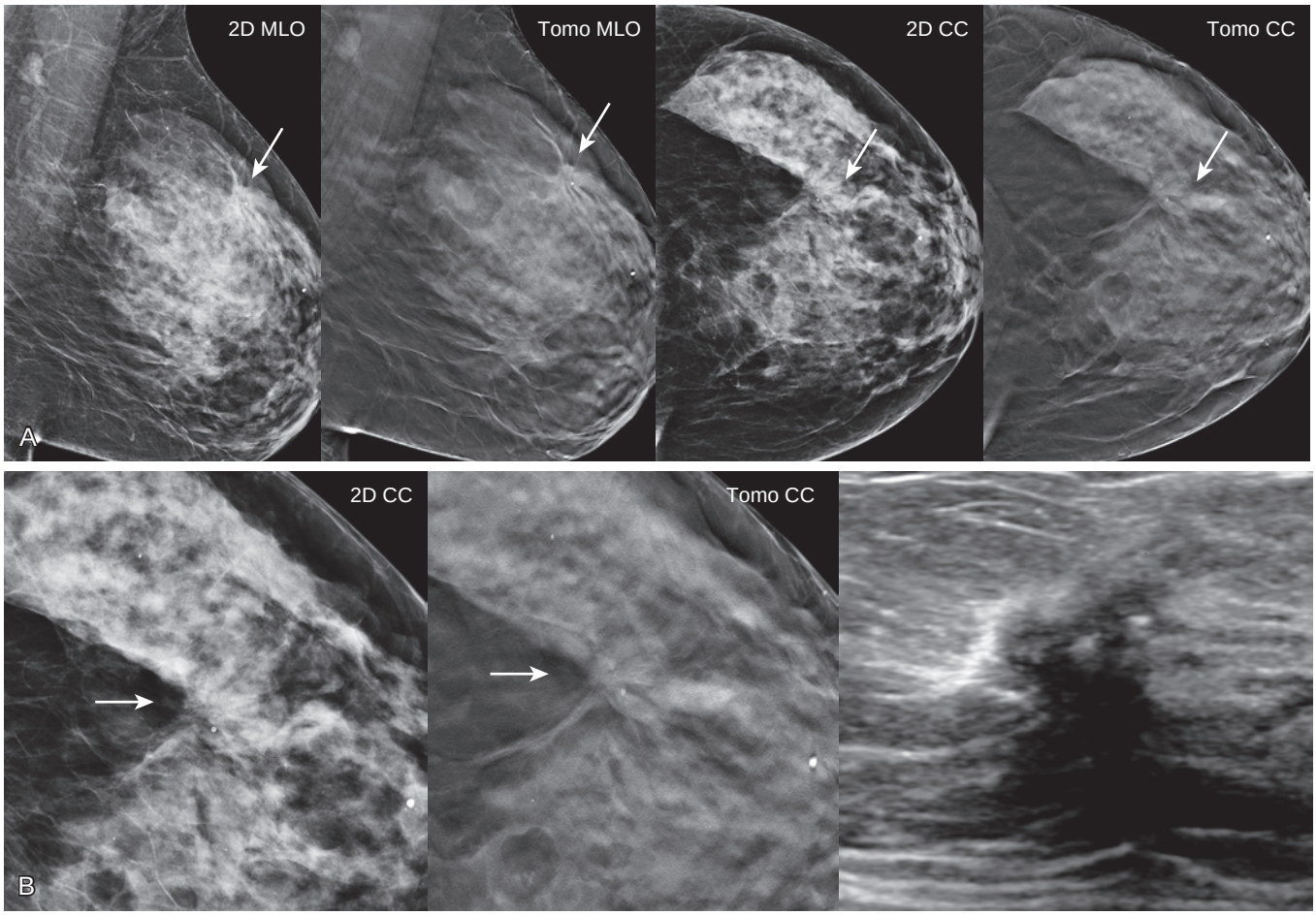


FIG. 10.9 Architectural distortion seen on 2D and tomosynthesis screening mammography. (A) Screening mammogram in a 50-year-old woman demonstrates an AD in the left upper outer breast *(arrows)*, better seen on tomosynthesis. **(B)** Close-up CC views show the AD with associated microCa^{++} *(arrows)* to be very obvious on tomosynthesis, and a diagnostic mammographic work-up was unnecessary. Targeted ultrasound revealed a corresponding heterogeneous predominately hypoechoic irregular mass with angular and indistinct margins, plus posterior acoustic shadowing. Ultrasound-guided core needle biopsy and surgical excision = IDC, grade 1 tubular subtype, ER/PR+, Her2–, 0/1 SLN.

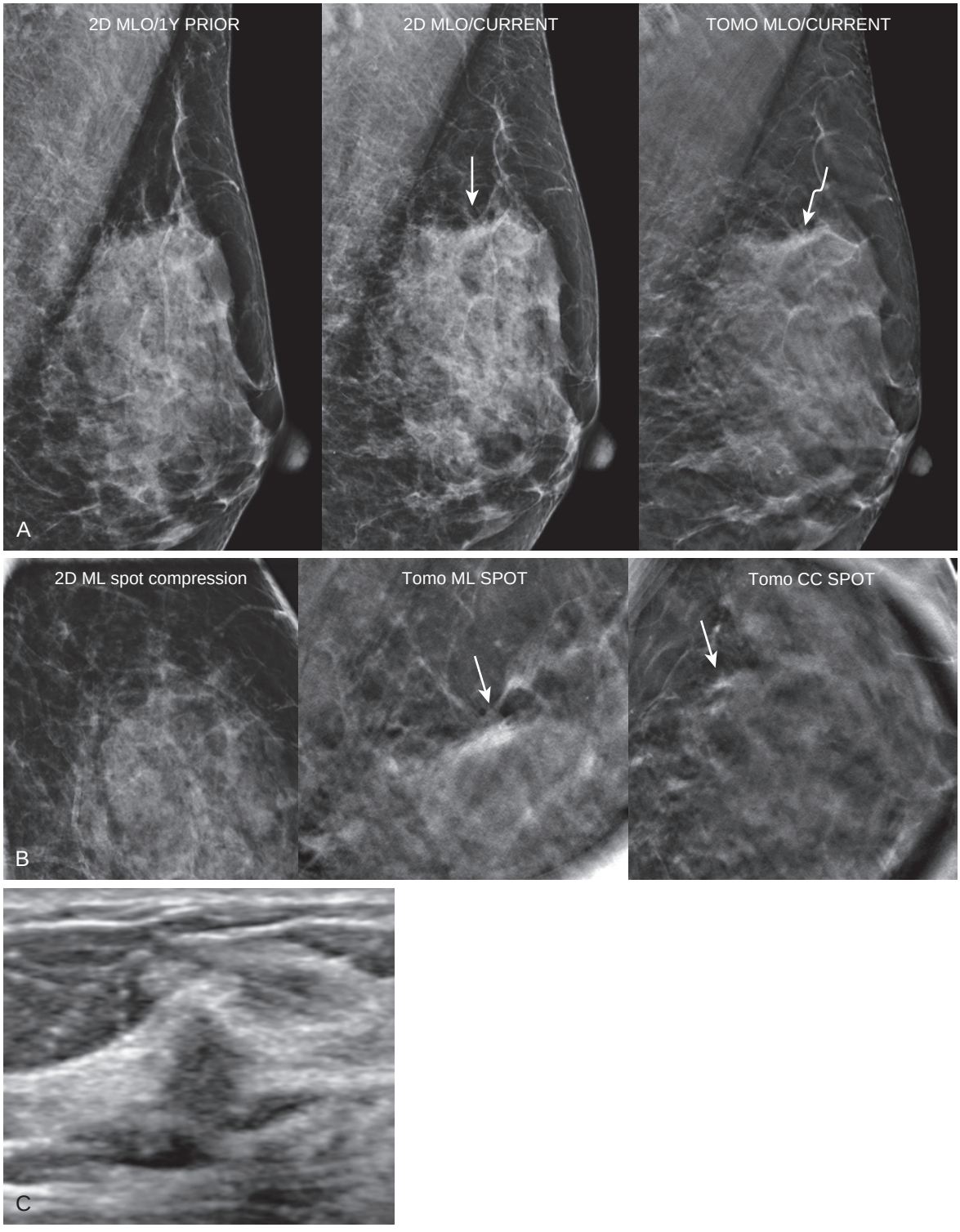


FIG. 10.10 Two-dimensional spot compression is inferior to tomosynthesis spot compression in evaluation of a "tomosynthesis only" architectural distortion. (A) Yearly diagnostic mammogram in a 54-year-old woman being followed for a probably benign finding in the right breast (not shown). A new subtle straightening of the superior fat parenchymal border on the left 2D MLO *(arrow)*. A corresponding subtle AD is seen on tomosynthesis *(curved arrow)*. **(B)** Because the AD was subtle even on the initial tomosynthesis views, spot compression views were obtained. The 2D spot compression view is not useful, as the AD was only initially seen on tomosynthesis. Tomosynthesis spot compression reveals a very subtle AD, really only seen on the ML (90-degree lateral) view and not well seen on the CC view (*arrows*). **(C)** Targeted ultrasound demonstrates a corresponding irregular isoechoic mass with indistinct borders and an anti-parallel orientation. Ultrasound guided core needle biopsy and excision = 1.5 cm IDC, grade 1 tubular subtype, ER/PR+. Her2–. Ki67 = 1%, 0/1SLN.

The Role of Ultrasound

Ultrasound (US) plays an important role in the work-up of suspected AD seen on tomosynthesis. In cases of obvious AD, the patients can proceed directly to ultrasound. Identification of a sonographic finding permits better characterization and can provide efficient biopsy guidance. If no suspicious sonographic lesion is found, then further work-up with mammography (tomosynthesis) may be performed (as detailed previously).

In malignant AD, US may reveal a hypoechoic irregularly shaped mass with indistinct, spiculated, and/or angular margins. For many radial scars and some malignant AD, the ultrasound findings may be that of a very subtle irregular isoechoic lesion, which may be identified only by slow and meticulous scanning over the region of concern. With high-resolution ultrasound transducers, tethered Cooper ligaments corresponding to spicules seen on mammography may be identified. If there is doubt that such a finding represents a true lesion that corresponds to the subtle tomographic finding, placing a BB marker over the lesion while performing the ultrasound exam and repeating the mammogram to determine if the lesions are the same can be very useful (Fig. 10.11). In addition, if biopsy is performed, deploying a biopsy marker and performing postbiopsy tomosynthesis mammograms is the best method to determine if the site of the AD has been accurately sampled.

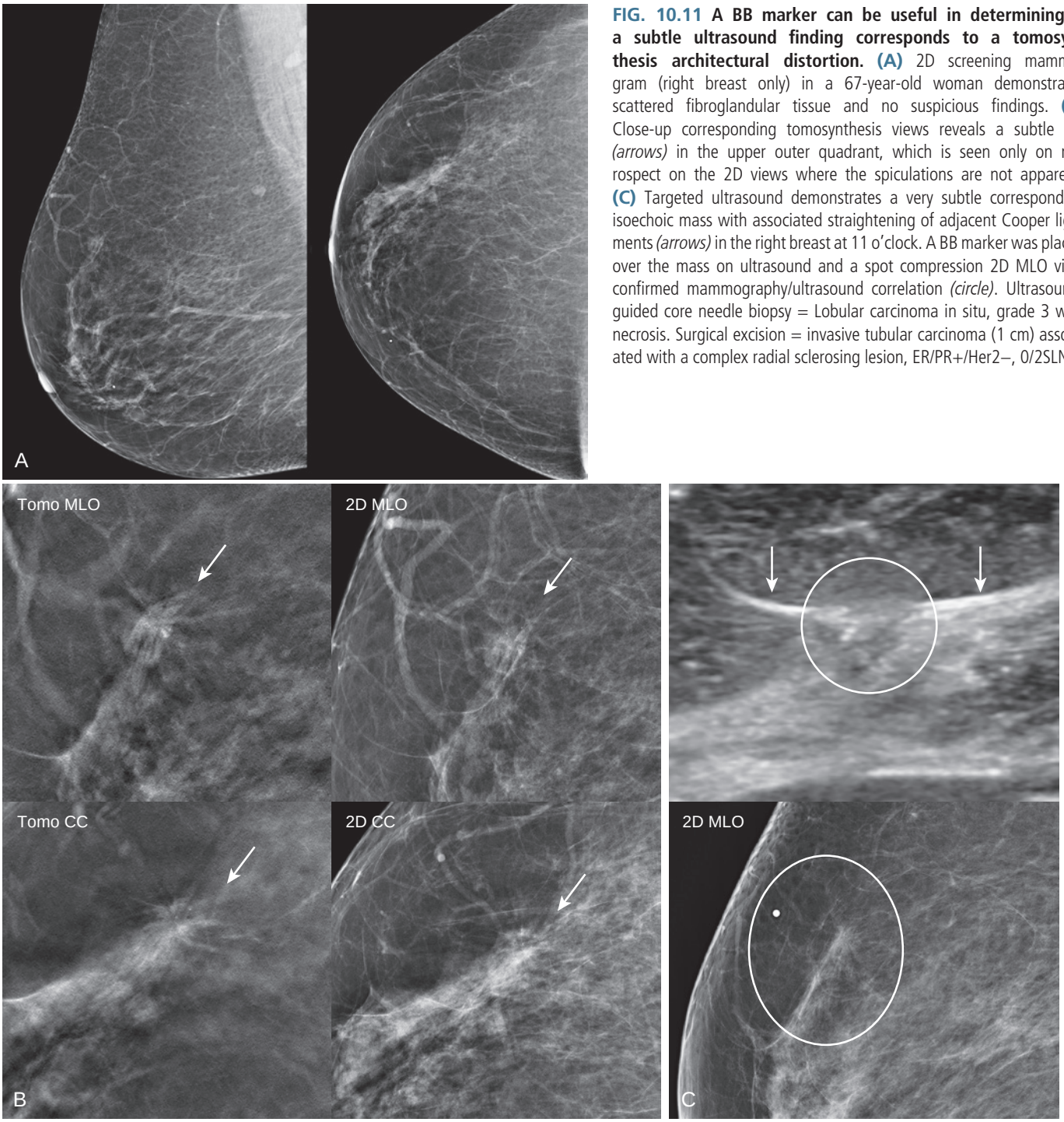


FIG. 10.11 A BB marker can be useful in determining if a subtle ultrasound finding corresponds to a tomosynthesis architectural distortion. (A) 2D screening mammogram (right breast only) in a 67-year-old woman demonstrates scattered fibroglandular tissue and no suspicious findings. **(B)** Close-up corresponding tomosynthesis views reveals a subtle AD *(arrows)* in the upper outer quadrant, which is seen only on retrospect on the 2D views where the spiculations are not apparent. **(C)** Targeted ultrasound demonstrates a very subtle corresponding isoechoic mass with associated straightening of adjacent Cooper ligaments *(arrows)* in the right breast at 11 o'clock. A BB marker was placed over the mass on ultrasound and a spot compression 2D MLO view confirmed mammography/ultrasound correlation *(circle)*. Ultrasound-guided core needle biopsy = Lobular carcinoma in situ, grade 3 with necrosis. Surgical excision = invasive tubular carcinoma (1 cm) associated with a complex radial sclerosing lesion, ER/PR+/Her2–, 0/2SLN.

The Role of Magnetic Resonance Imaging

If a suspicious AD is not identified on ultrasound, should an magentic resonance imaging (MRI) be performed? This decision is largely dependent on the individual radiologist because no standard proven protocol exists. A corresponding enhancing area identified on MRI will increase diagnostic confidence that a true lesion exists and can provide percutaneous biopsy guidance (Fig. 10.12). As with US, placement of a biopsy marker clip and performing a postbiopsy mammogram are essential to ensure that the lesion biopsied on MRI corresponds with the AD seen on tomosynthesis.

Performing a core needle biopsy (CNB) can be helpful if a diagnosis of cancer is made, but can be more problematic if pathology returns a radial sclerosing lesion, fibrosis, or benign breast tissue. The standard of care at many breast centers is to recommend surgical excision for radial sclerosing lesions, as the upgrade rate for malignancy of radial scars discovered on 2D mammography is 4% to 12%, but as previously stated, such management is evolving now that tomosynthesis detects many more of these lesions than 2D mammography alone.

If no corresponding lesion is seen using the MRI, biopsy of any suspicious AD may still be considered. The decision to

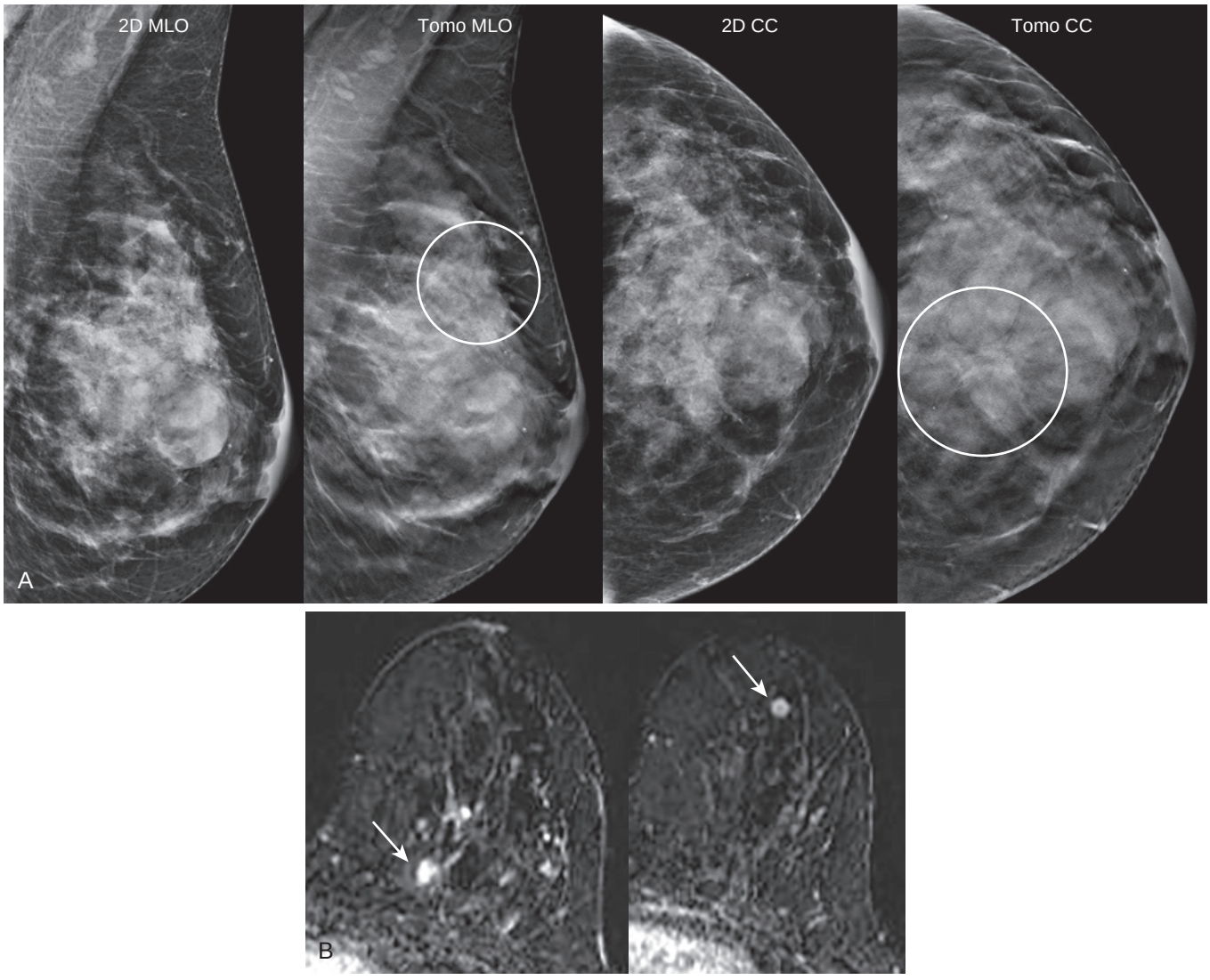


FIG. 10.12 Malignant architectural distortion confirmed with magnetic resonance imaging. (A) A 12-month follow-up bilateral diagnostic mammogram in a 52-year-old average risk woman being followed for probably benign calcifications in the right breast (not shown). Tomosynthesis reveals a subtle left AD best seen on the MLO view and thought to be in the upper breast *(circles)*. Targeted ultrasound was normal. Because the AD was large, a new MRI was recommended. **(B)** Axial fat-suppressed T1WC+ MRI revealed two suspicious enhancing lesions in the left breast *(arrows)*. The more posterior lesion was thought to possibly correspond with the mammographic finding. MRI-directed ultrasound was normal, and MR biopsy was performed. MRI-guided core needle biopsy posterior lesion = atypical lobular hyperplasia and a radial sclerosing lesion. MRI-guided core needle biopsy anterior lesion = classic LCIS and sclerosing adenosis. Surgical excision of both sites was performed, revealing the posterior lesion to be a radial sclerosing lesion and a 9 mm IDC, grade 1, ER/PR+, Her2−, 0/7 SLN. The anterior lesion proved to be benign.

biopsy a subtle but persistent AD seen only on tomosynthesis can be perplexing, particularly if the 2D mammogram suggests stability over many years in the region where tomosynthesis reveals the AD. The negative predictive value of MRI is high, and it is logical to believe that short-interval follow-up imaging may be an acceptable alternative to biopsy, because many of these lesions will represent benign radial sclerosing lesions, focal fibrosis, or even fibrocystic changes, although no scientific study has proven the efficacy of this approach. For this reason, some radiologists do not favor MRI in this setting, because a negative MRI does not always negate biopsy and because of the possibility that additional incidental benign lesions requiring additional work-up may be discovered.

Management of Architectural Distortion

A Breast Imaging Reporting and Data System (BI-RADS) 2 or 3 final assessment may be appropriate for selected cases of suspected AD seen on tomosynthesis. A history of remote benign breast biopsy may be elicited at the time of the diagnostic evaluation that was otherwise forgotten when the screening history intake form was obtained. If there is any uncertainty that the scar corresponds to the AD, a BB marker can be placed over the surgical scar on the skin, and tomosynthesis views can be obtained to ensure that the scar is in the near vicinity of the AD and a final BI-RADS 2 assessment can be made. Excluding AD due to scars, if very subtle AD does not persist on the diagnostic work-up, prior 2D images appear stable, and no corresponding lesion is seen on ultrasound, it would be reasonable that the patient may return to routine screening or 6-month short interval follow-ups at the discretion of the interpreting radiologist (Fig. 10.13).

If an AD is obvious on tomosynthesis and not related to postsurgical scarring, management is usually straightforward, as biopsy is necessary. If a corresponding lesion is seen on ultrasound, CNB can be performed. Clip placement and postbiopsy mammography should be also be obtained to confirm mammographic/ultrasound correlation.

If no corresponding lesion is seen on ultrasound, MRI can be considered in select cases, as previously discussed. If a corresponding lesion is seen, MRI-guided CNB can be performed. If there is no MRI correlate, biopsy could be considered with tomosynthesis-guided wire localization/surgical excision or tomosynthesis-guided CNB. Alternatively, tomosynthesis-guided biopsy can be performed without workup with MRI. Tomosynthesis-guided biopsy is reviewed in Chapter 14.

Finally, the management of radial scars detected on tomosynthesis is evolving. In a small cohort of 36 patients, Freer et al. demonstrated that 29% of radial scars presenting as AD seen only on tomosynthesis were associated with malignancy at surgical excisional biopsy and 52% of the radial scars were associated with high-risk lesions or malignancy. These findings

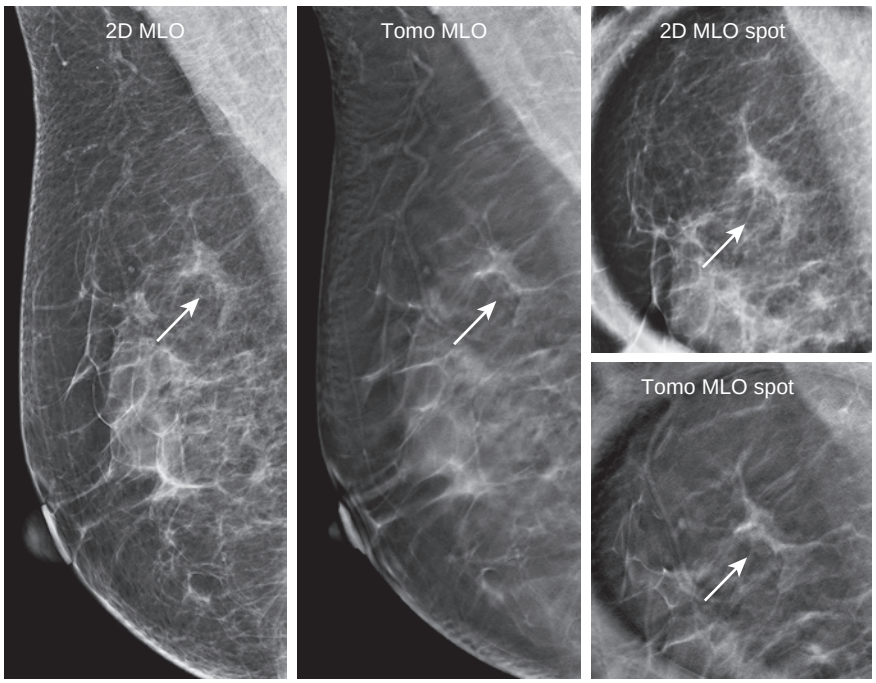
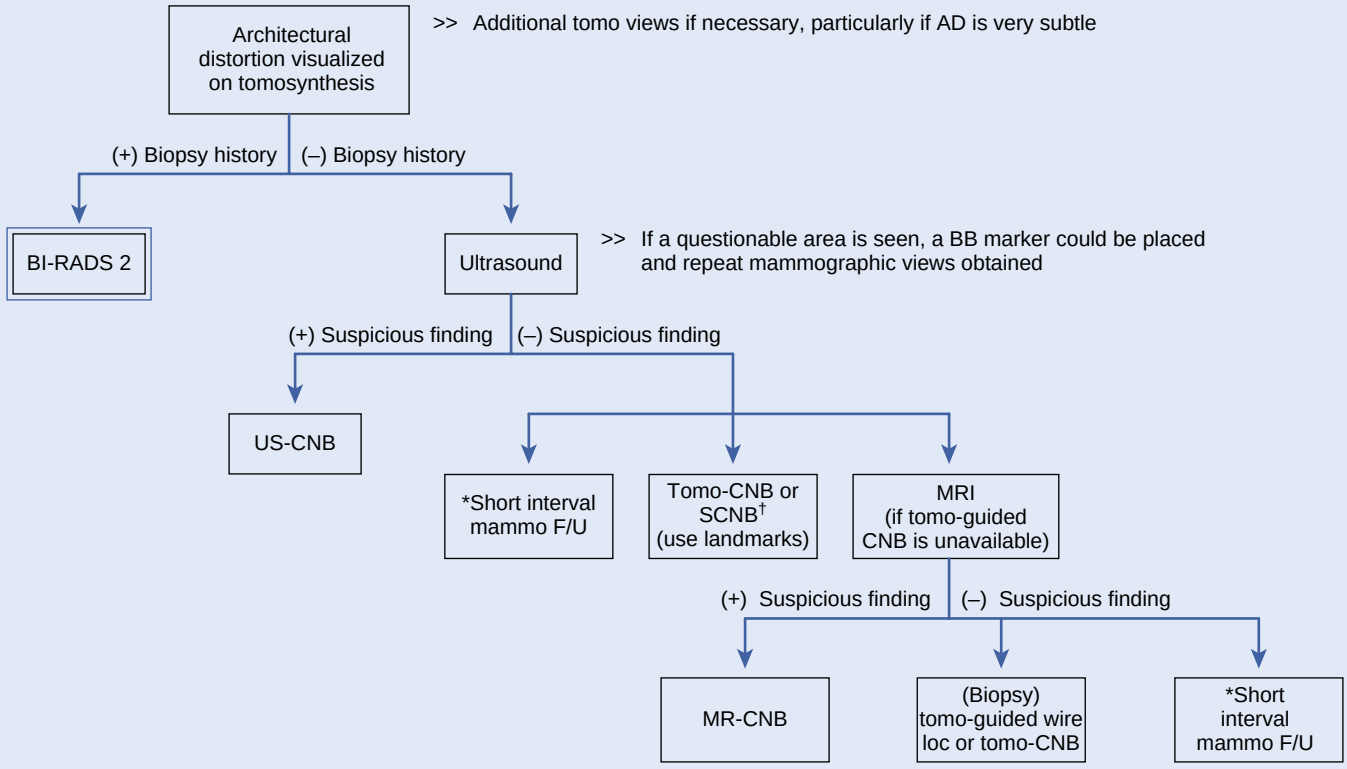


FIG. 10.13 Benign irregular asymmetry mimicking an architectural distortion on screening mammography with tomosynthesis. Baseline screening mammogram in a 43-year-old woman reveals an asymmetry possibly due to an AD *(arrows)* in the right upper breast, seen only on the MLO view. Spot compression views show that the asymmetry persists, but there are no definite fine spicules to suggest a true AD. Targeted ultrasound was normal, and this finding was assessed as BI-RADS 3, likely due to overlapping tissue, and was stable on mammographic follow-up. In this case, combination spot compression views were useful to exclude the presence of true spicules associated with a possible AD. The mammographic finding was seen only on the MLO view, and there were no comparison films, so the irregular asymmetry was likely benign.

suggest that excision of all radial scars found at tomosynthesis could be considered. Other authors propose that perhaps average-risk women with a diagnosis of a radial scar without associated atypia on CNB for an AD seen only on tomosynthesis and not found on ultrasound or MRI may be followed and not surgically excised. Certainly additional research is needed to establish a standard protocol for evaluation and management of AD seen only on tomosynthesis.

TOMO TIP ★ Proposed algorithm for management of tomosynthesis detected AD.



*The utility of short-interval F/U of tomo only AD has yet to be established.
†Stereotactic core needle biopsy (SCNB) can be performed for some lesions seen only on tomosynthesis if there are nearby landmarks (eg, benign calcification, lymph node, cysts).

Management algorithm for tomosynthesis-detected architectural distortion (AD). *BI-RADS,* Breast Imaging Reporting and Data System; *CNB,* core needle biopsy; *F/U,* follow-up; *loc,* needle localization; *mammo,* mammography; *MRI,* magnetic resonance imaging; *tomo,* tomosynthesis.

Potential Pitfalls/Complications

Tomosynthesis can depict intralesional fat very well, as it removes superimposed fibroglandular tissue not in the plane of focus. As a result, AD may appear as a low-density lesion that can be easily overlooked by the radiologist, due to either inexperience or distraction (Fig. 10.14). It is important to recognize this feature, as some AD detected on tomosynthesis will be less dense compared to the same region on the 2D images.

TOMO TIP ★ Intralesion fat is well seen on tomosynthesis. Cancers can entrap fat, and therefore a low-density, fat-containing AD may be malignant.

Because some malignant AD can be very subtle on tomosynthesis, there may be high interobserver variability among radiologists' agreement in identifying and recalling AD on screening mammography. Moreover, not only can it be difficult to differentiate a subtle AD from overlapping dense fibroglandular tissue, but there may be also reader variability in the terminology used to describe such lesions. For example, a subtle AD may be described as a spiculated mass or focal asymmetry by one reader or an AD by another (Fig. 10.15). Fortunately, despite such differences in terminology, in either case, management is usually the same.

With any new technology, cancer detection rates are higher on the first screening round and usually decrease on subsequent screening exams, as seen previously with mammography and MRI. Numerous early studies showing the benefit of

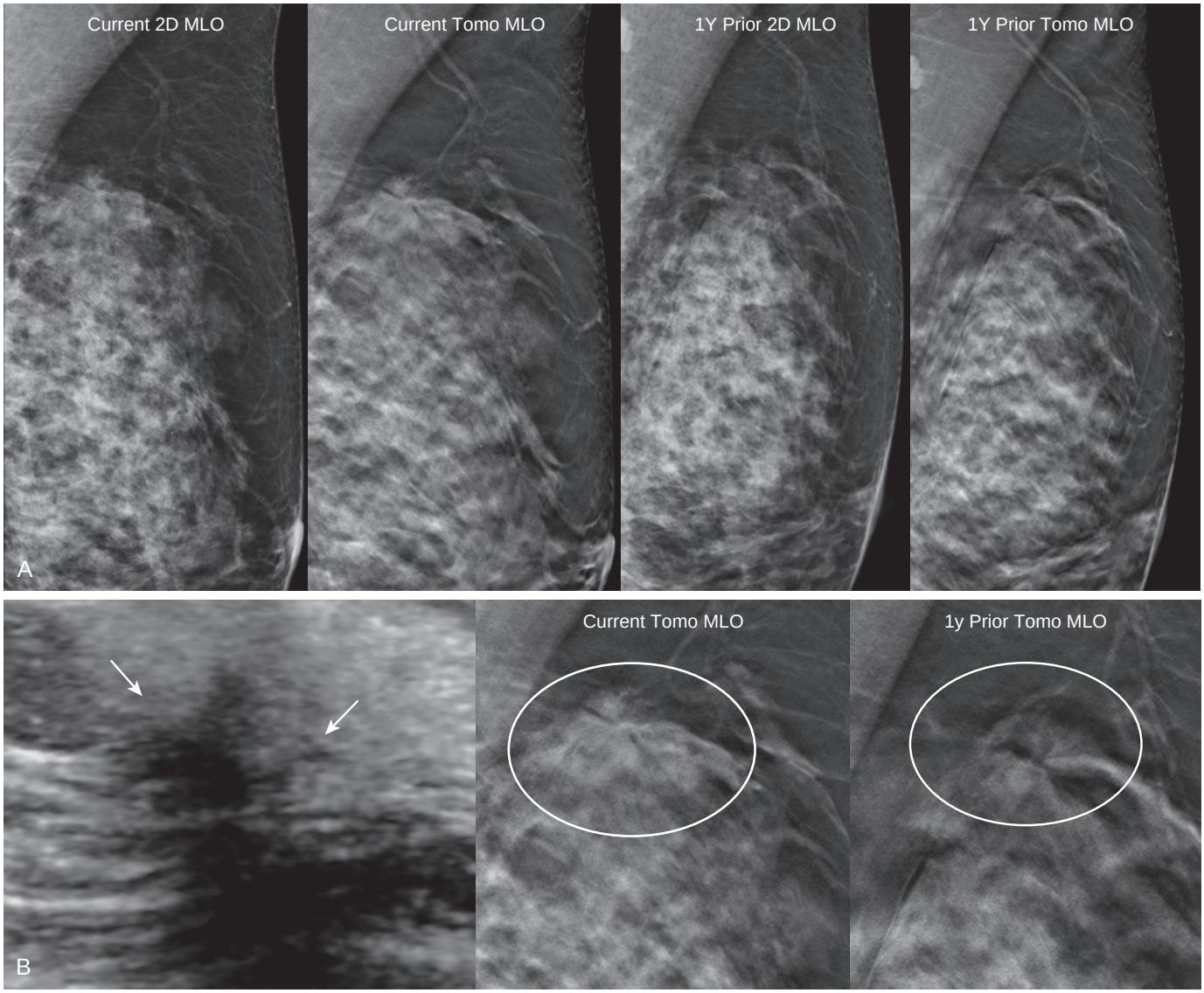


FIG. 10.14 False negative tomosynthesis screening mammogram. (A) Screening mammogram in a 46-year-old woman reveals extremely dense breast tissue and was interpreted as BI-RADS 1. **(B)** Four months later, the patient had a screening ultrasound exam that revealed an irregular 1-cm hypoechoic mass with indistinct border *(circles)*. In retrospect, a corresponding AD is seen in the left upper breast that was present on the prior mammogram *(circles)*. Ultrasound-guided core needle biopsy and excision = 1.2 cm IDC, grade 2, ER/PR+, Her2–, Ki67 = 10%, 0//1 SLN. The architectural distortion was originally missed on screening, likely due to interpretation error.

tomosynthesis in regard to increased cancer detection report only the initial/prevalence screening exam. While early studies show that more ADs are detected on tomosynthesis, the overall detection rate may be inflated. Moreover, some cases of subtle malignant AD—especially those cases where the 2D mammogram is stable for many years but the lesion is obvious on tomosynthesis—may be due to low-grade DCIS and invasive well-differentiated tubular cancers, possibly representing very indolent lesions that may never harm the patient even if left untreated. The initial elevated cancer detection rate and potential cases of overdiagnosis/overtreatment may decrease on subsequent incidence screening rounds. A new AD detected on subsequent tomosynthesis screening may more likely be malignant because it is a new finding. As a result, on incidence screening rounds, the PPV for AD could potentially increase beyond 40% to 50%, although more studies are needed.

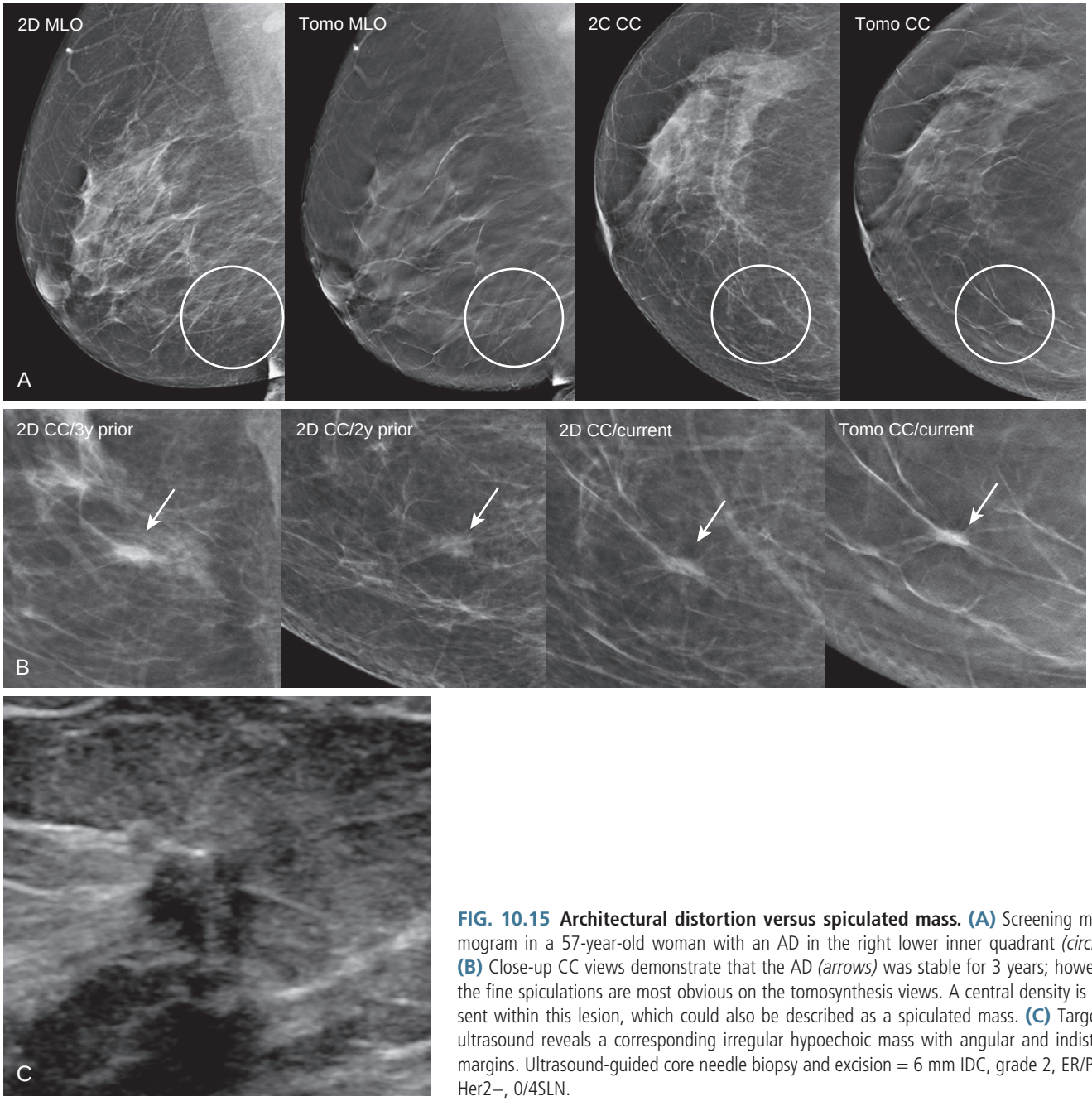


FIG. 10.15 Architectural distortion versus spiculated mass. (A) Screening mammogram in a 57-year-old woman with an AD in the right lower inner quadrant *(circles)*. **(B)** Close-up CC views demonstrate that the AD *(arrows)* was stable for 3 years; however, the fine spiculations are most obvious on the tomosynthesis views. A central density is present within this lesion, which could also be described as a spiculated mass. **(C)** Targeted ultrasound reveals a corresponding irregular hypoechoic mass with angular and indistinct margins. Ultrasound-guided core needle biopsy and excision = 6 mm IDC, grade 2, ER/PR+, Her2−, 0/4SLN.

Conclusion

Tomosynthesis will make subtle AD more conspicuous and will reveal AD that would otherwise be occult on 2D mammography alone. While the sensitivity of both invasive and in situ cancer presenting as AD will increase, more radial sclerosing lesions will also be diagnosed. Because the PPV for biopsy of AD seen on tomosynthesis is high, the increase in the diagnosis of radial sclerosing lesions and other benign findings is outweighed by the increase in cancer detection compared to 2D mammography alone. Surgical history is essential. An old biopsy scar not apparent for many years on 2D images may be more obvious and potentially worrisome on tomosynthesis because it is perceived as new. If no prior correlative surgical history is found, biopsy should be considered for most AD detected only on tomosynthesis. Future research is needed to validate various management protocols and better define the role of MRI and imaging surveillance instead of surgical excision, following benign CNB of AD detected on tomosynthesis.

CHAPTER 11

Integrating Tomosynthesis With Multimodality Imaging

Liva Andrejeva | Jaime Geisel | Liane E. Philpotts

Tomosynthesis has revolutionized the practice of mammography. Beyond the reduction of false-positive recalls and increased cancer detection in screening, tomosynthesis can also improve the diagnostic workflow. Work-ups are abbreviated and expedited because fewer additional images are required to fully characterize lesion morphology and location, thus permitting many women to avoid additional mammographic imaging and proceed directly to ultrasound. At another level the combination of tomosynthesis information along with findings on ultrasound and/or magnetic resonance imaging (MRI) can yield a far better diagnostic assessment compared with the diagnostic accuracy achieved using conventional two-dimensional (2D) mammography alone. The combined information from these imaging tests allows the breast imager to increase both sensitivity and specificity of interpretation. The improved diagnostic assessment provided by tomosynthesis also means that fewer patients will have findings that are classified as probably benign, decreasing the amount of imaging follow-up required. The positive predictive value (PPV) for biopsy recommendations can also be increased. Careful assessment of tomosynthesis images and incorporation of information from other modalities can provide women with a more accurate breast imaging diagnosis.

Assessment of Tomosynthesis Findings

The first step in using tomosynthesis properly relies on careful assessment of the tomosynthesis images. One must thoroughly evaluate the tomosynthesis findings, both in terms of morphology and location, before considering use of other modalities. As discussed previously, this involves careful scrolling through images in the standard projections and localizing findings to a specific region of the breast. Beyond what can be achieved with 2D mammography, when findings are questionable on a tomosynthesis projection, one can more precisely hone in on the corresponding area in another projection to determine how true a finding is. Upon careful review, most real lesions can be seen in both standard projections, although sometimes they are more apparent on one view compared with the other. The craniocaudal (CC) view is generally the most useful projection because findings are often more difficult to perceive on the mediolateral oblique (MLO) view, particularly if there is dense tissue in the upper-outer quadrant.

If a potentially worrisome finding is detected, one should ask if it is new or stable. Review of prior studies, even if 2D only, can often yield information as to whether a lesion has likely been present previously or not. Spot tomosynthesis views can sometimes be useful to further assess very subtle or one-view-only findings. If a subtle finding is again reproduced on spot view(s), the degree of suspicion that a true finding exists is heightened. Conversely, if a "soft" finding is not reproduced, further imaging may not be necessary. However, as with 2D mammography, beware of spotting away potentially significant findings, such as architectural distortion. With careful assessment of the standard CC and MLO tomosynthesis images, the level of suspicion of the finding is often already well established before any additional imaging is performed. The principal value of additional imaging is to determine management and facilitate biopsy, if necessary.

Targeted Ultrasound to Assess Tomosynthesis Findings

Targeted ultrasound is the primary modality used for secondary assessment of tomosynthesis findings, both for its negative predictive value (ie, a normal ultrasound helps to establish a questionable tomosynthesis finding as likely normal) and PPV (a correlative characteristically benign or suspicious sonographic finding helps to direct management and determine final Breast Imaging Reporting and Data System [BI-RADS] assessment). However, correlating tomosynthesis and ultrasound imaging can sometimes present challenges.

Distance from the nipple in centimeters on ultrasound is often different from what is measured on mammography and therefore not completely reliable in correlating with tomosynthesis images. Partly this is due to differences in measuring algorithms, measuring directly from the nipple to the lesion within the breast (mammography) versus to the overlying skin surface (ultrasound). In addition, in mammographic imaging the breast is pulled out and compressed, often yielding a total distance from nipple to chest wall in centimeters much greater than in the natural state. In the supine or posterior-oblique position used for ultrasound scanning, in which the breast tissue flattens out against the chest wall, the total distance may be a fraction of what it is on mammography. Knowledge of the approximate clock face and location of the lesion in the anterior, middle, or posterior breast is useful for honing in on the area for targeted scanning. Landmarks, such as cysts, large calcifications, or lymph nodes, in the vicinity may aid in detection of a subtle sonographic finding. It is important to carefully correlate the size and morphology of the lesion on mammography and ultrasound and avoid satisfaction of search. When using ultrasound to search for a spiculated mass detected on tomosynthesis, do not be satisfied when encountering a benign-appearing cyst.

In cases in which detection and correlation of imaging findings are performed, the radiologist should always scan the patient and not rely solely on the technologists' findings. This is essential to be confident that lesion location and appearance are concordant.

If a sonographic finding is identified in the expected location of a subtle tomosynthesis lesion, use of a skin marker, such as a BB, placed on the skin directly overlying the ultrasound findings with subsequent full or spot tomosynthesis images, can be very helpful to correlate findings between modalities. This provides a more confident determination as to whether the sonographic and tomosynthesis findings match and facilitates determination of the degree of suspicion. Such spot views can be performed in any projection. Spot views in the projection in which the finding was originally best seen are preferred in terms of optimally demonstrating correlation of the findings. Tangential views may be preferable for more superficial lesions but are not always necessary for deeper lesions. For deeper lesions, one must be cognizant that the BB is placed on the closest skin surface during ultrasound scanning when the patient is supine or in the semioblique position and that the breast is compressed against the pectoralis muscle by the ultrasound transducer. Therefore the lesion may appear farther away than expected on mammography, depending on the depth of the finding, size of the breast, and mammographic positioning. The BB should be used only as an approximate guide to assess whether the sonographic finding is in the general vicinity of the tomosynthesis finding.

In challenging tomosynthesis cases, such as an architectural distortion due to radial scars or invasive lobular carcinomas, subtle sonographic findings may be expected (Fig. 11.1). Lesions may be correctly identified on rigorous targeted ultrasound scanning that might otherwise have been overlooked. In some cases these subtle lesions do not always present with the common obvious sonographic findings. They may be seen as vague hypoechoic or isoechoic areas, possibly appearing smaller relative to tomosynthesis, because spiculations are not as obvious on ultrasound. Meticulous scanning can often further define a lesion as either real or not, as well as fine-tune the level of suspicion.

If a sonographic correlate is not initially identified for a convincing suspicious tomosynthesis finding, the backward BB method can be used. In this process an open window (needle localization) paddle is used in the projection at the closest skin surface, and a tomosynthesis spot image is obtained. The finding can be identified, and a mark can be made on the overlying skin. Targeted ultrasound can then be performed with more precise localization and may permit identification of otherwise overlooked subtle sonographic findings (Fig. 11.2).

If a sonographic correlate is established, then the next step is to determine whether or not the combination of findings is suspicious. If both tomosynthesis and ultrasound indicate a benign finding, then the patient can usually return to routine screening. This minimizes costs and patient anxiety that may be associated with a recommendation for short-interval diagnostic imaging follow-up. If there is uncertainty about correlation of imaging findings or if either tomosynthesis or ultrasound findings are not definitive, then such cases may be appropriately classified as probably benign with a recommendation for short-term imaging follow-up. Not unexpectedly, the percentage of BI-RADS 3 recommendations may decrease over time because of the improved diagnostic information provided by tomosynthesis and high-quality ultrasound, which together often permit a more accurate classification of lesions as benign, probably benign, or suspicious. This is a major benefit of tomosynthesis that stems from the careful use of the technology and meticulous hands-on ultrasound scanning.

If the tomosynthesis and/or ultrasound findings are suspicious, then biopsy will be indicated. Core needle biopsy is most easily performed using sonographic guidance. Following ultrasound-guided core needle biopsy, a marker clip should be placed and a post-biopsy mammogram should be obtained to provide the direct proof of sonographic and tomosynthesis correlation (Fig. 11.3). If the marker is found not to reside at the tomosynthesis finding or if no sonographic correlate was originally found, stereotactic biopsy under tomosynthesis guidance (if available) would be indicated. Otherwise, additional imaging with MRI would be appropriate. If MRI is performed and is negative in the region in question, mammographic follow-up would likely be reasonable. If MRI shows a suspicious correlative finding, then biopsy could be performed under MR- or tomosynthesis-guided biopsy, if available.

Numerous studies demonstrate that tomosynthesis reduces screening recalls; however, there are some instances where benign breast findings are accentuated on tomosynthesis. These cases may be infrequent but are important because they can present a challenge for both the novice and seasoned breast imager. Such cases include a phenomenon observed in tomosynthesis that could be termed *pseudo-architectural distortion*. Pseudo-architectural distortion can result from clumped fibroglandular tissue with crossing vascular and trabecular structures and, unlike most true architectural distortions produced by malignancies or complex sclerosing lesions, is usually perceived in only one tomosynthesis view. Some women with heterogeneously dense tissue will have areas mimicking a true architectural distortion.

With tomosynthesis, the perception of architectural distortion is heightened, potentially leading to false-positive recalls and additional diagnostic work-ups. In these cases spot tomosynthesis views may be performed in the projection in which the finding was originally identified. If the finding is not reproduced, it was likely summation artifact. Examination of the surrounding architecture of the tissue is crucial to ensure the lesion in question has indeed been included within the area covered by the compression paddle. Combined 2D and tomosynthesis spot views are usually preferred in this setting because this allows better evaluation of surrounding tissue landmarks to ensure the proper region was captured by the compression paddle. Frequently, spot compression views will result in effacement of the pseudodistortion. In patients with dense tissue, ultrasound of the region in question may still be warranted for complete assessment because some subtle malignant distortions can efface even on tomosynthesis spot compression views. Negative sonographic findings can lead to two different management scenarios. If completely normal tissue is noted in the region on ultrasound, it can increase confidence that the questioned tomosynthesis finding was not real. In such cases routine or short-interval follow-up can be recommended. However, if the tomosynthesis findings are concerning, then tomosynthesis-guided biopsy or further imaging with MRI may be indicated (Fig. 11.4).

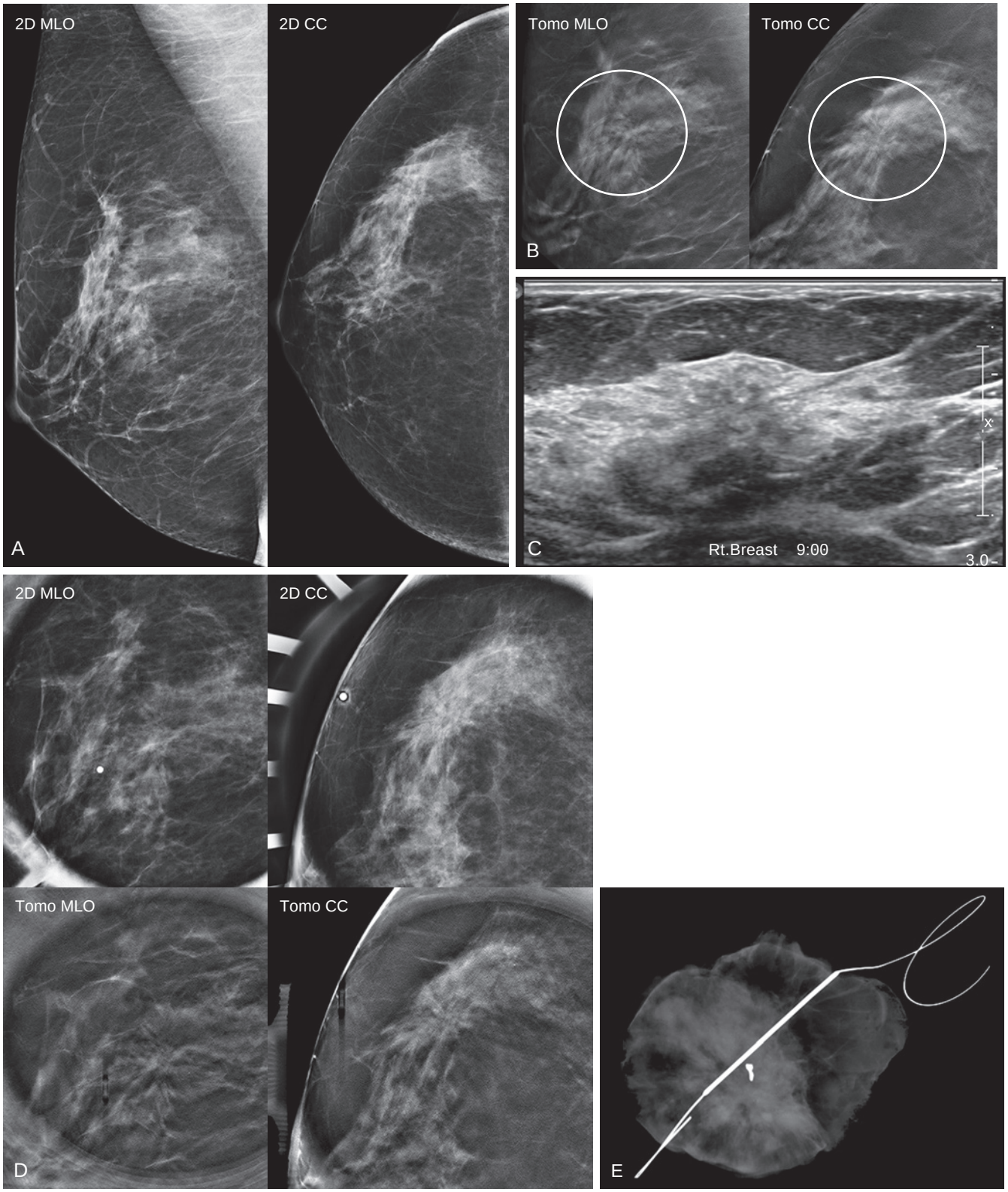


FIG. 11.1 (A) Screening mammogram in a 47-year-old woman shows architectural distortion in the upper-outer right breast best seen on the **(B)** tomosynthesis views *(circles)*. **(C)** Ultrasound reveals a subtle mixed echogenicity lesion with distortion of the architecture. **(D)** A BB was placed on the skin overlying the sonographic finding, and tomosynthesis spot views were repeated, proving the sonographic finding corresponded to the mammographic finding. Ultrasound core needle biopsy revealed a complex sclerosing lesion. **(E)** Final excision revealed a complex sclerosing papillary lesion.

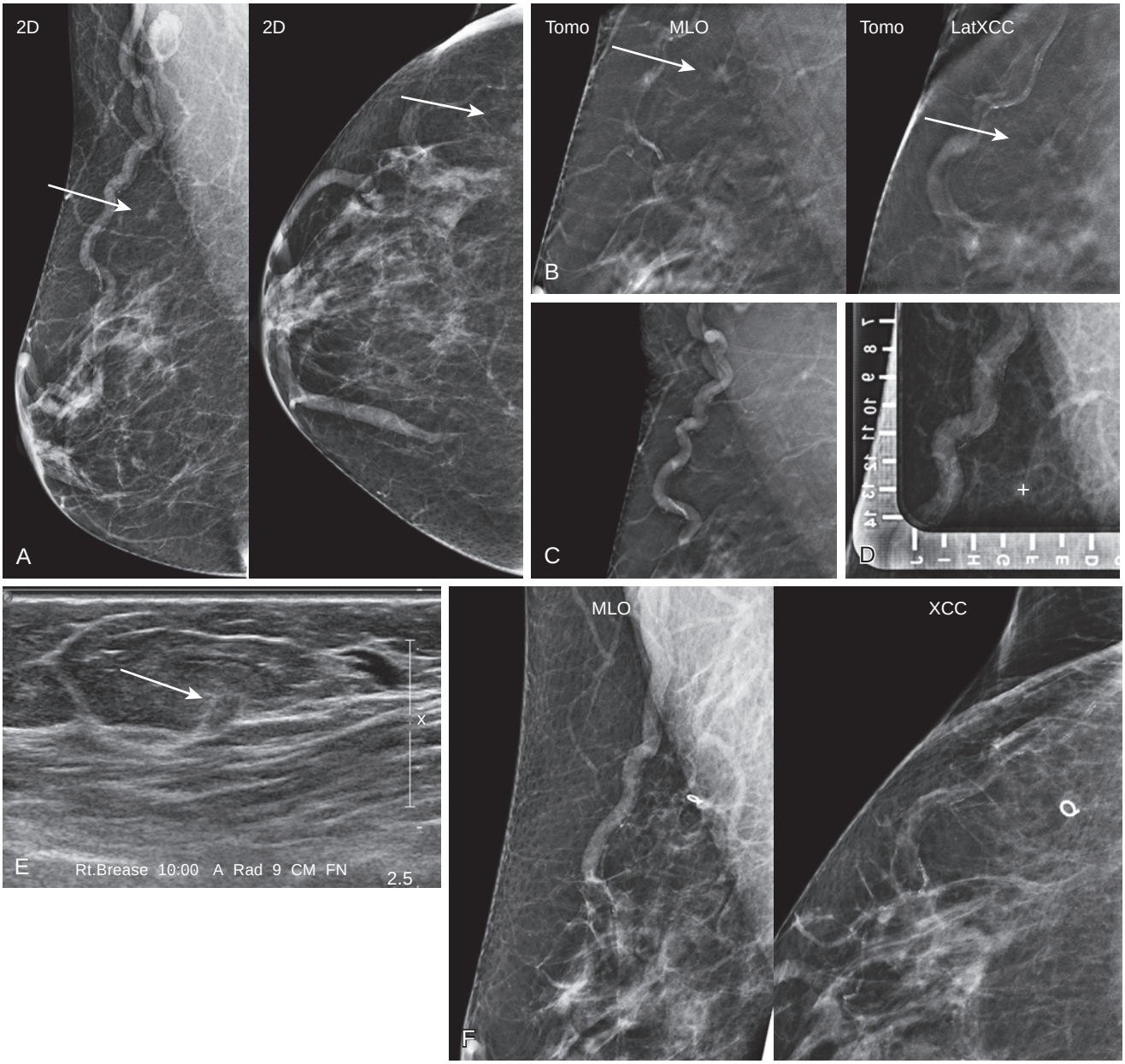


FIG. 11.2 (A) A small mass *(arrows)* was noted on a screening exam in a 66-year-old woman. **(B)** The tomosynthesis images in MLO and laterally exaggerated CC views show spiculated margins not apparent on 2D imaging. No ultrasound correlate could be found. Stereotactic biopsy was attempted at another facility, but the area could not be successfully targeted. **(C)** The patient returned to our facility 4 months later, when the lesion was again noted, but again no sonographic correlate could be initially identified. **(D)** A spot tomosynthesis image was obtained with the open window paddle against the lateral breast, and the alphanumeric area (F-13) was identified and marked with a permanent marker on the skin. **(E)** The patient was then taken back to ultrasound, where a very subtle isoechoic sonographic finding was successfully identified. **(F)** Post–ultrasound-guided biopsy shows the lesion to be mostly removed and the biopsy marker in the expected location. Pathology on core biopsy and surgical excision revealed well-differentiated invasive ductal carcinoma. ER+/PR+/Her2−.

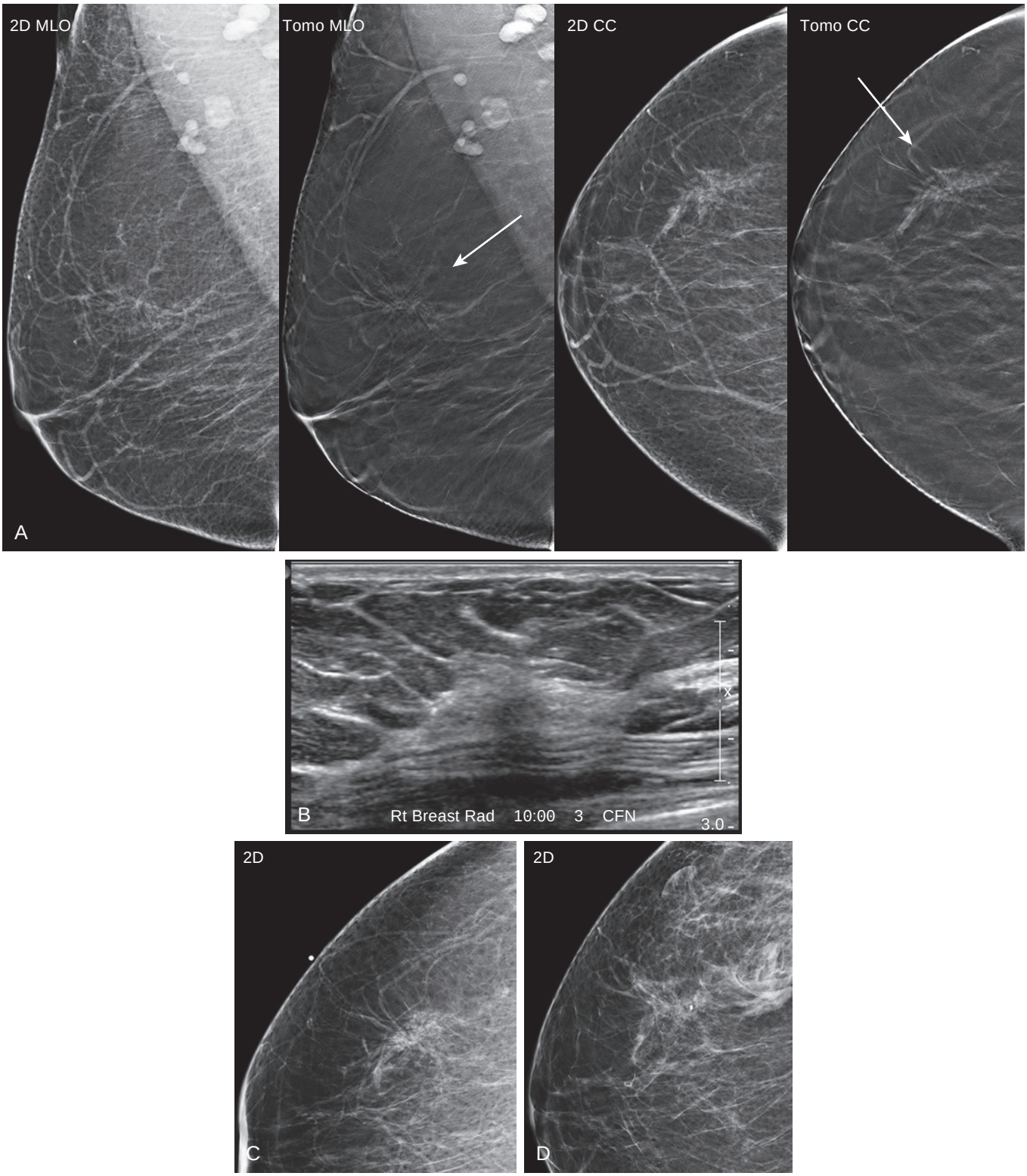


FIG. 11.3 (A) A 50-year-old woman presented for screening mammography, which revealed architectural distortion in the upper-outer aspect of the right breast, best seen on the tomosynthesis slice images *(arrows)*. **(B)** Targeted ultrasound reveals an ill-defined mixed echogenicity lesion in the upper-outer quadrant. **(C and D)** A BB was placed on the skin overlying the lesion, and mammographic views were repeated, which demonstrate the sonographic finding correlated with the mammographic finding. Ultrasound-guided biopsy demonstrated a complex sclerosing lesion and atypical ductal hyperplasia, confirmed with surgical excision.

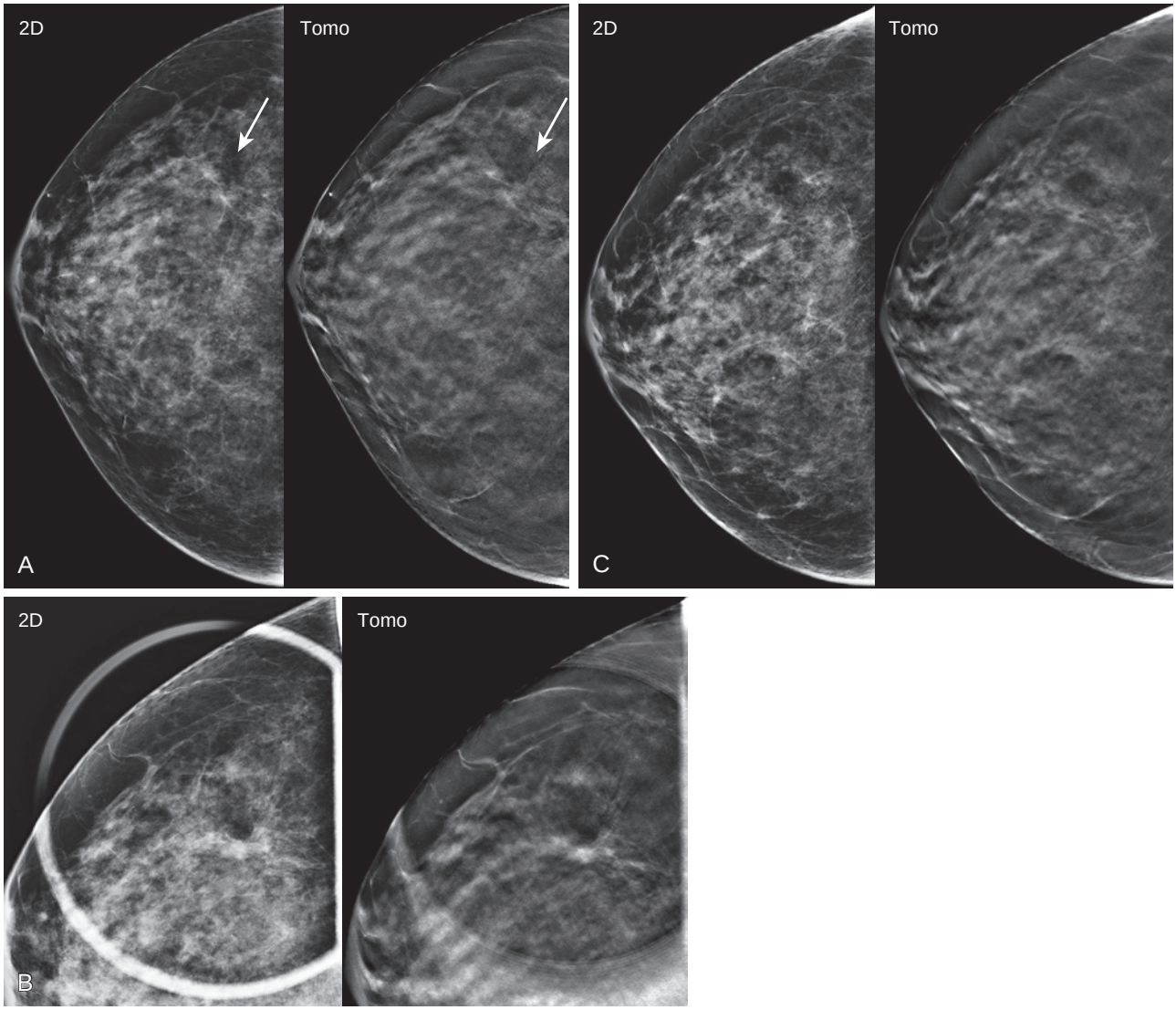


FIG. 11.4 (A) A 63-year-old woman with a history of left breast cancer presents for annual diagnostic surveillance mammography. An area of architectural distortion *(arrows)* was detected in the lateral aspect of the right breast, seen on the craniocaudal view only. **(B)** This finding persisted on tomosynthesis spot compression views. Ultrasound revealed no abnormalities in the lateral aspect of the breast. Given the patient's history and the persistence of architectural distortion, magnetic resonance imaging was performed, which showed no suspicious findings. Breast Imaging Reporting and Data System (BI-RADS) 3, short-interval follow-up was recommended. **(C)** A 6-month follow-up right mammogram revealed the architectural distortion to no longer be reproduced. BI-RADS 2.

Tomosynthesis and Evaluation of Extent of Disease

Tomosynthesis better estimates the size of malignant lesions, as well as detects additional sites of disease obscured on 2D mammography. This is particularly true of small lesions and lesions in heterogeneous and extremely dense tissue. Even in nondense tissue, additional cancers may be detected (Fig. 11.5). If a malignant lesion has been diagnosed, the rest of the remaining breast tissue and the contralateral breast should be carefully examined. Additional lesions may be detected, and targeted ultrasound and biopsies may be performed that may have a significant effect on management, potentially precluding the need for MRI and all the additional costs and associated procedures.

Contrast-Enhanced Breast Magnetic Resonance Imaging to Assess Tomosynthesis Findings

In instances in which tomosynthesis findings remain concerning despite negative sonographic findings, a problem-solving breast MRI may be warranted as a possible way to further characterize the finding or guide biopsy. As with correlation of sonography, it is important to recognize that positioning of the breasts in MRI is different than it is in mammography because the patient lies prone in the breast coil. It is important to have isotropic sagittal, axial, and coronal reconstructions for correlation, and the mammogram should obviously be available for direct comparison during the interpretation of the MRI.

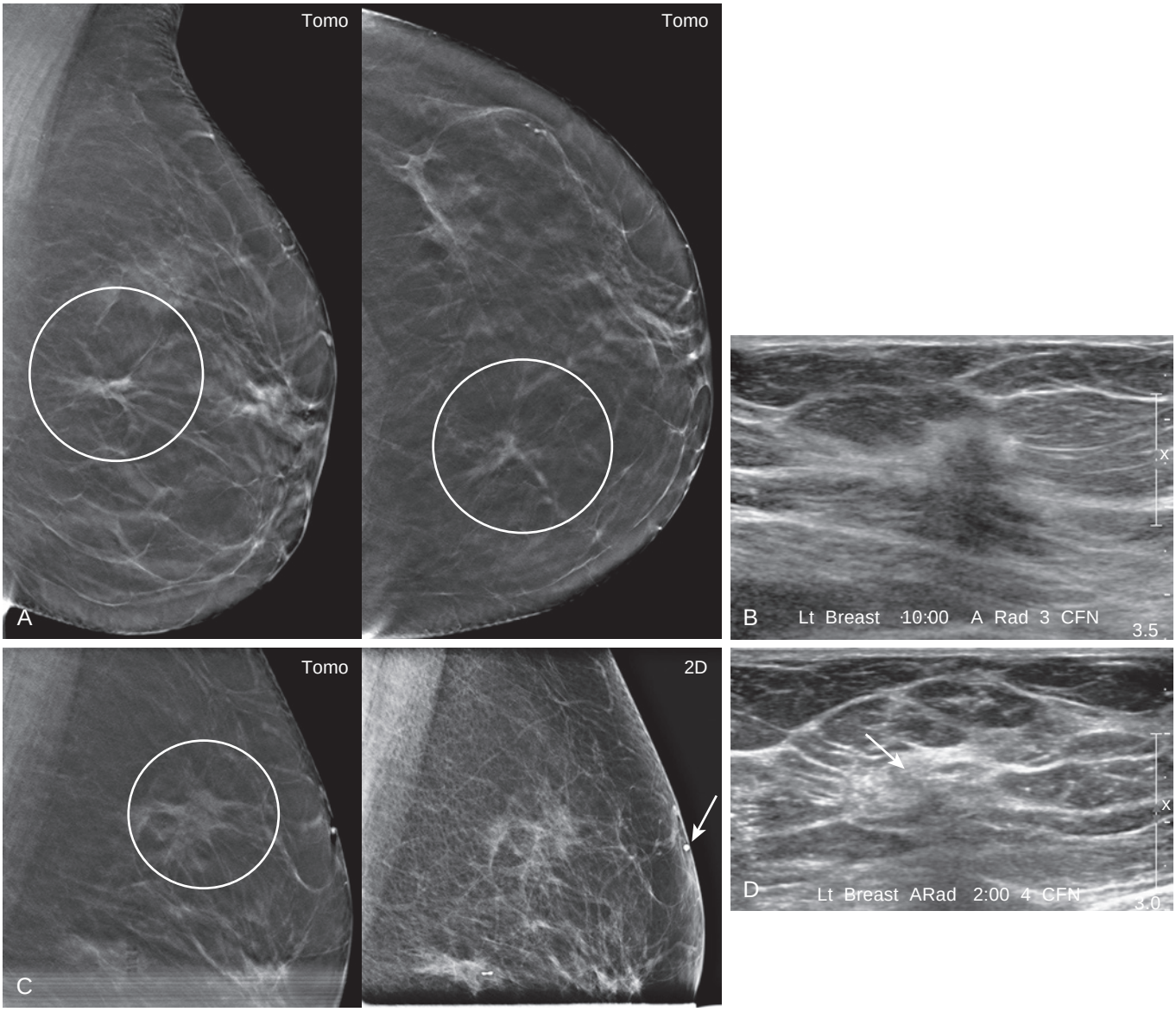


FIG. 11.5 (A) A 64-year-old woman presented at another institution for screening mammography, which demonstrates architectural distortion *(circles)* in the upper-inner quadrant of the left breast, seen best on tomosynthesis views. **(B)** Targeted ultrasound reveals an 0.8-cm, irregular, hypoechoic mass with an echogenic rim in the 10-o'clock position, correlating with the mammographic findings. **(C)** On further review of the case prior to surgery a second architectural distortion *(circle)* was noted in the upper-outer aspect of the breast. **(D)** Targeted ultrasound of this area reveals a subtle, hypoechoic lesion at the 2-o'clock position, shown by BB *(arrow)* to correlate with the second lesion. Biopsy of both areas showed invasive lobular carcinoma. The patient underwent mastectomy, which showed 6.3 cm of disease, ER+/PR+/Her–, spanning both the upper-outer and upper-inner quadrants.

The precontrast, T1-weighted, non–fat-suppressed series, which are standard sequences performed as part of all breast MRI examinations, may allow for correlation of the tissue architecture with its mammographic presentation. True architectural distortion can at times be perceived on these T1-weighted images. If the architectural distortion is identified on the T1 precontrast images as corresponding to the finding initially identified on the tomosynthesis study, then enhancement in the region should be viewed with more suspicion. If no architectural distortion is identified and no suspicious enhancement is present on the post-contrast images, one can be quite reassured that malignancy is unlikely. In such cases short-term (6 months) mammographic follow-up could be performed to assess the stability of the mammographic finding. Conversely, if a suspicious MRI correlate is found, then MR- or tomosynthesis-guided (if available) biopsy should be performed for diagnosis.

Second-Look Tomosynthesis for Ultrasound or Magnetic Resonance Imaging Findings

Although tomosynthesis increases cancer detection rates compared with 2D mammography, not all cancers are initially detected with tomosynthesis, particularly in women with dense breast tissue. Some patients still remain whose breast cancer is detected by ultrasound or MRI after a normal tomosynthesis. Supplemental screening with ultrasound or MRI is now more

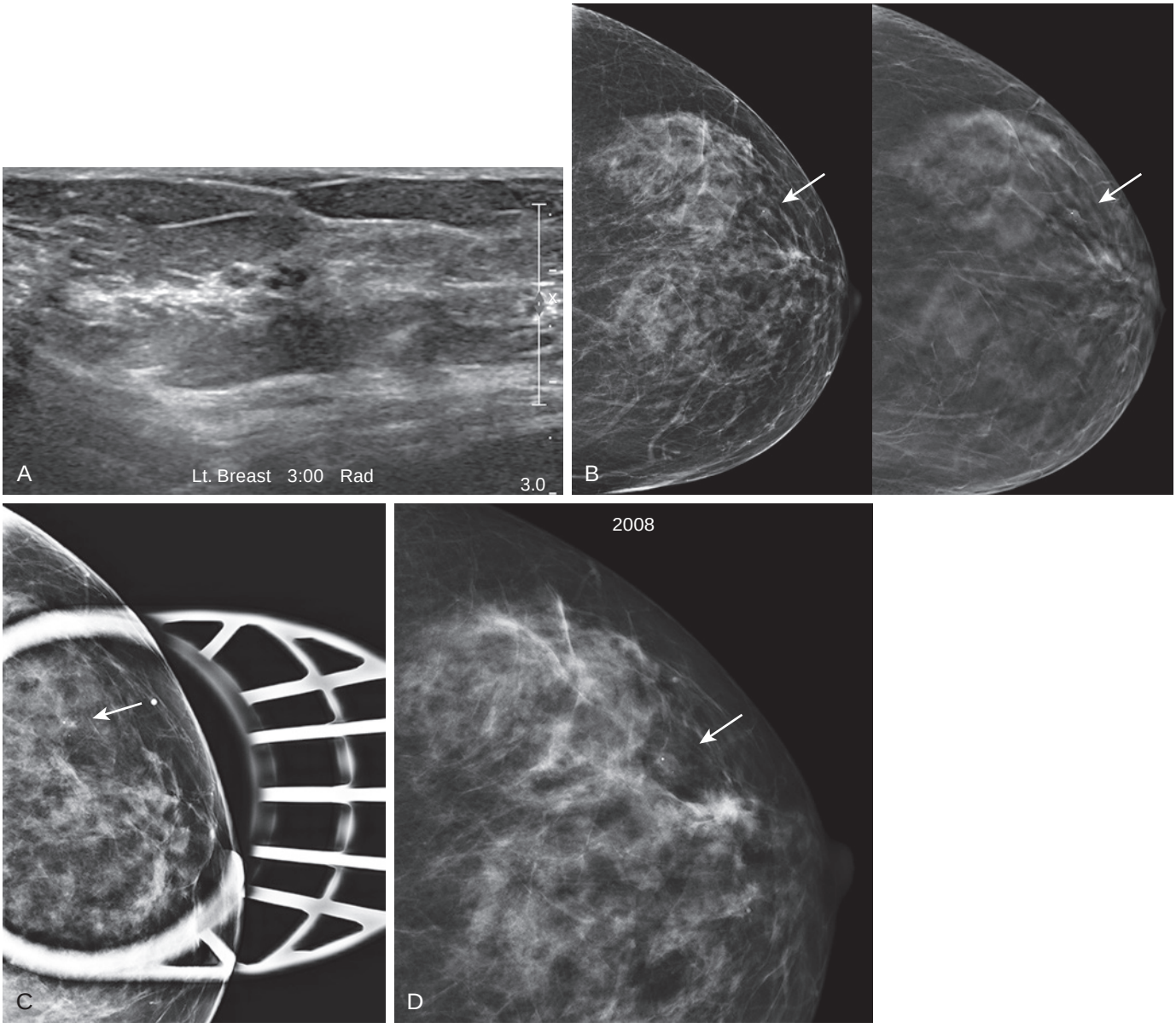


FIG. 11.6 (A) Screening ultrasound in a 63-year-old woman with heterogeneously dense breasts reveals a small lobulated mass in the left 3-o'clock position. **(B)** Review of a recent mammogram (reported as normal and stable) shows a small mass in the lateral breast *(arrow)* seen well on the tomosynthesis image, with an associated calcification. **(C)** A BB was placed on the skin over the sonographic finding, and a spot tomosynthesis view was obtained. **(D)** The finding was noted to correspond to the stable mass, not as obvious on two-dimensional imaging but seen to be present on multiple mammograms dating back to at least 2008.

widely used. These studies are known to generate false-positive findings. False positives lead to follow-up imaging and additional biopsies, adding to health care costs and increased anxiety for some women. Reducing false-positive ultrasound and MRI findings should be a major goal, and correlation with tomosynthesis mammography can help to achieve this.

Correlating Ultrasound Findings With Tomosynthesis

Screening ultrasound can be performed with automated equipment or by handheld transducer, usually by technologists. Despite the mechanism in which it is performed, positive findings will require targeted scanning and correlation with mammography. Many findings will be benign, particularly on baseline ultrasound screens. The majority of screening ultrasound-detected cancers are equal to or less than 1 cm in size and tend to be well-to-moderately well differentiated or invasive ductal or lobular carcinomas. The main goal of supplemental screening is to detect invasive cancers that are mammographically occult.

Similar to 2D mammography, careful correlation of tomosynthesis images is encouraged to further assess and refine the level of suspicion of ultrasound findings. Many findings can be established to be negative or benign, thus reducing the need for follow-up imaging and biopsy. For example, many small hypoechoic areas or small oval masses are encountered

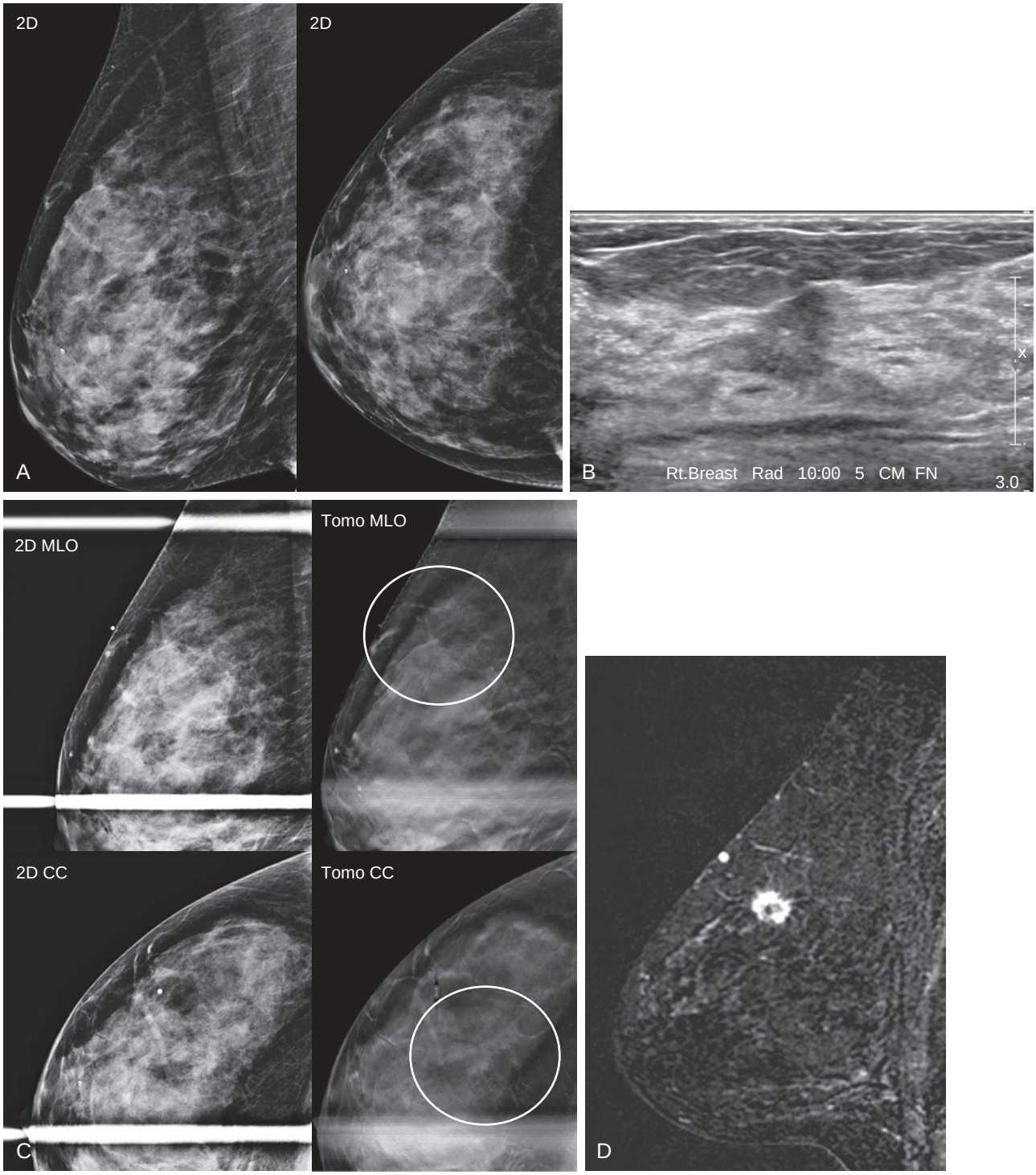


FIG. 11.7 (A) A screening mammogram in a 49-year-old woman with extremely dense tissue was interpreted as normal. **(B)** Screening ultrasound shows an irregular, hypoechoic mass with spiculated margins in the 10-o'clock region of the right breast. **(C)** A BB was placed over the lesion, and tomosynthesis spot views demonstrate the spiculated architectural distortion *(circled)* previously undetected. Ultrasound biopsy revealed grade 2 infiltrating ductal carcinoma with ductal carcinoma in situ, ER+/PR+/Her2–. **(D)** Staging preoperative sagittal, T1-weighted, post-contrast subtraction image from preoperative magnetic resonance shows the spiculated mass to be the only suspicious lesion.

frequently on screening ultrasound and are benign. Review of the corresponding area on tomosynthesis images may render the ultrasound finding less concerning (Fig. 11.6). If the tomosynthesis images reveal no underlying suspicious findings and only normal tissue, the finding may be an artifact and therefore less suspicious, or tomosynthesis may reveal a stable benign correlate. In contrast, subtle suspicious findings may be identified on tomosynthesis in retrospect that had been unrecognized (Fig. 11.7). "Synthesizing" the information from these modalities will result in greatly improved overall specificity.

