



MAKING SENSE of

Fluids and Electrolytes

A hands-on guide

Zoja Milovanovic
and Abisola Adeleye

 CRC Press
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Electrolyte

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List of abbreviations

| | |
|----------------|--|
| A&E | accident and emergency |
| AAA | abdominal aortic aneurysm |
| ABG | arterial blood gas |
| ACE | angiotensin converting enzyme |
| ADH | antidiuretic hormone |
| AF | atrial fibrillation |
| AKI | acute kidney injury |
| ALP | alkaline phosphatase |
| ALS | advanced life support |
| ALT | alanine aminotransferase |
| APTT | activated partial thromboplastin time |
| AST | aspartate aminotransferase |
| ATP | adenosine triphosphate |
| AVPU | alert, responsive to voice, responsive to pain, unresponsive |
| AXR | abdominal x-ray |
| BE | base excess |
| BMI | body mass index |
| BNF | British National formulary |
| BNP | brain natriuretic peptide |
| BP | blood pressure |
| BSA | burn surface area |
| CCF | congestive cardiac failure |
| CK | creatinine kinase |
| CKD | chronic kidney disease |
| CMV | cytomegalovirus |
| COPD | chronic obstructive pulmonary disease |
| CPAP | continuous positive airway pressure |
| CRP | c-reactive protein |
| CRT | capillary refill time |
| CT | computed tomography |
| CVP | central venous pressure |
| CXR | chest x-ray |
| Da | daltons |

| | |
|----------------|--|
| DIC | disseminated intravascular coagulation |
| DKA | diabetic ketoacidosis |
| GCS | Glasgow Coma Scale |
| EBV | Epstein-Barr virus |
| ECF | extracellular fluid |
| ECG | electrocardiogram |
| ECHO | echocardiogram |
| EF | ejection fraction |
| eGFR | estimated glomerular filtration rate |
| ERCP | endoscopic retrograde cholangiopancreatography |
| FBC | full blood count |
| FFP | fresh frozen plasma |
| G&S | group and save |
| GI | gastrointestinal |
| GORD | gastro-oesophageal reflux disease |
| GP | general practitioner |
| GTN | glyceryl trinitrate |
| Hb | haemoglobin |
| HCl | hydrochloric acid |
| HDU | high dependency unit |
| HES | hydroxyethyl starch |
| HF | heart failure |
| HLA | human leucocyte antigen |
| HPA | human platelet antigen |
| HR | heart rate |
| HRS | hepatorenal syndrome |
| HTN | hypertension |
| ICF | intracellular fluid |
| ICU | intensive care unit |
| IHD | ischaemic heart disease |
| IM | intramuscular |
| INR | international normalised ratio |
| ITU | intensive therapy unit |
| IU | international units |
| IVF | intravenous fluids |
| JVP | jugular venous pressure |
| KDIGO | kidney disease improving global outcomes |
| HIV | human immunodeficiency virus |
| LFTs | liver function tests |

LVEF left ventricular ejection fraction
MAP mean arterial pressure

| | |
|-----------------|--|
| MI | myocardial infarction |
| MONAC | morphine, oxygen, nitroglycerine, aspirin, clopidogrel |
| MRCP | magnetic retrograde cholangiopancreatography |
| MRI | magnetic resonance imaging |
| NBM | nil by mouth |
| NGT | nasogastric tube |
| NIV | non-invasive ventilation |
| NJT | nasojejunal tube |
| NICE | National Institute for Health and Clinical Excellence |
| NSAIDs | non-steroidal anti-inflammatory drugs |
| PCR | protein:creatinine ratio |
| PEA | pulseless electrical activity |
| PEG | percutaneous endoscopic gastrostomy |
| PMH | past/previous medical history |
| PND | paroxysmal nocturnal dyspnoea |
| PT | prothrombin time |
| RAS | reticular activating system |
| RAAS | renin-angiotensin-aldosterone system |
| RBC | red blood cell |
| RMP | resting membrane potential |
| RR | respiratory rate |
| SBP | systolic blood pressure |
| SBP | spontaneous bacterial peritonitis |
| SIADH | syndrome of inappropriate antidiuretic hormone secretion |
| SIRS | severe inflammatory response syndrome |
| SNS | sympathetic nervous system |
| SOB | shortness of breath |
| SSRIs | selective serotonin reuptake inhibitors |
| TCRE | transcervical resection of the endometrium |
| TEN | toxic epidermal necrolysis |
| TIPSS | transjugular intrahepatic portosystemic shunt |
| TRALI | transfusion-associated lung injury |
| TURP | transurethral resection of the prostate |
| U&Es | urea and electrolytes |
| USS | ultrasound scan |
| VBG | venous blood gas |
| VF | ventricular fibrillation |
| VT | ventricular tachycardia |

vWF von Willebrand factor
WBC white blood cell count

Làm thế nào sử dụng sách này

Đây là cuốn sách lâm sàng hướng dẫn thẳng bằng dịch và điện giải cũng như rối loạn kiềm toan. Trong chương đầu, hướng dẫn đánh giá tình trạng thể tích và xét nghiệm cần thiết. Chương sau sẽ gồm điều trị bệnh nhân với các tình trạng rối loạn khác nhau. Mỗi chương sẽ gồm các mục:

Đánh giá tình trạng thể tích:

- Tiền sử
- Thăm khám
- Xét nghiệm

Điều trị:

- Điều trị nguyên nhân
- Xử trí tình trạng rối loạn dịch hiện tại
- Đánh giá lại kết quả điều trị

Tình huống đặc biệt:

- Hướng dẫn và khuyến cáo
- Phân loại
- Điện giải
- Kiềm toan

Đánh giá thẳng bằng dịch là khía cạnh quan trọng ở tất cả các bệnh nhân có sử dụng liệu pháp truyền dịch tĩnh mạch (IVF) và bệnh nhân có dấu hiệu hay triệu chứng rối loạn thẳng bằng dịch. Guideline của tổ chức NICE đề nghị nên đánh giá hàng ngày gồm xét nghiệm máu, ở tất cả các bệnh nhân có truyền dịch tĩnh mạch.

Đây không phải cuốn sách hướng dẫn bạn truyền dịch mà nó hướng dẫn bạn thực hành lâm sàng. Điều trị phù hợp với từng bệnh nhân và bệnh lý của họ. Sách viết theo hướng dẫn của NICE, kinh nghiệm của tác giả và nguyên tắc chuẩn trong thực hành lâm sàng

Chương 1

Đánh giá tình trạng thể tích

ĐÁNH GIÁ THỂ TÍCH

Đánh giá tình trạng thể tích dựa trên lâm sàng, chú trọng các hệ thống liên quan tới thể tích dịch như: tim mạch, thận, nội tiết và dạ dày- ruột

Khi đánh giá lâm sàng, bạn cần chú ý sự phân bố dịch ở các khoang khác nhau trong cơ thể. Điều quan trọng phải biết đánh giá khoang nào thừa hay thiếu dịch. Ví dụ bệnh nhân có phù ngoại vi có thể thiếu dịch trong lòng mạch biểu hiện triệu chứng mạch nhanh, tụt huyết áp. Cuốn sách này tập trung vào những tình huống thách thức trong lâm sàng này.

TIỀN SỬ

VẤN ĐỀ HIỆN TẠI

Tại sao bệnh nhân đến viện?

Điều quan trọng là phải biết lí do vì sao bệnh nhân phải nằm viện. Đánh giá vấn đề điều trị và những vấn đề hiện có. Ví dụ, bệnh nhân có thể vào viện do tắc ruột, nhưng sau đó xuất hiện nhồi máu cơ tim

cả 2 vấn đề này sẽ ảnh hưởng tới liệu pháp truyền dịch.

TÌNH TRẠNG DỊCH HIỆN TẠI

Đánh giá tình trạng dịch đầu vào và nguyên nhân mất dịch: chúng có cân bằng?

Tiền sử là bước đầu tiên khi đánh giá tình trạng dịch. Bệnh nhân đã được dùng thuốc gì? Bệnh nhân thường có thể nói cho bạn biết họ đã ăn và uống bao nhiêu, cũng như lượng nước tiểu họ của họ. Điều trị hiệu quả khi nắm rõ thông tin về cân bằng dịch vào- ra của bệnh nhân

Đầu vào

Tình trạng bệnh/phẫu thuật làm bệnh nhân không uống đủ nước? nếu uống được nước, có uống đủ số lượng so với tuổi và cân nặng của họ? Luôn đánh giá tình trạng dinh dưỡng của bệnh nhân; Đây là trách nhiệm của mọi bác sĩ. Ví dụ, bệnh nhân phẫu thuật phải nhịn ăn cần truyền dịch tĩnh mạch (IVF). Đánh giá dịch đầu vào chú ý những điểm sau:

- Lượng uống vào: tất cả các loại dịch
- IVF: các loại dịch (tĩnh thể, keo, chế phẩm máu) và dịch chứa điện giải
- Cho ăn ngoài ruột: chú ý thành phần điện giải
- Cho ăn qua sonde dạ dày (NGT), sonde hồng tràng (NJ) và sonde mở dạ dày qua da (PEG)

Đầu ra

Đánh giá các đầu ra và lượng nước mất không nhận biết được ở bệnh nhân. Bao gồm:

- Tiêu chảy, nôn, nước tiểu và phân.
- Sonde, dẫn lưu, NGTs, NJs, PEGs.
- Mất ở khoang thứ 3, dịch di chuyển sang khoang mới do tăng lượng dịch ngoại bào (ECF) trong liệt ruột, viêm phúc mạc và

nguyên nhân gây “rò rỉ” từ mao mạch như sốc phân vệ và sốc nhiễm khuẩn.

- Lượng dịch mất không nhân biết được tuy không thể đo chính xác nhưng góp phần đáng kể vào lượng dịch mất của bệnh nhân (Figure 1.1):

- Hệ thống hô hấp: dịch bốc hơi qua đường hô hấp khi tăng tần số thở, thở bằng mồm và bệnh nhân có thông khí hỗ trợ
- da: mồ hôi và sốt cao làm tăng lượng dịch mất.
- Mất trong quá trình phẫu thuật: ở những vị trí phổi ra và trong quá trình phẫu thuật.

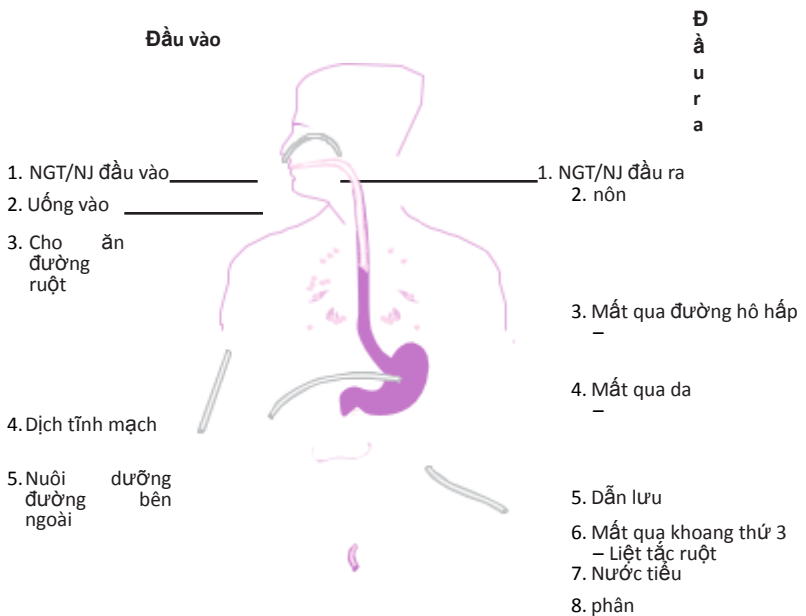
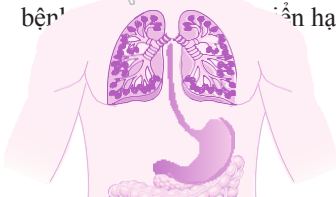


Figure 1.1 Lượng dịch đầu vào và ra. (NGT, nasogastric tube; NJ, nasojejunal; PEG, percutaneous endoscopic gastrostomy.)

Các dấu hiệu và triệu chứng mất/ thừa dịch có thể mơ hồ khó nhận biết, như: đánh giá cân bằng dịch để hỗ trợ chẩn đoán. Ví dụ, 1 bệnh nhân hạ huyết áp do mất dịch



(nếu không được bù dịch) bệnh nhân sẽ hạ huyết áp và mạch nhanh

GIẢM THỂ TÍCH

- **Triệu chứng:** khát, thiếu/vô niệu, hạ huyết áp tư thế, đau đầu, lú lẫn, nôn, tiêu chảy
- **Dấu hiệu:** giảm độ đàn hồi da, tăng thời gian đổ đầy mao mạch (>2 seconds), chi mát, khô niêm mạc, mạch nhanh, thở nhanh, hạ huyết áp, hôn mê

Tăng thể tích

- **Triệu chứng:** đa niệu/thiếu niệu, thở nhanh (SOB), Khó thở khi nằm
- **Dấu hiệu:** phù trung ương và ngoại vi, dịch ổ bụng, tĩnh mạch cổ nổi (JVP), thêm tiếng tim, tăng cân, nhức đầu, lú lẫn, hôn mê

Chú ý: dấu hiệu hạ Natri có thể có (nôn, lú lẫn, chán ăn, khó chịu).

Table 1.1 dấu hiệu và triệu chứng kết hợp với mỗi khoang

| Khoang | Triệu chứng mất dịch | Triệu chứng thừa dịch | Dấu hiệu mất dịch | Dấu hiệu thừa dịch |
|--------------|------------------------|-----------------------------|---|--|
| Lòng mạch | <i>Khát, buồn nôn</i> | | <i>Mạch nhanh, tụt áp hypotension</i> | <i>Tm cổ nổi</i> |
| Kê | <i>Khát, buồn nôn</i> | <i>SOB, Khó thở khi nằm</i> | <i>Không phù, khô niêm mạc, mắt véo da chậm</i> | <i>Phù, dịch ổ bụng, niêm mạc ẩm, véo da mất nhanh</i> |
| Trong tế bào | <i>Đau đầu, hôn mê</i> | | <i>Khó đánh giá trực tiếp</i> | <i>Khó đánh giá trực tiếp</i> |

Tiền sử

Chú ý vấn đề tiền sử, đánh giá nguy cơ đáp ứng với truyền dịch trong trường hợp bệnh nhân đang mất hay thừa dịch.

Tập trung vào các điểm sau:

- **Tim mạch:** thiếu máu cục bộ tim (IHD) và suy tim (HF) sẽ ảnh hưởng tới khả năng bơm máu đi khắp cơ thể. Thận trọng khi cho truyền dịch vì giảm cung lượng tim có thể gây tăng áp lực thủy tĩnh, dịch đi ra ngoài lòng mạch, đặc biệt ở bệnh nhân suy tim sung huyết (CCF). Cần đảm bảo tốt cung lượng tim và thể tích tâm thu (quy luật Frank–Starling). Liệu pháp truyền dịch ở những bệnh nhân này luôn là thách thức với các bác sĩ
- **Thận:** tùy thuộc vào mức độ và nguyên nhân gây tổn thương thận cấp (AKI) mà bệnh nhân có thể cần bù dịch hoặc thậm chí chạy thận. mất nước là 1 trong những nguyên nhân chính của AKI, do đó đa số bệnh nhân đòi hỏi truyền dịch (dịch tinh thể như Hartmann thường là lựa chọn đầu tiên). Bệnh thận mạn (CKD) sẽ ảnh hưởng tới bài tiết nước tiểu và điện giải. bệnh nhân bệnh thận giai đoạn cuối có thể cần lọc máu và không có khả năng sản xuất nước tiểu.
- **Gan:** bệnh gan mất bù có thể ảnh hưởng tới phân bố Na và nước. Vì vậy cần thận trọng khi bù dịch có Na
- **Tiêu hóa:** có thể gây mất lượng lớn dịch và điện giải (Đặc biệt Na và K) Do đó cần theo dõi và bù điện giải kịp thời
- **Nội tiết:** 1 số rối loạn nội tiết có thể ảnh hưởng tới áp lực thẩm thấu huyết tương và dịch cơ thể liên quan tới nồng độ glucose và Na huyết thanh

Hội chứng tiết ADH không phù hợp (SIADH) là nguyên nhân gây giữ nước quá mức gây giảm áp lực thẩm thấu máu và hạ Na. Có thể là hậu quả của nhiều nguyên nhân như rối loạn nội tiết, nhiễm khuẩn hay bệnh ác tính, thậm chí sau phẫu thuật. Thiếu ADH (đái tháo nhạt) có tác dụng ngược lại, bài tiết quá nhiều Na ở thận làm tăng áp lực thẩm thấu máu. Cũng có thể gặp tình trạng này sau phẫu thuật, ctsn hoặc bệnh ác tính. Đái đường không kiểm soát cũng làm tăng áp lực thẩm thấu huyết thanh do giảm tiết insulin, tăng glucose máu, hút nước từ trong tế bào ra



CẦN NHỚ

Thận trọng khi bù dịch ở bệnh nhân có tiền sử: IHD, HF, CKD và lọc máu, bệnh gan mất bù.

Điều chỉnh chính xác điện giải:

- *Kali ở bệnh nhân bệnh thận và tim*
- *Natri ở bệnh nhân xơ gan và suy tim HF*

Thuốc

Cần xem xét kỹ thuốc bệnh nhân đang dùng, tiền sử dùng thuốc và thuốc đang dùng hiện tại tại bệnh viện. 1 vài thuốc tác động trực tiếp tới điện giải và dịch, vì chúng tác động trên thận và liên quan thái điện giải hoặc giữ lại. Ví dụ, lợi tiểu quai tăng thải Na dẫn đến tăng bài tiết nước. 1 vài thuốc khác tác động tới phân bố dịch của hệ thống tim mạch. Ví dụ beta- blockers giảm nhịp tim và cung lượng tim Điều này làm nặng thêm tình trạng suy tim cấp và dẫn đến dịch ra khỏi lòng mạch gây phù

Ở đây, chúng ta sẽ xem xét thuốc tác động tới dịch và điện giải của bệnh nhân. Để cập nhật thông tin thuốc, hãy check *British National Formulary (BNF)* hoặc sách hướng dẫn thực hành dược lâm sàng

Các thuốc có tác động lên dịch và điện giải:

- Thuốc chẹn kênh canxi CCB: có thể là nguyên nhân gây phù cổ chân.
- Thuốc ức chế men chuyển (ACEi): có thể gây tụt huyết áp ở bệnh nhân lần đầu điều trị và tăng kali máu cũng như rối loạn nồng độ Na
- Beta-blockers: có thể làm giảm cung lượng tim.
- Lợi tiểu Thiazide: gây hạ kali, hạ Na, thiếu niệu, tăng glucose và tăng canxi
- Lợi tiểu quai: gây hạ kali, hạ Na, tăng glucose, hạ canxi, mất nước và giảm thể tích.
- Lợi tiểu giữ kali: gây tăng K, hạ Na và mất nước.
- Thuốc nhuận tràng: gây mất nước, rối loạn điện giải
- Thuốc bổ sung điện giải

Khám

Đánh giá lâm sàng của bệnh nhân đôi khi dựa vào các dấu hiệu hết sức tinh tế. Tuy nhiên, đánh giá trên bệnh cảnh cụ thể sẽ làm chẩn đoán dễ dàng hơn. (Table 1.2 và Figure 1.2).