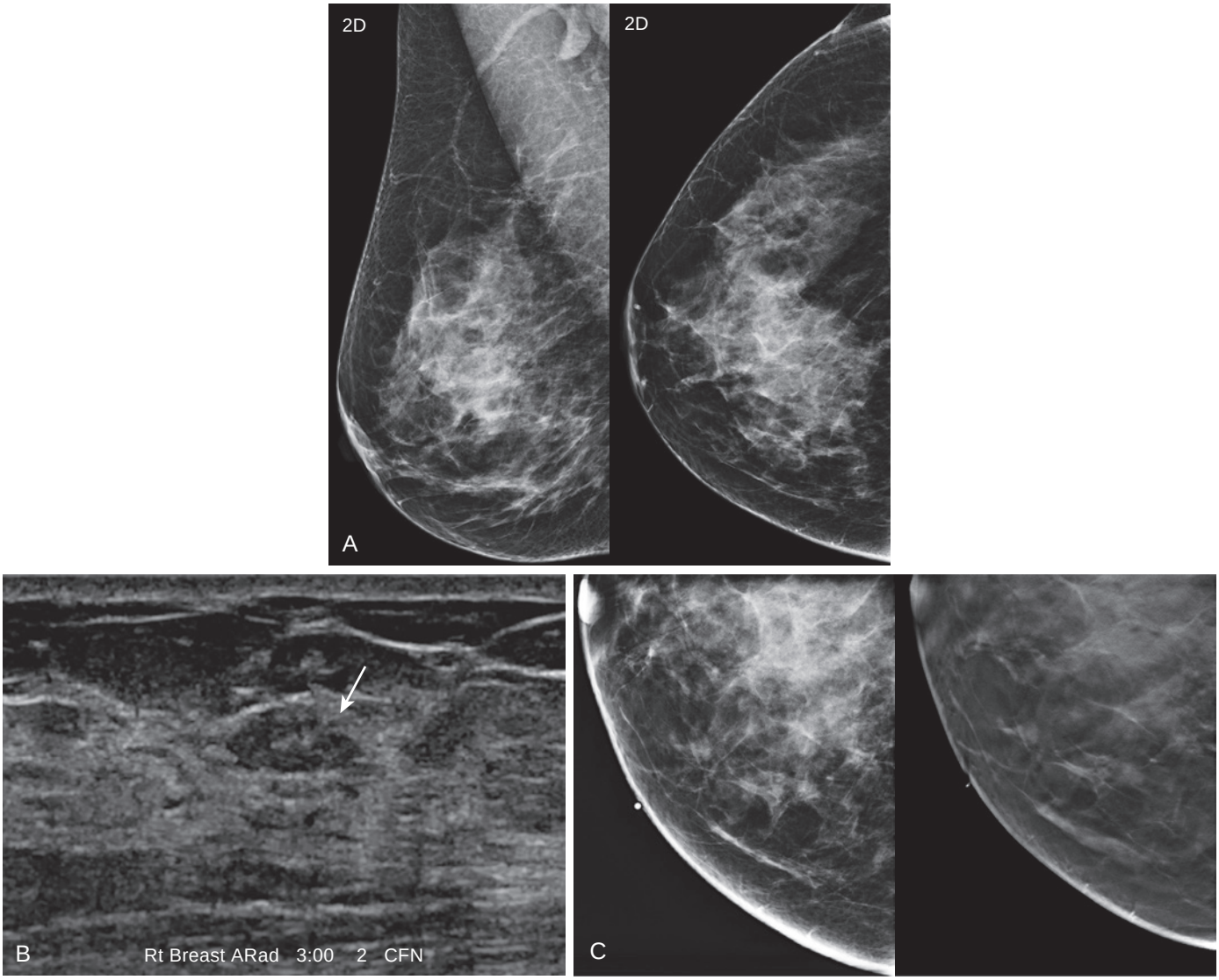


FIG. 11.8 (A) A 30-year-old woman with a history of mantle radiation for non-Hodgkin's lymphoma 5 years earlier presented for screening. Tomosynthesis mammography shows dense tissue but no focal abnormality. **(B)** Screening ultrasound demonstrates a wider-than-tall, hypoechoic, 1-cm mass in the right breast at the 3-o'clock position *(arrow)*. **(C)** A BB was placed on the skin over the sonographic abnormality, and a tomosynthesis spot view was obtained, which shows no definite abnormality. Due to her high-risk status, a biopsy was desired and revealed benign stromal fibrosis. A short-term follow-up would have also been appropriate.

TOMO TIP ★ Even if a mammogram was initially read as negative, a *second-look* tomosynthesis can be useful to detect and characterize ultrasound or MRI findings.

Fibrosis is a sonographically detected benign lesion found on screening ultrasound and for which biopsy is sometimes recommended. Fibrosis can be encountered anywhere in the breast, although the upper-outer quadrants are most common. It is often encountered in younger women, who are also more likely to have dense breast tissue, and can have a varied and sometimes suspicious sonographic appearance, mimicking malignancy due to its irregular shape, indistinct margins, and posterior acoustic shadowing. Though fibrosis may be symmetric and scanning the corresponding region in the opposite breast will frequently yield similar findings, asymmetric fibrosis can be encountered and pose a diagnostic dilemma. Fibrosis frequently has the appearance of normal fibroglandular tissue on tomosynthesis (Fig. 11.8). The technique of BB confirmation can be useful to determine if an underlying mammographic finding is present. If no suspicious asymmetry or architectural distortion is seen, short-term follow-up of the sonographic findings could be considered.

Some patients, particularly young women with palpable or other symptomatic findings, may undergo ultrasound as a first imaging test before mammographic imaging. This is often appropriate and sufficient for diagnosis. However, occasionally patients present with palpable findings for which ultrasound is not conclusive. Tomosynthesis may depict abnormalities that might be subtle, such as lipomas, in which the thin capsule can be seen surrounding the fatty lesion. Some sonographic findings can be complex or indeterminate, and tomosynthesis can aid in establishing a more confident assessment. For example, fat necrosis, due to its extremely variable tomographic and sonographic appearance, can present a challenge to the breast imager. Early-stage fat necrosis, especially when

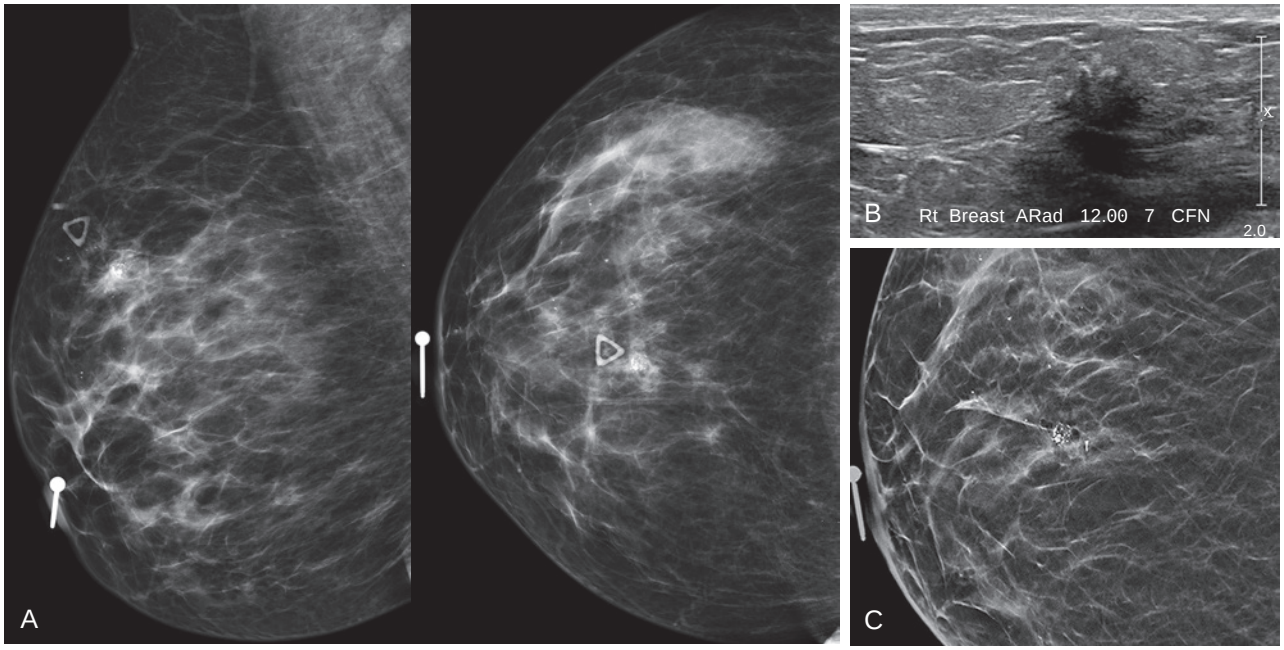


FIG. 11.9 (A) A 41-year-old woman presented to an outside facility with a palpable hard mass in an area of prior skin piercing (ornament since removed). Two-dimensional mammographic views demonstrate a focal asymmetry with an indistinct margin containing heterogeneous clustered calcifications. **(B)** A targeted ultrasound reveals an irregular hypoechoic mass with dense posterior acoustic shadowing and internal echogenic foci. The lesion was described as highly suggestive of malignancy, and an ultrasound-guided biopsy was performed revealing fat necrosis. **(C)** Tomosynthesis views performed at our institution showed biopsy clip in a fat-containing lesion with peripheral distribution of "egg-shell" calcifications, consistent with fat necrosis, and thus biopsy was not necessary.

due to trauma, can appear as ovoid hyperechoic lesions with an indistinct margin within superficial fat lobules. At a slightly later stage, areas of hypoechogenicity may develop within the echogenic lesions, producing the appearance of an indistinct hypoechoic lesion with an echogenic rim. Heterogeneous calcifications may eventually develop within these lesions that produce a hypoechoic, posteriorly shadowing structure on ultrasound. The sonographic appearance of fat necrosis can simulate a malignant lesion. Mammographic imaging can often simply resolve the findings as fat necrosis and preclude the need for follow-up or biopsy (Fig. 11.9). In addition to trauma, fat necrosis is frequently seen as a sequelae of surgery, and in these cases it must be differentiated from a breast cancer recurrence. Again, tomosynthesis will help to differentiate palpable, benign, fat-containing lesions from solid suspicious masses in postoperative patients.

Correlating Magnetic Resonance Findings With Tomosynthesis

MRI is often performed for screening high-risk women and to better assess the extent of disease in women with newly diagnosed breast cancers. Many high-risk patients choose annual screening breast MRI. Current screening guidelines are based on multiple studies comparing mammography, ultrasound, and MRI, which have consistently shown that MRI is the most sensitive test to detect early breast cancer (Fig. 11.10). However, it is important to recognize that those studies were performed with 2D mammography, not tomosynthesis. Because tomosynthesis is known to detect more cancers than 2D mammography alone, it is possible that some of the cancers found by MRI might now be detected with tomosynthesis. Mass lesions detected on screening MRI are more likely to have a multimodality correlate as compared with nonmass enhancement. However, even ductal carcinoma in situ (DCIS) can be detected by tomosynthesis or ultrasound, and every attempt should be made to try to detect worrisome MR findings with these modalities (Fig. 11.11).

The use of preoperative MRI is controversial, but many women still opt to have this test. In addition to demonstrating the extent of the primary index cancer, MRI detects additional ipsilateral and contralateral cancers that are occult on mammography. As with high-risk screening, these studies have involved 2D mammography, and it is possible that at least some of these additional sites of disease will likely be identifiable with tomosynthesis. Satellite lesions, lymph node disease, and even pectoralis involvement may all be better assessed on tomosynthesis than 2D images (Fig. 11.12). Reduction of false positives in MRI, as in screening ultrasound, is an important objective in both high-risk screening and newly diagnosed cancer populations. Particularly because MR-guided biopsy is more involved and expensive than ultrasound or mammographically guided procedures, finding a sonographic or tomosynthesis correlate is greatly beneficial.

For the work-up of suspicious MRI-detected abnormalities, careful review of any recent mammographic or sonographic studies is necessary. The benefit of second-look ultrasound has been established. However, second-look tomosynthesis can similarly prove very useful. If more than 6 months have passed since the patient's last mammogram, tomosynthesis is warranted to search for any corresponding abnormality. If a correlative finding is seen on either of these two modalities—tomosynthesis or sonography—biopsy is facilitated in lieu of MR-guided biopsy.

When MRI-detected lesions are identified and biopsied with other modalities, it is always important to assess the

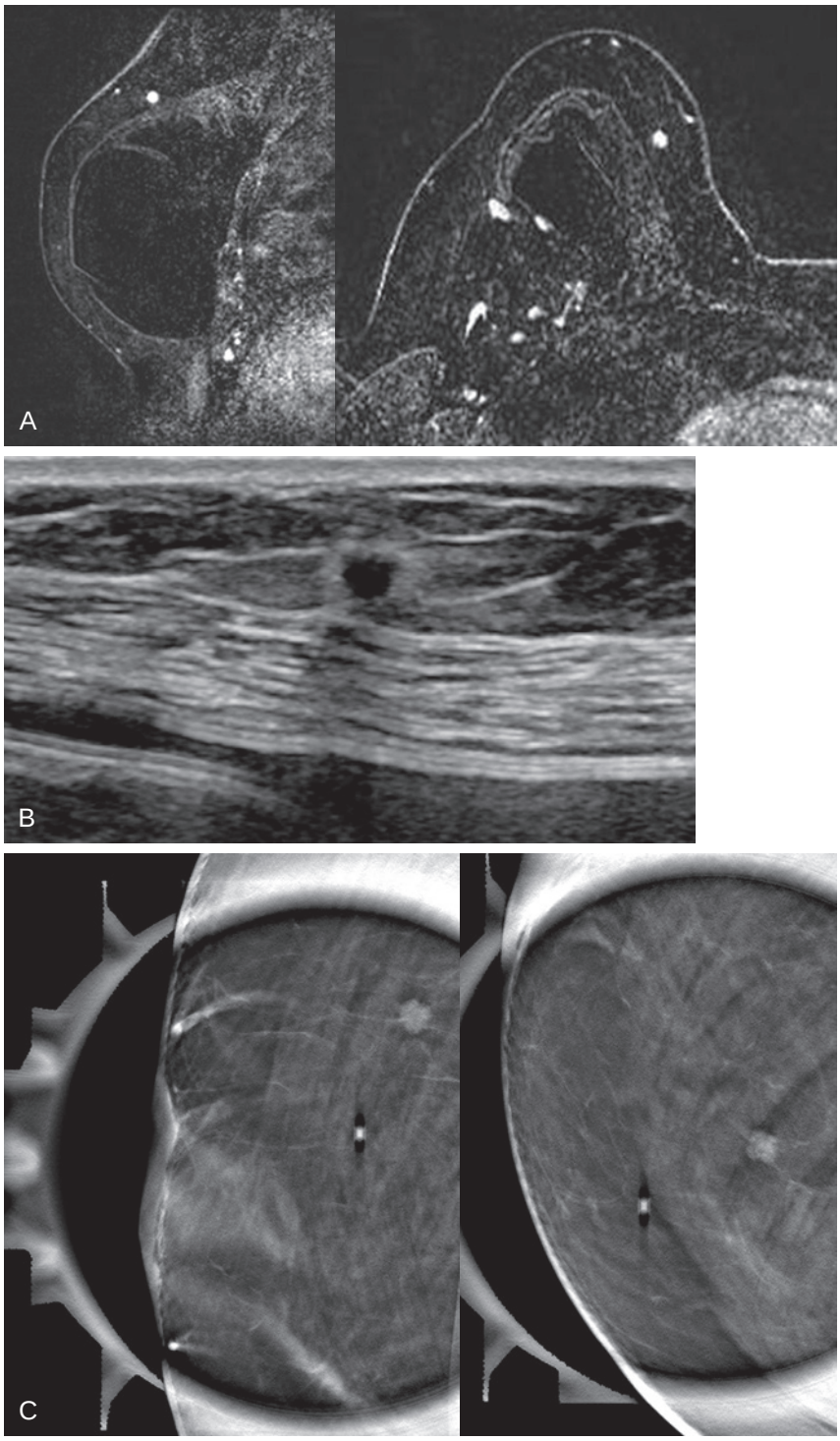


FIG. 11.10 (A) Screening magnetic resonance imaging (MRI) in a 62-year-old woman with a known BRCA-2 mutation and history of right breast cancer, status post-bilateral nipple sparing mastectomies with subpectoral implant reconstructions. T1-weighted sagittal and axial post-contrast subtraction images demonstrate a 6-mm enhancing, oval mass with a circumscribed margin in the upper-inner quadrant of the reconstructed right breast, new since the prior MRI 3 years ago. **(B)** Targeted ultrasound reveals a round hypoechoic mass with microlobulated margins and a hyperechoic rim. **(C)** A BB was placed on the skin overlying the abnormality, and spot tomosynthesis compression views reveal a lobulated mass with spiculated margins corresponding to the MRI and ultrasound findings. Pathology revealed a moderately differentiated infiltrating ductal carcinoma, ER+/PR+/Her–.

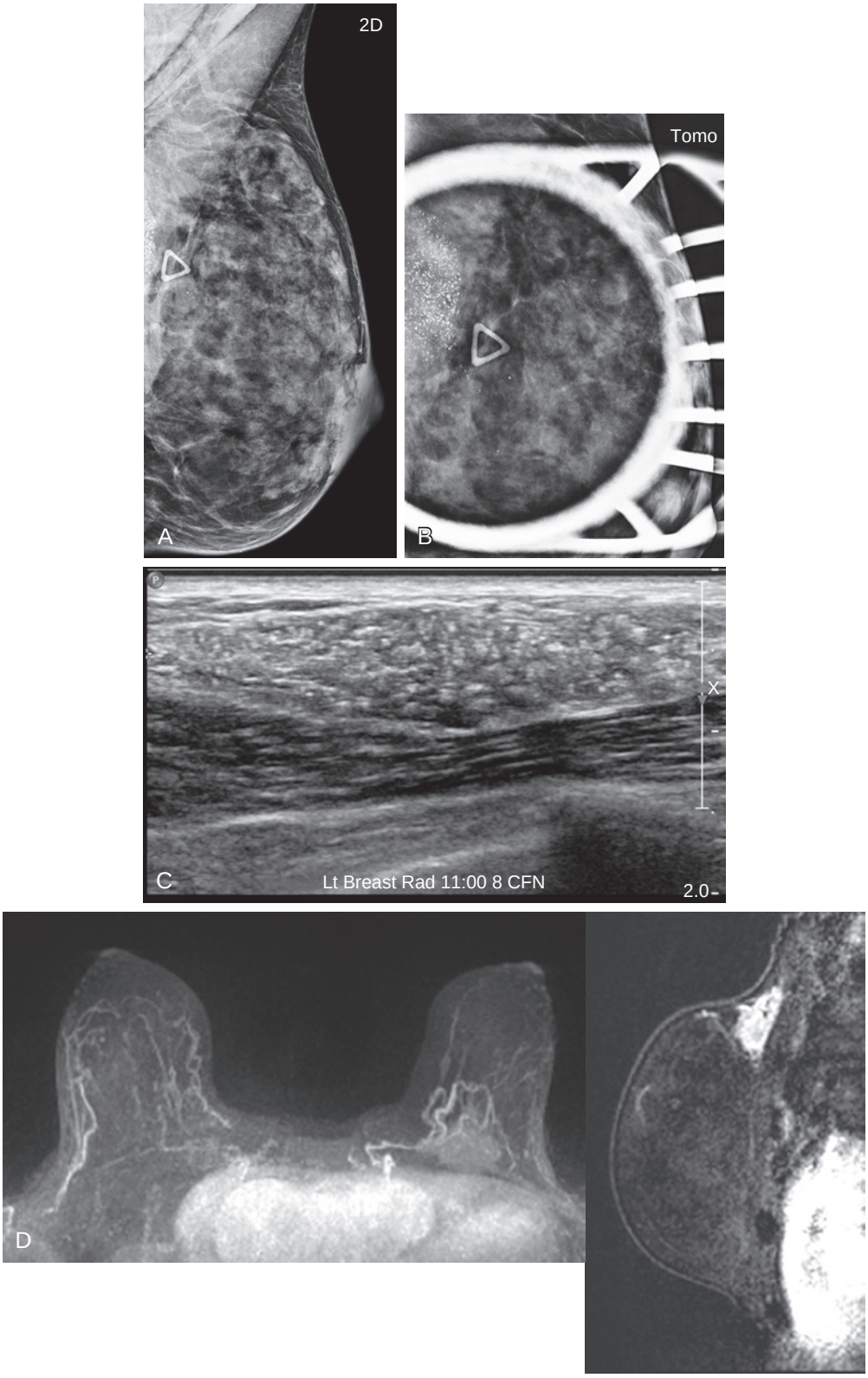


FIG. 11.11 (A) A 55-year-old woman presented with a palpable mass in the posterior left breast. Diagnostic mammogram shows clustered coarse pleomorphic calcifications spanning an area of 3.8 cm. **(B)** Spot tomosynthesis view shows the calcifications in extremely dense tissue. **(C)** Ultrasound shows an oval mixed echogenicity mass correlating with the palpable abnormality and mammography findings. Ultrasound biopsy revealed ductal carcinoma in situ (DCIS). **(D)** Maximum intensity projection and T1-weighted, sagittal, post-contrast subtraction views of MRI show a corresponding irregular mass in the left breast at the 11-o'clock posterior depth, abutting the chest wall with heterogeneous enhancement and delayed washout-type enhancement pattern. Lumpectomy showed DCIS, grade 2 to 3.

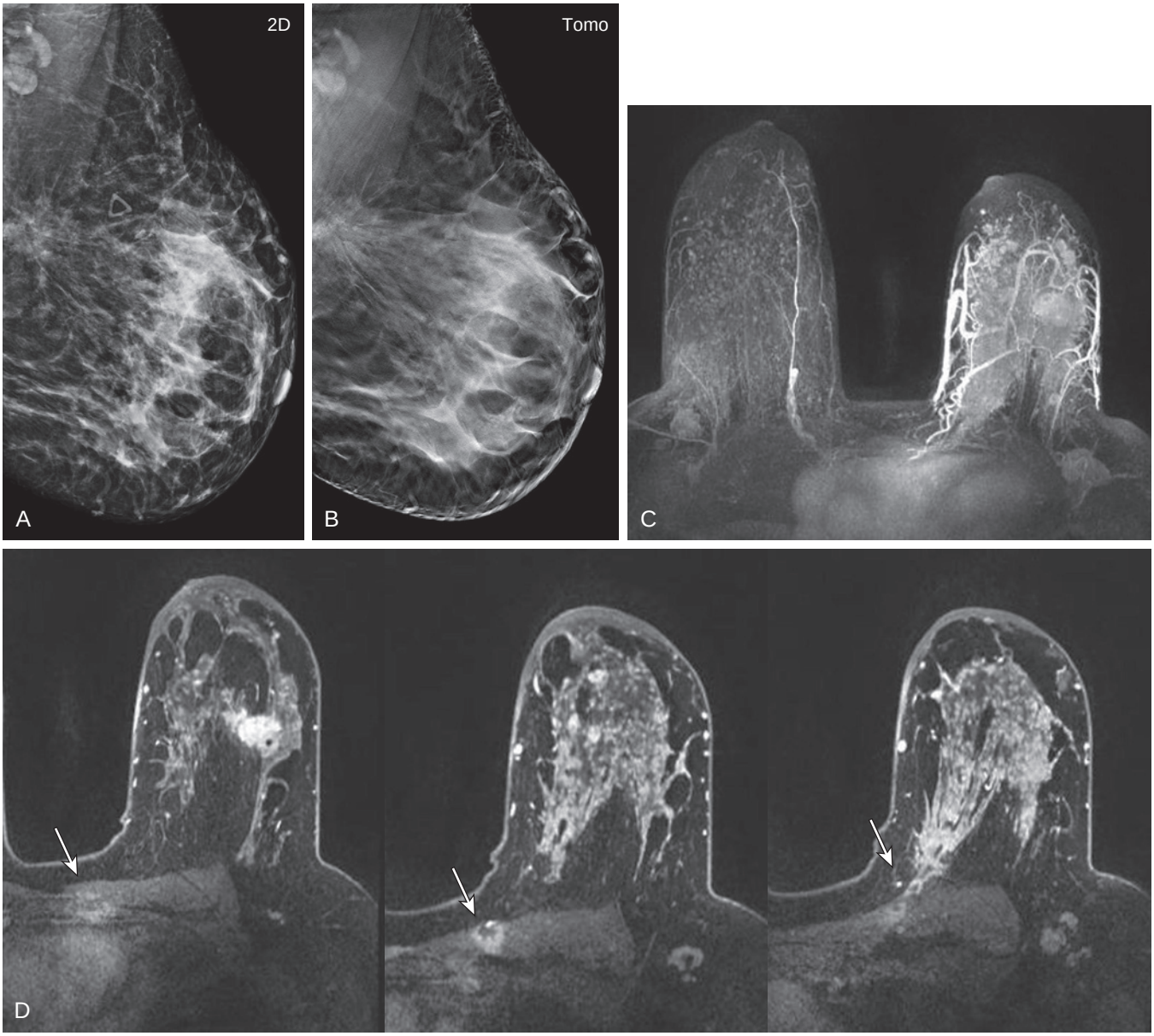


FIG. 11.12 (A) A 43-year-old woman presented with a large, palpable, spiculated mass in the left breast. **(B)** Tomosynthesis mediolateral oblique view demonstrates the cancer causing distortion of the underlying pectoralis muscle. Biopsy yielded invasive ductal carcinoma, ER+/PR+/Her2–. **(C)** Maximum intensity projection view of MRI shows the large extent of malignancy involving multiple quadrants of the left breast. **(D)** Multiple axial post-contrast post contrast images confirm the chest wall involvement with disease seen extending through the pectoralis and intercostal spaces *(arrows)*.

likelihood that the suspicious lesion initially identified on MRI was actually sampled. In particular, the prone position of the patient in MR scanning can render a lesion to appear more anterior in the breast compared with ultrasound when the patient lies supine. Placement of a biopsy marker after ultrasound-guided biopsy and obtaining a post-biopsy mammogram to verify the position of the biopsy marking clip is important. Even for mammographically occult disease, using surrounding geography of the breast tissue as cross-correlated with MRI, one can be relatively certain that the correct area was biopsied. If pathology results are benign and concordant, MRI follow-up may not be necessary. However, if the biopsy results are deemed to be discordant, repeat MRI is necessary to check marker position and, if incorrect, MR-guided biopsy can be performed.

Evaluation of Incidental Breast Lesions Seen on Chest Computed Tomography

On occasion, breast abnormalities are detected incidentally on a chest computed tomography (CT) examination performed for a health concern unrelated to the patient's breasts. In many cases these findings are simply due to asymmetric breast tissue, but on occasion, benign masses and cancers are detected (Fig. 11.13). Given the excellent resolution of today's CT examinations, even small (approximately 1 cm) breast cancers may be detected. Many breast cancers will enhance with iodinated contrast material compared with normal breast tissue, which does not enhance significantly. Usually cancers will have a typical spiculated appearance on CT, but aggressive cancers may appear round and relatively circumscribed with heterogeneous internal

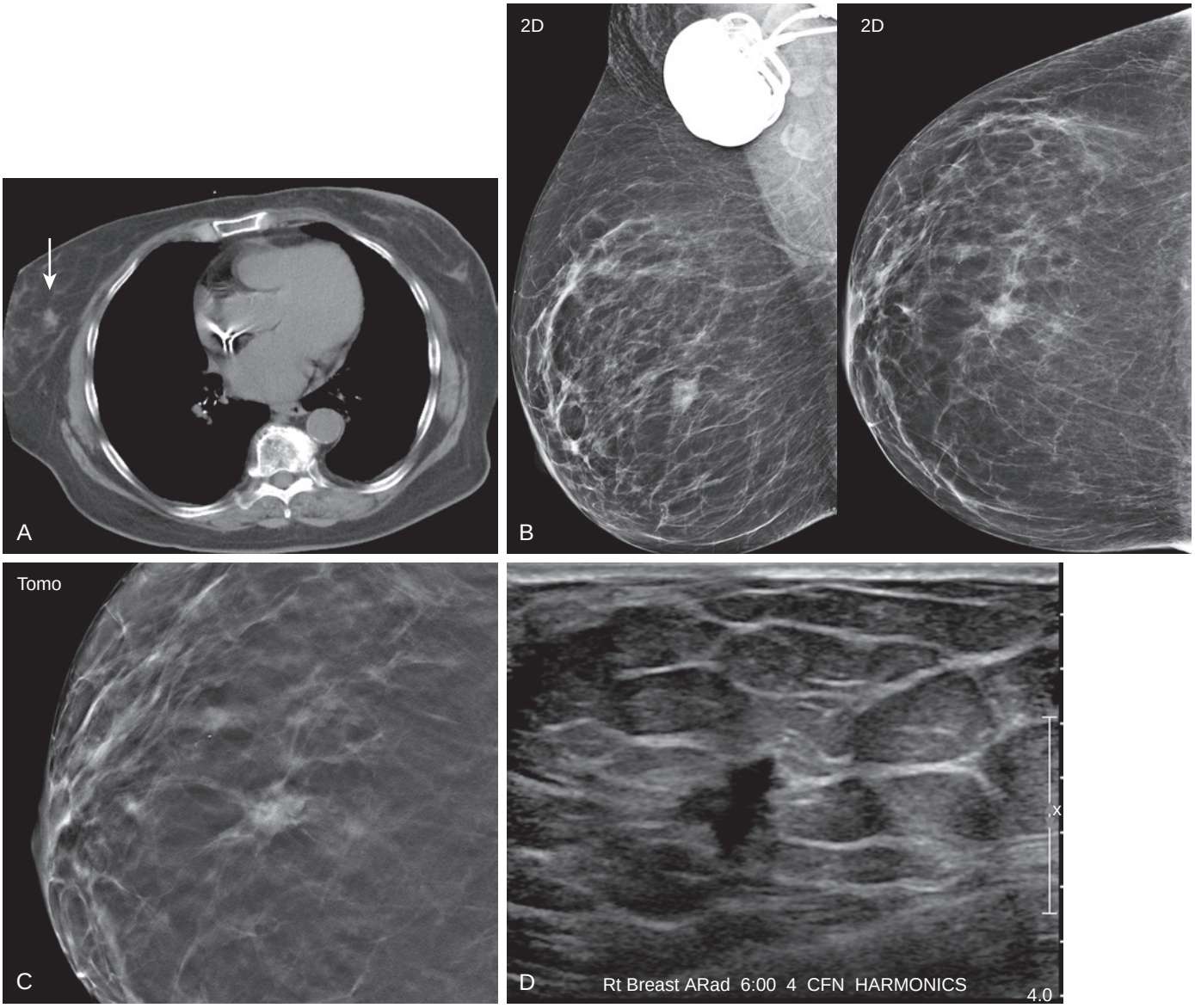


FIG. 11.13 (A) An 82-year-old woman underwent a chest computed tomography scan (for unrelated medical reasons), which demonstrates a spiculated mass in the right breast. **(B)** Diagnostic mammography was then performed, which shows a 1.2-cm irregular mass in the right breast central to the nipple. **(C)** Tomosynthesis better depicts the spiculated margins. **(D)** Targeted ultrasound demonstrates a lobulated hypoechoic mass with an irregular margin. Ultrasound-guided biopsy revealed a moderately differentiated infiltrating ductal carcinoma, ER+/PR+/ Her2−.

enhancement. If a concerning breast lesion is observed on a chest CT, the axillae and the supraclavicular region, which are usually very well visible on such a study, should also be evaluated for any suspicious lymph nodes. The internal mammary lymph node chain also warrants an assessment, especially if the suspicious mass is located in the inner aspect of the breast. Just as in MRI and ultrasound, features to assess when analyzing lymph nodes on CT include bilateral symmetry, preservation of fatty hila, and presence or absence of cortical thickening.

If mammography has not been performed recently, tomosynthesis should be obtained to further evaluate a CT finding. If the CT finding simply represented asymmetric tissue, tomosynthesis will nicely demonstrate normal glandular tissue without an underlying mass. Conversely, if a focal lesion is identified, the features, such as shape and margins, will also be better assessed and subsequent management will be determined.

Patients Presenting With Metastatic Disease: How Tomosynthesis and Other Modalities Can Help

Occasionally patients may present with metastatic disease of unknown etiology. Most commonly, palpable axillary lymph nodes are the presenting finding, but sometimes patients present with metastatic lesions in more remote locations, such as the spine or solid organs. Mammography is often indicated in such patients to search for an occult breast carcinoma. In some cases tomosynthesis may help in detecting subtle lesions that otherwise might have not been detected on 2D mammography (Fig. 11.14). Such findings can direct targeted ultrasound and subsequent biopsy and diagnosis, whereby the patient can be effectively treated with appropriate targeted therapy (Fig. 11.15).

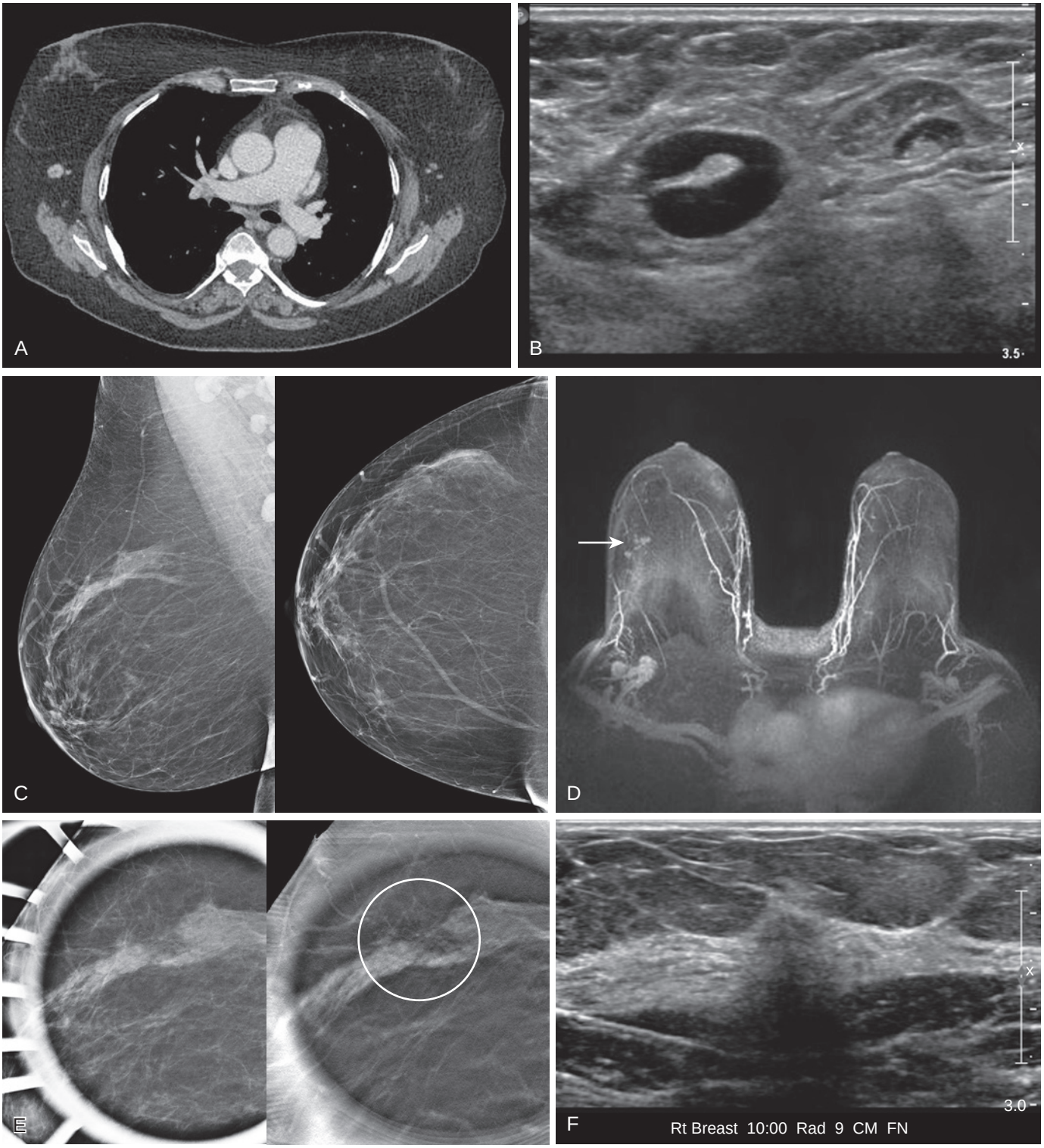


FIG. 11.14 (A) A 57-year-old woman, 5-year status posttreatment for melanoma, underwent her last staging computed tomography scan, in which slightly prominent nodes were noted in the right axilla. **(B)** Right axillary ultrasound demonstrates the prominent nodes and biopsy revealed adenocarcinoma, consistent with breast primary. **(C)** Initial right diagnostic mammogram shows nondense tissue and no abnormality. **(D)** Maximum intensity projection image from contrast-enhanced magnetic resonance imaging showed both the enlarged axillary nodes and a small enhancing mass in the lateral breast *(arrow)*. **(E)** Two-dimensional and tomosynthesis spot views demonstrate architectural distortion in a predominantly fatty area of tissue *(circle)*. **(F)** Targeted ultrasound reveals a corresponding ill-defined hypoechoic area with distortion of the tissue.

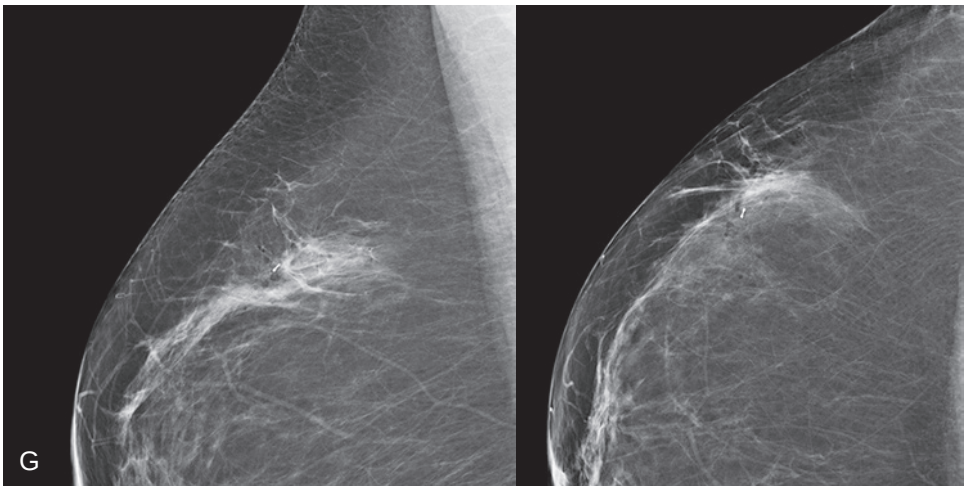
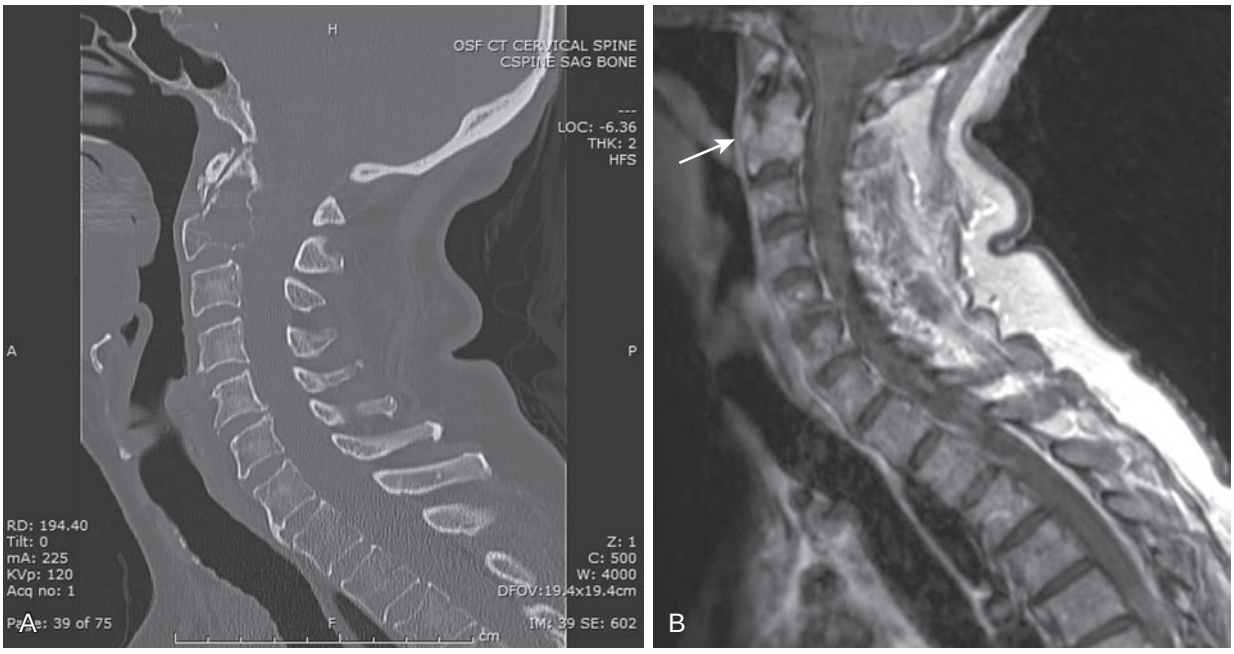


FIG. 11.14, cont'd (G) Post-biopsy images show the marker in the expected area. Ultrasound core biopsy revealed infiltrating ductal carcinoma, moderately differentiated, with lymphovascular invasion, ER+/PR+/Her2–.



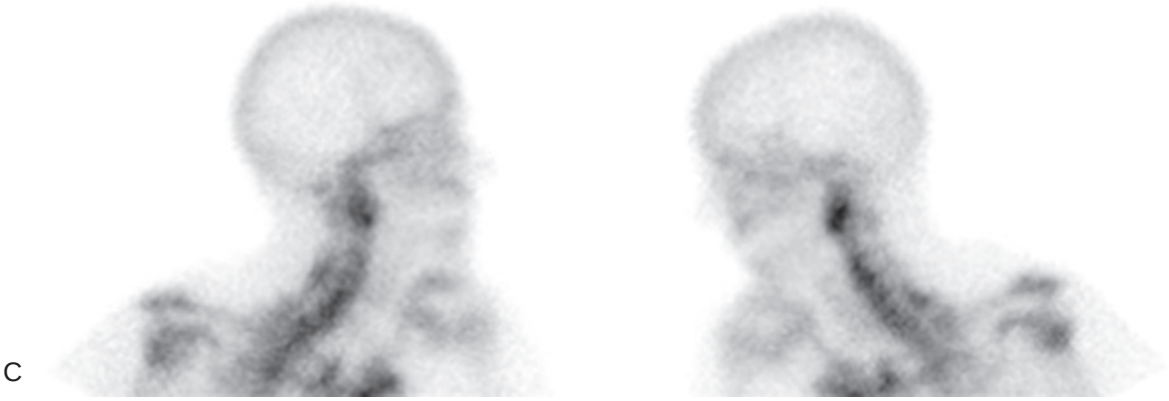


FIG. 11.15 (A) A 76-year-old woman presented with neck pain after falling down stairs. Cervical spine computed tomography scan shows a lytic expansile lesion involving the C2 vertebral body with associated pathologic fracture. **(B)** Magnetic resonance imaging (MRI) shows a T2 high-signal enhancing soft tissue mass *(arrow)* involving C2 vertebral body extending into bilateral pedicles, confined by the posterior longitudinal ligament without extension into epidural space. **(C)** Bone scan shows increased radiotracer uptake in the C1-C2 vertebral body region, correlating with the expansile enhancing lesion on MRI.

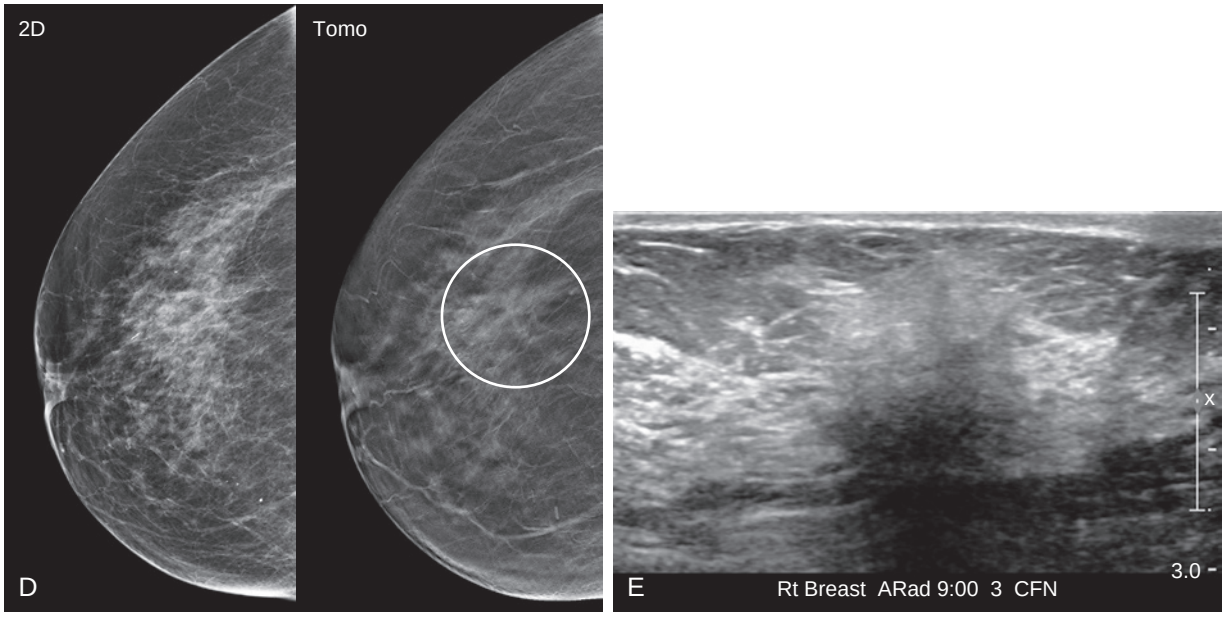


FIG. 11.15, cont'd (D) Mammography shows a subtle focal asymmetry in the right breast *(circle)*, centrally, best appreciated on tomosynthesis. **(E)** Ultrasound shows an irregular, hypoechoic lesion with indistinct margins. Ultrasound biopsy revealed invasive lobular carcinoma, ER+/PR–/Her equivocal.

Summary

Tomosynthesis provides improved diagnostic information compared with 2D mammography alone. On its own, it is a great step forward in mammographic assessment of breast lesions, but in conjunction with other imaging modalities, especially ultrasound, it provides the opportunity to yield confident and accurate assessments, thereby enabling radiologists to make definitive benign or suspicious recommendations. Patients will experience improved breast imaging services because fewer diagnostic images are required and the PPV for biopsies performed will be increased.

CHAPTER 12

The Postoperative Breast

Laura J. Horvath | Liane E. Philpotts

Postoperative changes in the breast are commonly encountered. Many women presenting for mammography have undergone past procedures, ranging from augmentation or reduction to benign biopsies (needle and/or surgical) or cancer treatments (lumpectomy, mastectomy, and adjuvant radiation therapy). These procedures leave their mark on breast tissue, and knowledge of both the patient's history and the typical findings found on mammography is important. Such cases have often presented challenges to interpretation because two-dimensional (2D) mammography can be limited, particularly in areas of dense scar tissue. Digital mammography is an advancement over film mammography, with improved visualization of breast tissue, yet mammographic interpretation of postoperative and radiation changes remains a common daily challenge to breast imagers. In these women, who often present with heightened anxiety, accurate and expedited imaging is desired. Attempts should be made to detect new or recurrent disease at the earliest stage while also minimizing undue false alarms.

Tomosynthesis helps to reach this desired goal by adding yet another level of improvement in the evaluation of the postoperative breast. In areas of postoperative scar, assessment of tissue in thin slices provides better differentiation of normal scarring processes versus new or recurrent malignant disease. Due to the exquisite ability of tomosynthesis to demonstrate the spiculations and architectural distortion related to scars, many benign scars not previously visible on 2D mammography will frequently be noted, requiring careful review of patient history and correlation with visible dermal scars. In addition, scar tissue will be visualized more clearly in patients with a history of reduction mammoplasty or mastopexy, allowing better differentiation of scar tissue versus a malignant process. This increased sensitivity tomosynthesis provides in the detection of postoperative changes presents a major advantage but also may present some challenges.

General Postoperative Assessment Tips

Scars can have an alarming appearance on tomosynthesis—presenting as a spiculated mass or architectural distortion often extending for large distances in the breast—and either not seen at all or not as well on 2D images. These findings can mimic malignancy and will catch the eye when viewing the tomosynthesis images (Fig. 12.1).

Any known breast scar or area of surgical procedure, no matter how remote, should be brought to the attention of the radiologist by the technologist performing the study. Although scar markers can cause distraction on both 2D and three-dimensional (3D) images and are not routinely necessary, the interpreting radiologist must nonetheless be made aware of the presence and location of all previous breast biopsies. A patient intake form or electronic medical record data entry system is typically used to note the location of each scar. In some cases in which concern persists, imaging can be repeated with dermal scar markers, particularly those composed of nonmetallic material designed specifically for tomosynthesis, on the appropriate area to permit correlation. Review of prior preoperative or needle localization images is the most direct method of correlating findings with prior surgical sites (Fig. 12.2). This is particularly important for periareolar incisions, in which the surface scar may be barely perceptible and not provide information as to the actual surgical site within the deeper breast tissues. Sometimes getting an accurate history of remote surgery can be difficult, especially if the patient is elderly and the scar has faded. It is important in cases of a suspected remote scar to spend time trying to elicit the correct biopsy history, from the patient or even her physician, to avoid unnecessary work-up of a patient for a very remote benign biopsy.

TOMO TIP ★ Tomosynthesis reveals many scars that are not visible on 2D imaging. Careful assessment with history and visible dermal scars is necessary to avoid recall of patients unnecessarily.

Scars typically present as architectural distortion or a focal asymmetry, varying from mostly fatty to very dense (Fig. 12.3). The radiating spicules can extend great distances in the breast, reaching from nipple to chest wall, depending on the type of surgery. Scars are often planar and more prominent on one mammographic projection than the other. When identified on one set of tomosynthesis projections and localized to a specific depth in the breast, a scar can usually be identified on the corresponding projection. Focal skin thickening and/or peripheral contour deformity may be present.

Postoperative changes are usually most pronounced on the first imaging exam performed generally 6 months to 1 year following most procedures. Some findings are common to many operative procedures, such as seromas and hematomas, which are found frequently in the early postoperative period. These are usually round or oval and circumscribed and are sometimes palpable. They resolve slowly over time in most patients, although some will become encapsulated and remain virtually unchanged for years (Fig. 12.4). With resolution, the circumscribed mass

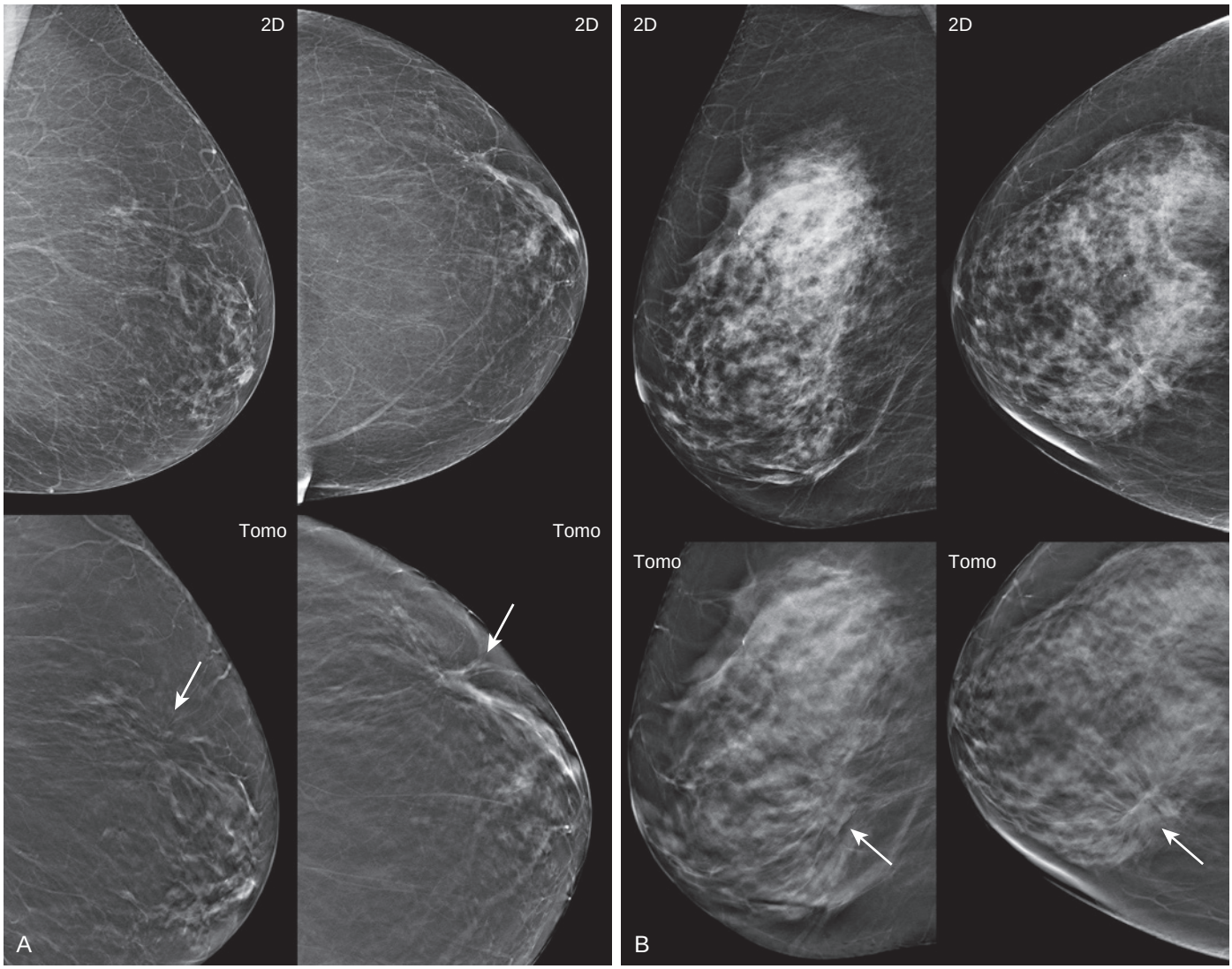


FIG. 12.1 Conspicuity of normal scars (two examples). (A) Thirteen years following an upper-outer quadrant benign biopsy, minimal asymmetry is seen in the lateral breast on the 2D CC view only. Tomosynthesis slices show the longstanding architectural distortion in both the MLO and CC projections *(arrows)*. **(B)** Ten years following excision of lobular carcinoma in situ, minimal distortion is apparent in the medial breast on the 2D CC view only. Heterogeneously dense tissue does not obscure the irregular scar on the MLO and CC tomosynthesis slices *(arrows)*. Tomosynthesis better demonstrates scars in both fatty and dense breast tissue.

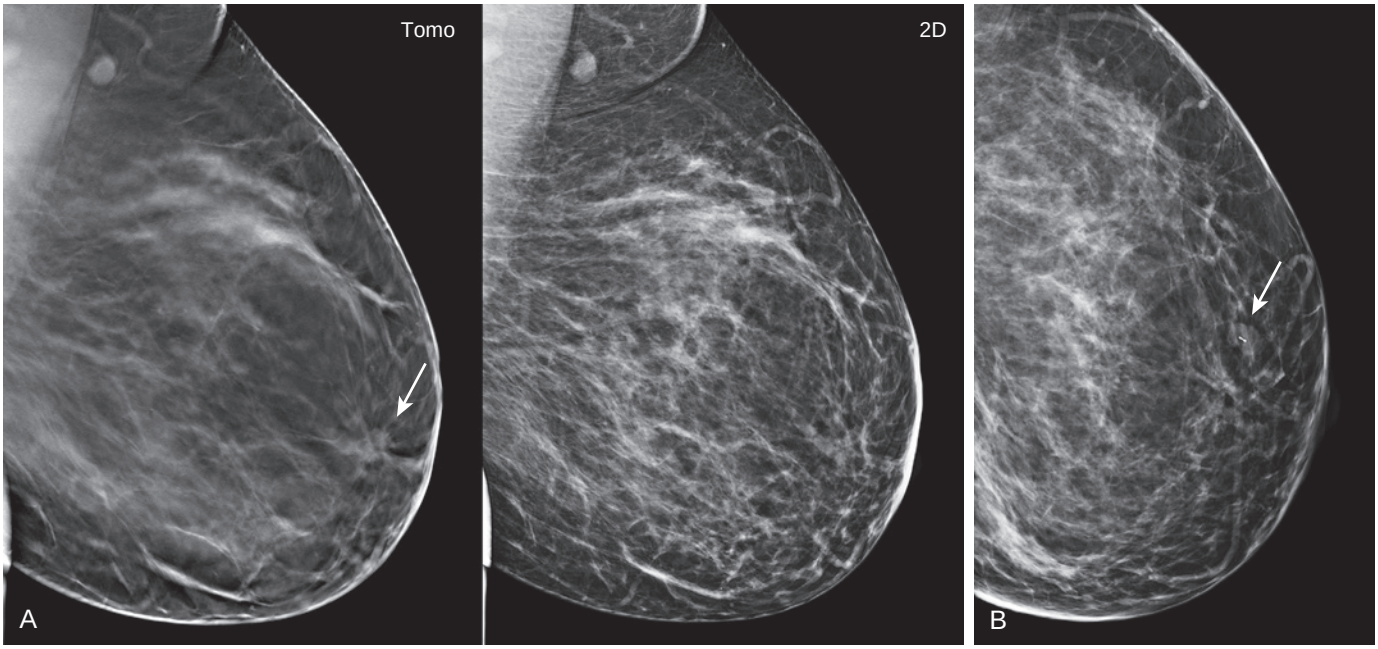


FIG. 12.2 Correlation with prior imaging studies. (A) Tomosynthesis shows a new, irregular, retroareolar asymmetry *(arrow)*, obscured by overlapping tissue on the two-dimensional view. There is a history of core biopsy demonstrating atypical ductal hyperplasia, followed by benign excision. **(B)** A preexcision comparison mediolateral view from 1 year earlier shows a percutaneous biopsy marker *(arrow)* at the same location and confirms the site of the surgical excision. The current asymmetry is consistent with postoperative scar.

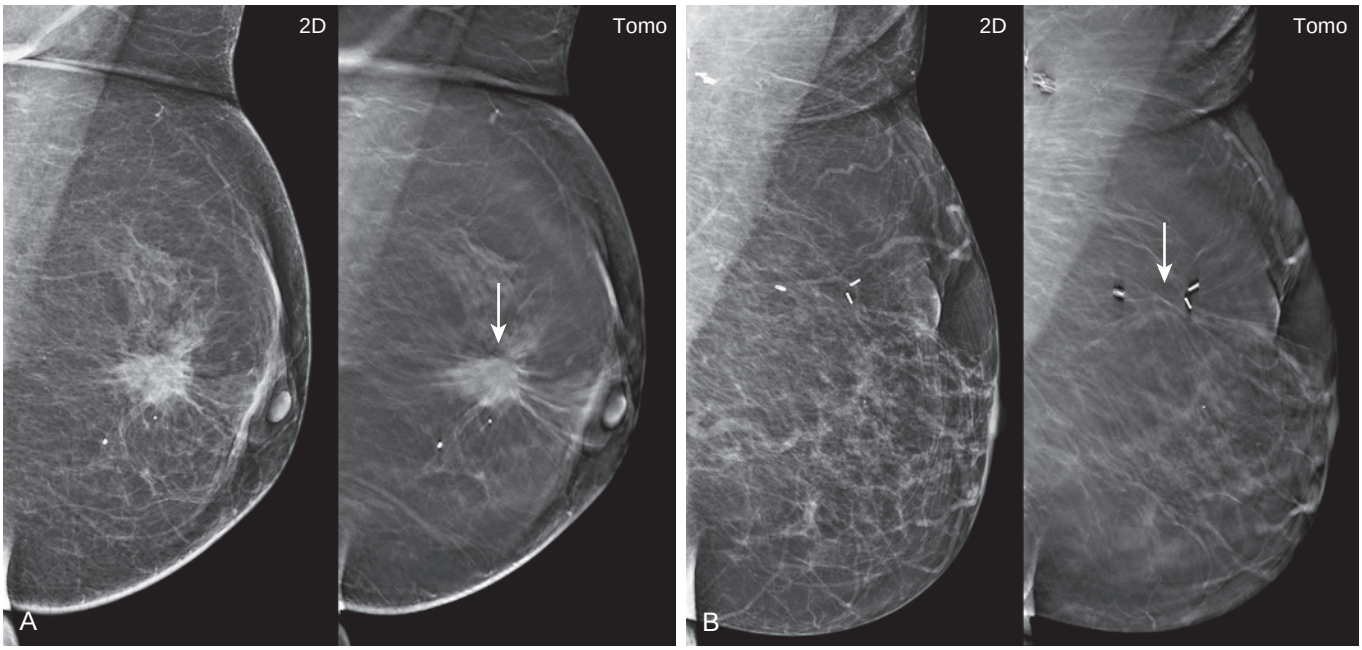


FIG. 12.3 Variable scar density (two examples). (A) Two years following lumpectomy and whole-breast radiation for invasive ductal carcinoma, there is dense scar *(arrow)*, prominent radiating spicules, and mild contour deformity. **(B)** In a different patient with the same history but 8 years following treatment, the scar is fatty *(arrow)*. Benign scars often decrease in density over time but should never increase.

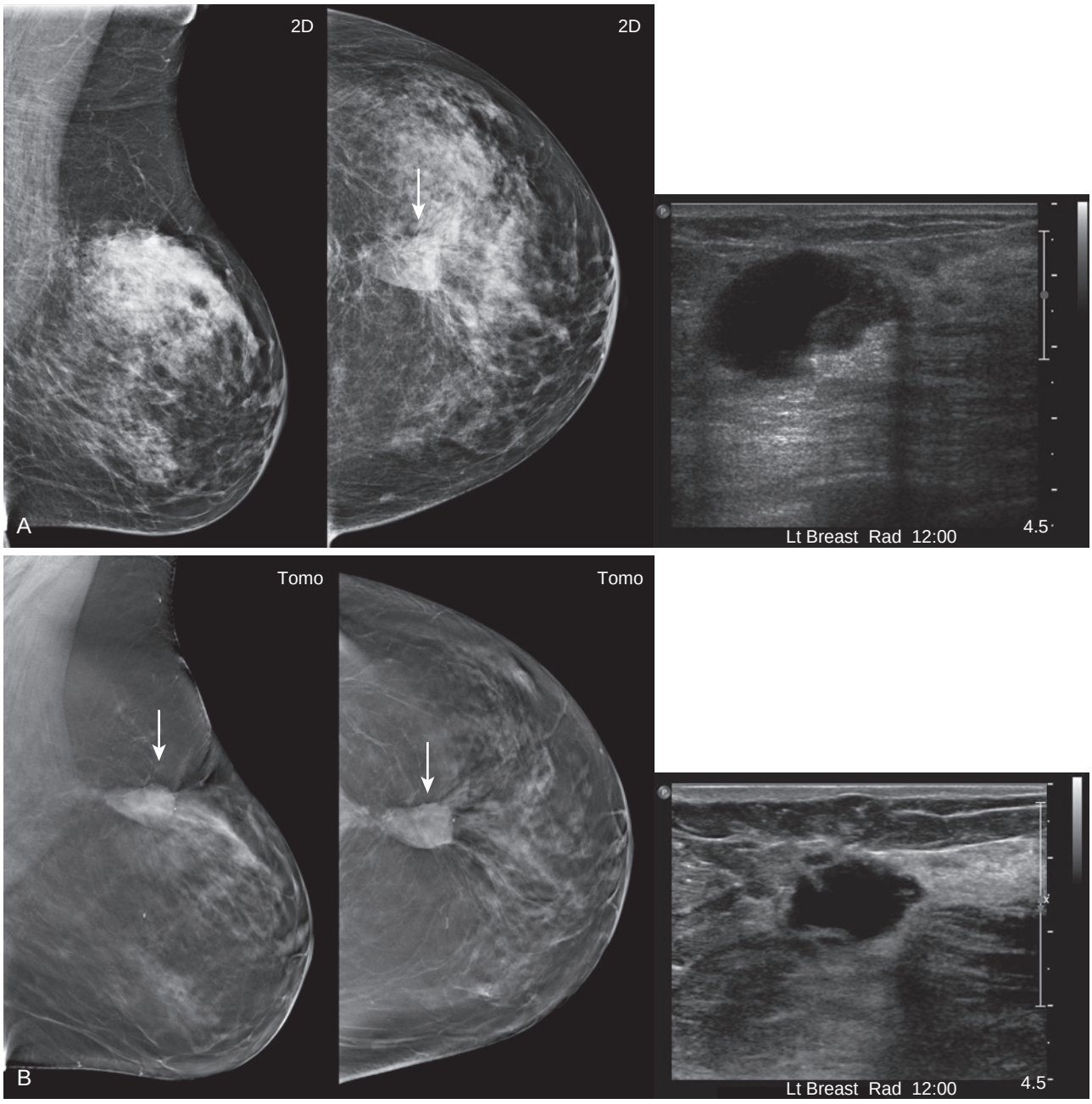


FIG. 12.4 Seroma. (A) A mammogram following lumpectomy and accelerated partial-breast radiotherapy for stage 1 invasive ductal carcinoma shows an obscured oval seroma at the operative site *(arrow)*. By ultrasound, the seroma is circumscribed, oval, and predominately anechoic with enhanced through transmission. **(B)** Ten years later, and well seen with tomosynthesis *(arrows)*, the seroma is only slightly smaller.

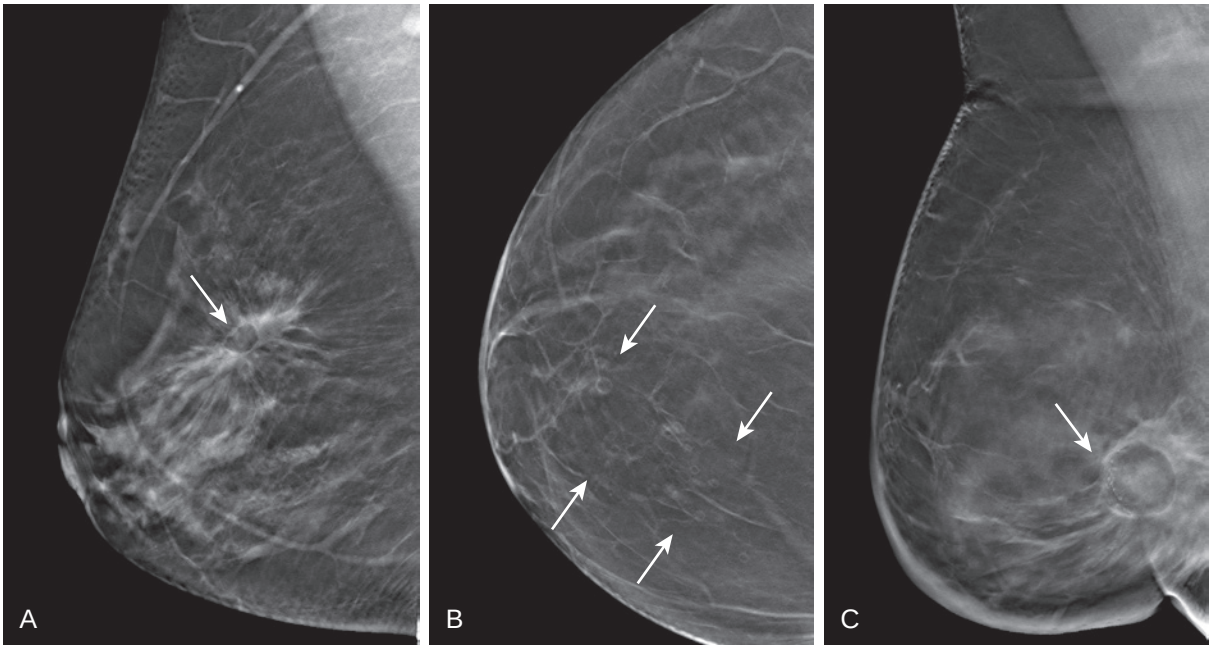


FIG. 12.5 Oil cysts (three examples). (A) A small oil cyst *(arrow)* is centrally located within a scar 3 months following excisional biopsy for atypical ductal hyperplasia. **(B)** Numerous tiny oil cysts *(arrows)* are present in the medial breast 1 year after reduction mammoplasty. **(C)** A large oil cyst with faint associated rim calcifications *(arrow)* has developed following partial mastectomy and whole-breast irradiation.

decreases and is replaced by scar, which is typically more spiculated. These findings rarely present interpretation difficulties.

Fat necrosis is a common postoperative finding after any type of breast surgery because there is an abundant amount of fat within breast tissue. Fat necrosis often presents as rounded lucencies or oil cysts (Fig. 12.5). These changes are usually solely noted on imaging but sometimes present as a palpable finding, particularly causing alarm in patients with a history of malignancy, in which case the differentiation from recurrent malignancy is paramount. Characteristic findings of fat necrosis include visualization of fat content within a mass. As discussed elsewhere, observation of fat within a lesion does not itself deem the finding benign. Many malignancies are shown by tomosynthesis to have fatty areas within them. Fat necrosis should ideally be encapsulated, fat-containing areas, often with thin, well-circumscribed margins, that may calcify over time. When such imaging findings are noted, the area can be confidently characterized as fat necrosis. However, in some instances, fat necrosis involving a postoperative scar can appear as an ill-defined or spiculated mass and mimic cancer. Biopsy of such lesions may be necessary (Fig. 12.6).

Calcifications associated with scarring may develop over time. Dystrophic calcifications are common in women who have undergone postoperative radiation therapy and typically present as coarse, heterogeneous calcifications in the surgical bed. Although these findings are often typically benign, in the early phase they may be difficult to differentiate from malignant findings. Tomosynthesis is particularly useful because viewing the tissue in thin slices permits better assessment of calcifications, which can often be located to small focal areas of fat within a larger scar (Fig. 12.7).

Infection is an early postoperative complication. Such cases are often managed clinically, but imaging may be requested to exclude abscess formation and/or monitor response to antibiotic treatment or drainage. These patients present with palpable, tender masses, and as in 2D imaging such masses have ill-defined borders, especially when within a surgical site. Ultrasound will be the imaging modality most appropriate for further assessment.

Retained foreign bodies are rare, but imaging can help to determine their presence and location. Likewise a missed lesion or clip following needle localization and excisional biopsy is also uncommon, but when these problems do occur, mammography is vital in documenting residual lesion or breast markers left behind at surgery (Fig. 12.8).

Metallic markers, or clips, are routinely used to mark percutaneous biopsy sites, and those placed in benign lesions not requiring excision will be seen repeatedly on subsequent imaging. Rarely, the collagen or gel pellet that houses the metal component may not get fully resorbed and will also be seen. Likewise, surgical clips placed during lumpectomy or axillary lymph node excision will also be visualized. Because metal can produce a black streak artifact on tomosynthesis, imaging-processing algorithms should be used to reduce artifact, which can obscure or detract from fully assessing the underlying tissue (Fig. 12.9).

Plastic surgery techniques, including reduction mammoplasty and mastopexy and different surgical techniques for lumpectomy and other oncoplastic surgeries, rearrange breast tissue to varying degrees. Concern has been raised over whether these surgeries may complicate subsequent mammographic interpretation and detection of malignancy. Several studies of 2D mammography have been performed that show the rates of imaging work-ups and biopsy recommendations in women who have undergone a variety of plastic surgery procedures, particularly reduction mammoplasty and oncoplastic surgery, are actually similar compared with those who have not undergone such surgery. Because tomosynthesis

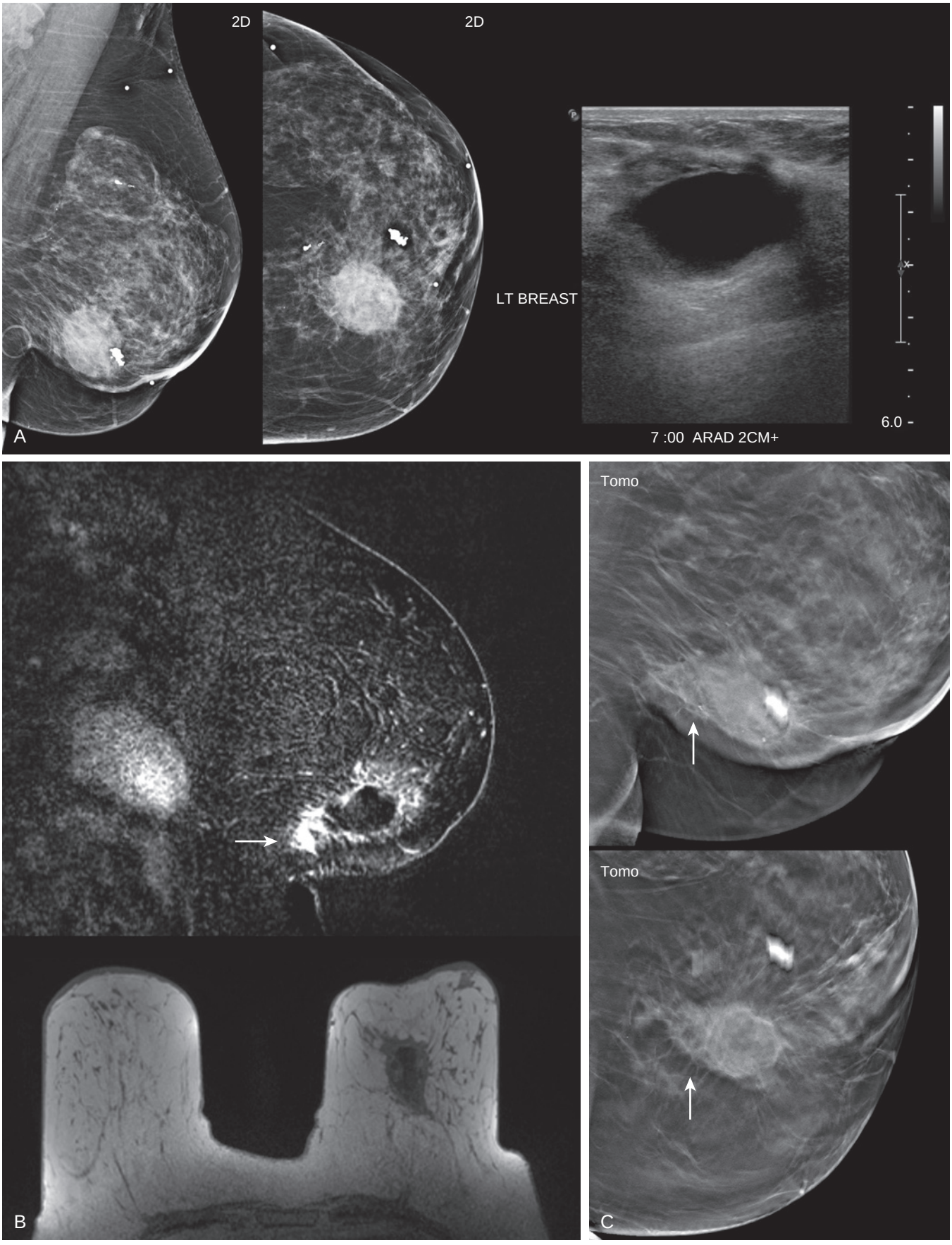


FIG. 12.6 Fat necrosis. (A) Three years following lumpectomy and partial-breast irradiation (balloon catheter) for invasive lobular carcinoma, a routine mammogram and ultrasound on a 69-year-old woman show a seroma and otherwise normal posttreatment changes. **(B)** Six years following treatment a screening magnetic resonance imaging shows new suspicious mass enhancement *(arrow)* with washout kinetics (not shown) along the posterior aspect of the seroma. Fat is not evident within the lesion on the precontrast non–fat-saturated T1 sequence. **(C)** However, mediolateral oblique and craniocaudal tomosynthesis slices show oval lucencies within a corresponding new indistinct asymmetry *(arrows)*. Ultrasound-guided biopsy reveals benign fat necrosis.

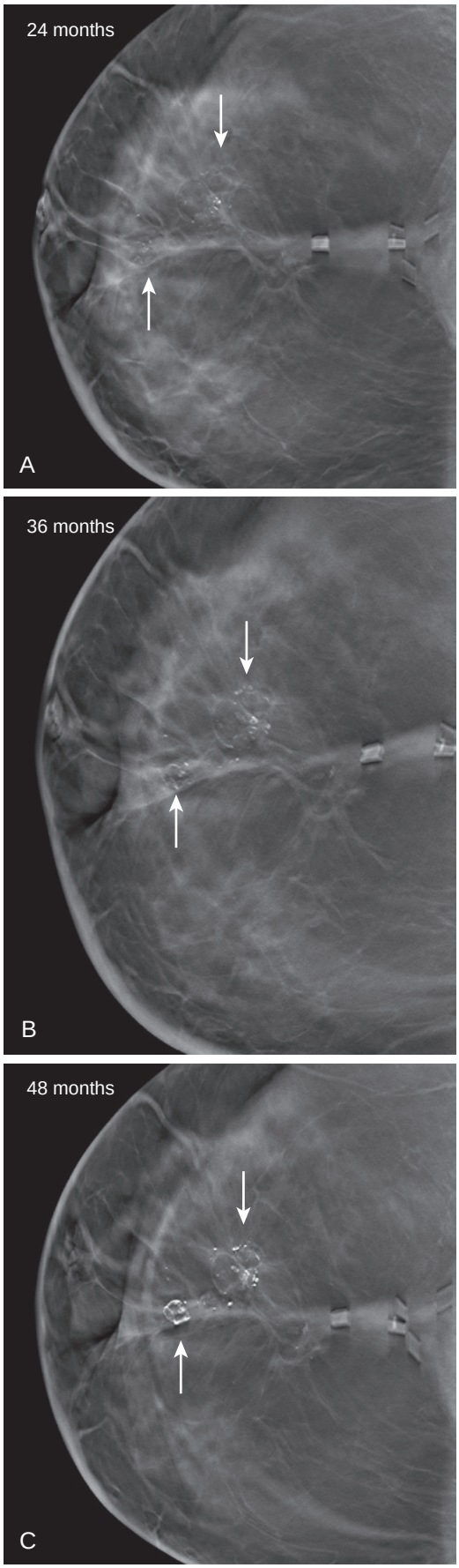


FIG. 12.7 Benign dystrophic calcifications. Craniocaudal tomosynthesis slices from similar anatomic levels at 24, 36, and 48 months (**A-C**, respectively) following lumpectomy and radiotherapy for invasive ductal carcinoma show multiple oil cysts anterior to the lumpectomy bed. Associated benign dystrophic rim calcifications *(arrows)* are increasing over time.

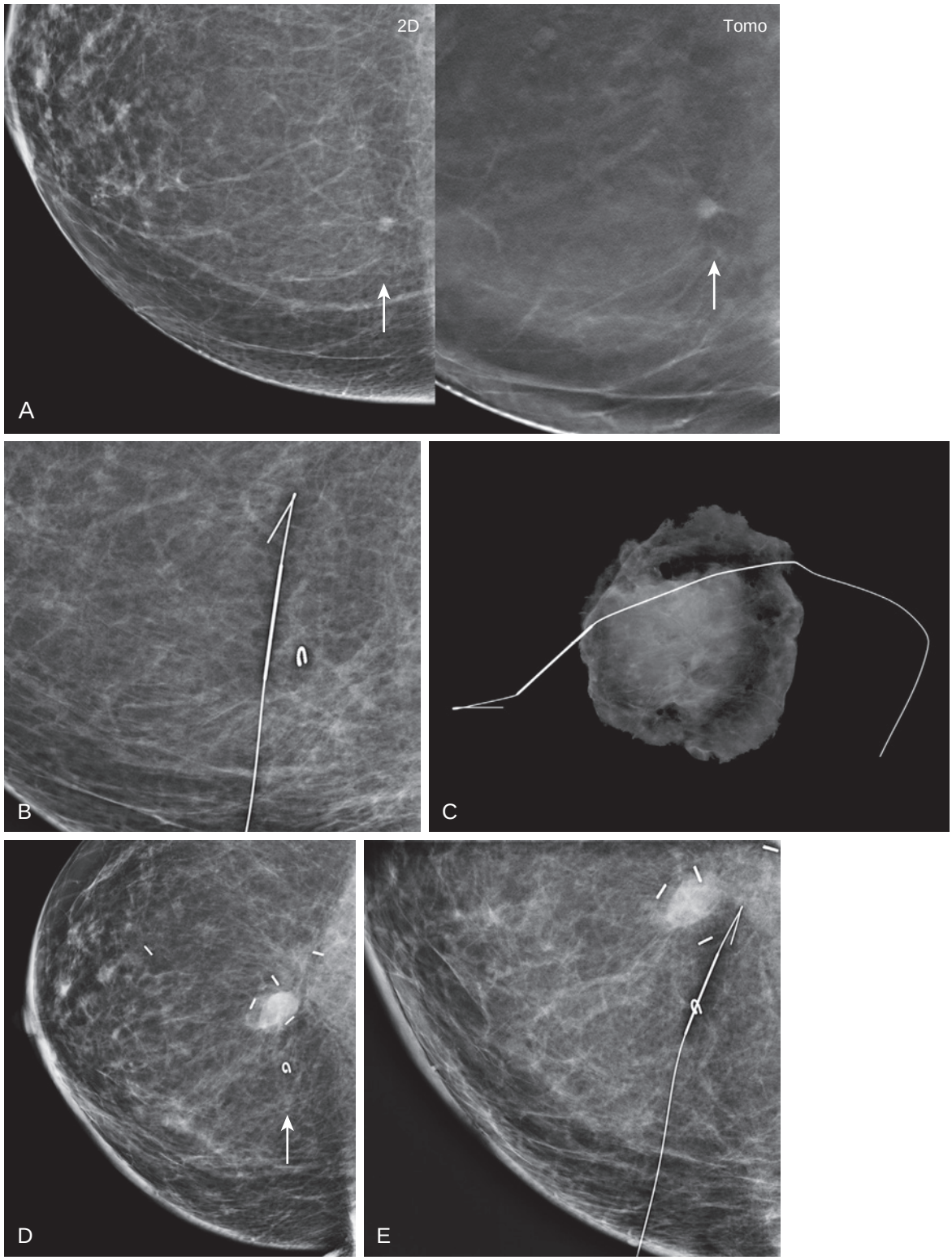


FIG. 12.8 Missed lesion. (A) A 73-year-old woman has a new small mass in the medial breast seen on tomosynthesis slice image to have spiculated margins *(arrow)*. Core needle biopsy showed invasive ductal carcinoma. **(B)** Needle localization image shows appropriate positioning of the wire adjacent to the clip marking the percutaneous biopsy site. **(C)** An intraoperative specimen radiograph does not demonstrate removal of the biopsy clip. Pathology reports ductal carcinoma in situ and postbiopsy change but no invasive component. **(D)** A postlumpectomy mammogram shows the retained clip *(arrow)*; the surgical cavity is more centrally located than expected. **(E)** Repeat localization and surgery is successful. The clip is excised along with the missed (triple negative) invasive ductal carcinoma.

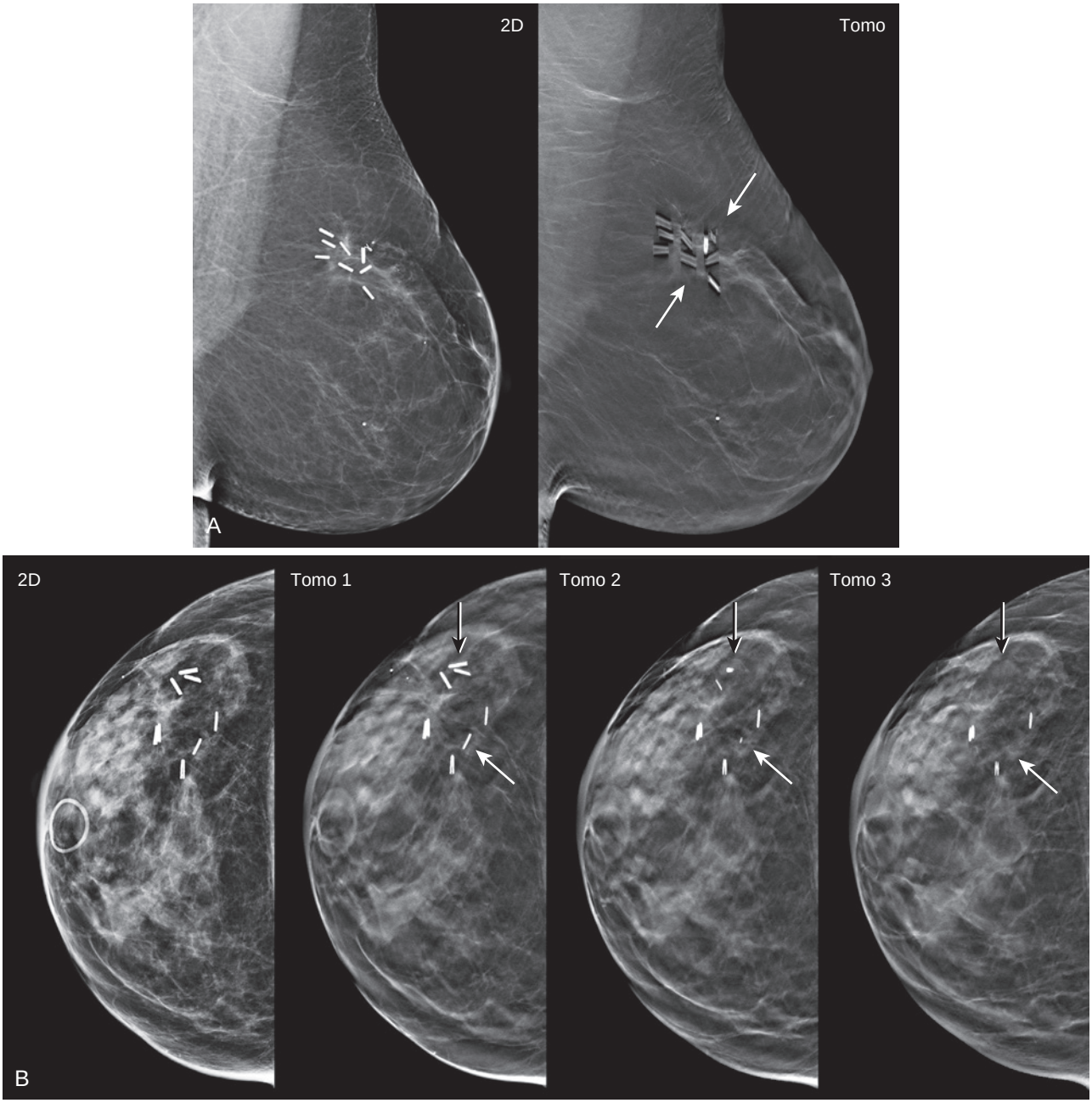


FIG. 12.9 Clip artifacts (two examples). (A) A 66-year-old woman is seen to have numerous surgical clips and a biopsy site marker in the upper breast. A tomosynthesis slice without artifact cancellation demonstrates incomplete blurring artifacts from the out of plane clips, as well as loss of signal around each clip in a bandlike distribution that is parallel to the axis of tube motion *(arrows)*. **(B)** A 67-year-old woman has numerous surgical clips in the lateral breast. Three tomosynthesis slices at slightly different levels with artifact cancellation demonstrate effective disappearance of the clips on the out of plane images *(arrows)*, as well as marked reduction of in plane artifacts.

is more sensitive to postoperative findings, it is possible that an increase in architectural distortions due to scars may lead to an increase in imaging follow-ups or even biopsies. However, when used carefully and by recognizing the common appearances of scars, the information gained from tomosynthesis will hopefully improve diagnostic performance beyond 2D imaging alone.

Needle Biopsy

Core needle biopsies have been used for diagnosis of breast lesions for more than 25 years. There are very few sequelae after a benign core needle biopsy. Unless the biopsy was complicated by bleeding and hematoma formation, which may leave a residual finding for many years, most uncomplicated biopsies leave no imaging finding. Occasionally, very subtle areas of architectural distortion may remain at a prior needle biopsy site noted on tomosynthesis and not seen on 2D imaging. Correlation with prior imaging should be performed to exclude a new suspicious finding at or near a prior benign biopsy site, and in some cases, short-term follow-up may be necessary (Fig. 12.10).