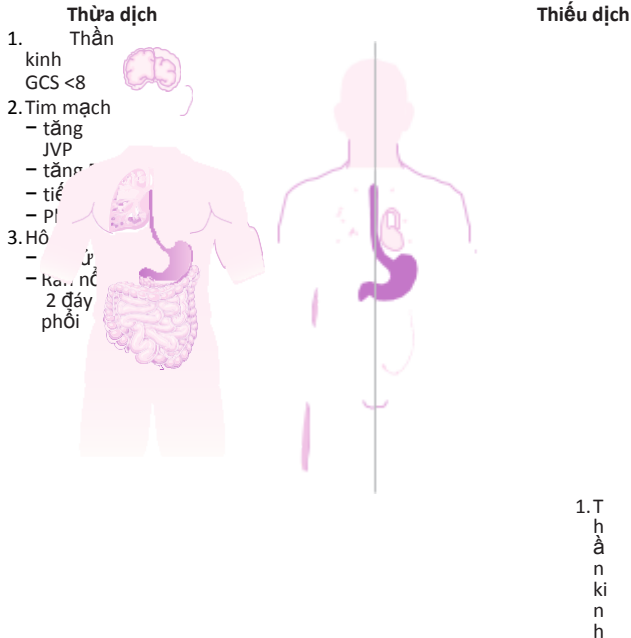
Table 1.2 Dấu hiệu và triệu chứng

| Hệ thống | Thiếu dịch | Thừa dịch |
|----------|---|---|
| Tim mạch | <ul style="list-style-type: none"> • mạch nhanh • Tụt huyết áp • t/gian đồ đầy mm >2 seconds • nếp véo da mất chậm • niêm mạc khô • hạ huyết áp tư thế | <ul style="list-style-type: none"> • THA • Xuất hiện T3 • Tăng JVP • Phù ngoại vi / ấn lõm cùng cụt |

(Continued)

Table 1.2 (Continued) dấu hiệu và triệu chứng mất cân bằng dịch

| Hệ thống | thiếu dịch | thừa dịch |
|---------------|---|--|
| Hô hấp | <ul style="list-style-type: none"> • thở >20 breaths/min | <ul style="list-style-type: none"> • SpO2 <92% • Thở >20 breaths/min • Ran 2 đáy phổi • Cò cữ • Tím tái • Tăng số lượng nước tiểu >0.5 mL/kg/hr |
| Thận | <ul style="list-style-type: none"> • nước tiểu giảm <0.5 mL/kg/hr • Nước | <ul style="list-style-type: none"> • Nước tiểu loãng |
| tiêu hóa | <ul style="list-style-type: none"> • tiêu chảy • Dịch gắn lưu ra nhiều • nôn • tắc ruột | |
| Nội tiết mmol | <ul style="list-style-type: none"> • glucose ≥ 11 | <ul style="list-style-type: none"> • GCS <8 • Hôn mê |
| Thần kinh | <ul style="list-style-type: none"> • glasgow giảm <8 • hôn mê | |



| | | | |
|-----------------------|--|--------------|--|
| G | | | - Mạch nhanh |
| C | | | - Hạ huyết áp |
| S | | | - Hạ huyết áp tư thế |
| < | | | - Thời gian đổ đầy mao mạch >2 seconds |
| 8 | | | |
| 2. Tim mạch | | | 3. Hô hấp |
| - Niêm mạc khô | | | RR >20 breaths/min |
| - Nếp véo da mất chậm | | Phù cùng cụt | 4. Tiêu hóa |
| | | | - Dịch tiêu hóa mất nhiều |
| - SpO2 <92% | | | - Tiêu chảy |
| 4. Thận | | | 5. Thận |
| ↑ nước tiểu | | | ↓ nước tiểu (<0.5 mL/kg/hr) |
| (>0.5 mL/kg/hr) | | Phù ngoại vi | Cô đặc nước tiểu (sau khi loại trừ tiểu máu) |

Figure 1.2 Sơ đồ các dấu hiệu lâm sàng thừa dịch và thiếu dịch (BP, blood pressure; GCS, Glasgow Coma Scale; JVP, jugular venous pressure; RR, respiratory rate.)

XÉT NGHIỆM

Xét nghiệm máu

Luôn làm khi đánh giá tình trạng bệnh nhân. Giúp ta đánh giá vấn đề gì đang xảy ra với bệnh nhân. (Table 1.3).

Table 1.3 Nguyên nhân rối loạn điện giải

| Điện giải | Thấp trong . . . | cao trong . . . |
|-----------|--|--|
| Sodium | SIADH Hội chứng thận hư suy gan/tim/thận Lợi tiểu quá mức thiếu Glucocorticoid quá tải dịch vd: h/c TURP | Đái tháo nhạt Cường aldoseron nguyên phát h/c Cushing bù Na không chuẩn |
| Kali | nôn/tiểu chảy Lợi tiểu qua mức hẹp môn vị h/c Cushing suy ống thận h/c Conn | suy thận lợi tiểu giữa kali tiêu cơ vân truyền máu (sll) bồng cường cận giáp bệnh ác tính Sarcoidosis |
| Calcium | viêm tụy cấp suy tuyến cận giáp thiếu Vitamin D Bệnh thận | Suy thận tiêu cơ vân bệnh ác tính suy thận nhược giáp |
| Phosphate | h/c cho ăn lại cường cận giáp DKA | |
| Magnesium | suy dinh dưỡng và giảm hấp thu Nghiện rượu | |
| Chloride | nôn | tăng Na bù Na quá mức |

Ure và điện giải

Creatinine là sản phẩm từ cơ. Nó được lọc qua thận, không hấp thu hay chuyển hóa mà được lọc toàn bộ qua thận.

vì vậy được dùng để tính mức lọc cầu thận GFR. Nó phụ thuộc vào khối lượng cơ và chế độ ăn kiêng của bệnh nhân. Ví dụ, bệnh nhân chán ăn dù creatinine thấp nhưng vẫn bị suy thận. Ở người thể trạng trung bình cần tối thiểu nước tiểu 400ml để duy trì nồng độ creatinine bình thường

Urea là sản phẩm chuyển hóa amino acid, tạo ra ở gan và lọc ở thận. tuy nhiên, 40%–60% được hấp thu lại trong vùng túy của thận.

- Tăng ure có thể do nhiễm khuẩn và xuất huyết tiêu hóa
- tăng ure > tăng creatinine (gọi là tỉ số ure/creatinine) có thể do giảm thể tích dẫn tới suy thận trước thận.
- tăng ure kèm tăng creatinine thường do suy thận mạn;
- ure thấp gặp trong bệnh gan mạn.



CẦN NHỚ

Xét nghiệm máu và chỉ định:

- CTM: tăng haemoglobin (Hb) và haemtocrit có thể do bệnh nhân mất nước và ngược lại khi bù dịch quá mức. tăng bạch cầu và tiểu cầu có thể do nhiễm khuẩn.
- U+E: tăng creatinine, urea và K^+ trong tổn thương thận cấp AKI hoặc suy thận mạn CKD.
- Bệnh gan: giảm albumin và tăng đông máu trong rối loạn chức năng gan.
- Men tim: Troponin, BNP.
- ABG: kiềm dư và lactate tăng trong giảm tưới máu mô

EKG

Những yếu tố đánh giá bao gồm:

- thiếu máu cục bộ tim hoặc nhịp bất thường: Liệu pháp truyền dịch phụ thuộc vào mức độ và nguyên nhân của vấn đề

- Nếu có thể xem lại các ECG cũ và so sánh tìm hình ảnh rung nhĩ, thiếu máu cục bộ, nhồi máu cơ tim cũ/mới, dẫn truyền bất thường, loạn nhịp
- Dấu hiệu rối loạn điện giải như hạ/tăng kali máu

Chẩn đoán hình ảnh

Giúp đánh giá tình trạng phân bố dịch bất thường như XQ phổi xác định phù phổi.

- X Quang: CXR tìm dấu hiệu quá tải dịch
- Siêu âm tim: đánh giá phân suất tống máu thất trái (LVEF), phì đại thất, suy tim phải/trái, tĩnh mạch chủ dưới xẹp hay phồng.
- Siêu âm: ú nước thận, kích thước thận, nang thận/carcinoma.
- CT: CT tìm hình ảnh tắc ruột và thủng tạng. Ct ngực tìm tràn dịch hoặc viêm màng phổi

A. TIẾP CẬN TRUYỀN DỊCH CÓ HỆ THỐNG _____

Cuốn sách này hướng dẫn tiếp cận hệ thống liệu pháp truyền dịch:

Điều trị nguyên nhân

Việc điều trị thuốc và phẫu thuật sẽ nói vấn tắt. Tập trung chính vào vấn đề liệu pháp truyền dịch.

Đánh giá tình trạng hiện tại

Điều trị bằng liệu pháp bù dịch phải tùy theo bệnh lý, phẫu thuật, khám lâm sàng và xét nghiệm

Đánh giá lại quá trình điều trị

Đánh giá các can thiệp và điều trị. Theo dõi tình trạng mất dịch, thừa dịch, rối loạn ý thức... Lý tưởng nhất, bệnh nhân phải tiến triển theo hướng tốt sau liệu pháp truyền dịch

Cần nhắc đặc biệt

- Guidelines: Điều trị theo guidelines của NICE về liệu pháp truyền dịch
- Điện giải: chú ý bất thường điện giải và cách bù điện giải từng loại

Further reading

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Olson J. *Clinical Pharmacology Made Ridiculously Simple*, 2nd edition. Miami, FL: Medmaster, 2003.

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Chapter 2

Giữ sự cân bằng: sinh lý, điện giải và dịch truyền tĩnh mạch

Giới thiệu

Trong chương này, chúng ta xem xét sinh lý của sự cân bằng dịch trong cơ thể. Sinh lý học điện giải, tìm mối liên quan và điều trị các rối loạn điện giải được nhắc ở cuối chương này. Để hiểu được liệu pháp truyền dịch, bạn phải hiểu cách dịch di chuyển, phân phối và hiệu quả đi em. Để đánh giá điều này, chúng ta phải hiểu rõ các khoang chứa dịch của cơ thể, cách chúng trao đổi và các yếu tố ảnh hưởng tới vị trí của chúng. Để bắt đầu, chúng ta sẽ đánh giá thành phần phân bố dịch trong cơ thể người. Vì đây là cuốn sách về liệu pháp truyền dịch tĩnh mạch (IVF), chúng ta cũng xem xét các loại dịch đang sử dụng, bao gồm thành phần và cách dùng. Nước trong cơ thể con người rất phức tạp liên quan đến điện giải. Phần cuối chương này là danh sách các định nghĩa của một số khái niệm thiết yếu..

Khoang chứa dịch

Cơ thể con người chứa khoảng hai phần ba là nước, nhưng điều này thay đổi theo độ tuổi và tổng phần trăm cơ thể của mô mỡ. Các giá trị thông thường áp dụng với một người đàn ông "trung bình" 70 kg. Tuy

nhiên, trên thực tế, thành phần chính xác phụ thuộc vào nhiều yếu tố: giới tính, tỷ lệ phần trăm mô mỡ và tuổi tác.

Hầu hết các tế bào người bao gồm phần lớn là nước, ngoại trừ các tế bào mỡ được tạo thành từ 20% nước. Phụ nữ nói chung có nhiều mỡ hơn đàn ông và điều này làm giảm tổng số phần trăm nước cơ thể ở phụ nữ: khoảng 50% so với 60% ở nam giới. Bệnh nhân có nhiều mô mỡ sẽ có ít nước cơ thể hơn khi so sánh với những người có cùng kích cỡ.

Khi chúng ta già đi, lượng nước trong cơ thể chúng ta giảm xuống. Trẻ sơ sinh có tỷ lệ nước trong cơ thể cao, xấp xỉ 70%, và điều này có thể tăng lên khi suy dinh dưỡng (do lượng mô giảm).

Nước trong cơ thể được chia chủ yếu vào khoang dịch nội bào (ICF) và khoang dịch ngoại bào (ECF) (xem hình 2.1). ECF hoạt động như một ống dẫn giữa các tế bào. Chất lỏng có thể di chuyển từ từ qua kẽ khe hoặc nhanh chóng qua huyết tương. Khi dung dịch đi qua các tế bào, nó cũng ảnh hưởng đến thể tích và độ thấm thấu của chúng để cân bằng thẩm thấu.

Ở người khỏe mạnh, nước và điện giải đi từ lòng mạch ra ngoài sau đó phân phối lại khắp cơ thể. Tương tự, tất cả các chất bài tiết sản xuất trong tế bào cuối cùng thải trừ qua huyết tương.

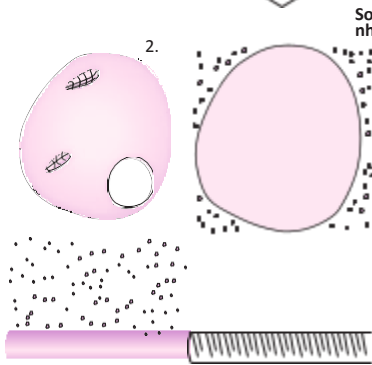
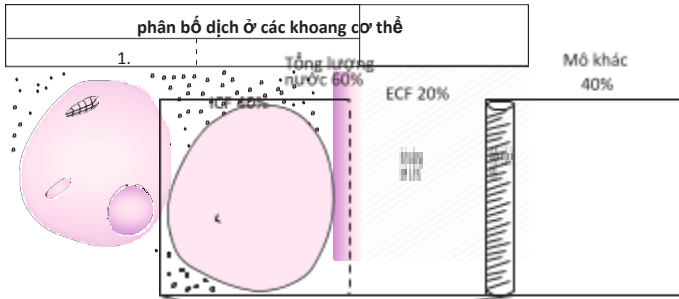
Phân bố nước: 2/3 trong nội bào ICF (40% trọng lượng cơ thể)

1/3 ngoại bào ECF (20% TLCT)

1/4 của ECF ở nội mạch (5% TLCT)

3/4 của ECF ở khoảng kẽ (15% TLCT)

Cần lưu ý về phân bố điện giải trong các tế bào. Ví dụ, gradient nồng độ canxi giữa lưới nội chất và tế bào chất của cơ trơn giúp co cơ. Điện giải và các bất thường liên quan đề cập ở cuối chương này.



So sánh sự phân bố dịch ở ICF và ECF ở bệnh nhân có cân nặng khác nhau

Phân bố dịch truyền:

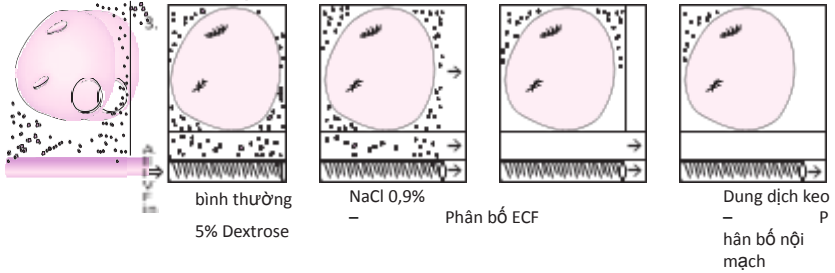


Figure 2.1 sơ đồ phân bố các loại dịch khác nhau. Mũi tên cho thấy sự mở rộng ra các khoang.

Lượng dịch đầu vào – đầu ra

Mặc dù có sự biến động lớn về lượng nước và điện giải vào và ra mỗi ngày, nhưng bạn cần biết con số trung bình để tính toán đầu vào/ra cho bệnh nhân (Table 2.1).

Table 2.1 Lượng dịch trung bình vào và ra ở người lớn

| Lượng vào (mL) | Lượng ra (mL) |
|---|--|
| Uống: 1500 | nước tiểu: 1500 |
| Nước trong thức ăn: 750 | phân: 100 |
| Chuyển hóa: 250 | mất không nhận biết: qua da: 500 |
| Bệnh: IVF và thuốc, ăn uống thất thường | Phổi (thở ra): 400 Bệnh: mồ hôi, các loại dịch khác |
| TỔNG khoảng 2500 mL | TỔNG khoảng 2500 mL |

Thành phần thực tế của dịch được cơ thể duy trì rất chặt chẽ. Nồng độ Ion rất cần thiết để duy trì chức năng cơ bản của tế bào, như điện thế động và giải phóng các chất dẫn truyền thần kinh. Mặc dù có thể có sự khác biệt lớn trong lượng nước và lượng điện giải, nhưng thành phần ion và độ thẩm thấu được duy trì trong giới hạn rất chặt chẽ. Những bất thường có thể xảy ra khi bệnh nhân không thể uống đủ lượng nước và chất điện giải (ví dụ khi họ bất tỉnh hoặc nuôi dưỡng ngoài tiêu hóa) hoặc khi lọc huyết tương ở bệnh nhân suy thận.

(Hướng dẫn NICE 2013) phác thảo yêu cầu cơ bản hàng ngày về nước, glucose và chất điện giải. Đôi khi, IVF là nguồn duy nhất có thể đáp ứng những yêu cầu cơ bản này, ví dụ khi bệnh nhân phải nhịn ăn uống trước phẫu thuật.

Table 2.2 nhu cầu hàng ngày

| Chất | nhu cầu hàng ngày |
|---------|-------------------|
| Nước | 25–30 mL/kg |
| Glucose | 50–100 g |
| Na/K/Cl | 1 mmol/kg |

Source: NICE Guideline. *Intravenous Fluid Therapy in Adults in Hospital*. 2013. <https://www.nice.org.uk/guidance/cg174>.

các giá trị ở Table 2.2 chỉ là nhu cầu cơ bản, ngoài ra còn các yếu tố ảnh hưởng. Ví dụ, bệnh nhân mất nước, kali, natri do nôn nhiều

loại dịch '1 muối và 2 đường' (1 L 0.9% saline và 2 L 5% dextrose) sẽ cung cấp:

- 3 L nước: nhu cầu 1 ngày của người đàn ông 100kg
- 100 g glucose: số lượng yêu cầu
- 150 mmol Natri: nhu cầu của người đàn ông 150kg
- 150 mmol chloride: nhu cầu của người đàn ông 150kg
- 0 mmol kali: cần 70 mmol với đàn ông 70kg

Sự di chuyển của dịch giữa các khoang

Có sự di chuyển của dịch và điện giải giữa các khoang. Thành phần mỗi khoang có cả nước và điện giải được điều chỉnh bởi các yếu tố

1. Màng tế bào

Ngăn dịch giữa các khoang, rõ nhất là ICF và ECF. Có sự khác biệt về nồng độ ion giữa ICF và ECF

- Cations:** SODIUM (Na^+) là cation ngoại bào ECF, POTASSIUM (K^+) là cation nội bào ICF.
- Anions:** BICARBONATE (HCO_3^-) và CHLORIDE (Cl^-) là anion ngoại bào ECF, PROTEINS và PHOSPHATES (PO_4^-) là anion nội bào ICF.