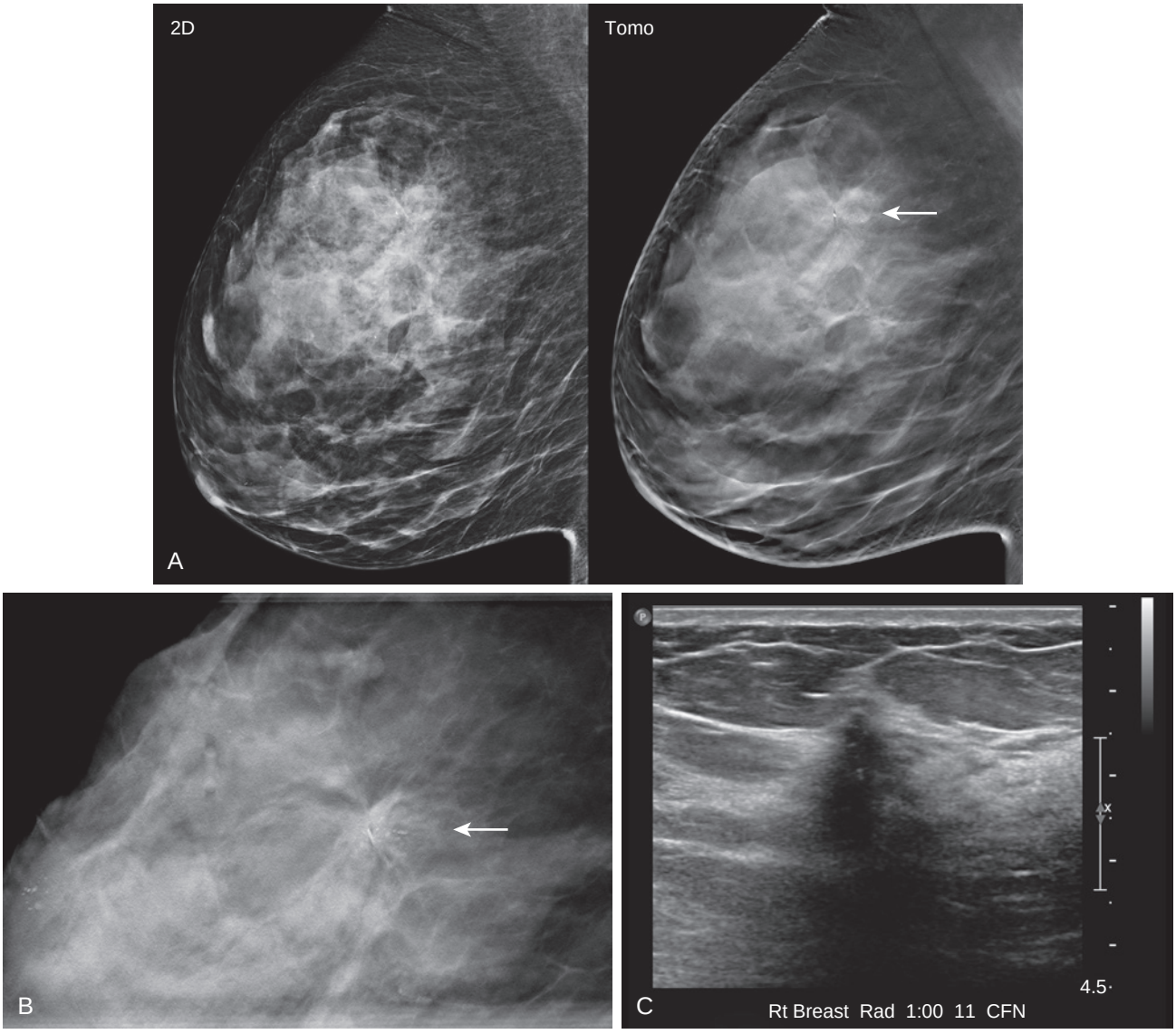


FIG. 12.10 Changing scar following benign biopsies: invasive ductal carcinoma. A 54-year-old woman with history of benign excisional and subsequent stereotactic biopsy for calcifications. **(A)** Two-dimensional and tomosynthesis images show a biopsy site clip, nearby amorphous calcifications, and minimal presumed postbiopsy distortion *(arrow)*. **(B)** One year later spot compression tomosynthesis demonstrates increasing architectural distortion *(arrow)*. **(C)** Ultrasound confirms a suspicious hypoechoic mass with posterior shadowing. Final diagnosis is invasive ductal carcinoma with calcifications, 1.3 cm, ER/PR+, Her2−, and sentinel lymph node micrometastases.

Surgical Biopsy

Surgical biopsies for benign or high-risk lesions may be performed as either excisional (removing the entire lesion) or incisional (representative sampling of a portion of the lesion) biopsies. In either case the goal is to remove adequate tissue while maintaining cosmesis. Because these nonmalignant cases do not require radiation therapy, the postsurgical effects seen on mammography are usually minimal. With 2D mammography, benign surgical scars are often not evident, and indeed it has been taught that one should regard a mammographically visible scar from remote benign biopsy with suspicion. This is certainly not the case with tomosynthesis imaging! The majority of postoperative scars will actually be seen even though they were previously occult on 2D mammography (Fig. 12.11). This is one of the challenges of tomosynthesis because old scars can present as subtle architectural distortion and, because they cannot be seen on prior 2D imaging, assessing for stability when comparing with 2D imaging alone may be difficult. As discussed previously, information about prior surgery and location of scars is important when interpreting tomosynthesis images. Most cases will not present a problem in interpretation and will be confidently regarded as benign. Scars should stabilize or regress over time. If suspicious changes are noted on tomosynthesis in an area of a prior scar, further investigation including ultrasound will be necessary.

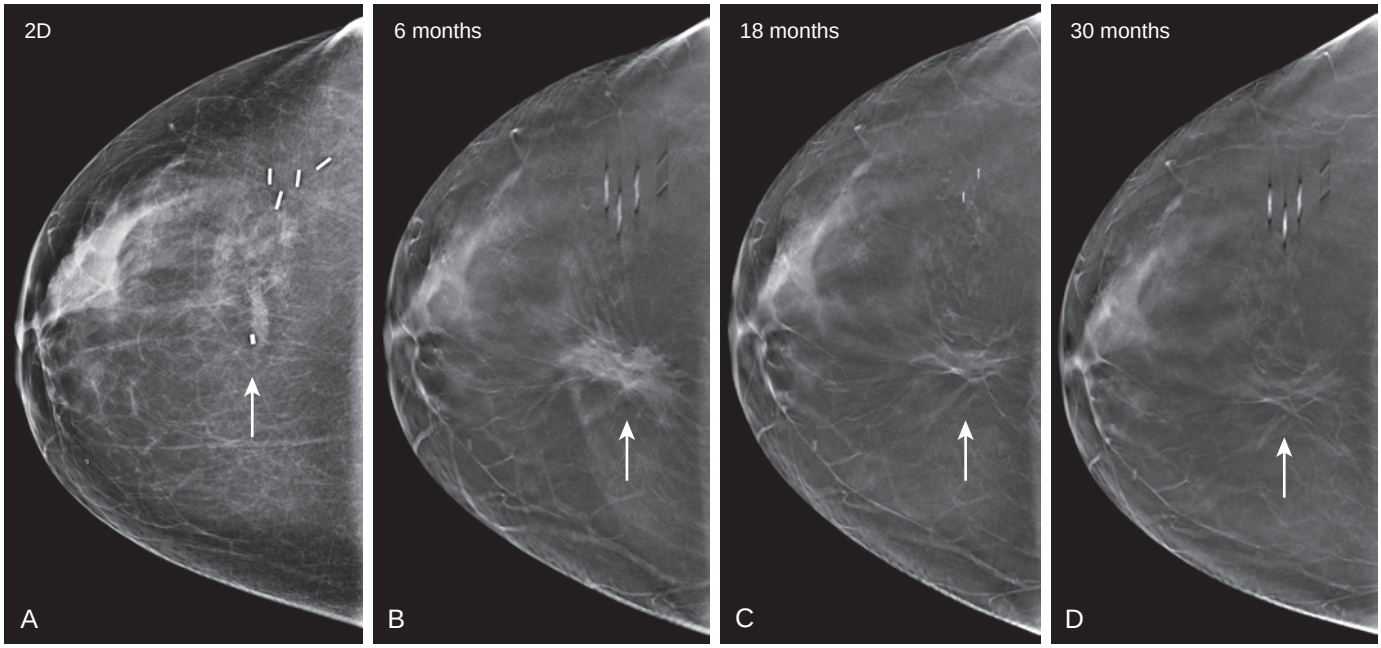


FIG. 12.11 Resolving scar following excision of high-risk lesion. A 51-year-old woman with a strong family history of breast cancer is referred for surgical excision of atypical ductal hyperplasia. A preoperative two-dimensional craniocaudal view **(A)** demonstrates the magnetic resonance imaging biopsy site marker *(arrow)*. Multiple surgical clips in the lateral breast correspond to a previous benign excision. Follow-up postoperative tomosynthesis slices from similar anatomic levels at 6, 18, and 30 months (**B-D**, respectively) demonstrate a diminishing irregular asymmetry *(arrows)* with a few associated oil cysts, consistent with resolving post-surgical changes. Mild architectural distortion persists.

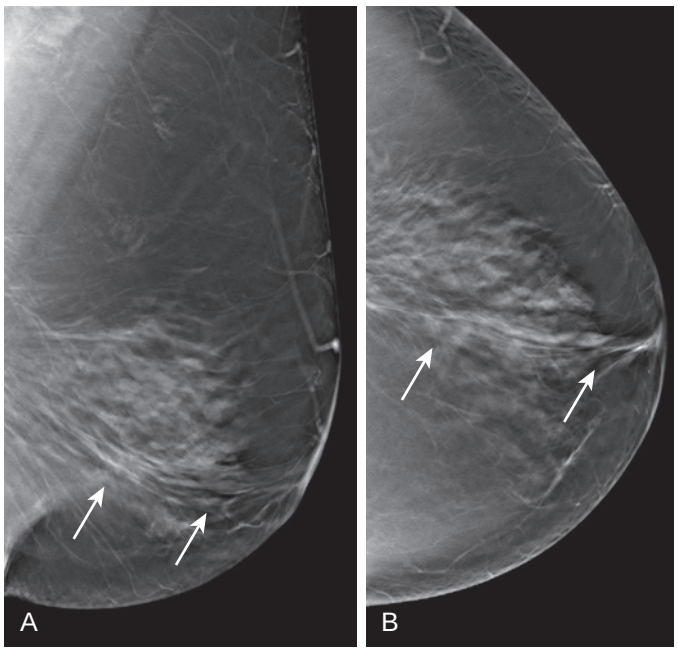


FIG. 12.12 Normal reduction mammoplasty scar. Curvilinear scar *(arrows)* extends from the nipple posteriorly toward the chest wall on both the mediolateral oblique **(A)** and craniocaudal **(B)** tomosynthesis slices.

Reduction Mammoplasty

Reduction mammoplasty is a common plastic surgery operation used in women who suffer from back or shoulder pain and/or restricted ability to exercise due to the size and weight of their breasts. This procedure has a very high efficacy and patient satisfaction rate. T-shaped or vertical incisions are most common and produce characteristic mammographic findings that usually do not pose interpretive problems. Architectural distortion is almost always seen, with a swirled appearance, particularly in the inferior breast due to repositioning after removal of variable amounts of tissue (Fig. 12.12). Disrupted tissue planes and islands of glandular tissue are noted to a varying degree. Tomosynthesis can be helpful in assessing such focal asymmetric areas as normal glandular tissue, even if areas of spiculation are seen, because these are generally to be expected with the normal scarring process. Dermal calcifications are common along the incision lines. Fat necrosis presenting as oil cysts, which may become coarsely calcified with time, are a common sequela. Such findings may or may not be palpable (Fig. 12.13).

The first postoperative imaging should be used as a new baseline in these patients, and postoperative changes should be noted to change over time in a benign manner (ie, areas of architectural distortion should remain stable or less prominent, whereas other benign findings, such as dermal calcifications and fat necrosis, may increase). In general, routine mammographic screening after these procedures is appropriate. Concern has been raised that the increased sensitivity of tomosynthesis to architectural distortion may lead to additional imaging and/or procedures in postoperative women, but this does not seem to be the case in clinical practice so far. Conversely, malignancies in women who have undergone reduction mammoplasty can be distinguished with tomosynthesis with similar high degree of accuracy as those who have not had surgery (Fig. 12.14).

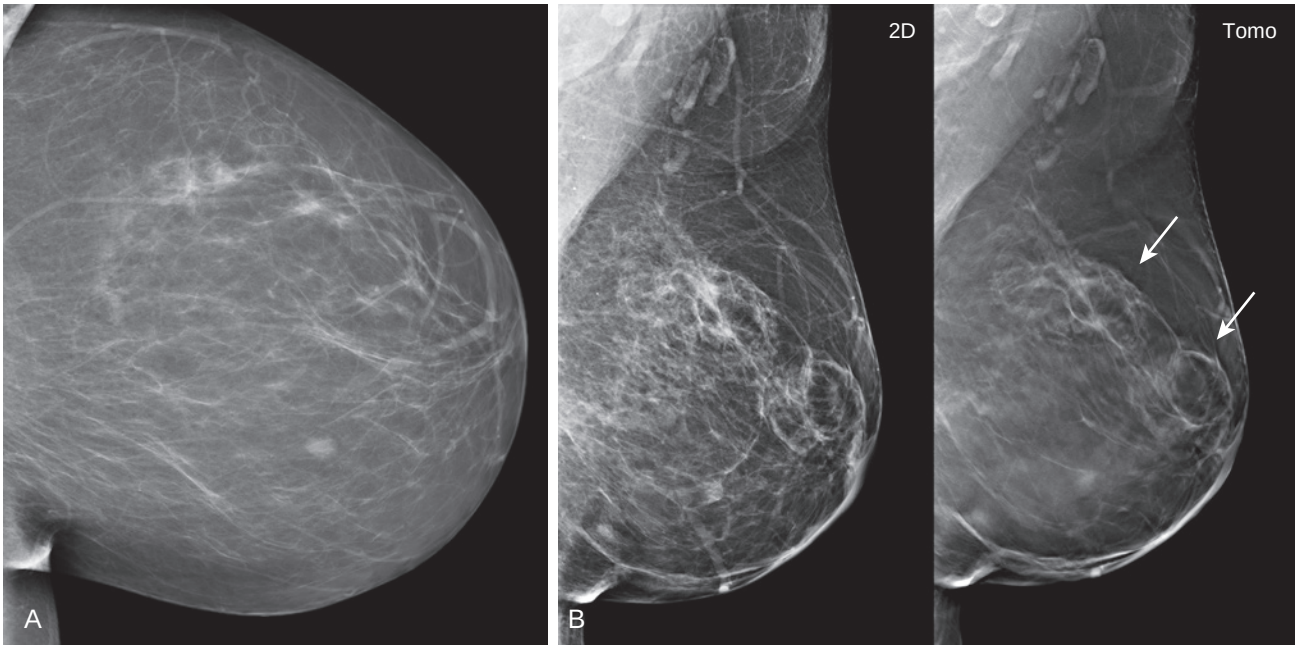


FIG. 12.13 Reduction mammoplasty with fat necrosis. (A) A prereduction, two-dimensional study shows scattered fibroglandular tissue and a benign-appearing mass in the lower breast. **(B)** One year later, postreduction, multiple new variable-sized oil cysts have developed in the upper breast *(arrows)*. Curvilinear scars in the lower breast extend from the nipple toward the chest wall. The previously noted mass remains.

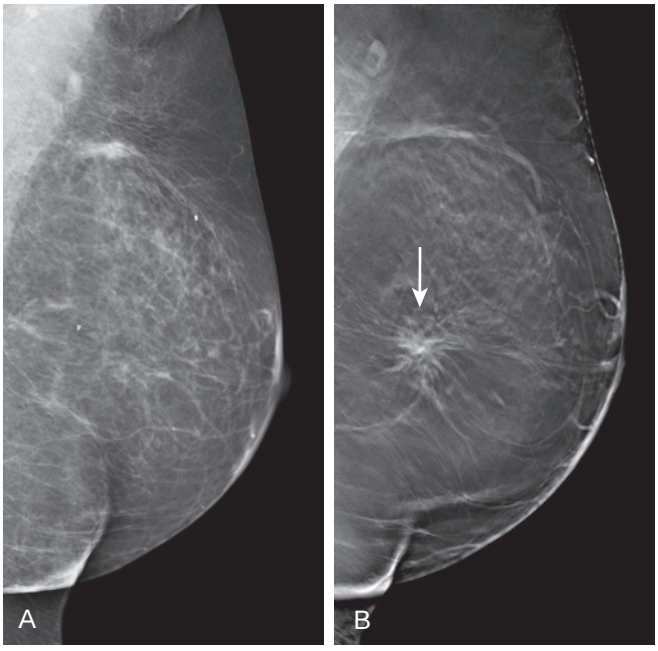


FIG. 12.14 Reduction mammoplasty and subsequent cancer. (A) A 70-year-old woman is 15-year status postreduction mammoplasty. Minimal postsurgical scar and two old biopsy site markers are seen. **(B)** Two years later a new irregular mass has developed, and tomosynthesis exquisitely demonstrates the spiculated margins and entrapped fat *(arrow)*. Final diagnosis is infiltrating carcinoma with ductal and lobular features, 4.2 cm, ER/PR+, Her2−, node negative.

Augmentation

Increasing breast size is most commonly achieved with implants, which may be composed of either saline or silicone, and placed in a retropectoral or subglandular location. Subglandular location of implants often results in marked capsular fibrosis and calcifications over time, which leads to limited mobility of the implant. Implant-displaced views, routinely performed for mammographic imaging of patients with implants, can be very difficult to perform, and even in the best cases a substantial portion of breast tissue may not be completely imaged. Retropectoral implants facilitate implant-displaced views. However, complete assessment of all parenchymal tissue is always somewhat limited, regardless of the implant location.

Because imaging of patients with implants already doubles the radiation dose due to the need for both routine full-breast and implant-displaced views, the additional radiation dose of tomosynthesis may be considered unreasonable. Some facilities use synthesized mammography combined with tomosynthesis for the implant-displaced views, gaining the benefit of tomosynthesis while keeping the radiation dose similar to 2D imaging. Patients with implants often have a small amount of native tissue, which is compressed circumferentially around the implant on mammographic positioning, and can be difficult to assess. Detecting malignancy in women with augmented breasts may be challenging, but tomosynthesis should improve the sensitivity and specificity of interpretation over 2D imaging in such women (Fig. 12.15).

Augmentation with fat grafting, also termed fat transfer or fat injections, is becoming an increasingly common augmentation method. In this technique, fat is withdrawn from elsewhere in the body, usually the abdomen, centrifuged to separate the adipocytes from the oil, and then injected selectively into the tissues of the breast to augment those areas. This forms multiple, rounded, fat-density lesions within the breast (Fig. 12.16).

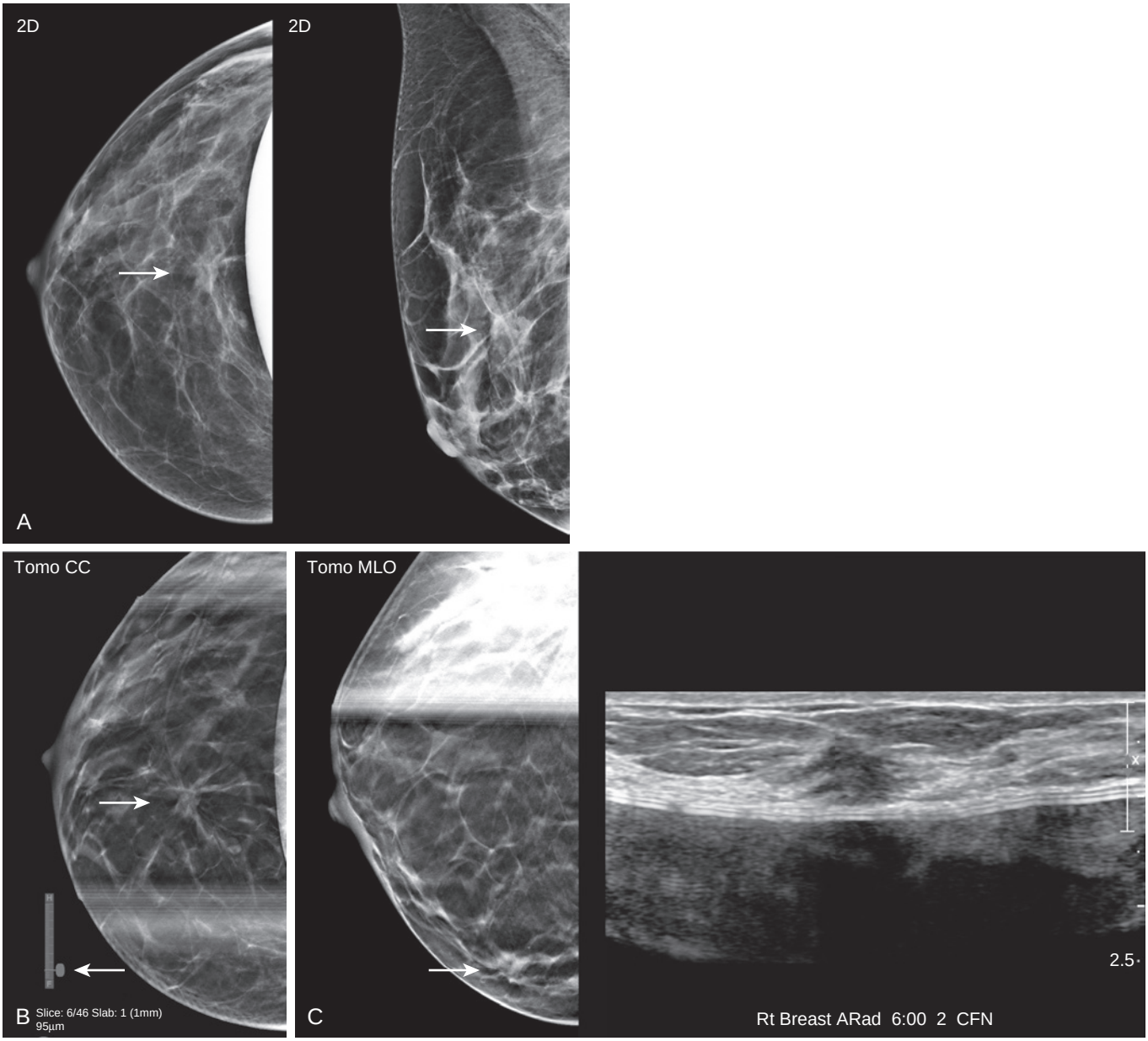


FIG. 12.15 Implant and new breast cancer diagnosis. (A) A 43-year-old woman with retropectoral silicone implants undergoes routine two-dimensional screening mammography. The craniocaudal and mediolateral oblique implant displacement views suggest a central asymmetry, possibly in the upper breast *(arrows)*. **(B)** A diagnostic spot compression craniocaudal tomosynthesis slice identifies an irregular spiculated mass, but in the lower and not the upper breast, as shown by the slice location indicator *(arrows)*. **(C)** The mass is confirmed in the lower breast on a spot compression mediolateral oblique tomosynthesis slice. Targeted ultrasound also shows the irregular hypoechoic mass at the 6-o'clock position, superficial to the implant. Final diagnosis is adenoid cystic carcinoma, 1.5 cm, triple negative, with negative sentinel lymph node biopsy.

Although these should be characteristically benign in appearance, cases associated with developing calcifications may be problematic to differentiate from malignancy. Tomosynthesis can provide yet another level of confidence that the findings are benign, by demonstrating the relationship of the calcifications at the periphery of these oil cysts.

Lumpectomy

The imaging of a postlumpectomy patient may present challenges. Such patients are often extremely anxious, even many years after their initial disease, worrying about recurrence and the traumatic experience of dealing with a previous breast cancer diagnosis. Tomosynthesis improves the imaging assessment of these patients. Not only is the surgical bed assessed more thoroughly with tomosynthesis, the entire imaging process is expedited, reducing the anxiety-provoking time spent in the department. Most patients are relieved by how quickly the entire process goes because extra images are not as commonly required as they are with 2D imaging alone.

The main goal of imaging lumpectomy patients is similar to any patient—finding small cancers at an early and more easily treatable stage. This means assessing both the ipsilateral and contralateral breast for any suspicious finding. With tomosynthesis this is accomplished by obtaining the standard craniocaudal (CC)

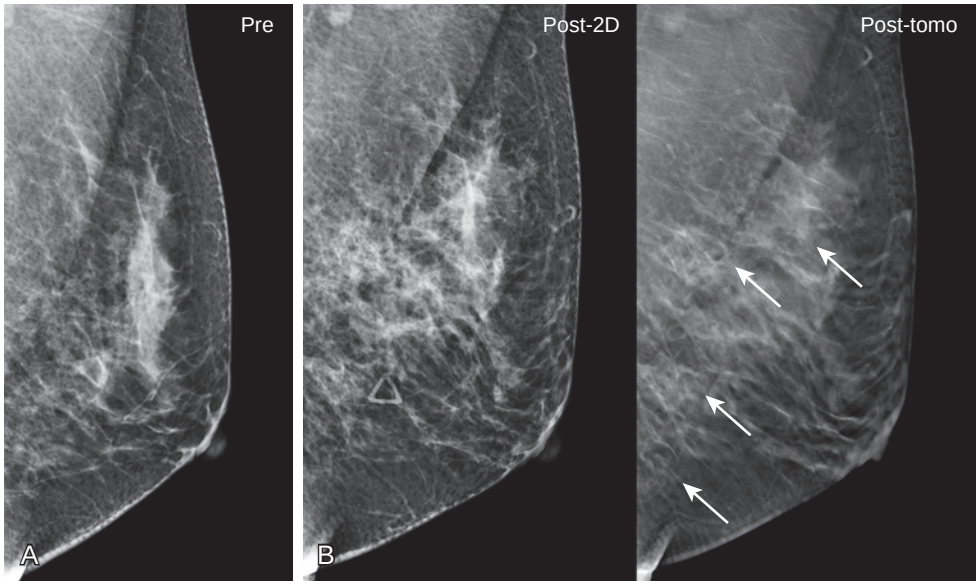


FIG. 12.16 Autologous fat transfer and breast augmentation. (A) A baseline preaugmentation mammogram on a 41-year-old woman shows scattered fibroglandular tissue. **(B)** Ten months following autologous fat injections, the patient reports a palpable region in the lower breast (triangular marker). There is diffuse increased tissue density on the two-dimensional mediolateral oblique view. Tomosynthesis better demonstrates innumerable, small, oval lucencies throughout the posterior breast *(arrows)*. The palpable area corresponds to fat and oil cysts.

and mediolateral oblique (MLO) views. As with all tomosynthesis studies, additional views are not usually needed. Magnification views may be necessary if suspicious calcifications are noted, but spot compression views are of less value. There are varying protocols for imaging postoperative patients with 2D mammography, including imaging every 6 months for several years or routinely performing magnification views of the lumpectomy site. There is little scientific evidence supporting these practices, and with the reduced need for excessive imaging afforded by tomosynthesis, this additional imaging is likely unnecessary. The authors' protocol is to perform the first posttreatment exam, usually at 12 months, as a diagnostic study. At this time, additional imaging of any important finding can be performed. Fortunately, this exam is most often unremarkable and in the authors' practice these patients are advised to return to annual screening mammography.

TOMO TIP ★ Imaging of surgical sites is greatly improved with tomosynthesis compared with 2D imaging, and assessment of typically benign changes over time and detection of recurrences should be enhanced.

Lumpectomy scars are usually more prominent than benign surgical excisional biopsy scars because lumpectomy specimens are often larger and such surgeries are usually followed by radiation therapy, which increases the overall tissue damage and produces more prominent scarring. As with all scars the lumpectomy site visualized on the first postoperative mammogram should appear the most prominent, with subsequent exams showing characteristic maturation—including stability or regression of the scar (Fig. 12.17). Surgical clips may demarcate the lumpectomy bed. Tomosynthesis imaging also frequently shows multiple fatty, round or oval masses within the surgical bed, which may be occult on 2D mammography. Irregular densities associated with the scar are often depicted surrounding these multiple fatty masses on tomosynthesis. Calcifications due to fat necrosis are nicely depicted at the periphery of such fatty masses. Similar postoperative findings may be seen in visualized portions of the axilla following sentinel lymph node biopsy or axillary dissection. Viewing the shape and margins of scar tissue in this fine detail permits a more complete yearly mammographic assessment. The ability to detect recurrences should be enhanced.

Radiation Therapy

Radiation therapy is administered to most patients undergoing partial mastectomy for cancer. The recurrence rate is markedly reduced compared with patients who do not undergo this adjuvant treatment. Postoperative radiation has traditionally been given as whole-breast irradiation, often with a boost to the surgical bed, but increasingly, partial-breast accelerated protocols are being used with success. Knowledge of the type of radiation a patient has received is important because the imaging findings can vary.

Radiation produces edema in the breast tissue in the early phase, which manifests as skin and trabecular thickening producing increased density of the breast tissue. With whole-breast irradiation, such findings are noted throughout the treated breast. Over time, this will progress to fibrosis. In some women the treated breast can sometimes become less dense because fibrocystic changes and other benign processes are less pronounced than in the untreated breast.

There are different techniques for administering accelerated partial-breast irradiation (APBI). All involve irradiation targeted to the lumpectomy bed, the area of breast tissue at greatest risk for local recurrence. Post-APBI changes include focal scar, seroma, focal skin thickening and skin retraction, and fat necrosis (Fig. 12.18). Because more distant breast tissue is spared the effects of radiation, the diffuse edema and diffuse skin thickening seen with whole-breast irradiation do not occur.

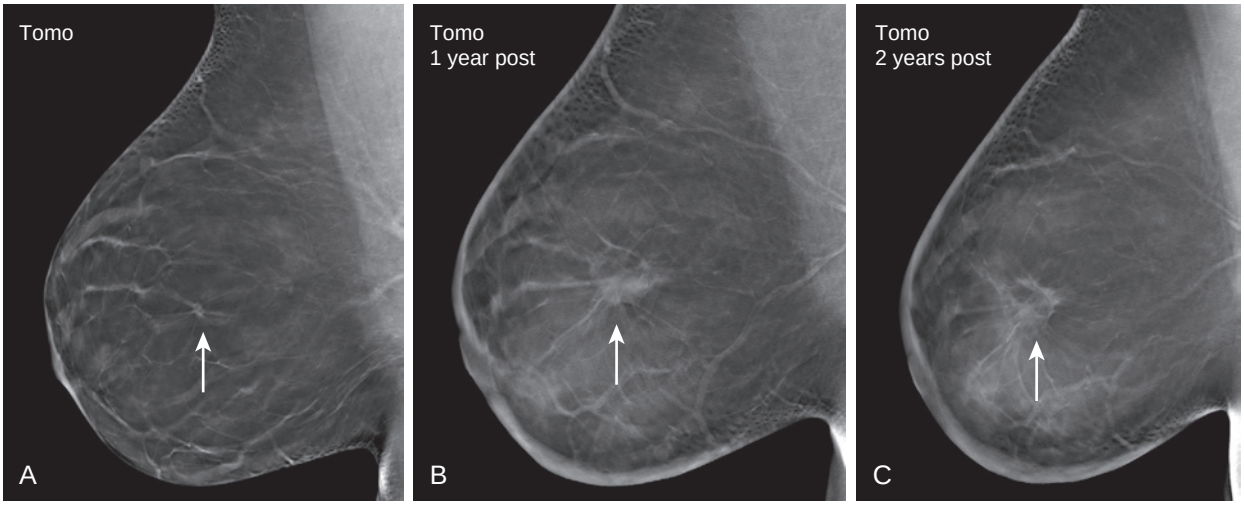


FIG. 12.17 Posttreatment changes following lumpectomy and whole-breast radiation. (A) A 43-year-old woman presents for baseline screening mammogram. Tomosynthesis reveals a small, subtle, spiculated mass in the mid-breast *(arrow)*, representing invasive ductal carcinoma, subsequently treated with lumpectomy and radiotherapy. **(B)** One year posttreatment the oval lumpectomy cavity appears as an area of mixed density with faint surrounding spiculations *(arrow)*. **(C)** Two years posttreatment the lumpectomy cavity is slightly smaller and the spiculations more easily seen *(arrow)*. Diffuse skin thickening secondary to radiation effects persists.

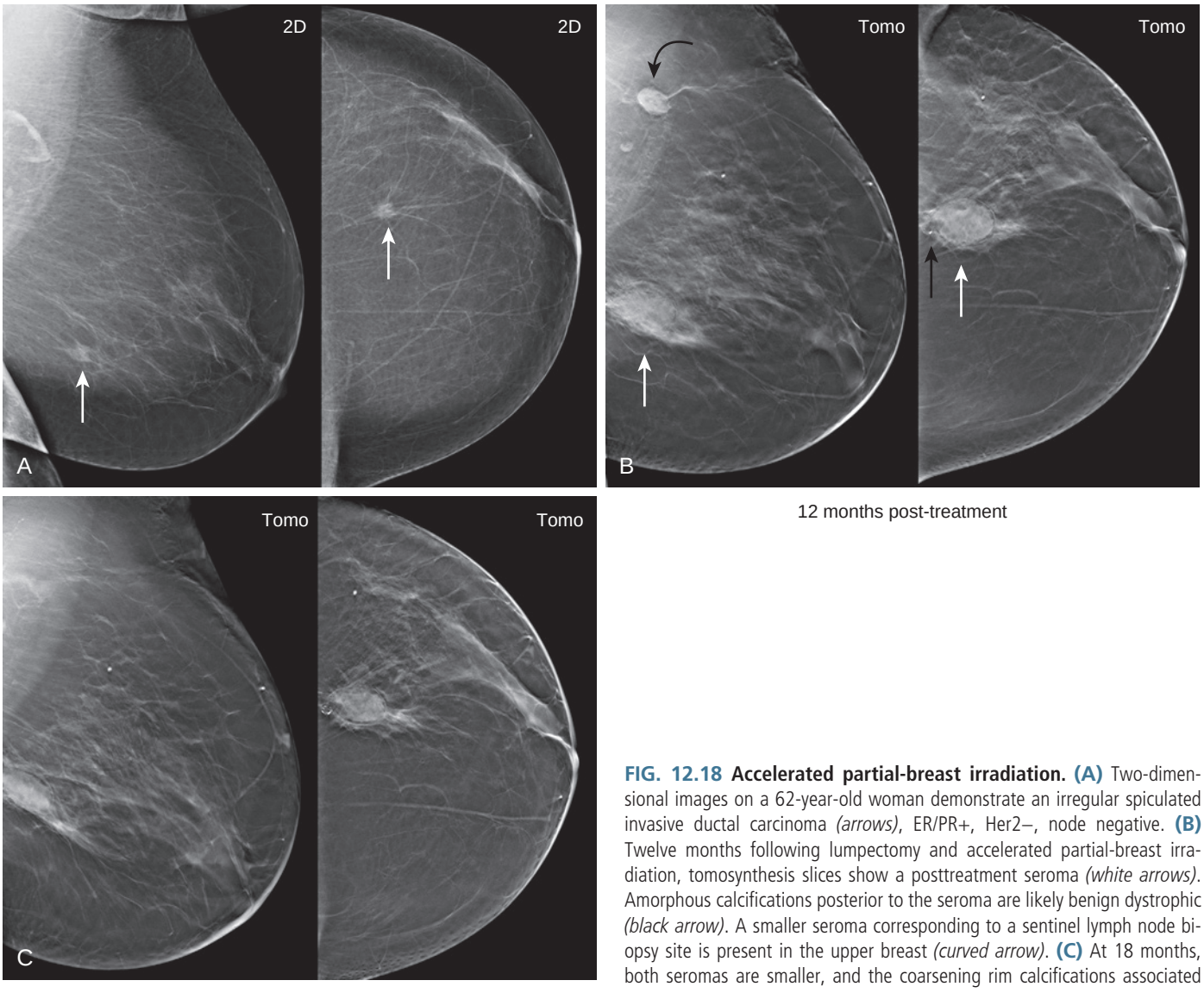


FIG. 12.18 Accelerated partial-breast irradiation. (A) Two-dimensional images on a 62-year-old woman demonstrate an irregular spiculated invasive ductal carcinoma *(arrows)*, ER/PR+, Her2–, node negative. **(B)** Twelve months following lumpectomy and accelerated partial-breast irradiation, tomosynthesis slices show a posttreatment seroma *(white arrows)*. Amorphous calcifications posterior to the seroma are likely benign dystrophic *(black arrow)*. A smaller seroma corresponding to a sentinel lymph node biopsy site is present in the upper breast *(curved arrow)*. **(C)** At 18 months, both seromas are smaller, and the coarsening rim calcifications associated with a small oil cyst have a clearly benign appearance.

Post-Mastectomy Reconstruction

There are several surgical approaches to reconstruction after mastectomy, including total or skin-sparing mastectomy with implant insertion, deep inferior epigastric perforator (DIEP) or transverse rectus abdominis myocutaneous (TRAM) flaps. Women who have undergone mastectomy, with or without reconstruction, do not undergo routine mammographic imaging. Diagnostic breast imaging may be used when there is a clinical problem, including a palpable mass or focal persistent breast pain. Breast sonography is often initially performed because the referring physician requests an ultrasound with the belief that there is no indication for mammography since the breast has been removed. But mammography, and more specifically tomosynthesis, can prove very useful in many cases. In patients presenting with palpable findings, the ability to differentiate areas of fat necrosis from recurrent disease can actually be easier with tomosynthesis than ultrasound. Fat necrosis can have a complex and indeterminate appearance on sonography. The ability to see the characteristic encapsulated fatty lucencies within an area of dense scar on tomosynthesis slices establishes the diagnosis and can provide immediate relief to an anxious patient and reduce the need for close clinical or imaging follow-up of complex ultrasound findings (Fig. 12.19). Such patients presenting with palpable lumps may be best served by including tomosynthesis in the imaging evaluation.

Recurrence

The early detection of recurrent cancer has a significant effect on survival. However, posttreatment changes can present a greater challenge to detecting malignancy. Detecting recurrent cancer while minimizing excessive unnecessary biopsies is desired. Tomosynthesis, with its ability to depict surgical scars better than 2D imaging, should improve the detection of recurrent disease while better demonstrating benign posttreatment findings, such as fat necrosis and fibrosis.

The average time range for local-regional recurrence is 3 to 7 years following lumpectomy. Tomosynthesis reveals most scars to be composed of areas of density (fibrosis) mixed with fatty lucencies. These scars usually shrink and become less prominent or stabilize over time. Nodularity in the margin or new focal density or spiculation in a lumpectomy bed or previously noted seroma should raise suspicion for recurrent malignancy (Fig. 12.20). Tomosynthesis can demonstrate such margin definition far better than 2D mammography alone. This should permit better detection of recurrences at the surgical site compared with 2D imaging.

In addition, a metachronous malignancy can also occur anywhere in either breast, and the entire mammogram should be examined carefully for new findings, including mass, distortion, and/or microcalcifications (Fig. 12.21). Tomosynthesis will help to deconstruct the complex appearance of the postsurgical breast and allow improved detection of second primary cancers.

Specimen Radiography

Specimen radiography using tomosynthesis is not typically necessary. Imaging of surgical specimens is most efficiently accomplished through the use of a small cabinet 2D x-ray system located in the surgical suite. The specimen images are immediately obtained and transmitted to the picture archiving and communication system (PACS), remotely viewed by a radiologist, with results called to the operating room. This approach shortens the time required for imaging and communication and lessens the need for specimen handling. Rarely, a subtle malignant tomographic finding will be excised, and the lesion will not be obvious on the standard 2D specimen radiography. In this scenario, tomosynthesis imaging of the specimen may help to confirm that the lesion was indeed appropriately excised.

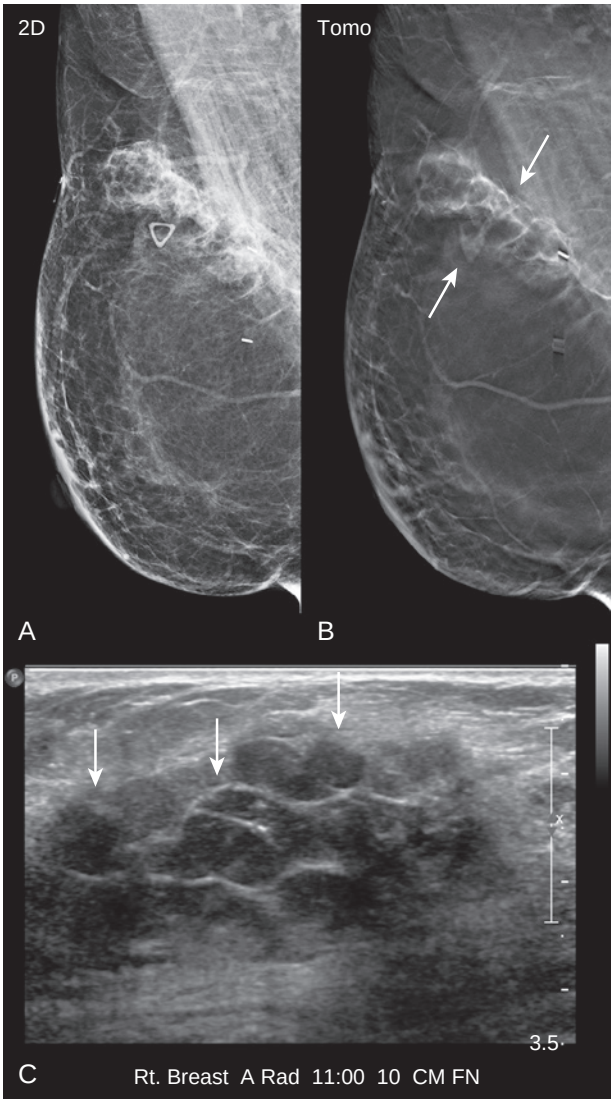


FIG. 12.19 Breast reconstruction following mastectomy and palpable fat necrosis. A 62-year-old woman with a history of invasive carcinoma treated with mastectomy and deep inferior epigastric perforator flap reconstruction reports palpable masses in the upper outer quadrant of the reconstructed breast following surgery. **(A)** A two-dimensional image shows a regional, ill-defined asymmetry with associated oval lucencies corresponding to the palpable finding (triangle skin marker). **(B)** Better seen with tomosynthesis are multiple oval lucencies consistent with benign fat necrosis *(arrows)*. **(C)** On targeted ultrasound the appearance is less specific.

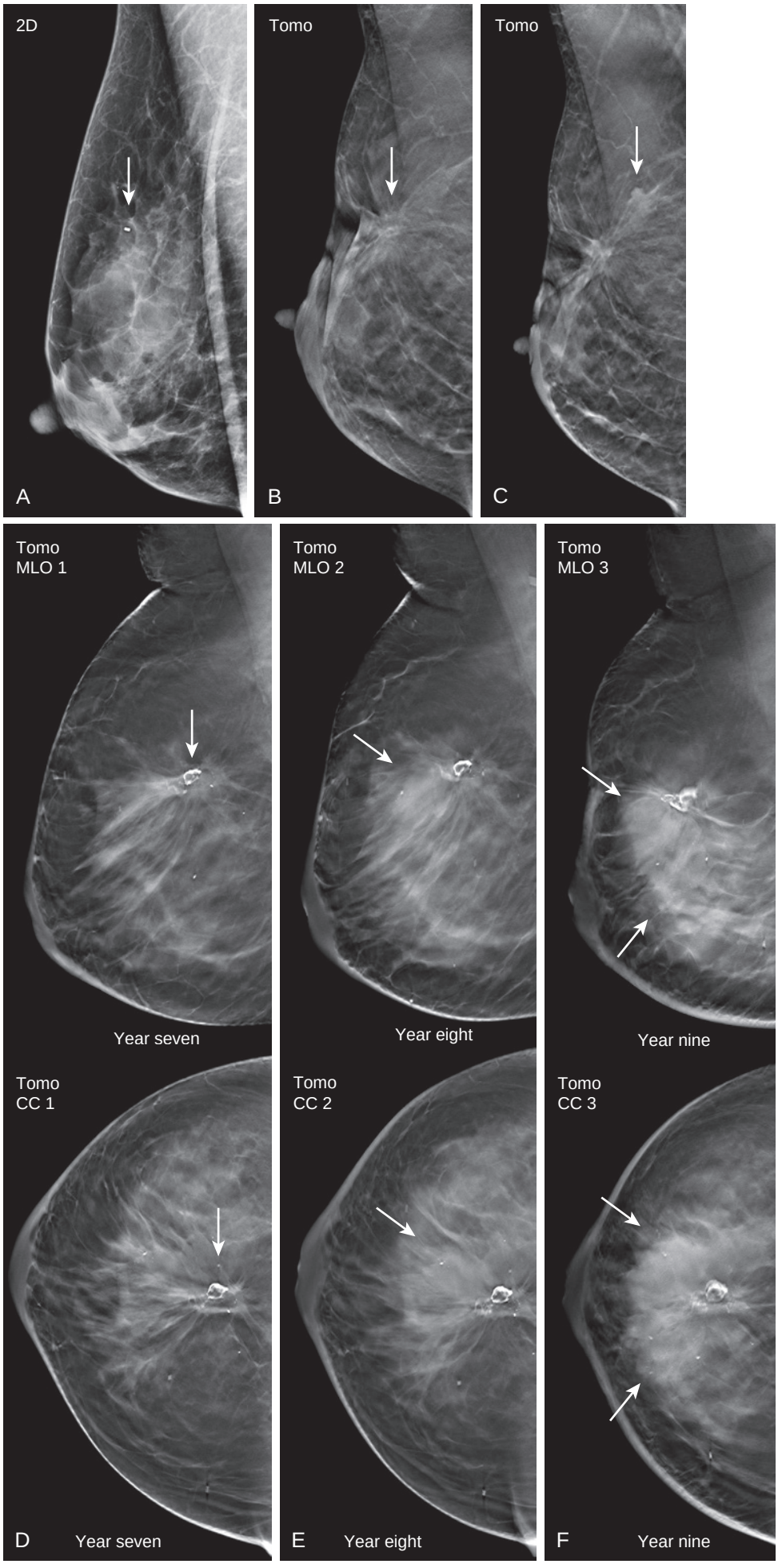


FIG. 12.20 Local recurrence (two examples). Case 1: **(A)** Following neoadjuvant chemotherapy, a clip *(arrow)* marks the site of the treated invasive ductal carcinoma (IDC) in a 37-year-old woman. **(B)** Six months later a baseline postlumpectomy mammogram demonstrates surgical scar *(arrow)*. **(C)** One year later there is a new focal density superior to the lumpectomy site in an area previously seen as fatty tissue *(arrow)*. Diagnosis is recurrent poorly differentiated invasive ductal carcinoma, ER-/PR+/Her2+. Case 2: **(D)** A 65-year-old woman has routine imaging 7 years following lumpectomy and whole-breast radiation for stage II IDC. Scar and associated benign dystrophic calcifications *(arrows)* are seen with tomosynthesis in the mediolateral oblique and craniocaudal projections. **(E)** At year 8, in retrospect, developing density is present anterior to the lumpectomy site *(arrows)*. **(F)** By year nine, there is a large irregular mass with pleomorphic calcifications *(arrows)*, skin thickening, and retraction. Biopsy reveals poorly differentiated IDC, triple negative, with grade 3 ductal carcinoma in situ.

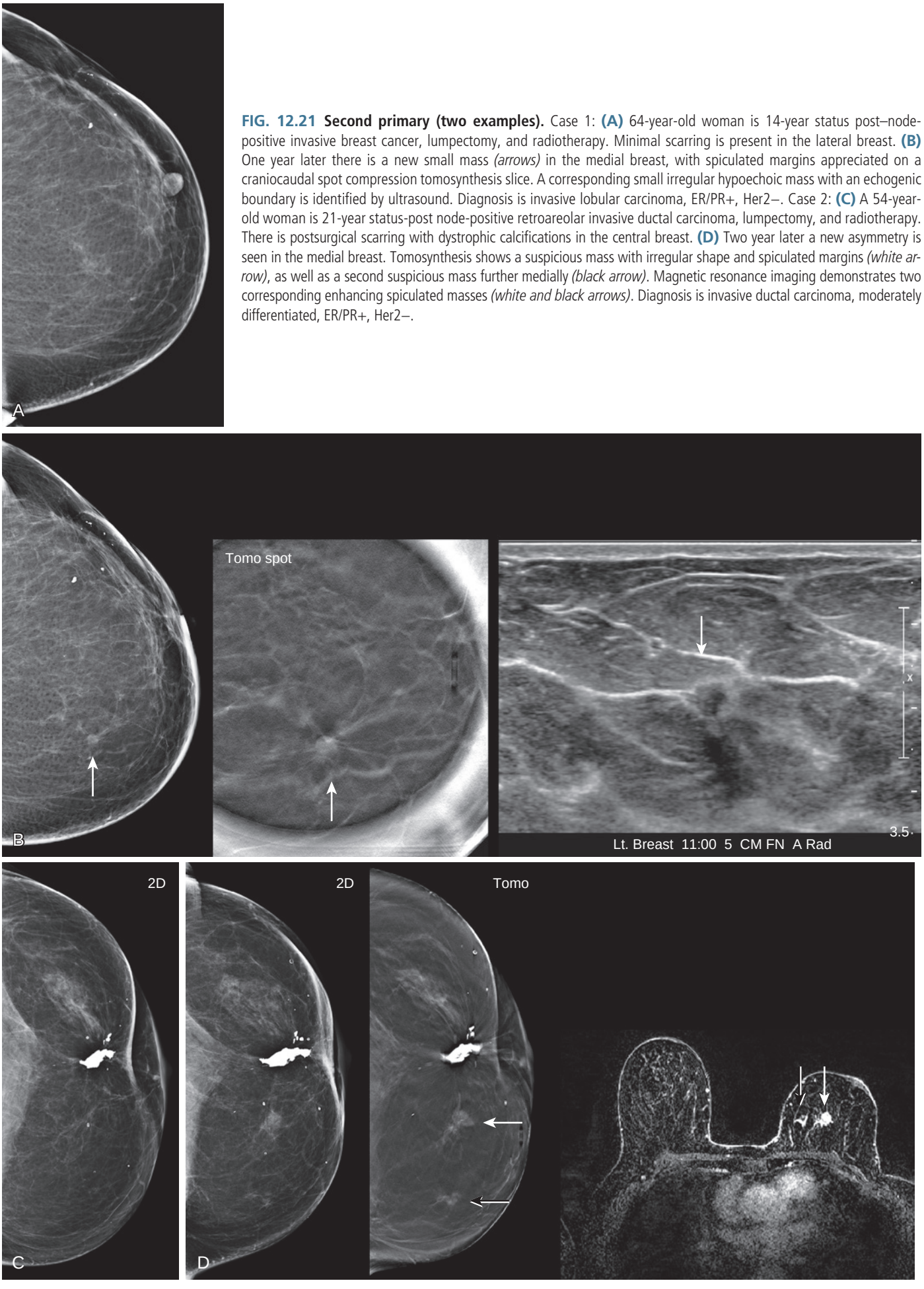


FIG. 12.21 Second primary (two examples). Case 1: **(A)** 64-year-old woman is 14-year status post–node-positive invasive breast cancer, lumpectomy, and radiotherapy. Minimal scarring is present in the lateral breast. **(B)** One year later there is a new small mass *(arrows)* in the medial breast, with spiculated margins appreciated on a craniocaudal spot compression tomosynthesis slice. A corresponding small irregular hypoechoic mass with an echogenic boundary is identified by ultrasound. Diagnosis is invasive lobular carcinoma, ER/PR+, Her2−. Case 2: **(C)** A 54-year-old woman is 21-year status-post node-positive retroareolar invasive ductal carcinoma, lumpectomy, and radiotherapy. There is postsurgical scarring with dystrophic calcifications in the central breast. **(D)** Two year later a new asymmetry is seen in the medial breast. Tomosynthesis shows a suspicious mass with irregular shape and spiculated margins *(white arrow)*, as well as a second suspicious mass further medially *(black arrow)*. Magnetic resonance imaging demonstrates two corresponding enhancing spiculated masses *(white and black arrows)*. Diagnosis is invasive ductal carcinoma, moderately differentiated, ER/PR+, Her2−.

Summary

Postoperative changes of the breast are routinely encountered on screening and diagnostic mammogram examinations. Such findings are usually more obvious with tomosynthesis, regardless of breast density, and easily recognized as benign when correlated with clinical history and prior imaging studies. Because benign scars and other associated findings should remain stable or regress over time, any increasing distortion, developing asymmetry, new mass, or changing calcifications mandates further evaluation. In the authors' experience, tomosynthesis improves visualization of surgical sites, and more accurately demonstrates both benign and malignant processes.

CHAPTER 13

Tomosynthesis in the Male Breast

Liane E. Philpotts

Male patients are not uncommon in breast imaging centers, where they usually present with clinical symptoms, including breast lumps, pain, or focal swelling. Men are usually distressed by these symptoms and are uncomfortable while in the department. Expediting the imaging process and communicating the results as quickly as possible are desirable.

Tomosynthesis can be very helpful in imaging the male patient because it can help to differentiate glandular tissue from true masses, similar in women's breasts. By far the most common finding among men presenting for breast imaging is gynecomastia. Breast cancer in men is uncommon, accounting for less than 1% of all breast cancer and less than 1% of all cancer in men. Differentiating gynecomastia from breast cancer is the main objective when imaging male breasts. There are also other specific diagnoses that may occasionally be encountered, such as lipomas, lymph nodes, sebaceous or epidermal inclusion cysts, hematomas, abscesses, fat necrosis, and malignant findings secondary to lymphoma or metastases.

Men do not routinely undergo mammographic screening. However, certain exceptions include those with a personal history of breast cancer (postmastectomy), a history of mantle radiation in childhood or young adulthood, a known genetic mutation (particularly BRCA 1 or 2 carriers), as well as male-to-female transsexuals receiving high-dose estrogen and men with rare syndromes known to increase breast cancer risk (eg, Klinefelter syndrome). For all these individuals the lifetime risk of breast cancer is high enough to justify annual mammography screening (Fig. 13.1). As awareness of individual and familial genetic profiles increases, it is possible that more men may seek breast cancer screening.

Imaging the Male Patient

Mammography is the main imaging modality for evaluating male patients. Bilateral mammography in the conventional craniocaudal (CC) and mediolateral oblique (MLO) projections is usually performed. This permits assessment of bilaterality and symmetry of findings, which is often the key to making a diagnosis. In young men under 35 years of age, ultrasound could be considered initially and mammography performed only if the mammographic findings are inconclusive or suspicious.

The normal male mammogram typically demonstrates fatty tissue, a minimal amount of subareolar tissue, intramammary or axillary lymph nodes, and prominent pectoralis muscles. Tomosynthesis would likely not be beneficial if most men presenting for imaging had this normal mammographic appearance because tomosynthesis does not add much benefit to the assessment of fatty tissue over two-dimensional (2D) mammography alone (Fig. 13.2). However, because most men undergoing mammography are symptomatic and often present with gynecomastia, a normal mammographic appearance is not common; thus tomosynthesis often can be helpful.

Most clinically palpable lumps in men occur near the nipple, and compression of this region may be suboptimal, especially if the patient has large pectoralis muscles. As a result, visualization of the subareolar area may be compromised. Clumped subareolar density may make it difficult to clearly differentiate an underlying mass from gynecomastia. Tomosynthesis allows improved assessment of the breast tissue due to the ability to scroll and visualize the tissue in thin slices (Fig. 13.3). If the pectoralis muscles are particularly prominent, additional views of the anterior breast, excluding the pectoralis muscles, can be performed. Gynecomastia has a similar appearance to fibroglandular tissue in a female breast and can be more confidently diagnosed with tomosynthesis. In addition, a focal mass can be more easily identified and better differentiated from adjacent tissue.

When imaging men presenting with palpable lumps eccentric to the nipple, placement of a skin marker overlying the abnormality is very important to permit better assessment of the area of clinical concern. Breast cancer and gynecomastia may coexist, particularly in older men, and identifying a suspicious mass in a background of bilateral gynecomastia can be challenging. In addition, isodense or hypodense masses, such as lipomas, may be difficult to detect. Occasionally, spot compression views with tomosynthesis may be necessary to further evaluate a focal area of concern. Tomosynthesis can also enhance the identification and characterization of a mass in the retroareolar region in men with gynecomastia.

Gynecomastia

Clinically, male patients usually present with symptoms of tenderness, swelling, and/or a subareolar lump. These symptoms are most commonly unilateral, but occasionally may be bilateral. Tenderness is usually the prime complaint and source of distress. Due to the troubling symptoms, the time frame of clinical complaints is usually relatively recent onset. Occasionally men will have had symptoms for months or even years. The appearance of gynecomastia varies with duration of symptoms. Careful clinical history, including medications, is necessary to help make the diagnosis. There are many causes of gynecomastia, including medications, street/illicit drugs and alcohol, and medical conditions such as liver disease. However, in some cases a definitive etiology is not identified.

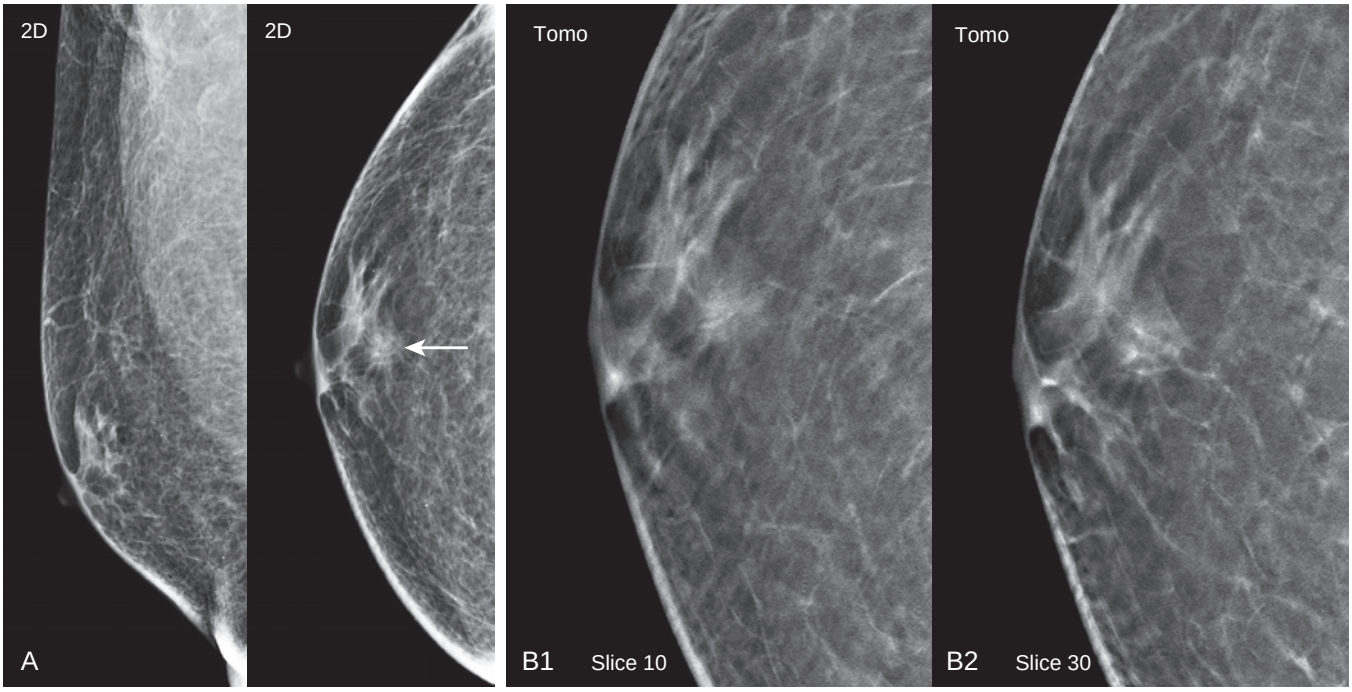


FIG. 13.1 Right breast screening. An 82-year-old man status post–left mastectomy 15 years prior presents for annual screening of the right breast. **(A)** Two-dimensional mammogram shows mild gynecomastia and a questionable spiculated asymmetry in the subareolar area on the craniocaudal view *(arrow)*. **(B)** Tomosynthesis slice images from the lower **(B1)** and upper **(B2)** halves of the breast help to establish that the asymmetry represents superimposed tissue.

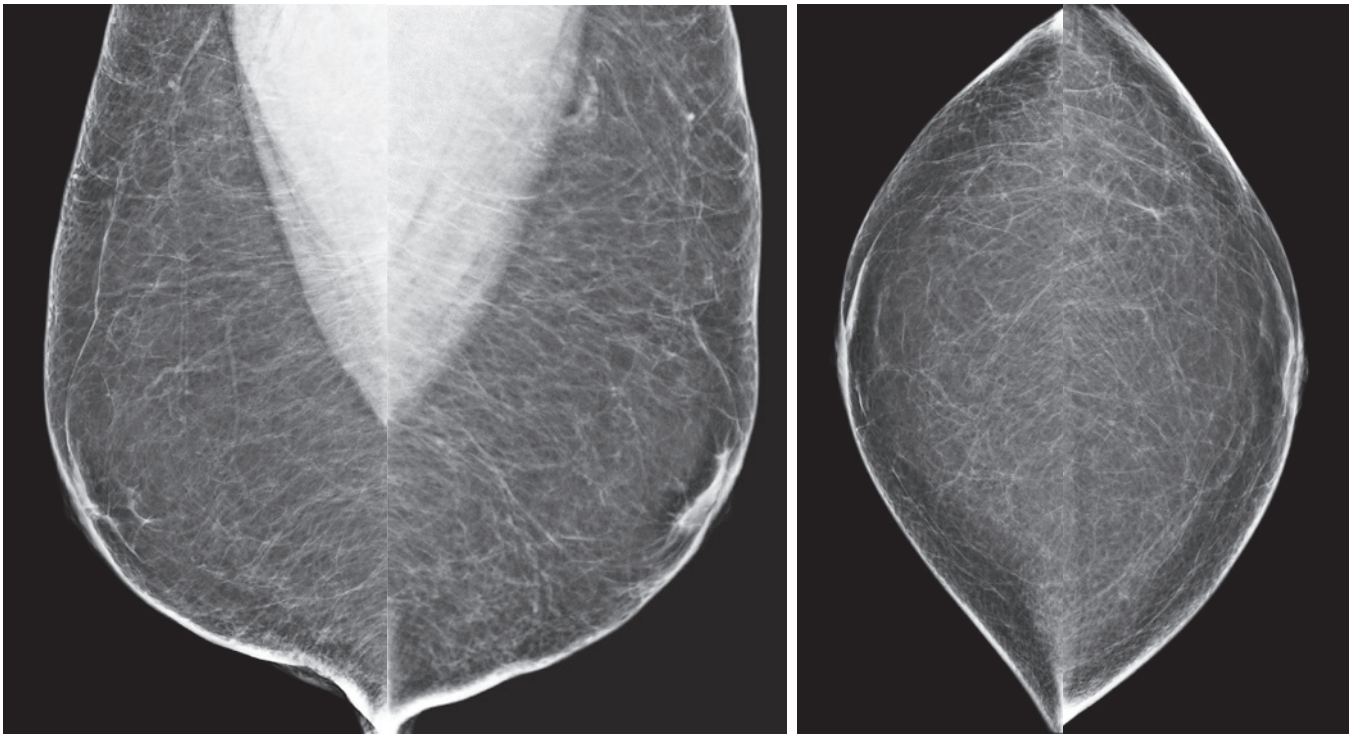


FIG. 13.2 Normal male mammogram. A 43-year-old man presents for imaging after his physician questioned a palpable finding in the right breast. No discrete lumps were felt on the day of the exam. The breast tissue is predominantly fatty with no abnormality seen in either breast.

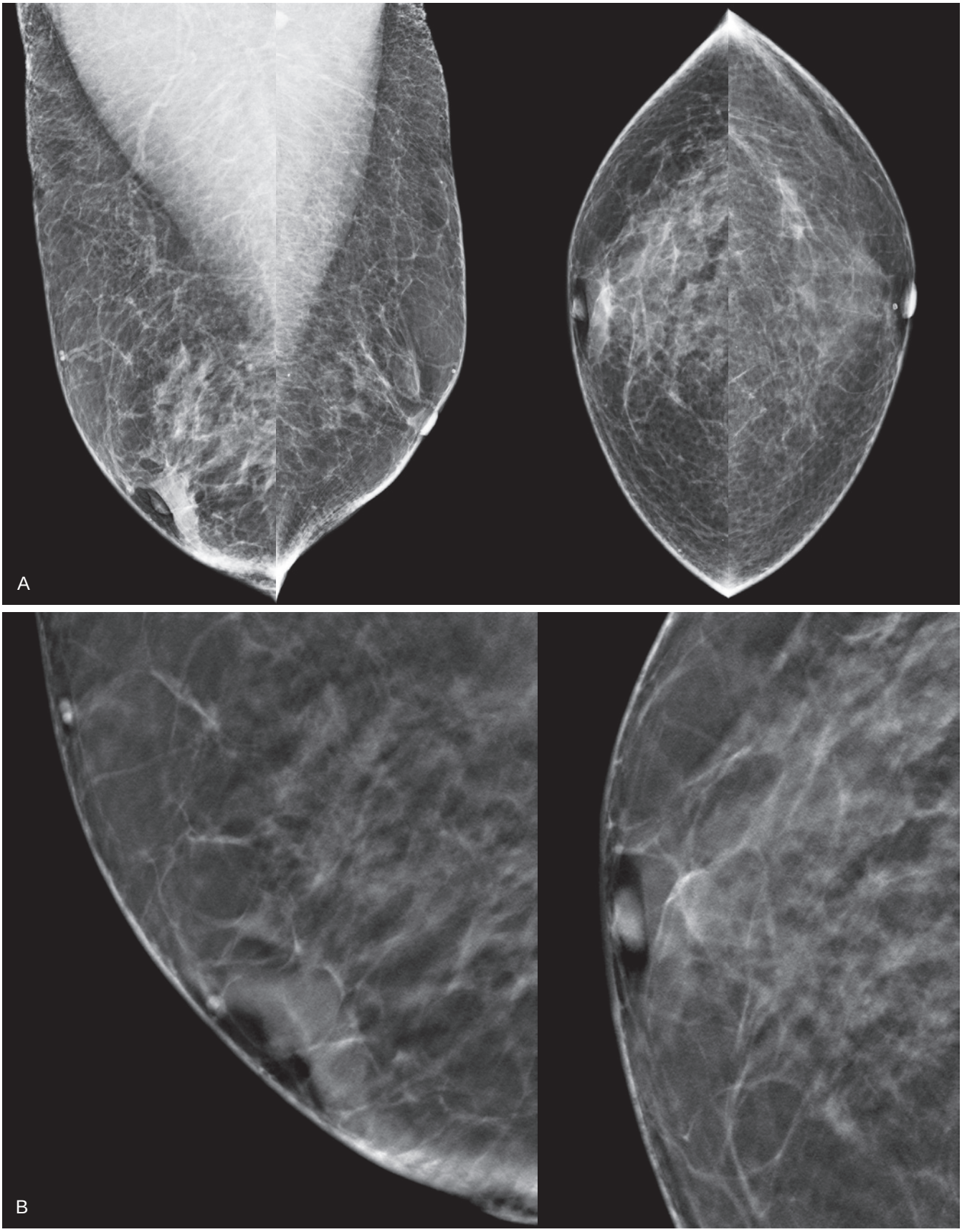


FIG. 13.3 Gynecomastia. An 85-year-old man with a history of prostate cancer presents with induration of the right breast. **(A)** Examination indicates gynecomastia in both breasts, right greater than left, causing nipple retraction during mammographic compression. **(B)** Mediolateral oblique and craniocaudal tomosynthesis slice images show normal tissue in the right breast subareolar area, excluding an underlying mass.

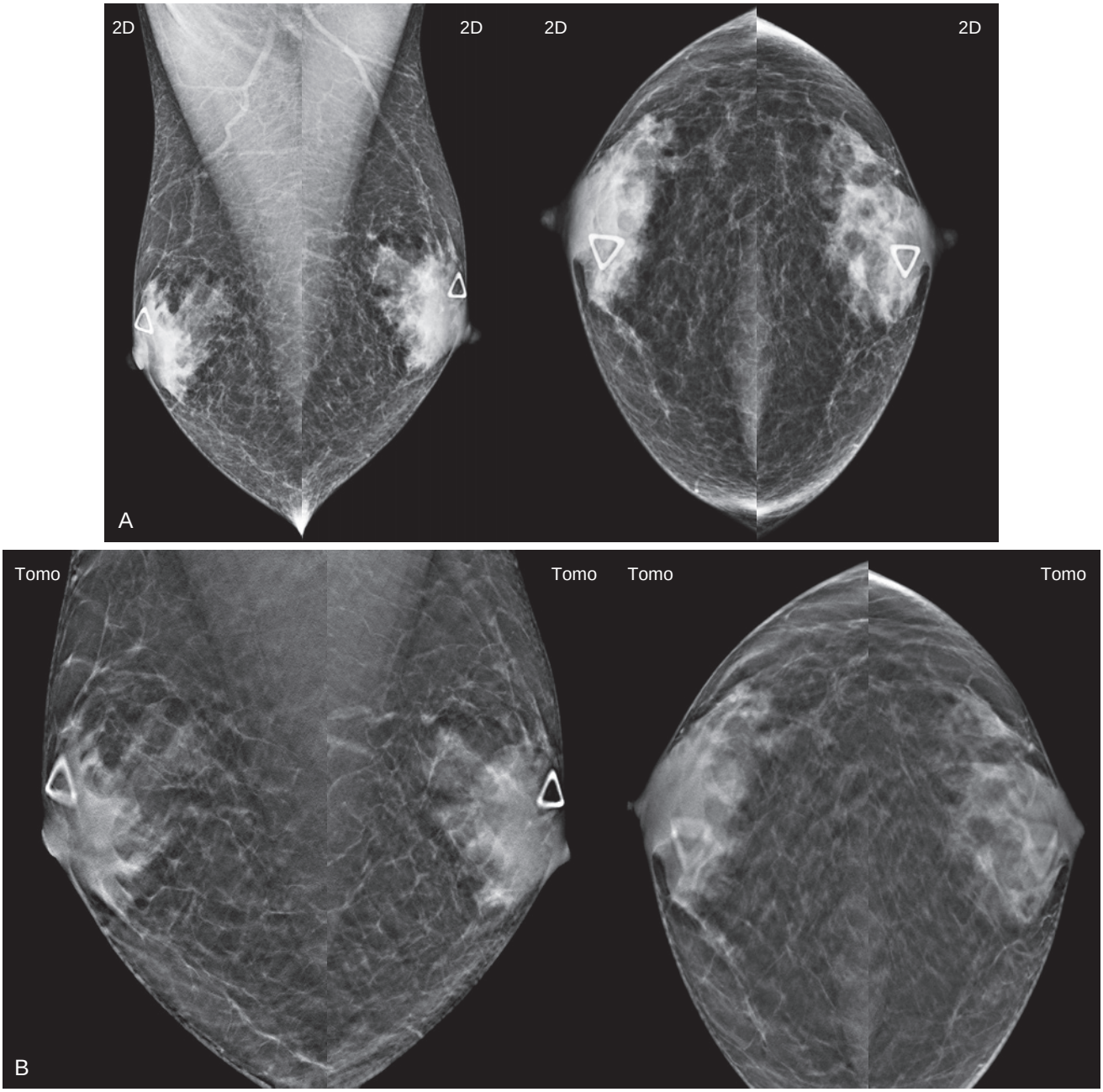


FIG. 13.4 Diffuse gynecomastia. A 67-year-old man on long-term spironolactone treatment presents with bilateral breast pain and lumps. **(A)** Two-dimensional images show very prominent dense tissue bilaterally, making exclusion of an underlying mass difficult. **(B)** Tomosynthesis images permit assessment of the tissue as normal dense fibrotic tissue with no focal abnormality detected such that further evaluation with ultrasound was not necessary.

Histologically, gynecomastia is a proliferation of the fibroglandular elements of the breast. The ductal tissue is rudimentary in men, but with stimulation due to hormonal imbalance of testosterone and estrogen or other exogenous factors, this tissue can proliferate. This most often results in prominent ducts directly behind the nipple. Men do not have lobules, and thus breast cysts and invasive lobular cancer are very rare.

Mammographically, gynecomastia presents as a focal tissue density originating and branching out for a variable extent from the subareolar area. In some cases, glandular proliferation can extend for several centimeters or more and be so extensive as to mimic a moderately dense female breast (Fig. 13.4). Gynecomastia is usually bilateral, although commonly markedly asymmetric, with the symptomatic breast showing more profound changes. The mammographic density should have the appearance of fibroglandular tissue, similar to the female breast. Tomosynthesis is especially helpful in demonstrating the density to be fibroglandular in origin because it can better depict the proliferative fibroglandular tissue blending into the surrounding fat. Different types of gynecomastia have been described: nodular, dendritic, and diffuse. The earliest phase is nodular gynecomastia, with a density seen radiating from the subareolar areas (Fig. 13.5). Over time the amount of fibrotic tissue proliferates, and the chronic dendritic pattern appears as a radiating pattern similar, as the name

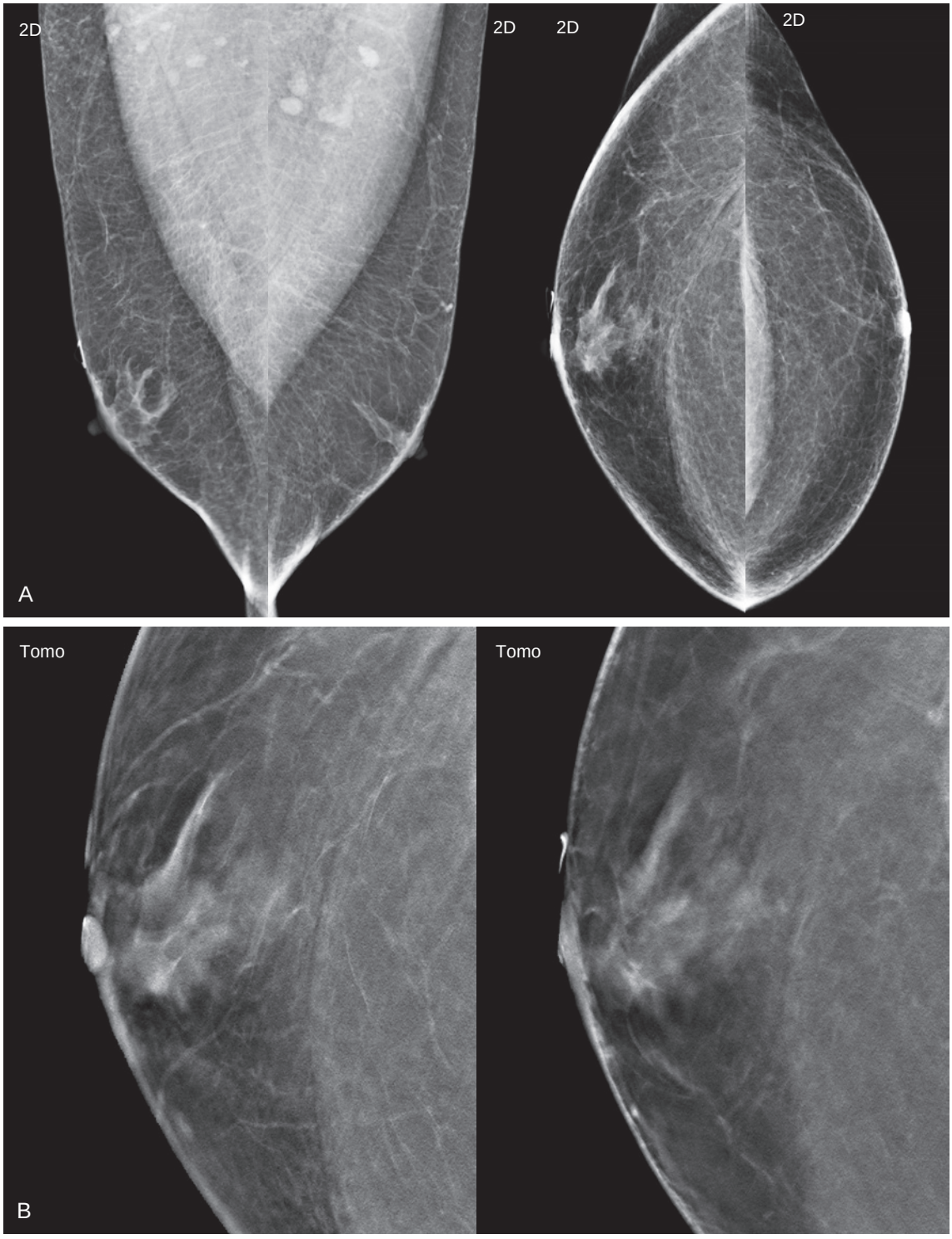


FIG. 13.5 Nodular gynecomastia. A 57-year-old man presents with a right breast lump. **(A)** Bilateral mild gynecomastia is noted on the 2D mammogram, more pronounced on the right and corresponding to the palpable area. **(B)** Two tomosynthesis slices in the craniocaudal projections demonstrate subareolar tissue, which superimposes to make the asymmetry in the 2D image.

implies, to tree branches (Fig. 13.6). Diffuse gynecomastia, seen in individuals receiving exogenous estrogen treatment, such as treatment for prostate cancer or transgender feminization, appears as florid, dense bilateral tissue density.

TOMO TIP ★ Tomosynthesis can better differentiate the fibroglandular tissue of gynecomastia from an underlying mass than 2D mammography can, and this may result in additional imaging not being required.

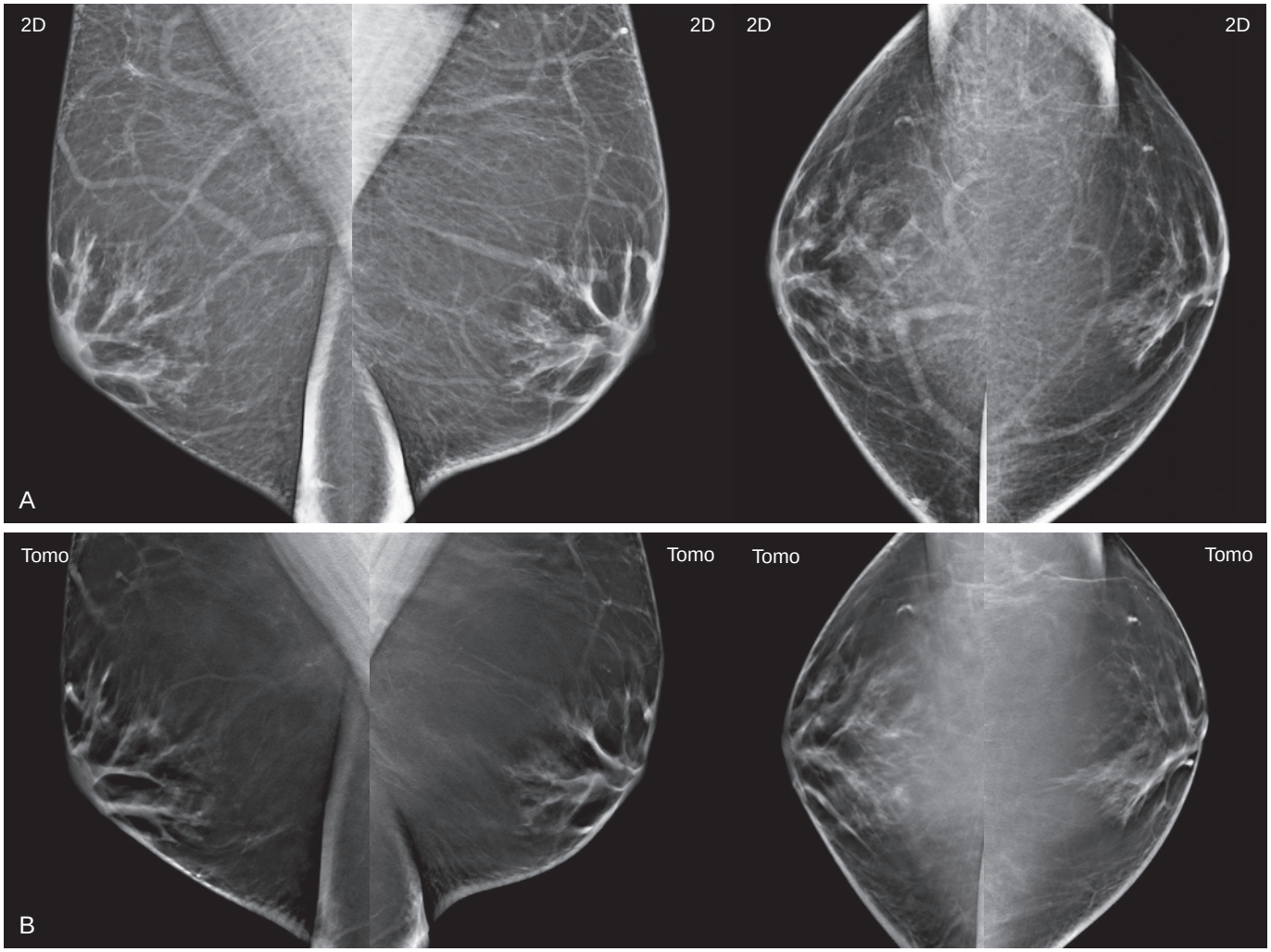


FIG. 13.6 Dendritic gynecomastia. A 50-year-old man with long-standing type 2 diabetes and hypertension (on metformin, lisinopril, and hydroclhlorothiazide) presents with bilateral breast lumps. **(A)** Two-dimensional mammogram shows a radiating dendritic gynecomastia pattern, which is exquisitely demonstrated on the **(B)** tomosynthesis slices.

Occasionally a true mass may be difficult to detect if surrounded by very dense fibroglandular tissue. With 2D imaging, additional imaging with spot compression views is often necessary. Ultrasound is often needed to exclude an underlying mass. Gynecomastia can have varying appearances on ultrasound, depending on the evolution of the disease. Assessment of the subareolar area on ultrasound, with the accompanying nipple artifact, can often be difficult and therefore limited. Although early disease may show hypoechoic tissue and radiating ducts without posterior shadowing, with the increasing fibrosis seen in later disease, intense shadowing can be encountered (Fig. 13.7). In a study by Chen and Slanetz 85% of men presenting with gynecomastia underwent ultrasound following mammography, which in most cases was felt to be unhelpful and sometimes led to unnecessary biopsy. Tomosynthesis can help by more confidently assessing the mammographic density as tissue and excluding an underlying mass; therefore it can often help to avoid the need to perform an ultrasound.

Breast Cancer

Breast cancer must be excluded for any man presenting with a palpable mass or other suspicious symptoms. Clinically a palpable lump eccentric or near the nipple is the most common presentation of malignancy, although other symptoms, such as nipple changes and skin thickening, can also occur (Fig. 13.8). The mean age of presentation of breast cancer in men is 68 years, approximately a decade later than in women. However, certain uncommon conditions may predispose some men to developing cancer at a younger age (Fig. 13.9). Most breast cancer in men is invasive ductal carcinoma with or without ductal carcinoma in situ (DCIS). Pure DCIS, inflammatory carcinoma, Paget disease, papillary carcinoma, and invasive lobular carcinoma are rare. Although typically thought to develop eccentric to the nipple, breast cancer generally arises in the subareolar ducts, so differentiation from gynecomastia is absolutely necessary.

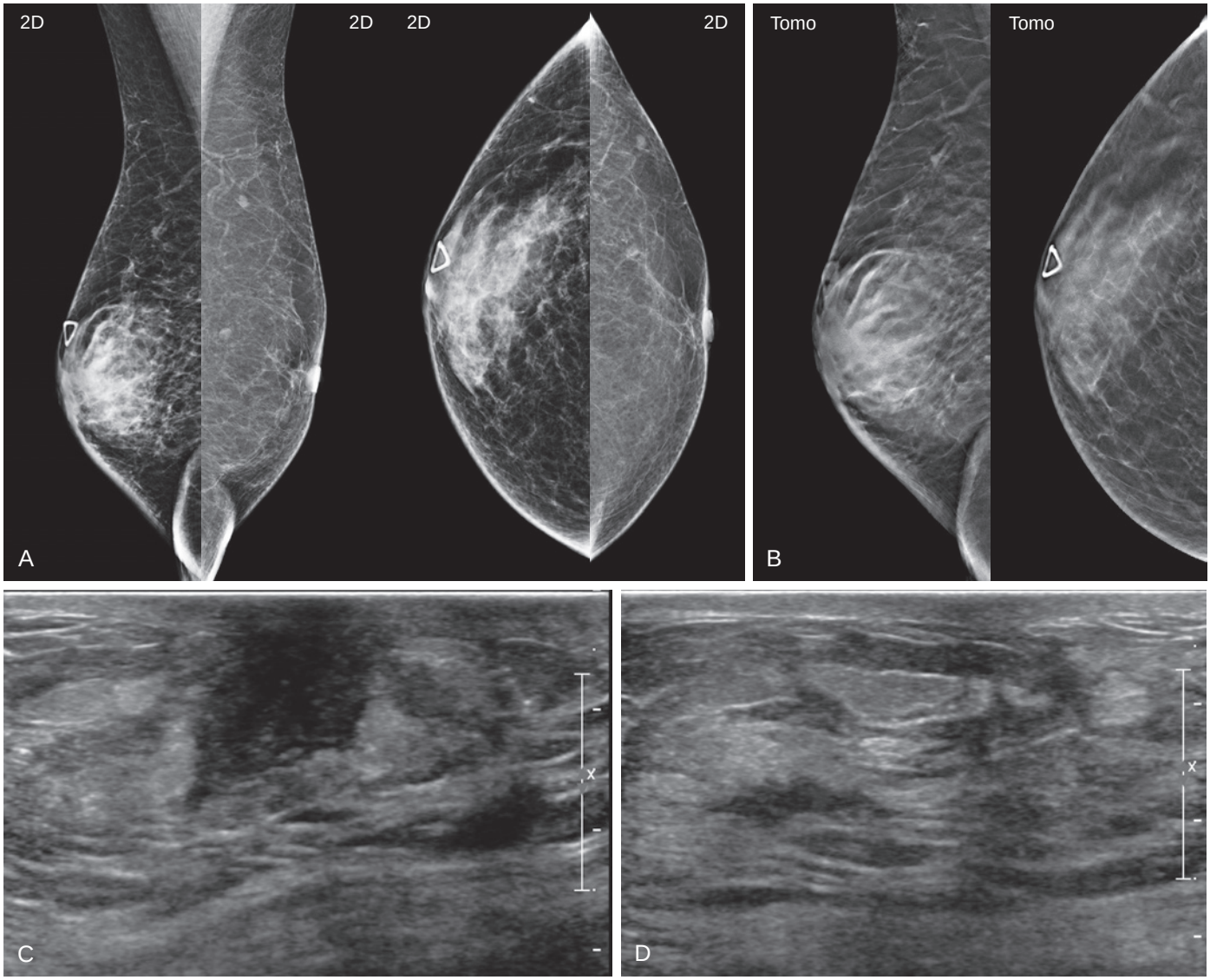


FIG. 13.7 Right gynecomastia. A 66-year-old man presents with right breast swelling and tenderness. **(A)** There is marked gynecomastia of the right breast, with associated skin and trabecular thickening. **(B)** Tomosynthesis slice images in the mediolateral oblique and craniocaudal projections show dense tissue in a dendritic pattern. **(C and D)** Ultrasound shows a hypoechoic area in the subareolar region **(C)** consistent with focal glandular proliferation and mixed glandular tissue in the upper right outer quadrant **(D)**.

The imaging features of breast cancer in men appear similar to those of invasive cancers in women. The usual presentation is an irregular mass with indistinct or spiculated margins, corresponding to the palpable lump. Calcifications can be found within the mass but rarely are the sole mammographic feature. Although most breast cancers in men are obvious, excluding a mass on mammography can be challenging in those men with moderate-to-marked gynecomastia. Tomosynthesis imaging aids in differentiating the more common gynecomastia because scrolling through the tissue slices permits a better assessment of whether it is fibroglandular tissue, a suspicious mass, or both. Tomosynthesis images depict the irregular shape and indistinct or spiculated borders, better differentiating a mass from the surrounding tissues.

In addition, cancers may present as cystic lesions appearing as a circumscribed mass. Cysts are very uncommon in men, and therefore ultrasound of a circumscribed mass is warranted. Some intraductal carcinomas may present as a complex cystic and solid mass (Fig. 13.10). The differential diagnosis for solid masses in men is limited because men usually do not develop the common, benign, palpable lesions found in women, such as fibroadenomas. Ultrasound-guided needle biopsy should be considered for most solid or complex masses presenting in men. Assessment of the axilla, on tomosynthesis and/or ultrasound, should be included in any patient with a suspicious breast mass because involved lymph nodes occur in approximately 50% of men presenting with breast cancer.

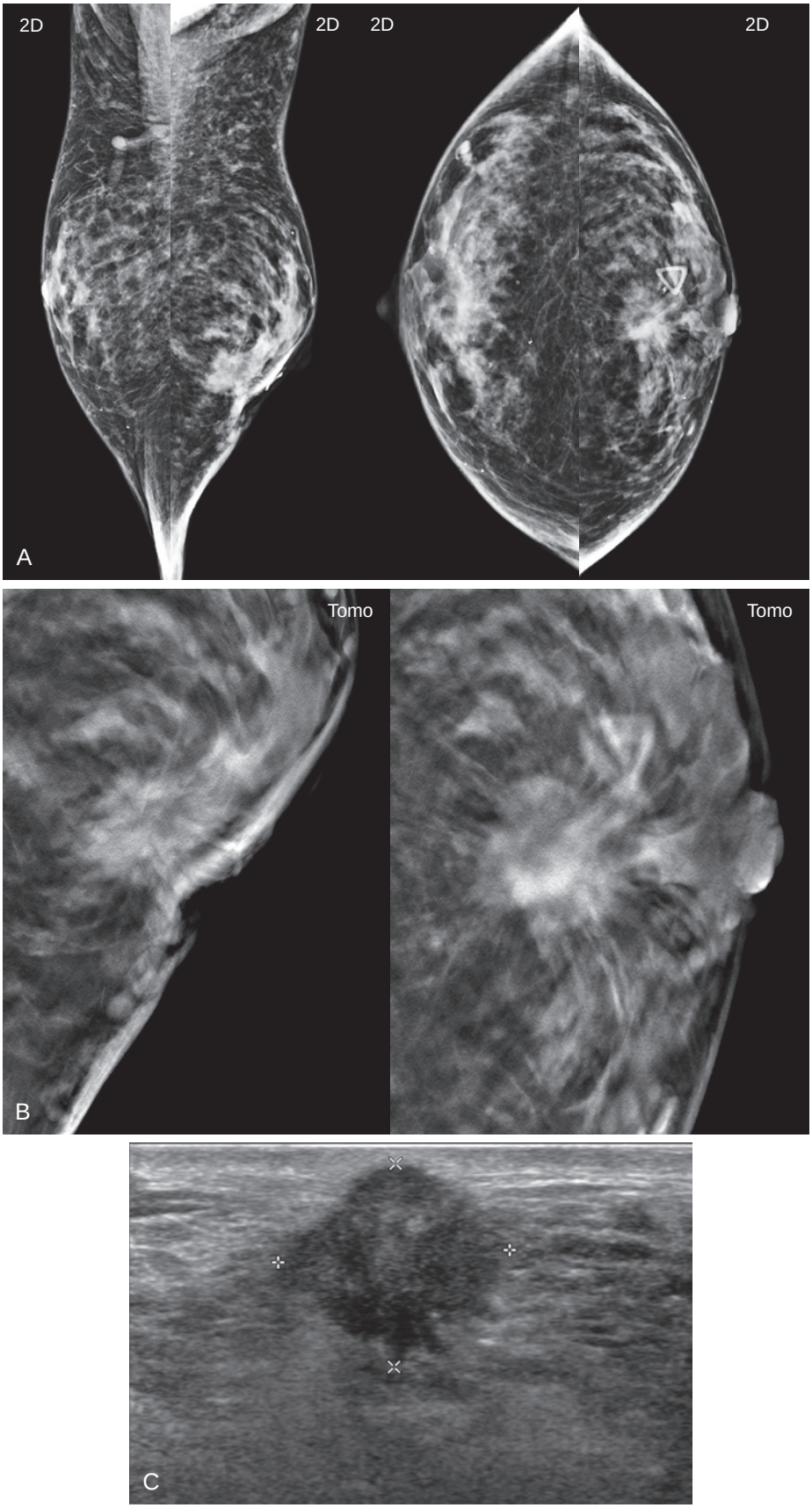


FIG. 13.8 Breast cancer. An 82-year-old man presents with a palpable lump in the left breast. **(A)** 2D mammogram reveals diffuse gynecomastia bilaterally. A spiculated mass corresponding to the palpable finding is noted in the inferior left breast, with associated skin thickening and retraction. **(B)** Tomosynthesis mediolateral oblique and craniocaudal slice images demonstrate the extensive spiculations. **(C)** Ultrasound shows a corresponding 2.5-cm irregular mass with spiculated margin. Ultrasound-guided core needle biopsy showed poorly differentiated invasive and in situ ductal carcinoma, ER/PR+, Her2−.

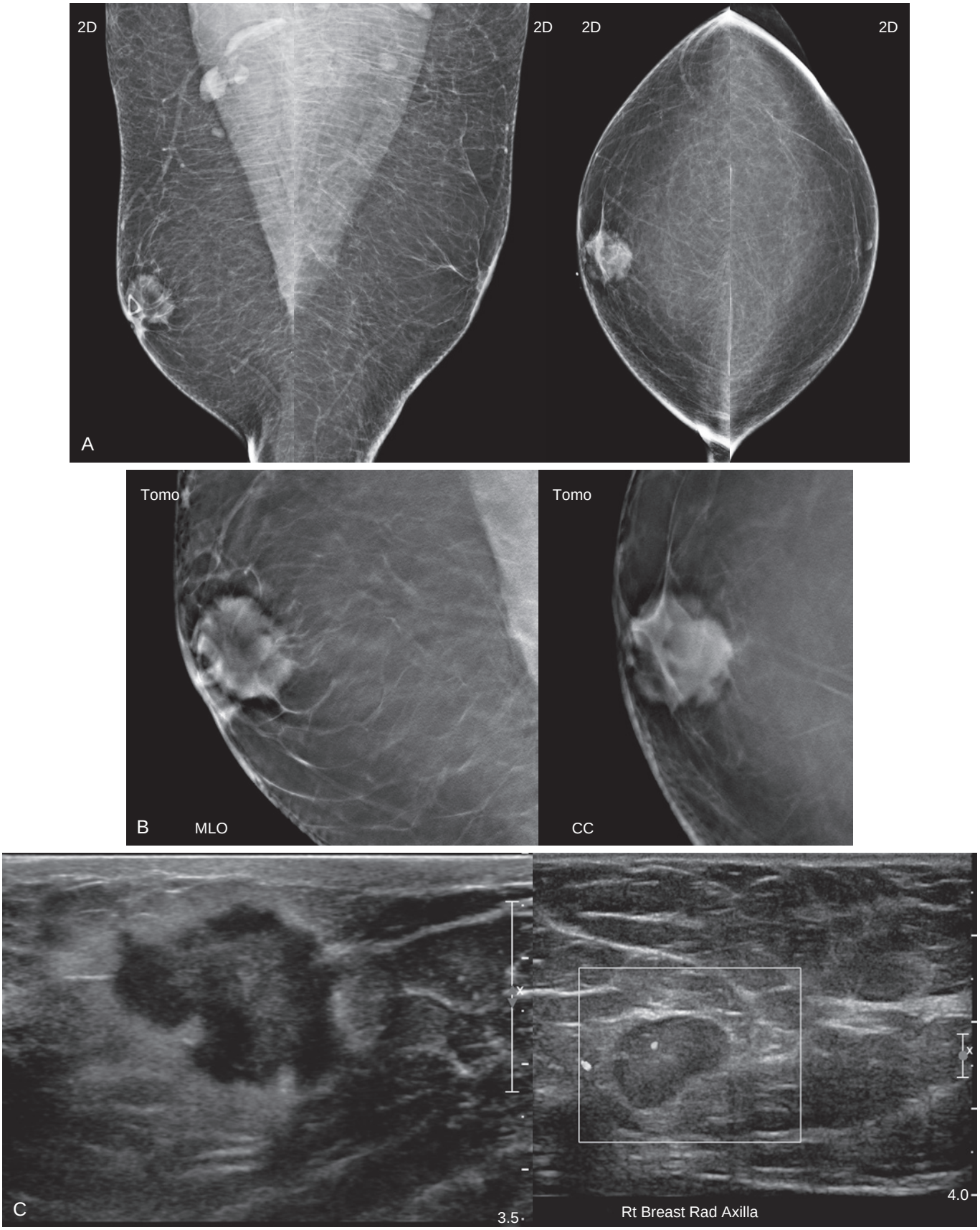


FIG. 13.9 Breast cancer in a young man. A 42-year-old man with neurofibromatosis presents with a palpable lump near the nipple in the right breast. **(A)** 2D mammogram reveals an irregular mass with indistinct margins and a prominent axillary lymph node. **(B)** Tomosynthesis MLO and CC slice views demonstrate the fine spiculations of the margins. **(C)** Ultrasound shows the markedly irregular mass and enlarged axillary lymph node. Core needle biopsy pathology showed invasive ductal carcinoma, ER/PR/AR+, Her2– with 2/8 nodes positive. Women with neurofibromatosis have a fourfold risk of breast cancer. No statistics are available on the risk for men with the syndrome.

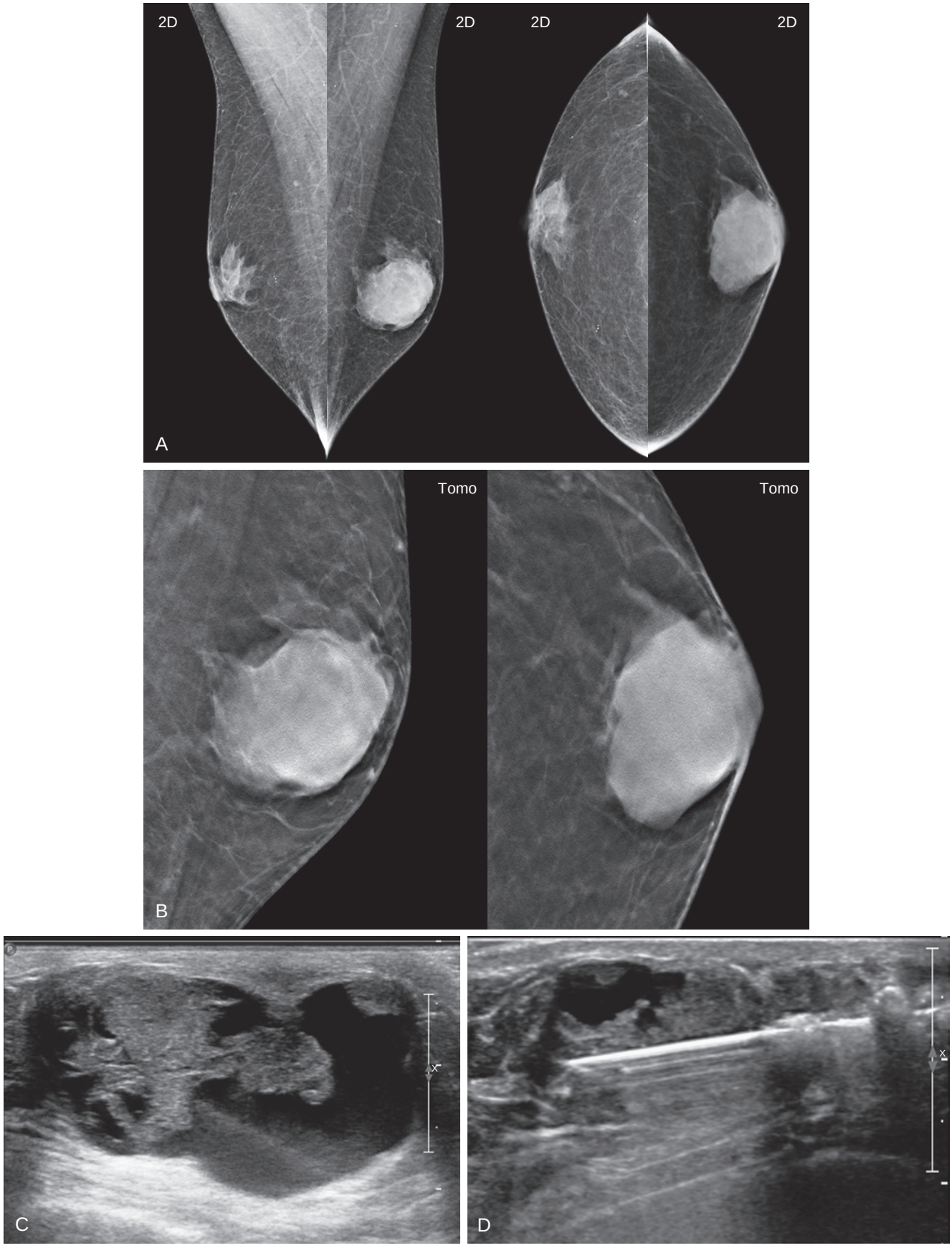


FIG. 13.10 Ductal carcinoma in situ. A 71-year-old man presents with a palpable left breast mass. **(A)** 2D mammography shows nodular gynecomastia bilaterally and a 3-cm lobulated mass corresponding to the palpable lump. **(B)** Tomosynthesis slice images show that the margins are predominantly circumscribed. **(C)** Ultrasound reveals a complex cystic and solid mass. **(D)** Ultrasound-guided core needle biopsy was performed showing ductal carcinoma in situ. Final pathology revealed papillary carcinoma with foci of invasive carcinoma, mucinous type, ER/PR/AR+, Her2−.

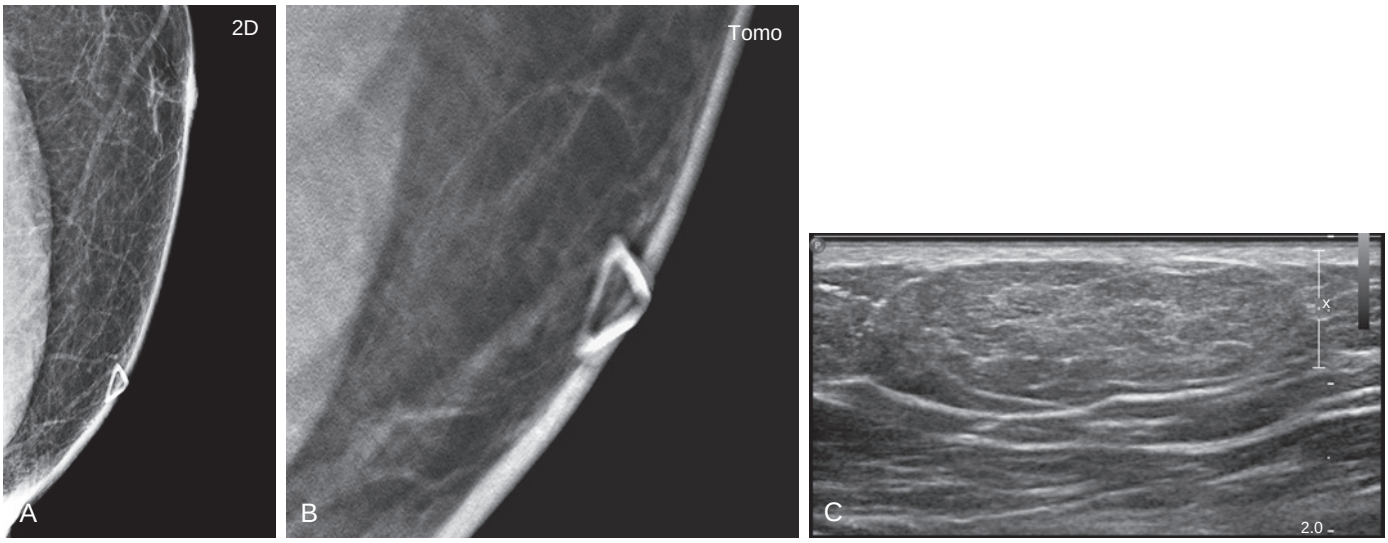


FIG. 13.11 Lipoma. A 59-year-old man presents with a palpable lump in the lower inner left breast. **(A)** Two-dimensional mammogram shows only fatty tissue. **(B)** Tomosynthesis slice view reveals a thin capsule surrounding a fat-density lesion. **(C)** Although not necessary for diagnosis, ultrasound shows a corresponding slightly hyperechoic, wider-than-tall, oval mass, confirming the lipoma.

Other Findings on Tomosynthesis

In addition to gynecomastia and breast cancer, other specific findings may be the source of the patient's symptoms or may be found incidentally. Lipomas, sebaceous cysts, epidermal inclusion cysts, abscesses, hematomas, fat necrosis, pseudoangiomatous stromal hyperplasia (PASH), diabetic mastopathy, and metastatic nodules can all be found in men. Clinical history is important for making the diagnosis. Imaging with tomosynthesis and/or ultrasound will depend on the clinical scenario.

Lipomas commonly present as a soft, mobile, nontender, palpable lump. Tomosynthesis can help to detect the fine capsule around the periphery of the lipoma, which can be more difficult to detect on 2D imaging. Ultrasound is not usually needed if this characteristic finding is noted on tomosynthesis. However, if ultrasound is performed, a circumscribed echogenic mass will be seen (Fig. 13.11).

Fat necrosis or oil cysts are other causes for palpable lesions in men. These present clinically as superficial lumps, and vary in firmness, depending on the degree of calcification. Sometimes they may be tender. There may be an identifiable etiology, such as motor vehicle collision or other trauma, but many times the patient will not be able to recollect a specific traumatic event. Fat necrosis and oil cysts typically present mammographically as lucent round or oval masses with a thin capsule, but they may have more complex appearance, including a variable amount of calcifications. On ultrasound, due to the mixed fat composition and possible calcifications, these lesions can appear complex, often with a suspicious sonographic appearance. Mammography and, in particular, tomosynthesis can be more definitive in such cases by depicting the characteristic appearance of lucent circumscribed masses with or without calcifications (Fig. 13.12).

Abscesses, sebaceous cysts or epidermal inclusion cysts, and hematomas are usually clinically apparent and rarely require imaging confirmation. Occasionally imaging confirmation may be requested to exclude an underlying mass. In these cases ultrasound may be performed first. If there are indeterminate or suspicious ultrasound findings, mammography, particularly tomosynthesis, could then be considered (Fig. 13.13).

PASH is uncommon in men but may be found, often in association with gynecomastia. It is a benign entity consisting of mammary stromal proliferation and usually appears as a discrete mass, although at times it can be indistinguishable from the fibroglandular tissue of gynecomastia (Fig. 13.14). If presenting as a discrete solid mass, biopsy should be considered, as for any solid mass in a male. Diabetic mastopathy, usually associated with long-standing type 1 diabetes mellitus, has been described in both men and women and may also present as a palpable finding. In this scenario the tissue mass can appear dense, and tomosynthesis imaging can help to depict the normal glandular tissue composition and exclude an underlying mass lesion. Although rare, hamartomas can be found in men, particularly in the background of gynecomastoid proliferation. Tomosynthesis demonstrates the characteristic, breast-with-a-breast appearance of mixed fibroglandular and fatty tissue. Finally, a history of previous procedures is important to document in men because, similar to the female breast, surgical scars in the male breast can look ominous on tomosynthesis (Fig. 13.15).

Individuals in the process of or who have completed a transgender sex change may desire mammography screening. Such processes often involve exogenous hormonal treatment followed by surgical procedures. Female-to-male transformation may involve first treatment with antiestrogens, followed by mastectomy. Mammography in such patients may reveal breast tissue that shows decreased density over time. Conversely, those undergoing male-to-female transformation may be treated with estrogens and thus demonstrate breast tissue that is increased in size and density over time. This is not gynecomastia, rather tissue that contains ductal and lobular elements. Therefore, these individuals may develop cysts or fibroadenomas. A few cases of breast cancer in male-to-female transsexuals receiving high doses of exogenous estrogen have been reported. In one case reported by Maglione et al., the cancer could only be seen on tomosynthesis (and magnetic resonance imaging) but not on conventional 2D mammography. As with screening any individual, tomosynthesis may help to differentiate normal breast tissue from any focal pathologic changes.

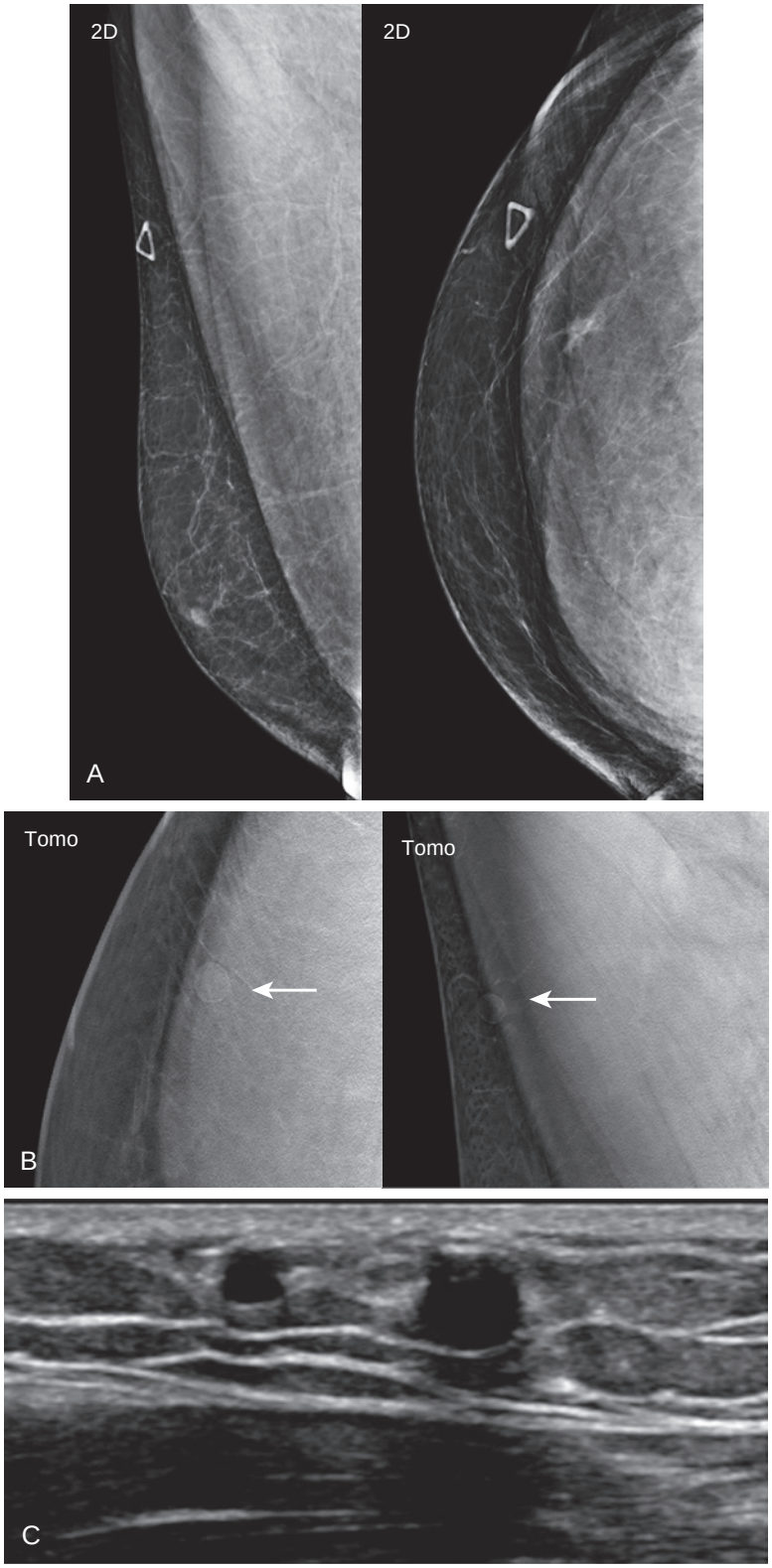


FIG. 13.12 Oil cysts. A 49-year-old man presents with a small palpable area in the right breast. **(A)** 2D mammography did not show a focal abnormality. **(B)** Tomosynthesis slice views demonstrate two round, fat-density masses *(arrows)*. **(C)** Targeted ultrasound demonstrates two small cysts consistent with oil cysts.

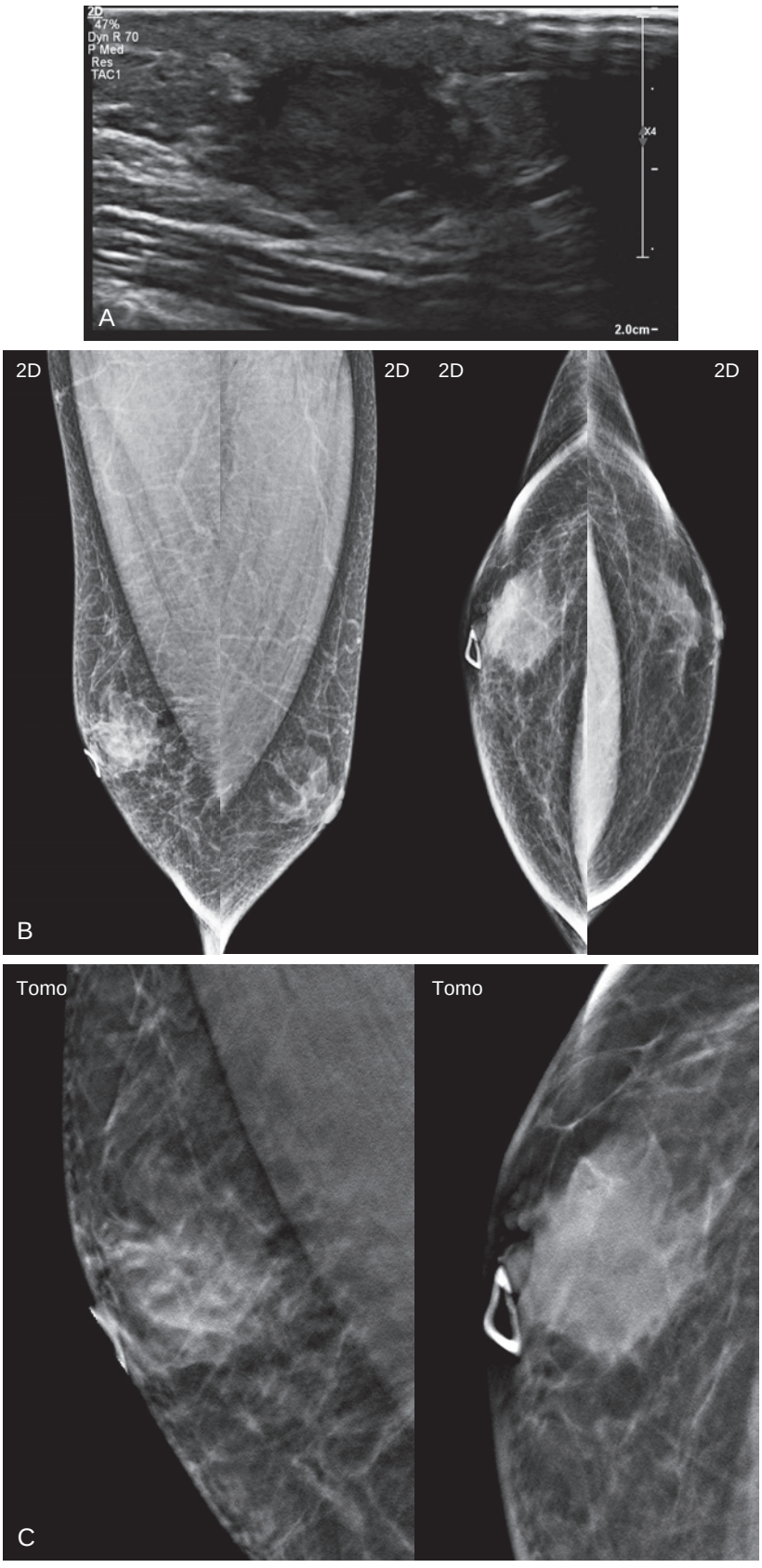


FIG. 13.13 Abscess. A 58-year-old man presents with swelling under his right nipple 6 days after completing antibiotic treatment, with a persistent palpable region. **(A)** Ultrasound shows a 2.5-cm irregular hypoechoic mass. **(B)** 2D images show bilateral gynecomastia and an irregular mass in the right breast. **(C)** Tomosynthesis slice images show the mixed density but indistinct margins of the mass. Biopsy was performed, revealing acute and chronic inflammation.

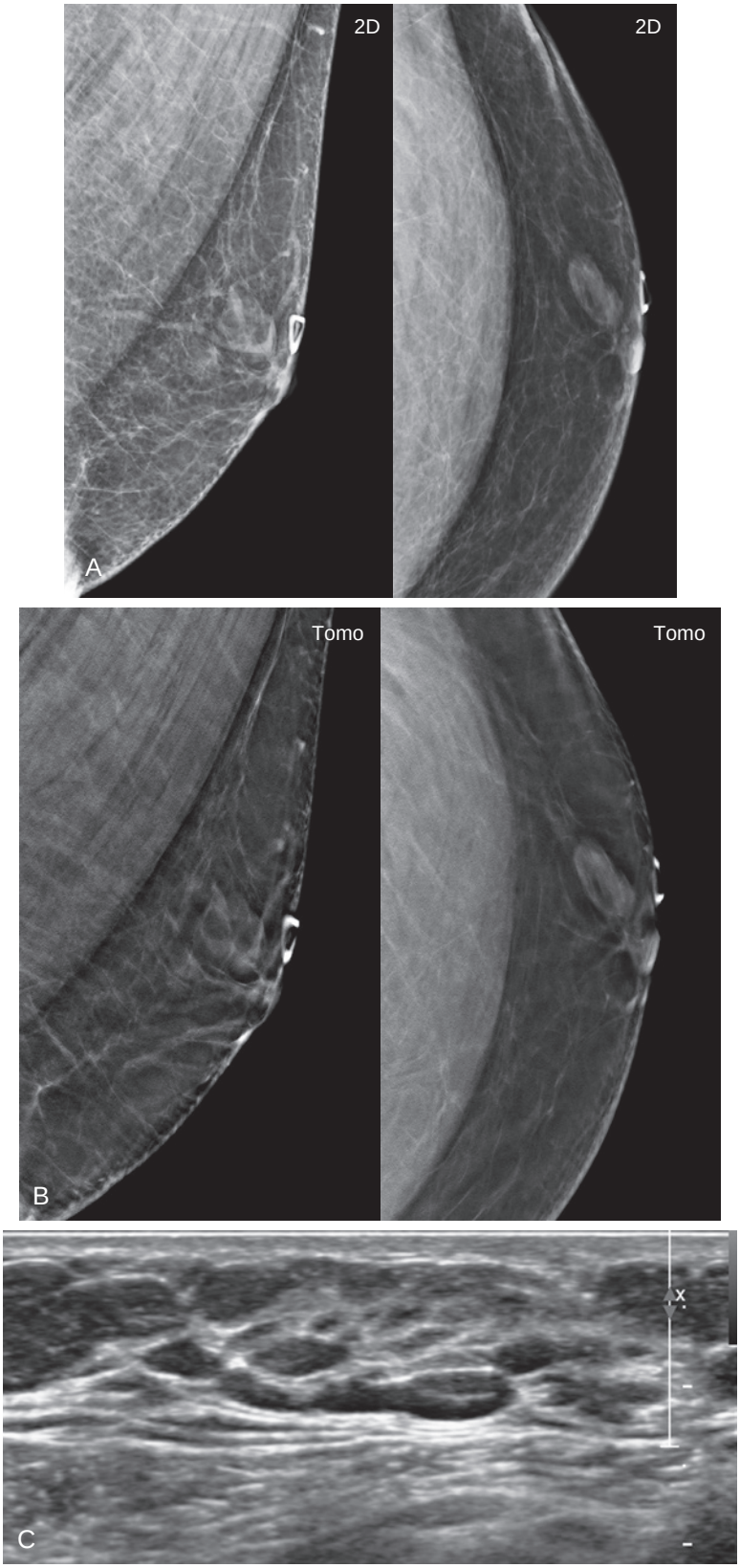


FIG. 13.14 Pseudoangiomatous stromal hyperplasia. (A) A 59-year-old man presents with a recurrent palpable lump in the periareolar area at the 1-o'clock position of the left breast. He has a history of previous excision of a mass in the same location, reported as benign. **(B)** An oval, fat-containing mass is seen in the subareolar region on the tomosynthesis views, correlating to the palpable abnormality. **(C)** Ultrasound shows an oval, mixed echogenicity lesion. Biopsy revealed pseudoangiomatous stromal hyperplasia.

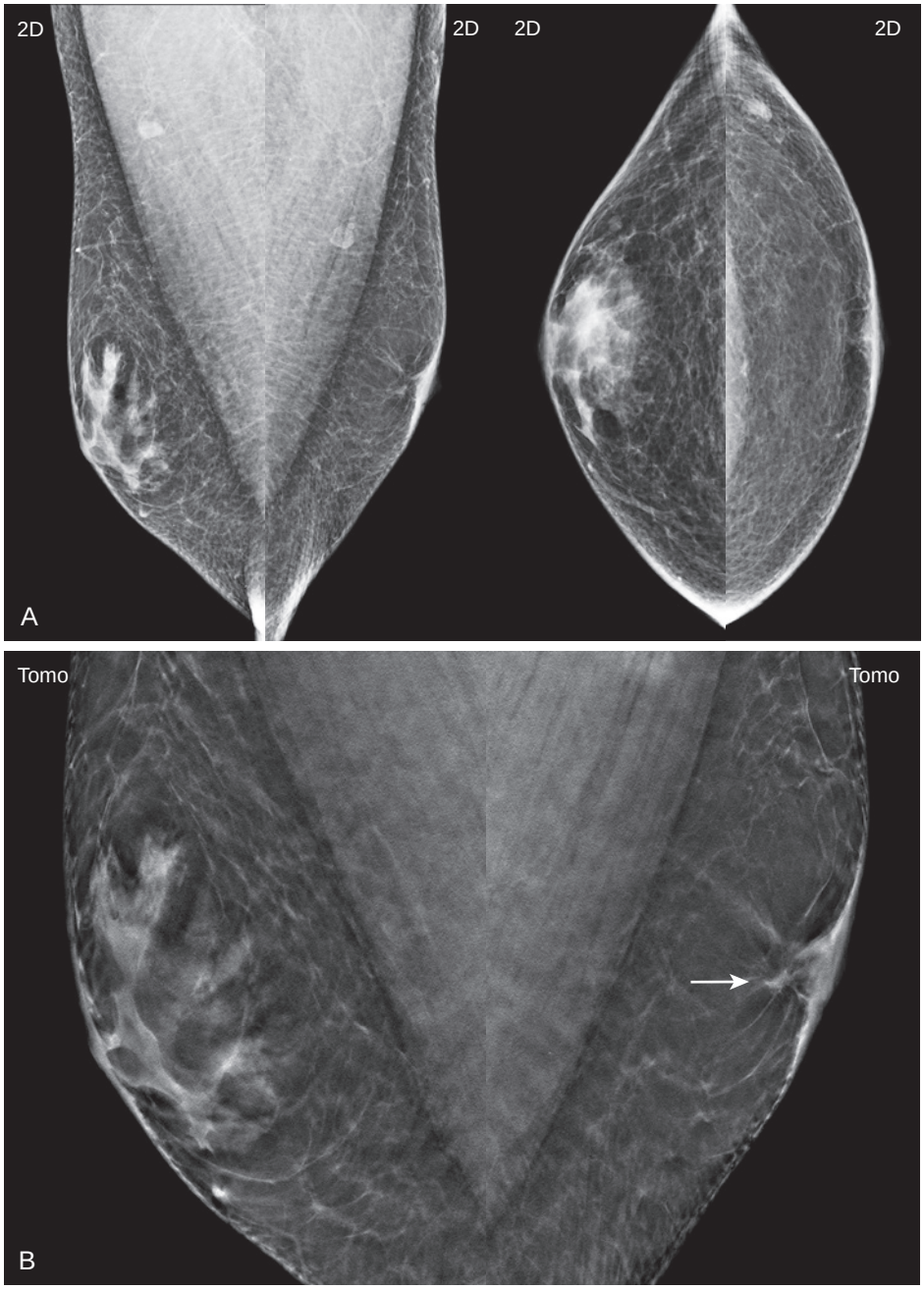


FIG. 13.15 Postoperative scar. A 72-year-old man presents with swelling and tenderness of the right breast. **(A)** Moderate gynecomastia is present in the right breast. **(B)** Tomosynthesis mediolateral oblique slice images show the right gynecomastia and the spiculated architectural distortion in the subareolar area of the left breast *(arrow)*. The patient had undergone previous surgery for left gynecomastia.

Summary

As with mammographic imaging of women, tomosynthesis can be helpful in assessing the breast tissue of men, whether presenting for high-risk screening or with breast-related symptoms. Tomosynthesis makes the diagnosis of gynecomastia more definitive and potentially reduces the diagnostic work-up and decreases the need for ultrasound. Male breast cancer can be more confidently differentiated from gynecomastia. Lymph nodes, fat necrosis, lipomas, and other benign findings can also be more easily diagnosed. Expedited and improving the breast imaging work-up with tomosynthesis is beneficial for the male patient.

CHAPTER 14

Interventional Procedures

Margarita Zuley | Ernestine Thomas | Jules H. Sumkin | Reni Butler

Similar to the need for magnetic resonance imaging (MRI) biopsy capability in a practice that performs breast MRI, the need for tomosynthesis-guided breast biopsies in a practice that uses tomosynthesis is inevitable because there are certain lesions seen only on tomosynthesis that would be impossible to biopsy using two-dimensional (2D) stereotactic guidance. This often leads to subsequent examinations, such as ultrasound and/or MRI, on which the lesion may also not confidently be identified. In addition, some subtle lesions (low-contrast and noncalcified lesions) that can be seen on 2D mammography are problematic to biopsy when using a stereotactic technique. Tomosynthesis-guided biopsies address both of these issues.

Advantages of Tomosynthesis-Guided Biopsy

The tomosynthesis biopsy unit has many advantages over dedicated prone stereotactic biopsy units. Targets visualized by tomosynthesis alone, subtle lesions better visualized with tomosynthesis compared with 2D mammography, or lesions seen only on one mammographic or tomosynthesis view are more readily biopsied under tomosynthesis guidance (Figs. 14.1 and 14.2). In addition, calcifications, architectural distortion, and small mammographic masses not seen on ultrasound may be biopsied with tomosynthesis guidance (Fig. 14.3). Tomosynthesis-guided breast biopsies are cost effective and easily integrated into the daily workflow, and the upright positioning of the currently available unit improves patient access by addressing barriers to prone stereotactic biopsies, such as patient comorbidities and lesion position.

Lesion Visualization

Masses and Architectural Distortion

Tomosynthesis units use high spatial resolution digital receptors, which have better signal-to-noise and contrast-to-noise ratios than the old charge-coupled device (CCD) receptors used for currently available prone stereo devices and therefore allow accurate sampling of lesions that are not visible with the CCD detector technology (Fig. 14.4). Furthermore, digital breast tomosynthesis uses the full detector size during the biopsy, as opposed to the prone stereotactic biopsy device in which there is a limited window of imaging due to a smaller compression paddle. The full detector provides a larger field of view and better orientation when targeting, which can be very helpful when performing biopsies of subtle findings. Localization of subtle lesions or one-view only findings is easier with tomosynthesis because their relative location on the orthogonal view may be determined by their depth (slice location) on the view on which they are visualized. In addition, the off-axis imaging pairs used for localization with traditional stereotaxis create a challenge when targeting subtle lesions because these lesions may be seen only on the scout view or one of the two stereotactic pair views. This issue is eliminated with the tomosynthesis scout because targeting is performed directly from the scout image.

Calcifications

Vascular and skin calcifications not obvious on 2D images are readily apparent on the tomosynthesis scout images, obviating the need for a biopsy. When there are multiple groups of calcifications or large groups of calcifications, determining which group on one 15-degree stereotactic view corresponds to which group on the other 15-degree stereotactic view can be very difficult (Fig. 14.5). This dilemma is eliminated by using tomosynthesis scout images because any single cluster of the calcifications can be easily isolated from distracting clusters within the same area but in other planes. Similarly, groups of calcifications overlapping on a 2D view can be distinguished on the tomosynthesis scout obtained prior to the biopsy. However, it is important to scroll through all of the tomosynthesis scout images to ensure that the appropriate group is targeted for biopsy (Fig. 14.6).

Cost Effectiveness

Tomosynthesis-guided breast biopsies are cost effective in part because the need to use MRI for troubleshooting subtle lesions not visible with traditional stereotaxis or ultrasound is obviated, resulting in savings of both cost and time. In 2013 Smith et al presented an abstract comparing upright tomosynthesis-guided breast biopsies with prone stereotactically guided breast biopsies found that there were fewer targeting attempts and fewer images obtained with tomosynthesis-guided breast biopsies compared with prone stereotactic breast biopsies, resulting in shorter biopsy times and decreased patient radiation. Shorter biopsy times not only improve patient comfort but also allow more biopsies to be performed during the workday. In addition, there may be confounding factors with MRI, such as significant background parenchymal enhancement and differences in the appearance of the breast tissue in the prone position that may make definitive identification of the lesion seen on mammography and/or tomosynthesis difficult. The search for subtle or small lesions with ultrasound may be time consuming and unsatisfactory. Areas thought to correspond to the mammographic abnormality on ultrasound and subsequently biopsied using ultrasound may not truly correspond. This

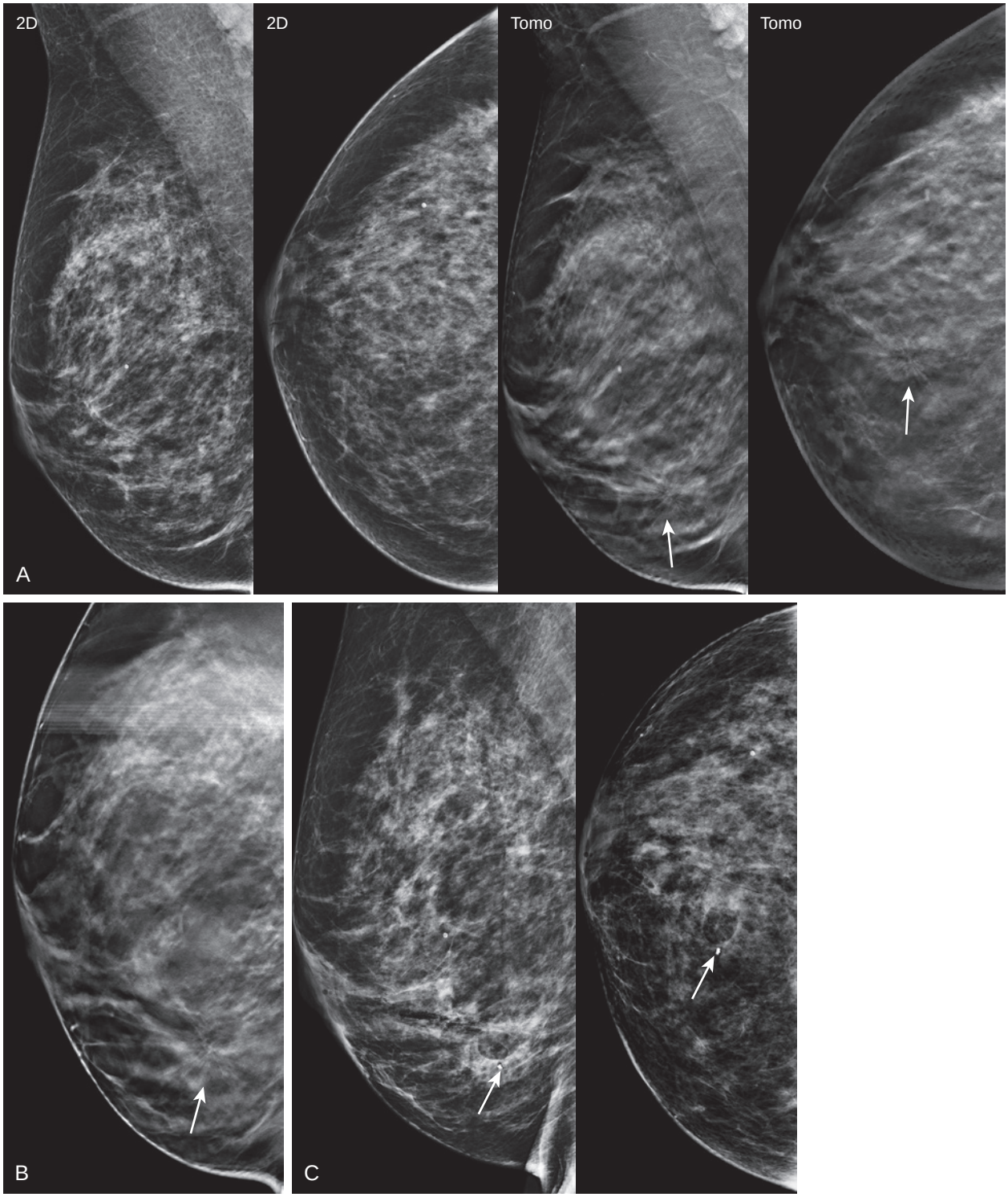


FIG. 14.1 (A) Right 2D MLO and 2D CC views and corresponding MLO and CC tomosynthesis images from a tomosynthesis screening exam in a 47-year-old woman demonstrate architectural distortion *(arrows)* in the lower-inner right breast visualized on tomosynthesis only. **(B)** Right 90-degree scout view from the tomosynthesis-guided biopsy shows the area of architectural distortion *(arrow)* targeted for biopsy. **(C)** Postprocedure right 90-degree and CC views demonstrate appropriate positioning of the T-shaped clip *(arrows)*. Pathology revealed a radial scar.

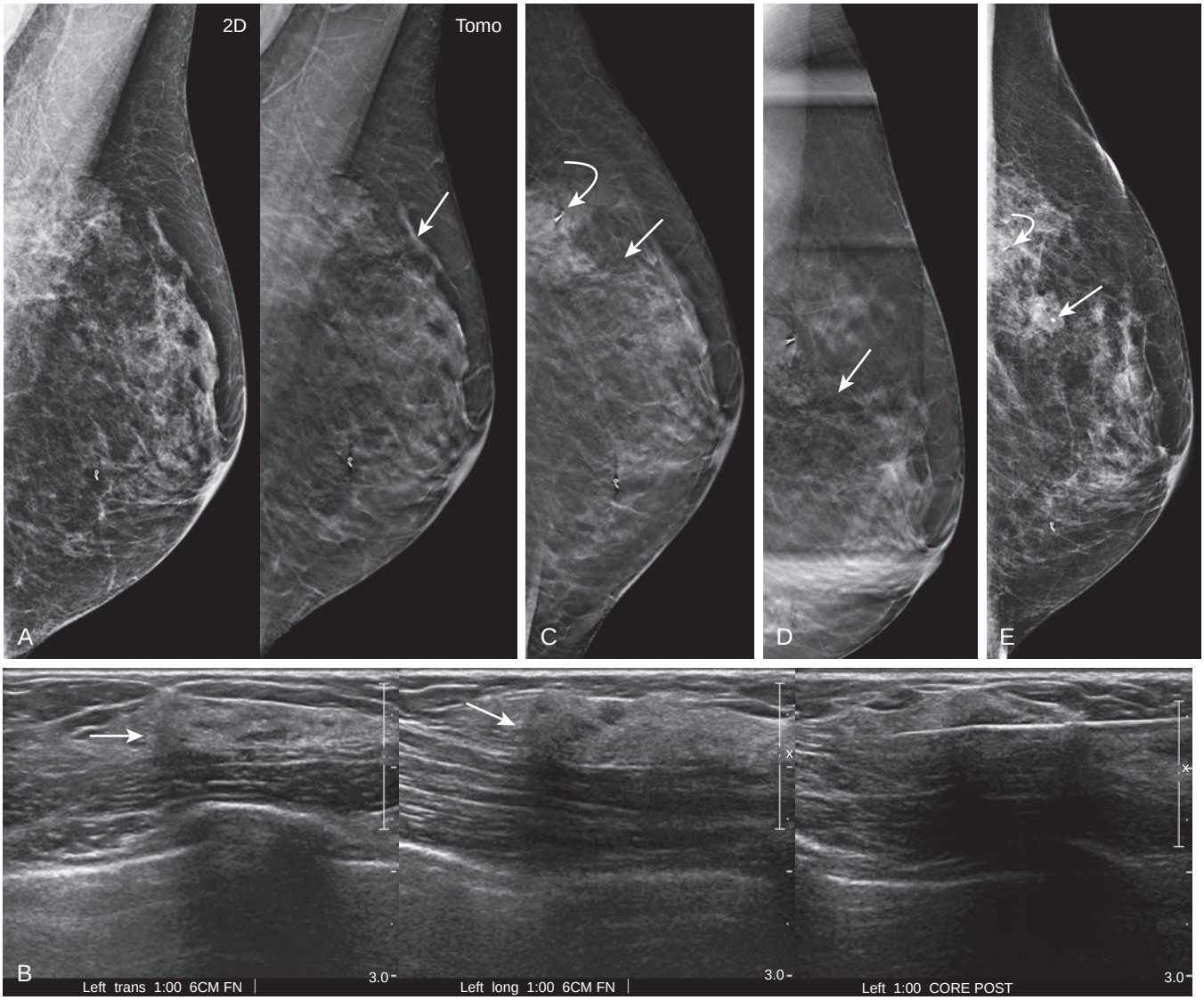


FIG. 14.2 (A) Left two-dimensional MLO and corresponding MLO tomosynthesis from a tomosynthesis screening in a 55-year-old woman demonstrate architectural distortion *(straight arrow)* in the upper-left breast visualized only on the tomosynthesis MLO view. The patient had a prior benign left breast biopsy (wing clip). **(B)** Two orthogonal sonographic images demonstrate a 5 × 3-mm hypoechoic lesion *(straight arrows)* at the 1-o'clock position in the left breast 6 cm from the nipple, thought to correspond to the distortion seen on tomosynthesis. This was biopsied under ultrasound guidance, with pathology revealing stromal fibrosis. **(C)** Left MLO tomosynthesis view following the biopsy demonstrates that the architectural distortion *(straight arrow)* is anterior and inferior to the ribbon biopsy clip *(curved arrow)*, so tomosynthesis-directed biopsy was performed. **(D)** Left 90-degree scout view from the tomosynthesis-guided biopsy demonstrates the area of architectural distortion *(straight arrow)* targeted for biopsy. **(E)** Postprocedure left 90-degree view demonstrates appropriate positioning of the T-shaped clip *(straight arrow)* inferior to the ribbon clip *(curved arrow)* placed during the ultrasound-guided biopsy. Pathology revealed a radial scar.

may result in unnecessary biopsies because the initially questioned suspicious area detected on tomosynthesis or mammography was not biopsied and the patient must undergo an additional biopsy to adequately sample the correct area (see Fig. 14.3). The cost-to-benefit ratio of implementation of this technology will be site specific and should be considered prior to implementation.

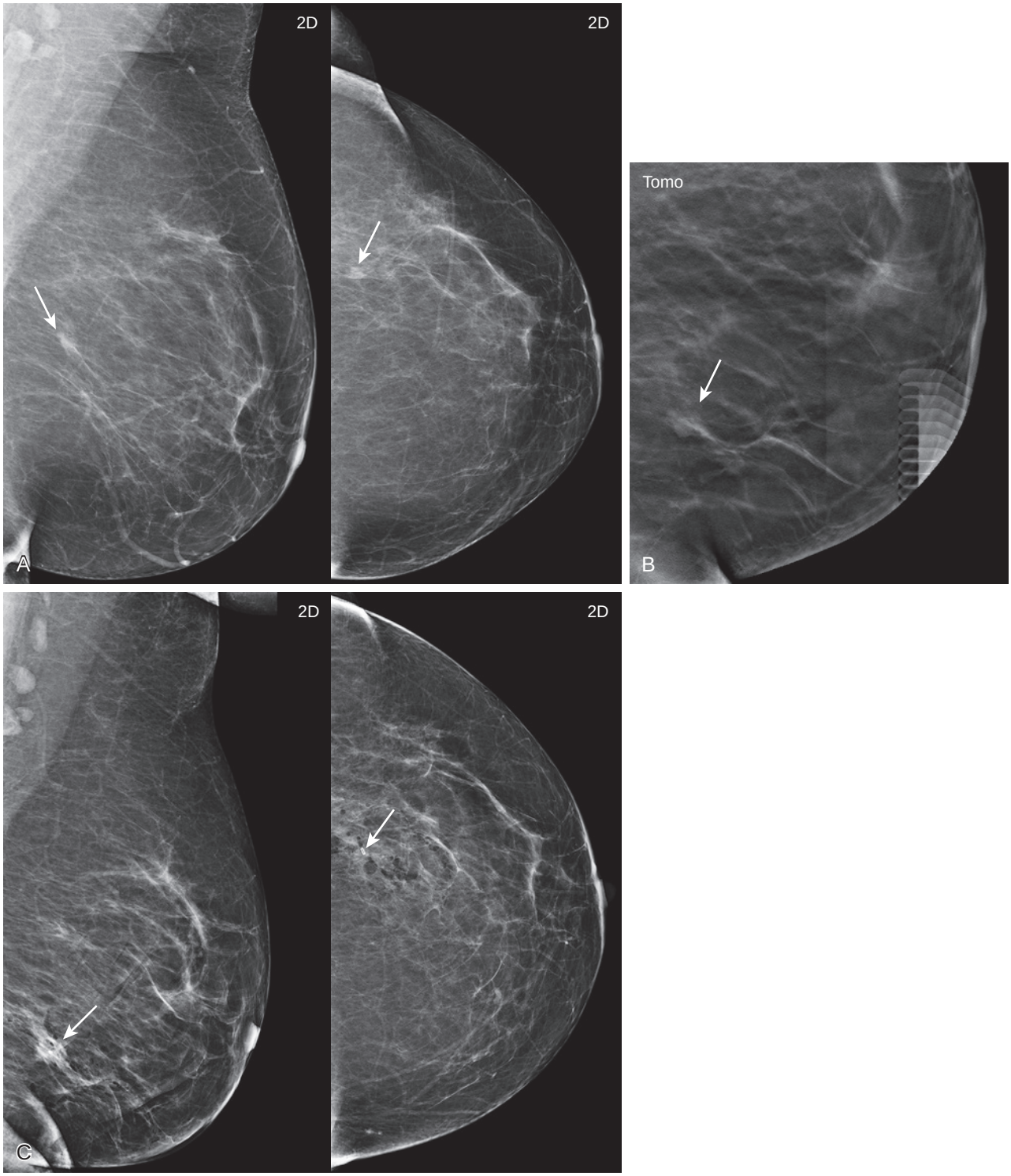


FIG. 14.3 (A) Left mediolateral oblique and CC views from a screening mammogram in a 48-year-old woman demonstrate a new focal asymmetry *(arrows)* in the posterior left breast. This was not sonographically visible. **(B)** Left 90-degree scout view from the tomosynthesis-guided biopsy demonstrates the focal asymmetry in the left breast *(arrow)*. **(C)** Postprocedure left 90-degree and CC views demonstrate appropriate positioning of the buckle clip. The final pathology revealed a hyalinzied fibroadenoma.

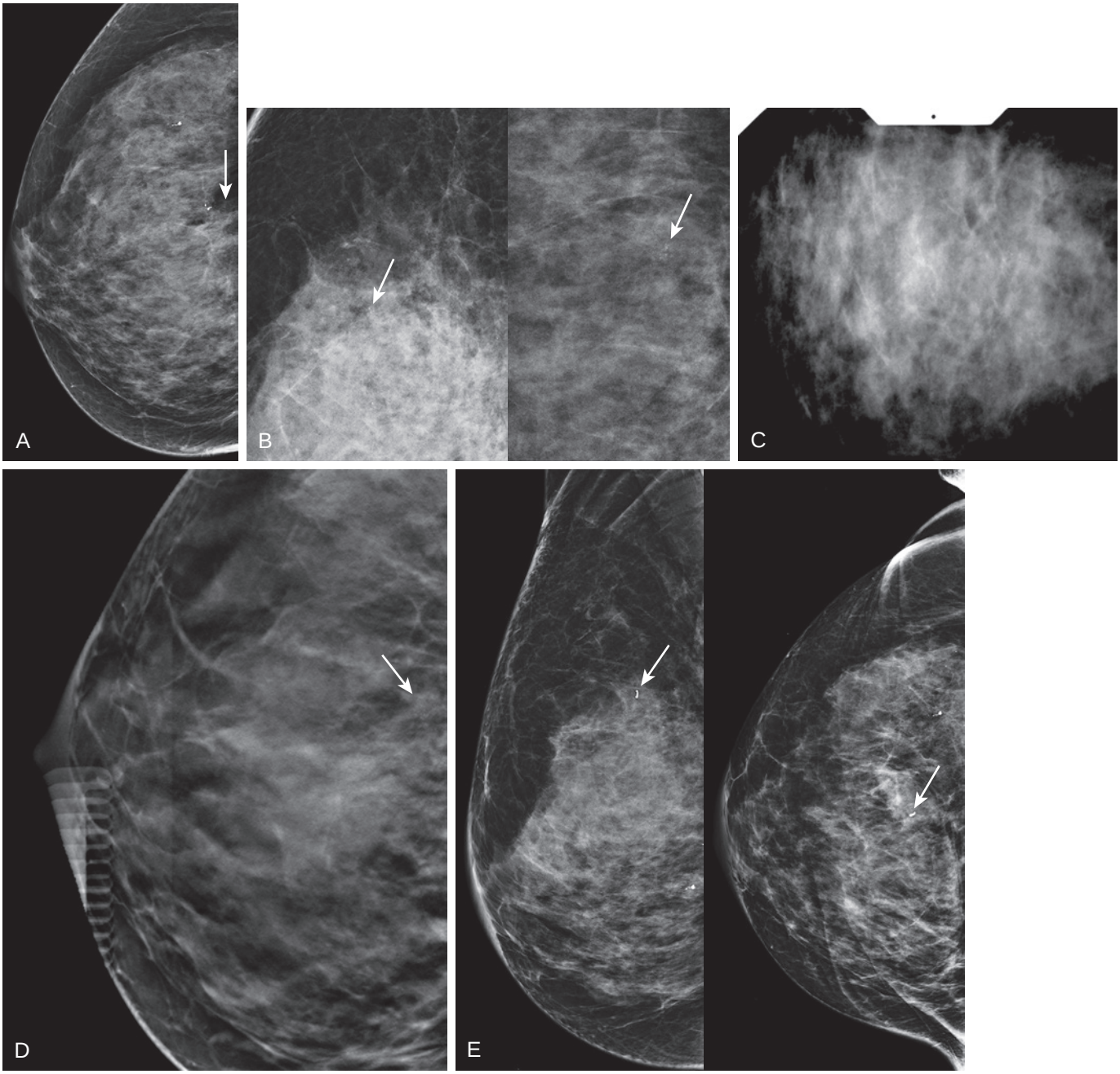


FIG. 14.4 (A) Right CC view from a screening mammogram in a 58-year-old woman demonstrates faint calcifications *(arrow)* in the 12-o'clock position of the right breast initially visualized only on the CC view. **(B)** Right magnification 90-degree and CC views demonstrate a group of faint amorphous calcifications *(arrows)* in the 12-o'clock position of the right breast. **(C)** Right CC scout view from the prone stereotactically guided biopsy. The calcifications were not visualized, and the biopsy was aborted. **(D)** Right CC scout view from the tomosynthesis-guided biopsy demonstrates the suspicious group of calcifications *(arrow)*, so the biopsy was performed and the calcifications were retrieved in the specimens. **(E)** Postprocedure right 90-degree and CC views demonstrate appropriate position of the buckle-shaped clip. The final pathology revealed fibrocystic changes and a fibroadenomatoid nodule.

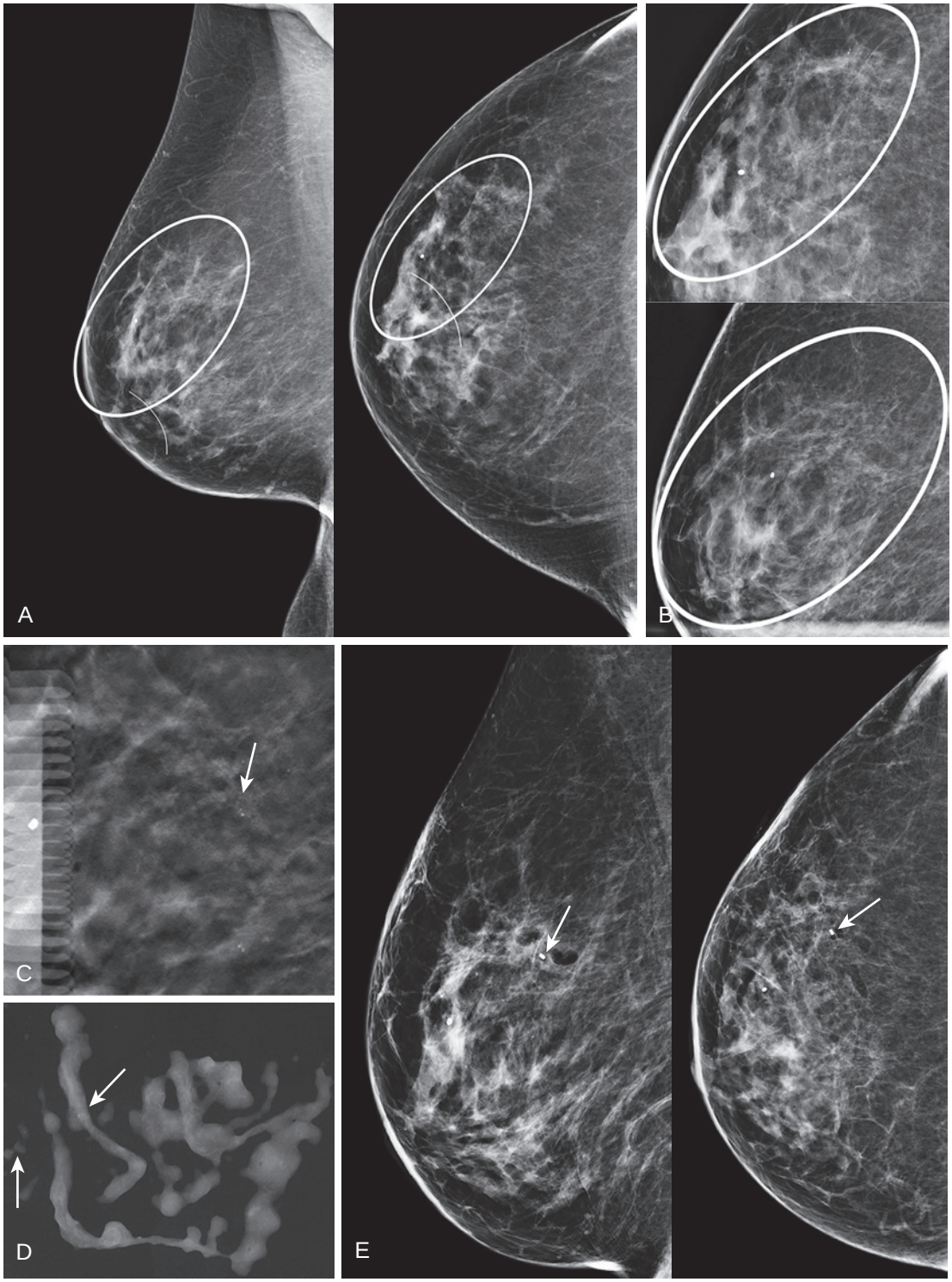


FIG. 14.5 (A) Right MLO and CC views in a 70-year-old woman with a history of left breast cancer demonstrate calcifications *(ovals)* in the upper-outer right breast. **(B)** Right magnification CC and MLO views demonstrate a 7.5 × 4.0-cm area of fine pleomorphic and amorphous calcifications *(circles)* in the upper-outer right breast. **(C)** Right 90-degree scout view from the tomosynthesis-guided biopsy shows a group of calcifications from this region targeted for biopsy. **(D)** Specimen radiograph shows representative calcifications *(arrows)* within several of the core specimens. **(E)** Postprocedure right 90-degree and CC views demonstrate appropriate position of the cylinder-shaped clip *(arrows)* with residual adjacent calcifications. The final pathology revealed ductal carcinoma in situ nuclear grade 2 and atypical ductal hyperplasia.

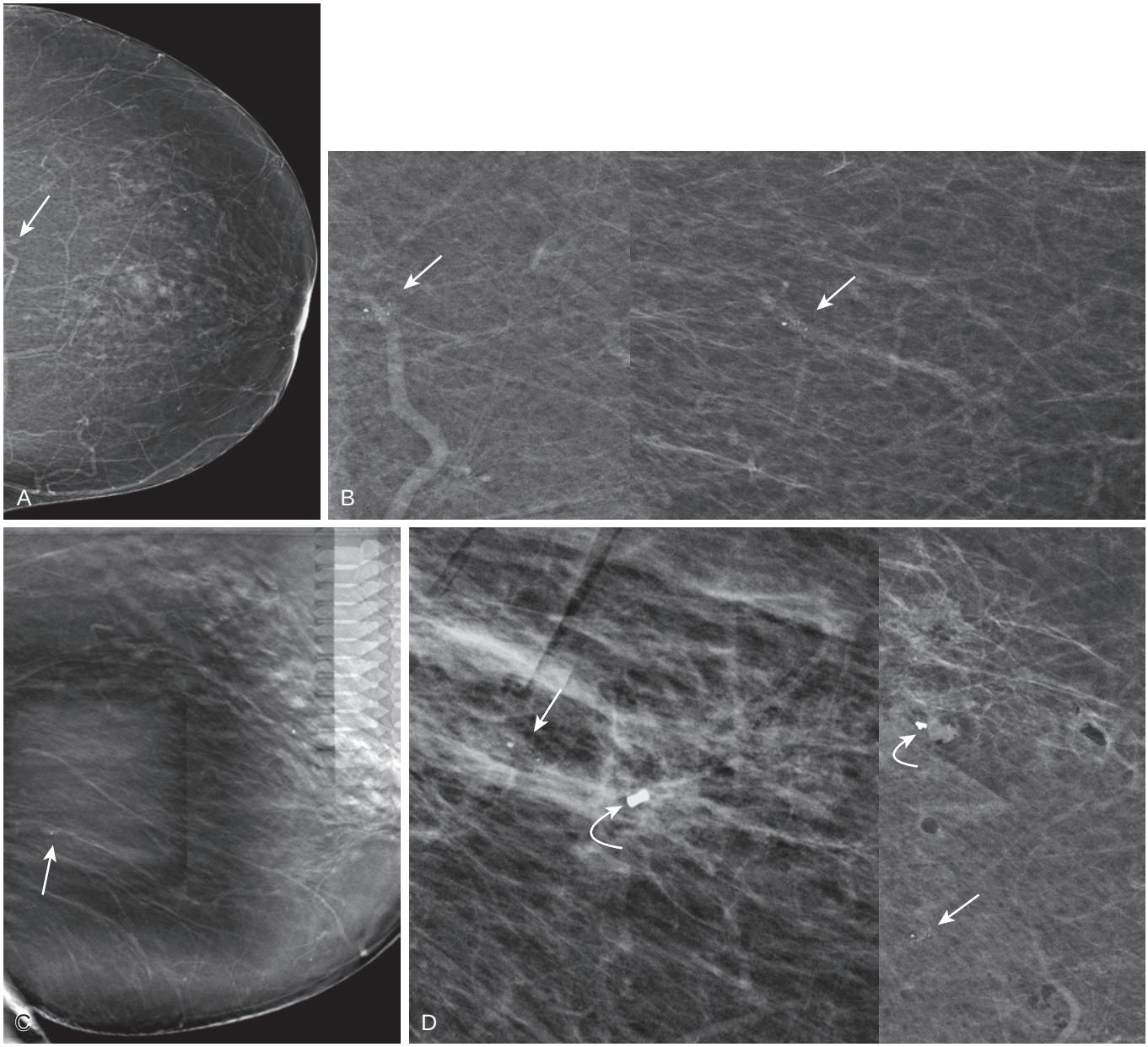


FIG. 14.6 (A) Left CC view from a screening mammogram in a 69-year-old woman demonstrates indeterminate calcifications *(straight arrow)* in the posterocentral left breast. **(B)** Left magnification CC and 90-degree view demonstrate a single group of fine pleomorphic calcifications *(straight arrows)* in the posterior inferior left breast. **(C)** Left 90-degree scout view from the tomosynthesis-guided biopsy shows the calcifications *(straight arrow)* intended for biopsy. **(D)** Postprocedure left 90-degree and CC and views show that the group of calcifications intended for biopsy was not sampled *(straight arrows)*. They are medial and slightly posterior to the T-shaped clip *(curved arrows)*. In retrospect, both groups of calcifications were in the same plane on the CC view and superimposed on the 90-degree magnification view. The lateral group was sampled because it was the first group encountered when targeting was performed from a lateral approach. The group of calcifications intended for biopsy was then targeted and sampled. Final pathology revealed a hyalinized fibroadenoma at both biopsy sites. This case illustrates the importance of scrolling through the entire tomosynthesis scout images when targeting because groups of calcifications may be in the same plane on one view as the calcifications intended for biopsy and inadvertently targeted and biopsied.

Patient Access

Biopsies can be performed in the upright or decubitus positions with these add-on systems. Therefore patients who exceed the table weight limit for the prone biopsy device are suitable candidates for tomosynthesis-guided biopsies. In addition, patients with comorbidities (such as respiratory issues, prior surgery, arthritic conditions, or limited mobility) that may prevent them from lying on the stereotactic table prone for a prolonged period of time are suitable candidates for these biopsies. Positioning is much easier with the upright device because there is no interference from the biopsy table. Far posterior lesions are more easily biopsied because the upright approach allows for better access to the posterior tissues (Fig. 14.7).

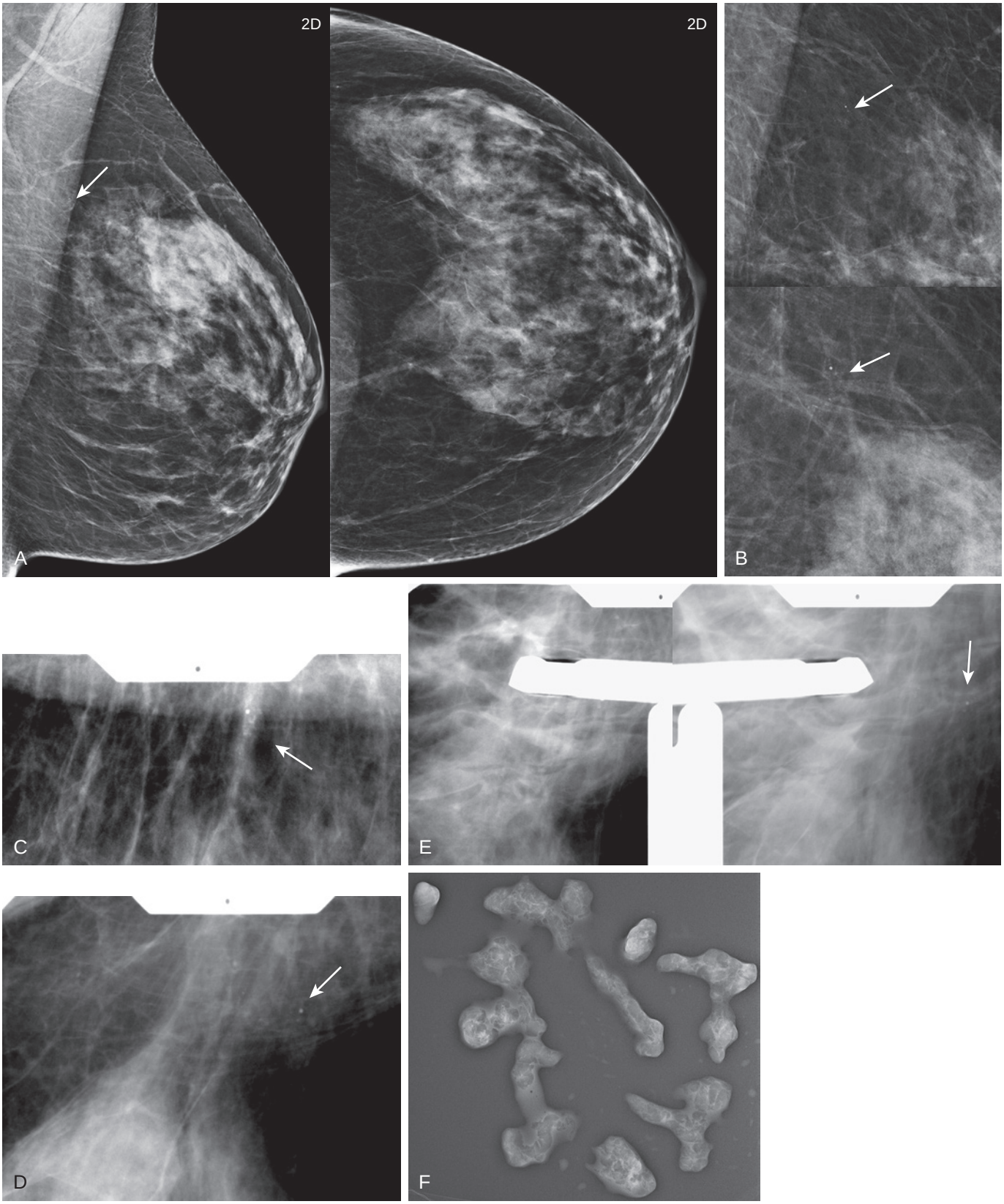


FIG. 14.7 (A) Left mediolateral oblique and CC views from a screening mammogram in a 48-year-old woman demonstrate indeterminate calcifications *(arrow)* in the far posterior upper-outer left breast. **(B)** Left magnification 90-degree and exaggerated craniocaudal (laterally) views demonstrate pleomorphic calcifications *(arrow)* in the far posterior upper-outer breast. **(C)** Left prone stereotactic biopsy scout view obtained at the time of diagnostic evaluation to show that the calcification *(arrow)* biopsy with stereotactic guidance should be feasible. **(D)** Left CC stereotactic biopsy scout image obtained at the time of biopsy demonstrating the targeted calcifications *(arrow)*. **(E)** Prefire stereotactic pair demonstrating the calcifications *(arrow)* away from the tip of the biopsy needle. **(F)** Specimen radiograph shows no calcifications within the core specimens.

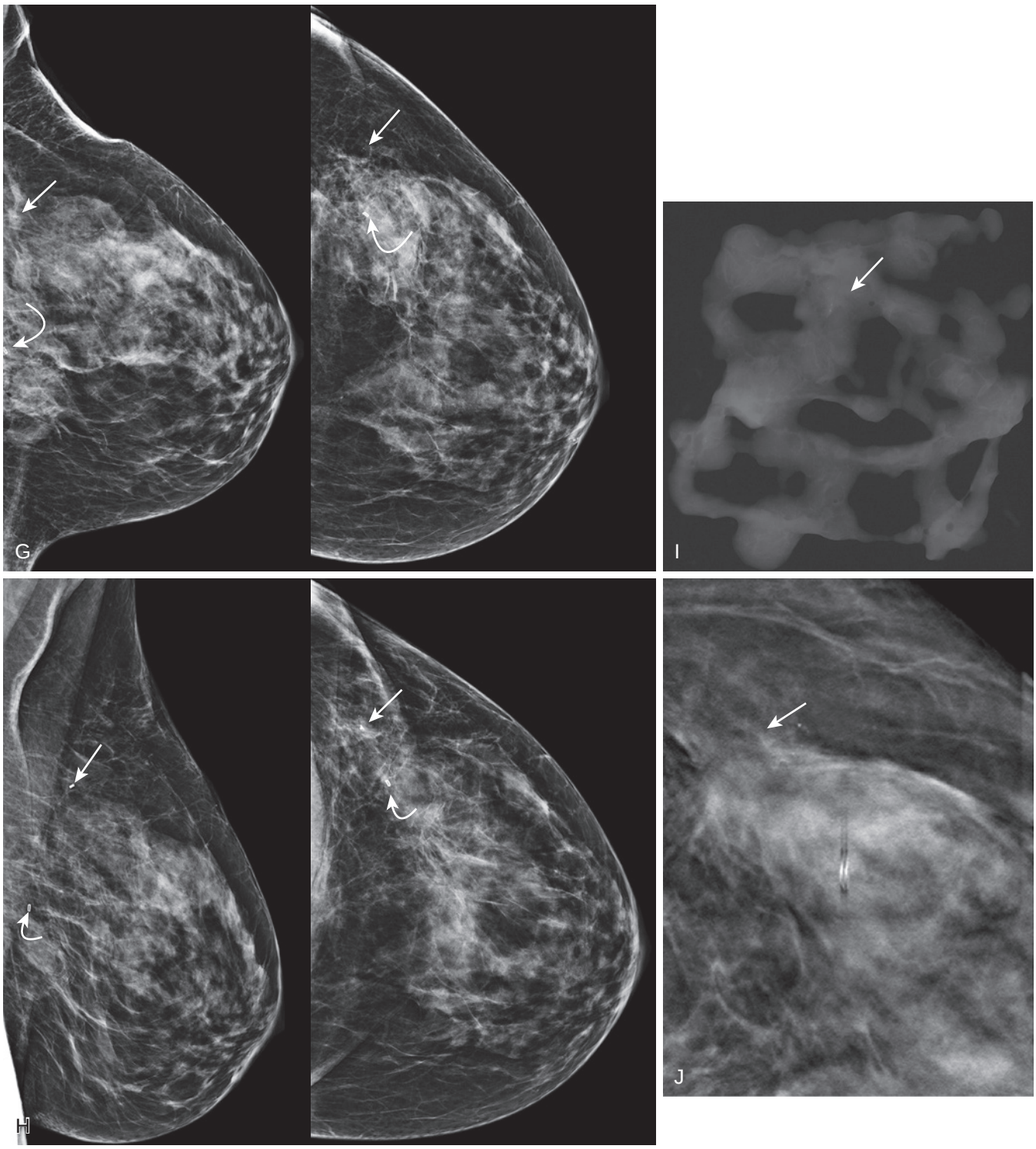


FIG. 14.7, cont'd (G) Left postprocedure 90-degree and CC views show the calcifications intended for biopsy *(straight arrows)* to be superior and lateral to the buckle clip *(curved arrows)*. Upright tomosynthesis-directed biopsy of the cluster was then performed. **(H)** Postprocedure left 90-degree and CC views demonstrate appropriate positioning of the T-shaped clip *(straight arrows)* superior and lateral to the buckle clip *(curved arrows)*. **(I)** Specimen radiograph shows representative calcifications *(arrow)* within one of the core specimens. The final pathology revealed fibrocystic changes. **(J)** Left CC scout view from tomosynthesis-guided biopsy shows the group of calcifications *(arrow)* intended for biopsy.

Workflow

After radiologists have gained expertise with the use of tomosynthesis-guided biopsies, patients may be triaged to the most appropriate modality for biopsy, thereby improving daily workflow. Because the current biopsy device is an attachment to the tomosynthesis unit, the unit can be used for screening and diagnostic evaluation when not in use for biopsies. At the authors' institution, patients requiring tomosynthesis-guided breast biopsy are scheduled in the morning so that the unit may later be used for diagnostic and screening exams. Alternatively, the biopsies may be scheduled at the end of the day or worked into the daily diagnostic workflow of the breast center.

Limitations of Tomosynthesis-Guided Biopsy

First, when the device is being used for tomosynthesis-guided biopsies, it is no longer available for use with diagnostic and screening patients. In contrast, a stand-alone biopsy device poses no interference to the daily workflow. A workaround to this issue is to identify the patients who need tomosynthesis biopsy up front so that they can be scheduled at a time of day or to a particular day that may not be as disruptive to the diagnostic and screening schedule. This type of scheduling will vary greatly depending on site preferences.

Second, biopsies performed with the upright tomosynthesis biopsy unit cannot be performed from an inferior approach due to interference from the patient's legs and inability of the tube to rotate 180 degrees. This is not a true limitation because most lesions can readily be biopsied via another approach (Fig. 14.8) or they may be performed with the patient in the lateral decubitus position on a gurney.

Third, there is a learning curve for tomosynthesis-guided breast biopsies. The orientation of the patient relative to the images is different with the currently available version. The biopsy device is positioned approximately 10 degrees off the perpendicular axis relative to the skin surface so that the images are not obscured by the device. Most radiologists and the technical support staff have trained with and have used prone stereotactic biopsies for years and are therefore more comfortable troubleshooting with the prone stereotactic device. Despite this, most breast imagers will rapidly adapt to the new modality.

Lastly, because the current device is within the direct vision line of the patient, this approach may result in a higher incidence of syncopal episodes relative to the prone stereotactic device in which the device is obscured from the patient's vision, although this was not found in a study by Smith et al. comparing vacuum-assisted prone stereotactic biopsies to upright tomosynthesis-guided biopsies. To minimize the potential for vasovagal events, patients can be advised to look away or close their eyes during the biopsy. The study by Smith et al. found that patients had slightly greater pain with upright tomosynthesis-guided biopsies than with prone stereotactic biopsies, although this was not statistically significant. Biopsies with both techniques were very low on a 1 to 10 pain scale with the averages of 2.49 for prone stereotactic biopsies and 3.04 for upright tomosynthesis-guided biopsies. Prone tomosynthesis units have been developed which could eliminate the potential syncopal and workflow issues of the add-on upright units.

Procedure

The patient is positioned to sit upright or lie in the lateral decubitus position for the procedure. The risks of the tomosynthesis-guided procedures are identical to that of stereotactically guided biopsy and include bleeding, infection, and bruising. In comparison with stereotactic biopsies, a tomosynthesis scout is obtained in place of a 2D scout. The images are scrolled through to the level at which the target (distortion, calcifications, etc.) is most sharply visualized. This determines the depth (Z). A location indicator allows the position of the target within the breast on that view to be clearly understood. This is extremely helpful when there are multiple groups of calcifications or when the lesion of interest is very superficial or deep. Unlike stereotactically guided biopsies on which it is obvious on the 2D scout image or stereotactic pair if a vessel overlies your target, this is not the case with tomosynthesis. When scrolling through the tomosynthesis scout, it is important to make sure that a vessel is not located in the path of the biopsy on the slices superficial or deep to the level of the target. In addition, it is important to scroll through all of the tomosynthesis images to be certain that the correct area is being sampled (see Fig. 14.6). Similar to stereotactically guided biopsies, a stereo pair should be obtained to show the prefire position of the needle. Alterations to the x and y positions may be made if necessary. Although tomosynthesis images may be obtained when the needle is in place, the quality of the image is degraded due to artifact. With the currently available tomosynthesis biopsy unit, the needle is advanced until the Z differential is zero. A postfire stereotactic pair may also easily be obtained if desired. After the samples are acquired and a specimen radiograph is performed, the needle is removed, leaving the sheath in place, and the biopsy clip is placed. Tomosynthesis images can be obtained to verify clip placement, and the Z value (depth) of the target on the original targeting images may be compared with the clip Z value to check for clip migration. As with stereotactically guided biopsies, a 2D mammogram with the breast in gentle compression is then performed to assess for clip migration. Postprocedure care is identical to that of biopsies performed with the prone stereotactic biopsy device.

Tomosynthesis-Guided Wire and Seed Localizations

Where tomosynthesis-guided stereotactic biopsy is not available or if the patient prefers surgical excision, tomosynthesis-guided localization presents an alternative option. Both wire and radioactive seed localization may be performed with tomosynthesis guidance. This procedure mirrors conventional preoperative needle localization with the added tool of three-dimensional (3D) imaging to identify lesions seen only on tomosynthesis slices. Preprocedure planning is identical to the 2D environment, with the preferred route—either shortest distance and/or best visualized projection—and appropriate needle length chosen on the basis of diagnostic images.

After the area of interest is in position within the localization grid, a tomosynthesis acquisition is obtained. The radiologist can then scroll through the imaged breast volume to the slice that best reveals the lesion. This can be performed directly on the acquisition workstation in the biopsy room with minimal delay. After the lesion is identified, the crosshairs are placed at the desired location, and the radiologist can scroll back to the

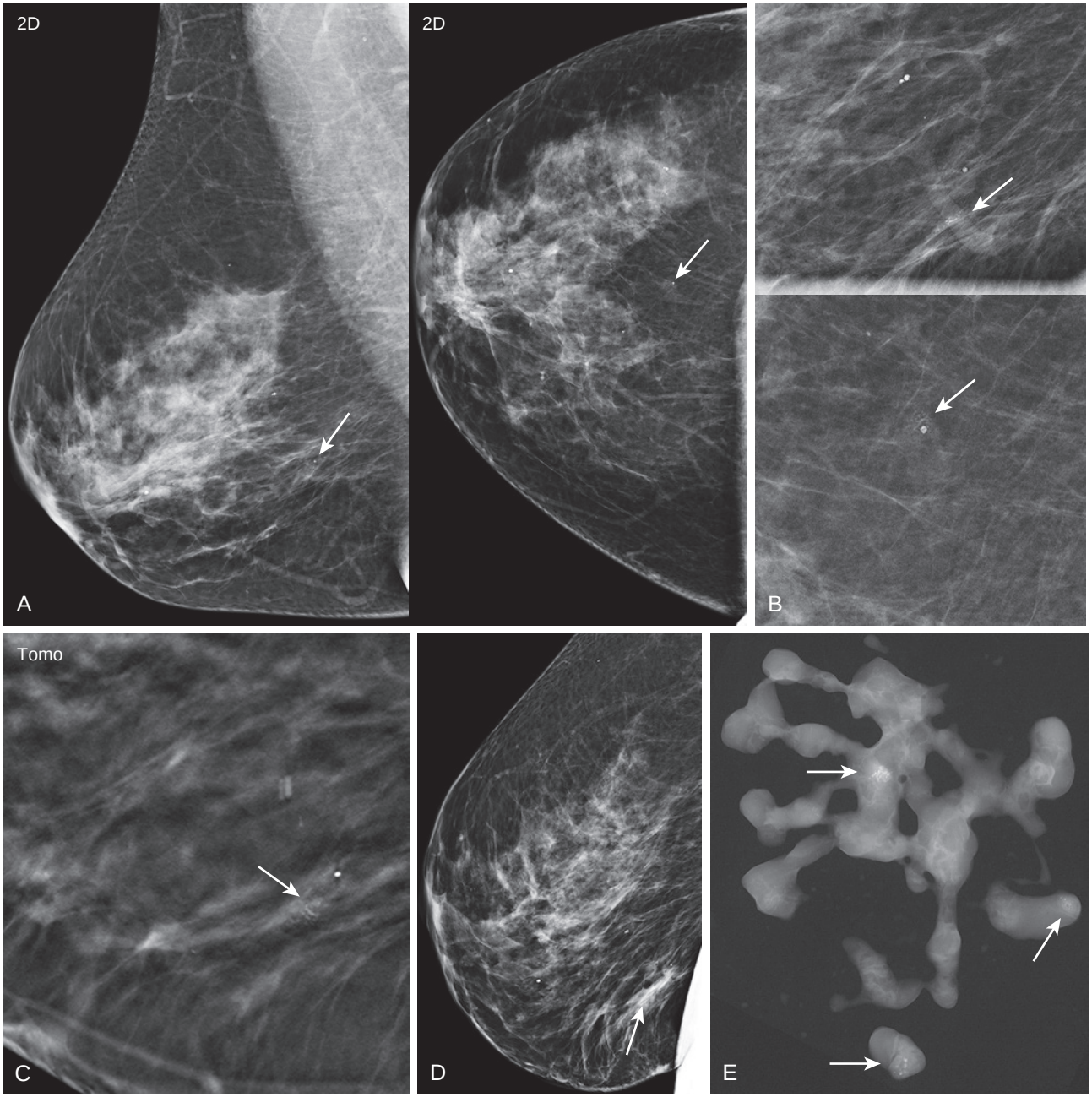


FIG. 14.8 (A) Right mediolateral oblique and CC views of a 47-year-old woman who was recalled from this screening mammogram due to increasing calcifications *(arrows)* in the inferior right breast. **(B)** Right magnification 90-degree and CC views demonstrate the calcifications *(arrows)*. **(C)** Right 90-degree tomosynthesis scout image from the tomosynthesis-guided biopsy demonstrates the suspicious group of calcifications *(arrow)*. An inferior approach is not possible with the tomosynthesis biopsy device currently available. **(D)** Postprocedure right 90-degree views demonstrate appropriate positioning of the T-shaped clip *(arrow)*. **(E)** Specimen radiograph demonstrating representative calcifications *(arrows)* within several of the core specimens. The final pathology revealed flat epithelial atypia, and the patient underwent seed-localized excisional biopsy.