Gradient nồng độ của các ion trong và ngoài màng tế bào được duy trì ổn định ở bệnh nhân khỏe mạnh, Ví dụ bơm Na-K-ATPase duy trì nồng độ Na và K

Tất cả các chuyển động của ion qua màng xảy ra thông qua các kênh ion (đòi hỏi năng lượng) hoặc thụ động (theo gradient nồng độ). Mặc dù có sự khác biệt về thành phần ion, ICF và ECF cũng có cùng độ thẩm thấu (trong khoảng 275-295 mOsm / kg). Nếu có nhiều osmolality (chất tan làm tăng áp lực thẩm thấu) trong ECF, nó sẽ ảnh hưởng đến osmolality ICF. gradient thẩm thấu sẽ được tạo ra và nước sẽ được phân phối theo gradient cho đến khi cân bằng

2. Thành mao mạch

Thành mao mạch phân chia mạch máu (huyết tương) và khoảng gian bào. Tuy nhiên, có sự chuyển động liên tục của nước và chất điện giải giữa hai ngăn vì các protein lớn có nồng độ cao hơn trong huyết tương, không thể di chuyển qua màng mao mạch. Những protein lớn sẽ gây ra hiệu ứng áp lực keo chống lại áp lực thủy tĩnh bằng cách co lại thành động mạch.

Áp lực keo do protein huyết tương tạo ra, kéo nước vào huyết tương từ các mô xung quanh. Áp lực thủy tĩnh trong các động mạch đẩy nước đi từ lòng mạch ra khoảng kẽ. Do đó, có sự dịch chuyển liên tục của nước trong lòng mạch và khoảng kẽ

Giả thuyết của Starling cho thấy có sự liên tục lọc dịch qua màng bán thấm do áp lực keo và áp lực thủy tĩnh. Sự dịch chuyển của dịch ra khỏi nội mạch do áp lực thủy tĩnh cao hơn áp lực keo

sự di chuyển nước từ khoang kẽ về nội mạch do áp lực keo lớn hơn áp lực thủy tĩnh. Cả 2 áp lực này rồi sẽ cân bằng nếu không sẽ dẫn đến phù

Starling's Equation

$$\text{Áp lực lọc} = (\text{C thủy tĩnh} - \text{I thủy tĩnh}) - (\text{C áp lực keo} - \text{I áp lực keo})$$

C – mao mạch
hydrostatic – áp lực thủy tĩnh
I – kẽ
oncotic – áp lực keo

Sinh lý thận

Thận lọc huyết tương, điện giải và bài tiết chất thải. Thận cũng duy trì độ pH bình thường và có chức năng nội tiết; Chúng điều chỉnh lượng tế bào hồng cầu thông qua erythropoietin, và mức canxi trong máu qua hormon cận giáp và sự trao đổi vitamin D.

The nephron

Thận lọc huyết tương qua các nephron.

- **Màng lọc cầu thận và bao Bowman.** Huyết tương lọc từ các tiểu cầu thận tới bao Bowman tốc độ 125ml/p. co động mạch đến và giãn động mạch đi làm tăng áp lực thủy tĩnh lên 45mmHg.
- **Ống lượn gần.** hầu hết quá trình tái hấp thu xảy ra ở đây. 70% nước và các chất điện giải sẽ trở lại huyết tương
 - Phần lớn Na được tái hấp thu ở đây, kéo nước trở lại tĩnh mạch.
 - *Glucose và amino acid tái hấp thu hoàn toàn ở đây*, sử dụng Na chất mang thụ động.
 - *Kali cũng tái hấp thu ở đây*, trao đổi với H⁺

- H^+ được bài tiết ở đây, PH dung dịch chỉ giảm xuống 0.4 (từ 7.4 xuống 7) vì HCO_3 được hấp thu (90%) đóng vai trò đệm
 - *Urea* tập trung ở đây nhưng do gradient cao nên được tái hấp thu
 - trở lại huyết tương
 - *Calcium và phosphate* tái hấp thu tự động ở đây.
- **Quai Henle.** Phần này của nephron cô đặc nước tiểu.

Nó làm điều này bằng cách tạo ra gradient thẩm thấu lớn trong vùng túy để nước được tái hấp thu trở lại giường mao mạch.

Nồng độ osmolal trong thận là từ 900 đến 1400 mOsm / kg (cao hơn nhiều so với 285 mOsm / kg trong huyết tương) và được tạo ra bằng vận chuyển clorua tích cực, sau đó là natri, vào trong túy ở đoạn lên quai henle. Natri clorua được bài tiết ra ở đoạn lên quai henle. Magnesium chủ yếu được hấp thu ở đây.

- **ống lượn xa và ống góp.** Chỉ tái hấp thu 5% điện giải nhưng kiểm soát lượng nước tiểu ra chủ yếu ở đây bởi aldosterone và hormone chống bài niệu (ADH). Na được tái hấp thu ở ống góp và bài tiết kali do aldosterone

Hormones

- **Aldosterone.** tái hấp thu natri thông qua ba cơ chế trong ống góp: làm tăng tính thấm màng của natri, trao đổi $Na + cho H +$ trên bề mặt ống và ở bơm $Na + / K +$ trên bề mặt mao mạch. Tương tự, aldosterone làm tăng tính thấm cho $K +$ di chuyển từ tế bào vào lòng ống 1 cách thụ động do chênh lệch gradient nồng độ

nồng độ kali cao sẽ gây tiết aldosterone từ vỏ thượng thận. Nó cũng làm tăng hấp thu natri từ mồ hôi và nước mắt.

- **ADH.** Còn gọi là vasopressin, ADH tác động lên ống lượn xa và ống góp làm tăng tái hấp thu nước. do đó, nước được tái hấp thu trở lại mao mạch. Nó được kích hoạt bởi các thụ thể cảm nhận thay đổi áp lực thẩm thấu ở vùng dưới đồi khi tăng nồng độ Na và thụ thể cảm áp ở nhĩ trái và tĩnh mạch lớn khi huyết áp giảm. (Figure 2.2).



CẦN NHỚ

TIỂU CẦU THẬN VÀ BAO BOWMAN: lọc huyết tương và các chất tan nhỏ từ tĩnh mạch.

ống lượn gần: tái hấp thu hầu hết điện giải, nước, glucose và amino acids.

quai Henle: cô đặc nước tiểu do tái hấp thu hầu hết nước do chênh lệch gradient nồng độ tạo ra khi tái hấp thu các ion K, Na, Cl gây ưu trương khoảng kẽ

ống lượn xa và ống góp: điều chỉnh thành phần điện giải cuối cùng xảy ra ở đây, do đó điều chỉnh PH và điện giải trong máu. Aldosterone tác động lên ống góp tái hấp thu Na còn ADH giúp tăng tái hấp thu nước.

Thận điều chỉnh điện giải

Điều chỉnh Na thông qua 3 cơ chế:

1. Hệ RAA Renin–angiotensin–aldosterone: giữ Na
2. Hệ giao cảm: giữ Na
3. Yếu tố lợi niệu nhĩ: thải Na

Kali tái hấp thu chủ yếu ở ống lượn gần và thải ở ống góp do aldosterone. trao đổi Kali ảnh hưởng tới PH huyết tương.

Nước hấp thu ở các đoạn của nephron. Lượng nước của cơ thể điều chỉnh bởi ADH và 3 cơ chế.

Tiểu cầu thận

1. Lọc huyết tương
2. Lọc điện giải và acid amin trừ protein và phân tử lớn

Ống lượn gần

1. tái hấp thu hầu hết điện giải:
 - 70% Na và H₂O
 - 0% K⁺ và HCO₃⁻
 - glucose
 - amino acids
2. H⁺ ions
3. Tất cả nước tiểu
4. Không sinh lợi tiểu

Sợi đờ

1. Chức năng chính
2. Di chuyển vào lòng ống
3. Di chuyển ra ngoài lòng ống
4. Thuộc

1. cò đặc nước tiểu.
2. Đoạn xuống
 - Nước được tái hấp thu do áp lực thẩm thấu cao trong vùng tủy thận
 - đoạn nằm ngang: không hấp thu Na⁺.
3. Đoạn lên
 - Na⁺ và Cl⁻ vẫn chuyển ra ngoài, không thấm nước
4. Lợi tiểu quai

Ống lượn xa

1. Điều chỉnh thành phần điện giải của nước tiểu
2. K⁺, H⁺, urea
3. Na⁺ và K⁺ điều chỉnh bởi aldosterone
4. Thiazides

ong gop
aldosterone
3. Na+
1. tái hấp thu nước do ADH và 2. Kali do aldosterone
4. Lợi tiểu giữ Kali

Figure 2.2 sơ đồ cấu tạo nephron và chức năng chính.

cân bằng nước và natri

Lượng nước trong cơ thể được xác định bằng lượng natri. Điều này là do nước có thể di chuyển tự do giữa tất cả các khoang và sự thẩm thấu của nó được xác định bởi ion Na ECF.

Nồng độ natri huyết tương phản ánh sự thẩm thấu huyết tương trong hầu hết các trường hợp, ngoại trừ khi có các chất tan khác làm tăng osmolality, như glucose trong đái tháo đường (DKA). ADH và cơ chế khát là những lý do chính khiến độ thẩm thấu huyết tương được duy trì chặt chẽ giữa 275 và 295 mOsm / kg.



Cần nhớ

Nồng độ Na quyết định thể tích ngoại bào ECF. Giảm nồng độ Na dẫn đến giảm thể tích ngoại bào và ngược lại. Thể tích nước quyết định bởi nồng độ Na.

Các loại dịch tĩnh mạch

Giới thiệu

dịch truyền tĩnh mạch (IVF) sẵn có cho thực hành lâm sàng bao gồm dịch tinh thể, dịch keo và chế phẩm máu (sẽ được trình bày trong Chương 6). Các tính chất lâm sàng của chúng khác nhau về thành phần, chất điện giải và các phân tử của chúng, thêm vào đó sẽ có ảnh hưởng đến môi trường xung quanh của chúng sau khi được truyền vào cơ thể người. chúng có thể được phân loại dựa vào tính chất đẳng trương, nhược trương hoặc ưu trương. Trong cơ thể người, khoang chúng ta quan tâm nhiều nhất là các tế bào, do đó, trọng lực xem xét liên quan tới chuyển động nước vào và ra khỏi tế bào.

Nước

Nước chiếm hơn nửa cơ thể người nhưng không bao giờ chúng ta truyền nó cho bệnh nhân

(Ít nhất là không tiêm tĩnh mạch!). Trong thực hành lâm sàng, nước được sử dụng để pha trộn một số thuốc nhưng nó không bao giờ được sử dụng dưới dạng tinh khiết tiêm trực tiếp vào tĩnh mạch của bệnh nhân. Điều này là do nước có thể xâm nhập vào các tế bào một cách tự do dẫn đến tan tế bào. Tuy nhiên, chúng ta sẽ nhanh chóng xem xét một số nguyên nhân của nước ảnh hưởng đến IVF và ảnh hưởng đến các loại thuốc hoạt động trong cơ thể như thế nào.

Nước có một số tính chất đặc biệt do liên kết cộng hóa trị và các liên kết hydro. Những điểm này cho nhiệt độ nóng chảy và sôi cao hơn nhiều và độ căng bề mặt cao hơn so với các phân tử mol tương tự. Nước được tạo thành từ một nguyên tử oxy chia sẻ một electron với mỗi nguyên tử hydro được gắn vào. Oxy là một nguyên tử lớn hơn và thu hút các electron chia sẻ nhiều hơn các nguyên tử hydro, do đó tạo ra một phân cực cho các liên kết cộng hoá trị. Các nguyên tử oxy sẽ có điện tích âm hơn và hydro một chút dương, dẫn đến thu hút giữa các phân tử gọi là liên kết hydro. Nước là một phân tử phân cực và các phân tử ưa nước sẽ phân giải dễ dàng hơn các phân tử không phân cực; Các phân tử tương tự sẽ hòa tan lẫn nhau. Lượng điện tích âm và dương nhẹ đối với các nguyên tử oxy và hydro giúp nước phân giải các phân tử ion xung quanh chúng và thu hút các ion tích điện dương. Điều này có nghĩa là nước là một dung môi rất tốt, trong đó ion kim loại và phi kim loại có thể được hòa tan, chẳng hạn như natri, clo, kali và canxi.

Dung dịch keo

Dung dịch keo là dung dịch truyền tĩnh mạch để bồi phụ thể tích tuần hoàn vì chúng hoạt động bằng cách protein như protein nội sinh và tăng áp lực nội mạch. Áp lực ngày càng tăng để giữ nước ở khoang nội mạch lâu hơn và kéo nước về khoang nội mạch. đã có một cuộc tranh luận kéo dài về việc sử dụng dung dịch keo để hồi sức bệnh nhân. Dung dịch keo đắt hơn và đôi khi có thể gây phản ứng phụ nghiêm trọng như tổn thương thận cấp và rối loạn đông máu.

1 số dung dịch keo có thể dẫn đến sốc phản vệ. 1 số nghiên cứu về so sánh dùng dung dịch keo và dung dịch tinh thể trong hồi sức cho thấy không nên dùng các dung dịch keo (HES) để hồi sức, vì phản ứng phụ nhiều trong khi lợi ích thì không đáng kể.

Thuật ngữ colloid (keo) mô tả một hỗn hợp gồm hai hoặc nhiều chất được trộn đều; có thể bao gồm các chất khí, chất lỏng hoặc chất rắn trộn lẫn trong dung dịch. Trong thực hành lâm sàng, các chất lỏng này bao gồm các hạt lớn hơn 10.000 Da cho phép dung dịch có thể gây áp lực keo và duy trì nước trong nội mạch. Các phân tử lớn hơn từ động vật, thực vật hoặc glucose; Chúng ta sẽ xem xét từng loại dung dịch keo lần lượt.

1. Gelatins

Gelatins là chất keo bán tổng hợp được làm từ các mô liên kết động vật (collagens thủy phân). Các phân tử protein 30.000 Da và không thể chui qua màng mao mạch, nhưng có thể gây sốc phản vệ.

Một ví dụ là Gelaspan gồm gelatin cải biến, gel succinylated với trọng lượng phân tử 26.500 Da.

Thành phần Gelaspan: Na + 151 mmol / L, K + 4 mmol / L, Cl-103 mmol / L, Ca²⁺ + 1 mmol / L, Acetate 24 mmol / L, Mg²⁺ + 1 mmol / L, và 40 g gel succinylated trong 1000 mL.

2. Dung dịch hồ

Dung dịch hồ làm từ thực vật, amylopectins liên kết với nhóm hydroxyethyl. Dung dịch này có thể vẫn ở lại trong hệ tuần hoàn tới 24h sau truyền do trọng lượng phân tử lớn tới 200.000Da. chúng khá đắt, ví dụ dung dịch HES 10%.

Dung dịch này có thể gây tác dụng phụ: ngứa, rối loạn đông máu, tổn thương thận cấp và sốc phản vệ. vì tác dụng phụ nhiều nên đã cấm dùng tại Mỹ (Government Medical Safety Alert for HES 2013).

3. Dextrans

Dextrans gồm các glucose cao phân tử. ví dụ, Dextran 70 trọng lượng phân tử 70,000 Da. Nó làm tăng áp lực keo và giảm độ nhớt huyết tương. Nó có thể làm tăng đường huyết và tăng áp lực thẩm thấu.

4. Albumin

Albumin là một protein tự nhiên tách ra từ albumin người. Nó có các điểm mạnh khác nhau (5% và 20% trong dung dịch muối 0,9%), và đáng trưng ở các nồng độ thấp hơn như 5%. Nó thường sử dụng truyền tĩnh mạch ở bệnh nhân có dịch ổ bụng để tránh mất dịch nhưng có nguy cơ gây phản ứng quá mẫn

Tóm lại

1 vài điểm khi muốn dùng dung dịch keo:

- Dung dịch keo chỉ nên dùng ở bệnh nhân hồi sức.
- Dung dịch keo có giá trị ở bệnh nhân hồi sức bù dịch, không dùng sốc mất máu, thay thế máu (Chapter 6).
- Dung dịch keo thường pha trong NaCl 0,9%
- Sử dụng dung dịch keo có thể gây tổn thương thận và sốc phản vệ
- Gelatins là dung dịch keo được sử dụng phổ biến nhất.

Kết luận, những bằng chứng ủng hộ việc sử dụng dung dịch keo trong hồi sức vẫn chưa rõ ràng (xem chương 3). Không có bằng chứng hỗ trợ việc sử dụng các dung dịch có chứa tinh bột

Còn tùy quan điểm cá nhân sẽ dùng dung dịch keo hay tinh thể trong hồi sức bệnh nhân, tuy nhiên, hiện này khuyến cáo dùng các dung dịch đẳng trương như Hartmann hoặc Plasmalyte (e.g. NICE, KDIGO, *Surviving Sepsis Campaign*).

DỊCH TINH THỂ

Dịch tinh thể bổ sung nước và ion, và/hoặc glucose tùy theo từng loại dịch. Thành phần ion hay glucose sẽ ảnh hưởng tới sự phân bố của chúng khi truyền tĩnh mạch vào các khoang, phụ thuộc chúng nước, ưu hay đẳng trương so với huyết tương

Dịch đẳng trương

Dịch đẳng trương có áp lực thẩm thấu gần giống với huyết tương bằng cách mô phỏng thành phần cation và anion, đặc biệt là đối với áp lực thẩm thấu của huyết tương. Vì dịch này có chứa ion lại đẳng trương nên chúng sẽ phân bố đều qua toàn bộ ECF. Các chất tan là các phân tử nhỏ và chúng sẽ đi qua một cách tự do trên màng bán thấm mao mạch nhưng chúng sẽ không thể ra vào tự do trong tế bào vì lớp màng kép lipid. Do đó, dịch đẳng trương sẽ không ảnh hưởng tới thành phần của tế bào, nước sẽ không thể đi vào tế bào.

Các dung dịch đẳng trương phân phối đều ở ECF; Khoảng 25% ở lại lòng mạch và 75% ở khoảng kẽ. Điều này có nghĩa là trong 1 l tinh thể chỉ 250 mL dịch ở trong lòng mạch. Do đó cần truyền lượng lớn dịch tinh thể để duy trì thể tích nội mạch so với dung dịch keo hoặc máu. Do phân bố ở ECF, việc sử dụng quá nhiều dịch đẳng trương có thể dẫn đến phù ngoại vi và tăng áp suất trong mạch máu. Tùy thuộc vào bệnh nhân và sinh lý hiện tại của họ, đặc biệt là chức năng tim, có thể gây tăng áp lực lên tim và dẫn đến phù phổi. Trong trường hợp nhiễm trùng huyết, màng mao mạch trở nên 'rò rỉ' (xem chương 3) do tác động của các cytokine tiền viêm.

0.9% normal saline

Thành phần: Na^+ 154 mmol/L, K^+ 0 mmol/L, Cl^- 154 mmol/L, Osmolarity 308 mOsm/L.

Chloride trong dung dịch cao hơn nồng độ trong huyết tương (95–105), do đó sử dụng quá đà sẽ gây toan máu tăng chloride. Trong vài năm trước, có nhiều bằng chứng cho thấy tăng chloride

có thể làm tình trạng bệnh nhân nặng hơn. Tăng chloride làm giảm lưu lượng máu phế quản và thận, cản trở chức năng bạch cầu lympho T và rối loạn đông máu. Do đó, hầu hết các hướng dẫn của NICE, với bệnh thận, sau ghép thận, tổn thương thận cấp, sốc nhiễm khuẩn nên dùng loại dịch có tính cân bằng như Hartmann hoặc Plasmalyte để hồi sức. Tuy nhiên, nó là một trong những loại dịch tinh thể được sử dụng rộng rãi nhất trong điều trị và phẫu thuật.

Natri trong dung dịch cũng cao hơn nồng độ trong huyết tương 1 chút, dùng nhiều có thể gây tăng Na trong ECF có thể gây phù ngoại vi. Lưu ý rằng khi bù dịch tinh thể mà không có kali có thể gây hạ kali máu rất nguy hiểm. Vì vậy, cần bù kali 20-40mmol/l bù kali phải bù tốc độ chậm (xem phần điện giải chương này)

CÂN BẰNG DỊCH SINH LÝ

Dịch tinh thể có thành phần điện giải tương tự huyết tương được gọi là các dung dịch cân bằng sinh lý và chúng ít gây rối loạn về mặt sinh lý hơn dung dịch muối khi sử dụng với số lượng lớn vì chúng không gây ra nhiễm toan.

1. Ringers

Thành phần: Na^+ 147 mmol/L, K^+ 4 mmol/L, Cl^- 156 mmol/L, Ca^{2+} 2.2 mmol/L, Osmolarity 309 mOsm/L.

Na và K ở ngưỡng ngang nồng độ trong huyết tương.

2. Hartmann's (Lactated Ringer's solution)

Thành phần: Na^+ 131 mmol/L, K^+ 5 mmol/L, Cl^- 111 mmol/L, Ca^{2+} 2 mmol/L, Lactate (HCO_3^-) 29 mmol/L, Osmolarity 279 mOsm/L.

Na, K và độ thẩm thấu như trong huyết tương nhưng chlor thì cao hơn. Gan nhanh chóng chuyển Na, lactate thành bicarbonate và nước. vì vậy, Hartmann là dung dịch kiềm thích hợp với bệnh nhân toan chuyển hóa.

Toan chuyển hóa thường có tăng kali máu, do trao đổi với H^+ đi vào trong tế bào

tuy nhiên, khi dùng dung dịch kiềm như Hartmann, quá trình này sẽ bị đảo ngược, kali sẽ quay trở lại tế bào.

3. Plasmalyte 148

Thành phần: Na^+ 140 mmol/L, K^+ 5 mmol/L, Cl^- 98 mmol/L, Gluconate 23 mmol/L, Acetate 27 mmol/L, Mg^{2+} 1.5 mmol/L, Osmolarity 295 mOsm/L.

Dịch đẳng trương có tính kiềm.

4. 1.26% Bicarbonate

Thành phần: Na^+ 150 mmol/L, K^+ 0 mmol/L, Cl^- 0 mmol/L, Ca^{2+} 0 mmol/L, Bicarbonate (HCO_3^-) 150 mmol/L, Glucose 0 g, Osmolarity 300 mOsm/L

Bicarbonate nên sử dụng thận trọng, bù bicarbonate ở bệnh nhân có nồng độ bicarbonate thấp (<20 mmol/L) trong trường hợp tổn thương thận cấp, mất bicarbonate

DỊCH NHƯỢC TRƯƠNG

Dung dịch nhược trương có độ thẩm thấu thấp hơn và hút nước ICF ít hơn. Về cơ bản, chúng cung cấp nước cho các tế bào bằng cách có độ thẩm thấu thấp hơn ICF, do đó nước sẽ đi vào tế bào. 33% ở lại ECF, 66% đi vào ICF nên sử dụng trong lâm sàng nên hạn chế

1. 5% Dextrose

Thành phần: Glucose 50 g (50 mg/mL), Na^+ 0 mmol/L, K^+ 0 mmol/L, Cl^- 0 mmol/L, Ca^{2+} 0 mmol/L, Osmolarity 278 mOsm/L.

Glucose là thành phần duy nhất bên cạnh nước trong dịch này, và nó không ảnh hưởng tới áp lực thẩm thấu máu. Khi dùng, glucose sẽ đi vào tế bào, bỏ nước ở lại bên ngoài. Vì vậy, bù 11 glycose 5% sẽ có 1 lit nước được bù

sẽ gây hạ Na nếu bù quá mức. nó không thích hợp dùng để hồi sức, vì nếu truyền lượng lớn chỉ 1 lít ở lại được trong lòng mạch. Dịch này không bao giờ được truyền ở bệnh nhân hạ Na máu

2. 0.45% NaCl

Thành phần: Na^+ 75 mmol/L, K^+ 0 mmol/L, Cl^- 75 mmol/L, Ca^{2+} 0 mmol/L, Glucose 0 mmol/L, Osmolarity 150 mOsm/L.

Là dung dịch nhược trương dùng điều trị hội chứng tăng Na huyết. cần kiểm tra nồng độ Na thường xuyên bù chậm không giảm quá 0.5–1 mmol/L/hr.

3. glucose/NaCl (0.18% NaCl + 4% dextrose)

Thành phần: Na^+ 30 mmol/L, K^+ 0 mmol/L, Cl^- 30 mmol/L, Ca^{2+} 0 mmol/L, Glucose 40 g, Osmolarity 284 mOsm/L.

Dịch nhược trương cung cấp glucose và lượng Na thấp hơn NaCl 0,9%

Không nên dùng cho trẻ dưới 16 tuổi



Cần nhớ

Cả dung dịch glucose và NaCl 0,45% đều dùng điều trị tăng Na máu, nhưng cần theo dõi và điều chỉnh tốc độ giảm Na xuống chậm (tối đa 0.5–1 mmol/hr).

Dịch ưu trương

Dung dịch ưu trương có áp lực thẩm thấu cao hơn huyết tương. Việc sử dụng loại dịch này sẽ dẫn đến gradient ngoại bào cao hơn trong trong tế bào dẫn đến nước đi ra ngoài gây teo tế bào. Vì chúng có thể gây ra những thay đổi lớn trong thể tích tế bào nên chúng chỉ nên được sử dụng bởi bác sĩ có kinh nghiệm. Ví dụ NaCl 1,8%, 3%, 5% hoặc 7,5%

Dịch này thì thoáng được dùng cho bệnh nhân chấn thương sọ não có phù não hoặc bệnh nhân tụt huyết áp nặng, bệnh nhân co giật hoặc ngừng tim

không nên sử dụng nếu không có kinh nghiệm (Table 2.3).

Table 2.3 tóm tắt các loại dịch tinh thể và thành phần điện giải của chúng

| IVF | Na mmol/L | K mmol/L | Chloride mmol/L | Glucose | Osmolarity mOsm/L | tăng |
|--|--------------|-------------|--------------------|---------|----------------------|---|
| 0.9% NaCl | 154 | 0 | 154 | 0 | 308 | pH 5.5 |
| Hartmann | 131 | 5 | 111 | 0 | 279 | pH 6.5 Lactate 29 mmol/L Calcium 2 mmol/L |
| Plasmalyte 148 | 140 | 5 | 98 | 0 | 295 | pH 6.5–8, Mg ₂₊ 1.5 mmol/L Acetate 27 mmol/L Gluconate 23 mmol/L |
| Dextrose/ NaCl (0.18% NaCl + 4% dextrose) | 30 | 0 | 30 | 40 g | 284 | |
| 5% Dextrose | 0 | 0 | 0 | 50 g | 278 | |
| 0.45% NaCl | 75 | 0 | 75 | 0 | 150 | |
| 1.26% Bicarbonate | 150 | 0 | 0 | 0 | 300 | Bicarbonat e (HCO ₃ ⁻) 150 mmol/L |
| Giá trị bthuong | 135–145 | 3.5–5.5 | 95–105 | | 280–295 | |

BẤT THƯỜNG ĐIỆN GIẢI

Rối loạn điện giải có thể đe dọa đến tính mạng, điện giải rất quan trọng trong nhiều phản ứng trong cơ thể người, chẳng hạn như sự co cơ, mất phản xạ hoặc bất thường trên ECG...

Như đã đề cập ở trên, sự phân bố điện giải rất khác nhau giữa trong và ngoài tế bào. Kết quả xét nghiệm urea và điện giải (U + E) chỉ biểu thị giá trị trong huyết tương (xem Bảng 2.4 về thành phần điện giải). Thành phần điện giải trực tiếp liên quan đến thể tích nước và độ pH. Điện giải cân bằng với nhau, nên rối loạn điện giải có thể dẫn đến rối loạn nồng độ điện giải khác

Table 2.4 thành phần điện giải mỗi khoang

| Điện giải | Trong tb | Khoảng kẽ | Trong lòng mạch |
|-------------|----------|-----------|-----------------|
| Na | 10 | 144 | 140 |
| K | 160 | 4 | 4 |
| Magnesium | 13 | 0.5 | 1 |
| Calcium | 2 | 114 | 102 |
| Phosphate | 57 | 1 | 1 |
| Bicarbonate | 8 | 30 | 26 |
| Protein | 55 | 0 | 16 |

Source: Adapted from National Institute for Health and Care Excellence, CG174 Intravenous Fluid Therapy in Adults in Hospital. Manchester, UK: NICE, 2013. Available from <https://www.nice.org.uk/guidance/cg174> Reproduced with permission.

Cách đánh giá rối loạn điện giải và điều trị thành công:

1. đảm bảo kết quả sinh hóa là chính xác
2. đánh giá tình trạng bệnh nhân và dấu hiệu rối loạn điện giải
3. xử trí các dấu hiệu và triệu chứng đe dọa tính mạng như:
 - a. hạ/tăng Na máu nặng
 - b. tăng kali
 - c. Hạ kali

4. làm các xét nghiệm thích hợp.
 - a. U+E
 - b. Calcium, phosphate và magnesium
 - c. ECG – đặc biệt khi có bất thường về K, Mg
 - d. Áp lực thẩm thấu nước tiểu và máu
 - e. Na và K niệu
5. Cố gắng tìm nguyên nhân và điều trị
6. Điều trị rối loạn điện giải bằng truyền tĩnh mạch hoặc chế độ ăn
7. Làm lại U+E để đảm bảo đã điều chỉnh rối loạn điện giải về bình thường (Table 2.4).



Cần nhớ

- Xét nghiệm sinh hóa không thể đặc trưng cho điện giải của toàn bộ cơ thể
- Rối loạn điện giải nhanh chóng khi có sự di chuyển vào hoặc ra khỏi tế bào. Ví dụ tăng kali điều trị bằng insulin và salbutamol để đẩy kali vào tế bào

Rối loạn Na

Natri chủ yếu ở ngoại bào ECF xác định lượng nước trong cơ thể. Xét nghiệm Na từ kết quả sinh hóa chỉ mang tính tương đối, không nói lên tổng lượng Na của cơ thể.

Hạ Na máu

Nhẹ 130 – 135 mmol/L

Vừa 129 – 125 mmol/L

Nặng <125 mmol/L

natri là ion ngoại bào sẽ ảnh hưởng tới lượng nước trong và ngoài tế bào. Rối loạn nồng độ Natri có thể gây phù tế bào, đặc biệt ở não. Các tế bào não phù nề có thể chết tế bào do không gian trong hộp sọ bị hạn chế

Tốc độ khởi phát hạ natri máu rất quan trọng trong việc đánh giá và điều trị hạ natri huyết. Hạ natri huyết cấp tính là mức natri huyết thanh giảm đột ngột (<48 giờ). Mạn khi (> 48 giờ) dẫn đến thay đổi độ thấm thấu từ từ và có thể không tương xứng với lâm sàng. Ngoài ra, có thể gây lú lẫn và suy giảm nhận thức. guideline của NICE về hạ natri máu rất chi tiết và dễ áp dụng. Chúng tôi đã đúc rút ra các nguyên tắc sau (2015).

Hạ thể tích + hạ Natri

Hậu quả của mất Na và nước có thể do các nguyên nhân sau:

- Mất qua tiêu hóa: ỉa chảy và nôn
- Lợi tiểu quá mức
- Tăng glucose gây lợi tiểu thẩm thấu
- Xuất huyết
- Suy tuyến thượng thận
- Đa niệu sau tổn thương thận cấp
- Bỏng
- Mất dịch khoang thứ 3, như viêm tụy cấp và tắc ruột non

Thể tích tuần hoàn bình thường + hạ Natri

Mất Na nhưng thể tích tuần hoàn bình thường có thể do:

- Tiết ADH không phù hợp (SIADH)
- Khát tâm căn

- tăng glucose máu
- Suy giáp
- Nghiện rượu

Hạ Na + tăng thể tích tuần hoàn

Thừa nước nhưng lượng Na bình thường có thể do:

- Suy tim
- Suy gan
- Giảm albumin
- Suy thận và thiếu niệu

Thuốc gây hạ Na

Thuốc có thể gây hạ Na thường làm tăng tiết ADH. Các thuốc hay gặp:

- Lợi tiểu: Thiazides hay gập nhất
- (NSAIDs): kết hợp mất nước do tăng ảnh hưởng của ADH lên thận
- Carbamazepine do tăng tiết ADH.
- Thuốc ức chế chẹn lọc serotonin (SSRIs).
- Thuốc chống loạn thần: Haloperidol và phenothiazine.

Tiếp cận 1 trường hợp hạ Na:

1. Cấp hay mạn
2. Nhẹ, nặng hay vừa: bệnh nhân có triệu chứng không?
3. Nếu hạ Na nhẹ có thể tìm nguyên nhân hạ Na và điều trị thích hợp.
4. Tình trạng thể tích của bn: thiếu, bình thường hay thừa dịch.
5. Áp lực thẩm thấu máu.
 - a. Nếu thấp (<275 Osm/kg) → hạ Na thật sự
 - b. Nếu bình thường (275–295 Osm/kg) → có thể giả hạ Na do thừa protein hoặc lipid.
 - c. Nếu cao (>295 Osm/kg) → có thể thừa chất tan như tăng glucose

6. áp lực thẩm thấu niệu.

- Đánh giá áp lực thẩm thấu niệu khi đánh giá Na niệu và tình trạng thể tích của bệnh nhân
- Xem *NICE* guidelines về hạ Na

Dấu hiệu và triệu chứng

- Không triệu chứng
- Đau đầu
- Lú lẫn
- Buồn ngủ
- Co giật
- Hôn mê

Điều trị

- Bù Na chậm $0.5-1 \text{ mmol/L/hr}$ để tránh hội chứng để tránh hội chứng hủy bao myelin
- Theo dõi sát nồng độ Na
- Ngừng các thuốc làm nặng thêm hạ Na.
Tiếp cận điều trị hạ Na gồm:
 - **Nhẹ và không triệu chứng:** chỉ theo dõi
 - **Trường hợp nặng:** NaCl ưu trương
 - **Giảm thể tích/SIADH:** hạn chế nước, dưới 500 mL/day
- **Giảm thể tích:** $0.9\% \text{ NaCl}$ đến khi phục hồi ECFs

TĂNG NATRI

$Na > 145 \text{ mmol/L}$

Tăng Na luôn làm tăng áp lực thẩm thấu ngoại bào, làm nước bị hút từ tế bào ra ngoài. Dù tăng Na có thể gặp trong thiếu/thừa hay thể tích tuần hoàn bình thường

Nguyên nhân

- Đái tháo nhạt trung ương (DI) (thiếu ADH)
- Đái tháo nhạt tại thận
- Mất nước: bỏng, sốc nhiệt và tăng thông khí
- Do dùng thuốc: dịch ưu trương, truyền nhiều NaCl và thuốc chứa Na
- Đầu vào thiếu: bệnh nhân mất ý thức, mất cảm giác khát

Dấu hiệu và triệu chứng

- khát
- buồn nôn và nôn
- lú lẫn
- co giật
- đa niệu và khát nhiều ở bệnh nhân tiểu đường

Điều trị

- hạ Na xuống 0.5–1 mmol/L/hr.
- theo dõi nồng độ Na thường xuyên.
- Uống: bù nước đường uống ở bệnh nhân có giảm thể tích (>0.5 mmol/L/hr).
- IVF: 5% glucose hoặc 0.45% NaCl
- Dùng lợi tiểu ở bệnh nhân có chức năng thận bình thường.
- Ngừng thuốc tổn thương và gây độc cho thận.

Đặc biệt

- Đái tháo nhạt trung ương: Desmopressin dùng để thay ADH.
- Đái tháo nhạt nói chung cần bù lượng lớn dịch.

Rối loạn kali

Kali là cation nội bào quyết định PH của cơ thể khi nó trao đổi với ion H^+ qua màng tế bào và trong thận. Việc kali di chuyển qua màng xác định khả năng hoạt động và nghỉ của màng tế bào. Về mặt lâm sàng, điều này rất quan trọng với các tế bào tim, rối loạn kali có thể dẫn đến các rối loạn nhịp tim gây đe dọa tính mạng

Để hiểu được cách điều trị rối loạn kali, cần biết nguyên nhân gây ra sự thay đổi kali trong và ngoài lòng mạch. Kali tự nhiên lấy từ chế độ ăn uống và nồng độ trong huyết tương tăng lên do sự di chuyển kali ra khỏi tế bào. Sự thải trừ kali chủ yếu được kiểm soát bởi ba cơ chế: mất qua thận, mất qua tiêu hóa (như ói mửa và tiêu chảy) và di chuyển vào các tế bào.