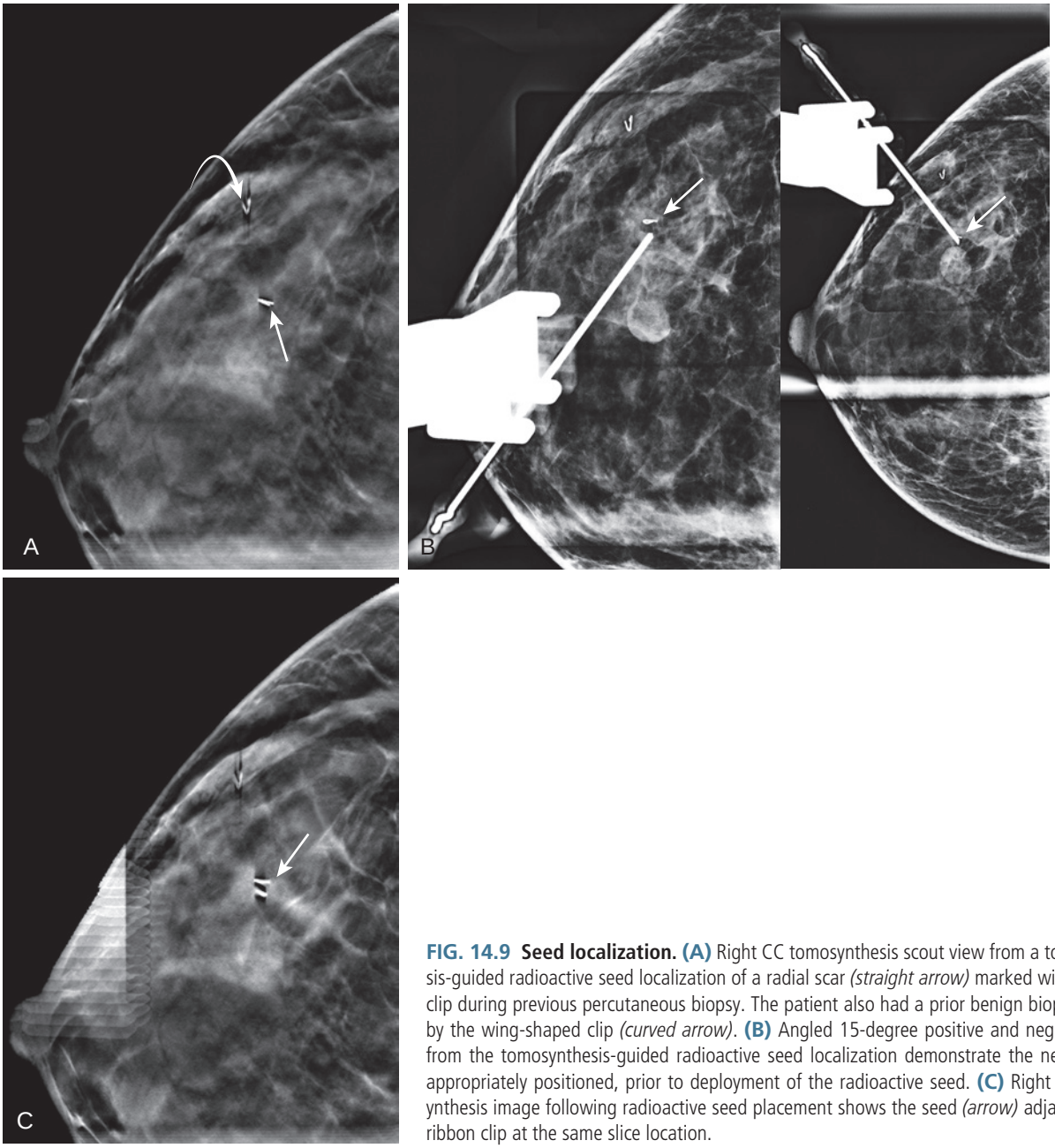


FIG. 14.9 Seed localization. (A) Right CC tomosynthesis scout view from a tomosynthesis-guided radioactive seed localization of a radial scar *(straight arrow)* marked with a ribbon clip during previous percutaneous biopsy. The patient also had a prior benign biopsy marked by the wing-shaped clip *(curved arrow)*. **(B)** Angled 15-degree positive and negative views from the tomosynthesis-guided radioactive seed localization demonstrate the needle to be appropriately positioned, prior to deployment of the radioactive seed. **(C)** Right CC tomosynthesis image following radioactive seed placement shows the seed *(arrow)* adjacent to the ribbon clip at the same slice location.

skin surface to visualize the corresponding grid coordinates. The needle is then placed as usual using the shadow of the crosshairs within the localization grid, and a confirmatory second tomosynthesis acquisition is obtained. Once again, the radiologist can scroll through the imaged breast volume and ensure that the needle has been placed through the targeted site.

For seed locations, the needle containing the seed may be placed at the correct 3D position within the breast without the need for an orthogonal image to readjust the needle tip prior to deploying (Fig. 14.9).

For wire localizations, the breast is positioned in the orthogonal plane, and a tomosynthesis acquisition is again obtained. Again, the radiologist can scroll through the breast to the tomosynthesis slice that best demonstrates the lesion and evaluate the relative depth of the needle (Fig. 14.10). As in 2D localization, adjustments in depth can be made prior to deploying the wire with further confirmatory acquisitions performed as needed. A final tomosynthesis acquisition is obtained to demonstrate the placement of the wire through the targeted lesion on tomosynthesis slices.

When lesions seen only with tomosynthesis are localized, a 2D specimen radiograph may or may not demonstrate the finding. With less overlying breast tissue, some tomosynthesis-only lesions are rendered visible on 2D imaging of the specimen. This is a reasonable first step, especially if a specimen radiography unit is available in the operating room to save the time required by specimen transport to the radiology department. However, if the presence of the lesion cannot be verified, the specimen can be brought to the department where a tomosynthesis specimen radiograph can be performed, which may provide more definitive proof that the lesion was successfully removed.

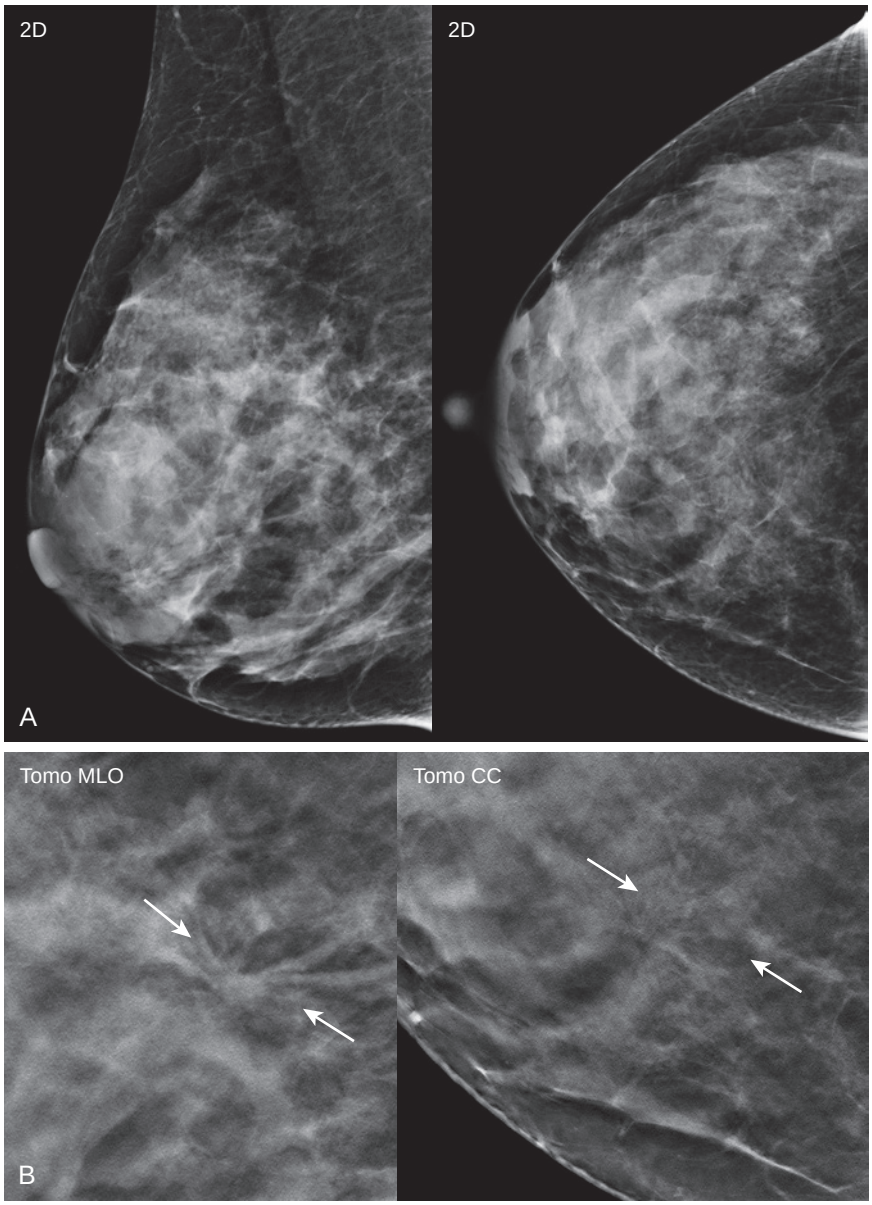


FIG. 14.10 Wire localization. A 44-year-old woman with family history of breast cancer presents for annual screening mammography. **(A)** 2D MLO and CC views show heterogeneously dense breast tissue with no suspicious findings. **(B)** Tomosynthesis reveals focal architectural distortion in the superior medial breast *(arrows)*, best seen in the MLO projection. Ultrasound was negative (not shown).

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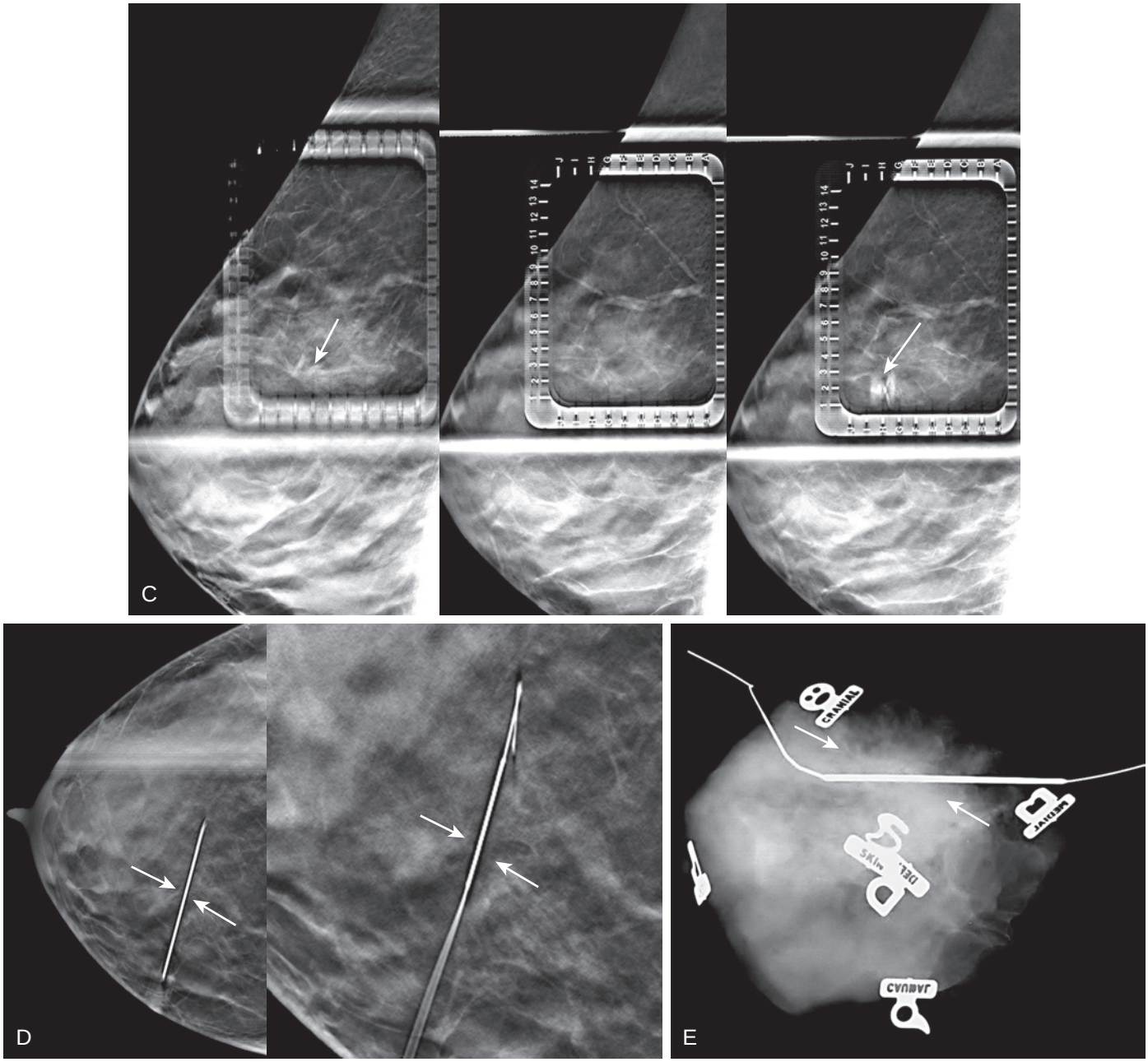


FIG. 14.10, cont'd (C) After placing the region of interest in the localization grid in the mediolateral projection, the finding is identified on tomosynthesis slices. The corresponding coordinates, in this case H and 2, are identified by scrolling back to the plane of the localization grid, and the needle is placed at the targeted site. **(D)** The breast is then positioned in the orthogonal CC projection, and tomosynthesis sections are used to confirm that the needle *(arrows)* traverses and extends beyond the lesion before the wire is placed at the desired location. **(E)** 2D specimen demonstrates subtle architectural distortion adjacent to reinforced portion of localization wire *(arrows)*. Surgical pathology revealed a benign radial scar.

Conclusion

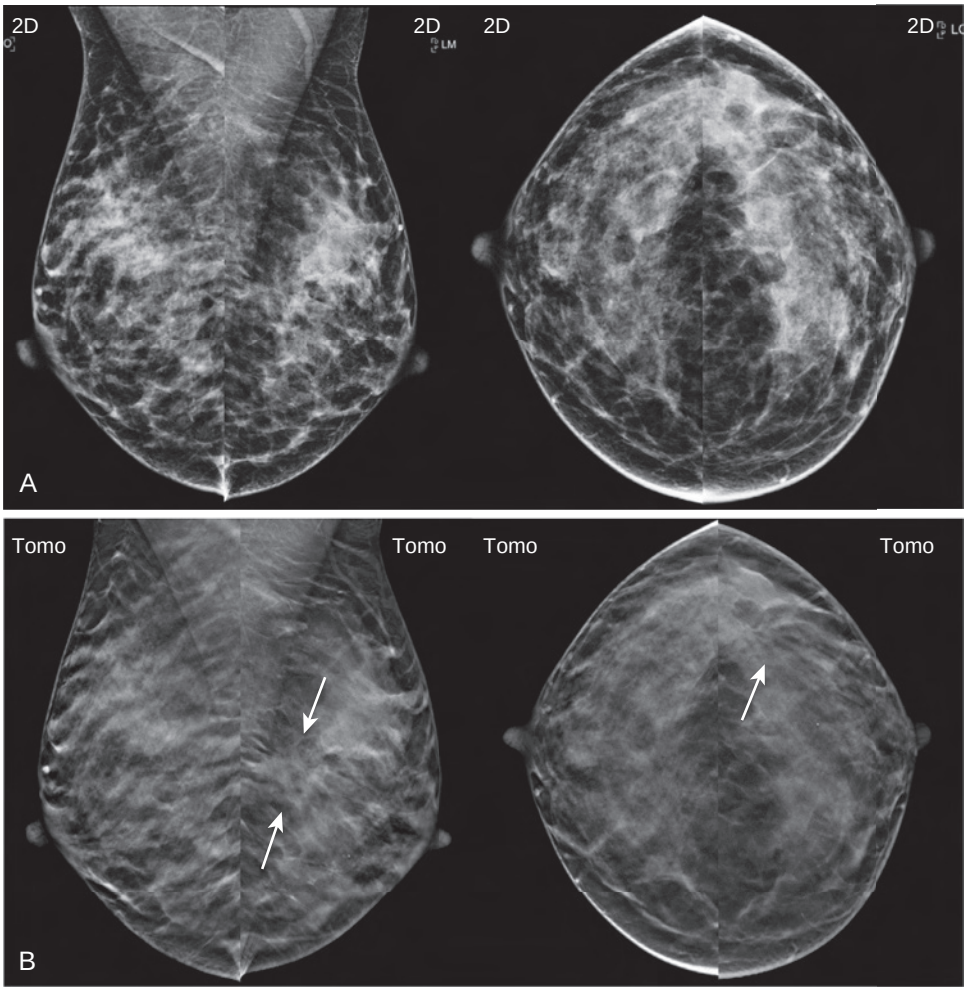
Akin to MRI, it is imperative for practices that use breast tomosynthesis in both the diagnostic and screening settings to have tomosynthesis-guided biopsies capabilities. Inevitably there will be lesions identified solely by tomosynthesis or better visualized with tomosynthesis that will require tomosynthesis guidance for biopsy. In addition to better lesion visibility, there are many advantages to tomosynthesis-guided breast biopsies, such as cost effectiveness, patient accessibility, and improvement in workflow.

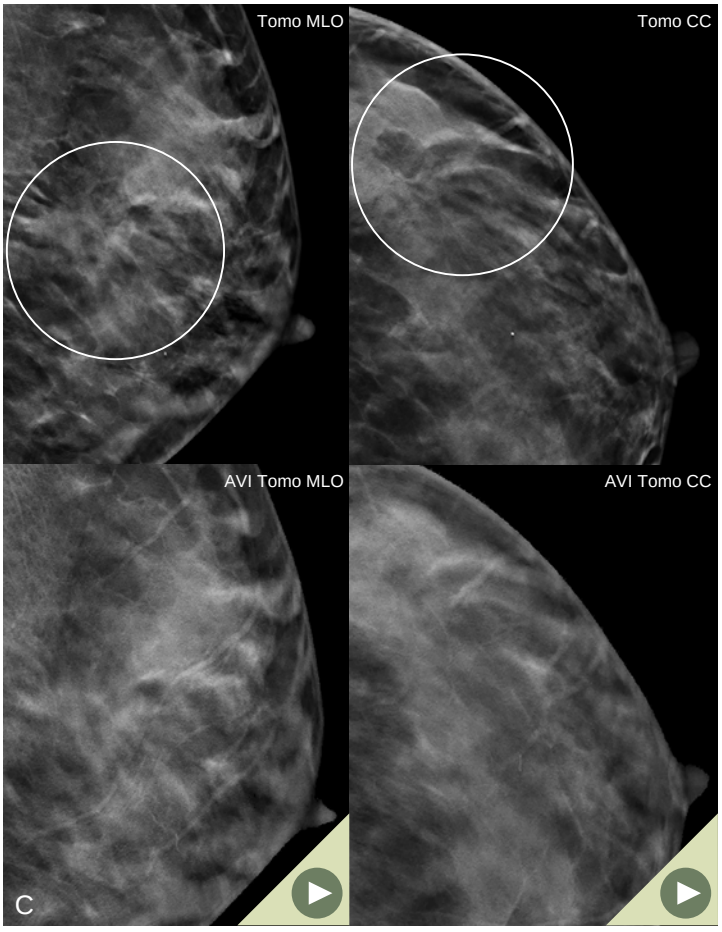
Video Case Studies

Note: Tomosynthesis video files are included in the e-book version.

Chapter 1

CASE STUDY 1.1 Bilateral screening mammogram in a 48 year-old woman. **(A)** Extremely dense breast tissue is noted, although no suspicious abnormality is seen on the 2D images. **(B)** However, tomosynthesis reveals an architectural distortion in the left posterior outer breast at the 3-o'clock position *(arrows)*. **(C)** Close-up MLO and CC views plus AVI better depict the architectural distortion *(circles)*. **(D)** Targeted ultrasound reveals a corresponding hypoechoic irregular mass with posterior acoustic shadowing, as well as a second focal irregular hypoechoic mass with indistinct margins and posterior acoustic shadowing in the left lateral breast. **Diagnosis: Ultrasound-guided CNB = infiltrating lobular carcinoma, moderately differentiated at both sites, ER/PR+, Her–, 0/1 SLN. Tumor size was 6 cm at excision/partial mastectomy**.




Tomo MLO
Tomo CC
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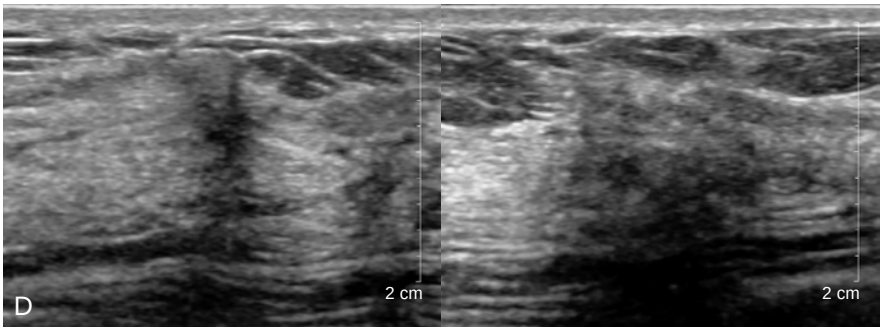
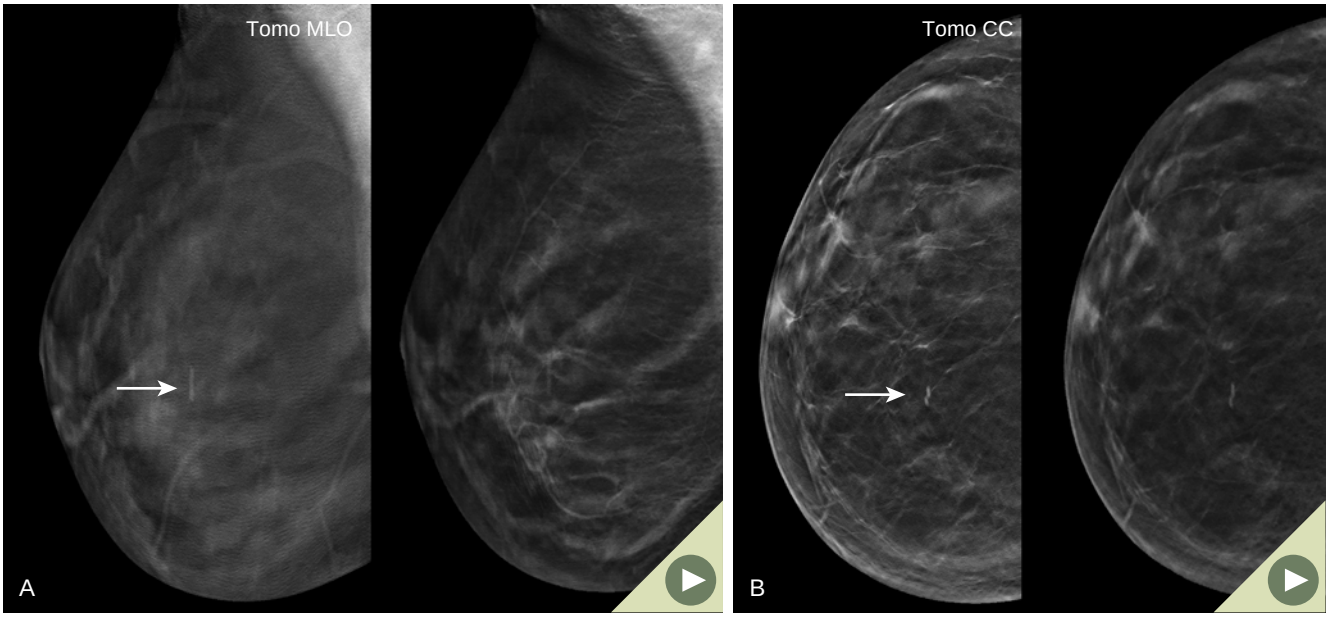
AVI Tomo CC
C

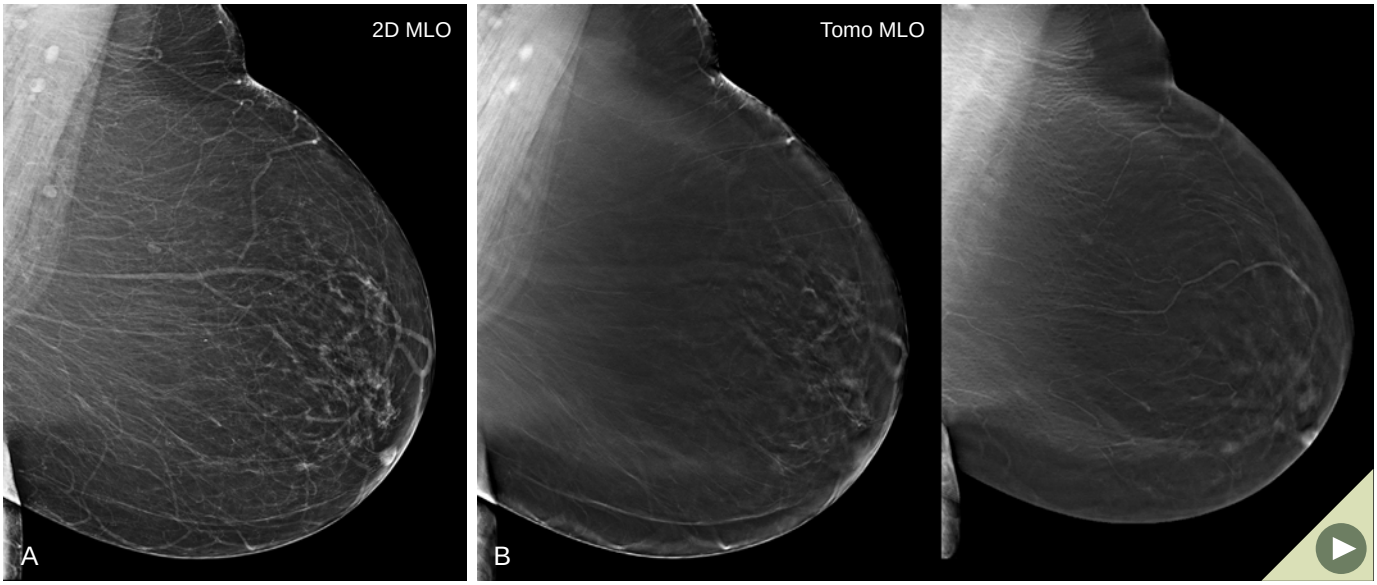

2 cm
2 cm
D

Chapter 3

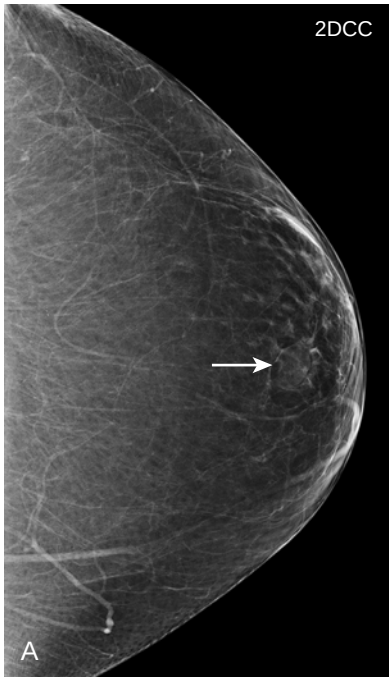
CASE STUDY 3.1 (A) ▶ A coarse calcification in the right central breast is noted to have a straight slinky artifact on the out of plane MLO tomosynthesis view *(arrow)*. **(B)** ▶ This calcification appears serpiginous on the CC tomosynthesis view *(arrow)*. Note that the Cooper ligaments are not as sharp on the CC view. **Conclusion: CC motion artifact.**

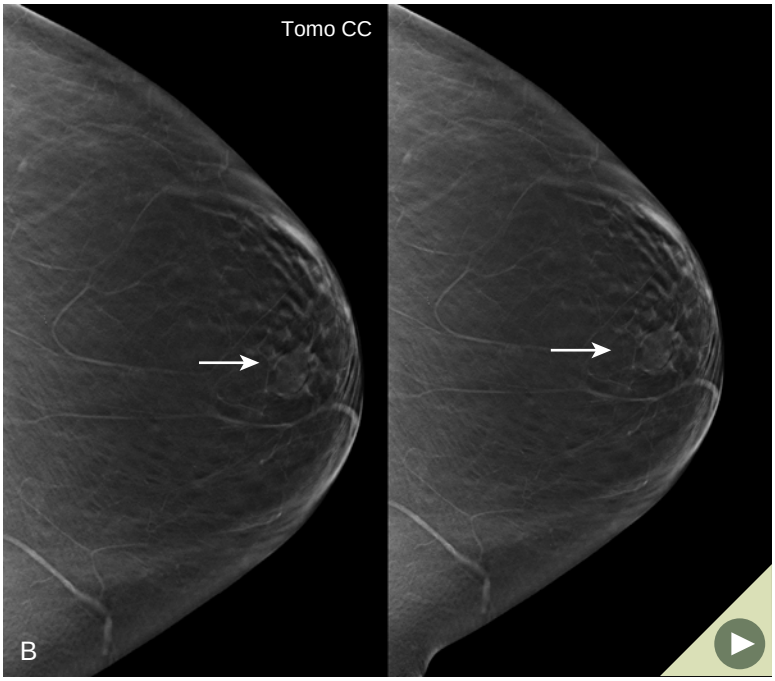


CASE STUDY 3.2 (A) 2D MLO demonstrates scattered fibroglandular tissue and no abnormalities. **(B)** ▶ Tomosynthesis MLO reveals a foggy ground-glass appearance along the posterior breast. Because the 2D portion of the exam is normal, the possibility of a detector abnormality is excluded. **Conclusion: Tomosynthesis processing artifact.**



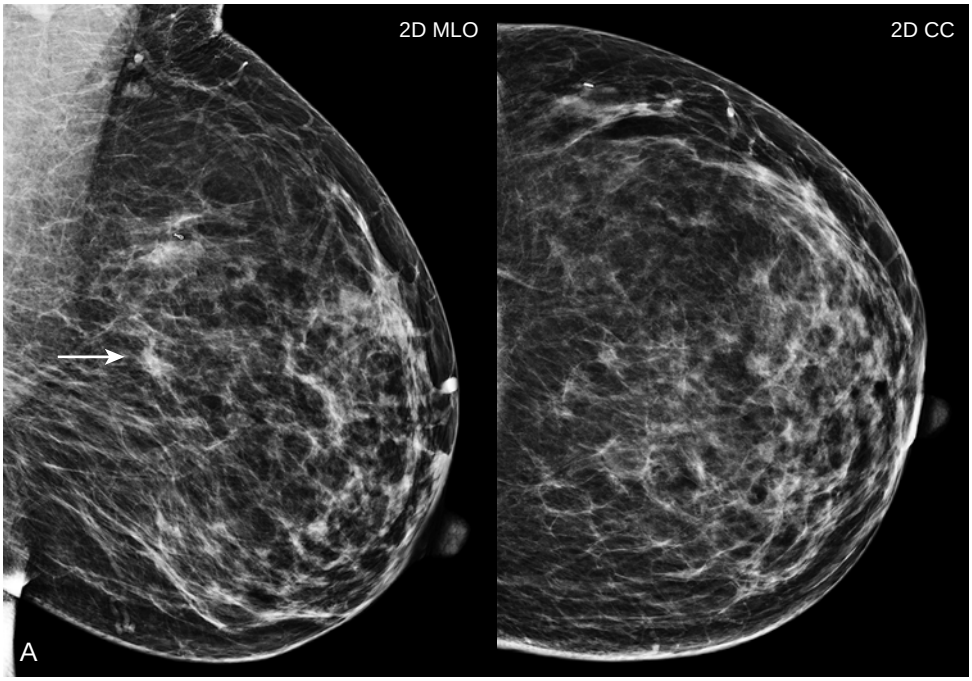
CASE STUDY 3.3 This screening mammogram reveals predominately fatty breast tissue. **(A)** On the 2D CC view, an oval asymmetry is noted in the anterior breast, most likely the nipple. **(B)** ▶ On tomosynthesis, the asymmetry is best seen on the first slice. **Conclusion: Although for optimal positioning nipples should be in profile, it is not always possible, and some technical repeats can be avoided as tomosynthesis permits visualization of the underlying tissue.**

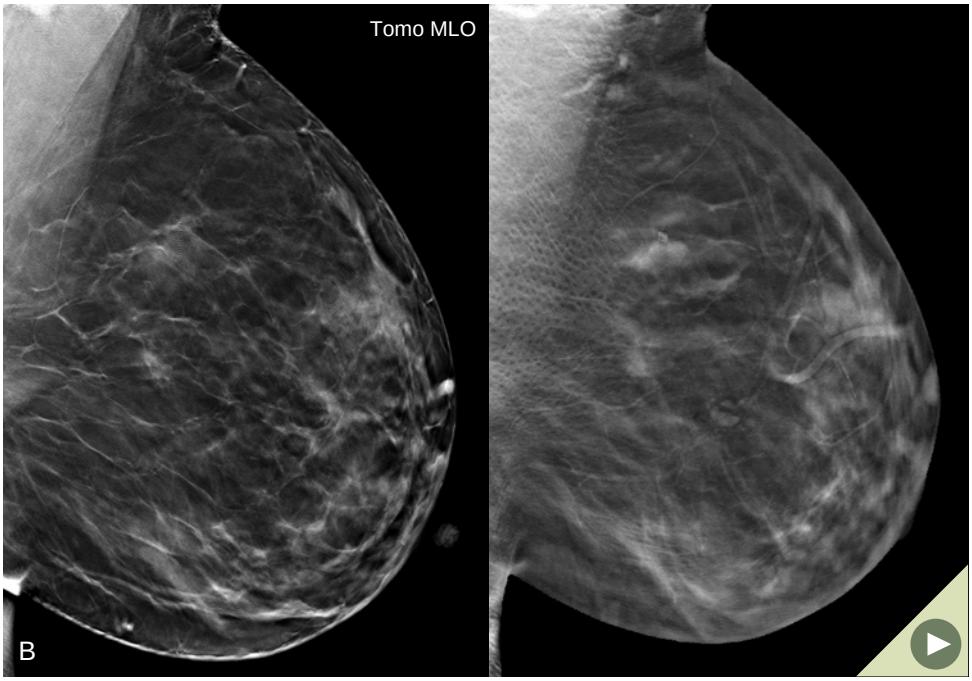




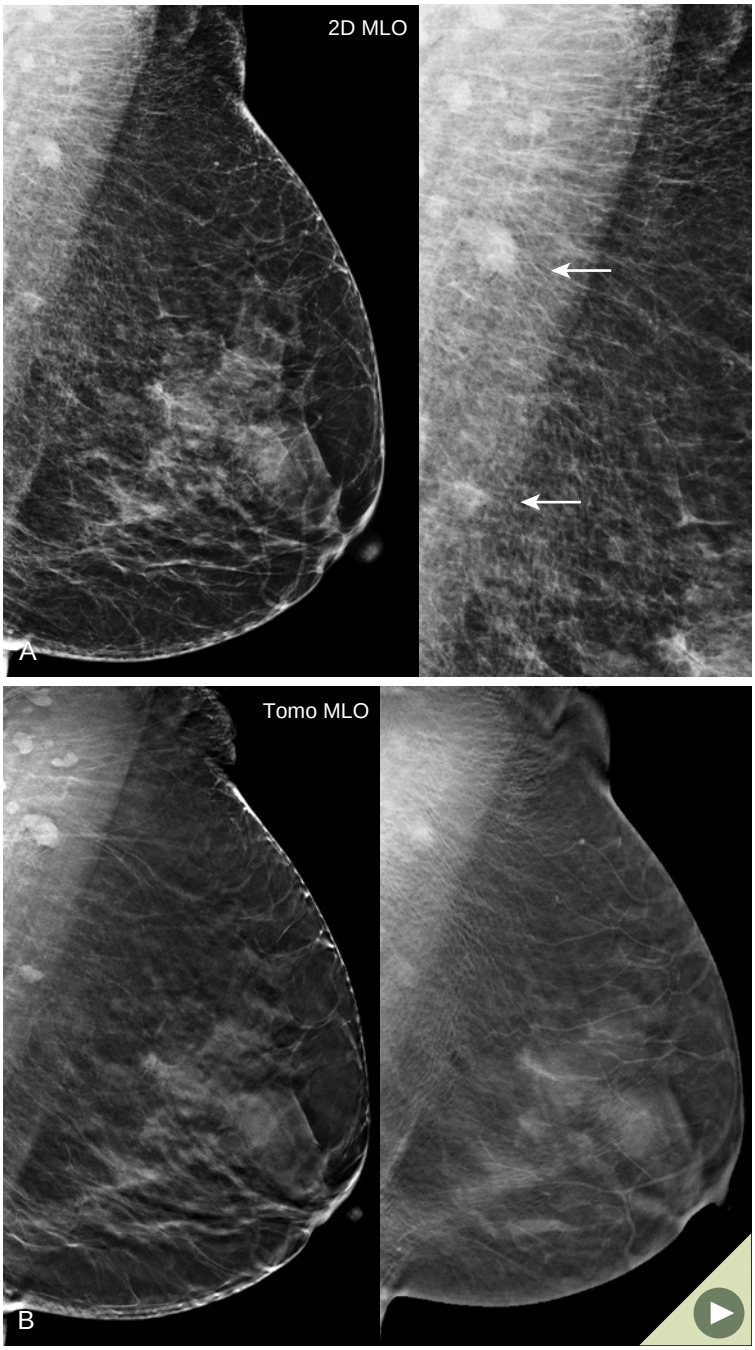
Chapter 5

CASE STUDY 5.1 (A) A focal asymmetry is noted on the left breast 2D MLO view only of a screening exam on a 44-year-old woman with scattered fibroglandular tissue. **(B)** ▶ Tomosynthesis images show that the asymmetry is caused by superimposed normal tissue because no underlying mass is seen when scrolling through the entire stack of images. **Diagnosis: Normal tissue. No recall necessary.**

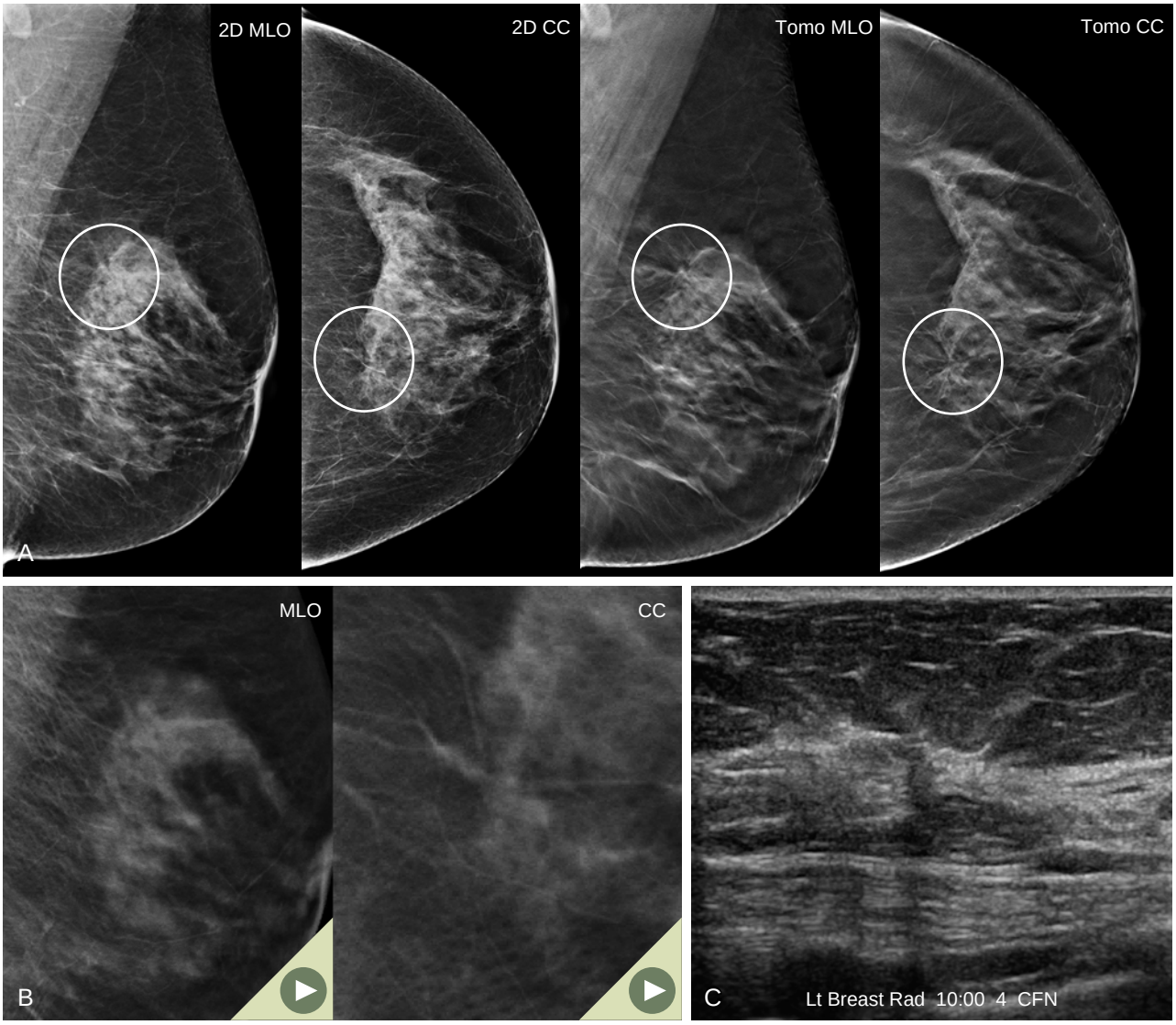




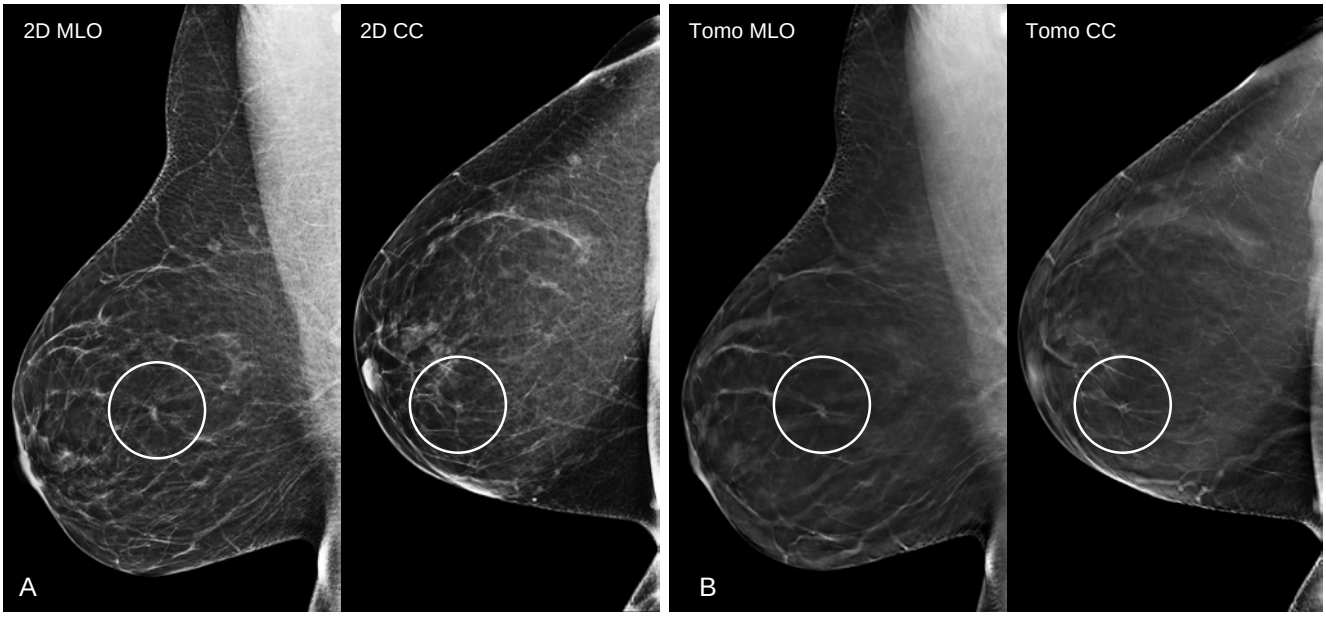
CASE STUDY 5.2 (A) Screening mammogram of a 64-year-old woman shows several masses in the posterior left breast that appear ill-defined on the 2D image. **(B)** ▶ Tomosynthesis slice and movie images demonstrate the reniform shape, circumscribed margins, and fatty hilum of benign-appearing lymph nodes. **Diagnosis: Benign lymph nodes. No recall necessary.**

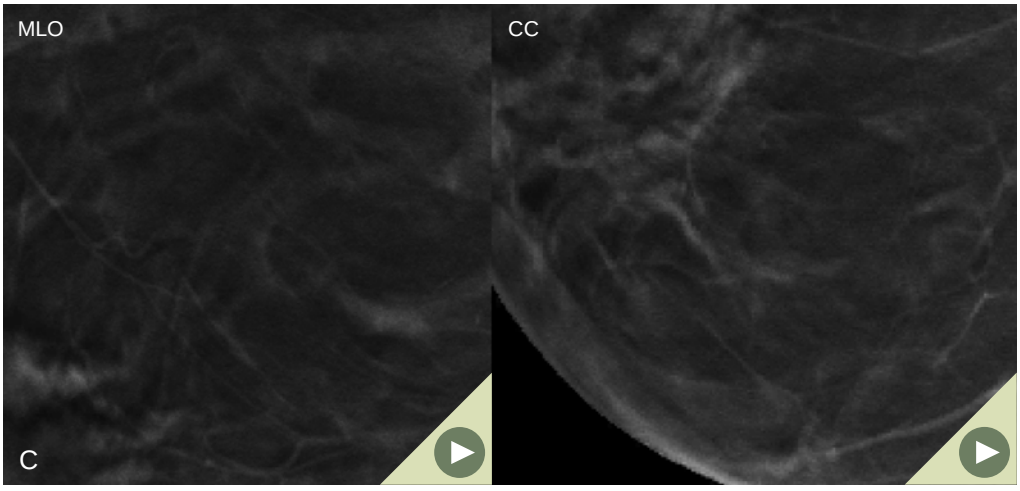


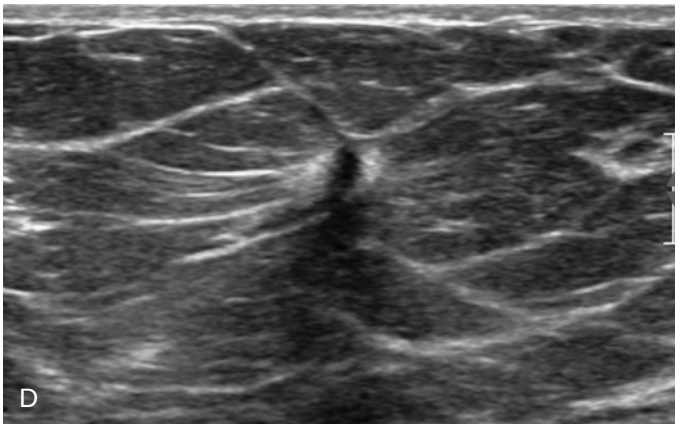
CASE STUDY 5.3 A 67-year-old woman with heterogeneously dense breasts was recalled from screening for architectural distortion in the left breast, better seen on tomosynthesis images. **(B)** ▶ ▶ The spiculations are well demonstrated on the tomosynthesis movie images. **(C)** Ultrasound shows an isoechoic, taller-than-wide mass. **Diagnosis: Ultrasound-guided core needle biopsy was performed, with concordant pathology of radial scar.**



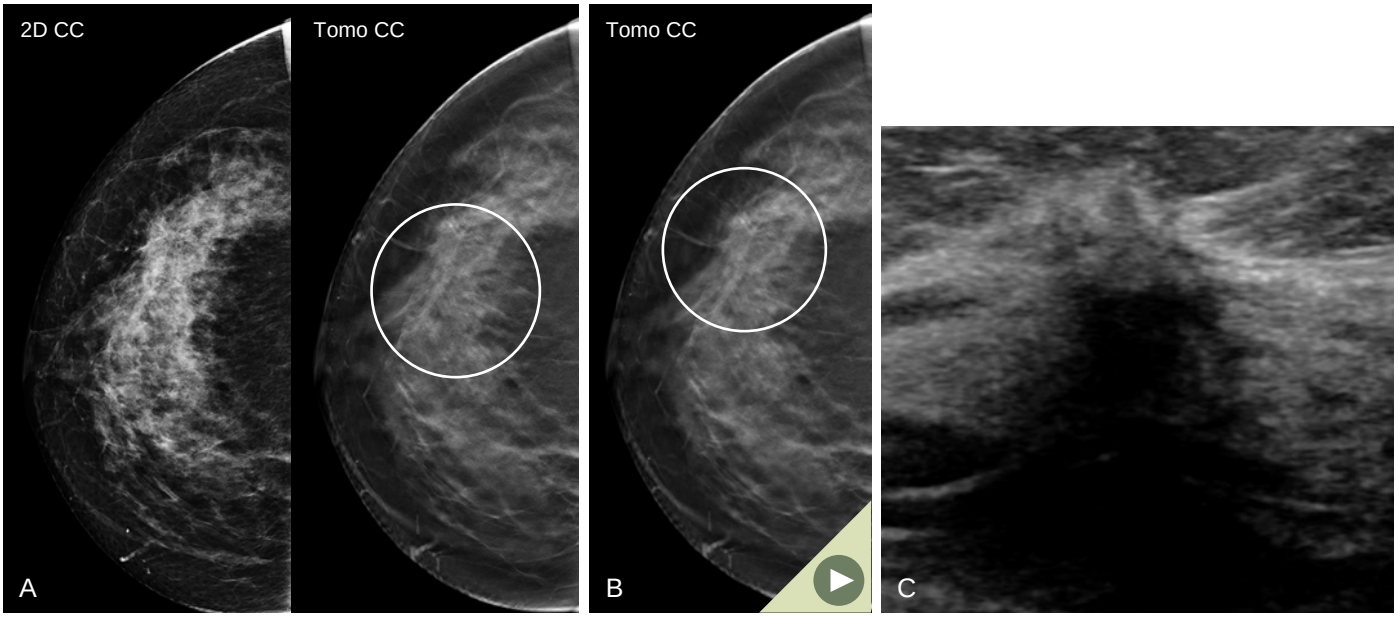
CASE STUDY 5.4 **(A)** A baseline screening mammogram of a 43-year-old with nondense tissue showed a small subtle mass in the right breast. **(B)** Associated spiculations are better seen on tomosynthesis slice and **(C)** ▶ ▶ movie images. **(D)** US showed a small, taller-than-wide hypoechoic mass. **Diagnosis: Final pathology invasive ductal carcinoma, T1cN0, ER/PR+, Her2–.**



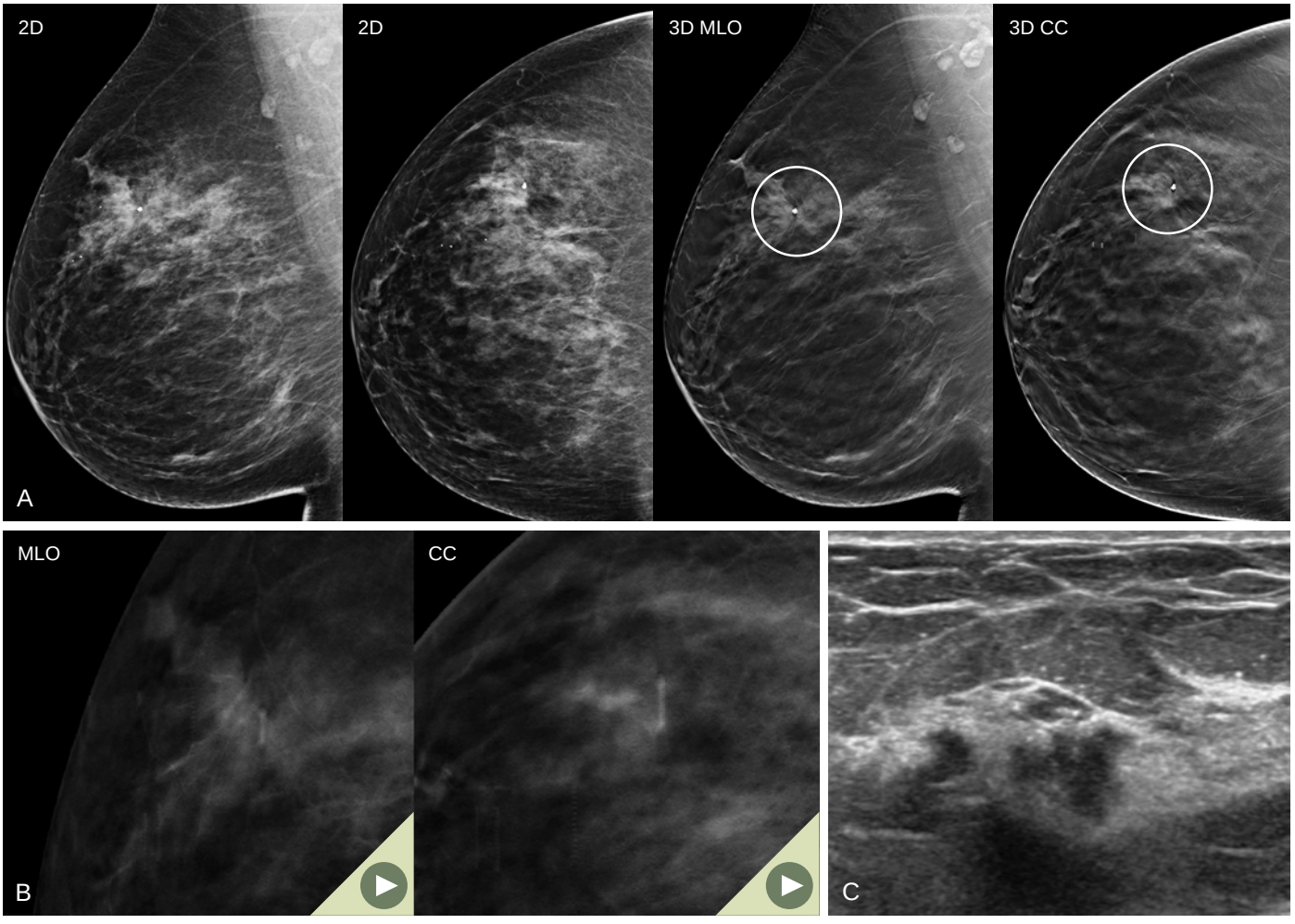




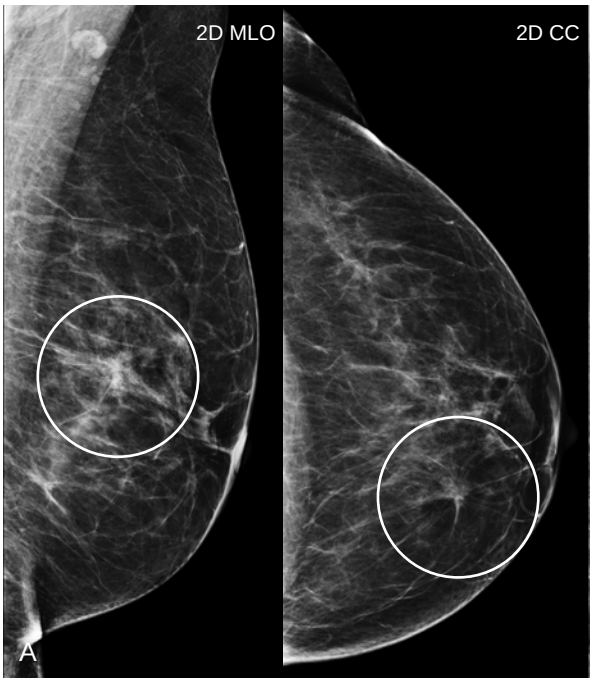
CASE STUDY 5.5 (A) A 54-year-old woman with heterogeneously dense breasts was recalled for a mass *(circle)* in the lateral right breast, identified on the tomosynthesis images. **(B)** ▶ The spiculations highlight the mass and are much better appreciated on the tomosynthesis movie images. **(C)** Ultrasound confirmed a hypoechoic spiculated, shadowing mass. **Diagnosis: Ultrasound-guided core needle biopsy yielded invasive ductal carcinoma, T1c N2a, ER+, PR–, Her2+.**

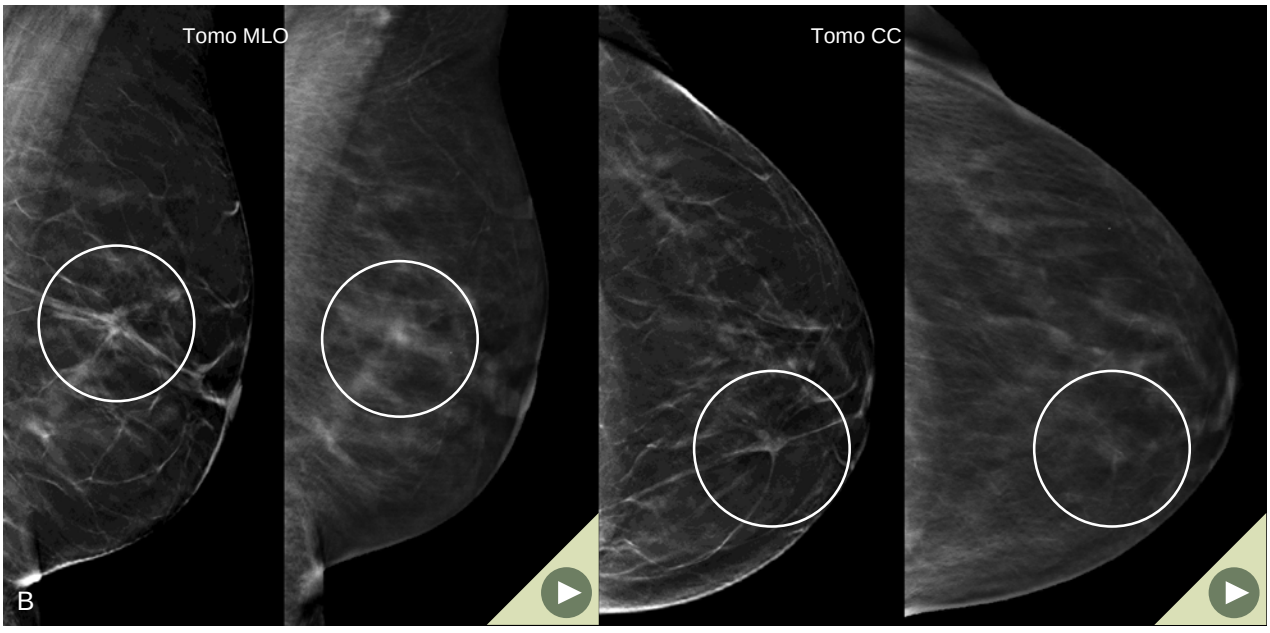


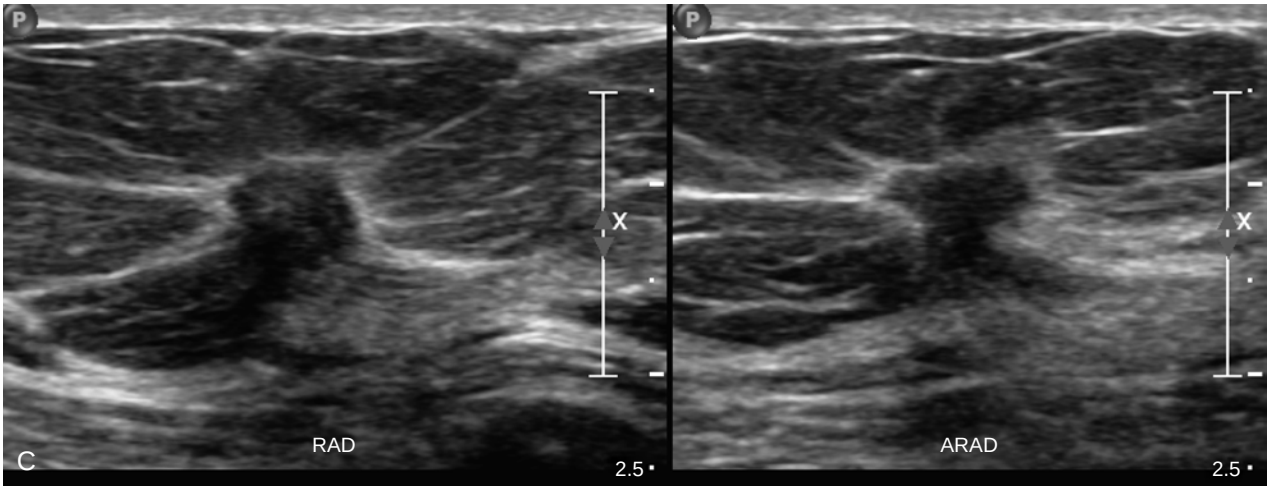
CASE STUDY 5.6 (A) A 62-year-old with right breast upper-outer quadrant mass obscured by superimposed tissue on 2D images, but more definite on tomosynthesis images *(circle)*. **(B)** ▶ ▶ Tomosynthesis movie images highlight the associated architectural distortion. **(C)** An ill-defined hypoechoic mass was found on US and core needle biopsy performed. **Diagnosis: Invasive ductal carcinoma, T2N0 , ER/PR+, Her2–.**



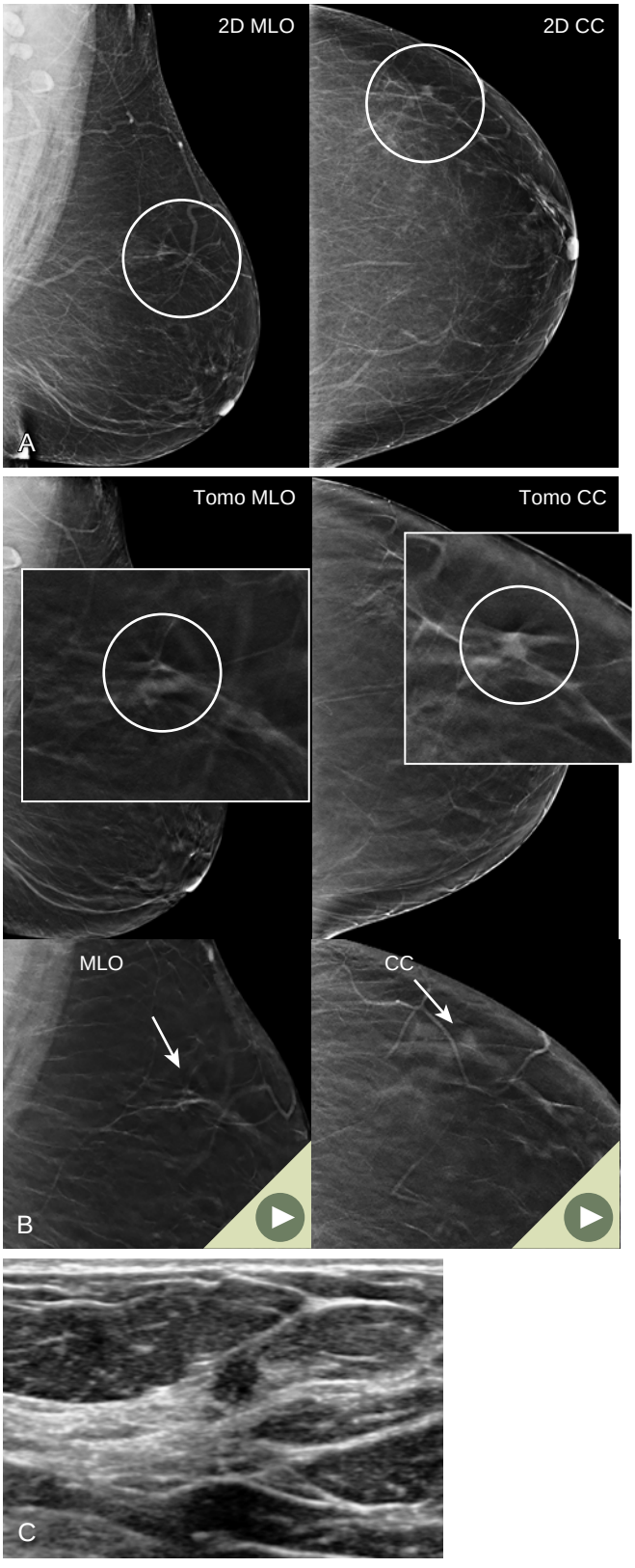
CASE STUDY 5.7 (A) A 53-year-old with left breast mass seen on screening mammogram. The spicules on the 2D image could be dismissed as adjacent fibroglandular tissue. **(B)** ▶▶ Tomosynthesis slice and movie images demonstrate that the spicules radiate distantly from the mass. **(C)** Ultrasound shows an irregular mass with angular and spiculated margins. **Diagnosis: Final pathology invasive ductal carcinoma, T1c N0, ER/PR+, Her2–.**



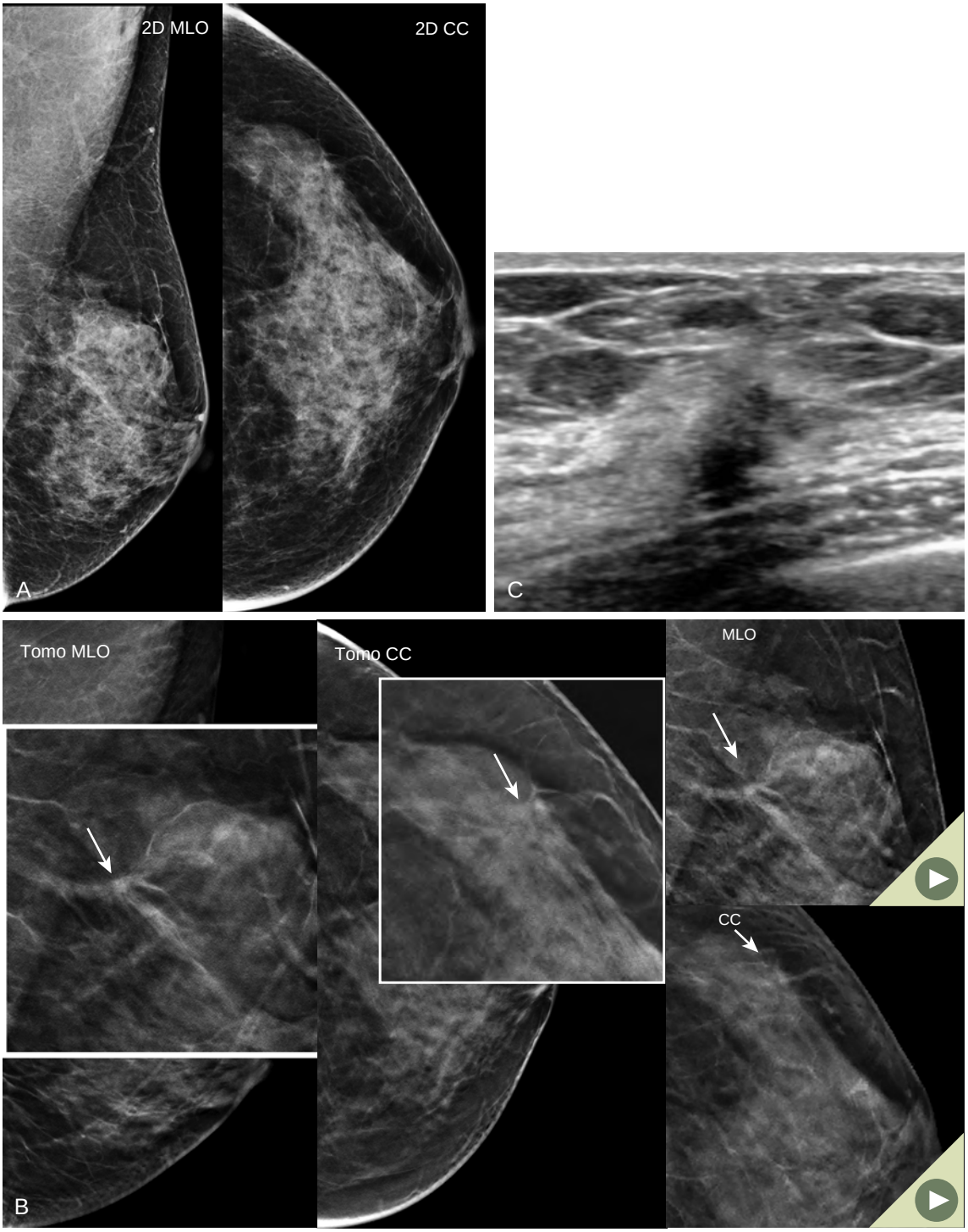




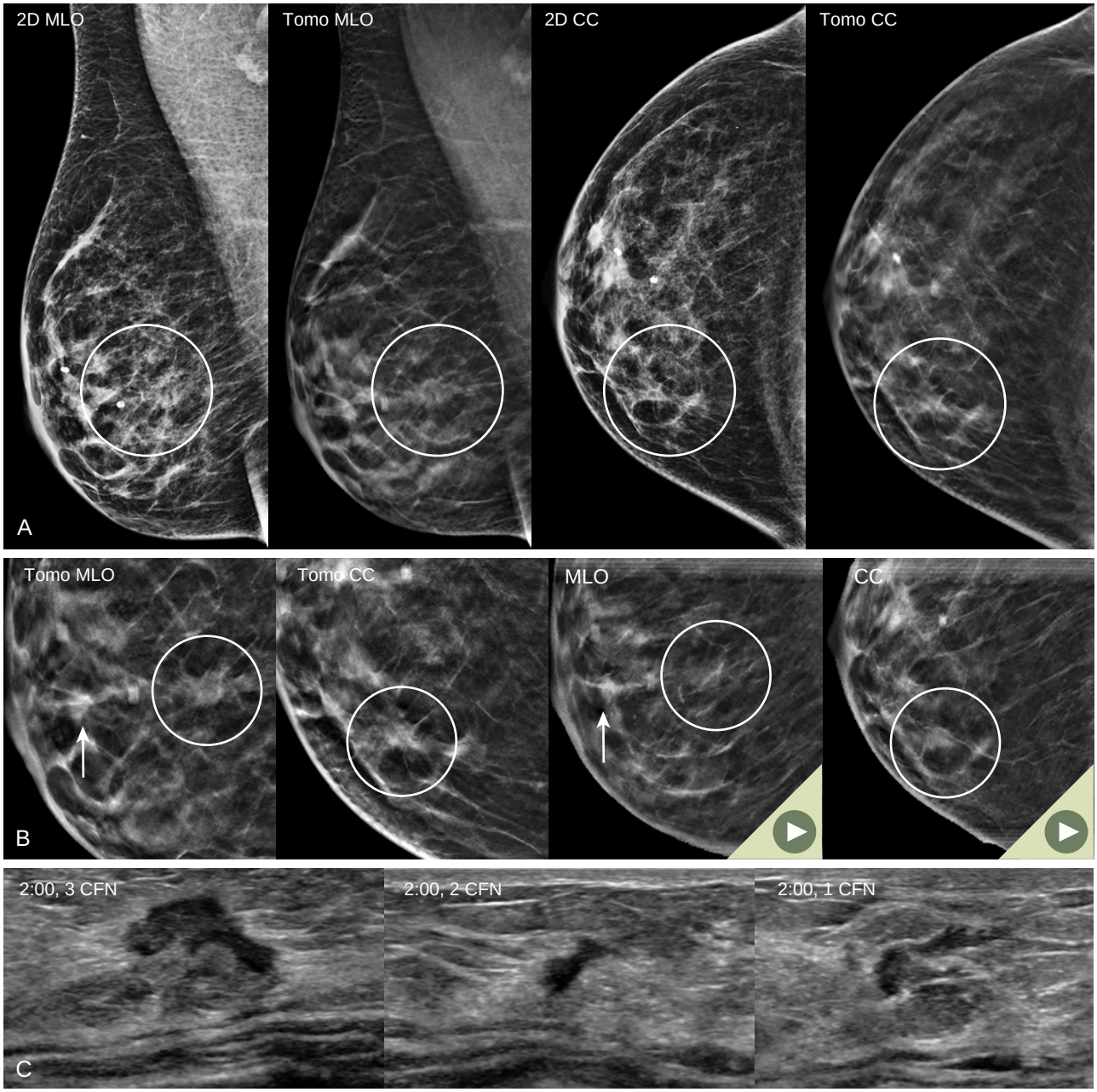
CASE STUDY 6.1 **(A)** A 62-year-old woman presents for annual screening mammography. 2D MLO and CC views show small focal asymmetry in left superior lateral breast *(circles)*. **(B)** ▶ ▶ Tomosynthesis shows associated spiculation, increasing the probability of malignancy. In this case, additional spot compression views were unnecessary. **(C)** Targeted ultrasound shows an irregular hypoechoic mass with spiculated margins and an anti-parallel orientation. Ultrasound-guided CNB and surgical excision were performed. **Diagnosis: Moderately differentiated invasive lobular carcinoma, ER/PR+, Her2–, 0/1 SLN.**



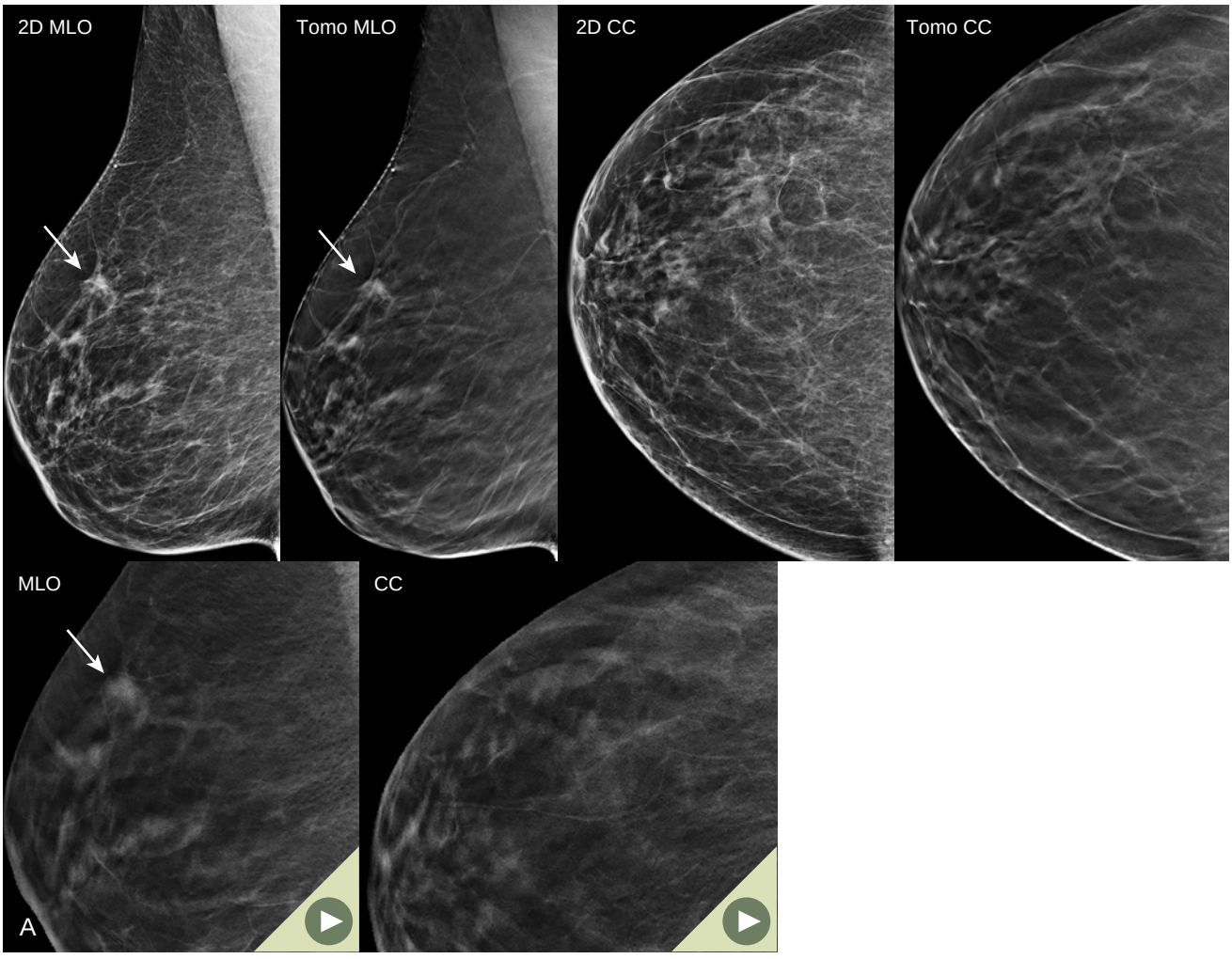
CASE STUDY 6.2 **(A)** 2D screening mammogram in 43-year-old woman reveals dense breast tissue and no suspicious findings. **(B)** ▶ ▶ Tomosynthesis MLO and CC views demonstrate a very subtle focal architectural distortion in left breast at the 3-o'clock position *(arrows)*. **(C)** Targeted ultrasound demonstrates a corresponding predominately hypoechoic mass with indistinct margins and anti-parallel orientation. Ultrasound-guided CNB and surgical excision were performed. **Diagnosis: 1.5 cm well-differentiated infiltrating ductal carcinoma, ER/PR+, Her2–, 0/1 SLN.**

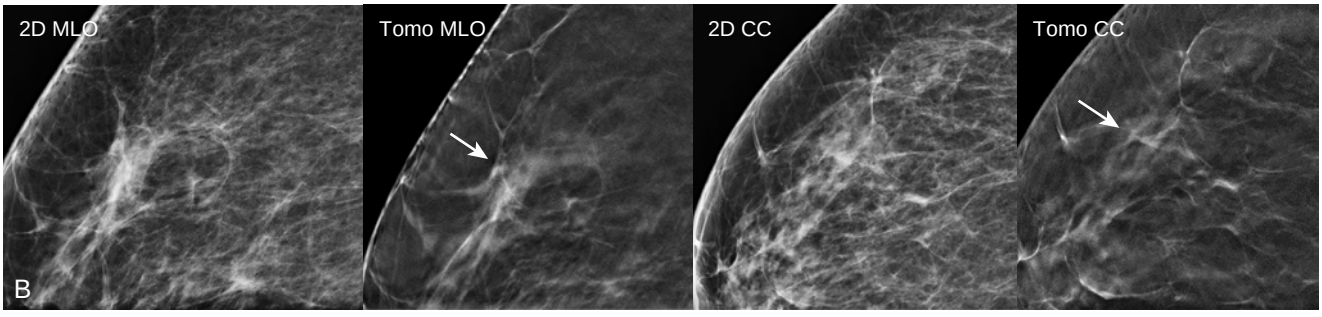


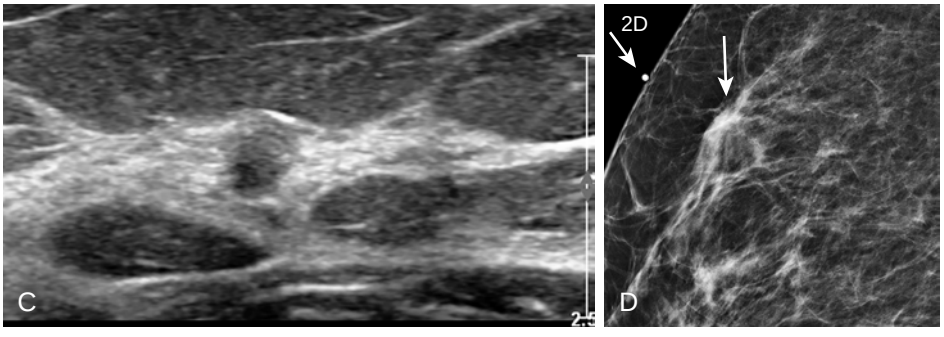
CASE STUDY 6.3 (A) A 71-year-old woman presents for annual screening mammography. 2D + tomosynthesis MLO and CC views show subtle architectural distortion in right breast posteriorly at the 3-o'clock position *(circles)*, which is better appreciated on the tomosynthesis images. **(B)** Spot compression tomosynthesis views performed to assess the extent of disease confirm architectural distortion *(circle)*, as well as demonstrate extension toward the nipple with at least one additional focal lesion in the retroareolar region *(arrow)*. **(C)** Ultrasound demonstrates intraductal extension with multiple lesions along the radial plane toward the nipple. Ultrasound-guided CNB and surgical excision were performed. **Diagnosis, all three lesions: Poorly differentiated invasive ductal carcinoma, ER/PR–, Her2–, 1/1 SLN.**



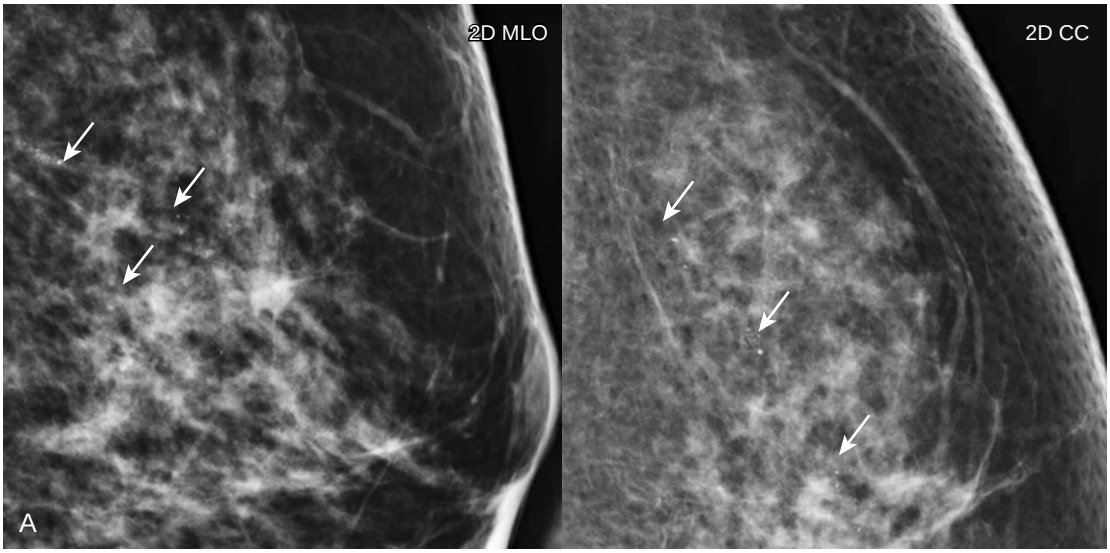
CASE STUDY 6.4 (A) Screening right mammogram in a 69-year-old woman with a focal asymmetry in the right upper breast initially seen only on the MLO view *(arrows)*. Using the tomosynthesis localizer tool bar (not shown), the asymmetry was thought to lie in the outer breast on the CC view. **(B)** Combination MLO and CC spot compression views demonstrate a very subtle architectural distortion on the tomosynthesis views *(arrows)*. In this case, spot compression views were helpful because the initial finding was very subtle. **(C)** Targeted ultrasound demonstrates an oval isoechoic mass. **(D)** A BB was placed on the skin over the mass seen on US, and a repeat 2D MLO view was obtained, confirming that the mass seen on US corresponded to the irregular asymmetry seen on mammography *(arrows)*. US-guided CNB and surgical excision were performed. **Diagnosis: Infiltrating ductal carcinoma, grade 1, ER/PR+, Her2–, 0/2 SLN.**

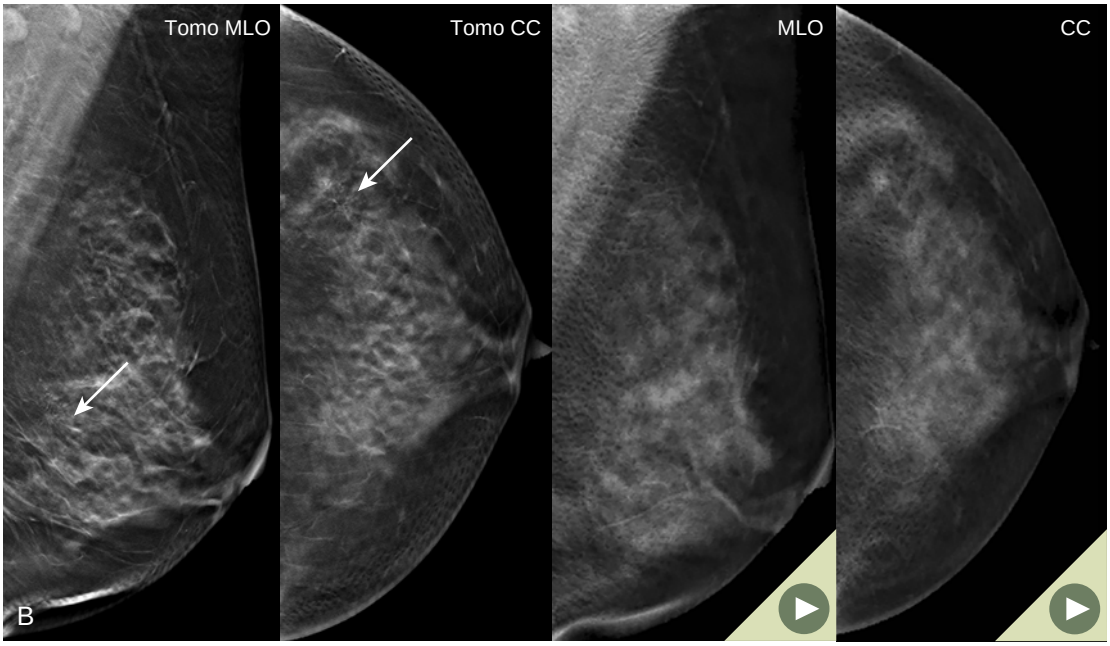


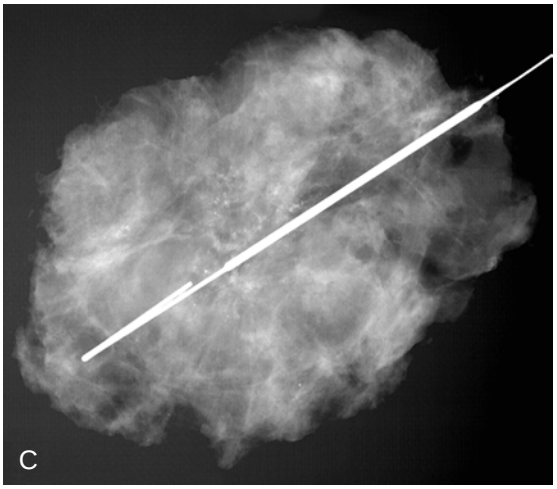




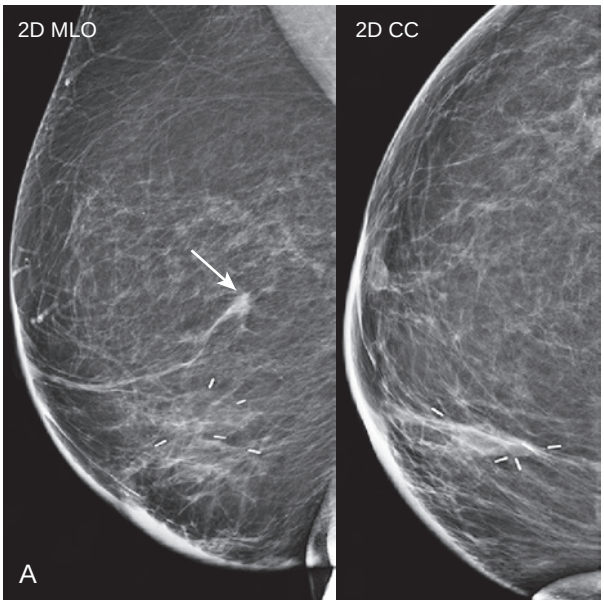
CASE STUDY 6.5 (A) Close-up views of a screening mammogram in 55-year-old woman shows multiple groups of calcifications in the left breast *(short arrows)*. **(B)** ▶ ▶ However, tomosynthesis reveals associated architectural distortion *(long arrows)*, raising the level of suspicion. Targeted ultrasound (not shown) was negative. The architectural distortion in this case represented the most suspicious focal finding within the larger region of multiple groups of calcifications. Rather than sampling the calcifications with 2D stereotactic biopsy, it was felt to be more important to target the architectural distortion. **(C)** Tomosynthesis-guided preoperative wire localization was performed. **Diagnosis: Radial sclerosing lesion with focal ADH**.