Do đó, rối loạn kali do các nguyên nhân sau:

1. **Mất do thận:** Aldosterone gây mất kali và ion H^+ trao đổi với Na ở ống góp.
 - a. Mất K: tăng aldosterone và alkalosis (do tăng thải ion H^+).
 - b. Potassium gain: Decreased aldosterone and acidosis.
2. **Gastrointestinal source:** Gastrointestinal juices are rich in potassium and their losses result in decreased potassium.
 - a. Stomach: Can result in 10 mmol/L of potassium loss.
 - b. Diarrhoea: Can result in 10–30 mmol/L of potassium loss.
 - c. Small intestine: Ileus can result in potassium shift into the 'third space' and result in decreased serum potassium.
3. **Cellular shift:** Most of the body's potassium is inside the cells and vast changes in serum values can be seen when potassium goes in and out of the cells.
 - a. Decreased serum potassium (shift into the cells): Insulin, salbutamol (β -adrenergic receptors stimulators) and theophylline.
 - b. Increased serum potassium (shift out of the cells): Acidosis (potassium ions are exchanged for H^+ ions), α -adrenergic receptor stimulators, cell death resulting in release of potassium (e.g. gut ischaemia).

Hypokalaemia

Potassium <3.5 mmol/L

Hypokalaemia can develop suddenly, for example with diarrhoea and vomiting, and needs urgent treatment to ensure arrhythmias do not develop (cardiac patients are at particular risk). Alternatively, hypokalaemia can have a slow insidious onset, for example with diuretic use, or iatrogenic due to IVF replacement without potassium when using 0.9% saline or 5% dextrose.

Causes

- Dietary insufficiency: inadequate intake from food, e.g. patients that are NBM or intubated and ventilated
- Renal disease: renal tubular damage, renal tubular acidosis, rare renal syndromes (Bartter's, Gitelman's, Liddle's)
- Hyperaldosteronism secondary to: Conn's syndrome, Cushing's syndrome, heart failure, liver failure, nephrotic syndrome
- Losses from the gut: vomiting, diarrhoea, ileus, overproductive stomas
- Potassium shift into the cells: salbutamol, theophylline, insulin, alkalosis
- Iatrogenic: thiazides, loop diuretics, IVF without potassium supplementation (0.9% saline, 5% dextrose)

Signs and symptoms

- Asymptomatic
- Nausea and vomiting
- Ileus and constipation
- Atrial and ventricular atopic beats, and serious arrhythmias
- ECG: Flattened T waves
- Muscle weakness (<2.5 mmol/L)
- Paraesthesia
- Hyponatremia and associated signs and symptoms
- Increased risk of digoxin toxicity

Treatment

- Correct K slowly; fast administration of potassium can be very dangerous. Patients may also require continuous ECG monitoring depending on the rate of correction.

- Oral replacement if mild: Potassium supplements, e.g. Sando K (contains 470 mg [12 mmol] of potassium and 285 mg [8 mmol] of chloride per tablet).
- IVF potassium replacement: 20 or 40 mmol added to 1 L of 0.9% saline: Maximum 40 mmol in 1-L IVF over 4 hours.
- Ensure magnesium (Mg) is within range and replace if low (intractable hypokalaemia may be due to Mg deficiency).
- Severe hypokalaemia may require continuous cardiac monitoring.

Specific

- Hyperaldosteronism: Spironolactone or eplerenone under senior direction only.
- Natural deficiency: Increase dietary intake or oral supplements, e.g. Sando K.

Hyperkalaemia

Potassium >5.5 mmol/L

Potassium >6.5mmol/L in an emergency

Hyperkalaemia can be a medical emergency, as very quickly it can result in arrhythmias, cardiac arrest and death. Potassium is the major ICF cation and as such contributes the most to the RMP. With increased ECF potassium, the RMP becomes more positive and the cells become more easily excitable. This is of particular importance in the myocardial cells, because if they become more excitable it can result in arrhythmias. In patients who are post-MI or prone to arrhythmias it is desirable to keep potassium above 4.0 mmol/L.

Causes

- Renal: acute kidney injury, deteriorating chronic renal failure, acute or chronic renal failure
- Potassium shift out of cells: cell death (gut ischaemia), exercise (e.g. after marathons), DKA, acidosis
- Hormonal: aldosterone deficiency, Addison's disease
- Iatrogenic: angiotensin converting enzyme (ACE) inhibitors, spironolactone, NSAIDs, Heparin
- Blood transfusion

Signs and symptoms

- Asymptomatic
- Anxiety
- Diarrhoea and abdominal cramps
- ECG changes: Tall T waves, widened QRS complex
- Muscle weakness
- Paraesthesia
- Signs of metabolic acidosis: Kussmaul's breathing

Treatment

- Calcium gluconate 10%: 10 mL over several minutes if there are ECG changes, as it is cardio-protective but does not decrease overall body potassium
- Stop any medication causing hyperkalaemia
- Correct severe acidosis: 1.26% sodium bicarbonate

Decrease potassium

- Insulin–dextrose infusion: 10 units of insulin and 50% dextrose 50 mL over 30 minutes, check blood glucose
- Salbutamol nebulisers or salbutamol infusion (0.5 mg of salbutamol in 5% dextrose 100 mL)
- Haemodialysis if hyperkalaemia is not responding to medical management

Magnesium abnormalities

Magnesium is an ICF cation, primarily found in the cells of bones. However, magnesium balance is not related to bone reabsorption (as in phosphate) but mainly to dietary intake and renal excretion. Although not routinely measured, magnesium is very important for many of the essential reactions in the body. Magnesium is used for treatment of acute exacerbation of asthma and to protect against seizures in pre-eclampsia.

Hypomagnesaemia

Magnesium <0.7 mmol/L

Hypomagnesaemia can be common in malnourished patients and those with decreased oral intake, for example intubated patients in

ITU. Hypomagnesaemia can also cause or exacerbate other electrolyte disturbances, such as hypokalaemia and hypocalcaemia, so should be corrected alongside deficiencies in these electrolytes.

Causes

- Dietary insufficiency: Malnutrition and chronic alcohol excess
- Renal losses: DKA, SIADH, hyperaldosteronism
- Losses from the gut: Diarrhoea, fistulae
- Pancreatitis
- Iatrogenic: Aminoglycosides, digoxin, loop diuretics, thiazide diuretics, proton pump inhibitors

Signs and symptoms

- Weakness and fatigue
- Confusion
- Tremor
- Ataxia
- Hyper-reflexia
- Irritability, confusion, hallucinations
- Epileptic seizures
- ECG changes: Flattened and broad T waves, prolonged QT interval

Treatment

- Magnesium replacement: usually with a magnesium infusion
- Stop medication causing decreased magnesium, e.g. diuretics

Hypermagnesaemia

Magnesium >1.1 mmol/L

Hypermagnesaemia is mainly caused by excessive intake of magnesium in patients with renal failure that are not able to excrete the ion. For example, this can occur with aggressive magnesium replacement or medication containing magnesium (laxatives and enemas).

Causes

- Renal failure: AKI or chronic renal failure
- Addison's disease (acute adrenocortical failure)
- Iatrogenic: Magnesium-containing medication, e.g. antacids
- Iatrogenic: Magnesium replacement infusions for pre-eclampsia

Signs and symptoms

- Weakness
- Hypo-reflexia: Especially useful when assessing patients with pre-eclampsia on a magnesium infusion
- Cardiac arrhythmias
- Respiratory paralysis
- Narcosis

Treatment

- Stop precipitating medication
- As with hyperkalaemia:
 - 10% calcium gluconate 10 mL: Unlike in hyperkalaemia it is used to counter the magnesium effect on nerve cells
 - Insulin–dextrose to drive Mg into cells
- Diuretics in patients with good renal function
- Haemodialysis (with magnesium-free dialysate)

Phosphate abnormalities

Phosphate is primarily an ICF anion mostly found in bone cells. Serum phosphate is only a minute percentage of total body phosphate, but since serum phosphate is in continuous equilibrium with total phosphate it can be used as an indicator of phosphate levels. Phosphate balance is maintained by oral intake, release from bones and renal reabsorption and excretion. It is an important electrolyte for fundamental reactions and is found in nucleic acid. Phosphate levels are closely linked with calcium, sodium and vitamin D.

Hypophosphataemia

Phosphate <0.8 mmol/L

Phosphate is mainly an ICF and shift into the cells can cause low serum phosphate levels.

Causes

- Dietary insufficiency: malnutrition and vomiting
- Vitamin D deficiency
- Hyperparathyroidism and after parathyroidectomy
- Re-feeding syndrome
- Dent's disease

Signs and symptoms

- Lethargy
- Muscle weakness and pain
- Decreased coordination
- Decreased cardiac contraction
- Diaphragmatic weakness
- Confusion
- Memory loss
- Hallucinations
- Convulsions

Treatment

- Oral phosphate replacement in mild cases
- Calcitriol
- Intravenous phosphate in severe cases

Hyperphosphataemia

Phosphate >1.15 mmol/L

Phosphate is excreted in the kidneys and therefore chronic renal failure is a major cause of hyperphosphataemia. As phosphate is one of the primary intracellular ions, its release from the cells is another cause of hyperphosphataemia. Excess phosphate can result in calcification of vessels and joints due to calcium phosphate.

Causes

- Chronic kidney failure
- Phosphate shift out of cells: rhabdomyolysis and tumour-lysis
- Iatrogenic: enemas containing phosphate

Signs and symptoms

- Asymptomatic
- Anorexia
- Nausea and vomiting
- Itching
- Hyper-reflexia
- Calcification of blood vessels and joints

Treatment

- If not severe, no treatment may be required
- Phosphate binders, e.g. magnesium antacids
- Dialysis

DEFINITIONS OF ESSENTIAL CONCEPTS

Some revision of basic biochemical concepts is crucial to understand the movement of fluids and electrolytes. We will look at the definitions of the essential forces responsible for water and electrolyte distribution throughout the body.

Osmosis: The movement of solutes across a semi-permeable membrane, from a solution with a lower concentration of particles (osmoles) to a solution with a higher concentration. In the human body, the solvent is water and the semi-permeable membranes are the cell membranes and capillary vessel walls. Water travels freely throughout all fluid compartments and is distributed via osmosis. Osmosis of water depends on the main osmole concentrations. Measurement of osmotic pressure is expressed in millimetres of mercury. This is a measure of the hydrostatic pressure needed to stop the osmosis of water.

Osmoles: Particles within a solution that cannot cross the semi-permeable membrane and hence exert an osmotic effect. The particles are measured in moles once dissolved in a solution, irrespective of whether they are atoms or molecules. Molecules that become ionised when dissolved (that is the compound dissociates into its components that have an electric charge once in solution) will have an effective osmolality depending on the number of particles they dissociate into.

Osmoles in the body: these include sodium, glucose, mannitol and sorbitol. Sodium is the main solute as it is the major ECF cation and cannot freely enter the cells. Glucose becomes relevant in diabetes mellitus because, unlike in health, it is not absorbed by cells and thus will have an osmotic effect on water.

Osmolality: The result of solute concentration. The number of particles within the solution will determine its osmolality, irrespective of their size. It is the measure of osmoles per kilogram of solvent (Osm/kg). It is not affected by temperature so it is often the preferred value when dealing with serum values.

Osmolarity: Measure of the osmoles of solute per litre of a solution (Osm/L). Is often used in IVF composition. However, the two definitions are very similar for plasma.

Plasma osmolarity = $2 \times (\text{Sodium} + \text{Potassium}) + \text{Glucose} + \text{Urea}$

Osmolar gap: OSM (measured) – OSM (calculated). If this is bigger than 10 it suggests the presence of another solute not measured, typically due to an excess of alcohol, sugars, proteins or lipids in the blood.

Tonicity: This is the force which moves water between compartments, across the semi-permeable membrane, and it is caused by the combined effect of all solutes within a single compartment. Tonicity is the ‘effective osmolality’. It is the concentration of particles in a solution and the effect this has on the diffusion of water. In the human body, the tonicity and osmolality effects are the same. Essentially, it is about movement of water across a semi-permeable membrane. So, increased tonicity means an increased concentration of osmoles in a solution and this attracts water from the neighbouring compartment. Tonicity stimulates thirst and ADH release.

- *Hypertonicity* reduces the cell volume and *hypotonicity* expands the cell volume due to the osmosis of water (more water = bigger size).
- *Hypertonicity* means that water will diffuse INTO the compartment and thus a reduction of water in the neighbouring compartment.
- *Hypotonicity* means water will diffuse OUT of the compartment and thus cause an increase in water in the neighbouring compartment. These terms are especially used in reference to IVFs.

CONCLUSION

In this chapter, we have reviewed the wide range of topics that underpin the physiological basis of water and electrolytes in the human body, and the IVFs and electrolytes we use to replace them when needed.

First, we have covered the water composition of the human body in the different compartments which should always be at the forefront of your mind when assessing a patient’s fluid status. The basics of movement of water throughout the body were outlined to help you understand the impact of prescribing different IVFs and electrolytes. To help with your fluid assessment, average human water inputs and outputs are highlighted and you can refer back to Table 2.1 when needed. To further aid with your IVF prescribing daily human water

and electrolyte requirements as per *NICE* guidelines are summarised in Table 2.2.

Second, we have summarised renal physiology. This is not a replacement for a dedicated physiology textbook, but we have outlined the main functions of the nephron. Furthermore, we have covered the kidneys' hormonal function with respect to water and electrolyte handling. Renal electrolyte handling was outlined for each electrolyte in order to provide you with some background knowledge when thinking about electrolytes.

Third, we have analysed IVF in both the subtypes (colloid and crystalloid) and individually. An in-depth overview of each IVF should be useful when debating which IVF to prescribe and hopefully should prompt you to tailor your prescribing, even on long night shifts. Specific uses of some IVFs and the need for prescribing by a senior were also highlighted.

Fourth, electrolyte abnormalities were summarised. Specific signs, symptoms, investigation and management of each electrolyte excess and deficit were covered.

Finally, we have expanded on some commonly used definitions. The grasp of these terms and their clinical application will not only aid you in better understanding this book but also more advanced texts and research on IVF should your interest take you further!

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Chapter 3

Cardiac arrest and shock

INTRODUCTION

Emergency situations such as peri-arrest, cardiac arrest and shock require prompt recognition and action to prevent significant morbidity or indeed mortality. As a junior doctor, you may well be the first person on the scene in an inpatient setting and are expected to help resuscitate and stabilise the patient, as part of a multidisciplinary team. This is the time to put your emergency care training into practice; do not hesitate to participate, your contribution is invaluable.

Specifically, this chapter focuses on those emergency situations that require consideration of the most appropriate intravenous fluid (IVF) therapy to administer: cardiac arrest, hypovolaemic shock, sepsis and anaphylaxis. Comprehensive management of these conditions is beyond the scope of this book; instead we aim to improve your knowledge of the IVF therapy aspects of management.

ASSESSMENT

The assessment of the unwell or collapsed patient is the same in hospital and in community settings and allows you to quickly determine if urgent resuscitation including fluid resuscitation is required. This involves the 'ABCDE' approach, using the team to simultaneously check and address problems at each stage. Assess your surroundings, ensure it is safe to approach the patient, and shake and shout to determine whether they are able to respond or not.

Airway

Airway obstruction is the partial or complete limitation of the entry of air into the lungs. A state of altered consciousness (sepsis, drug toxicity), airway inflammation (asthma attack, anaphylaxis) or physical obstruction by inhaled objects could cause this medical emergency. There is a risk of hypoxaemia, irreversible damage to vital organs and death. Symptoms and signs of airway obstruction are listed in Table 3.1. Remove any large debris within easy reach, gently tilt the head back-wards and lift the chin forwards to open the airway. If a neck injury is suspected, stabilise the neck but thrust the jaw forwards to maintain the airway. High-flow oxygen at 15 L/min should be commenced via a bag-valve mask and airway adjuncts can be used to maintain the airway in unconscious patients.

Table 3.1 Signs and symptoms of airway obstruction

| Symptoms | Signs |
|---|---|
| <ul style="list-style-type: none"> • Abnormal or absent breath sounds • Choking sounds • Stridor • Wheeze | <ul style="list-style-type: none"> • See-saw pattern of respiration • Accessory muscle use • Central cyanosis • Oxygen saturation <92% |

Breathing

Abnormal breathing can occur for several reasons including pulmonary oedema, severe pneumonia and tension pneumothorax. Determine if respiratory distress is present (Table 3.2), and look, listen and feel (<10 seconds) for signs of breathing. Inspect, percuss and auscultate the chest for clues to the underlying cause of respiratory distress.

Although the treatment of acute breathing problems depends on the underlying cause, all patients require high-flow oxygen to reduce the risk of hypoxaemia, respiratory arrest and death. Administer oxygen at 15 L/min via a bag-valve or pocket mask to maintain oxygen saturation greater than 92% and respiratory rate (RR) at 12–20 breaths/min. In those with known carbon dioxide retention secondary to chronic obstructive pulmonary disease (COPD), high oxygen levels may rarely lead to type II respiratory failure, so aim for oxygen saturation of 88%–92% instead. A 24% or 28% Venturi mask with a fixed flow rate can help with achieving these parameters. Review management and titrate oxygen flow rates in line with the patient's response to therapy, both clinically and on arterial blood gases (ABGs). Consider non-invasive ventilation if the patient tolerates it and does not require intubation.

Table 3.2 Signs and symptoms of respiratory distress

| Symptoms | Signs |
|---|---|
| <ul style="list-style-type: none"> • Abnormal or absent breath sounds • Sweating • Rattling airway noises • Altered consciousness | <ul style="list-style-type: none"> • See-saw pattern of respiration • Accessory muscle use • Central cyanosis • Oxygen saturation <92% • Respiratory rate outside the normal range of 12–20 breaths/min • Bronchial breathing • Chest hyper-resonance or dullness • Tracheal deviation |

Circulation

Assessing a patient's circulation refers to identifying haemodynamic collapse, otherwise known as circulatory failure; blood is either not being pumped around the body effectively or the amount of blood that is supplied to tissues is inadequate, leading to clinical manifestations of hypotension (see Table 3.3). Hypovolaemia (especially in haemorrhage) is a common cause of haemodynamic collapse and therefore should be considered and addressed quickly when faced with an acutely unwell patient. Whilst looking for the source of haemorrhage (overt or concealed), in the presence of hypotension, be sure to administer fluid challenge(s) (warm colloid, 500 mL stat or 250 mL if existing heart failure or trauma) to help replace lost intravascular fluid volume. If there is ongoing bleeding, crossmatch at least two units of red blood cells and consider instigating your hospital's major haemorrhage pro- tocol; large volumes of lost blood need to be replaced with similar volumes of transfused blood components.

Arrhythmia, underlying structural cardiac disease, chronic heart failure and of course problems with breathing (e.g. tension pneumothorax) can also cause haemodynamic collapse. The pathophysiology of haemodynamic collapse is covered in more detail in the 'Hypovolaemic Shock' section of this chapter.

Treating circulatory failure is multi-factorial and depends on the underlying cause; however, universal resuscitation aims to replace lost intravascular fluid, control haemorrhage and restore systemic circulation. Attach a defibrillator or cardiac monitor to the patient as soon as possible after identifying circulatory failure and follow the advanced life support (ALS) algorithm (see Figure 3.1 later in the chapter), prioritising chest compressions (30 chest compressions: 2 rescue breaths for adults).

After the initial fluid challenge, reassess the patient, and check the blood pressure (BP), heart rate (HR), RR and temperature every 5–15 minutes. Aim to restore the patient's normal BP or a sustained level above 100/60 mmHg. Auscultate the chest for pulmonary crepitations suggestive of fluid overload. Adjust the rate of fluid infusion accordingly if this occurs. If acute coronary syndrome is suspected or confirmed, administer Aspirin 300 mg, Clopidogrel 300 mg, Oxygen 15 L/min, Nitroglycerine and IV Morphine (MONAC). Arrange percutaneous coronary intervention if there is ST-elevation or a new left bundle branch block present.

Table 3.3 Signs and symptoms of circulatory

| failure Symptoms | Signs |
|--|---|
| <ul style="list-style-type: none"> • Pale, blue or mottled skin • Grey mucosal surfaces in dark-skinned people • Altered consciousness • Dizziness, pre-syncope • Dyspnoea • Bleeding from mucosal or wound surfaces • Bleeding into wound drains, packs, incontinence pads | <ul style="list-style-type: none"> • Capillary refill time (CRT) >2 seconds • Collapsed veins • Poorly palpable or bounding pulses • Tachycardia or bradycardia • Arrhythmia • Heart murmur or diminished heart sounds • Narrowed pulse pressure (<35–45 mmHg) • Low diastolic blood pressure (BP) (<50 mmHg) • Decreased urine output (<0.5 mL/kg/hr) |

Disability

This involves determining the level of unconsciousness in an unwell patient and identifying and managing the underlying causes of this. Ensure that the 'ABC' aspects of assessment have been identified and properly treated before moving on to 'D'. Causes of altered consciousness include cerebral hypoperfusion, profound hypoxia, hypercapnia, hypoglycaemia, sedatives and opioid analgesia. A rapid initial assessment can be made using the 'AVPU' method or Glasgow Coma Scale (GCS). If the patient is unresponsive to all stimuli or scores eight or less on GCS, a severe injury is indicated, their airway needs to be protected (intubation) and further investigation is required.

Venous or arterial blood gas measurement of blood glucose is more reliable than capillary measurement in a collapsed or unwell patient. If less than 4 mmol/L, administer 50-mL doses of 10% glucose intravenously until the patient becomes conscious or 250 mL is

given, whilst monitoring the blood glucose level.

Exposure

Whilst maintaining the patient's dignity, remove all outer clothing that impedes full patient assessment, remove wound dressings, inspect external surgical packs and roll the patient onto their sides. Aim to find more clues as to why the patient has deteriorated or become unconscious.

Once the initial 'ABCDE' assessment has been made and the patient is stable, further investigations such as an ABG, blood tests and imaging



4Hs and 4Ts

Hypoxia: Ventilate the patient with high-flow oxygen or via an advanced airway.

Hypovolaemia: Often caused by haemorrhage. Replace intravascular fluid volume with fluids or blood components. Stop ongoing loss.

Hypo-/Hyperkalaemia or other metabolic disturbances – quickly detect with an ABG/VBG. Reverse the disturbance and monitor cardiac activity in severe cases. IV calcium chloride in marked hyperkalaemia and hypocalcaemia.

Hypothermia: Use a low-reading thermometer to detect and correct with a warming unit and warm IVF.

Ensure you also pay attention to the patient's blood glucose level – many physicians advocate 'hypoglycaemia' as the fifth 'H'! It is easily missed but very easily treated.

Thrombosis: May cause pulseless electrical activity, consider thrombolysis.

Tension pneumothorax: Can occur after chest trauma or central line placement. Signs (absent breath sounds, deviated trachea, hyper-resonance) may indicate urgent thoracocentesis.

Tamponade (cardiac): Confirmed by echocardiography, treated in severe cases by pericardiocentesis.

Toxins: Have a low threshold for toxicology screens of blood, urine and hair. Consider antidotes and counter-agents such as naloxone and activated charcoal.

Early consideration and treatment of one or more of these conditions can improve the chances of successful resuscitation.

can be conducted to help determine the cause of the patient's abnormal state. These can provide clues to reversible causes such as electrolyte disturbances, sepsis and hypoxia, otherwise known as the 4Hs and 4Ts. See Chapter 2 for more on electrolyte disturbances.

IVF for resuscitation

There is still wide variation in clinical practice when it comes to selecting the most appropriate type of IVF to administer in initial resuscitation. This may be due to a reliance on clinical experience and difficulty applying findings from clinical trials to everyday practice. In general, several review and consensus bodies are currently advocating the use of balanced crystalloids (e.g. Hartmann's, Plasmalyte) in resuscitation of acutely unwell patients. This advice is based on several large studies comparing outcomes when different types of fluids are used for initial resuscitation (SAFE, CHEST, CRYSTMAS, GIFTASUP, FEAST, included in the 'further reading' list at the end of this chapter). Balanced crystalloids have a similar ion composition to plasma, as they are isotonic (see Chapter 2 for definitions of these terms). This means that ions distribute within the intravascular space and through the semi-permeable capillary membrane into the interstitial space. There is no forward movement into cells as they do not penetrate the cell's lipid bilayer membrane. Balanced crystalloids distribute between the intravascular space and the interstitial space at a ratio of approximately 25%–75%, respectively.

Intravascular volume is restored by increasing the oncotic pressure in the intravascular space, i.e. water moves into the intravascular space, increasing circulatory volume. However, this effect is short-lived with balanced crystalloids, as the majority of fluid administered migrates into the interstitial space. This means that a larger volume of balanced crystalloid is required to initially replace the deficit in the intravascular volume and then to maintain it over time.

Balanced crystalloids are not always the ideal IVF to administer as initial resuscitation, so we will also discuss the pathophysiology behind common emergency situations that may indicate alternative IVF.



IVF for initial resuscitation in an acutely unwell patient.

Secure a large bore cannula (14G or 16G).

Administer warm balanced crystalloids that contain sodium in the range 130–154 mmol/L (e.g. Hartmann's or Plasmalyte), with a bolus of 500 mL over 15 minutes or less (250-mL bolus if known to have chronic heart failure or elderly).

Review the implemented treatment within 15 minutes. Have the vital signs moved closer to normal levels? Or is there

no improvement? Consider further fluid boluses, remaining watchful for signs of leakage into the interstitial space and fluid overload.

If the patient is persistently hypotensive, consider better intravascular fluid volume expansion with a colloid infusion (500 or 250 mL of e.g. Gelofusin) or replace blood lost with appropriate blood transfusions. Investigate and manage reversible causes of acute clinical deterioration.

Colloid or crystalloid?

So far, we have established that current expert advice is to administer a balanced crystalloid in bolus form as part of initial resuscitation of an acutely unwell patient. The aims of administering IVF (balanced crystalloid, colloid, both or blood components) in this situation are to restore intravascular fluid volume, stabilise haemodynamics and maintain tissue perfusion.

Reduction or loss of circulating fluid volume decreases venous return, preload and in turn cardiac output. This leads to clinical manifestations of hypotension and poor peripheral and eventually central perfusion. The initial IVF in this situation acts as a rapid plasma volume expander; oncotic pressure in the intravascular space increases, water is drawn in and circulating volume increases. Improved central venous pressure (CVP), cardiac output, stroke volume, BP and tissue perfusion follow.

On the whole, colloids are good plasma volume expanders; they contain large molecules that do not easily cross the semi-permeable capillary membrane and the volume required to replace the deficit of fluid is 1:1. The ratio of required volume of balanced crystalloid to volume of fluid lost is 3:1 in comparison. Infused colloids also stay within the intravascular space for a longer period of time than crystalloids do. When used for resuscitation, colloids can cause anaphylactic reactions or peripheral/ pulmonary/cerebral oedema or heart failure, especially when used in

excessive volumes. Oedema occurs later than in crystalloid use, but is more sustained. In sepsis, anaphylaxis, severe trauma and other forms of inflammation, the capillary vessel walls become leakier, allowing the colloid molecules to cross into the interstitial layer – oedema. Some studies have also shown an increased risk of mortality with the use of colloids in these situations – avoid using them. In addition, large volumes of some colloids (starches, dextran) can contribute to coagulopathy by interfering with platelet function, and clotting factor complexes, especially if clotting factors are depleted and not replaced – avoid using them.

Although more robust clinical trials have been conducted and meta-analysed recently, a common outcome measured is mortality; starch-based colloids used as resuscitation fluids have been associated with a higher risk of mortality and therefore their use is advised against. Starch-based colloids and gelatins are also advised against in severe sepsis and those at risk of acute kidney injury.

In summary, balanced crystalloids (Hartmann's, Plasmalyte) are now the recommended fluid of choice for initial resuscitation of an acutely unwell patient, where there is no ongoing bleeding. Gelatin-based colloids (Volplex, Gelofusin) are useful when there is ongoing bleeding, whilst waiting for replacement blood to arrive. Treat the patient individually; they may need more than one type of fluid to restore adequate circulation and tissue perfusion, and in varying amounts. Monitor electrolyte levels to avoid life-threatening imbalances. As always, review your implemented treatment quickly, consider additional measures and seek senior and multidisciplinary help.

CARDIAC ARREST

If a patient is found to be unresponsive, not breathing and without a pulse, they are in cardiac arrest; there is a sudden cessation of organised electrical activity and the heart stops pumping effectively enough to maintain circulation and tissue perfusion. This emergency situation requires prompt action to have any chance of restoring life (see Figure 3.1).

Cardiac arrest is more common in those with coronary heart disease or with other underlying structural or electrical cardiac problems. An exacerbation such as sepsis, electrolyte disturbances, ischaemia or pro-arrhythmic drugs may trigger cardiac arrest in those with existing cardiac conditions such as myocarditis, long QT syndrome and chronic heart failure. Alternatively, cardiac arrest can be non-cardiac

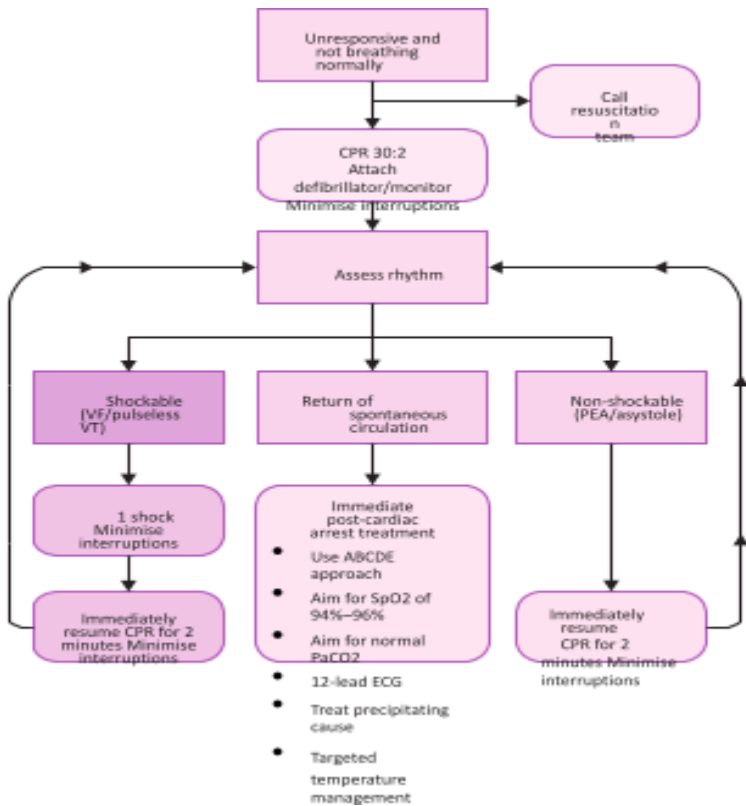


Figure 3.1 UK adult ALS algorithm. (From Resuscitation Council UK, *Adult Advanced Life Support*, 2016. <https://www.resus.org.uk/resuscitation-guidelines/adult-advanced-life-support/>. With Permission.)

in origin: near-drowning, pulmonary embolism or, drug toxicity for instance.

Essentially, the coronary and myocardial blood supply becomes disrupted by processes such as acute ischaemia in plaque rupture, electrolyte abnormalities or progressive worsening of cardiovascular function. These processes lead to un-coordinated electrical activity: ventricular fibrillation (VF), ventricular tachycardia (VT), asystole or pulseless electrical activity (PEA). In some cases, one abnormal heart rhythm can lead to another, such as sustained VT to VF.

Most hospitals have a rapid response team or similar; a multidisciplinary team tasked with assessing and stabilising the deteriorating patient

and one in whom cardiac arrest has been identified. If resuscitation is successful, the most immediate threat is haemodynamic collapse. The circulatory system attempts to restore perfusion to vital organs, but in this fragile state, hypotension and circulatory failure can develop. Aim to maintain a balance between restoring intravascular volume, perfusing vital organs and avoiding excess strain on the heart. Balanced crystalloids are preferred in the initial stage, but the risk of ensuing cerebral or pulmonary oedema with large volumes may indicate an early switch to a colloid infusion instead. Aim for a mean arterial pressure (MAP) of 80–100 mmHg, CVP of 8–12 mmHg and urine output of ≥ 0.5 mL/kg/hr.

The inflammatory response to cardiac arrest often leads to peripheral vasodilatation severe enough to require treatment with vasopressors and inotropes. Vasopressors like noradrenaline work predominantly by increasing peripheral vasoconstriction and thus peripheral vascular resistance to maintain cardiac output and circulation. An inotrope like dobutamine acts on β_1 receptors to increase the force of cardiac contractility and therefore cardiac output and circulation. Other factors to consider post-cardiac arrest are oxygenation, ventilation, correction of electrolyte disturbances and therapeutic cooling (to help minimise hypoxic-ischaemic brain injury). Note that decisions to use inotropes or vasopressors or therapeutic cooling are universally expected to be made by senior clinicians with the involvement of the high dependency/intensive care team. The patient is going to require close monitoring and is therefore often nursed in a high dependency, critical or intensive care setting anyway.

**REMEMBER****IVF for initial resuscitation in a patient surviving cardiac arrest**

Balanced crystalloids are preferred in the initial stage, but monitor the patient's response closely and alter the volume and type of administered fluid as necessary.

Aim for a mean arterial pressure (MAP) of 80–100 mmHg and urine output of ≥ 0.5 mL/kg/hr. Some clinicians still aim for central venous pressure (CVP) of 8–12 mmHg.

SEVERE SEPSIS AND SEPTIC SHOCK

Sepsis features systemic inflammation secondary to infection, the severity of which varies and can be fatal. Septic shock is a form of distributive shock whereby peripheral vasodilatation is impaired by the inflammatory process. The following criteria help to identify these conditions:

- **Severe inflammatory response syndrome (SIRS) criteria:**
 - Temperature $>38^{\circ}\text{C}$ or $<36^{\circ}\text{C}$
 - Pulse >90 bpm
 - RR >20 breaths/min or $\text{PaCO}_2 <32$ mmHg
 - White cell count $>12,000/\text{mm}^3$ or $<4,000/\text{mm}^3$
- **Sepsis criteria (SIRS + source of infection):** Suspected or identified source of infection
- **Severe sepsis criteria (organ dysfunction, hypotension or hypoperfusion):** Lactic acidosis, systolic BP <90 mmHg or drop ≥ 40 mmHg from normal
- **Septic shock criteria:** Severe sepsis with hypotension despite adequate fluid resuscitation
- **Multiple organ dysfunction syndrome criteria:** Evidence of ≥ 2 organs failing

The *Surviving Sepsis* guidance is now commonly used in most developed countries and aims to help clinicians identify and manage sepsis effectively, to reduce the incidence of significant morbidity and mortality from this treatable condition.

Infection or inflammation causes injury or death of cells, which coupled with the release of both pro- and anti-inflammatory mediators could lead to organ dysfunction and death; the body's defence mechanisms become overwhelmed. Circulatory dysfunction is common in sepsis and occurs via the following mechanisms:

- **Vasodilation:** Vasoactive mediators such as nitric oxide and cytokines relax vascular smooth muscle, capillaries become leakier and endothelial cells are damaged.
- **Hypotension:** Systemic vascular resistance is reduced, although not uniformly across vascular beds. Hypotension in sepsis does not respond to sympathomimetic vasopressors in the same way as

occurs in other causes of hypotension, perhaps due to endothelial damage. Vasopressin, however, does work.

- **Intravascular fluid redistribution:** The permeability of the capillary endothelium increases, allowing abnormal transport of ions and water across gradients. Intravascular fluid volume reduces (hypovolaemia) whilst interstitial fluid volume increases.
- **Ventricular function:** The myocardium becomes depressed, systole is not as forceful and the myocardium is more lax in diastole. Initially, tachycardia becomes a compensatory mechanism to help maintain cardiac output (Starling's mechanism), but over time, this diminishes.
- **Tissue hypo-perfusion:** Injury to cells and the increased permeability of capillary walls impairs the delivery of oxygen to tissues and therefore their normal function is affected; no organ is spared the possibility of this phenomenon, which can be irreversible.

Use the 'ABCDE' approach to help recognise sepsis, then start initial resuscitation quickly, aiming to stabilise the patient within the first 6 hours. Early goal-directed therapy involves following particular protocols that enable MAP ≥ 65 mmHg, urine output ≥ 0.5 mL/kg/hr and if available, central venous oxygen saturation of 70%. Lactate levels can also be used as a measure of response to resuscitation, as this normalises as resuscitation succeeds. Antibiotics should be administered; follow your local protocol when making a choice. The source of infection should be identified and attempts should be made to limit the spread of infection; change lines and catheters, and isolate if necessary.

Balanced crystalloids are the IVF of choice in resuscitation of sepsis: boluses of 500 mL or 250 mL in chronic heart failure or the elderly, or 30 mL/kg within 15 minutes. Stay with the patient, if the bolus works, an improvement in hypotension, tachycardia and RR should occur. Further fluid challenges, vasopressors and inotropes may be required to achieve the patient's measured goals. Seek the input of your seniors and the high dependency/intensive care team.



REMEMBER

IVF for initial resuscitation in a patient identified as having sepsis

Administer warm balanced crystalloids as a bolus of 500 mL over 15 minutes or less. 250-mL bolus if known to have

chronic heart failure or elderly. 30 mL/kg is recommended by the *Surviving Sepsis* guidelines.

Consider vasopressors and inotropes early in severe sepsis and septic shock.

Aim for a MAP ≥ 65 mmHg, urine output ≥ 0.5 mL/kg/hr, reducing lactate levels, and if available, central venous oxygen saturation of 70%.