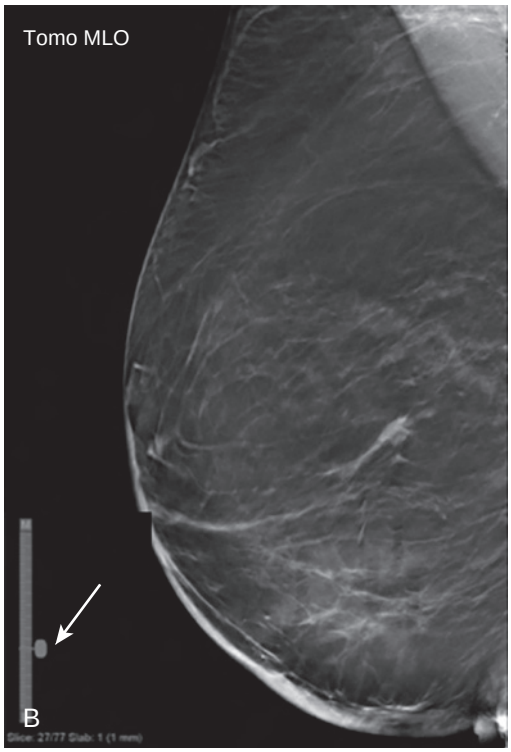


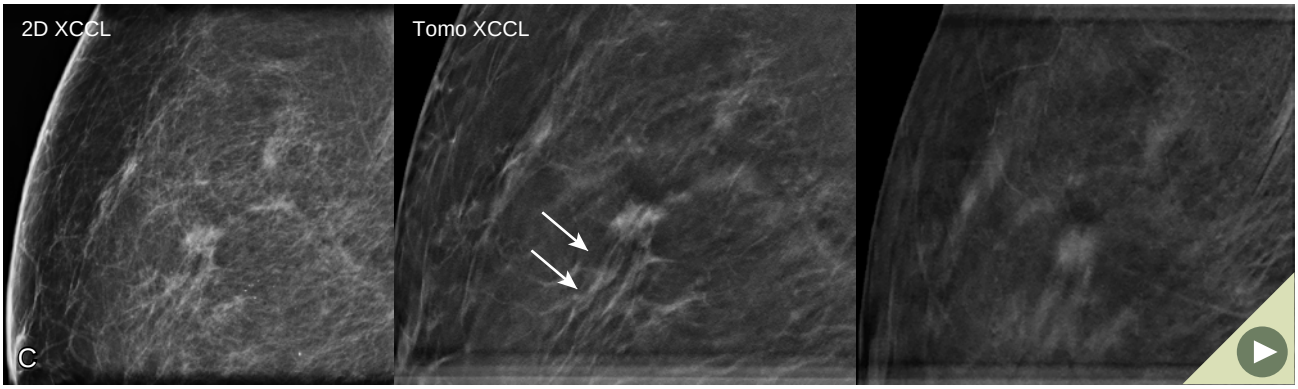


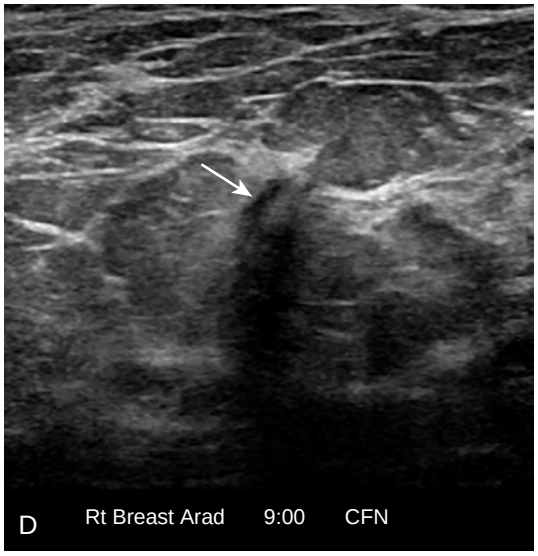


CASE STUDY 6.6 **(A)** Yearly mammogram in a 77-year-old woman with a remote history of bilateral breast cancer, including right reduction mammoplasty and lumpectomy. Right 2D mammogram demonstrates a developing asymmetry in the central breast above the lumpectomy scar, seen only on the MLO view *(arrow)*. **(B)** Using the tomosynthesis localizer tool *(arrow)*, the asymmetry was determined to be in the lateral aspect of the breast. **(C)** ▶ Spot compression combination 2D and tomosynthesis XCCL slice and movie images view reveals a corresponding asymmetry with subtle spiculated margins extending inferiorly, best seen on tomosynthesis *(arrows)*. **(D)** Targeted ultrasound shows a hypoechoic irregular mass with indistinct margins and posterior acoustic shadowing *(arrow)*. **(E)**. A BB was placed on the skin overlying the mass seen on US, and a repeat 2D CC view shows that the BB corresponds to a subtle asymmetry *(arrows)*. US-guided core needle biopsy was performed. **Diagnosis: Recurrent invasive ductal carcinoma, grade 2, ER/PR, Her 2–, 0/3 SLN.**






2D XCCL
Tomo XCCL
C


D
Rt Breast Arad
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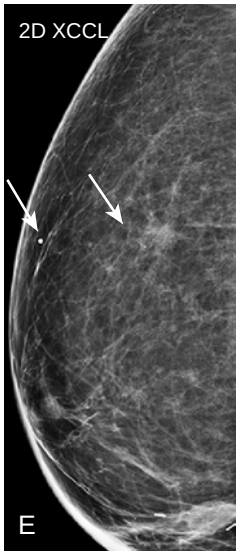
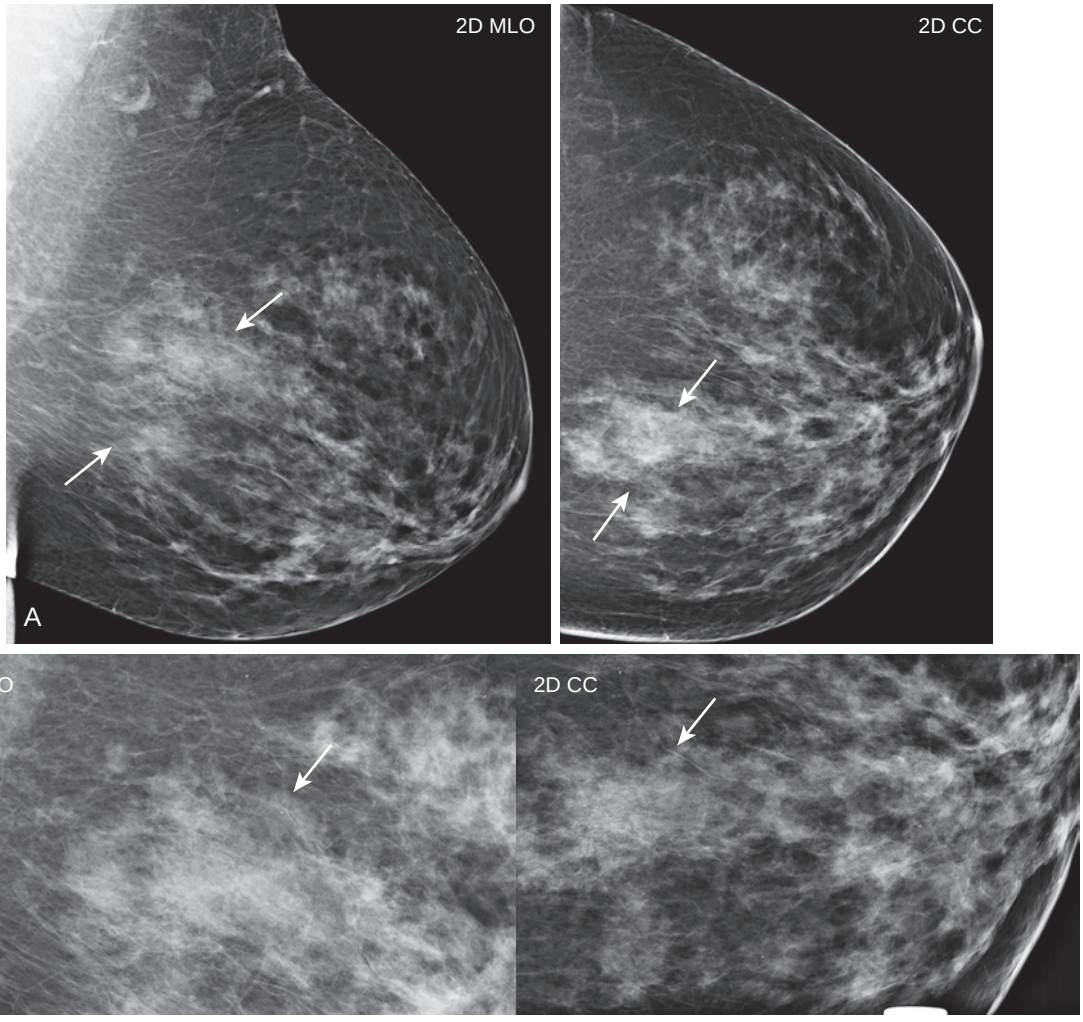
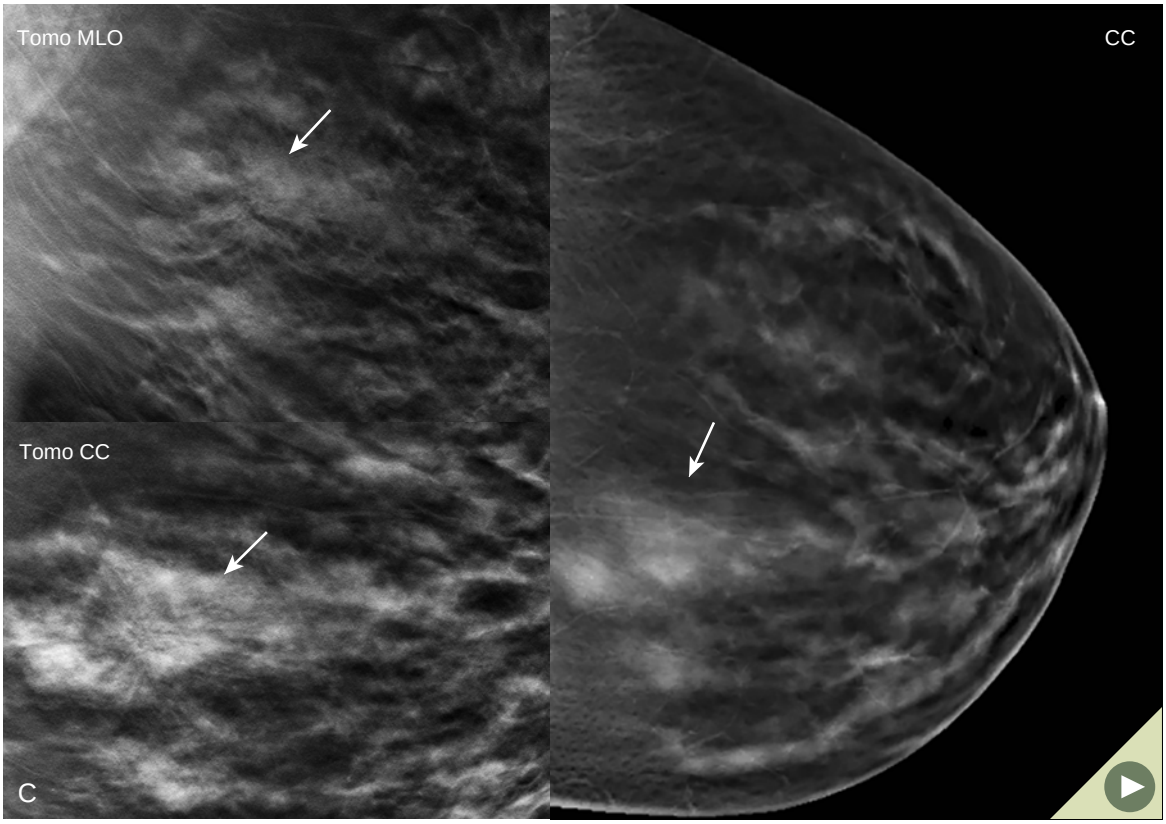
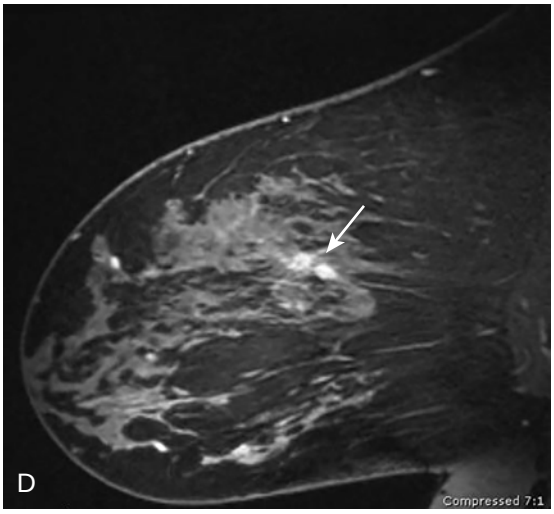
CFN


2D XCCL
E

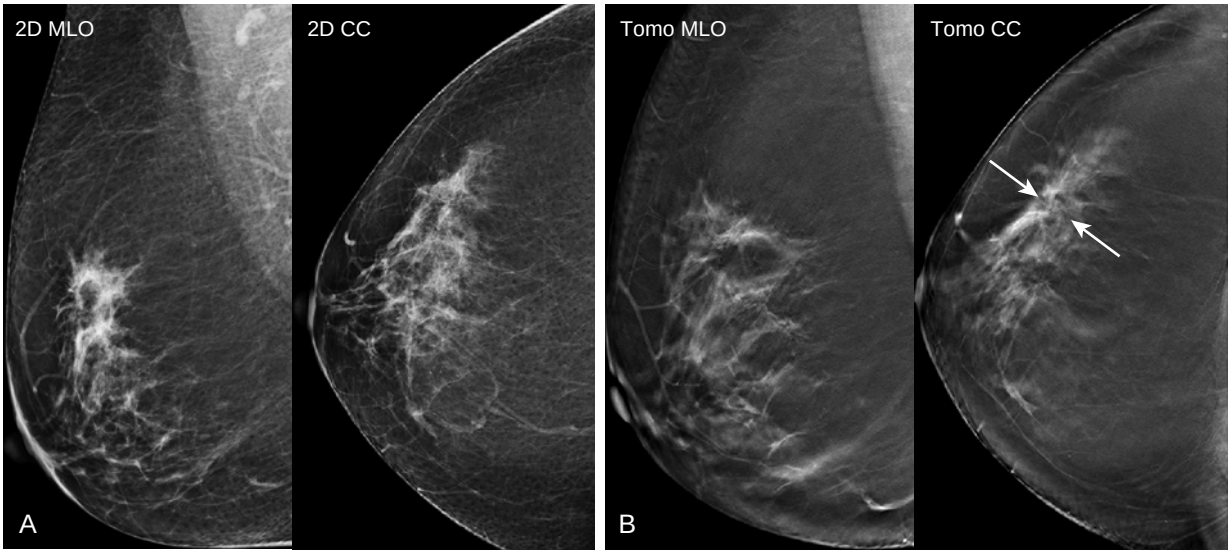
CASE STUDY 6.7 **(A)** 2D screening mammogram in 57-year-old woman demonstrates focal asymmetry in the superior medial breast *(arrows)*. **(B)** 2D spot compression views redemonstrate persistent focal asymmetry without associated suspicious findings. **(C)** ▶ Tomosynthesis images reveal architectural distortion associated with the focal asymmetry, raising the level of suspicion. Targeted ultrasound (not shown) was negative. **(D)** T1-weighted, fat-suppressed, postcontrast, sagittal MR reveals nonmass enhancement in region of architectural distortion *(arrow)*. MR image-guided biopsy was performed. **Diagnosis: Complex sclerosing lesion with ADH, which was upgraded to DCIS, Grade 2, ER/PR+ at surgical excision.**

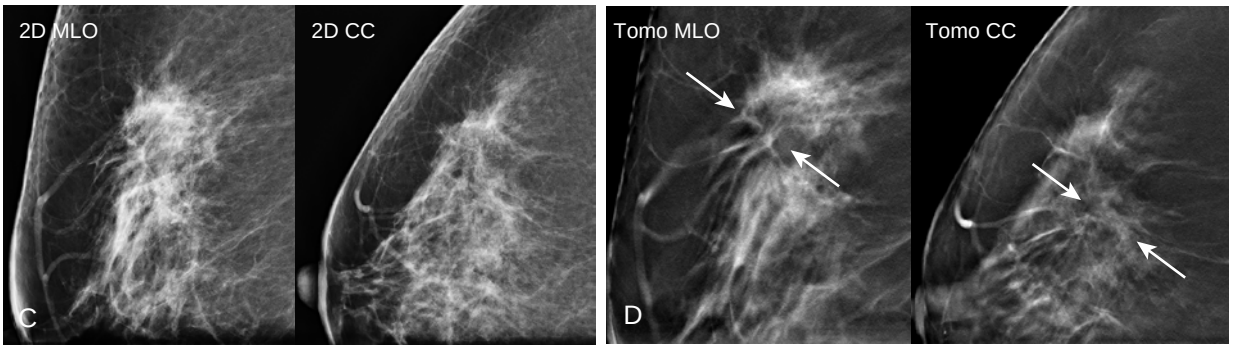


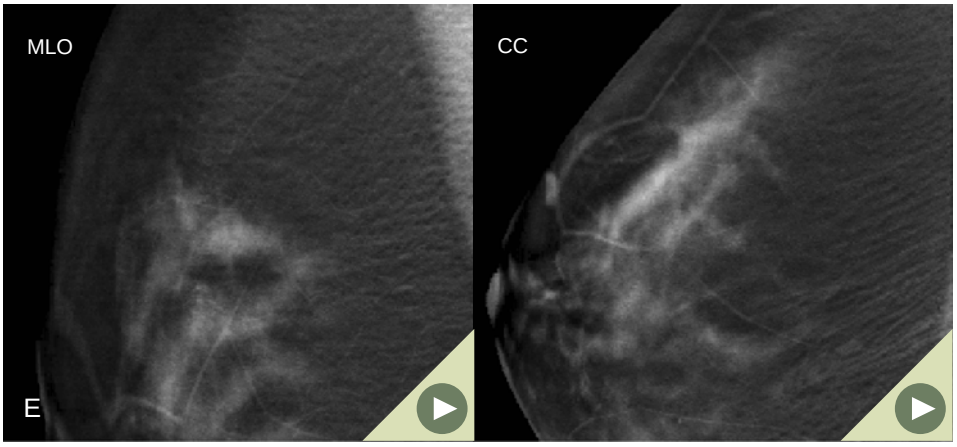

Tomo MLO
Tomo CC
C
CC

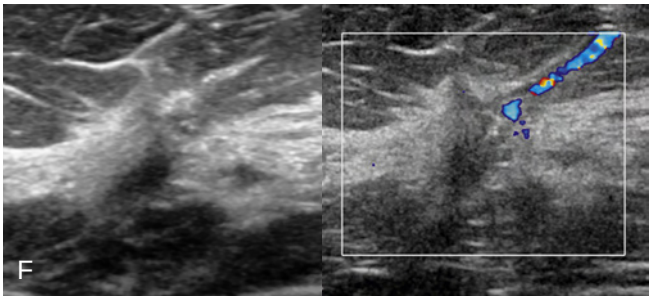

D
Compressed 7:1

CASE STUDY 6.8 **(A)** A 57-year-old woman presents for routine screening mammography. 2D MLO and CC views show no suspicious findings. **(B)** 3D CC view shows possible architectural distortion in right lateral breast *(arrows)*, and the patient was recalled for a diagnostic work-up. **(C)** Tomosynthesis spot compression views do not reveal the finding. **(D)** Tomosynthesis spot compression clarifies the finding by dispersing breast tissue in the region of interest and confirming persistent architectural distortion *(arrows)*. Note the fat within the lesion. **(E)** ▶ ▶ Tomosynthesis in ML and CC views reveals architectural distortion not visible on 2D views. **(F)** Ultrasound demonstrates an irregular mass with anti-parallel orientation and indistinct margins. Color Doppler interrogation shows a prominent adjacent vessel. Ultrasound-guided CNB was performed. **Diagnosis: Complex sclerosing lesion with minimal ductal hyperplasia upgraded to focal atypical hyperplasia on surgical excision.**



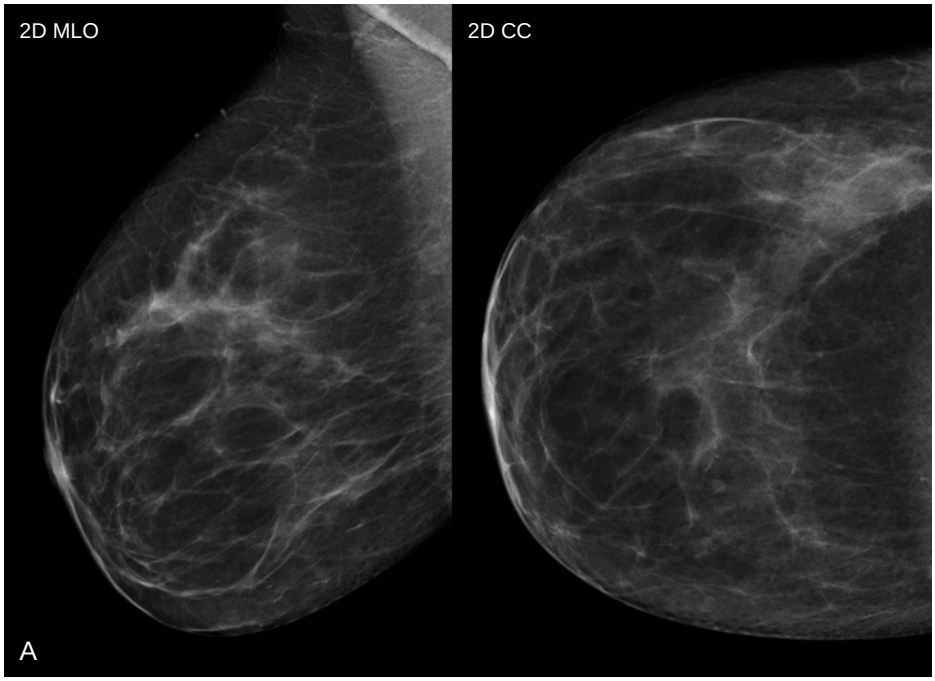


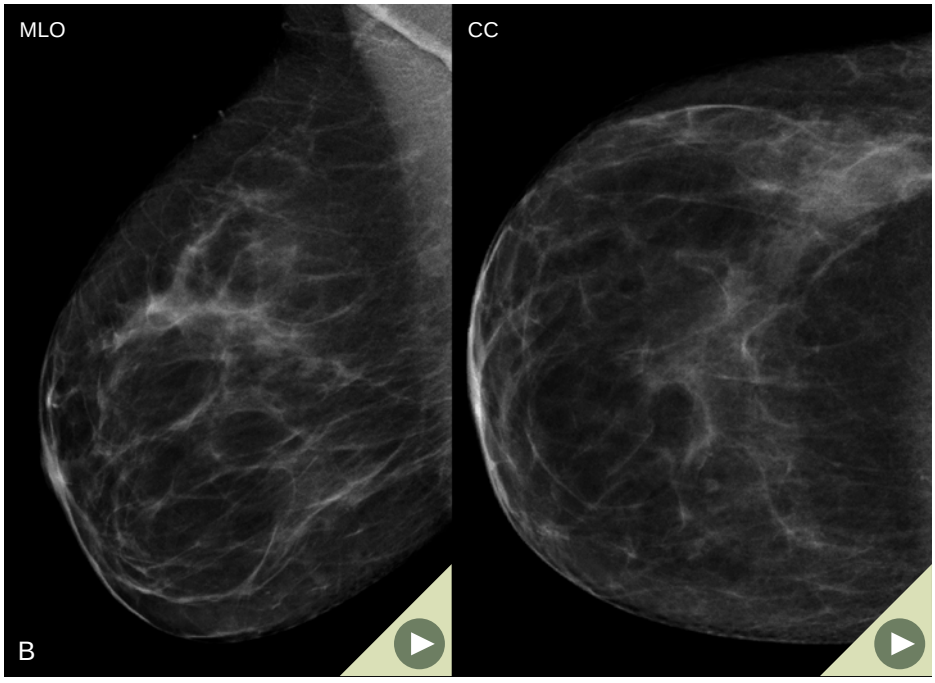




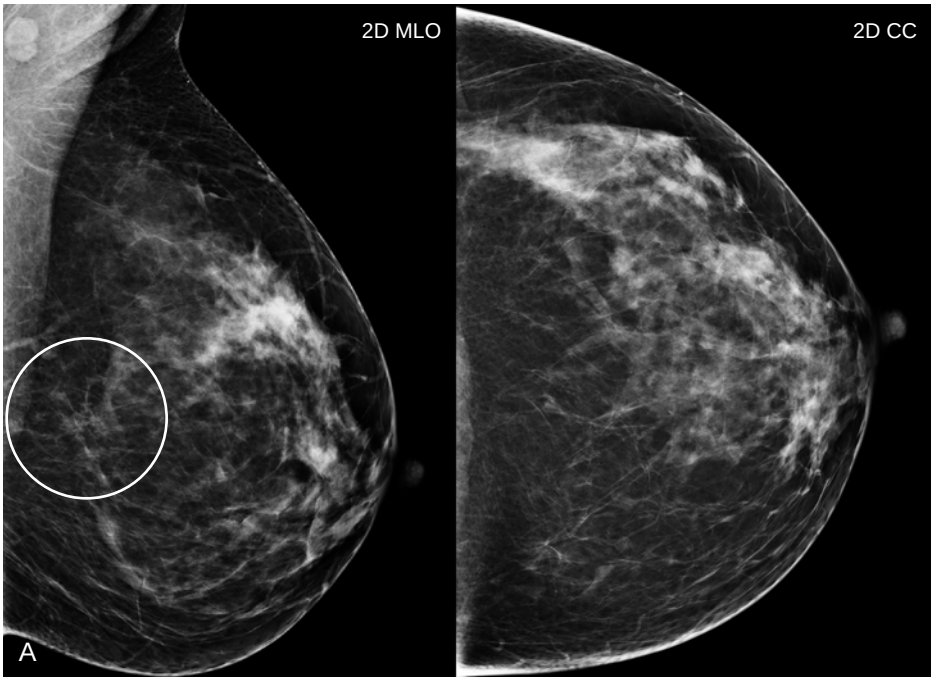
Chapter 7

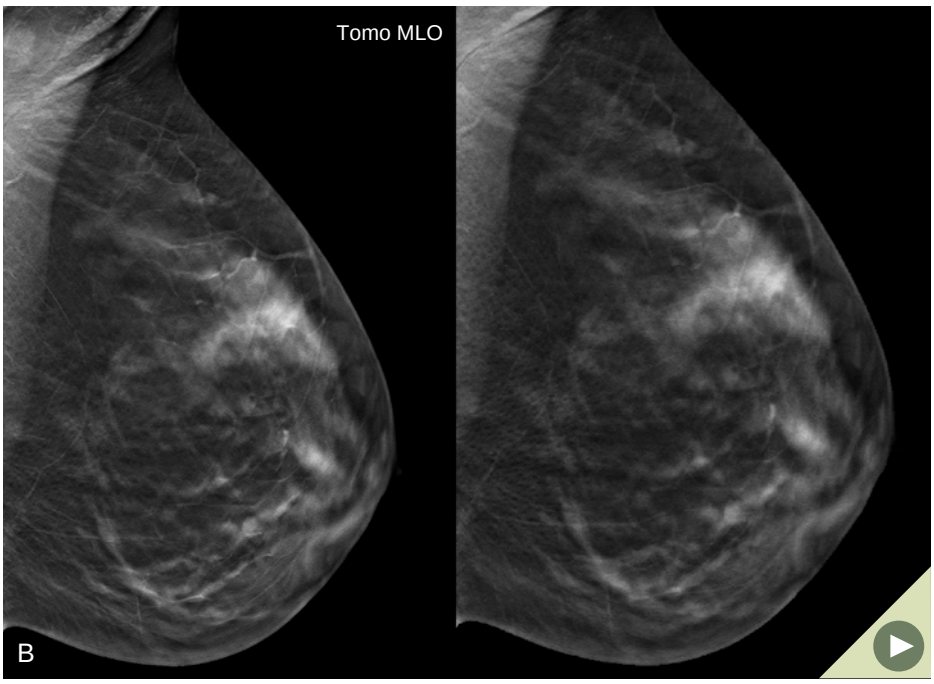
CASE STUDY 7.1 (A) Source projection images of the right breast in MLO and CC views in a woman with scattered fibroglandular tissue. **(B)** ▶ ▶ Viewing the images by rotating in real time helps separate different areas of tissue and can help determining whether a focal finding on 2D images or tomosynthesis slices is simply normal tissue or a mass. **Diagnosis: Normal tissue**.

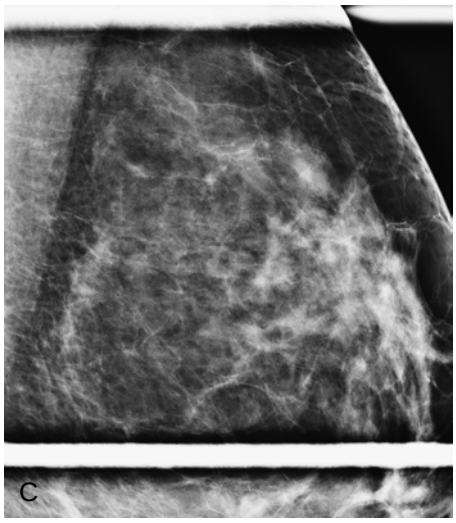




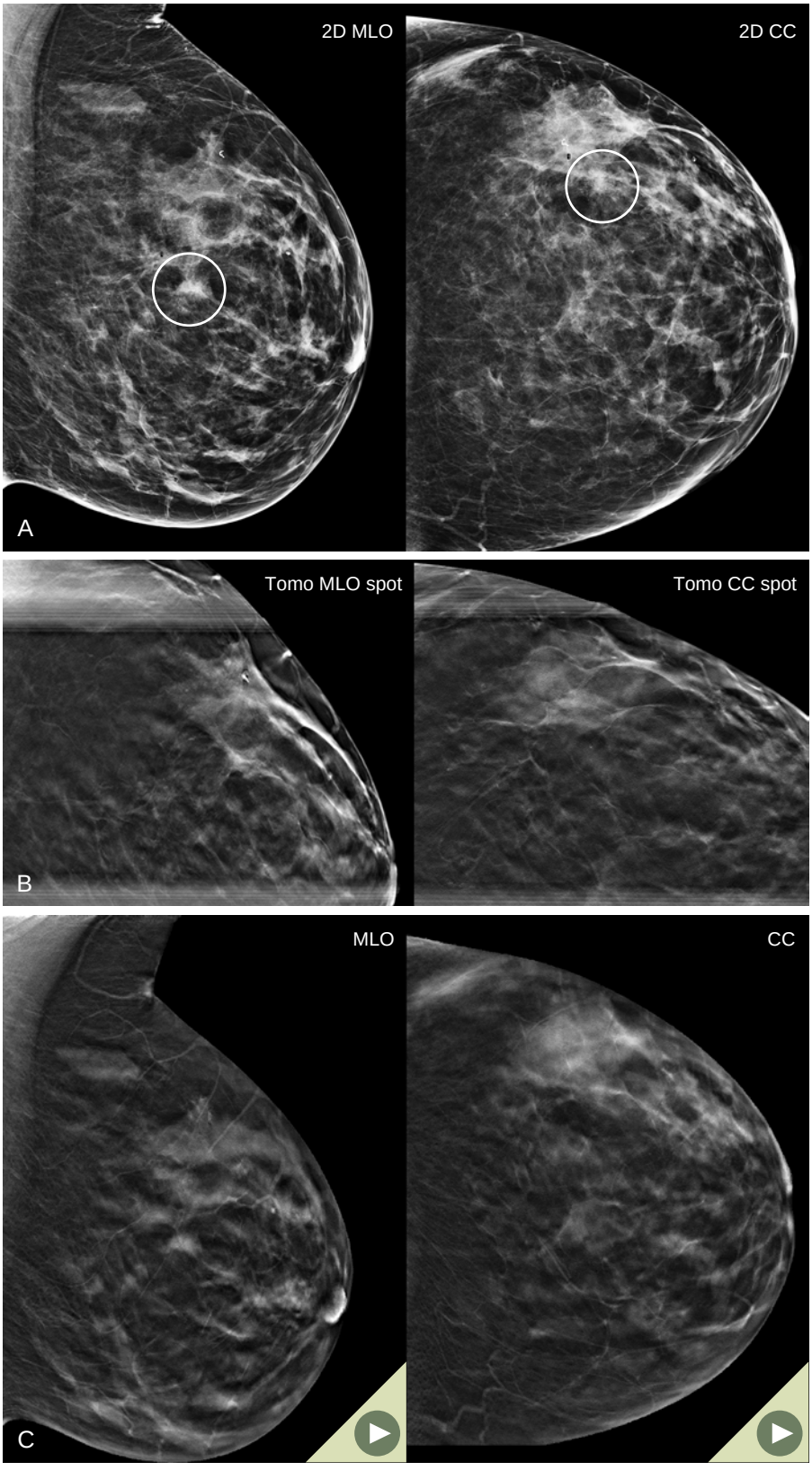
CASE STUDY 7.2 (A) Screening mammogram in a 42-year-old woman shows a questionable architectural distortion in the 2D MLO view only *(circle)*. No correlate is seen on the CC view. **(B)** ▶ Review of the MLO tomosynthesis views show areas of superimposed tissue with no reproducible distortion. **(C)** Spot compression view does not show a finding (2D only shown). US was negative. This finding was thought to represent normal tissue and recall could probably have been avoided. BI-RADS 2. **Diagnosis: Summation shadow, normal tissue.**



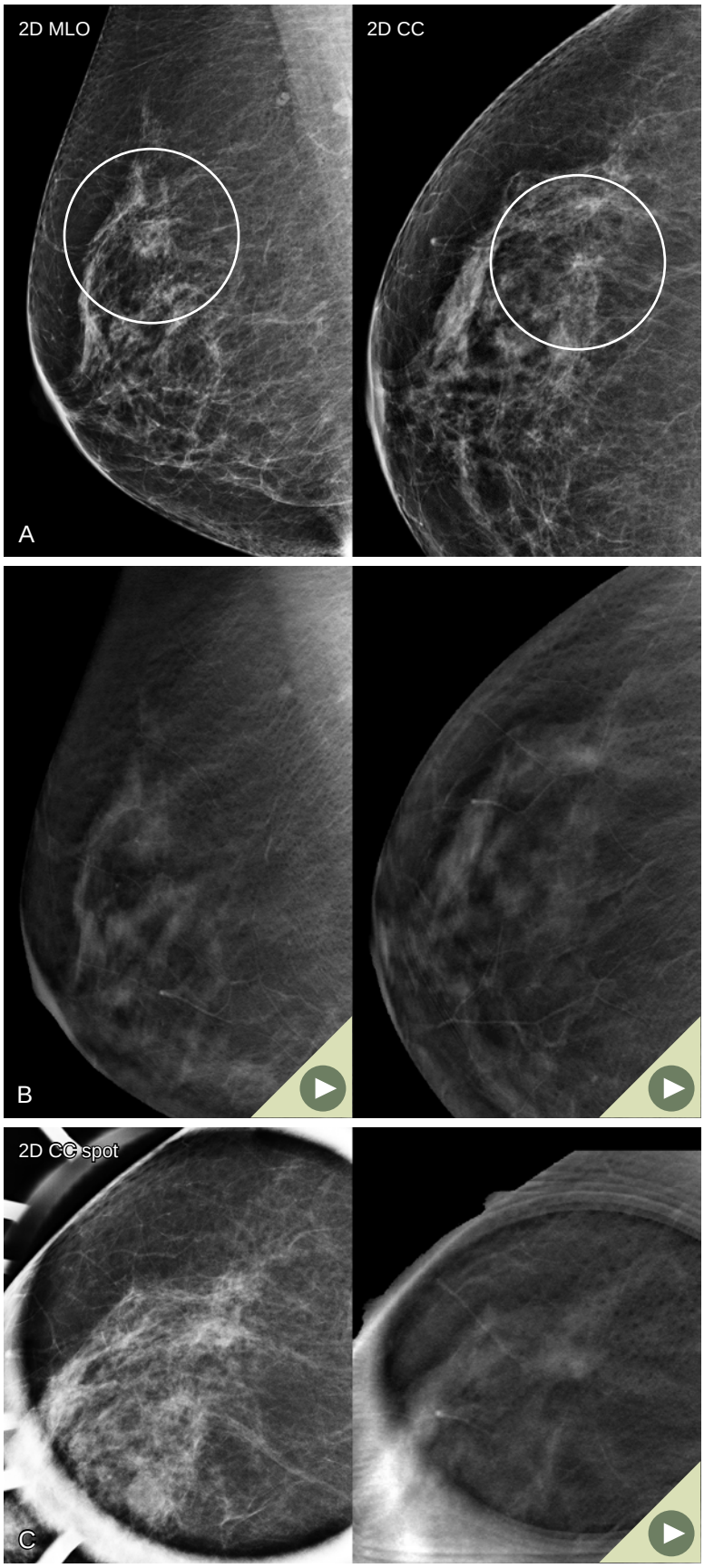




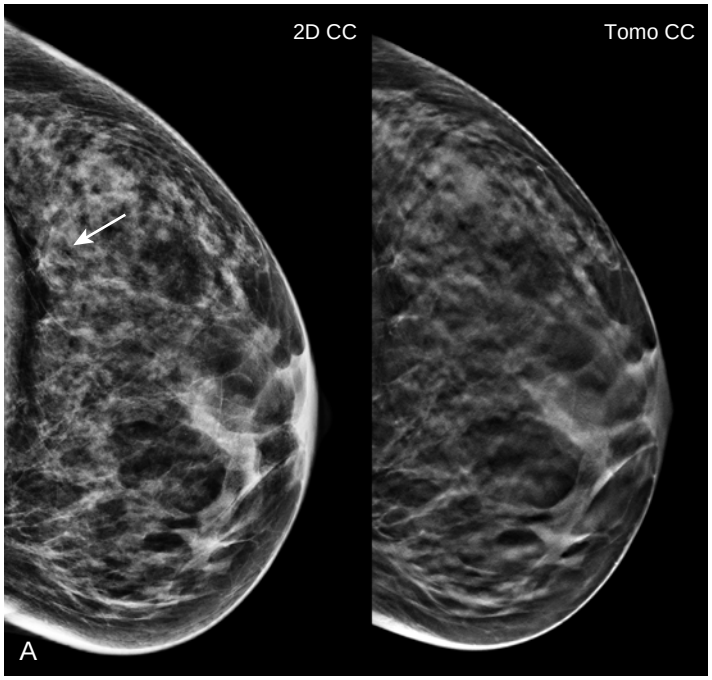
CASE STUDY 7.3 (A) A screening mammogram in 49-year-old woman shows a 1-cm asymmetry in the left breast which appeared concerning on the 2D images *(circles)*. (Clip from prior benign biopsy is also noted.) **(B)** Tomosynthesis spot slice views show that the area mostly resolves on CC view but is not completely resolved on the MLO tomosynthesis, similar to that seen on full tomosynthesis views **(C)** ▶ ▶ because there remains a focal asymmetry on several MLO slice images. Recall is justified in such a case because dense tissue makes it difficult to exclude an underlying abnormality. **Diagnosis: Ultrasound showed normal fibroglandular tissue and a few incidental cysts otherwise negative and on 6-month follow-up was normal.**

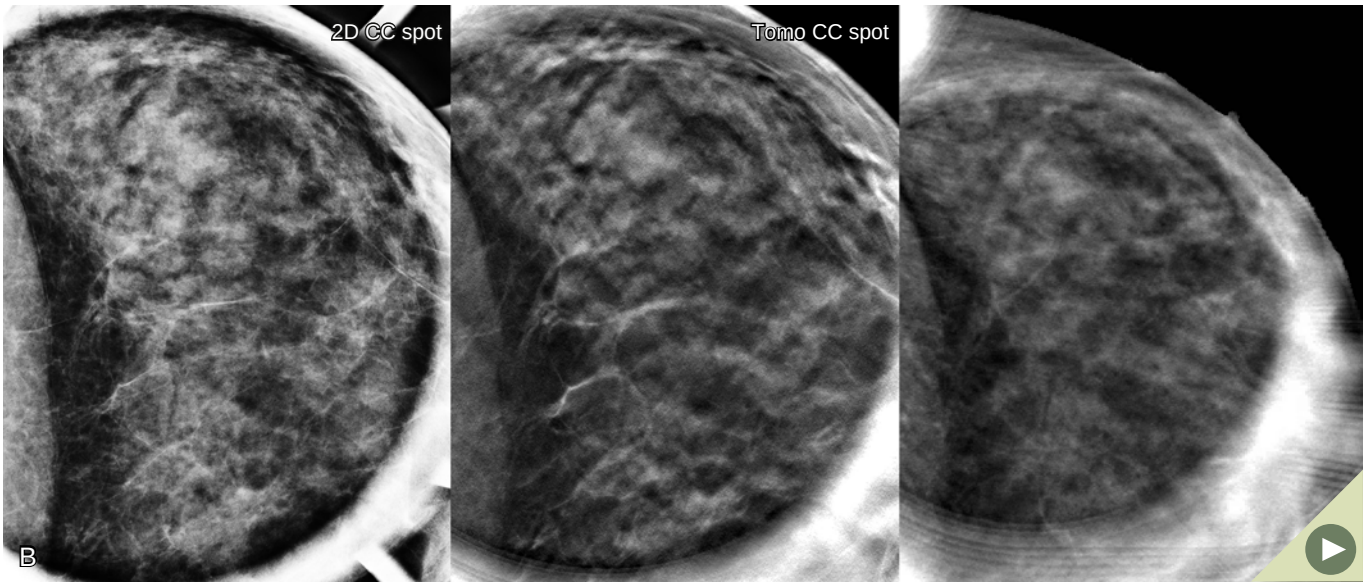


CASE STUDY 7.4 (A) Screening tomosynthesis mammogram in a 51-year-old woman showed a focal asymmetry on the 2D images *(circles)*, appearing spiculated in the CC view. **(B)** ▶ ▶ However, review of the corresponding tomosynthesis images in the MLO and CC projections does not reveal a corresponding focal finding. **(C)** ▶ The patient was recalled, and no suspicious finding was reproduced on spot tomosynthesis views (CC view shown) or ultrasound. Subsequent mammography follow up at 1 year was unremarkable. **Diagnosis: Normal tissue. Recall could have been avoided.**

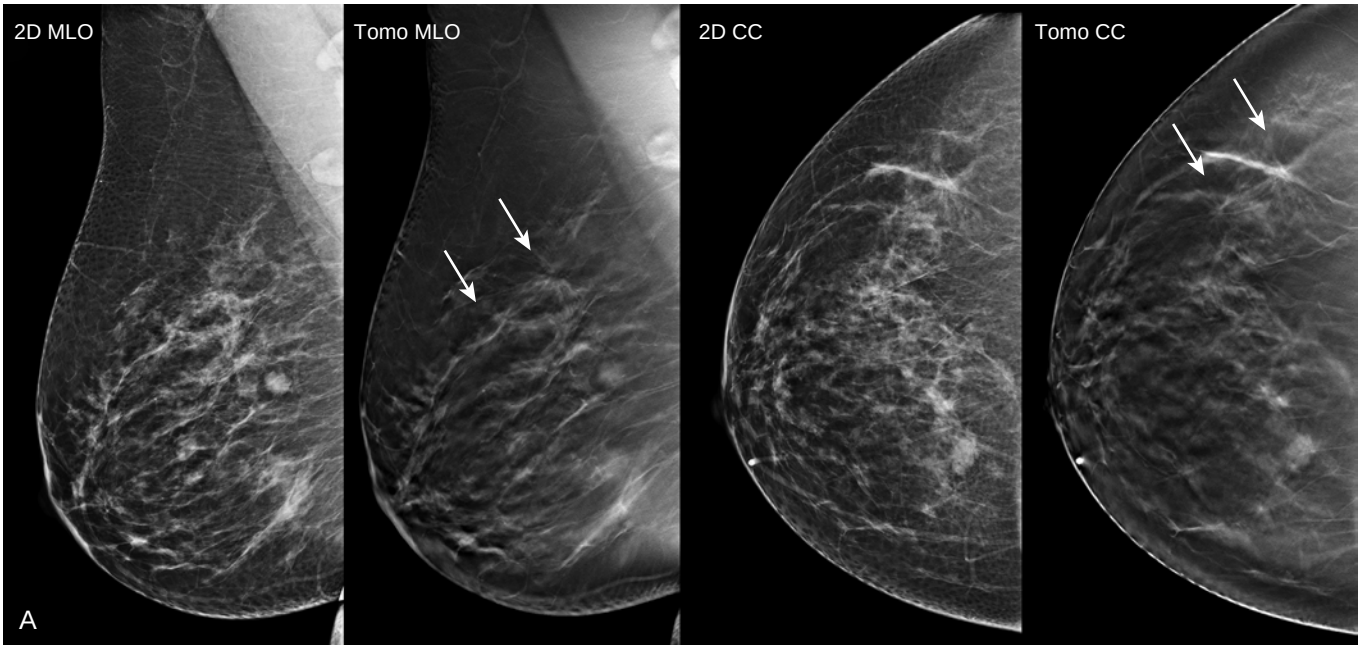


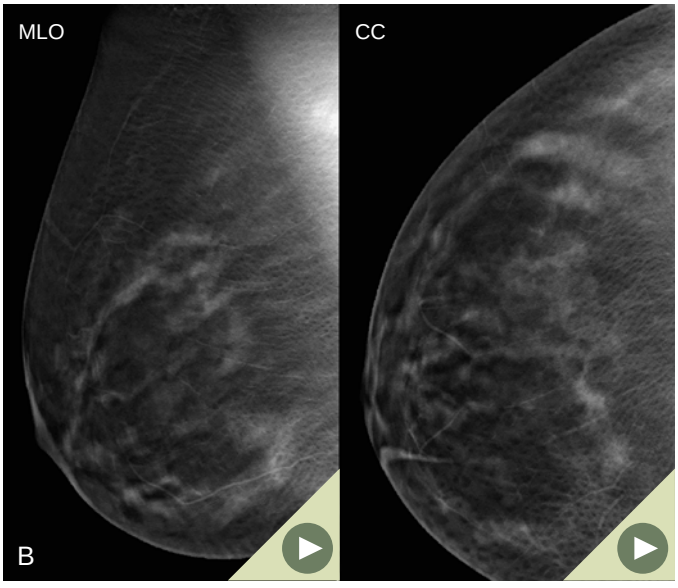
CASE STUDY 7.5 (A) Screening mammogram in a 69-year-old woman with heterogeneously dense tissue shows a questionable area of architectural distortion in the left breast *(arrow)* on the CC view, which could not be fully resolved on the tomosynthesis view. **(B)** ▶ Spot compression tomosynthesis shows no focal finding. Ultrasound was performed because the patient has dense tissue and was normal. Subsequent annual mammogram was also normal. With dense heterogeneous tissue, pseudodistortions and asymmetries are possible. Careful scrolling through the whole breast or spot tomosynthesis slices and can help to resolve such findings. **Diagnosis: Dense heterogeneous tissue and pseudodistortion; normal.**

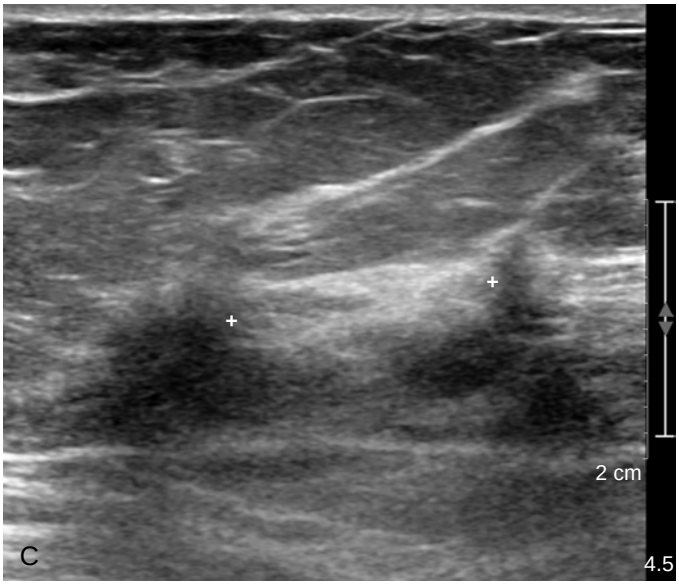




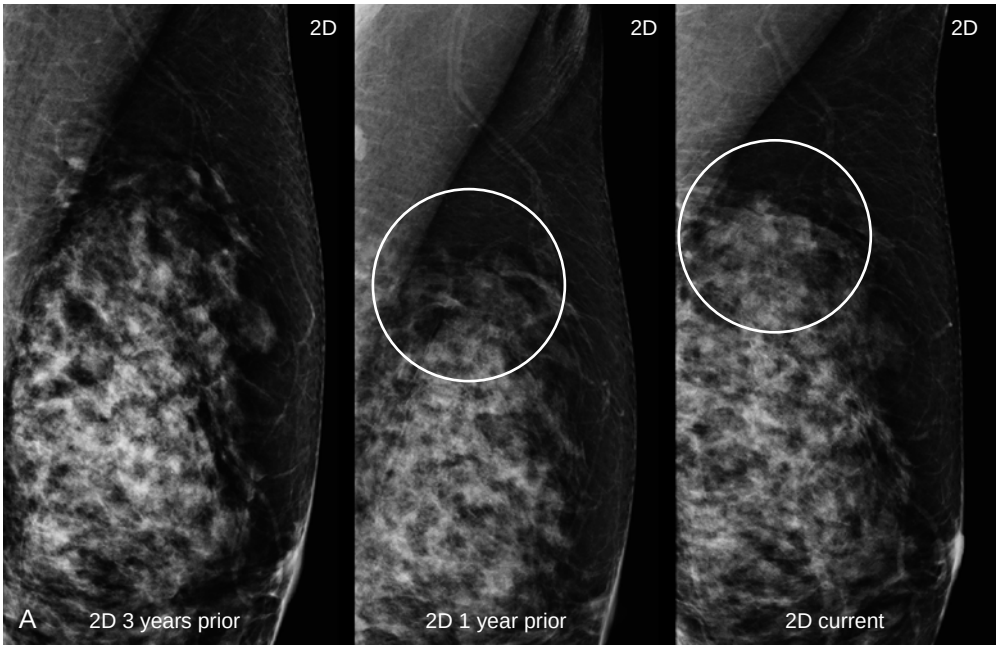
CASE STUDY 7.6 (A) Two areas of architectural distortion are noted in the upper-outer right breast in the tomosynthesis mammogram of a 51-year-old woman *(arrows)*. **(B)** ▶▶ The preceding year's tomosynthesis mammogram had been reported as normal with a benign mass noted in the right breast. Observation of the benign mass elsewhere in the breast may have distracted from observing the architectural distortion. **(C)** Ultrasound showed two adjacent corresponding suspicious irregular hypoechoic masses. Ultrasound-guided biopsy was performed. **Diagnosis: Invasive lobular carcinoma in both sites.**

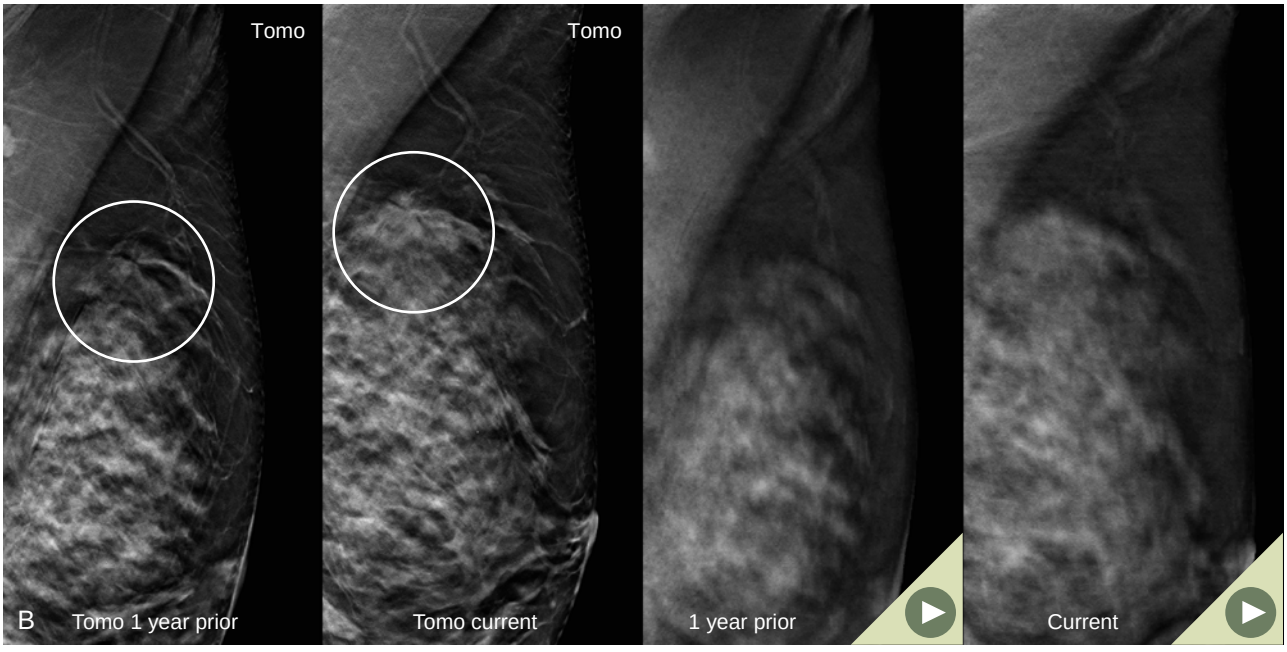


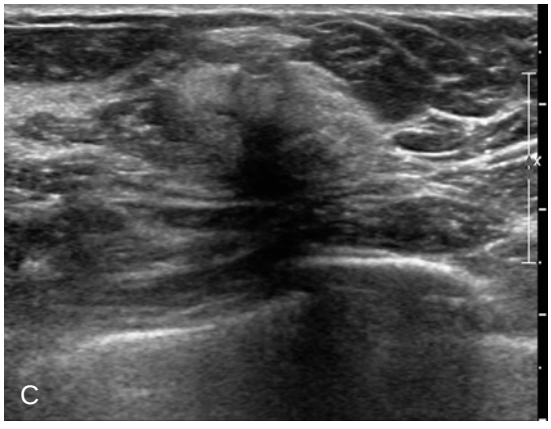




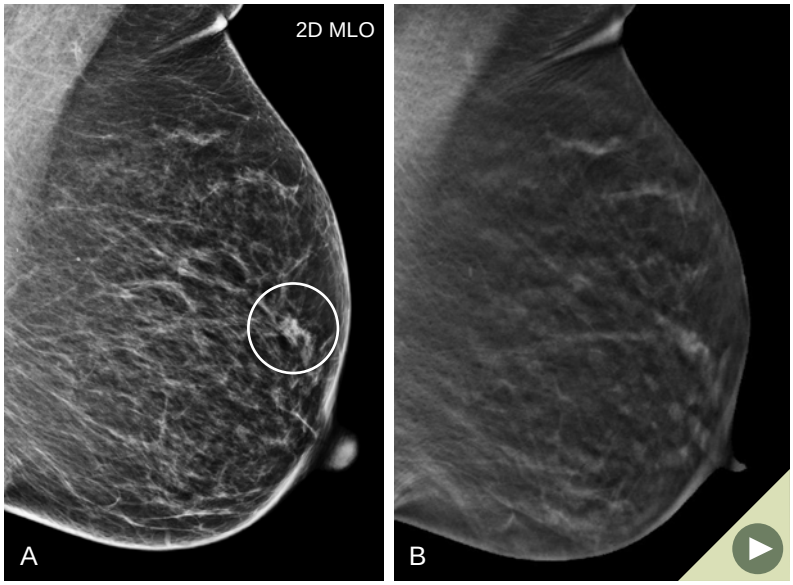
CASE STUDY 7.7 Screening mammogram in a 56-year-old woman. **(A)** A developing irregular asymmetry in the left upper breast is seen only on the MLO views *(circle)*. **(B)** ▶ ▶ On tomosynthesis, a fat-containing architectural distortion is seen with straightening of the surrounding tissue. This lesion was overlooked, and the mammogram interpreted as normal. **(C)** The patient returned 2 months later for a dense breast screening ultrasound and a mixed echogenic irregular mass was found in the left upper breast and in retrospect determined to correspond to the missed mammographic finding. Ultrasound-guided CNB was performed. **Diagnosis: Infiltrating lobular carcinoma, moderately differentiated, ER/PR+, Her–, Ki-67 = 10%, 0/1 SLN.**



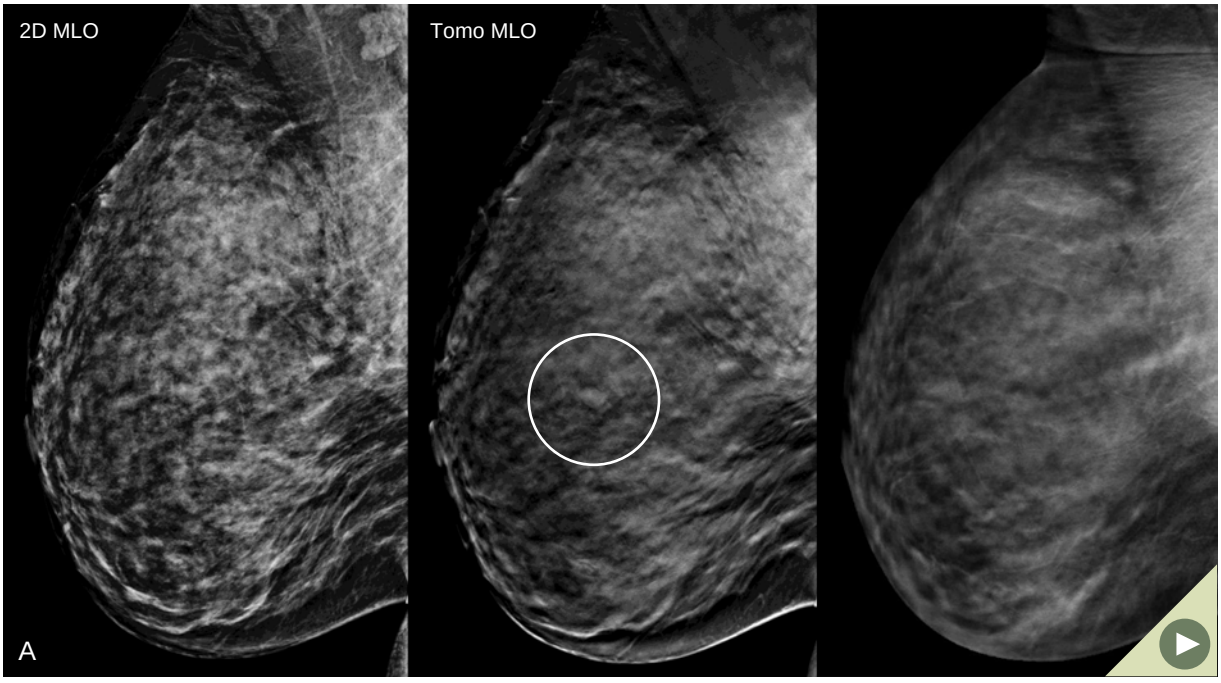


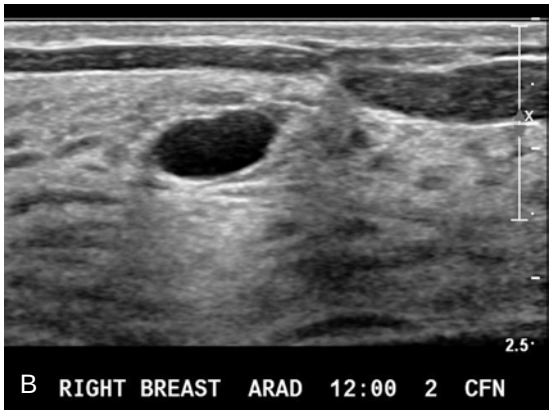


CASE STUDY 8.1 A 46-year-old woman presented for screening mammogram. **(A)** 2D left MLO view suggests an asymmetry in the superior breast, anterior plane *(circle)*. **(B)** ▶ Corresponding tomosynthesis images in MLO projection reveal superimposed tissue simulating an asymmetry on 2D imaging. Recall was avoided by the use of tomosynthesis. BI-RADS 2. **Diagnosis: Normal finding, no recall necessary.**

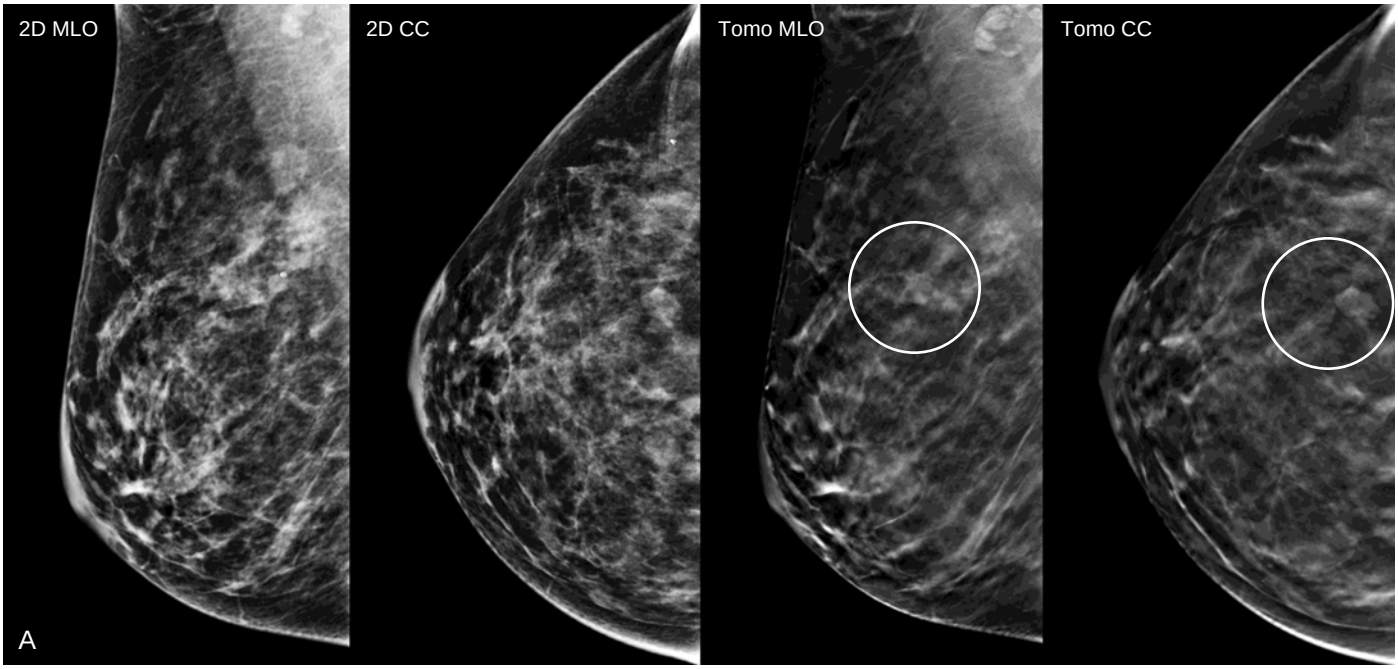


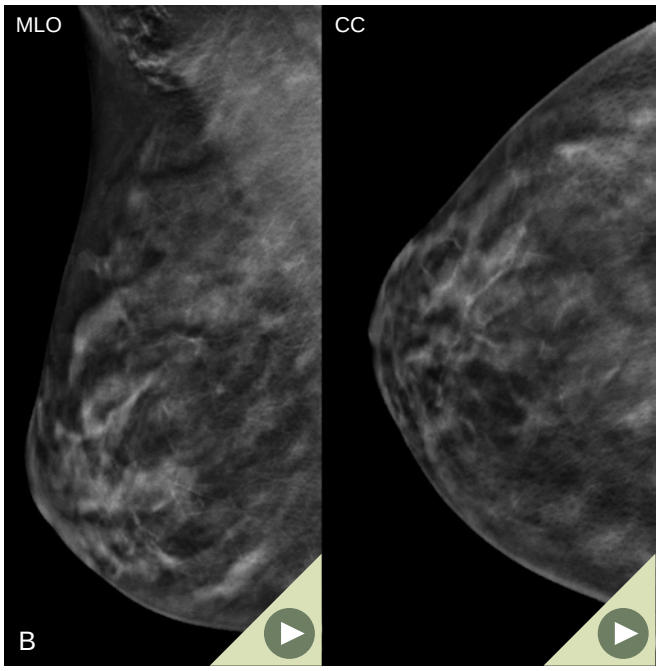
CASE STUDY 8.2 A 41-year-old woman with extremely dense breast tissue and history of a prior benign excision biopsy in the upper outer quadrant presented for screening mammogram. **(A)** ▶ A 1-cm mass is seen in the central right breast on tomosynthesis images in MLO projection, not seen on the 2D view *(area marked with circle)*. **(B)** Ultrasound performed on the same day for supplemental screening demonstrates a corresponding simple cyst at the 12-o'clock position. **Diagnosis: Simple cyst**.



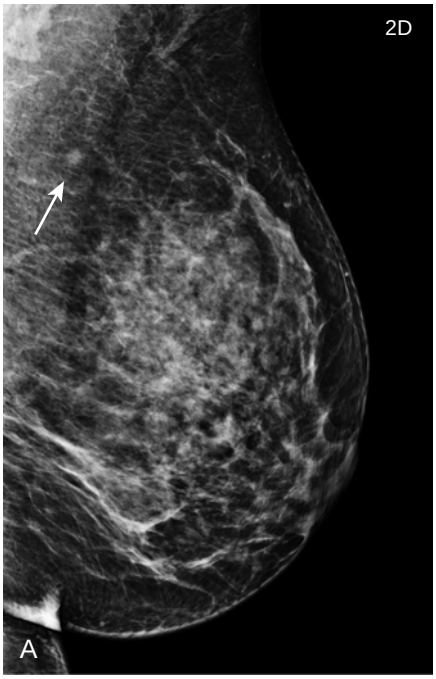


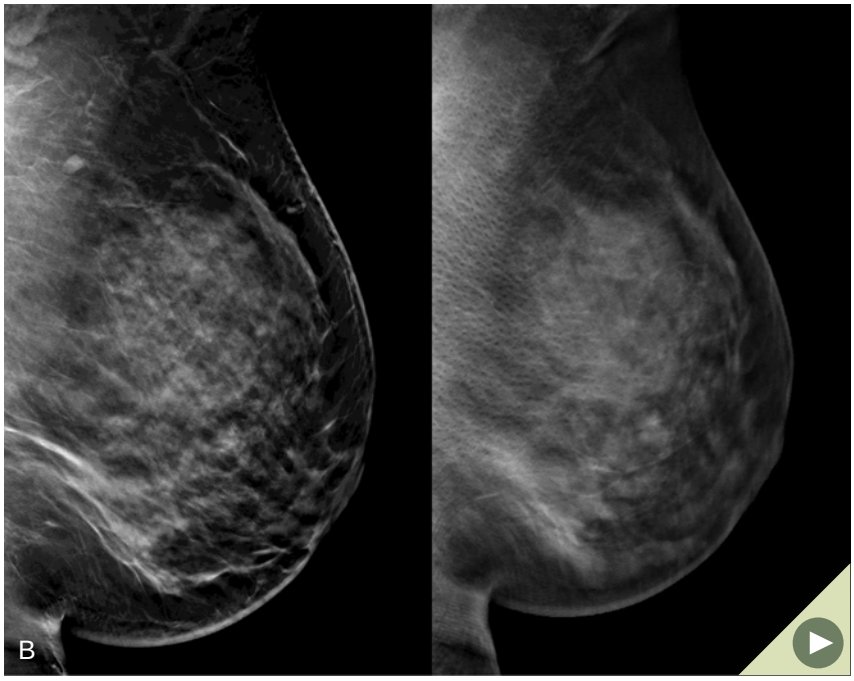
CASE STUDY 8.3 A 47-year-old woman presented for her first tomosynthesis screening mammogram. **(A)** Two oval masses are seen on tomosynthesis views in the right upper-outer quadrant, not seen well on 2D images *(area circled)*. **(B)** ▶ ▶ One of these masses underwent ultrasound-guided biopsy. **Diagnosis: Fibroadenoma; both masses stable at 3-year follow-up.**



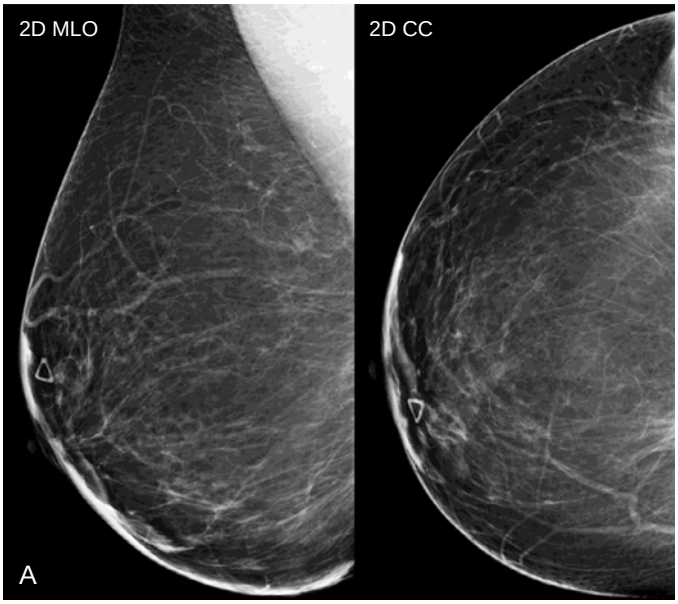


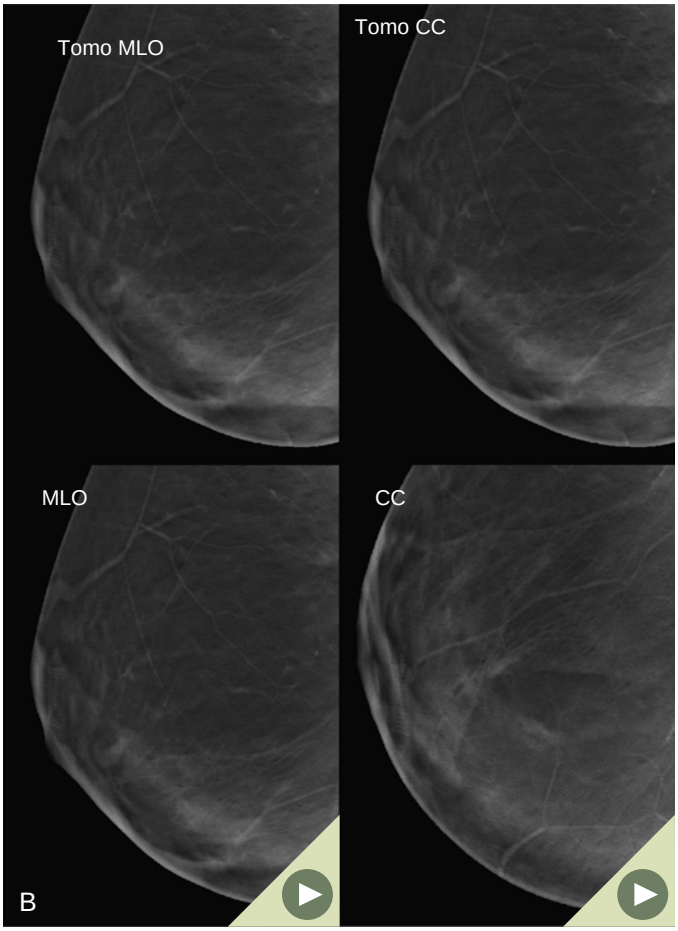
CASE STUDY 8.4 (A) Routine screening mammogram demonstrates a small mass with indistinct margins in the superior left breast posteriorly on 2D MLO view *(arrow)*. **(B)** ▶ Tomosynthesis images in MLO projection reveal a fatty notch within a circumscribed mass, consistent with a normal-appearing lymph node. BI-RADS 2. **Diagnosis: Normal finding.**

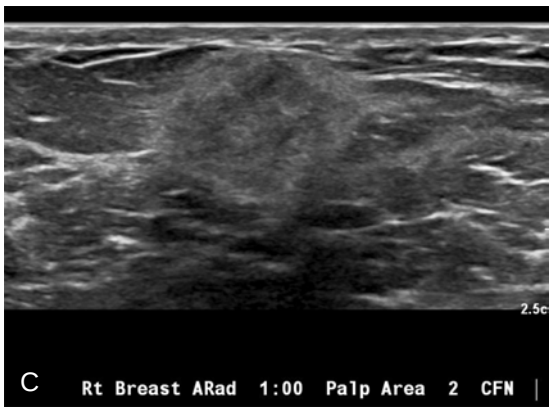




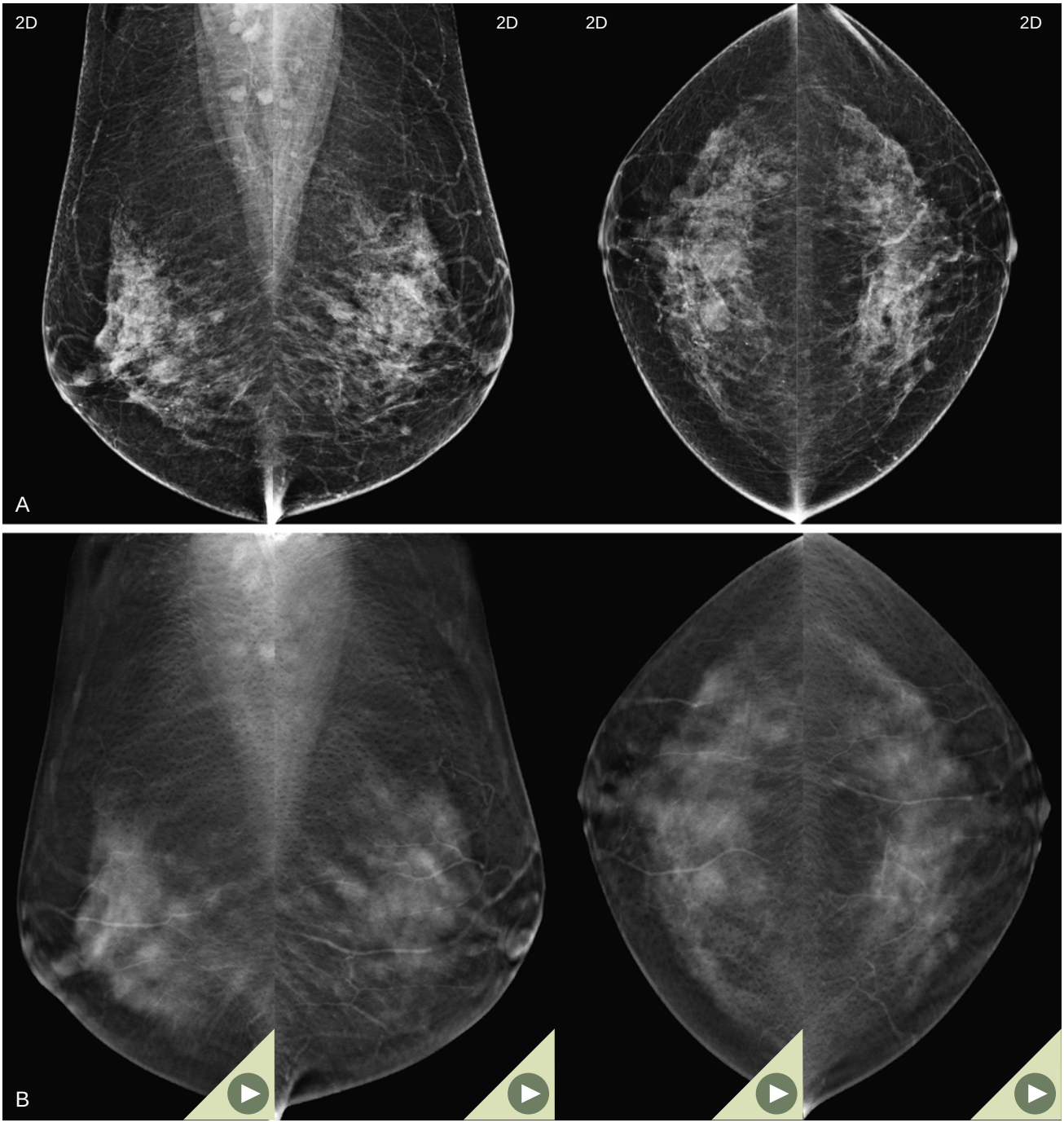
CASE STUDY 8.5 (A) A 33-year-old woman status post reduction mammoplasty presents with a palpable right breast lump. An ill-defined mass is noted in the area of palpable concern which on tomosynthesis images **(B)** ▶ ▶ is noted to have central lucency characteristic of fat necrosis from prior surgery. **(C)** Ultrasound shows a hyperechoic lesion with ill-defined borders. At the patient's request, she underwent ultrasound-guided biopsy of the palpable mass. **Diagnosis: Benign fat necrosis.**





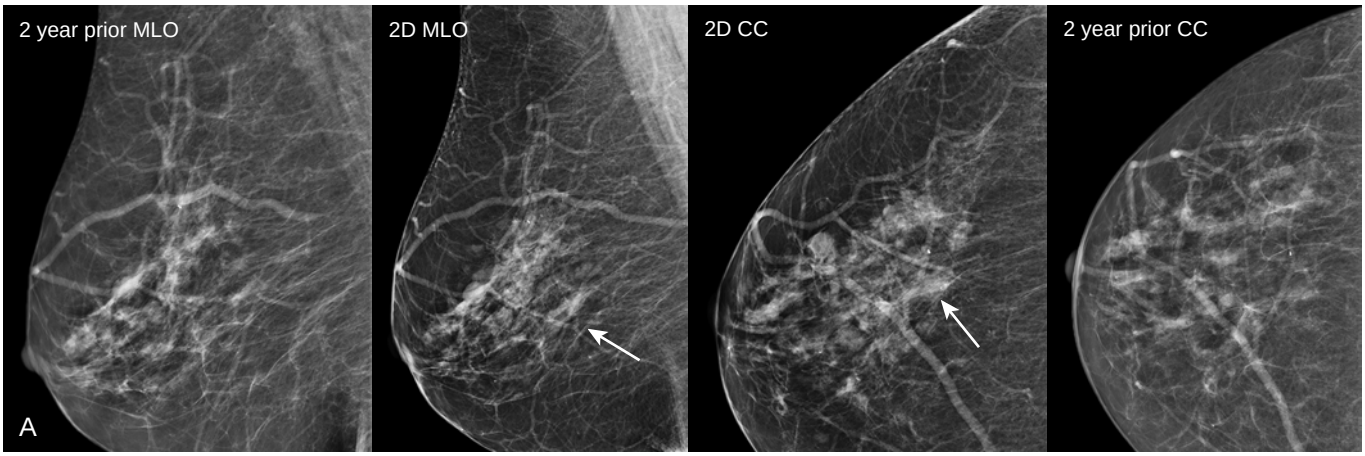


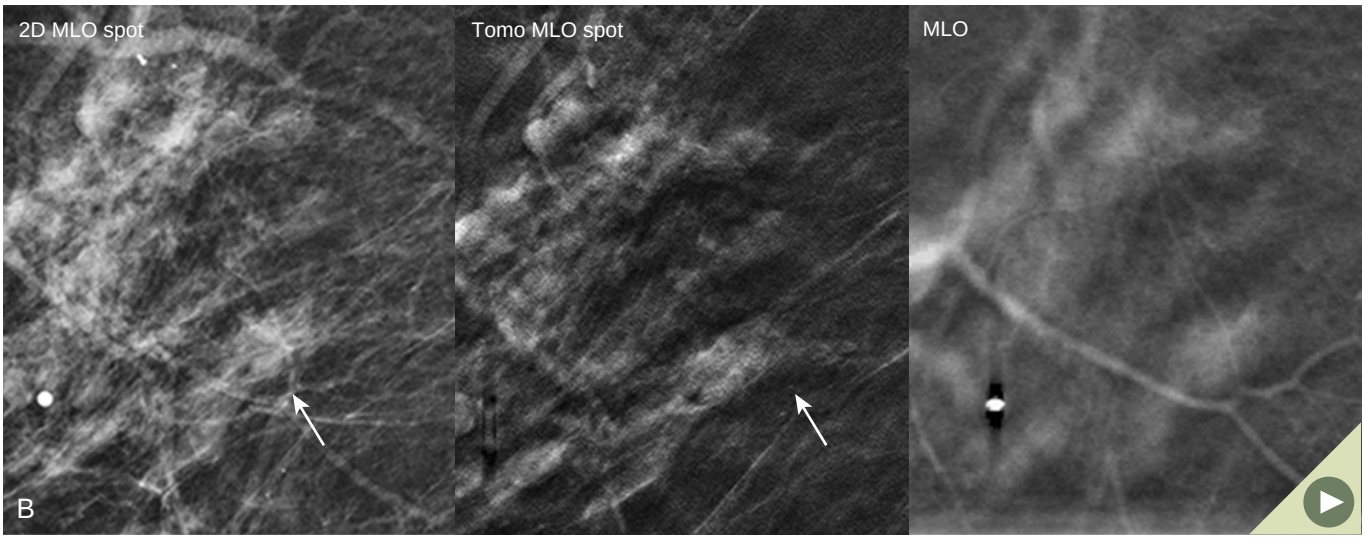
CASE STUDY 8.6 (A) 2D images from routine screening mammogram demonstrate multiple bilateral circumscribed masses. **(B)** ▶▶▶▶ Additional masses can be detected on tomosynthesis that are not appreciated on the 2D imaging. The patient had a screening breast ultrasound on the same day that revealed numerous cysts in both breasts. **Diagnosis: Multiple bilteral cysts.**

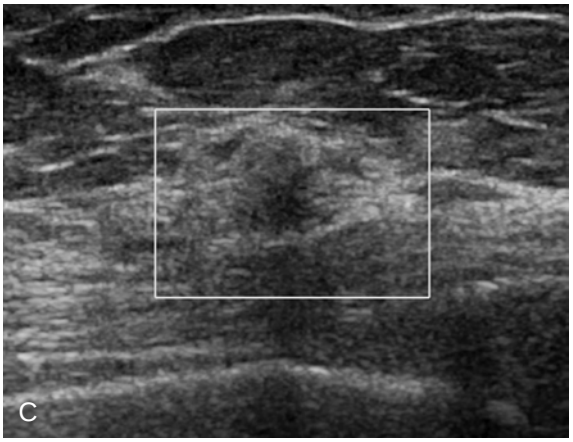


Chapter 9

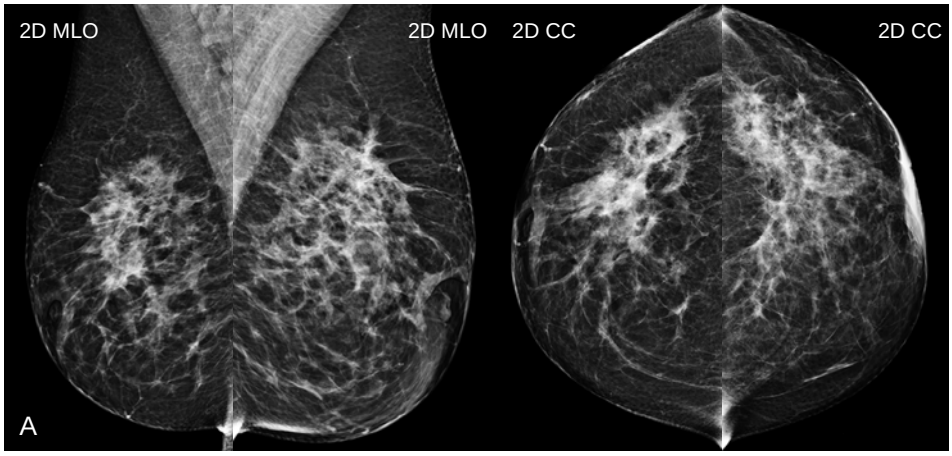
CASE STUDY 9.1 **(A)** Yearly mammogram in a 66-year-old woman with a remote history of left breast cancer reveals a new focal asymmetry in the right central breast *(arrows)*, best seen on the MLO view. **(B)** ▶ MLO spot compression reveals a persistent asymmetry, although no definite mass was identified on tomosynthesis. **(C)** Targeted ultrasound reveals a corresponding subtle isoechoic mass with indistinct borders. Ultrasound-guided biopsy was performed. **Diagnosis: Infiltrating ductal carcinoma, grade 2, ER/PR+, Her2–, 0/2 SLN.**