ANAPHYLACTIC SHOCK

Anaphylaxis is an acute, severe, life-threatening, generalised or systemic hypersensitivity reaction mediated by the immune system. The majority of reactions involve IgE-dependent mechanisms, such as those triggered by foods, medications, insect stings and latex. Other reactions may be independent of IgE (IgG-dependent, clotting cascade activation), idiopathic or non-immunological; exercise, temperature extremes, contrast agents inducing a sudden massive mast cell or basophil degranulation without immunoglobulin presence.

Overall, anaphylaxis is a form of both distributive and hypovolaemic shock whereby multiple organs become compromised, especially the heart, circulatory system and lungs; circulatory collapse or respiratory arrest can occur if not treated promptly. Capillary permeability is increased by inflammatory processes, resulting in massive fluid shifts into the interstitial space, intravascular volume depletion and hypotension. There is reduced venous return and depressed myocardial contractility, which may progress to myocardial ischaemia and arrhythmias. The body tries to compensate for massive fluid shifts by releasing catecholamines and other vasoconstrictors to increase peripheral vascular resistance; however, shock can still persist if intravascular fluid volume is not restored. Tissue perfusion is decreased, which may lead to more widespread end-organ damage.

Symptoms may be non-specific, but the patient becomes rapidly unwell, requiring assessment with the 'ABCDE' approach and then appropriate resuscitation. Symptoms may include airway obstruction, facial swelling, itching, wheeze, hives/wheals and confusion. The onset of symptoms is often within minutes to hours of exposure to a trigger, although

in some cases, this can take several weeks. Most commonly, symptoms appear, intensify, peak and then wane; however, in some cases, there may be a biphasic or prolonged reaction. Patients can deteriorate very quickly making anaphylaxis a challenging situation to manage.

Immediate treatment involves removing the antigen (e.g. stopping the antibiotic infusion), calling for help, 'ABCDE' assessment, intramuscular (IM) or IV adrenaline, high-flow oxygen and volume resuscitation with crystalloids. Give a fluid challenge of 500–1000-mL Hartmann's/ Plasmalyte stat: larger volumes may be required, especially if there is slow improvement despite adrenaline. This implies ongoing intravascular volume depletion despite peripheral vasoconstriction.

In selecting a balanced crystalloid over other fluids, consider the following points:

- No benefit has been shown of colloids like gelatins over crystalloids such as Hartmann's and 0.9% normal saline in anaphylaxis resuscitation. There is a potential risk of anaphylaxis to infused colloid, especially in the immune system's already hyper-alert state.
- Dextrose rapidly migrates from the intravascular space to the interstitial space, therefore not correcting hypotension.

Antihistamines (offer relief from itching and urticaria), steroids (reduce the late-phase response and risk of prolonged anaphylaxis) and oxygen-nebulised bronchodilators (offer relief from bronchospasm) are also administered.



REMEMBER

IVF for initial resuscitation in a patient identified as having anaphylaxis

Identify and address the trigger for anaphylaxis, call for help and administer adrenaline as soon as possible.

Large volumes (several litres) of balanced crystalloid (Hartmann's or Plasmalyte) may be required to maintain intravascular fluid volume. Start with a bolus of 500–1000 mL stat, review the observations within 15 minutes and administer more as necessary.

Colloids may trigger anaphylaxis and have not been shown to have any significant benefit over crystalloids in resuscitation from anaphylaxis.

HYPOVOLAEMIC SHOCK

Hypovolaemic shock arises as a result of loss of blood or salt and water from plasma. This can therefore be haemorrhagic or non-haemorrhagic in origin. Haemorrhagic causes include trauma, gastrointestinal (GI) bleeding, ruptured aneurysm and post-partum haemorrhage. Non-haemorrhagic causes include loss through the GI tract (diarrhoea, stoma output), renal system (diabetes insipidus, osmotic diuresis), skin (burns) or into the third space in the post-operative state. This text will focus on haemorrhagic shock.

There is a phased response to hypovolaemia, depending on the volume of fluid or blood lost and the time scale. Initially, the body tries to compensate; baroreceptors detect the reduced intravascular volume and trigger the release of catecholamines (peripheral vasoconstriction). This increases intravascular fluid volume (leading to increased preload), systemic vascular resistance (measured as afterload), BP and therefore tissue perfusion. Cardiac sympathetic drive also increases to produce tachycardia and increased cardiac output. Other early compensatory mechanisms include movement of fluid from the intracellular and interstitial spaces to the intravascular space.

As further intravascular fluid volume depletion occurs with advancing hypovolaemic shock, the compensatory mechanisms become overwhelmed; systemic vascular resistance and BP are not well maintained, and profound hypotension occurs. Vasopressors may be used to address this if there is no improvement despite restoring intravascular fluid volume. The initial tachycardia becomes bradycardia, and the force of ventricular contractility diminishes. Haemorrhagic shock in particular causes a significant lactic acidosis; reduced tissue perfusion means oxygen is in short supply, anaerobic metabolism occurs, and insufficient ATP is produced leading to cell death and end-organ dysfunction.

Compensation for hypovolaemia shifts to a longer term phase with a reduction in glomerular filtration rate, salt and water reabsorption (mediated by aldosterone, vasopressin) and increased erythropoiesis (more red blood cells providing increased oxygen-carrying capacity). These effects are thought to occur once effective arterial blood volume reduces by approximately 30%. The patient's clinical status changes, and signs and symptoms of hypovolaemia and end-organ dysfunction develop; the situation can deteriorate into circulatory collapse and cardiac arrest if not treated promptly.

The aims of resuscitation in haemorrhagic shock are to stop the bleeding and restore intravascular fluid volume, tissue perfusion and oxygen delivery to prevent irreversible organ damage and death.

In haemorrhagic shock, fluid challenges of warm, balanced crystalloids can still be used initially, but then follow this with red blood cells as soon as possible or with a colloid if there is a delay. Remember that 0.9% normal saline can cause hyperchloraemic acidosis and renal impairment, so avoid its use in large amounts. Consider transfusion of blood components (see Chapter 6) early in the process of resuscitation, especially if haemorrhage has not been stemmed yet. Remember that the volume of replacement blood should match the volume of lost blood; if 2 L of blood has been lost, this is the volume that should be replaced. In the immediate period after haemorrhage, there will not be a drop in haemoglobin count; emptying half of a bucket of blood will leave you with the same concentration of blood in your bucket, just at a lower volume. A drop in haemoglobin count occurs over time, when dilution takes place by physiological fluid shifts between compartments or when intravascular fluid is administered.

Do not wait for laboratory results of full blood count (FBC) and clotting profiles before requesting cryoprecipitate, fresh frozen plasma or platelet transfusions. If there is ongoing bleeding, clotting factor replacement is essential, before disseminated intravascular coagulation (DIC) develops. Thromboelastography-guided transfusion is a newer concept that uses real-time collation of coagulation test results to determine the performance of the clotting system and therefore guide blood component administration.

Stay with the patient, closely monitor and review the implemented treatment, and summon the emergency response team to help. Use the major haemorrhage protocol to alert the multidisciplinary team (including the laboratory technician) and summon help in dealing with this emergency.

Observations should be checked every 5–15 minutes in hypovolaemic shock, as they are a good indicator of improving intravascular fluid volume and restoration of tissue perfusion. BP, HR, oxygen saturation and urine output should be improving; if not, re-assess, and use the ‘ABCDE’ approach again. Is there any further intervention possible to help the patient? Is imaging required to help determine whether there is ongoing concealed bleeding? Does the patient need a surgical procedure to explore for and stem ongoing bleeding? Gastroenterologists should be involved if upper GI bleed is suspected. Interventional radiologists may be required

to perform embolisation or other procedures to stem bleeding from the mid-GI tract or other areas that are difficult to access surgically.



IVF for initial resuscitation in a patient identified as having hypovolaemic shock

Secure a large bore cannula (14G or 16G). Instigate the major haemorrhage protocol if appropriate.

Administer warm balanced crystalloids that contain sodium in the range 130–154 mmol/L (e.g. Hartmann's or Plasmalyte), with a bolus of 500 mL over 15 minutes or less. Follow with a colloid (e.g. Gelofusin or Volplex) if hypotension persists and whilst awaiting the arrival of blood to transfuse.

Do not wait for full blood count (FBC) and clotting profile results before ordering cryoprecipitate, fresh frozen plasma or platelets; ongoing bleeding depletes clotting factors, so consider replacement early in the resuscitation process.

Central venous and arterial lines can be sited to help with

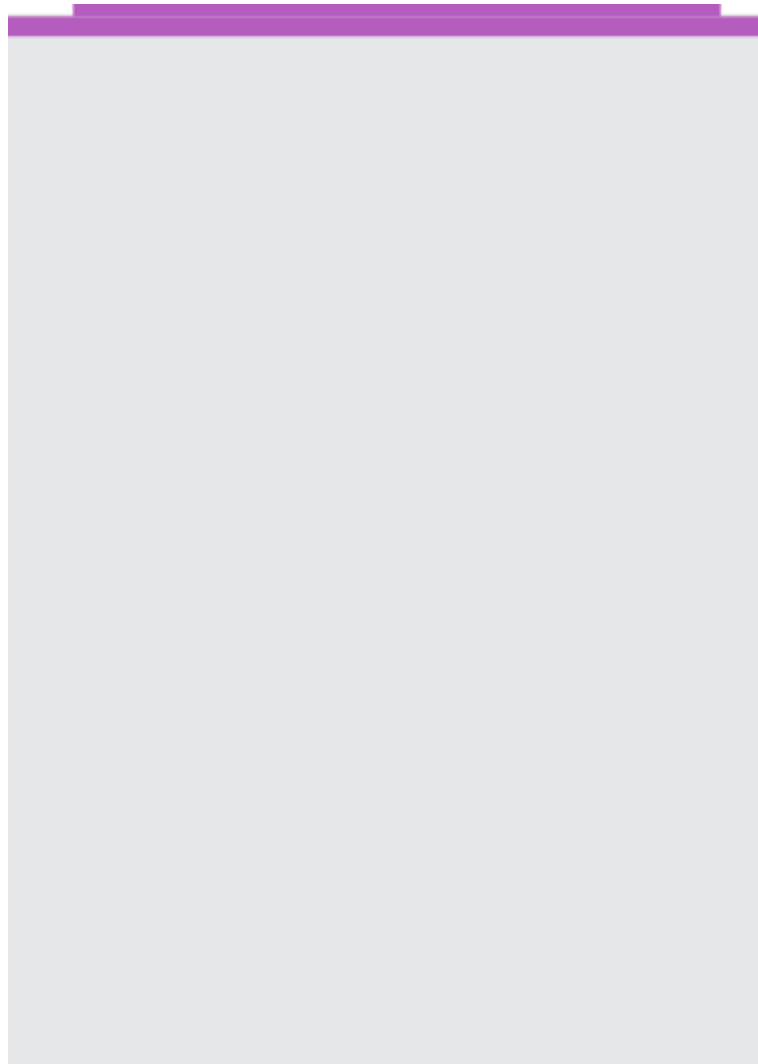
monitoring of the response to resuscitation. Aim for a MAP ≥ 65 mmHg, urine output ≥ 0.5 mL/kg/hr, reducing lactate levels, and if available, central venous oxygen saturation of 70%.

ABG/VBG readings can be obtained to help monitor lactate, electrolyte and haemoglobin levels and determine if acidosis is improving with resuscitation.

CONCLUSION

Overall, recognition of the critically ill or unresponsive patient should trigger prompt action to resuscitate and treat the underlying cause. Use the 'ABCDE' approach to identify the deteriorating patient and monitor for signs of improvement once resuscitation is underway. A good choice for initial fluid resuscitation is a 500 or 250 mL challenge of a balanced crystalloid. Monitor for signs of improvement; if none are apparent, consider more of the same, or an alternative such as a colloid fluid or blood components. Once the patient is stabilised, the next steps should include decisions about the location of care (general ward, high dependency unit [HDU], intensive care unit [ICU], tertiary

centre), as well as whether further attempts at resuscitation should be made if the situation occurs again. These decisions should be made in conjunction with senior colleagues and the intensive care team, including discussion with the patient's family where possible.



A 32-year-old woman with no significant past medical history is

admitted with a productive cough. She has right-sided basal crackles on chest auscultation.

Her observations are as follows:

HR 110 bpm (normal sinus rhythm)

BP 90/50 mmHg

RR 22 breaths/min

SpO₂ 95% on room air

Temperature 38.5°C

CRT of 4 seconds

Venous blood gas (VBG):

pH 7.28

BE -8

Bicarbonate 16

Lactate 4.0

Sodium 145

Chloride 112

Potassium 4.9

Urea 9.1

Creatinine 180

What is the likely diagnosis?

The likely diagnosis in this patient is sepsis secondary to community acquired chest infection/pneumonia.

What are your priorities in treating this patient?

Address abnormalities found during the 'ABCDE' assessment.

Implement the 'Sepsis Six' – high-flow oxygen, antibiotics, IV fluid resuscitation, blood cultures, urine output and lactate measurement.

Hallmarks

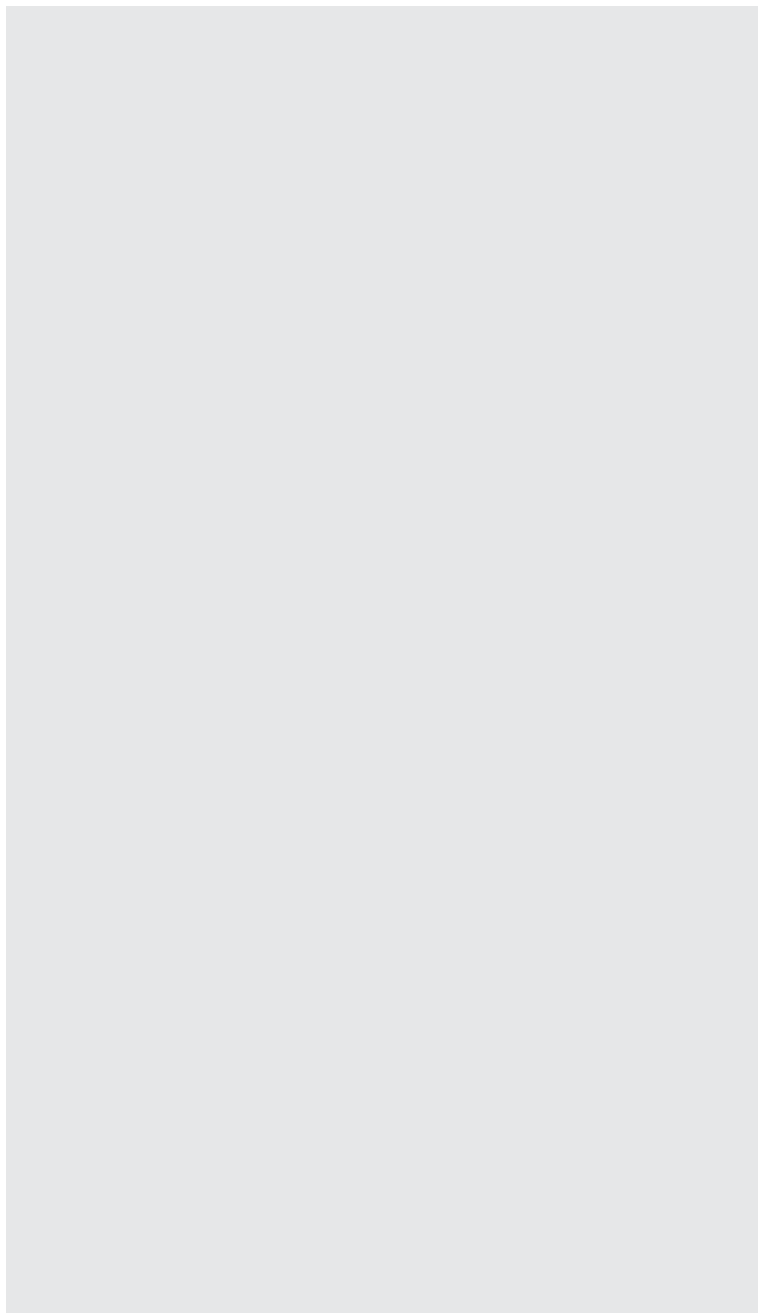
Temperature >38°C or <36°C

Pulse >90 bpm

RR >20 or PaCO₂ <32 mmHg

White cell count >12,000/mm³ or <4000/mm³

Suspected or identified source of infection



Management

Focusing on suitable fluid management in this case, a balanced crystalloid, like Hartmann's solution, would be the recommended

fluid as per *Surviving Sepsis* guidelines.

Sodium chloride should be avoided because the patient is already profoundly hyperchloraemic and hyperchloraemia is linked to poor tissue perfusion and renal impairment requiring renal replacement therapy.

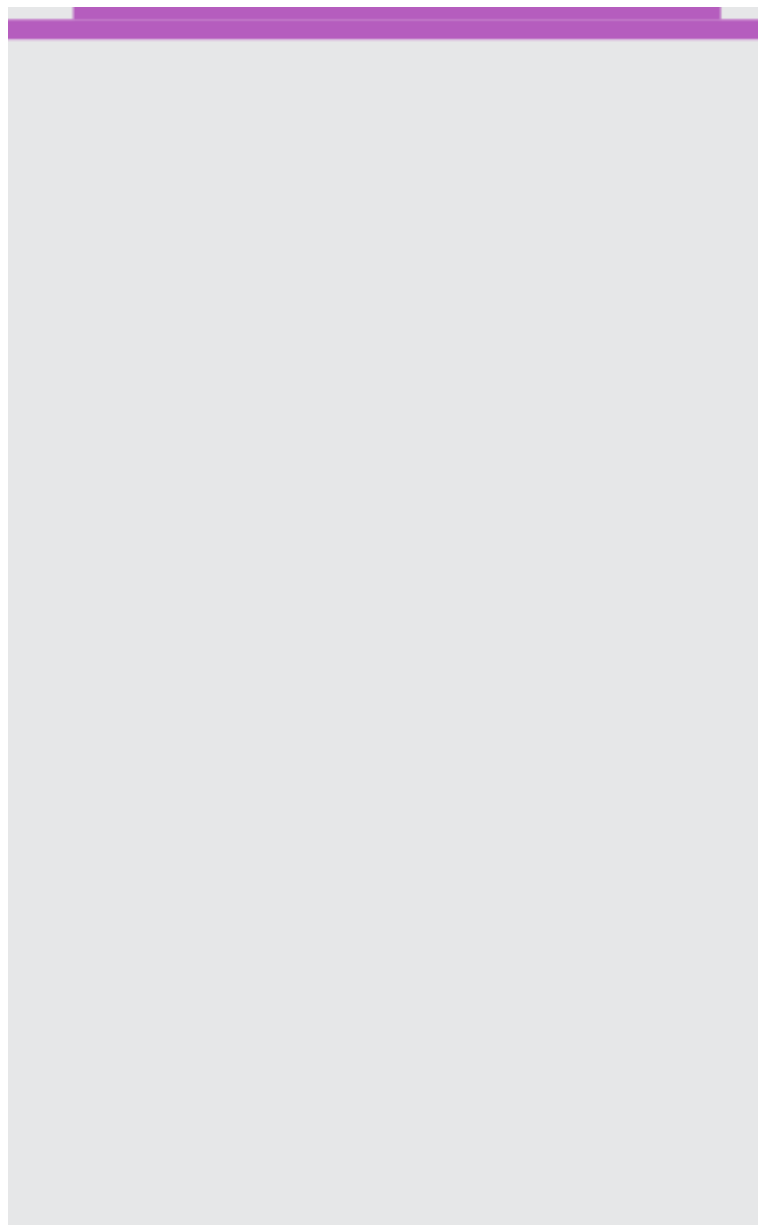
Of note, there is a tendency amongst junior doctors to avoid administering Hartmann's in patients with a raised lactate level. This would seem like common sense because Hartmann's in itself contains sodium lactate. However, it is important to remember that the sodium lactate component is metabolised to bicarbonate and water by the liver, thus acting as a buffer in patients with metabolic acidosis.