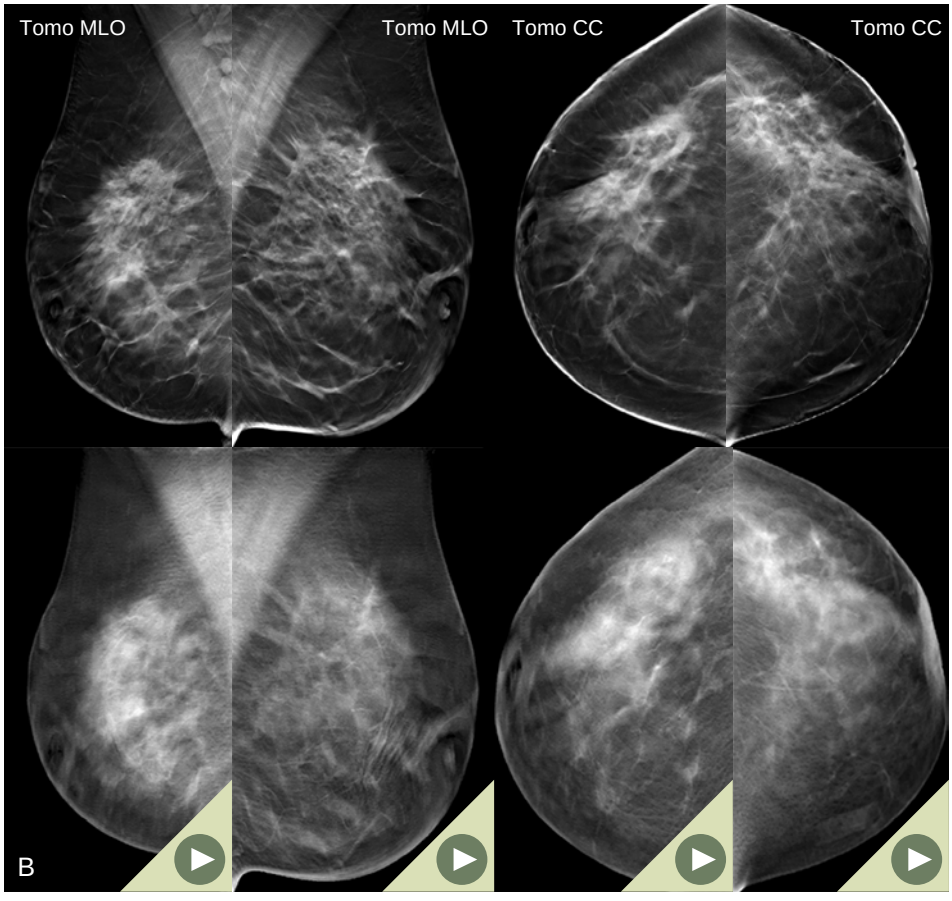


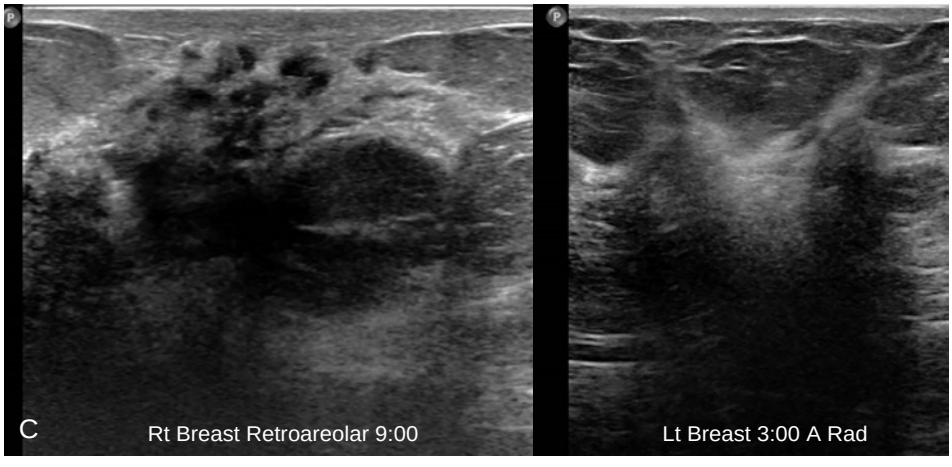




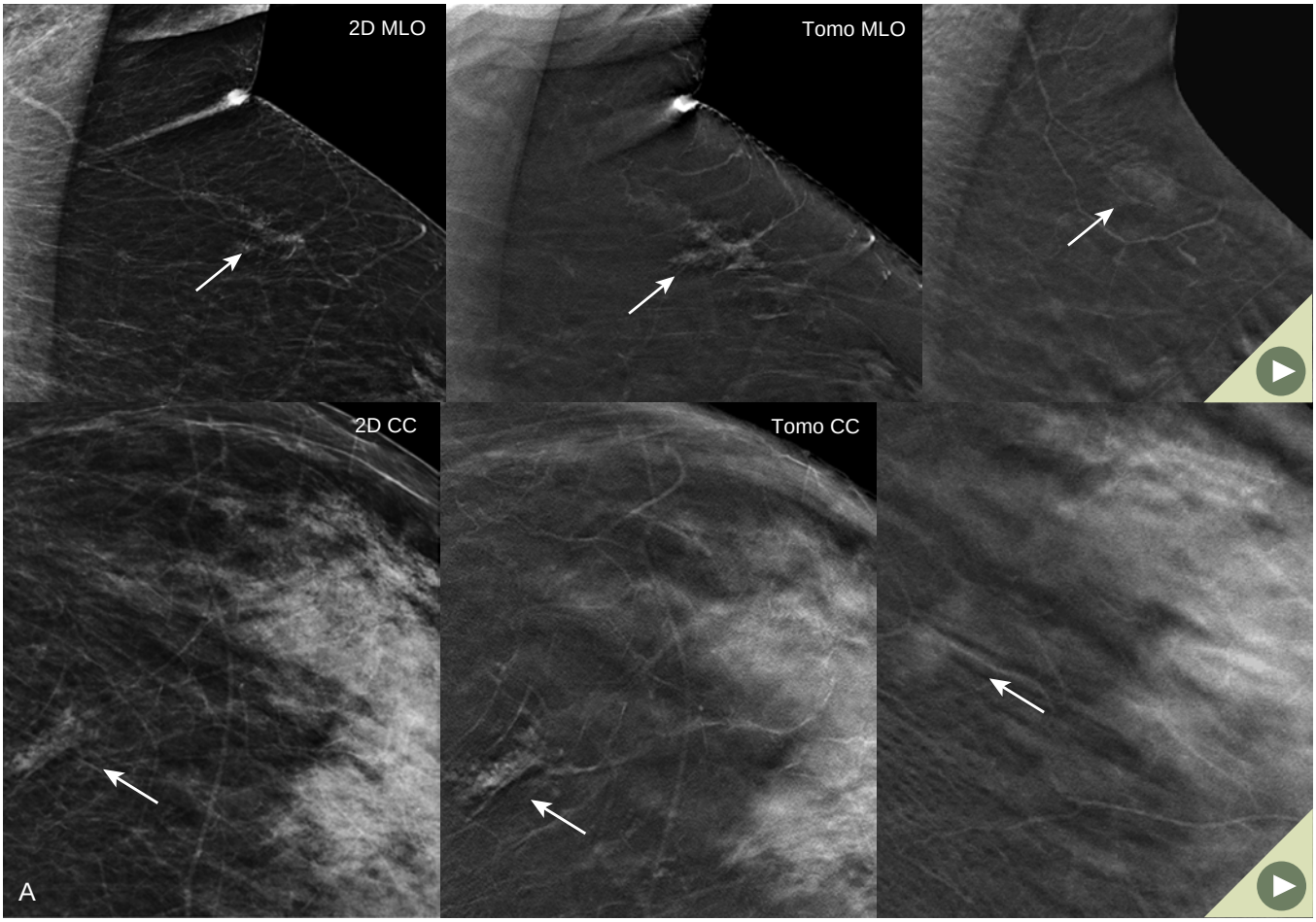
CASE STUDY 9.2 (A) A 48-year-old woman who initially presented to the emergency department with left flank pain. CT showed obstructing left distal ureteral stone and lucent boney vertebral metastases. Mammography was ordered to rule out an occult metastatic breast cancer and revealed bilateral trabecular and architectural distortion with nipple retraction. At time of the mammogram, the patient informed the technologist that both breasts were becoming more firm and smaller, believing this was due to normal aging. **(B)** Tomosynthesis more clearly demonstrates the extent of the architectural distortion, which involves almost all of the glandular tissue. Note that fat is present bilaterally throughout the both lesions. **(C)** Bilateral ultrasound demonstrates bilateral irregular masses with indistinct borders corresponding to the mammographic findings. Bilateral ultrasound-guided biopsy was performed. **Diagnosis: Bilateral shrinking breasts due to grade 2 invasive lobular carcinoma ER/PR+, Her–. The patient was subsequently found to also have ovarian and liver metastases, as well as lung carcinomatosis.**

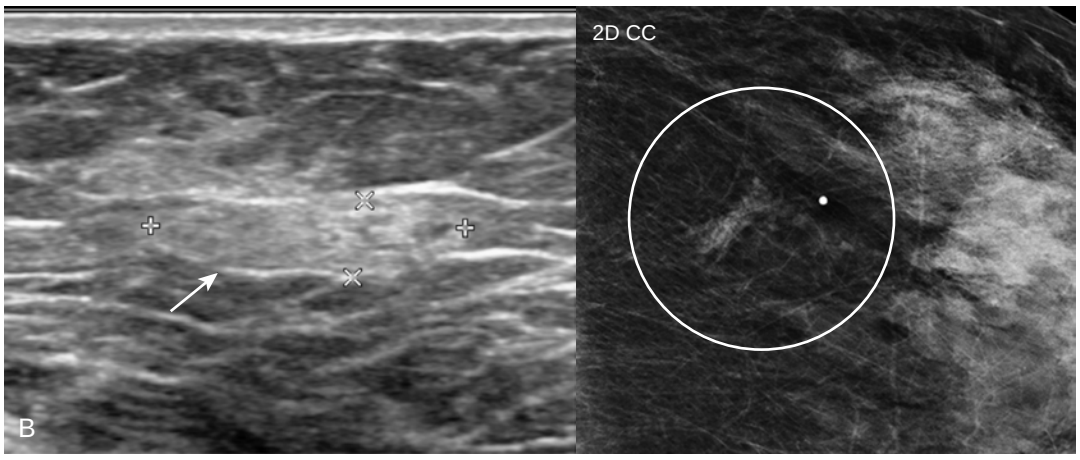




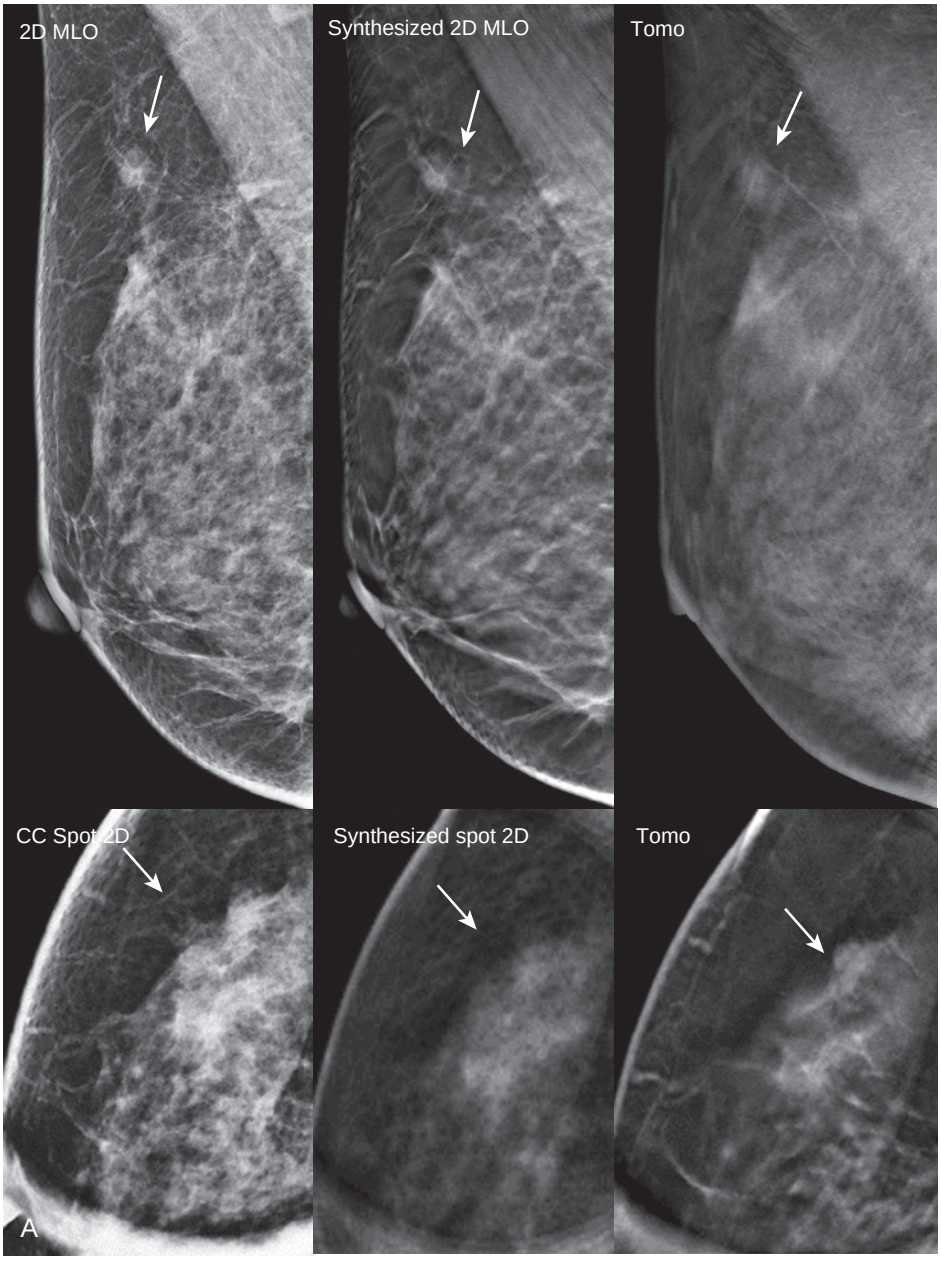


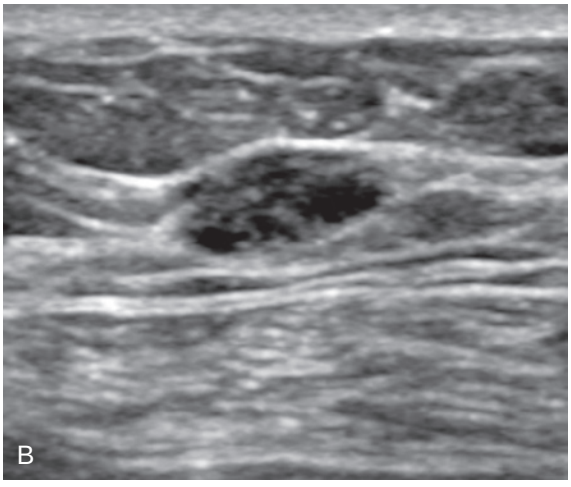
CASE STUDY 9.3 (A) New developing asymmetry in the left upper breast seen on both 2D mammography and tomosynthesis screening mammography *(arrows)* in an 81-year-old woman. Targeted ultrasound did not reveal a focal mass. The lesion was classified as BI-RADS 3, probably benign. **(B)** The patient returned for 6-month follow-up mammography and the focal asymmetry appeared slightly more prominent. Targeted ultrasound reveals a very subtle hyperechoic lesion with indistinct margins *(arrow)*. A metallic BB was placed over the lesion seen on ultrasound and a repeat CC view confirmed that the ultrasound finding corresponded to the focal asymmetry *(circle)*. Ultrasound-guided core needle biopsy was performed. **Diagnosis: Low-grade B-cell lymphoma.**

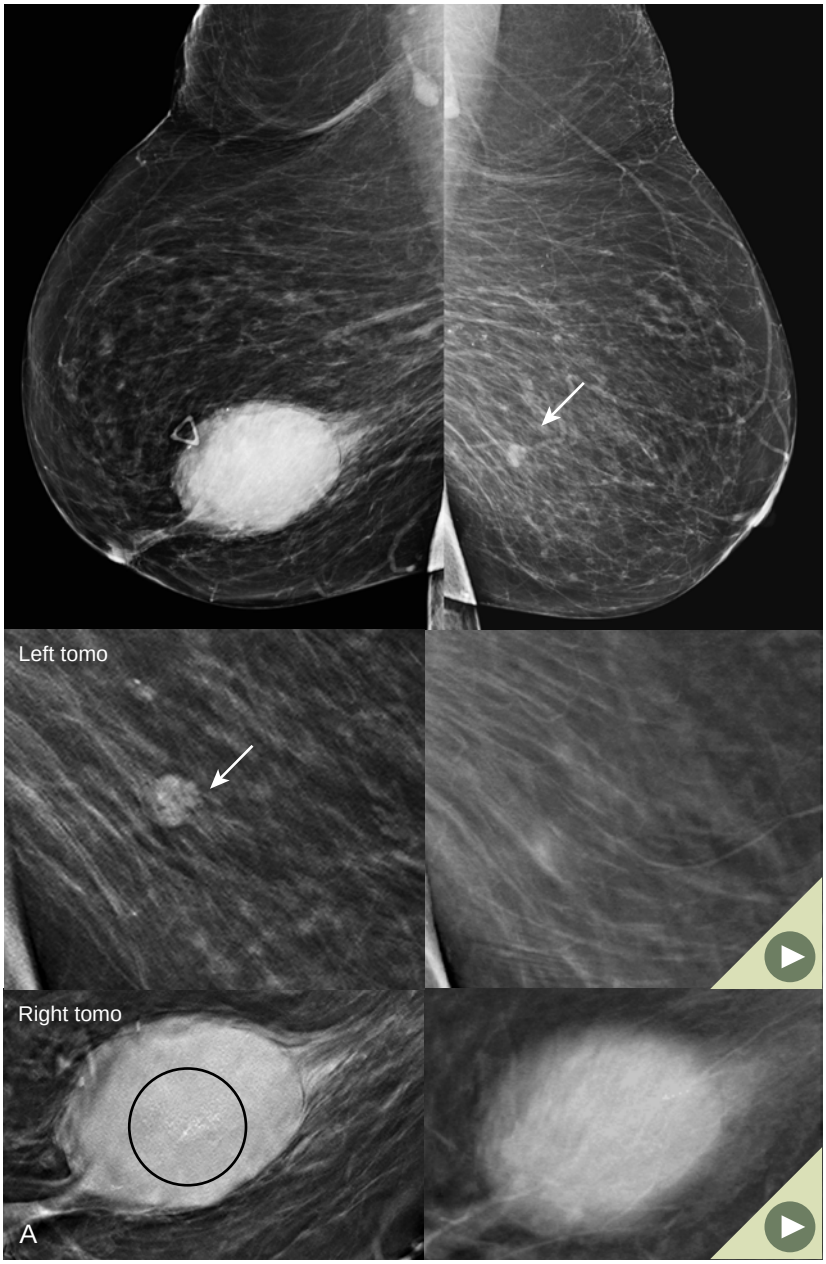


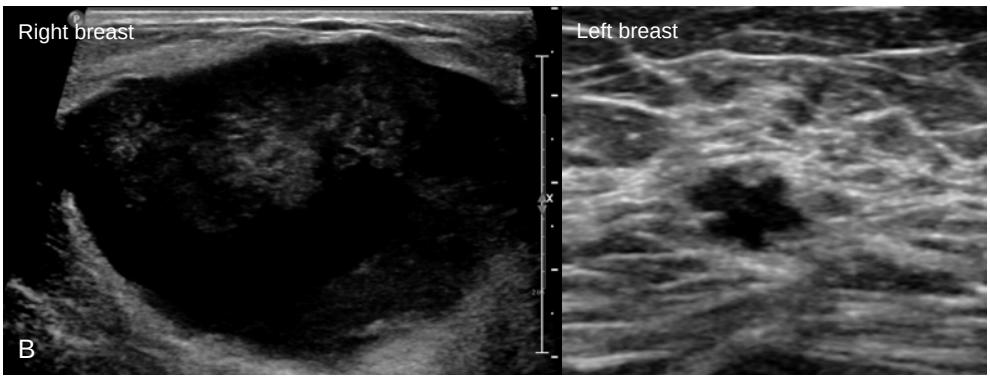


CASE STUDY 9.4 (A) Screening mammogram in a 45-year-old woman demonstrates a developing asymmetry in the right upper breast, initially seen only on the MLO views *(arrows)*. A corresponding mass is present in the right lateral breast on the spot compression CC view *(arrows)*. **(B)** Targeted ultrasound shows an oval mixed echogenic circumscribed mass corresponding to the mammographic finding. Ultrasound-guided CNB was performed. **Diagnosis: Infiltrating ductal carcinoma, grade 2, with a lymphoplasmacytic infiltrate, ER/PR+, 0/1 SLN. The patient had a complete pathologic response to neoadjuvant chemotherapy.**



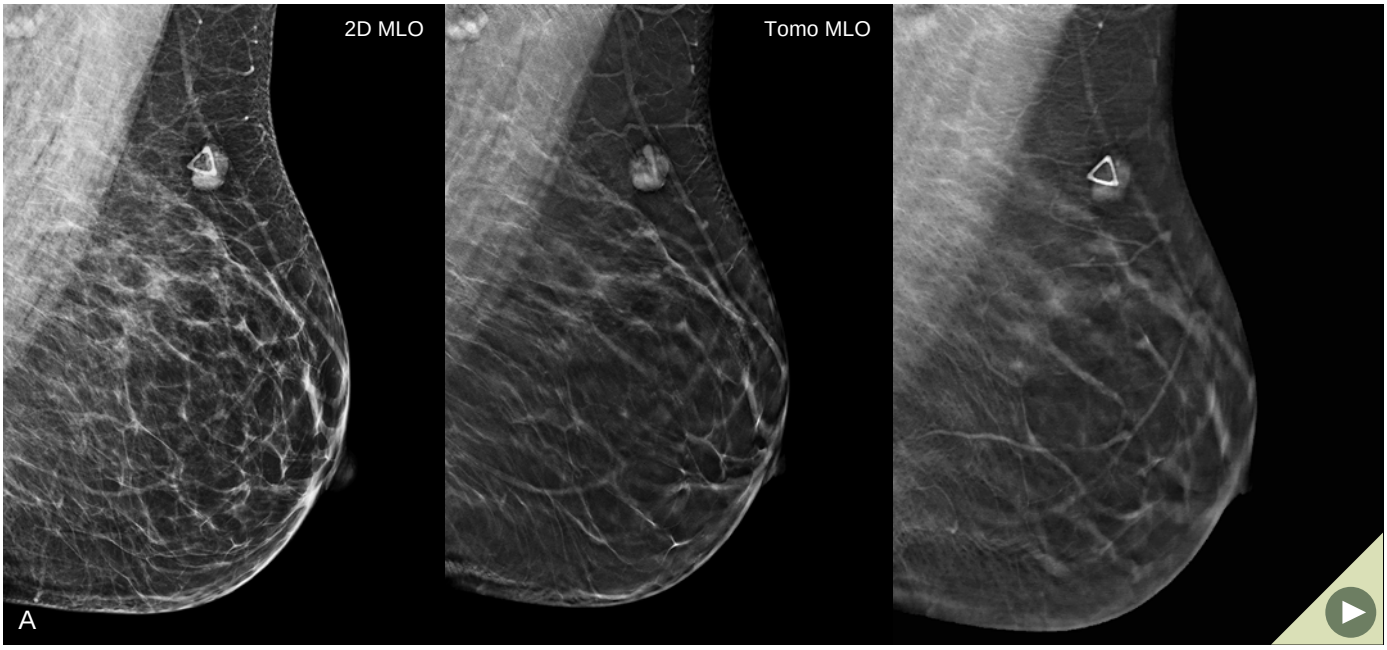


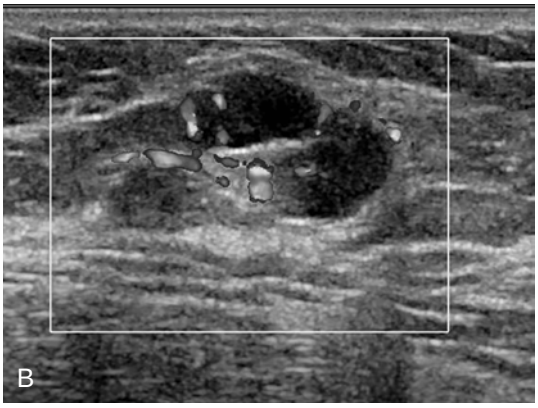


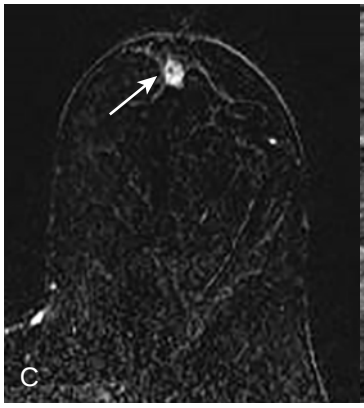


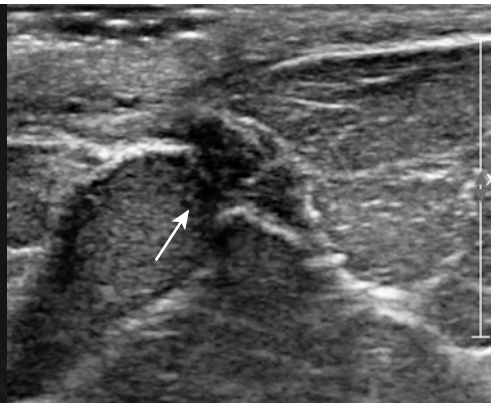
CASE STUDY 9.5 A 85-year-old woman with a slowly enlarging palpable mass in the right inferior breast. **(A)** Bilateral 2D MLO views show a dominant mass in the right inferior breast corresponding to the palpable abnormality and a smaller mass in the left inferior breast *(arrows)*. Close-up tomosynthesis MLO views shows calcifications associated with the dominant mass in the right inferior breast *(circle)*. These calcifications were not seen on the 2D images. **(B)** Targeted ultrasound demonstrates a complex cystic mass in the right breast and a hypoechoic lobulated mass with angular margins in the left breast, both corresponding to the mammographic finding. Ultrasound-guided core needle biopsy was performed. **Diagnosis: Right breast = triple negative metaplastic carcinoma (invasive squamous cell carcinoma and spindle cell components), Left breast = invasive ductal carcinoma, poorly differentiated, ER/PR+, Her2–, 0/1SLN. The patient underwent bilateral mastectomy.**

CASE STUDY 9.6 (A) ▶ A 45-year-old woman with a new palpable mass in the left upper outer breast, as noted by the triangular skin marker on the 2D diagnostic mammograms. Tomosynthesis shows the mass more clearly without the skin marker which is not in the plane of the tomosynthesis slice. No additional lesions were seen. **(B)** Targeted ultrasound was performed and demonstrates a lobulated hypoechoic mass with an echogenic vascular center consistent with an abnormal intramammary lymph node. No other lesions were identified on tomosynthesis or ultrasound. Ultrasound-guided CNB yielded moderately differentiated IDC with no lymphoid tissue identified, likely due to complete tumor replacement of the intramammary lymph node. **(C)** T1-weighted, subtracted contrast enhanced MR reveals an irregular enhancing mass in the left retroareolar region, likely the index cancer *(arrow)*. Targeted second-look ultrasound demonstrates a subtle hypoechoic mass with irregular margins. Ultrasound-guided CNB was performed. **Diagnosis: Tomosynthesis occult infiltrating ductal carcinoma with metastatic intramammary lymph node, grade 2, ER/PR+, Her2–. The patient underwent bilateral mastectomy.**



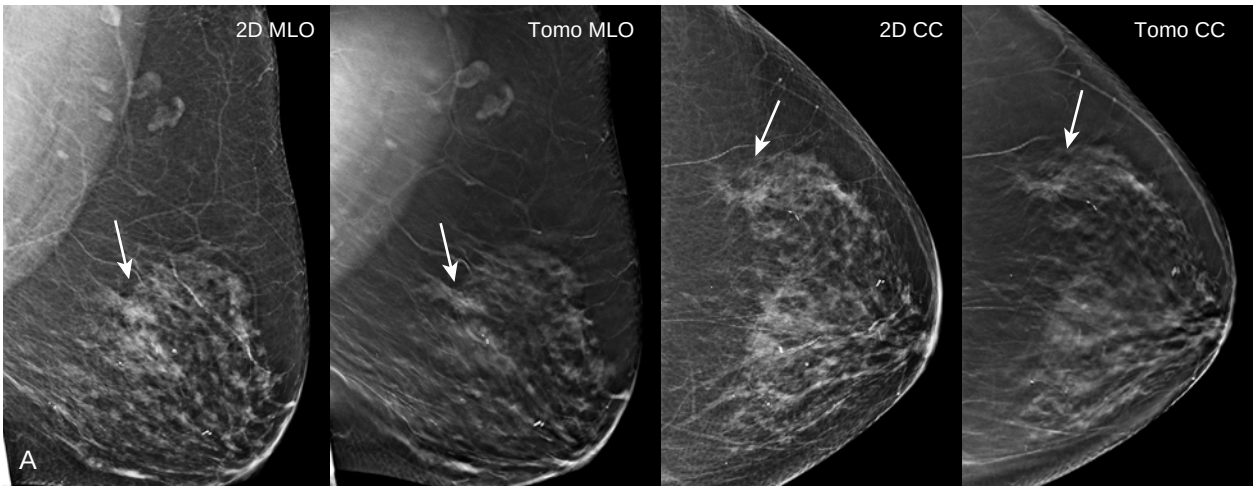


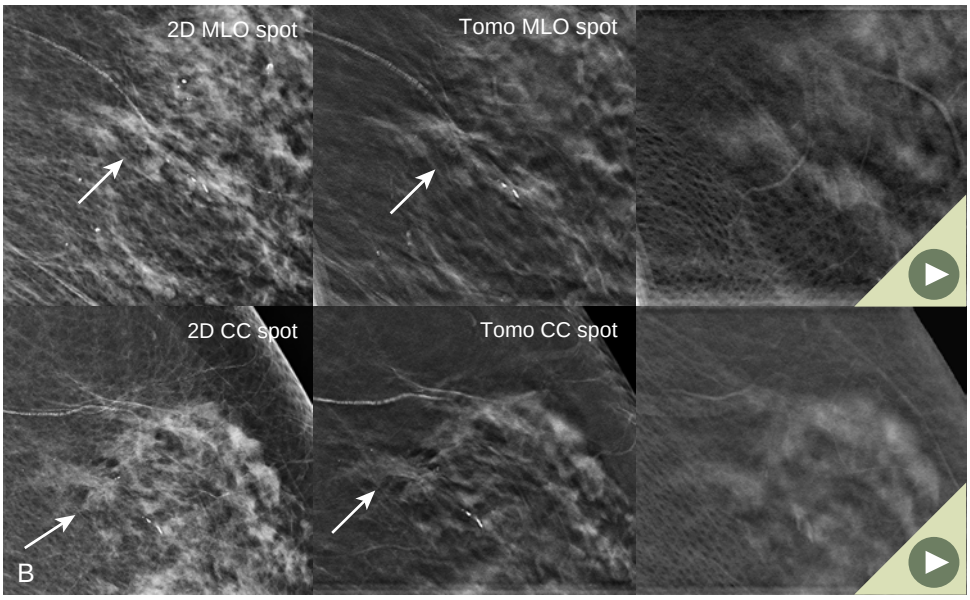




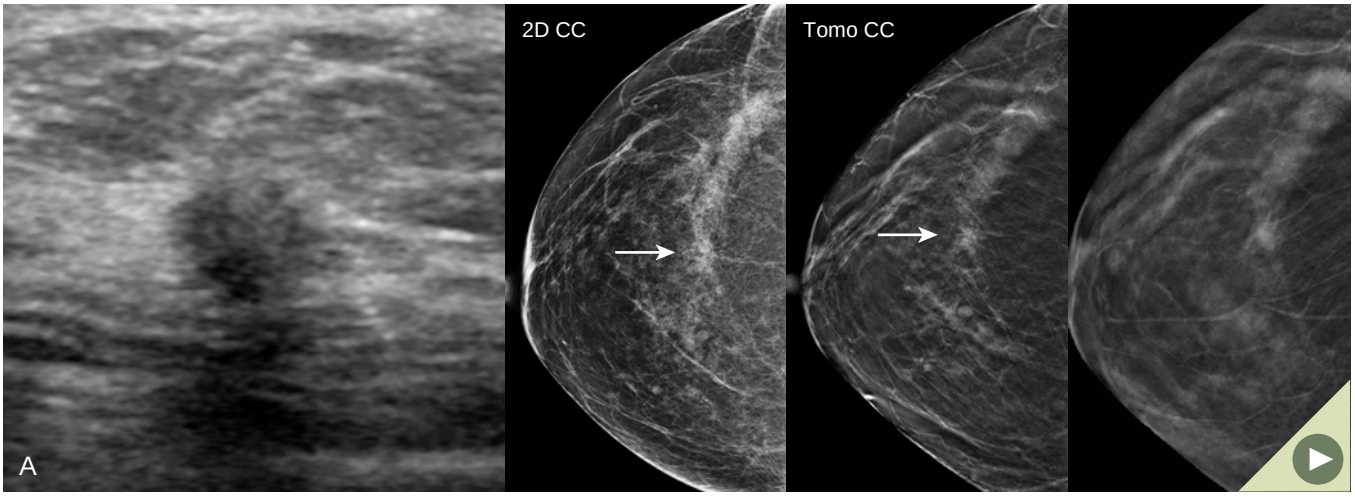
Chapter 10

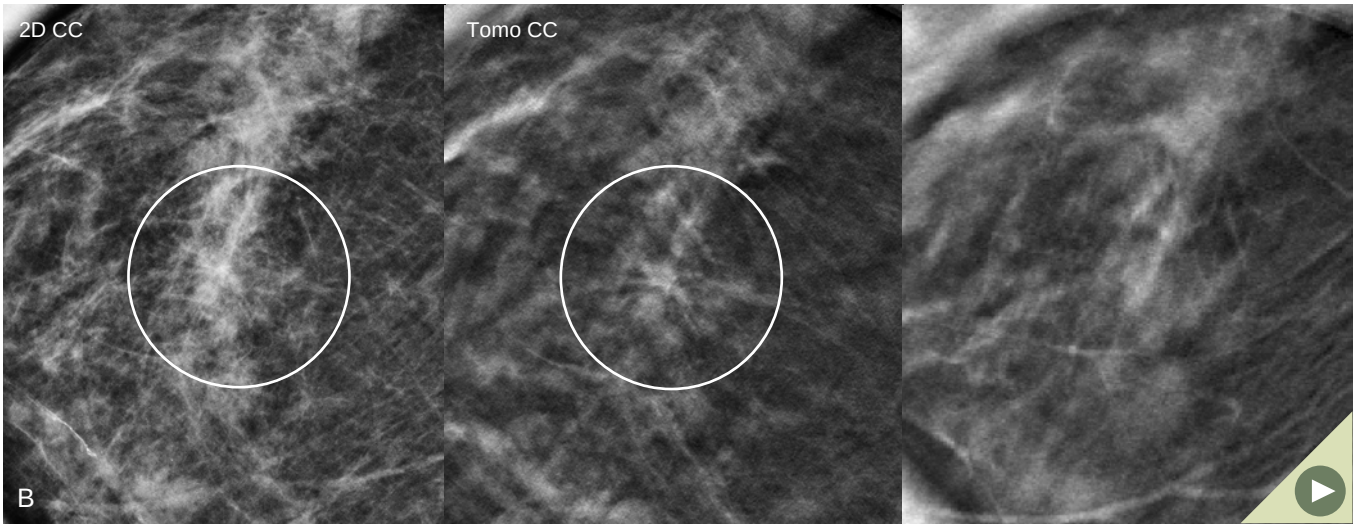
CASE STUDY 10.1 (A) Screening mammogram in a 67-year-old woman reveals heterogeneous breast tissue and an AD in the left upper-outer quadrant *(arrows)*, which is more obvious on tomosynthesis and could be overlooked on the 2D images alone. **(B)** ▶ ▶ Tomosynthesis spot compression views confirm the AD. No corresponding mass was seen on targeted ultrasound. Stereotactic CNB was performed using the nearby Ca++ as a targeting landmark. **Diagnosis: Atypical ductal hyperplasia (ADH) + complex sclerosing lesion (CSL). Surgical excision revealed the prior biopsy site and ususal ductal hyperplasia without residual CSL or ADH.**



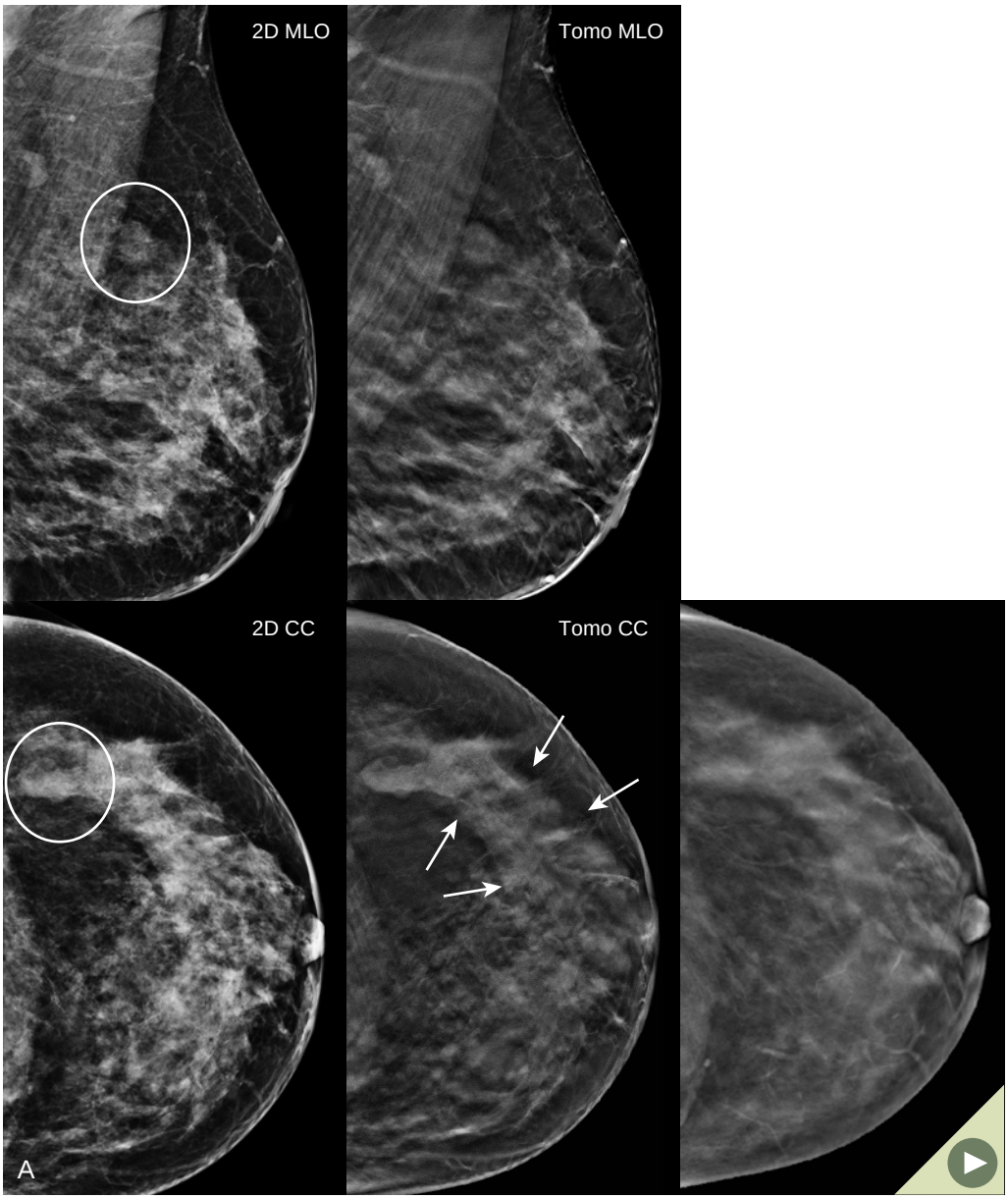


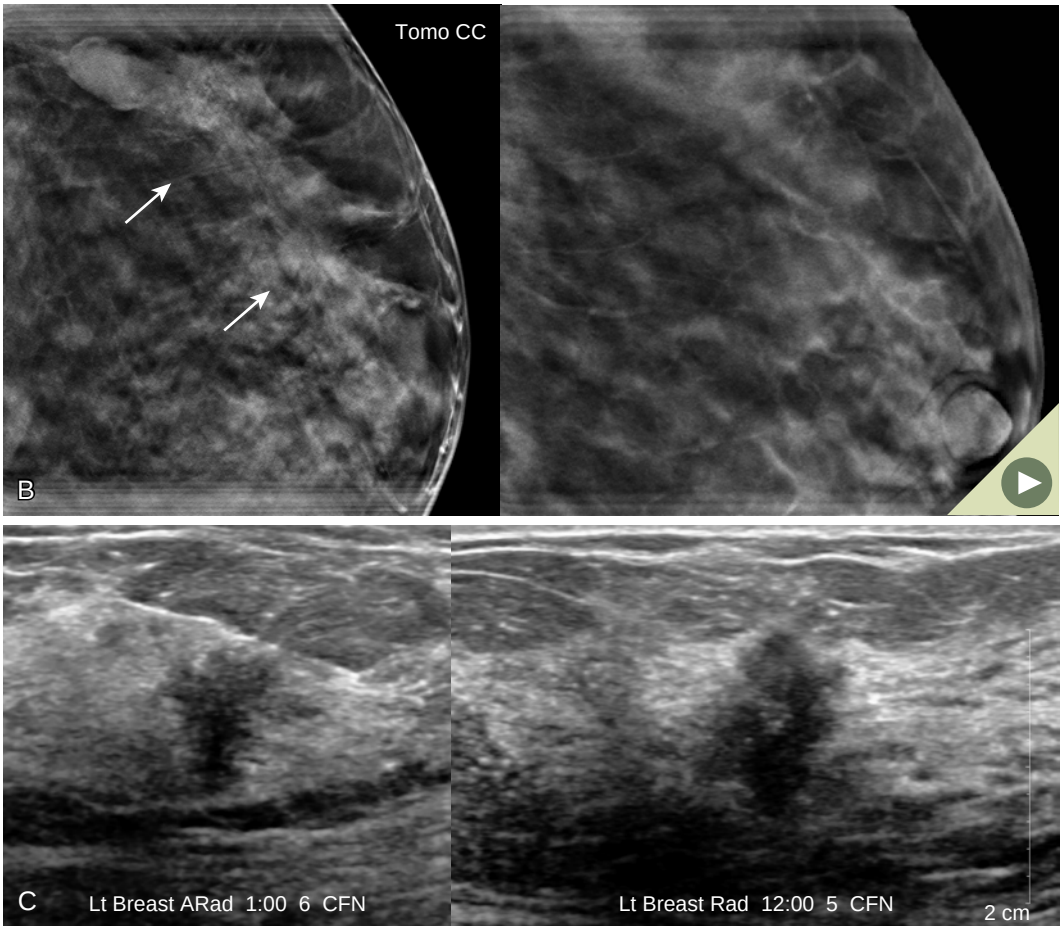
CASE STUDY 10.2 (A) Screening ultrasound detected suspicious 8-mm hypeoechoic mass with indistinct margins in the right breast at the 12-o'clock position. Although the screening mammogram performed on the same day was initially interpreted as normal, in retrospect a corresponding AD was suspected and seen only on the CC view, best seen on tomosynthesis *(arrows)*. **(B)** Diagnostic spot compression views confirm the presence of a small AD, better seen on tomosynthesis *(circles)*. In this case diagnostic spot compression views did not add any additional diagnostic information. Ultrasound-guided CNB was performed. **Diagnosis: Infiltrating lobular carcinoma, grade 2, confirmed with surgical excision, ER/PR+, Her2–, 1/2 SLN**.



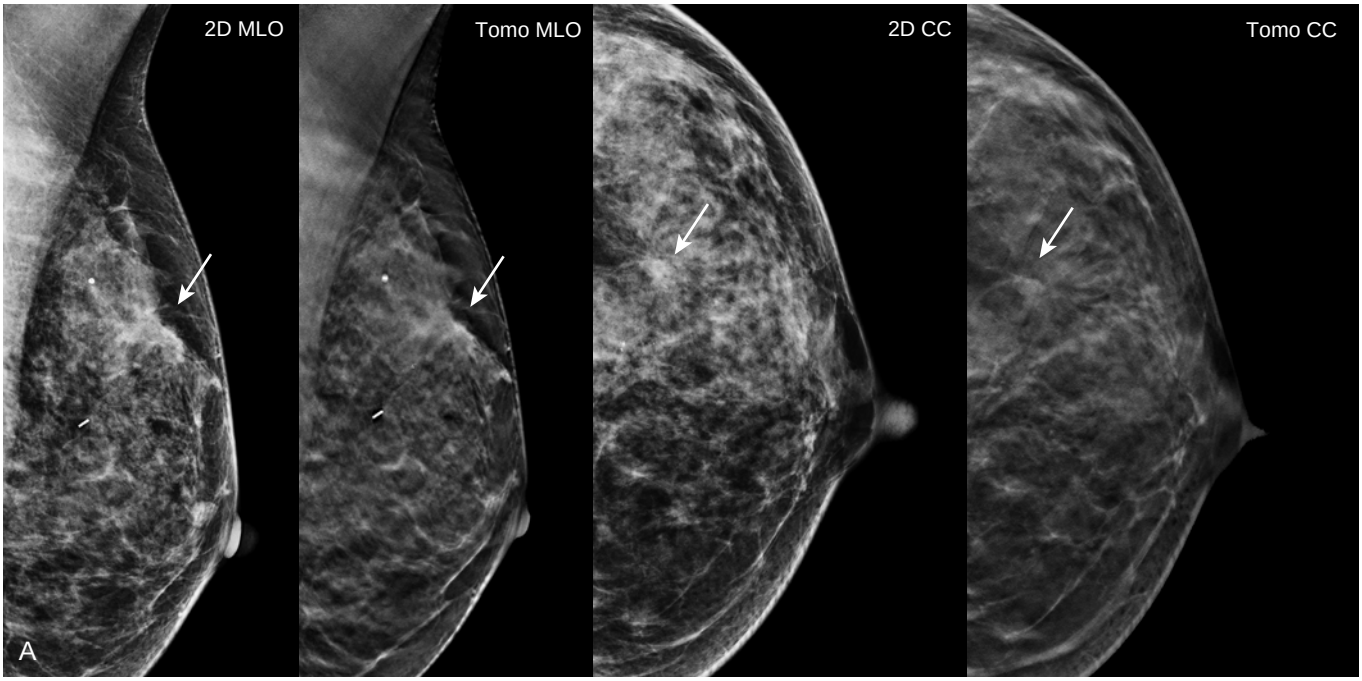


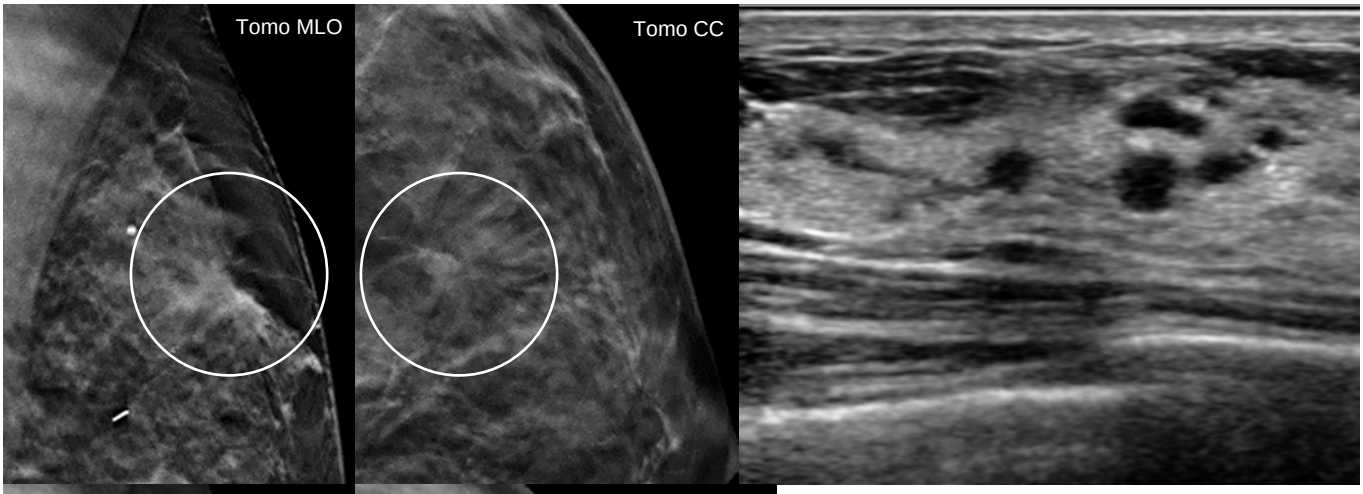
CASE STUDY 10.3 (A) ▶ A 51-year-old woman referred for further work-up of a biopsy-proven, high-risk lesion in the left breast at the 10-o'clock position seen on screening ultrasound (not shown). The original screening mammogram was read as BI-RADS 2, and a biopsy marker clip was not placed after biopsy of the lesion at the 10-o'clock position. Diagnostic left mammogram demonstrates a complex heterogeneous breast parenchymal pattern. An oval mass in the posterior left upper-outer quadrant is a stable biopsy proven fibroadenoma *(circle)*. A single CC tomosynthesis slice demonstrates two very subtle possible ADs in the outer breast *(arrows)*, not seen on any other view. **(B)** ▶ Tomosynthesis CC spot compression views confirms the presence of extensive distortion in the left outer breast *(arrows)*. **(C)** Targeted ultrasound demonstrates two separate corresponding masses at the 12- and 1-o'clock positions. Ultrasound-guided CNB. **Diagnosis: Multifocal infiltrating ductal carcinoma, grade 2, ER/PR+, Her2–, 0/2 SLN. The patient underwent bilateral mastectomy.**

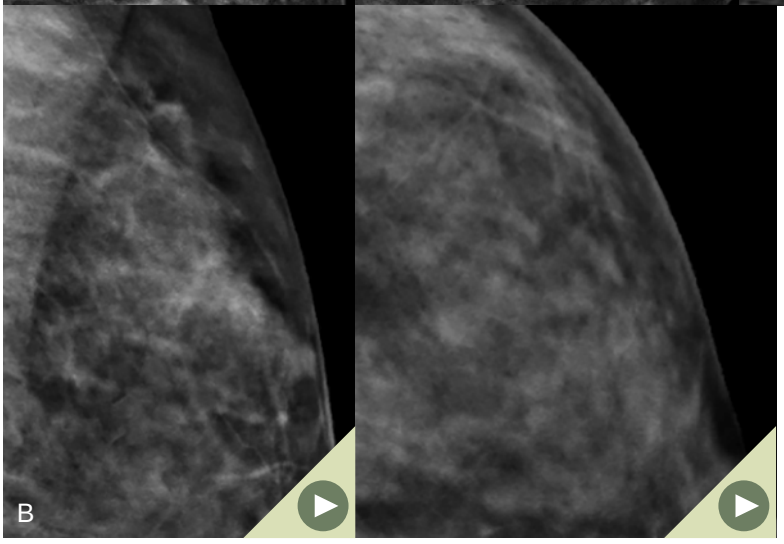



Tomo CC
B
C
Lt Breast ARad 1:00 6 CFN
Lt Breast Rad 12:00 5 CFN
2 cm

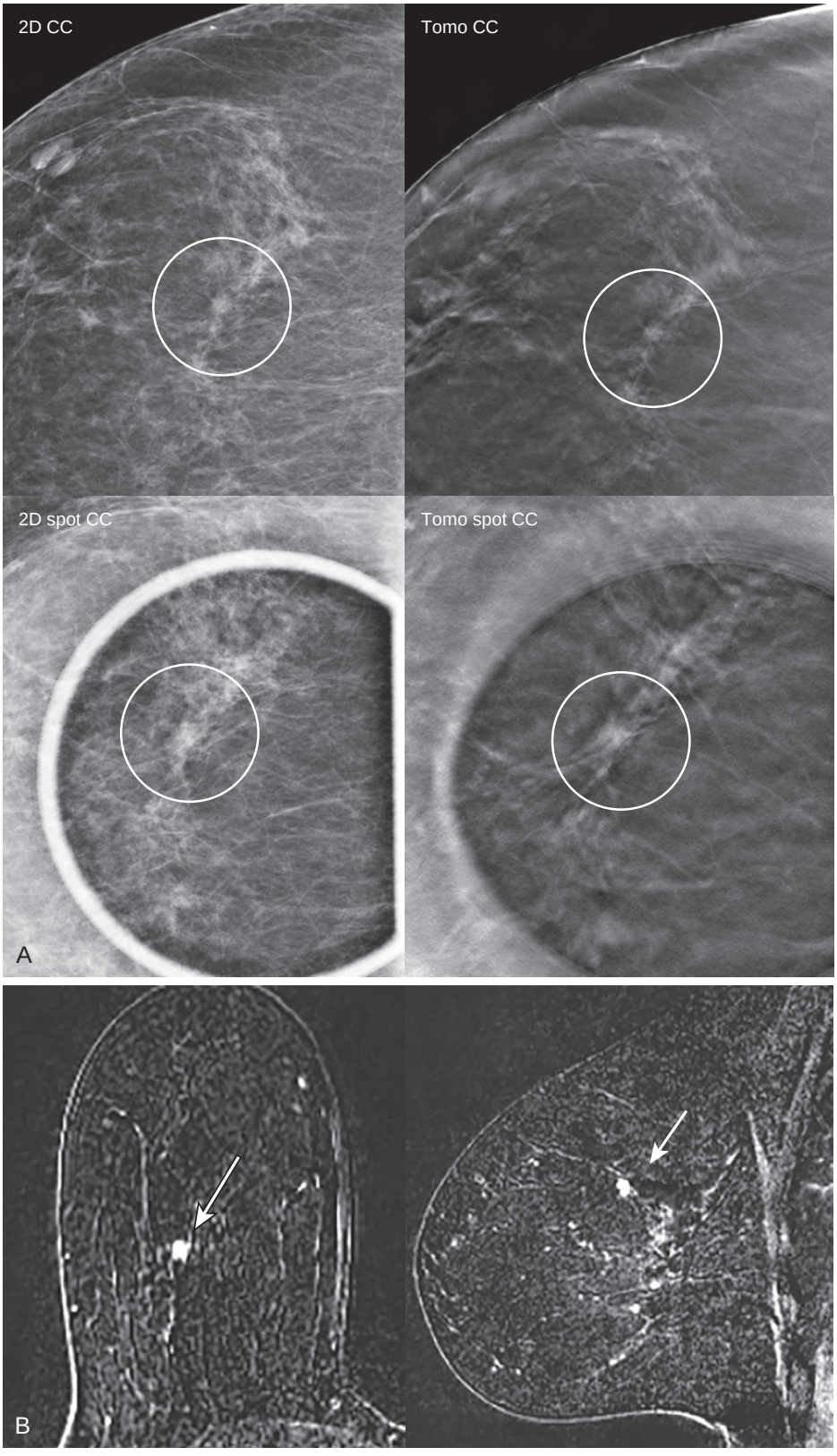
CASE STUDY 10.4 (A) AD in the left upper-outer quadrant *(arrows)* seen on a baseline screening mammography in a 42-year-old woman. **(B)** ▶ ▶ Close-up tomosynthesis views demonstrate that the associated fine spicules, best seen on the CC view *(circles)*. Targeted ultrasound demonstrated a corresponding cluster of anechoic cystic masses. Ultrasound-guided CNB was performed. **Diagnosis = radial scar and fibrocystic changes. The patient was referred for surgical consultation and surgical excision was not performed, and this AD was stable on follow-up imaging**.



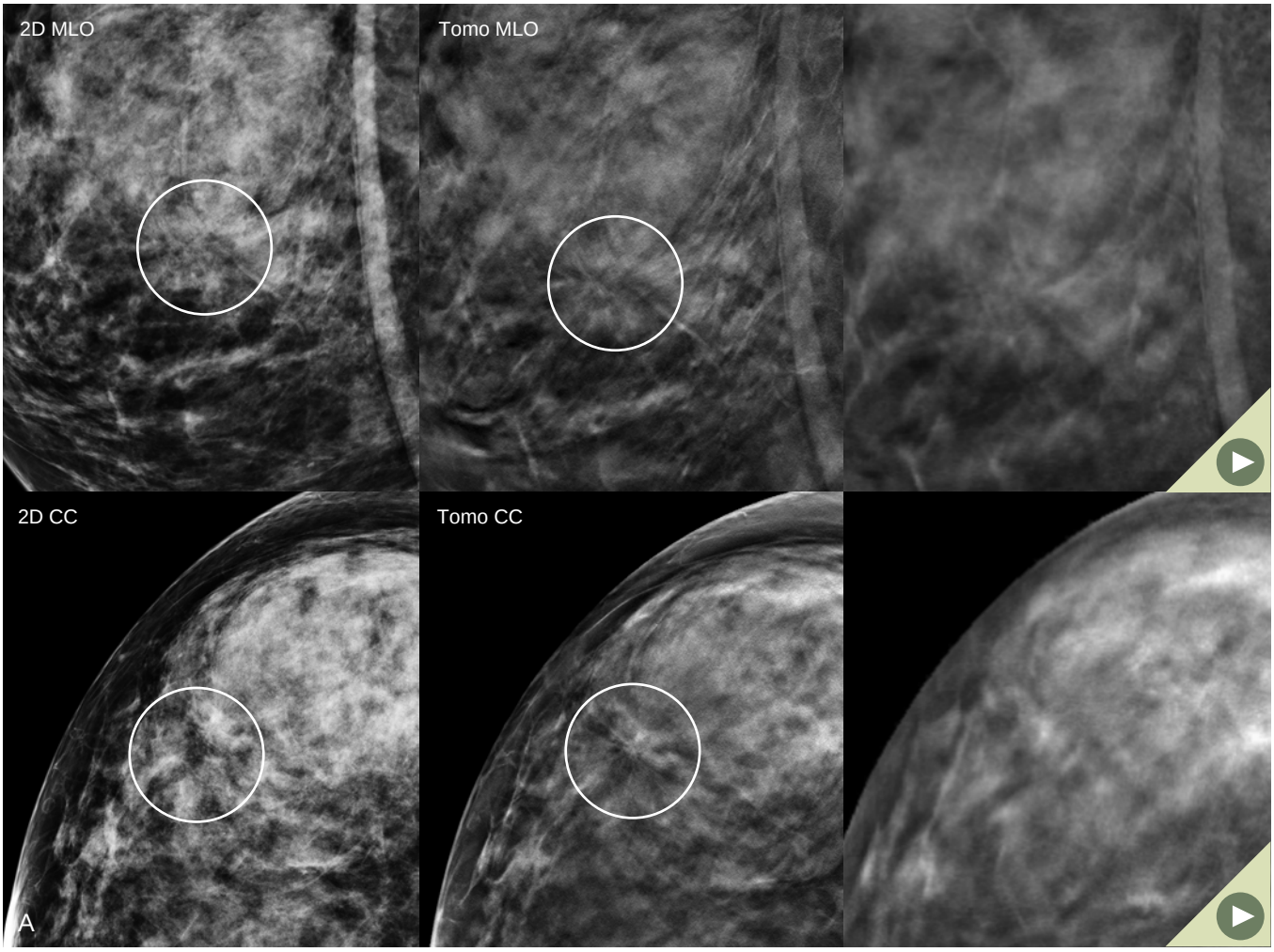


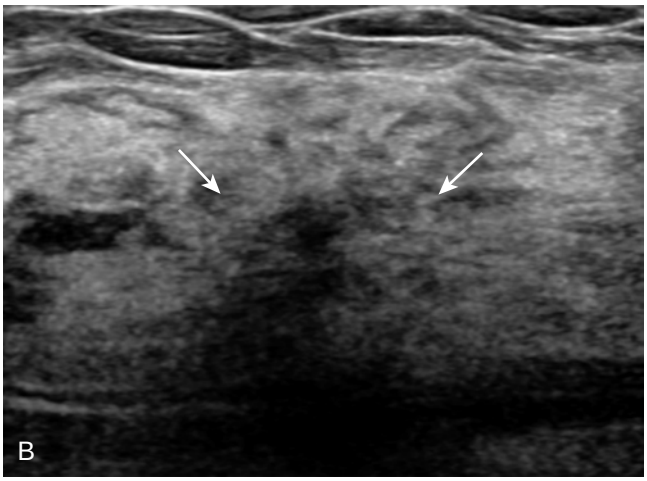


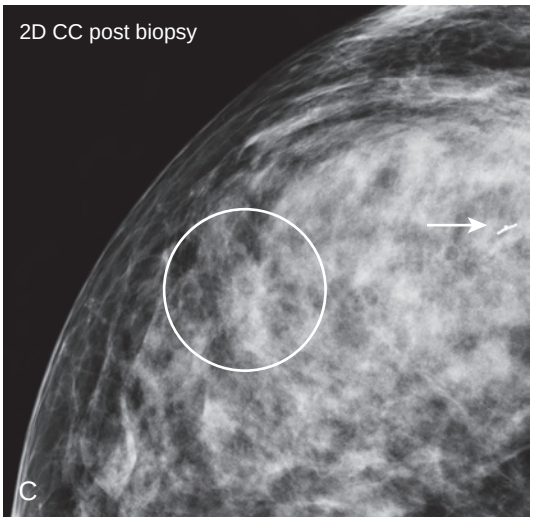
CASE STUDY 10.5 (A) Screening mammogram in a 62-year-old woman with subtle AD visualized on the CC projection only. The AD was seen on the 2D image but more obvious on tomosynthesis. Additional spot compression views demonstrated that the abnormality was obvious in the tomosynthesis images but appeared to efface on the 2D image. No sonographic correlate was found. Because of the suspicious persistent single view finding on tomosynthesis, MR was recommended. Note, in this case, tomosynthesis spot compression views were helpful to confirm the subtle AD not seen on ultrasound. If 2D spot compression were only obtained, this finding could have been incorrectly dismissed as benign. **(B)** T1-weighted, fat-suppressed, contrast-enhanced axial and sagittal MR images demonstrate an irregular mass in the upper-outer right breast, with irregular margins and heterogeneous internal enhancement. MRI-guided biopsy and surgical excision were performed. **Diagnosis: Infiltrating ductal carcinoma, grade 1, ER+, PR+, Her2: indeterminate, Ki67: 8%, 0/1 SLN.**

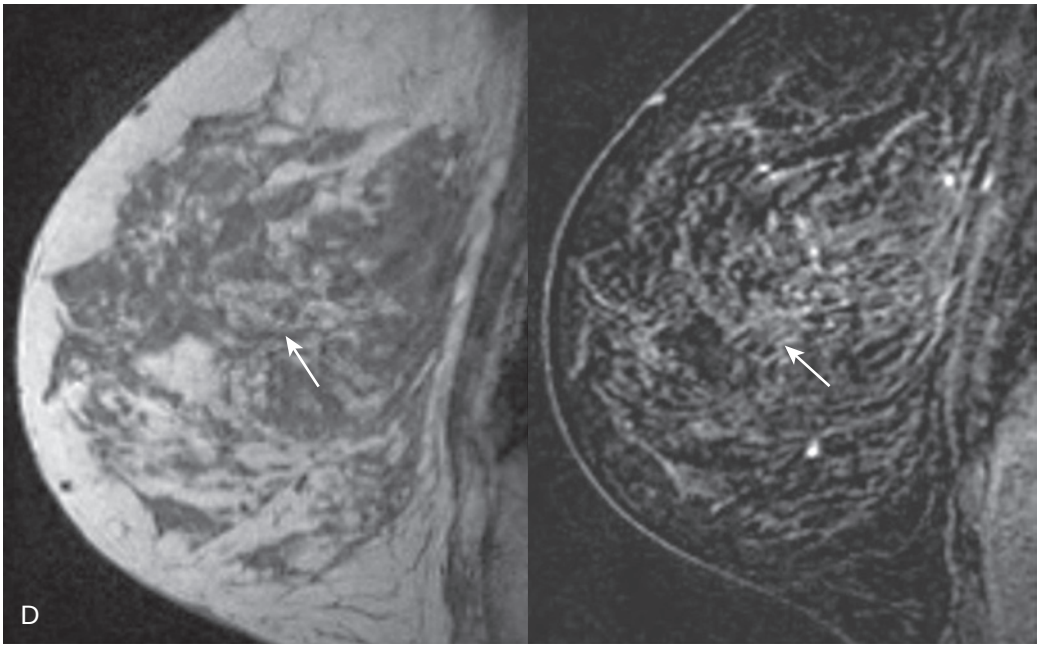


CASE STUDY 10.6 (A) Screening mammogram in a 62-year-old woman a remote history of mastectomy on the left and reduction mammoplasty on the right. A new subtle area of AD was visualized in the right breast *(circles)*. **(B)** Ultrasound demonstrated a vague hypoechoic, irregular mass with indistinct margins and posterior shadowing in the right breast at 9-o'clock position *(arrows)*. **(C)** Ultrasound-guided biopsy proved stromal fibrosis which was thought to be discordant with the mammographic findings. Also the clip *(arrow)* did not correspond with the AD *(circle)*. **(D)** Subsequent MRI was performed. T1 precontrast sagittal image *(right)* showed a subtle AD, which did not enhance on the subtracted post contrast T1-weighted image *(left)*. **Diagnosis: Benign post-surgical changes, BI-RADS 2, and stable on mammographic follow-up.**

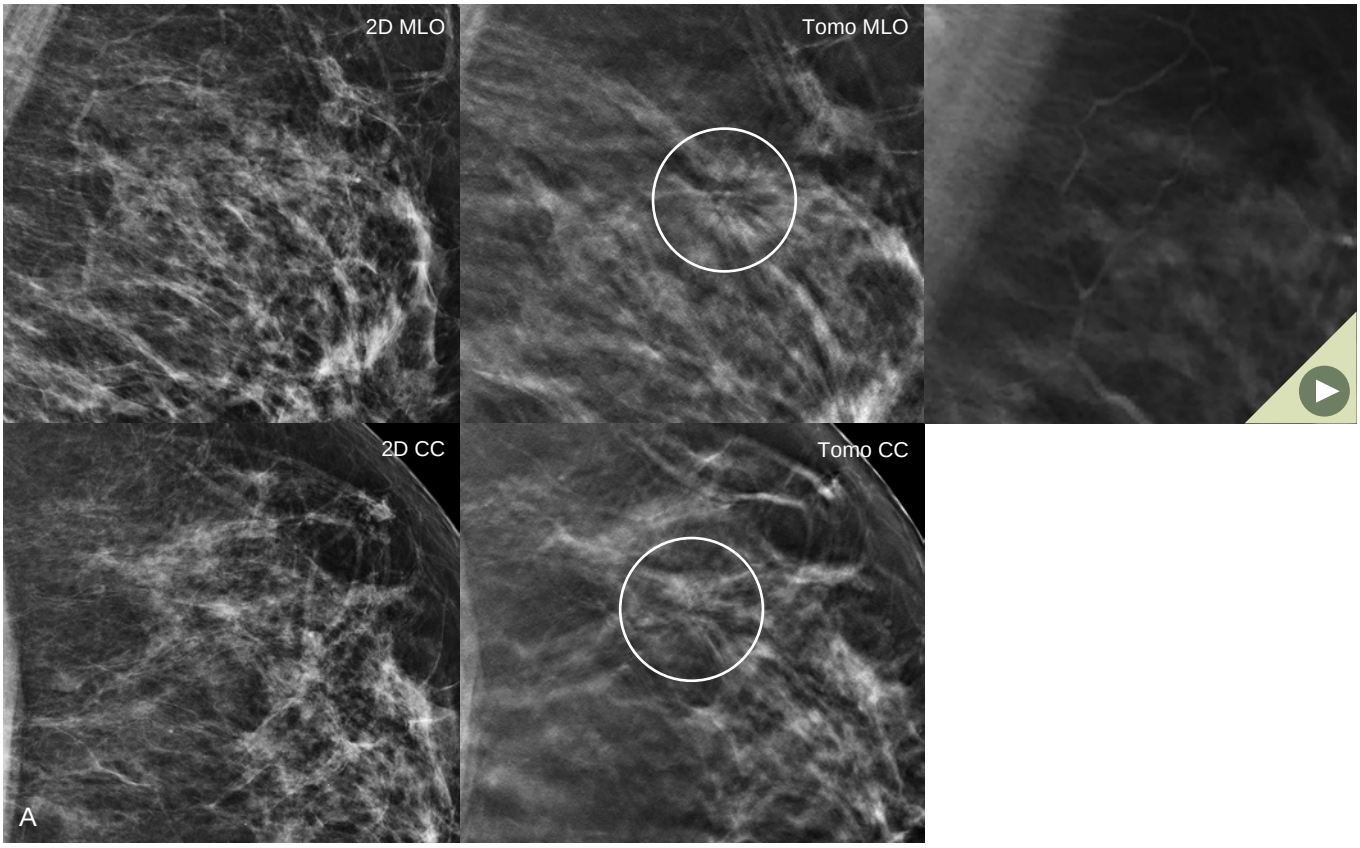


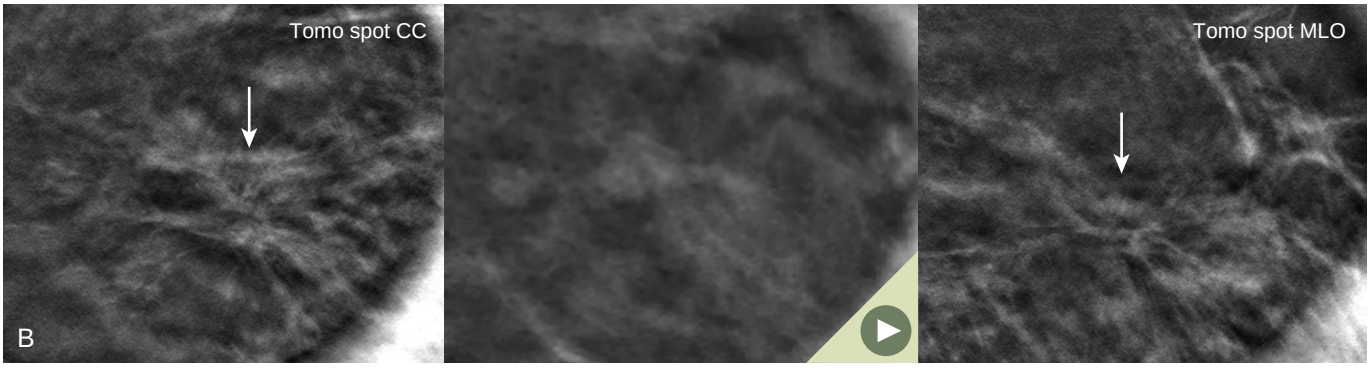


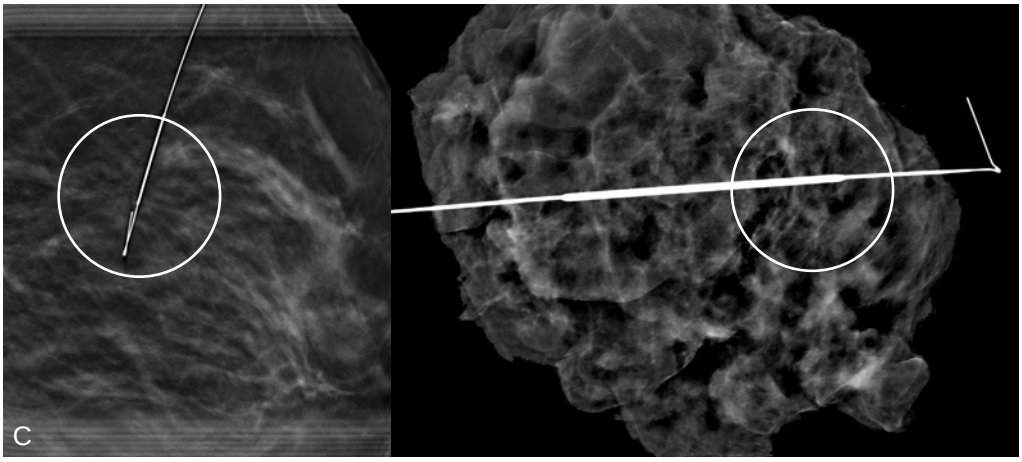

2D CC post biopsy
C


D

CASE STUDY 10.7 (A) A 46-year-old woman presenting with bloody nipple discharge from the right breast. Bilateral diagnostic mammogram was performed, which demonstrated subtle AD in the upper-outer left breast evident on the tomosynthesis slices only. Although no mammographic or sonographic abnormality was seen in the right breast (not shown), subsequent central duct excision of the right breast demonstrated a papilloma. **(B)** Additional views with tomosynthesis demonstrated persistence of the AD in the left breast, although no sonographic correlate was found. **(C)** Tomosynthesis-guided needle localization was performed. The area of distortion is visualized along the thick portion of the localization wire as well as the surgical specimen. **Diagnosis: 1.2 mm benign radial scar**.

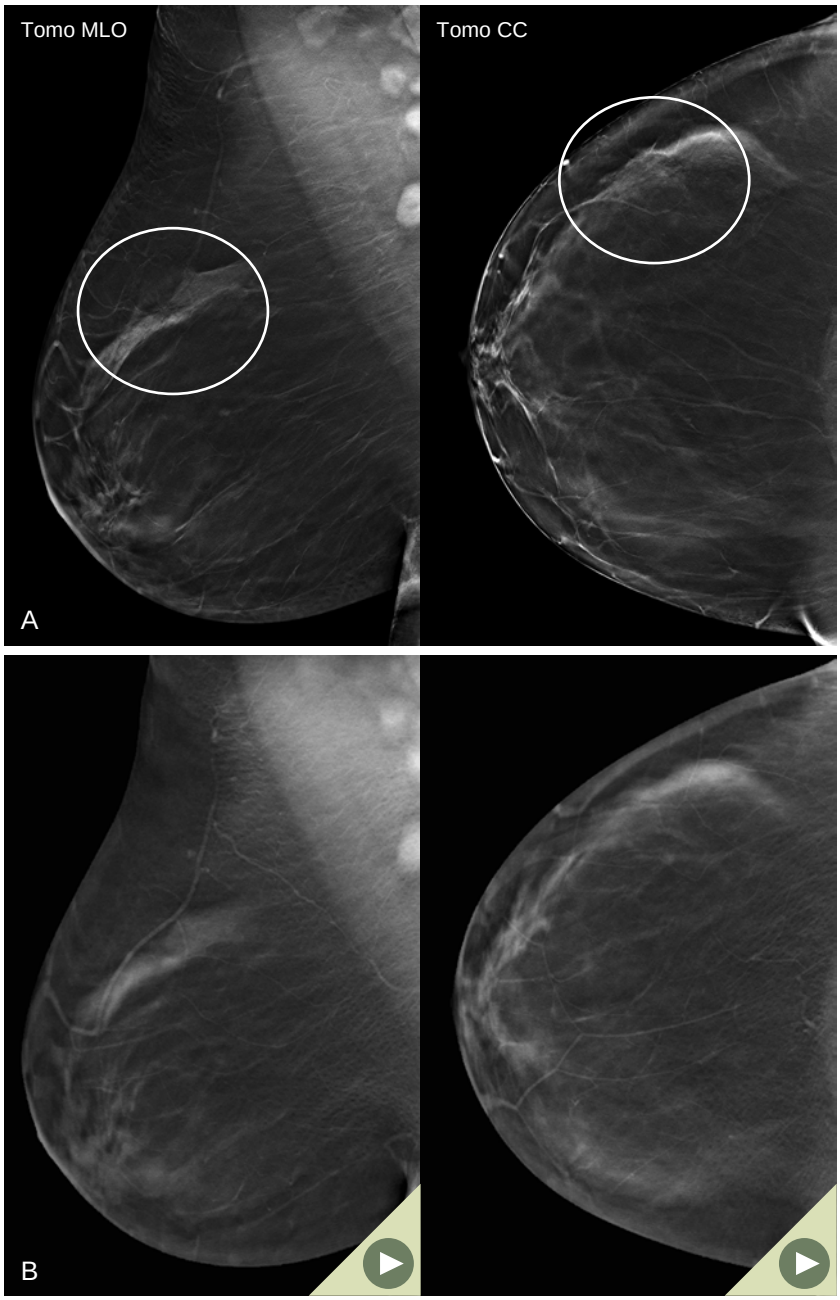




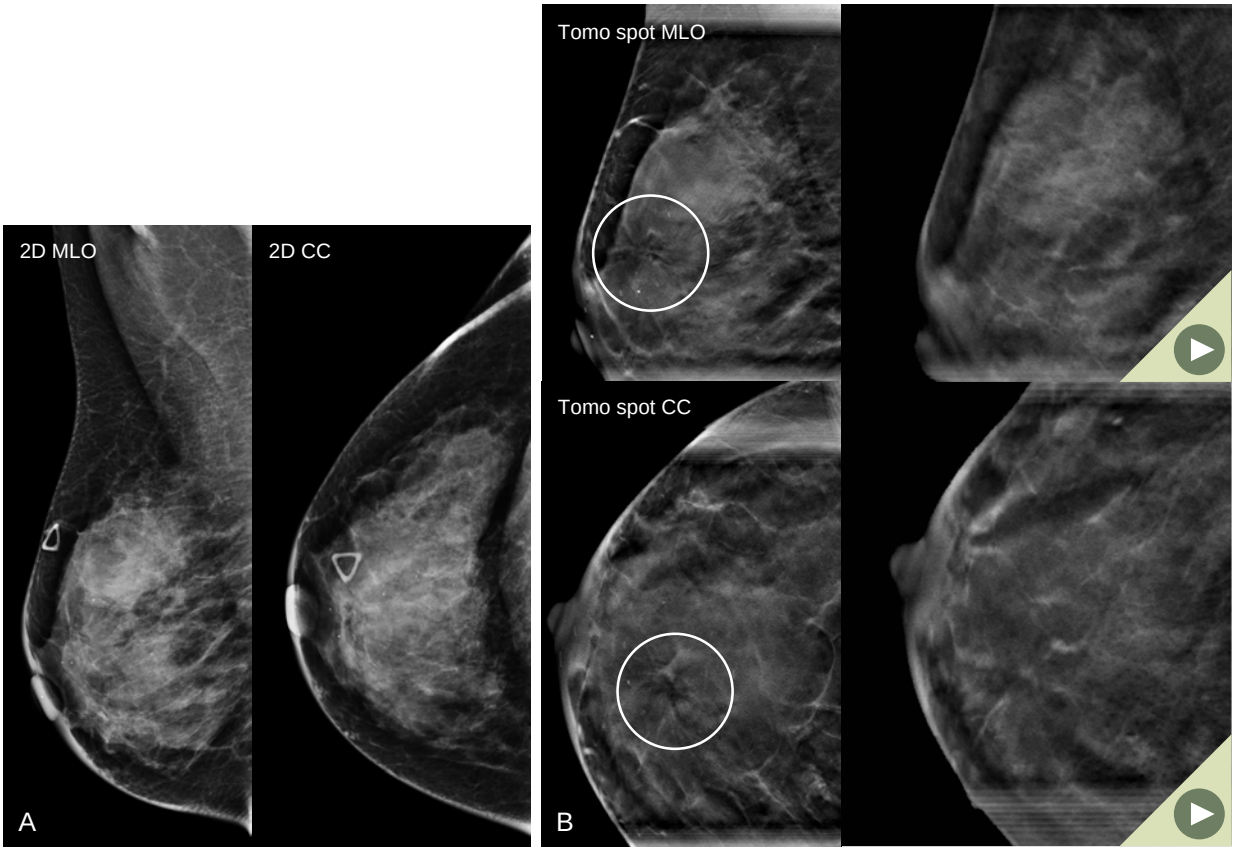


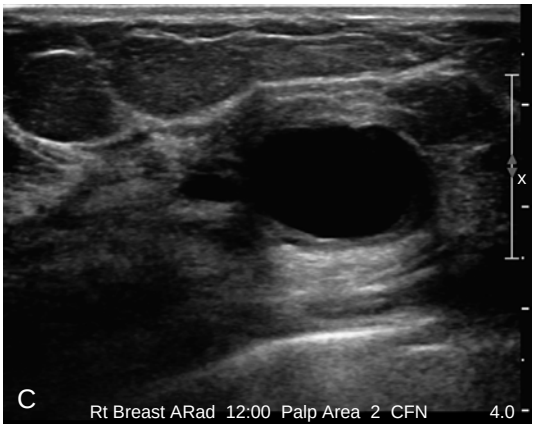
Chapter 11

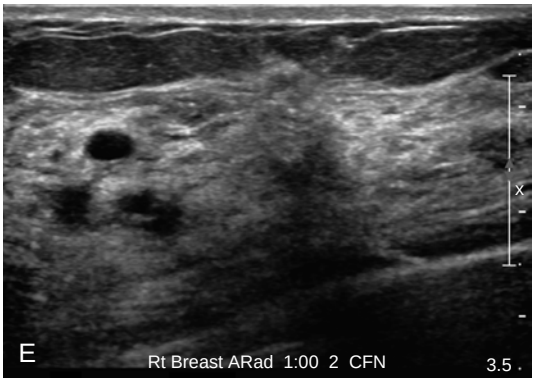
CASE STUDY 11.1 Note this is the same patient as Fig. 11.14. A 57-year-old woman, 5 years status post treatment for melanoma, was found to have right axillary biopsy proven adenocarcinoma suggestive of breast primary. **(A)** Single tomosynthesis MLO and CC slices show malignant architectural distortion *(circles)*. **(B)** ▶ ▶ Review whole-breast tomosynthesis MLO and CC movie series to try to detect the malignancy presenting as subtle architectural distortion in a mostly focally fatty area. **Diagnosis: Infiltrating ductal carcinoma, moderately differentiated, with lymphovascular invasion, ER+, PR+, Her2–.**

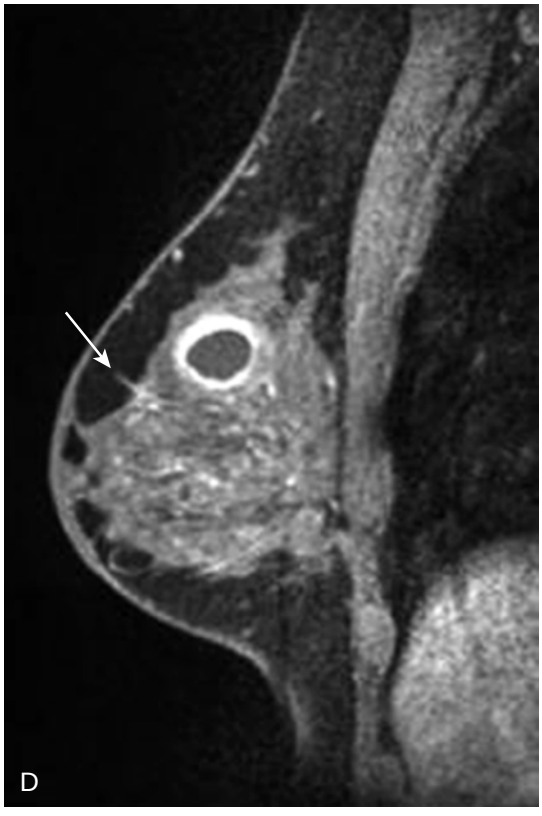


CASE STUDY 11.2 **(A)** A 51-year-old female presented for diagnostic mammography due to a palpable mass in her right breast. **(B)** An oval mass with an obscured margin is noted to correlate with the palpable abnormality, but a 1.5 cm area of architectural distortion is incidentally seen on tomosynthesis spot views anterior to the palpable abnormality *(circles)*. **(C)** An ultrasound was performed, which confirms that the palpable abnormality is a benign-appearing cyst, but no definite correlate was found for the architectural distortion. **(D)** MRI was performed which shows the cyst with a thin enhancing rim and architectural distortion at 12-o'clock position, anterior depth, associated with mostly persistent nonmass enhancement *(arrow)*. Tomosynthesis guided needle localization and surgical excision revealed benign radial scar. **(E)** In retrospect, an ill-defined area in the right breast anterior 1-o'clock location likely represents the radial scar lesion. **Diagnosis: Benign radial scar.**

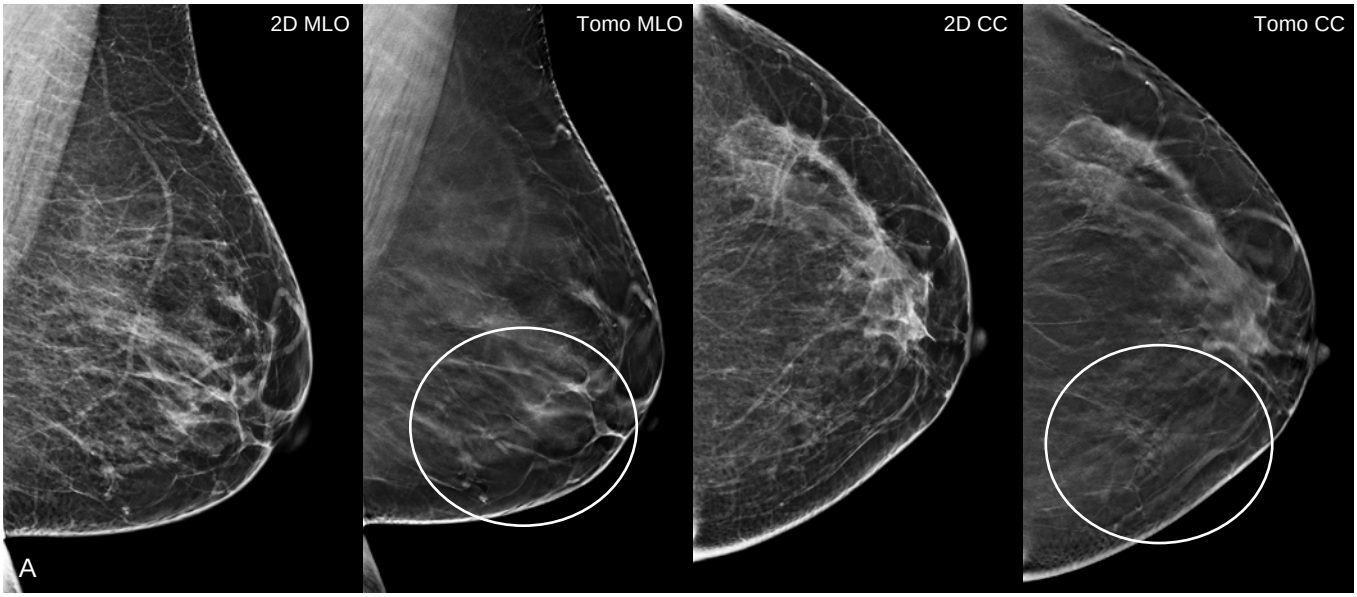


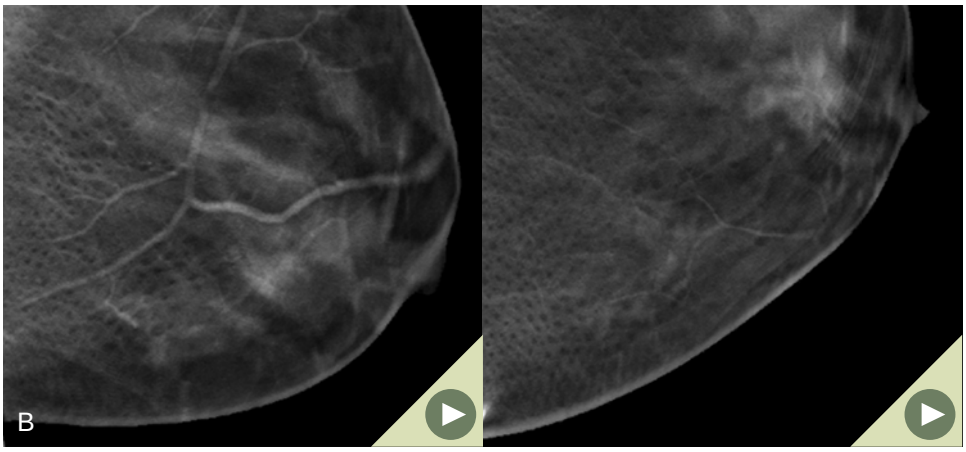


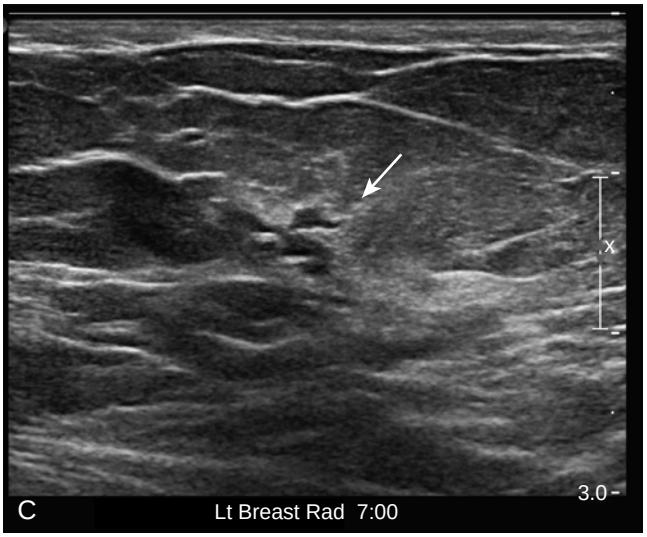


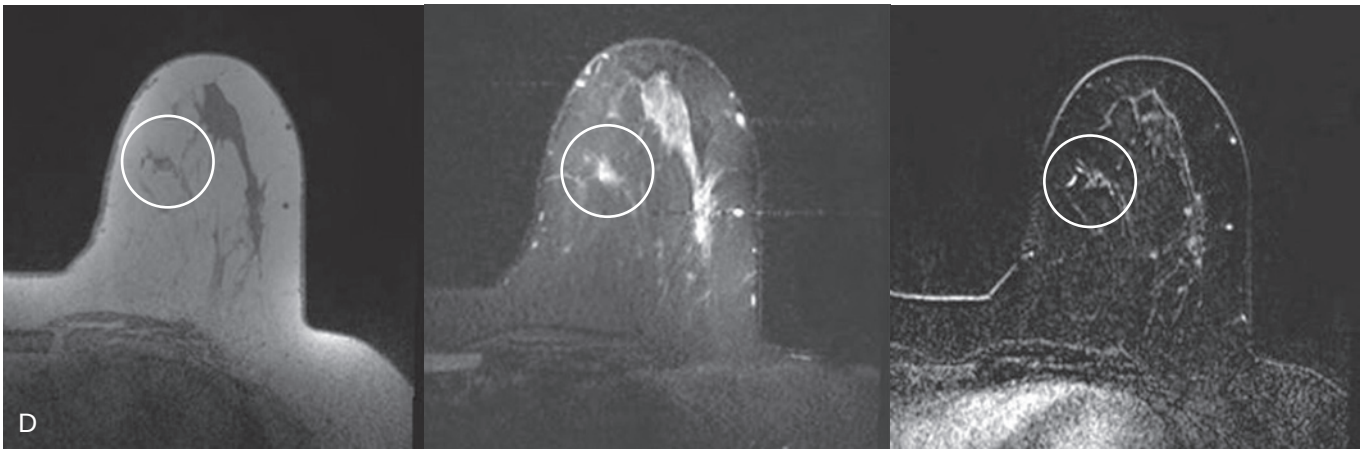


CASE STUDY 11.3 (A) A 45-year-old woman was found to have an area of architectural distortion in the medial left breast on a screening exam. **(B)** ▶ ▶ Diagnostic spot tomosynthesis movie images show persistence of the abnormality. **(C)** Targeted ultrasound was performed in which only small clustered cysts are detected and reported as "no sonographic correlate." **(D)** MRI was recommended and shows an area of distortion with increased T2 intensity and only minimal persistent enhancement. **(E)** Review of all imaging at that point suggested that the clustered cysts were likely in the vicinity of the architectural distortion. Repeat ultrasound was performed, a BB placed on the skin overlying the clustered cysts, and repeat mammographic views confirm the area correlates with the architectural distortion *(arrows)*. **(F)** Ultrasound-guided vacuum biopsy was performed, and post-biopsy images show the biopsy marker in the expected location at the center of the distortion. **Diagnosis: Pathology revealed benign radial scar.**





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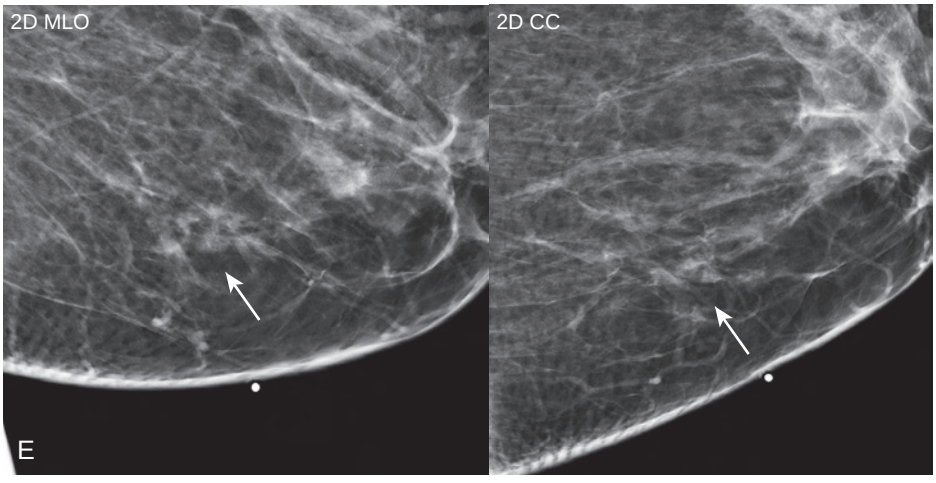
2D MLO
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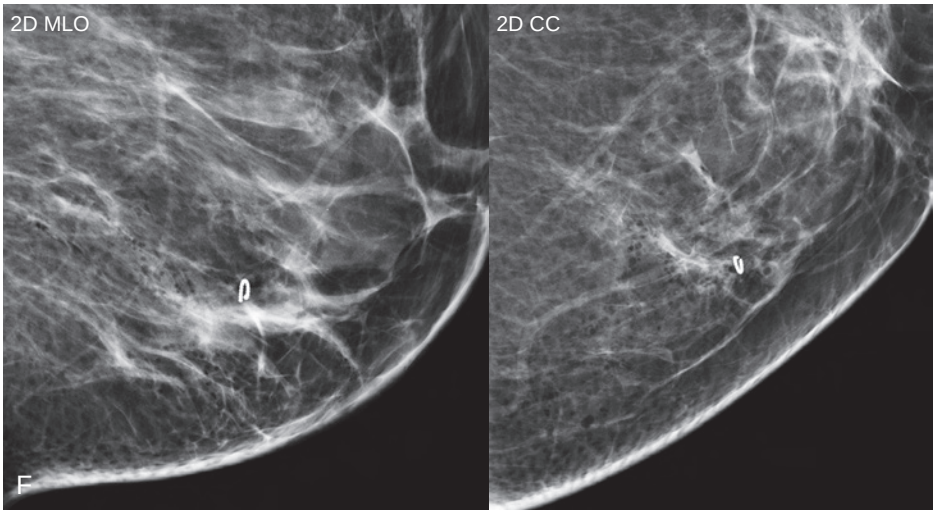
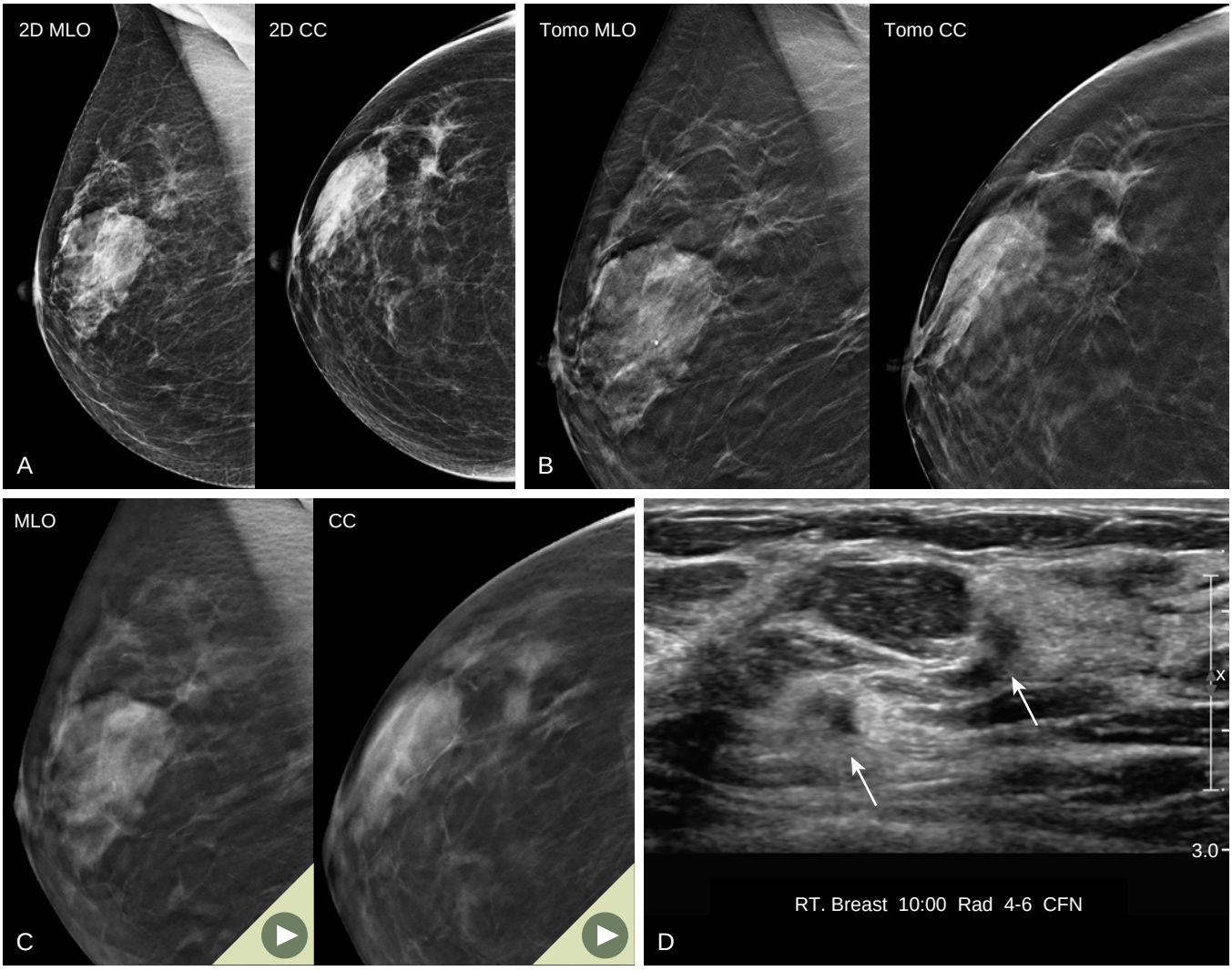
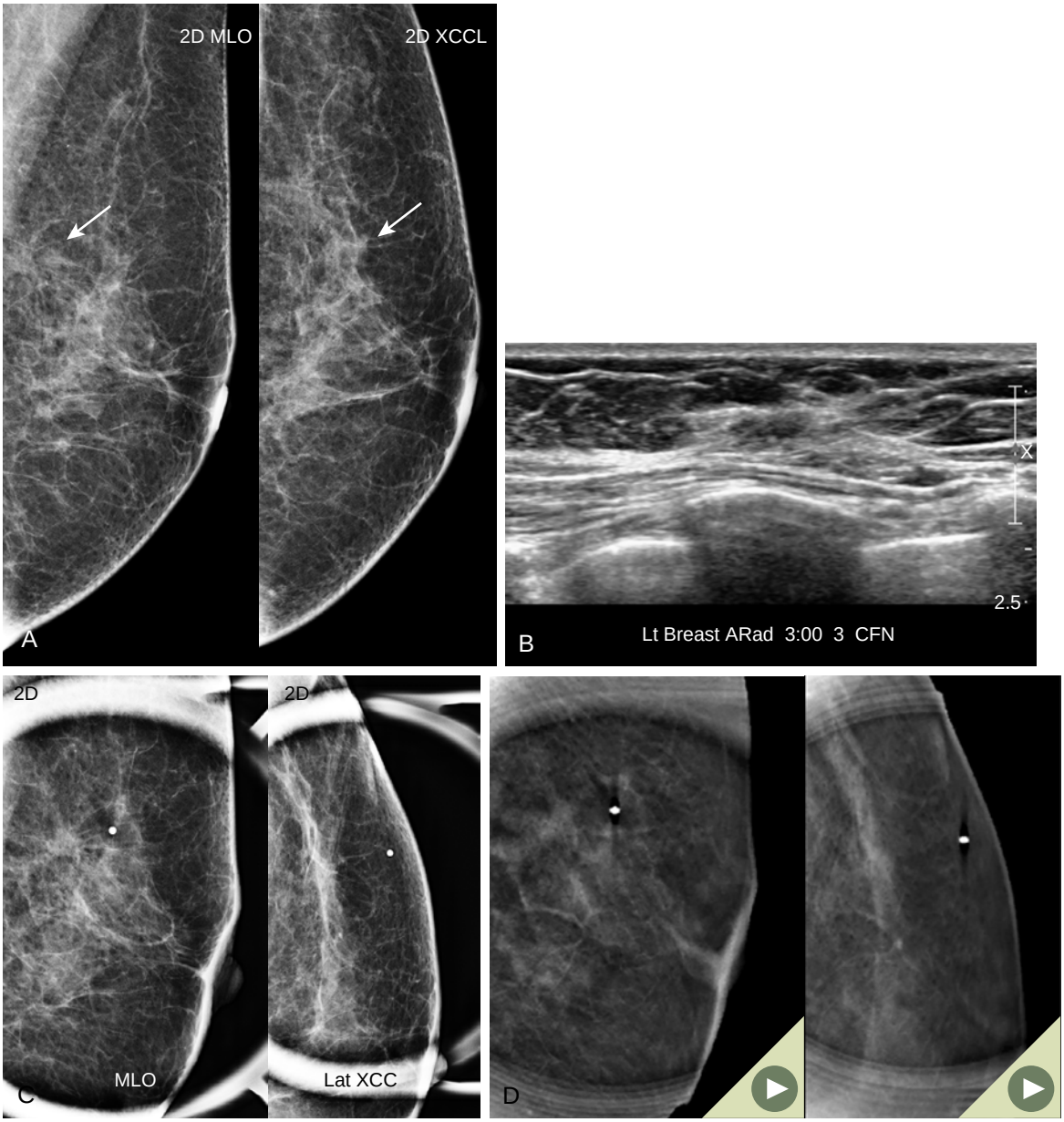
E


2D MLO
2D CC
F

CASE STUDY 11.4 (A) A 63-year-old woman was found to have an area of distortion in the upper-outer quadrant of her right breast. **(B)** Tomosynthesis slice and **(C)** ▶ ▶ movie images show multiple spiculated masses. **(D)** Ultrasound shows multiple irregular hypoechoic masses with indistinct margins and hyperechoic rims. **Diagnosis: Ultrasound biopsy of two of the lesions revealed invasive carcinoma. At mastectomy, 6.5 cm of invasive ductal carcinoma with lobular features was found, ER+/PR+/Her2–, with eight positive axillary lymph nodes.**

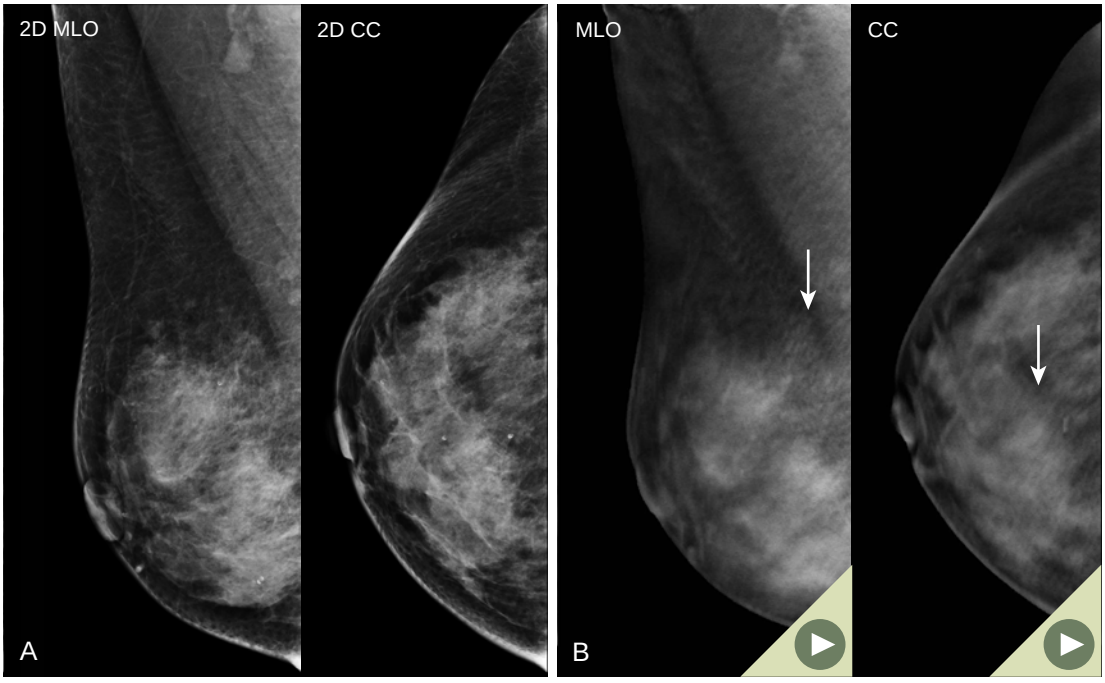


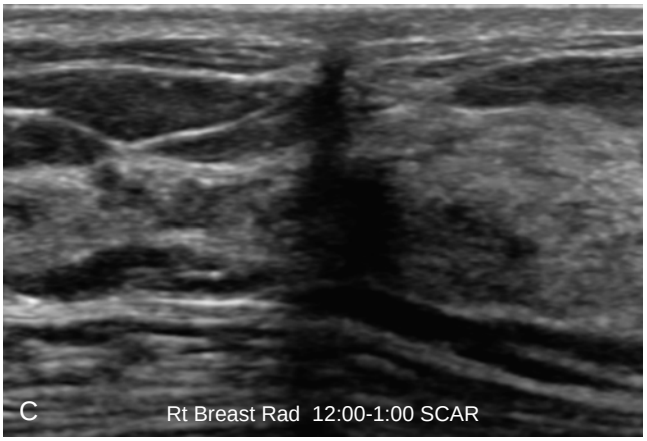
CASE STUDY 11.5 (A) A 62-year-old woman presented for mammography prior to stem cell transplant for acute lymphocytic leukemia. No prior mammograms were available. Left MLO and laterally exaggerated CC views reveal a focal asymmetry in the posterior depth, 3-o'clock position. **(B)** Targeted ultrasound reveals an ill-defined hypoechoic mass with indistinct margins at the 3-o'clock position. A BB was placed on the overlying skin. **(C)** Spot (2D) views in the MLO and XCC reveal a small spiculated mass at the 3-o'clock position in the left breast that corresponds to the sonographic finding. **(D)** ▶▶ Tomosynthesis movie series in the spot MLO and CC projections show a spiculated mass. **Diagnosis: Ultrasound-guided core biopsy revealed focal atypical apocrine adenosis involving a complex sclerosing lesion confirmed at surgical excision.**



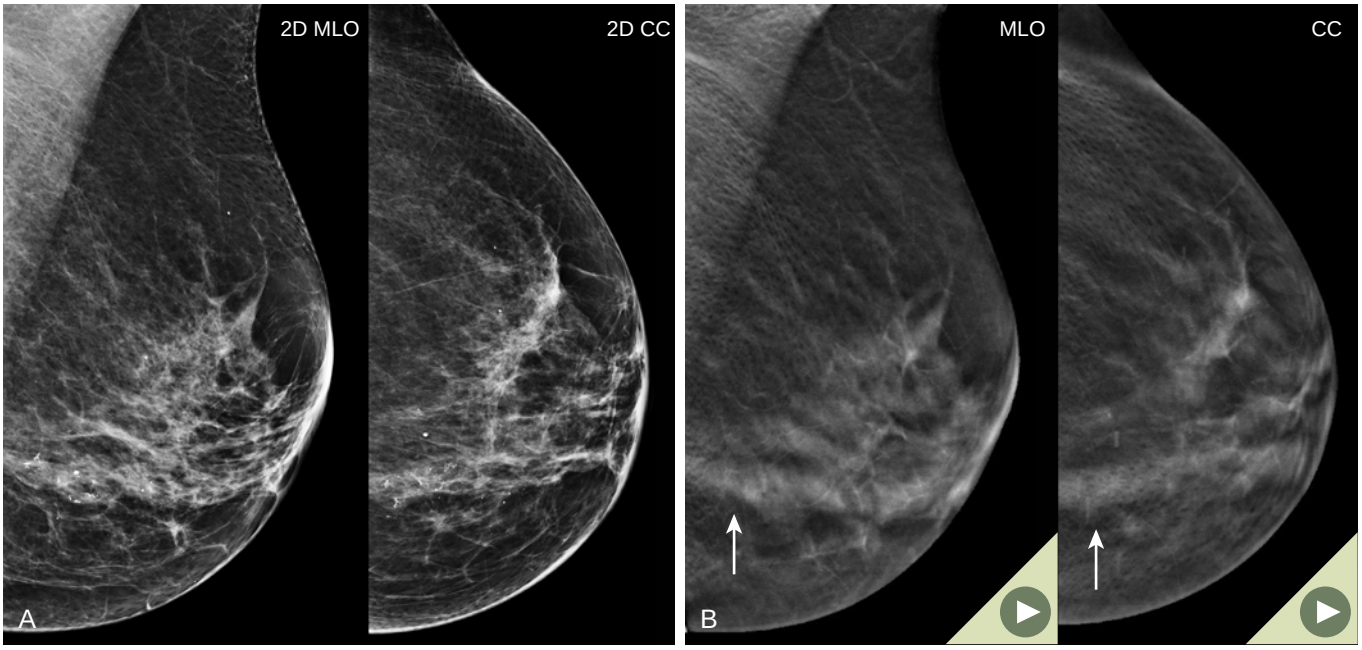
Chapter 12

CASE STUDY 12.1 (A) MLO and CC views 7 years following excision of a benign fibroadenoma are unremarkable. **(B)** ▶▶ However, with tomosynthesis a definite irregular scar is visible at the 12-o'clock position *(arrows)*. **(C)** Ultrasound shows a hypoechoic region with posterior acoustic shadowing extending to the skin. **Diagnosis: Benign scar detected on tomosynthesis and confirmed with ultrasound.**

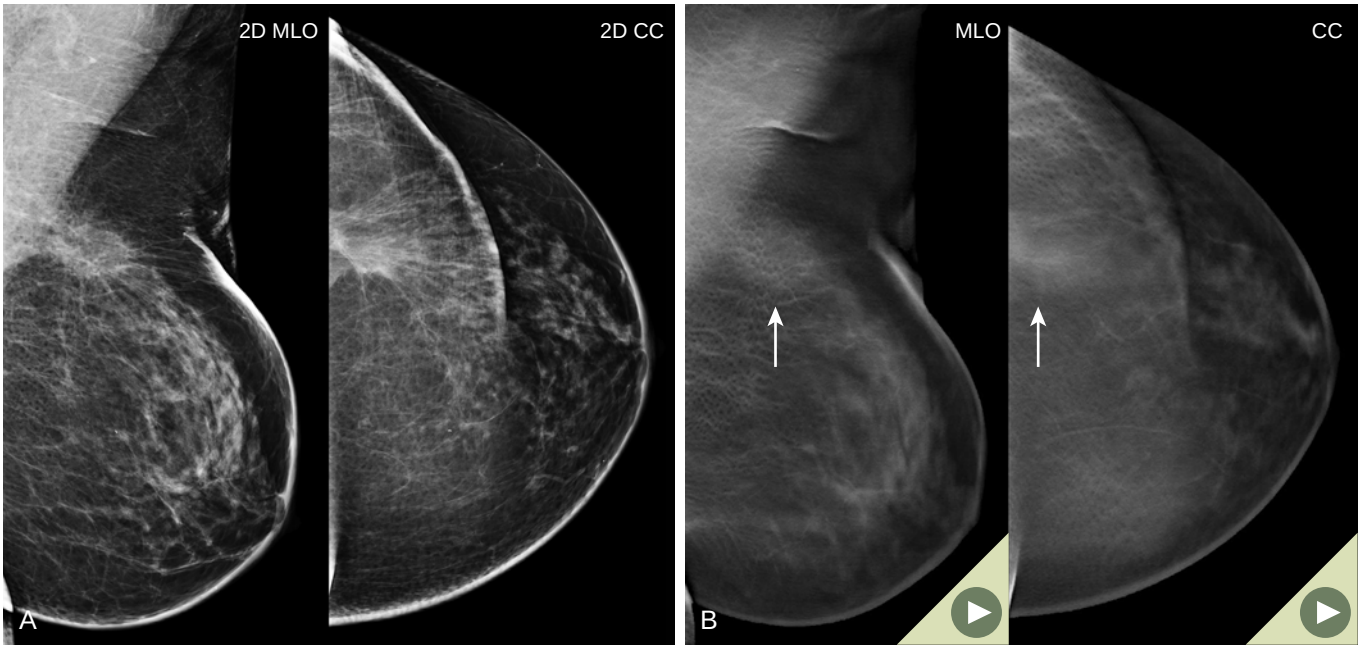




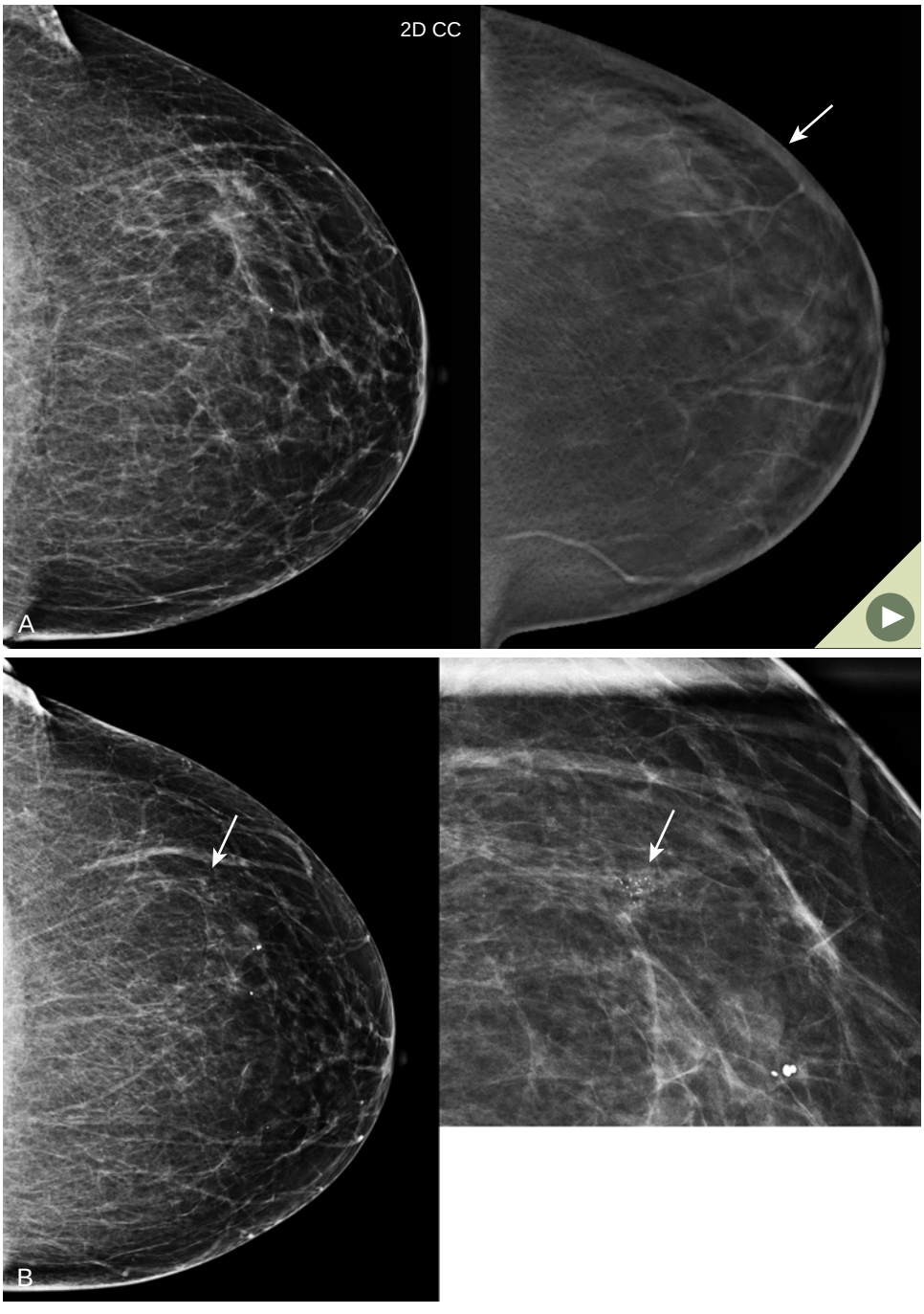
CASE STUDY 12.2 (A) Lower inner quadrant calcifications are present in a 75-year-old woman 20 years following ipsilateral mastopexy and contralateral mastectomy. **(B)** ▶ ▶ Tomosynthesis clearly shows benign calcified oil cysts associated with a long-standing surgical scar that extends from the nipple toward the chest wall *(arrows)*. **Diagnosis: benign calcified oil cysts.**



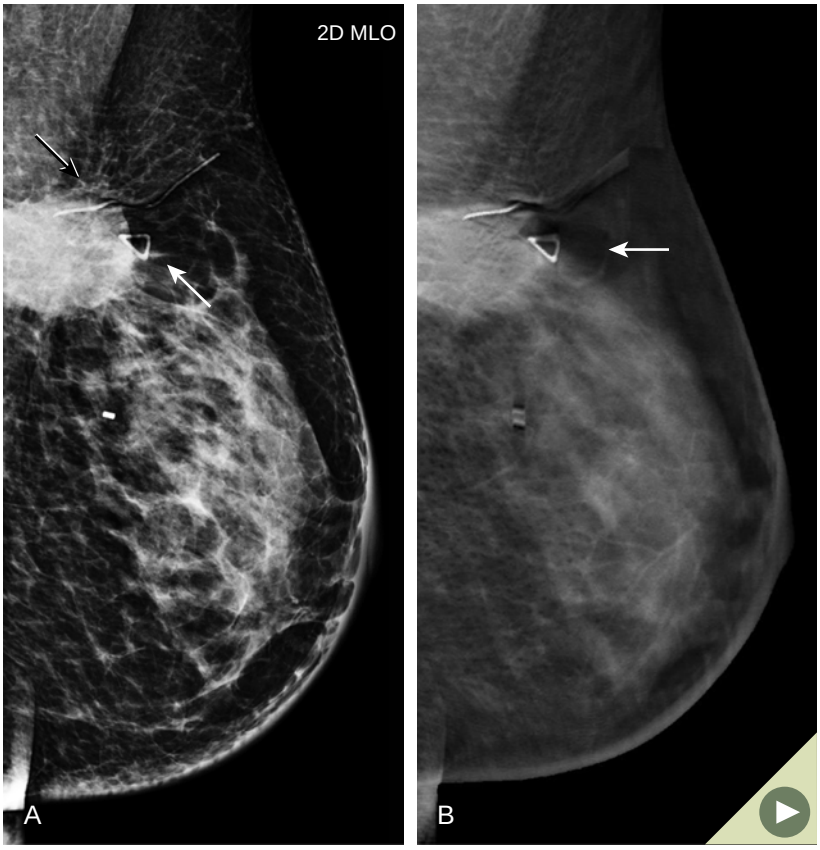
CASE STUDY 12.3 (A) Two years after treatment for stage IA invasive ductal carcinoma, there is a focal scar in the upper outer quadrant. **(B)** ▶ ▶ Tomosynthesis better shows the mixed density scar, surrounding spiculations, small adjacent oil cysts, and dystrophic calcifications, which are otherwise obscured by overlapping tissue. **Conclusion: Common postoperative findings.**

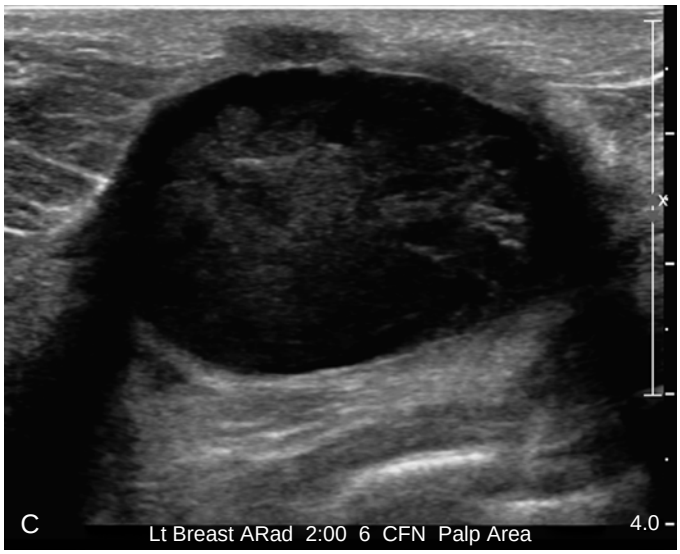


CASE STUDY 12.4 (A) A subtle asymmetry is present in the lateral breast. Better seen with tomosynthesis is the associated architectural distortion *(arrow)*. **(B)** Comparison images from 1 year earlier show grouped calcifications diagnosed as 6-mm grade 3 DCIS *(arrows)*. The follow-up mammogram is consistent with post-treatment change. Note the absence of lumpectomy clips and little apparent skin and trabecular thickening from the radiation. **Conclusion: When interpreting tomosynthesis, the history of any prior breast biopsies or surgery is necessary, as scars are usually well visualized.**

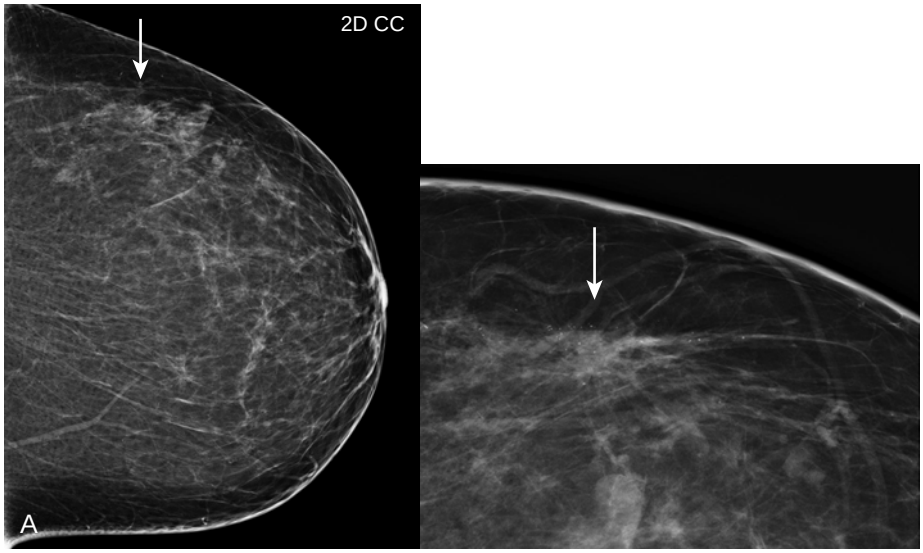


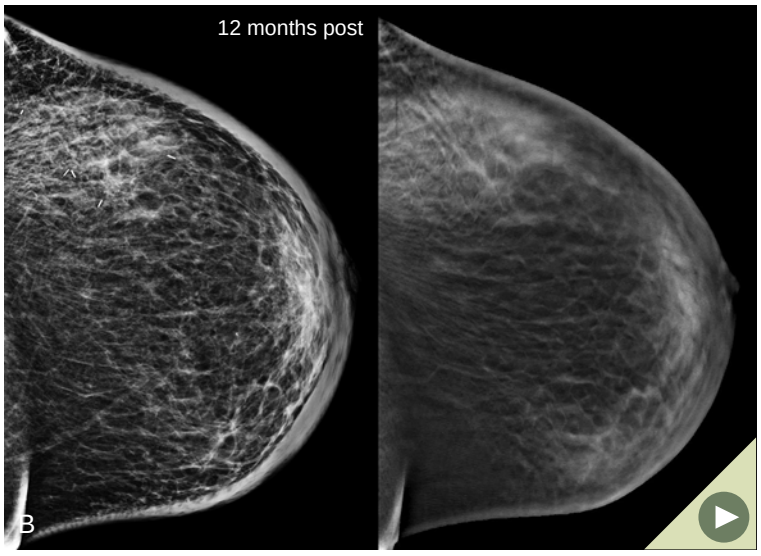
CASE STUDY 12.5 One year following lumpectomy and whole-breast radiation for invasive ductal carcinoma stage IIA, a 54-year-old woman reports a painful palpable lump at the operative site. **(A)** A 3-cm oval mass in the upper breast corresponds to the palpable finding *(triangular skin marker, white arrow)* and the lumpectomy site *(linear skin marker, black arrow)*. **(B)** ▶ The circumscribed margins and surrounding scar are well seen with tomosynthesis *(arrow)*. **(C)** Targeted ultrasound shows an oval complex cystic mass. Aspiration was performed at the patient's request and retrieved degenerated blood. **Conclusion: The finding is consistent with post-treatment seroma or hematoma and appears benign.**

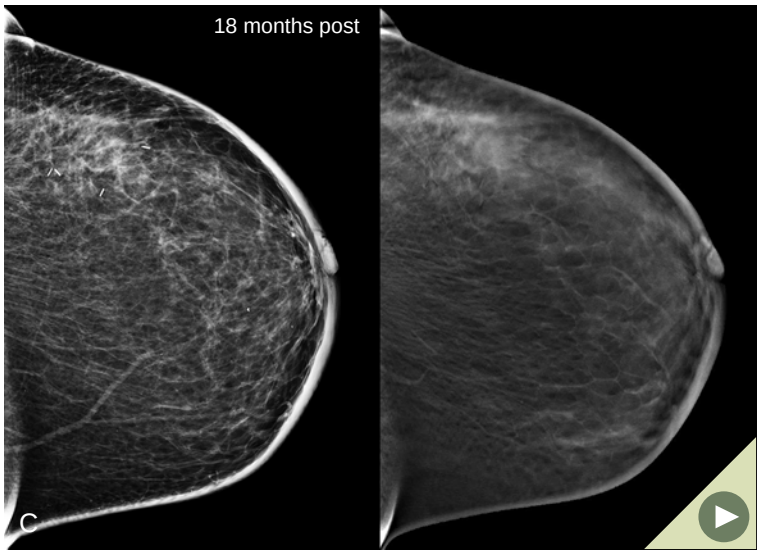




CASE STUDY 12.6 (A) A 54-year-old woman presents with suspicious calcifications and an irregular mass in the lateral breast, secondary to invasive lobular carcinoma ER/PR+, Her2–, stage IIA *(arrow)*. **(B)** ▶ Tomosynthesis 12 months following partial mastectomy and whole-breast radiation demonstrates marked skin and trabecular thickening, as well as focal asymmetry with associated distortion at the operative site. Surgical clips are present. **(C)** ▶ At 18 months, the post-treatment changes have diminished. **Conclusion: Normal progression of postoperative changes.**

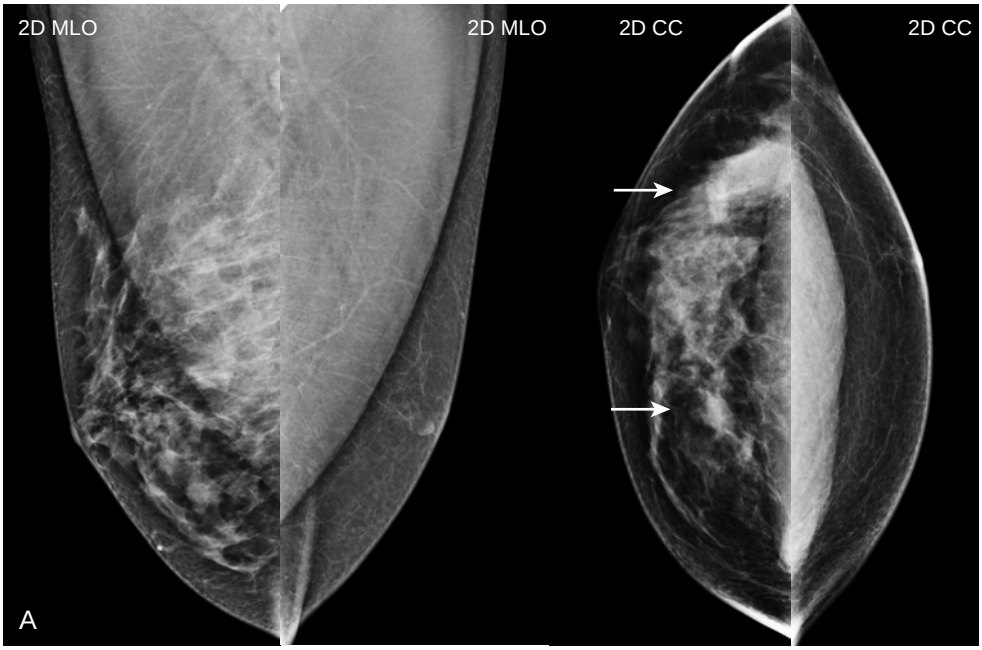


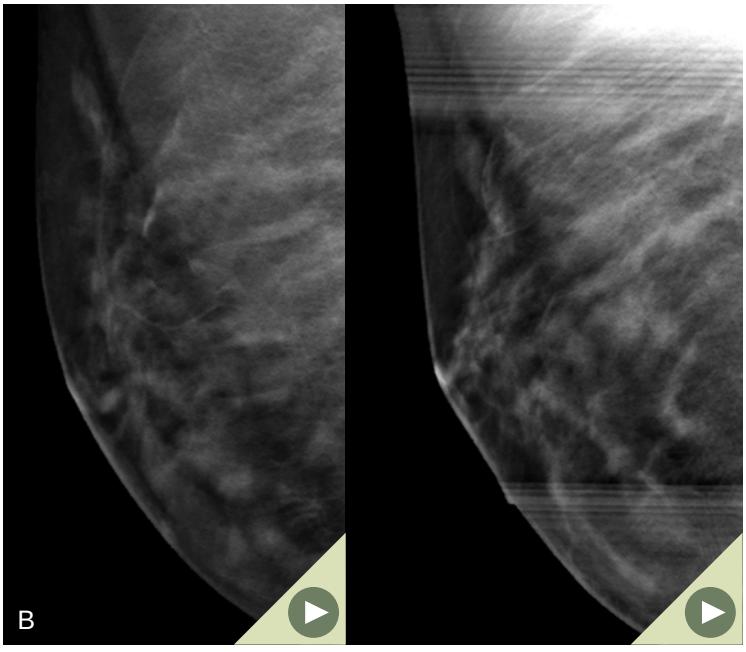




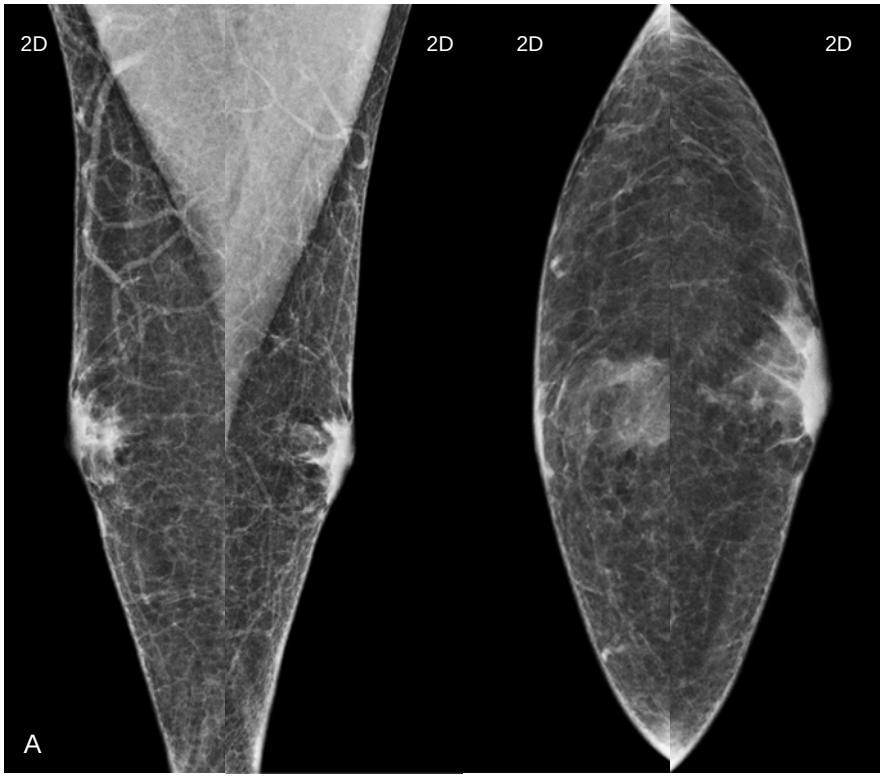
Chapter 13

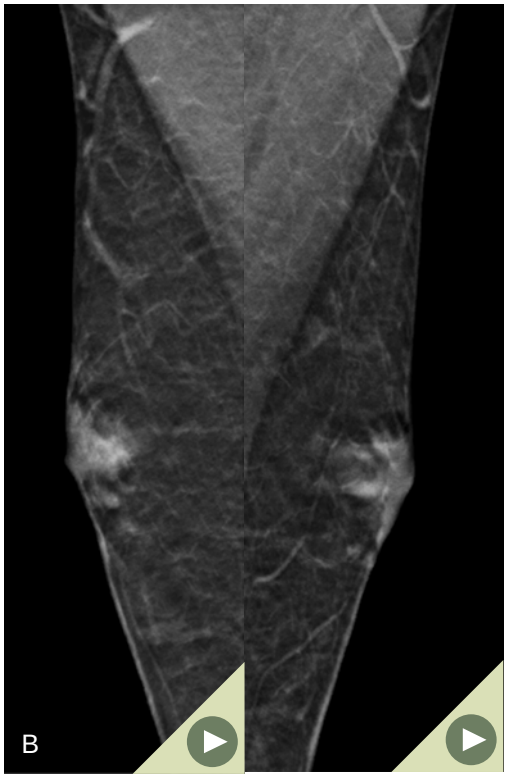
CASE STUDY 13.1 A 29-year-old man presents with swelling of the right breast. Marked gynecomastia is noted in the right breast only. **(A)** Focal asymmetries noted on the CC view appear *(arrows)* to be superimposed tissue on the tomosynthesis slice image. **(B)** ▶▶ Spot tomosynthesis images in the MLO and XCC projections confirm the presence of normal tissue and no underlying mass. Ultrasound is unnecessary in such a case. **Diagnosis: Normal tissue.**



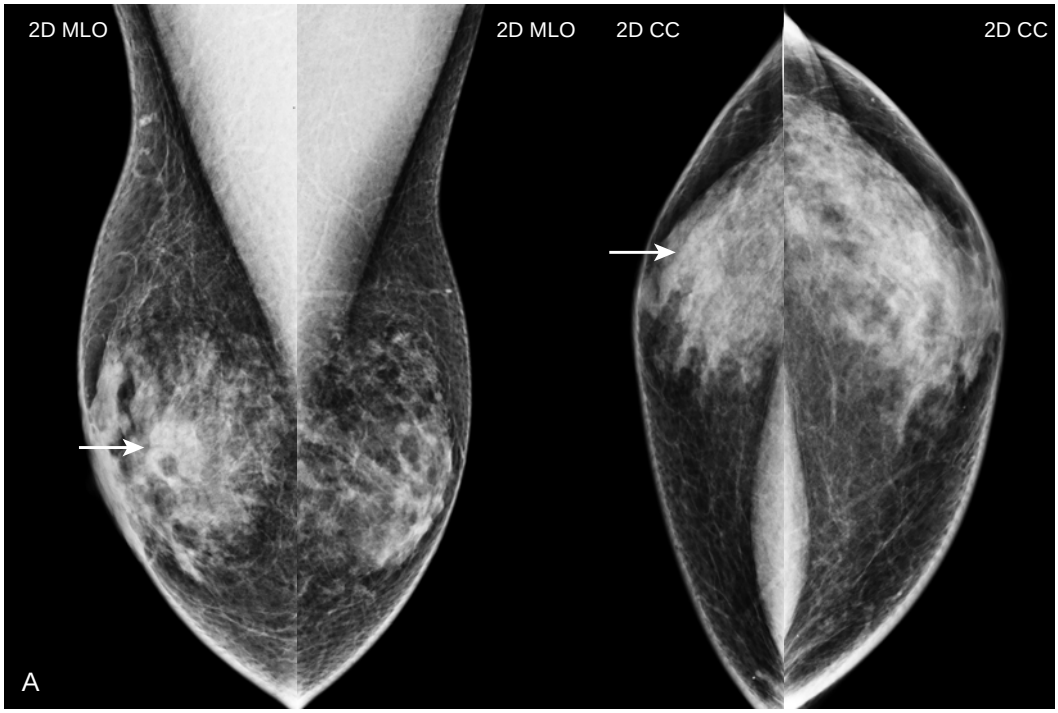


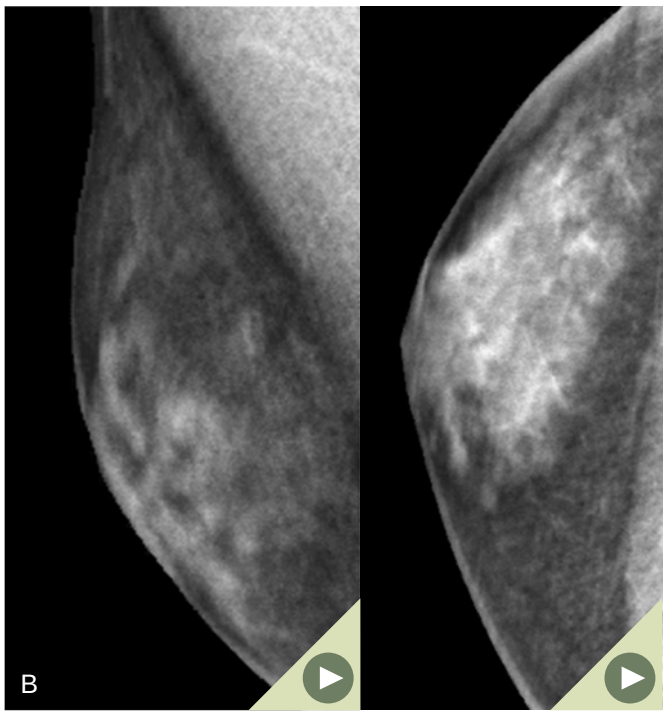
CASE STUDY 13.2 A 32-year-old man presented with breast pain and bilateral milky discharge. **(A)** Nodular gynecomastia is noted bilaterally. **(B)** ▶ ▶ Tomosynthesis images in the MLO projection of both breasts demonstrate mixed fatty and fibroglandular tissue characteristic of gynecomastia. **Diagnosis: Gynecomastia.**



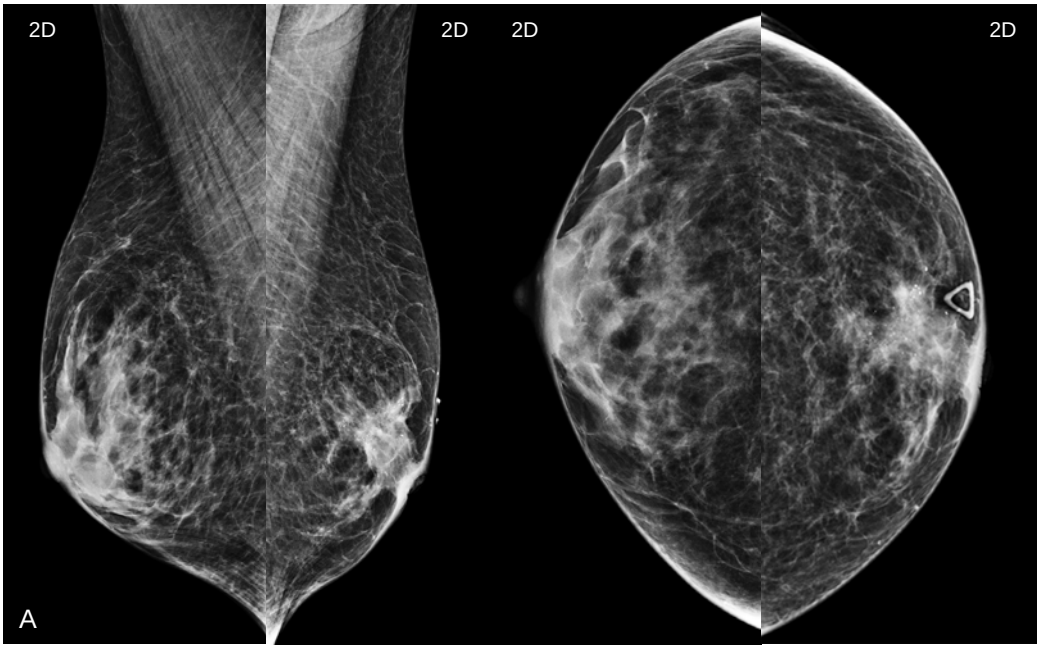


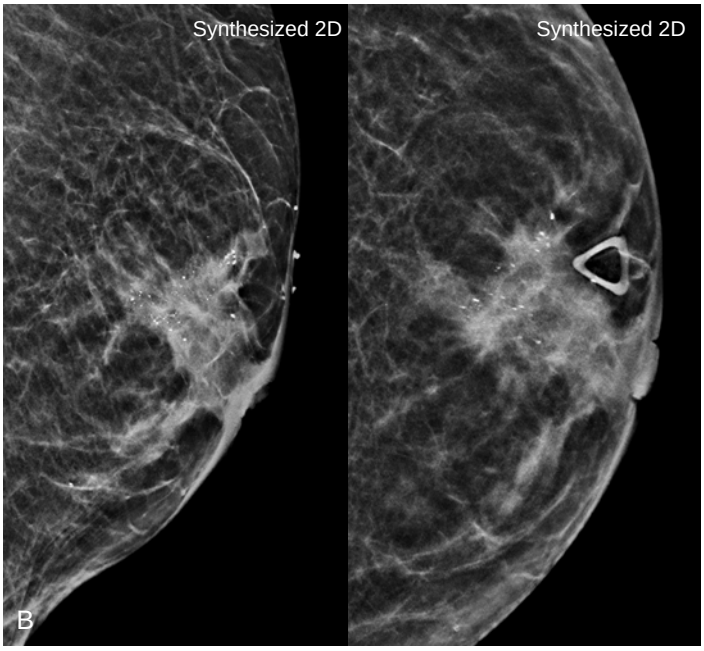
CASE STUDY 13.3 A 58-year-old man with multiple medical issues (including alcoholic cirrhosis, hepatosplenomagaly, cardiomyopathy, and latent tuberculosis) presents with left breast pain. **(A)** 2D images reveal extensive bilateral gynecomastia. Focal areas of asymmetry are noted in the right breast *(arrows)*. **(B)** ▶ ▶ MLO and CC tomosynthesis images reveal dense glandular tissue that superimposes on the 2D image to form the asymmetries. **Diagnosis: Bilateral gynecomastia.**

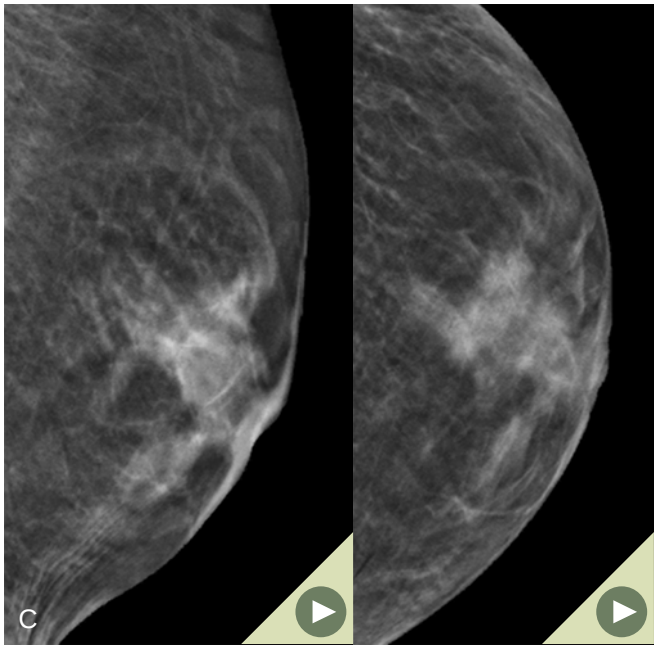


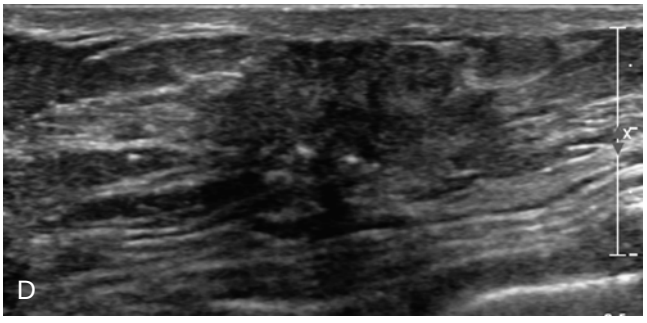


CASE STUDY 13.4 An 80-year-old man undergoing treatment for metastatic prostate cancer presents with left breast tenderness. **(A)** 2D mammography shows diffuse gynecomastia in both breasts. A 2.5-cm irregular mass with heterogeneous calcifications is noted in the left 1-o'clock region associated with mild nipple retraction. **(B)** Synthesized 2D CC views depict the irregular shape, spiculations, and associated calcifications. **(C)** ▶ ▶ Tomosynthesis images permit full assessment of the suspicious mass. **(D)** Ultrasound shows a large irregular mass with internal calcifications, highly suspicious for malignancy. **Diagnosis: Biopsy revealed well-differentiated invasive ductal carcinoma, ER/AR+, PR–, Her2-.**









Selected Readings

Alakhras MM, Brennan PC, Rickard M, Bourne R, Mello-Thoms C. Effect of radiologists' experience on breast cancer detection and localization using digital breast tomosynthesis. *Eur Radiol*. 2015;25(2):402–409.

Allen LR, Lago-Toro CE, Hughes JH, et al. Is there a role for MRI in the preoperative assessment of patients with DCIS? *Ann Surg Oncol*. 2010;17(9):2395–2400.

American Cancer Society. *Cancer Facts & Figures 2015*. Atlanta, GA: American Cancer Society; 2015.

Andersson I, Ikeda DM, Zackrisson S, et al. Breast tomosynthesis and digital mammography: a comparison of breast cancer visibility and BIRADS classification in a population of cancers with subtle mammographic findings. *Eur Radiol*. 2008;18(12):2817–2825.

Andersson I, Rosso A, Tingberg A, Timberg P, Zackrisson S. Performance of one-view breast tomosynthesis as a stand-alone breast cancer screening modality: results from the Malmo Breast Tomosynthesis Screening Trial, a population-based study. *Eur Radiol*. 2016;26(1):184–190.

Anello MI, Cohen CS, Ganott MA, et al. Impact of and interaction between the availability of prior examinations and DBT on the interpretation of negative and benign mammograms. *Acad Radiol*. 2014;21(4):445–449.

Appelbaum AH, Evans GF, Levy KR, Amirkhan RH, Schumpert TD. Mammographic appearances of male breast disease. *Radiographics*. 1999;19(3):559–568.

Arasu VA, Joe BN, Lvoff NM, et al. Benefit of semiannual ipsilateral mammographic surveillance following breast conservation therapy. *Radiology*. 2012;264(2):371–377.

Barry-Brooks M, Baird GL, Tuttle A, Mainiero MB. Changes in recall type and patient treatment following implementation of screening digital breast tomosynthesis. *Radiology*. 2015;274(2):337–342.

Berg W, Yang WT. *Diagnostic Imaging Breast*. 2nd ed. Canada: Amirsys; 2013.

Berg WA, Blume JD, Cormack JB, et al. Combined screening with ultrasound and mammography vs mammography alone in women at elevated risk of breast cancer: results of the first year screen in ACRIN 6666. *J Am Med Assoc.* 2008;299(18):2151–2163.

Berg WA, Yang WT. *Diagnostic Imaging. Architectural Distortion*. Amirsys; 2013;4:152–157.

Berg WA, Zhang Z, Cormack JB, Mendelson EB. Multiple bilateral circumscribed masses at screening breast US: consider annual follow-up. *Radiology*. 2013;268:673–683.

Berg WA, Zhang Z, Lehrer D, et al. Detection of breast cancer with addition of annual screening ultrasound or a single screening MRI to mammography in women with elevated breast cancer risk. *J Am Med Assoc.* 2012;307(13):1394–1404.

Bernard Jr JR, Vallow LA, DePeri ER, et al. In newly diagnosed breast cancer, screening MRI of the contralateral breast detects mammographically occult cancer, even in elderly women: the mayo clinic in Florida experience. *Breast J*. 2010;16(2):118–126.

Bernardi D, Caumo F, Macaskill P, et al. Effect of integrating 3D-mammography (digital breast tomosynthesis) with 2D-mammography on radiologists' true-positive and false-positive detection in a population breast screening trial. *Eur J Cancer*. 2014;50(7):1232–1238.

Bernardi D, Ciatto S, Macaskill P, et al. Incremental effect from integrating 3D-mammography (tomosynthesis) with 2D-mammography: Increased breast cancer detection evident for screening centres in a population-based trial. *Breast*. 2013;23(1):76–80.

Bernardi D, Ciatto S, Pellegrini M, et al. Application of breast tomosynthesis in screening: incremental effect on mammography acquisition and reading time. *Br J Radiol*. 2012;85:e1174–e1178.

Bernardi D, Ciatto S, Pellegrini M, et al. Prospective study of breast tomosynthesis as a triage to assessment in screening. *Breast Cancer Res Treat*. 2012;133(1):267–271.

Bernardi D, Macaskill P, Pellegrini M, et al. Breast cancer screening with tomosynthesis (3D mammography) with acquired or synthetic 2D mammography compared with 2D mammography alone (STORM-2): a population-based prospective study. *Lancet Oncol*. 2016;17(8):1105–1113.

Bian T, Lin Q, Cui C, et al. Digital breast tomosynthesis: a new diagnostic method for mass-like lesions in dense breasts. *Breast J*. 2016;22(5):535–540.

Brandt KR, Craig DA, Hoskins TL, et al. Can digital breast tomosynthesis replace conventional diagnostic mammography views for screening recalls without calcifications? A comparison study in a simulated clinical setting. *AJR Am J Roentgenol*. 2013;200(2):291–298.

Brennan PC, Rickard M, Bourne R, Mello-Thoms C. Effect of radiologists' experience on breast cancer detection and localization using digital breast tomosynthesis. *Eur Radiol*. 2014;25(2):402–409.

Brenner RJ, Jackman RJ, Parker SH, et al. Percutaneous core needle biopsy of radial scars of the breast: when is excision necessary? *AJR Am J Roentgenol*. 2002;179(5):1179–1184.

Burrell H, Evans A, Wilson A, Pinder S. False negative breast screening assessment: what lessons can we learn? *Clin Radiol*. 2001;56:385–388.

Butler RS, Duarte MP, Andrejeva L, Hooley RJ, Horvath LJ, Philpotts LE. *Comparison of Tomosynthesis versus 2D Spot Compression Views in the Assessment of Malignant Lesions*. Washington, DC: American Roentgen Ray Society Annual Meeting; 2013.

Butler RS, Hui A, Staib LH, Hooley RJ, Philpotts LE. *Downstream Effect of Tomosynthesis Screening—A More Efficient Diagnostic Work-Up of Screening Recalls*. Chicago, IL: RSNA Annual Meeting; 2012.

Butler RS, Venta LA, Wiley EL, Ellis RL, Dempsey PJ, Rubin E. Sonographic evaluation of infiltrating lobular carcinoma. *AJR Am J Roentgenol*. 1999;172(2):325–330.

Carbonaro LA, Di Leo G, Clauser P, et al. Impact on the recall rate of digital breast tomosynthesis as an adjunct to digital mammography in the screening setting. A double reading experience and review of the literature. *Eur J Radiol*. 2016;85(4):808–814.

Caumo F, Bernardi D, Ciatto S, et al. Incremental effect from integrating 3D-mammography (tomosynthesis) with 2D-mammography: Increased breast cancer detection evident for screening centres in a population-based trial. *Breast*. 2014;23(1):76–80.

Chae EY, Kim HH, Cha JH, Shin HJ, Choi WJ. Detection and characterization of breast lesions in a selective diagnostic population: diagnostic accuracy study for comparison between one-view digital breast tomosynthesis and two-view full-field digital mammography. *Br J Radiol*. 2016;89(1062):20150743.

Chan HP, Goodsitt MM, Helvie MA, et al. Digital breast tomosynthesis: observer performance of clustered microcalcification detection on breast phantom images acquired with an experimental system using variable scan angles, angular increments, and number of projection views. *Radiology*. 2014;273(3):675–685.

Chen C, Durand M, Butler R, Flynn C, Tavassoli F, Philpotts L. *Comparability of Digital Breast Tomosynthesis with Conventional Mammography, Ultrasonography and MRI for Tumor Measurement*. Chicago, IL: RSNA Annual Meeting; 2012.

Chen L, Chantra PK, Larsen LH, et al. Imaging characteristics of malignant lesions of the male breast. *RadioGraphics*. 2006;26(4):993–1006.

Chen PH, Slanetz PJ. Incremental clinical value of ultrasound in men with mammographically confirmed gynecomastia. *Eur J Radiol*. 2014;83:123–129.

Choi JS, Han BK, Ko EY, et al. Comparison between two-dimensional synthetic mammography reconstructed from digital breast tomosynthesis and full-field digital mammography for the detection of T1 breast cancer. *Eur Radiol*. 2016;26(8):2538–2546.

Ciatto S, Houssami N, Bernardi D, et al. Integration of 3D digital mammography with tomosynthesis for population breast-cancer screening (STORM): a prospective comparison study. *Lancet Oncol*. 2013;14:583–589.

Clauser P, Carbonaro LA, Pancot M, et al. Additional findings at preoperative breast MRI: the value of second-look digital breast tomosynthesis. *Eur Radiol*. 2015;25(10):2830–2839.

Conant EF. Clinical implementation of digital breast tomosynthesis. *Radiol Clin North Am.* 2014;52:499–518.

Conant EF, Beaber EF, Sprague BL, et al. Breast cancer screening using tomosynthesis in combination with digital mammography compared to digital mammography alone: a cohort study within the PROSPR consortium. *Breast Cancer Res Treat*. 2016;156(1):109–116.

Dang PA, Freer PE, Humphrey KL, Halpern EF, Rafferty EA. Addition of tomosynthesis to conventional digital mammography: effect on image interpretation time of screening examinations. *Radiology*. 2014;270(1):49–56.

Destounis S, Arieno A, Morgan R. Initial experience with combination digital breast tomosynthesis plus full field digital mammography or full field digital mammography alone in the screening environment. *J Clin Imaging Sci.* 2014;4:9.

Destounis S, Arieno A, Morgan R. Preliminary clinical experience with digital breast tomosynthesis in the visualization of breast microcalcifications. *J Clin Imaging Sci.* 2013;3:65.

Dominguez A, Durando M, Mariscotti G, et al. Breast cancer risk associated with the diagnosis of a microhistological radial scar (RS): retrospective analysis in 10 years of experience. *Radiol Med*. 2015;120(4):377–385.

D'Orsi CJ, Sickles EA, Mendelson EB, et al. *ACR BI-RADS® Atlas, Breast Imaging Reporting and Data System*. Reston, VA: American College of Radiology; 2013.

Doyle EM, Banville N, Quinn CM. Radial scars/complex sclerosing lesions and malignancy in a screening programme: incidence and histological features revisited. *Histopathology*. 2007;50(5):607–614.

Drukteinis JS, Gombos EC, Raza S, Chikarmane SA, Swami A, Birdwell RL. MRI imaging assessment after breast conservation therapy: distinguishing benign from malignant lesions. *Radiographics*. 2012;32(1):219–234.

Durand MA, Haas BM, Yao X, et al. Early clinical experience with digital breast tomosynthesis for screening mammography. *Radiology*. 2015;274(1):85–92.

Durand MA, Hooley RJ, Raghu M, et al. Effect of experience on tomosynthesis screening recall patterns: is there a learning curve? *RSNA*. 2014. [abstract]. Radiological Society of North America 2014 Scientific Assembly and Annual Meeting, Nov 30, 2014 to Dec 5, 2014, Chicago.

Durand MA, Wang S, Hooley RJ, Raghu M, Philpotts LE. Tomosynthesis-detected architectural distortion: management algorithm with radiologic-pathologic correlation. *Radiographics*. 2016;36(2):311–321.

Fornvik D, Zackrisson S, Ljungberg O, et al. Breast tomosynthesis: accuracy of tumor measurement compared with digital mammography and ultrasonography. *Acta Radiol*. 2010;51(3):240–247.

Freer PE, Niell B, Rafferty EA. Preoperative tomosynthesis-guided needle localization of mammographically and sonographically occult breast lesions. *Radiology*. 2015;275(2):377–383.

Freer PE, Wang JL, Rafferty EA. Digital breast tomosynthesis in the analysis of fat-containing lesions. *Radiographics*. 2014;34(2):343–358.

Friedewald SM, Rafferty EA, Rose SL, et al. Breast cancer screening using tomosynthesis in combination with digital mammography. *J Am Med Assoc.* 2014;311(24):2499–2507.

Gennaro G, Toledano A, di Maggio C, et al. Digital breast tomosynthesis versus digital mammography: a clinical performance study. *Eur Radiol*. 2010;20:1545–1553.

Gilbert FJ, Tucker L, Gillan MGC, et al. Accuracy of digital breast tomosynthesis for depicting breats cancer subgroups in a UK retrospective reading study (TOMMY Trial). *Radiology*. 2015;277(3):697–706.

Good WF, Abrams GS, Catullo VJ, et al. Digital breast tomosynthesis: a pilot observer study. *AJR Am J Roentgenol*. 2008;190:865–869.

Greenberg JS, Javitt MC, Katzen J, Michael S, Holland AE. Clincal performance metrics of 3D digital breast tomosynthesis compared with 2D digital mammography for breast cancer screening in community practice. *AJR Am J Roentgenol*. 2014;203:687–693.

Gur D, Abrams G, Chough D, et al. Digital breast tomosynthesis: observer performance study. *AJR Am J Roentgenol*. 2009;193(2):586–591.

Gur D, Bandos AI, Rockette HE, Sumkin JH, Chough DM, Hakim CM. Localized detection and classification of abnormalities on FFDM and tomosynthesis examinations rated under an FROC paradigm. *AJR Am J Roentgenol*. 2011;196:737–741.

Gur D, Zuley ML, Anello MI, et al. Dose reduction in digital breast tomosynthesis (DBT) screening using synthetically reconstructed projection images: an observer performance study. *Acad Radiol*. 2012;19:166–171.

Gur DM, Abrams GS, Chough DM, et al. Digital breast tomosynthesis: observer performance study. *AJR Am J Roentgenol*. 2009;193:586–591.

Haas BM, Kalra V, Geisel J, Raghu M, Durand M, Philpotts LE. Comparison of tomosynthesis plus digital mammography and digital mammography alone for breast cancer screening. *Radiology*. 2013;269:694–700.

Hakim C, Chough D, Ganott M, Sumkin J, Zuley M, Gur D. Digital breast tomosynthesis in the diagnostic environment: a subjective side-by-side review. *AJR Am J Roentgenol*. 2010;195(2):W172–W176.

Hakim CM, Catullo VJ, Chough DM, et al. Effect of availability of prior full-digital mammography and digital breast tomosynthesis images on the interpretation of mammograms. *Radiology*. 2015;276(1):65–72.

Hardesty L. Issues to consider before implementing digital breast tomosynthesis into a breast imaging practice. *AJR Am J Roentgenol*. 2015;204:681–684.

Hardesty LA, Kreidler SM, Glueck DH. Digital breast tomosynthesis utilization in the United States: a survey of physician members of the Society of Breast Imaging. *J Am Coll Radiol*. 2014;11:594–599.

Harish MG, Konda SD, MacMahon H, Newstead GM. Breast lesions incidentally detected with CT: what the general radiologist needs to know. *Radiographics*. 2007;27(Suppl):S37–S51.

Hooley RJ, Greenberg KL, Stackhouse RM, Geisel JL, Butler RS, Philpotts LE. Screening US in patients with mammographically dense breasts: initial experience with Connecticut Public Act 09-41. *Radiology*. 2012;265(1):59–69.

Houssami N, Skaane P. Overview of the evidence on digital breast tomosynthesis in breast cancer detection. *Breast.* 2013;22(2):101–108.

Houssami N, Turner R, Morrow M. Preoperative magnetic resonance imaging in breast cancer: meta-analysis of surgical outcomes. *Ann Surg*. 2013;257(2):249–255.

Ibrahim NB, Anandan S, Hartman AL, et al. Radiographic findings after treatment with balloon brachytherapy accelerated partial breast irradiation. *Radiographics*. 2015;35(1):6–13.

Ikeda DM, Andersson I. Ductal carcinoma in situ: atypical mammographic appearances. *Radiology*. 1989;172(3):661–666.

Iuanow E, Kettler M, Slanetz PJ. Spectrum of disease in the male breast. *AJR Am J Roentgenol*. 2011;196(3):W247–W259.

Kim WH, Chang JM, Moon HG, et al. Comparison of the diagnostic performance of digital breast tomosynthesis and magnetic resonance imaging added to digital mammography in women with known breast cancers. *Eur Radiol*. 2016;26(6):1556–1564.

Knutzen AM, Gisvold JJ. Likelihood of malignant disease for various categories of mammographically detected, nonpalpable breast lesions. *Mayo Clin Proc.* 1993;68:454–460.

Kolb TM, Lichy J, Newhouse JH. Comparison of the performance of screening mammography, physical examination, and breast US and evaluation of factors that influence them: an analysis of 27,285 patient evaluations. *Radiology*. 2002;225(1):163–175.

Kopans D. Digital breast tomosynthesis from concept to clinical care. *AJR Am J Roentgenol.* 2014;202(2):299–308.

Kopans D, Gavenonis S, Halpern E, Moore R. Calcifications in the breast and digital breast tomosynthesis. *Breast J*. 2011;17(6):638–644.

Lakshmaiah KC, Kumar AN, Purohit S, et al. Neurofibromatosis type I with breast cancer: not only for women! *Hered Cancer Clin Pract*. 2014;12(1):5.

Lang K, Bernardi D, Tagliafico A, Zackrisson S, Skaane P. Digital breast tomosynthesis (3D-mammography) screening: A pictorial review of screen-detected cancers and false recalls attributed to tomosynthesis in prospective screening trials. *Breast*. 2016;26:119–134.

Lang K, Nergarden M, Andersson I, Rosso A, Zackrisson S. False positives in breast cancer screening with one-view breast tomosynthesis: An analysis of findings leading to recall, work-up and biopsy rates in the Malmo Breast Tomosynthesis Screening Trial. *Eur Radio*. 2016 Mar 4. [Epub ahead of print].

Lee CI, Lehman CD. Digital breast tomosynthesis and the challenges of implementing an emerging breast cancer screening technology into clinical practice. *J Am Coll Radiol*. 2013;10:913–917.

Lehman CD, Gatsonis C, Kuhl CK, et al. MRI evaluation of the contralateral breast in women with recently diagnosed breast cancer. *N Engl J Med*. 2007;356:1295–1303.

Lei JY, Zhang J, Wang L, Yinzhong Yang K. Diagnostic accuracy of digital breast tomosynthesis versus digital mammography for benign and malignant lesions in breasts: a meta-analysis. *Eur Radiol*. 2013;24(3):595–602.

Leung JW, Sickles EA. Multiple bilateral masses detected on screening mammography: assessment of need for recall imaging. *AJR Am J Roentgenol*. 2000;175(1):23–29.

Li L, Chen Y, Chen J, et al. Complications in breast surgery. *Surg Clin North Am*. 2007;87(2):431–451.

Lourenco AP, Barry-Brooks M, Baird GL, Tuttle A, Mainiero MB. Changes in recall type and patient treatment following implementation of screening digital breast tomosynthesis. *Radiology*. 2015;274(2):337–342.

Madanikia SA, Bergner A, Ye X, Blakeley JO. Increased risk of breast cancer in women with NF1. *Am J Med Genet A*. 2012;158A:3056–3060.

Madhukar M, Chetlen A. Multimodality imaging of benign and malignant male breast disease. *Clin Radiol*. 2013;68(12):e698–e706.

Maglione KD, Margolies L, Jaffer S, et al. Breast cancer in male-to-female transsexuals: use of breast imaging for detection. *AJR Am J Roentgenol*. 2014;203(6):W735–W740.

Mann RM, Hoogeveen YL, Blickman JG, Boetes C. MRI compared to conventional diagnostic work-up in the detection and evaluation of invasive lobular carcinoma of the breast: a review of existing literature. *Breast Cancer Res Treat*. 2008;107(1):1–14.

Margolies L, Cohen A, Sonnenblick E, et al. Digital breast tomosynthesis changes management in patients seen at a tertiary care breast center. *ISRN Radiol*. 2014;2014:658929. http://dx.doi.org/10.1155/2014/658929. [eCollection 2014].

Margolis NE, Morley C, Lotfi P, et al. Update on imaging of the postsurgical breast. *Radiographics*. 2014;34(3):642–660.

Mariscotti G, Durando M, Houssami N, et al. Digital breast tomosynthesis as an adjunct to digital mammography for detecting and characterising invasive lobular cancers: a multi-reader study. *Clin Radiol*. 2016;71(9):889–895.

Mariscotti G, Houssami N, Durando M, et al. Digital breast microcalcification detection on breast phantom images acquired with an experimental system using variable scan angles, angular increments, and number of projection views. *Radiology*. 2014;273(3):675–685.

Mariscotti G, Houssami N, Durando M, et al. Digital breast tomosynthesis (DBT) to characterize MRI-detected additional lesions unidentified at targeted ultrasound in newly diagnosed breast cancer patients. *Eur Radiol*. 2015;25(9):2673–2681.

Matthew J, Perkins GH, Stephens T, Middleton LP, Yang WT. Primary breast cancer in men: clinical, imaging, and pathologic findings in 57 patients. *AJR Am J Roentgenol*. 2008;191(6):1631–1639.

McDonald ES, McCarthy AM, Aktar AL, Synnestvedt MB, Schnall M, Conant EF. Baseline screening mammography: performance of full-field digital mammography versus digital breast tomosynthesis. *AJR Am J Roentgenol*. 2015;205:1143–1148.

McDonald ES, Oustimov A, Weinstein SP, Synnestvedt MB, Schnall M, Conant EF. Effectiveness of digital breast tomosynthesis compared with digital mammography: outcomes analysis from 3 years of breast cancer screening. *JAMA Oncol*. 2016;2(6):737–743.

Morra L, Sacchetto D, Durando M, et al. Breast cancer: computer-aided detection with digital breast tomosynthesis. *Radiology*. 2015;277(1):56–63.

Mun HS, Kim HH, Shin HJ, et al. Assessment of extent of breast cancer: comparison between digital breast tomosynthesis and full-field digital mammography. *Clin Radiol*. 2013;68(12):1254–1259.

Narin O, Levesque P, Andrejeva-Wright A, et al. *Detailed Analysis of Breast Cancer Appearance on Tomosynthesis: Correlation with Molecular Profile*. Chicago, IL: RSNA Annual Meeting; 2015.

Nguyen C, Kettler MD, Swirsky ME, et al. Male breast disease: pictorial review with radiologic-pathologic correlation. *RadioGraphics*. 2013;33:763–779.

Niklason L, Christian B, Niklason L, et al. Digital tomosynthesis in breast imaging. *Radiology*. 1997;205(2):399–406.

Nori J, Meattini I, Giannotti E, et al. Role of preoperative breast MRI in ductal carcinoma in situ for prediction of the presence and assessment of the extent of occult invasive component. *Breast J*. 2014;20(3):243–248.

Noroozian M, Hadjiiski L, Rahnama-Modhadam S, et al. Digital breast tomosynthesis is comparable to mammographic spot views for mass characterization. *Radiology*. 2012;262(1):61–68.

Ojeda-Fournier H, Olson LK, Rochelle M, Hodgens BD, Tong E, Yashar CM. Accelerated partial breast irradiation and posttreatment imaging evaluation. *Radiographics*. 2011;31(6):1701–1716.

Park JM, Franken EA, Garg M, Fajardo LL, Niklason LT. Breast tomosynthesis: present considerations and future applications. *Radiographics*. 2007;27:S231–S240.

Partyka L, Lourenco AP, Mainiero MB. Detection of mammographically occult architectural distortion on digital breast tomosynthesis screening: initial clinical experience. *AJR Am J Roentgenol*. 2014;203(1):216–222.

Peppard HR, Nicholson BE, Rochman CM, Merchant JK, Mayo RC, Harvey JA. Digital breast tomosynthesis in the diagnostic setting: indications and clinical applications. *Radiographics*. 2015;35(4):975–990.

Phillips J, Fein-Zachary VJ, Mehta TS, Littlehale N, Venkataraman S, Slanetz PJ. Breast imaging in the transgender patient. *AJR Am J Roentgenol*. 2014;202:1149–1156.

Philpotts LE, Kalra VB, Butler R, Crenshaw J. *Patient Work-up and Resource Optimization with 3D Tomosynthesis Mammography*. Chicago, IL: RSNA Annual Meeting; 2013.

Philpotts LE, Steenbergen SL, Geisel JL, et al. *Getting worked up over nothing: strategies to further reduce false positives from tomosynthesis screening mammography*. RSNA; 2014. [Electronic poster].

Pinel-Giroux FM, El Khoury MM, Trop I, Bernier C, David J, Lalonde L. Breast reconstruction review of surgical methods and imaging findings. *Radiographics*. 2013;33(2):435–453.

Pisano ED, Gatsonis C, Hendrick E, et al. Diagnostic performance of digital versus film mammography for breast-cancer screening. *N Engl J Med*. 2005;353(17):1773–1783.

Poplack S, Tosteson T, Kogel C, Nagy H. Digital breast tomosynthesis: initial experience in 98 women with abnormal digital screening mammography. *AJR Am J Roentgenol*. 2007;189(3):616–623.

Rafferty EA, Durand MA, Conant EF, et al. Breast cancer screening using tomosynthesis and digital mammography in dense and nondense breasts. *JAMA*. 2016;315(16):1784–1786.

Rafferty EA, Park JM, Philpotts LE, et al. Assessing radiologist performance using combined digital mammography and breast tomosynthesis compared with digital mammography alone: results of a multicenter, multireader trial. *Radiology*. 2013;266(1):104–113.

Raghu M, Durand MA, Andrejeva L, et al. Tomosynthesis in the diagnostic setting: changing rates of BI-RADS final assessment over time. *Radiology*. 2016;281(1):54–61.

Ravakhah K, Javadi N, Simms R. Hamartoma of the breast in a man: first case report. *Breast J*. 2001;7:266–268.

Ray KM, Turner E, Sickles EA, Joe BN. Suspicious findings at digital breast tomosynthesis occult to conventional digital mammography: imaging features and pathology findings. *Breast J*. 2015;21:538–542.

Rose SL, Tidwell AL, Bujinoch LJ, Kushwaha AC, Nordmann AS, Sexton Jr R. Implementation of breast tomosynthesis in a routine screening study: an observational study. *AJR Am J Roentgenol*. 2013;200:1401–1408.

Rose SL, Tidwell AL, Ice MF, Nordmann AS, Sexton RJ, Song R. A reader study comparing prospective tomosynthesis interpretations with retrospective readings of the corresponding FFDM examinations. *Acad Radiol*. 2014;21(9):1204–1210.

Rosso A, Lang K, Petersson IF, Zackrisson S. Factors affecting recall rate and false positive fraction in breast cancer screening with breast tomosynthesis: a statistical approach. *Breast*. 2015;24(5):680–686.

Roth RG, Maidment ADA, Weinstein SP, Roth SO, Conant EF. Digital breast tomosynthesis: lessons learned from early clinical implementation. *Radiographics*. 2014;34:E89–E102.

Schrading S, Distelmaier M, Dirrichs T, et al. Digital breast tomosynthesis-guided vacuum-assisted breast biopsy: initial experiences and comparison with prone stereotactic vacuum-assisted biopsy. *Radiology*. 2015;274(3):654–662.

Sekine K, Tsunoda-Shimizu H, Kikuchi M, Saida Y, Kawasaki T, Suzuki K. DCIS showing architectural distortion on the screening mammogram—comparison of mammographic and pathological findings. *Breast Cancer*. 2007;14(3):281–284.

Semturs F, Sturm E, Gruber R, Helbich TH. Physical aspects of different tomosynthesis systems. *Radiologe*. 2010;50(11):982–990.

Sharpe RE, Venkataraman S, Phillips J, et al. Increased cancer detection rate and variations in the recall rate resulting from implementation of 3D digital breast tomosynthesis into a population-based screening program. *Radiology*. 2016;278(3):698–706.

Sickles EA, D'Orsi CJ, Bassett LW, et al. ACR BI-RADS mammography. In: ACR BI-RADS Atlas, ed. *Breast Imaging Reporting and Data System*. Reston, VA: American College of Radiology; 2013.

Skaane P, Bandos AI, Eben EB, et al. Two-view digital breast tomosynthesis screening with synthetically reconstructed projection images: comparison with digital breast tomosynthesis with full-field digital mammographic images. *Radiology*. 2014;271(3):655–663.

Skaane P, Bandos AI, Gullien R, et al. Comparison of digital mammography alone and digital mammography plus tomosynthesis in a population-based screening program. *Radiology*. 2013;267:47–56.

Skaane P, Bandos AI, Gullien R, et al. Prospective trial comparing full-field digital mammography (FFDM) versus combined FFDM and tomosynthesis in a population-based screening programme using independent double reading with arbitration. *Eur Radiol*. 2013;23(8):2061–2071.

Skaane P, Eben EB, Jebsen IN, et al. *Trends in Time to Interpretation of Tomosynthesis Based Screening Examinations with Increasing Experience [Abstract]*. Chicago, IL: RSNA Annual Meeting; 2013.

Smith A. *Fundamentals of Breast Tomosynthesis—Improving the Performance of Mammography*. Hologic Breast Imaging White Papers; 2008.

Smith A, Sumkin J, Zuley M, et al. *Comparison of Prone Stereotactic vs. Upright Tomosynthesis Guided Vacuum Assisted Core Biopsies*. Chicago, IL: Radiological Society of North America 2013 Scientific Assembly and Annual Meeting; December 1-6, 2013.

Smith AP, Rafferty EA, Niklason L. Clinical performance of breast tomosynthesis as a function of radiologist experience level. *Digital Mammogr*. 2008;5116:61–66.

Solin LJ. Counterview: pre-operative breast MRI (magnetic resonance imaging) is not recommended for all patients with newly diagnosed breast cancer. *Breast J*. 2010;19(1):7–9.

Spangler M, Zuley M, Sumkin J, et al. Detection and classification of calcifications on digital breast tomosynthesis and 2D digital mammography: a comparison. *AJR Am J Roentgenol*. 2011;196(2):320–324.

Sumkin JH, Gannott MA, Chough DM, et al. Recall rate reduction with tomosynthesis during baseline screening examinations. *Acad Radiol*. 2015;22(12):1477–1482.

Svahn TM, Chakraborty DP, Ikeda D, et al. Breast tomosynthesis and digital mammography: a comparison of diagnostic accuracy. *Br J Radiol*. 2012;85:e1074–e1082.

Svahn TM, Houssami N, Sechopoulos I, Mattsson S. Review of radiation dose estimates in digital breast tomosynthesis relative to those in two-view full-field digital mammography. *Breast*. 2015;24(2):93–99.

Svahn TM, Macaskill P, Houssami N. Radiologist' interpretive efficiency and variability in true- and false-positive detection when screen-reading with tomosynthesis (3D mammography) relative to standard mammography in population screening. *Breast*. 2015;24(6):687–693.

Tagliafico A, Astengo D, Cavagnetto F, et al. One-to-one comparison between digital spot compression view and digital breast tomosynthesis. *Eur Radiol*. 2012;22(3):539–544.

Tagliafico A, Mariscotti G, Durando M, et al. Characterisation of microcalcification clusters on 2D digital mammography (FFDM) and digital breast tomosynthesis (DBT): does DBT underestimate microcalcification clusters? Results of a multicentre study. *Eur Radiol*. 2015;25(1):9–14.

Tagliafico AS, Calabrese M, Mariscotti G, et al. Adjunct screening with tomosynthesis or ultrasound in women with mammography-negative dense breasts: interim report of a prospective comparative trial. *J Clin Oncol*. 2016 Mar 9. [Epub ahead of print].

Teerstra HJ, Loo CE, van den Bosch M, et al. Breast tomosynthesis in clinical practice: initial results. *Eur Radiol*. 2010;20:16–24.

Tse GM, Niu Y, Shi HJ. Phyllodes tumor of the breast: an update. *Breast Cancer*. 2010;17:29–34.

Viala J, Gignier P, Perret B, et al. Stereotactic vacuum-assisted biopsies on a digital breast 3D-tomosynthesis system. *Breast J*. 2013;19(1):4–9.

Wallis MG, Moa E, Zanca F, Leifland K, Danielsson M. Two-view and single-view tomosynthesis versus full-field digital mammography: high-resolution x-ray imaging observer study. *Radiology*. 2012;262(3):788–796.

Weinstein SP, Conant EF, Orel SG, Lawton TJ, Acs G. Diabetic mastopathy in men: imaging findings in two patients. *Radiology*. 2001;219:797–799.

Yaffe MJ, Mainprize JG. Digital tomosynthesis: technique. *Radiol Clin North Am*. 2014;52(3):489–497.

Zahir MN, Minhas K, Shabbir-Moosajee M. Pleomorphic lobular carcinoma of the male breast with axillary lymph node involvement: a case report and review of literature. *BMC Clin Pathol*. 2014;14:16.

Zuley M, Bandos A, Ganott M, et al. Digital breast tomosynthesis versus supplemental diagnostic mammographic views for evaluation of noncalcified breast lesions. *Radiology*. 2013;266(1):89–95.

Zuley M, Guo B, Catullo V, et al. Comparison of two-dimensional synthesized mammograms versus original digital mammograms alone and in combination with tomosynthesis images. *Radiology*. 2014;271(3):664–671.

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