Lactate level is a reliable marker of tissue hypoperfusion.

Of note, this patient's potassium at 4.9 mmol/L is at the upper limit of normal. Despite Hartmann's solution containing 5 mmol/L of potassium, it is still the best option. The reason for this is that hyperchloraemia is often linked with metabolic acidosis. The body tries to compensate physiologically for the acidosis by shifting hydrogen ions into the cell in exchange for potassium which moves out of the cell into the plasma. If an alkalinising solution such as Hartmann's or Plasmalyte is administered this process gets reversed and potassium shifts back into the cell. Hence, as acidosis is reversed with appropriate fluid resuscitation, potassium will move back into the cells and the relative hyperkalaemia will correct.

Hartmann's solution should be administered as a 500-mL stat infusion since the patient is young and has no comorbidities. A more cautious initial fluid challenge of 250 mL would be recommended in frail or elderly patients or those with chronic heart failure.

The patient should constantly be reassessed for the response to the fluid challenge. The expected response in this patient to 500 mL of Hartmann's would be a drop in HR, increase in BP and an improving blood gas picture. If the response is only temporary, this suggests that there is room for more filling, whereas if sustained improvement results, then normovolaemia/euvolaemia is achieved. In this case, it would be likely that this young patient has a much greater fluid deficit in view of decompensated metabolic acidosis and would need further fluid boluses.



A 19-year-old male attends A&E on the advice of staff at the sexual health clinic he went to first. Upon seeing the FY2 doctor,

he states that he has developed a tingling sensation in the back of his throat and itching around the genital area. He has had these symptoms for about 12 hours and does not feel quite right; he has been unable to go to work. There is no significant PMH. Here is a summary of your assessment:

Airway: Patent. He is able to complete full sentences and when you inspect the throat and neck, there is no obvious abnormality. During the consultation, he starts to cough more and more violently.

Breathing: No wheeze or abnormal breath sounds auscultated. RR 22 breaths/min. Oxygen saturation 98% on air.

Circulation: Flushed appearance of the face and trunk. Cool peripheries, CRT 4 seconds. HR 100 bpm. BP 90/70 mmHg.

Disability: GCS score 15/15. Cranial and peripheral nerve examinations are normal. Capillary blood glucose level is 6.0 mmol/L. Urinalysis shows moderate leucocytes only.

Exposure: As he mentioned genital itching, an examination of the genitalia is performed. There is marked erythema and swelling around the mons pubis, scrotum and penis.

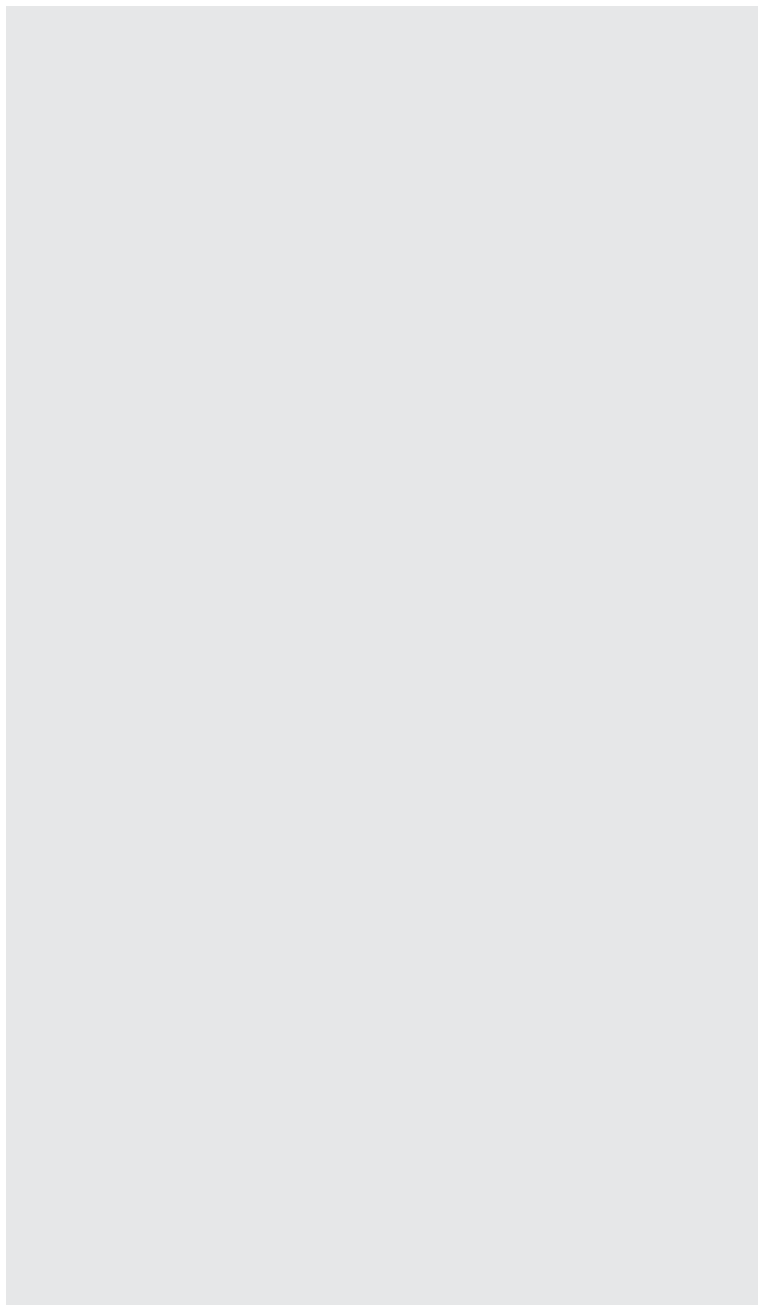
Upon further questioning, he reveals that he had sexual intercourse the previous night, and as this was with a new partner, he used a latex condom.

What is the likely diagnosis?

The likely diagnosis in this patient is mild/early stages of anaphylaxis triggered by latex condom use.

What are your priorities in treating this patient?

Measures should be taken to prevent this progressing to a severe reaction to latex. Call for help and move the patient to an area where he can be monitored for signs of deterioration, as it is not often possible to predict how quickly this can happen. The trigger has already been removed. His airway is patent; however, he is showing signs of abnormalities in breathing and circulation. Administer adrenaline (1:1000) 500 micrograms, assess if further doses are required. Administer high-flow oxygen and insert a wide-bore cannula. Although he is currently normotensive, the pulse pressure is narrow; administer a balanced crystalloid or normal saline to help maintain intravascular fluid volume. If he suddenly



becomes hypotensive, the rate of fluid administration can be sped up. He should be advised to use latex-free condoms in future.

Hallmarks

- Variable symptoms
- Exposure to a suspected or known allergen
- Acute onset of illness involving skin, mucosa or both, with respiratory or circulatory compromise (or both)

Management

The mainstay of management of anaphylaxis is to aim to prevent further clinical deterioration. Adrenaline acts as a vasopressor and is given intramuscularly at an adult dose of 0.5 mg (= 500 micrograms = 0.5 mL of 1:1000) or intravenously by a specialist at adult bolus doses of 50 micrograms = 0.5 mL of 1:10,000. An adrenaline infusion may be required. Do not delay adrenaline use, it must be administered as soon as possible after anaphylaxis has been recognised; this is why patients are given their own administration devices once the condition has been diagnosed.

Administer high-flow oxygen at 15 L/min via a non-rebreather mask. Start IVF as soon as possible, to address hypotension and circulatory collapse. Large volumes of fluid can shift from the intravascular space into the interstitial space due to the increased permeability of capillaries. A balanced crystalloid should be given as a fluid challenge of 500 mL over 15 minutes; assess the response to this with measurement of BP, HR, RR and urine output and administer more as necessary. Use the 'ABCDE' approach to assess and manage the patient. After immediate resuscitation, administer chlorphenamine, hydrocortisone and bronchodilators, and in specialist settings (intensive care), other vasopressors or inotropes may be used to keep the patient stable. They should remain in hospital for at least 8 hours for observation, and upon discharge, arrangements should be made for the patient to have an adrenaline auto-injector and for follow-up for investigation of other allergens.

Investigations

Baseline FBC, U&Es, clotting and liver profiles should be obtained. ABG or VBG can provide quick information about the patient's acid-base status and electrolyte abnormalities. Specifically, in anaphylaxis, mast cell tryptase levels (peak at 1–2 hours after onset) are useful in confirming anaphylaxis, especially when the diagnosis is unclear or there are concurrent conditions like asthma.

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| 3. 70 kg = 10,5 L | 6. 100 kg = 15 L | | | | | | |
| Dịch lòng mạch (5% TLCT) | | | | | | | |
| 1. 2,5 L 2. 3 L 3. 3,5 L 4. 4 L 5. 4,5 L 6. 5 L | | | | | | | |

Chapter 4

Intravenous fluid therapy in medical patients

INTRODUCTION

The optimal fluid management of medical patients is of great importance and is often poorly managed. The role of the physician in accurately assessing fluid status, losses and requirements is critical.

Medical patients can present with multiple co-morbidities that make fluid management challenging, for example the septic patient with congestive cardiac failure (CCF).

Medical wards cannot provide the invasive monitoring and high staff to patient ratios that are found in an intensive therapy unit/high dependency unit (ITU/HDU) environment and some patients may not be appropriate for escalation to these levels of care. This means that good clinical fluid assessment, scrupulous fluid balance monitoring, and sound clinical judgement and knowledge are required by all junior doctors working on medical wards.

Decisions regarding intravenous fluid (IVF) therapy are often far from routine – do not hesitate to seek senior or specialist advice, for which this chapter is no substitute.



Maintenance fluids in medical patients

'Doctor, could you just come up to the ward to write up some fluids?'

Prescribing maintenance intravenous fluids should not be considered a robotic or routine task; it is the same as prescribing medication. Careful assessment of fluid status and exacting fluid prescription is of paramount importance, as is checking the patient's most recent blood results.

When asked to prescribe maintenance fluids always consider the **reason** for IVF therapy (is it still necessary?).

Check:

- Patient fluid status
- Electrolyte requirements, recent U+Es
- Any special considerations from their medical history

Aim to encourage oral intake as much as possible.

MEDICAL CONSIDERATIONS IN FLUID

ASSESSMENT AND MANAGEMENT

To cover both urine output and insensible losses, healthy adults require around 30–40 mL/kg of water over 24 hours. This equates to 2–2.5 L of fluids/day in a 70-kg adult. These requirements will be different in some groups of patients, for example those in renal failure or the frail elderly. This is discussed in detail in the sections that follow.

No fluid balance available:

- Estimated maintenance from weight
- Estimate insensible losses (0.5–1.5 L/24 hours)
- Estimate deficit: From your fluid assessment

Fluid balance available:

- Recorded intake and losses from chart
- Estimate insensible losses (0.5–1.5 L/24 hours)
- Estimate deficit: From your fluid assessment

Once the fluid requirements are known they can be written up as 500- and 1000-mL bags at the appropriate rate. Do not forget to factor in oral intake. **Where it is safe to do so**, prescribe fluids so that they will run out during the next working day so that the team looking after the patient can reassess.

Table 4.1 A guide to clinically estimating fluid deficit

| Fluid deficit | Mild | Moderate | Severe |
|---------------------|---------------|--|---|
| Heart rate (HR) | Normal (N) | >100 | >120 |
| Blood pressure (BP) | N | SBP < 20 mmHg decrease DBP < 10 mmHg decrease | SBP > 20 mmHg decrease DBP > 10mmHg decrease |
| Urine output | >0.5 mg/kg/hr | <0.5 mg/kg/hr | <0.3 mg/kg/hr |
| % Body weight loss | 3–5 | 5–10 | 10–15 |
| Estimated deficit | <750 mL | 750 mL–1.5 L | >1.5 L |



REMEMBER

Ask your patient if they feel thirsty - a good sign they are not fluid depleted! However, it is important to note that elderly patients often lose their thirst awareness so in these patients it is not a good marker of fluid depletion.

Also, ensure that they have access to oral fluids and if not able to feed themselves that they are being

assisted in doing so – 10 minutes spent helping a patient drink some water is time well spent!

Typical maintenance fluid regimes in medical patients

There are a number of factors to consider when prescribing maintenance fluids in medical patients; in summary:

- ‘1 salt and 2 sweet’: This rigid approach is completely outdated and no longer valid, as fluid therapy should be based on an individual patient’s needs.

- Balanced fluids, such as Hartmann's solution and Plasmalyte, are generally the first-line choice.
- NICE guidance gives a clear approach to replacement and maintenance of fluids (see 'Further Reading' section).
- Colloids: Semi-synthetic colloids such as Geloplasma/Gelofusine are used less frequently in clinical practice. They would be a reasonable choice in patients who are thought to be in hypovolaemic cardiac arrest. They should also be considered in bleeding patients, whilst waiting for blood products to arrive.
- Blood components are the best replacement for lost blood and act as the natural colloid (see Chapter 6).
- Hypertonic solutions: Generally reserved as a 'holding measure' for patients with intracranial pathology who have evidence of raised intracranial pressure and are awaiting definitive therapy. Hypertonic saline is also used in patients with severe symptomatic hyponatraemia. Hypertonic saline should not be used outside ITU unless under direction of the endocrine team. Never give hypertonic solutions without seeking specialist, senior advice.

IVF THERAPY IN THE CONTEXT OF SPECIFIC MEDICAL PRESENTATIONS

In this section, we consider IVF therapy in the context of specific medical presentations. These have been split into the following four broad categories:

1. Fluid depletion/dehydration (for example, diarrhoea and vomiting)
2. Fluid overload (for example, CCF)
3. Complex fluid states (for example, hepatorenal syndrome [HRS])
4. Other presentations (for example, fluids at the end of life)

Fluid depletion

The management of fluid depletion is essentially to replace the fluid and electrolytes that have been lost. A large amount of fluid can be lost from the gastrointestinal (GI) tract and we have covered the basic physiology of how water and electrolytes move in and out of cells. However, one must also consider why and how fluid is depleted (Table 4.1):

- a. Is my patient fluid depleted?
- b. What have they had?

- c. How much fluid are they taking in?
- d. How much are they losing/passing as urine?

Has the patient responded to a fluid challenge?

If a fluid challenge has not made a difference after what is considered an adequate amount for the patient, patient care must be escalated to a senior clinician immediately and HDU care should be considered.

Topics covered:

- a. Acute kidney injury (AKI): Including rhabdomyolysis and chronic renal failure
- b. Diarrhoea and vomiting
- c. Burns and toxic epidermal necrolysis
- d. GI bleeds: Covered in a case in Chapter 6 (see section ‘Blood Components’)

Fluid overload

Fluid overload is when there is too much water in the body or it has entered the wrong compartment, like excess fluid in the interstitial tissue. Management of these states is very much dependent on the origin of the fluid overload and treating the underlying cause, while ensuring symptomatic relief and off-loading the excess fluid.

Cardiac failure is one of the major causes of fluid overload and so an explanation of how cardiac failure causes fluid overload is outlined.

Topics covered:

- a. CCF and pulmonary oedema
- b. Liver failure and ascites
- c. Chronic renal failure: Covered under AKI in fluid depleted states

Complex fluid states

In patients where complex overlapping pathology has led to fluid shifts, secondary to a variety of processes, the way ahead is rarely clear. Seek senior help early and escalate promptly to the HDU/ITU if there is

not a satisfactory response to treatment. For example, consider this in cases such as the following:

- a. Sepsis and CCF, chronic kidney disease (CKD)
- b. AKI and CCF

These medical presentations can be very complex and each patient should be treated individually depending on the extent of each pathology. We cannot cover such complex management in a step-wise manner, and for such cases a thorough fluid assessment (outlined in Chapter 1) and senior input should be undertaken swiftly.

Electrolyte abnormalities can also cause complex fluid states as their serum concentration can be simultaneously dependent and influence the body's water content. For example, consider hyponatremia, covered in Chapter 2 in the section Electrolyte Abnormalities.

Topics covered:

- a. Hepato-renal syndrome (HRS)
- b. Hypercalcaemia of malignancy: Covered in Cases at the end of this chapter

Other fluid states

This includes management of conditions that are complex and do not fit into the previously mentioned categories.

Topics covered:

- a. Fluids at the end of life
- b. Fluids in the elderly

FLUID DEPLETION

Acute kidney injury

AKI is commonly seen in hospitalised patients. Essentially AKI encompasses acute renal deterioration of any cause.

History

Current medical problem

There are many risk factors for AKI such as the following:

- Sepsis
- Liver failure

- Heart failure (HF)
- Diabetes mellitus
- Major surgery
- Trauma
- Old age and physical frailty
- Ischaemic heart disease (IHD)
- Nephrotoxic drugs

Broadly speaking, the causes for AKI can be divided into three groups, which are as follows:

- Pre-renal
- Renal
- Post-renal

Pre-renal AKI, which is the most commonly seen type, is caused by volume depletion. Renal AKI may be caused by drugs (such as angiotensin-converting enzyme [ACE]-inhibitors) or autoimmune conditions. Post-renal AKI is caused by obstruction. It is vital to identify the cause for the AKI early, as this dictates management. It is equally important to treat the underlying condition and stop any nephrotoxic drugs.

Current fluid status

A thorough clinical assessment of the patient's volume status, as already described in Chapter 1, is of utmost importance. Patients who are deemed volume-depleted require fluid resuscitation, patients who are deemed euvoelaemic do not necessarily require any IVF and patients who are clinically fluid-overloaded require loop diuretics or even emergency haemofiltration in an HDU setting (see the 'Management' section for haemofiltration criteria). The clinical aim is to achieve and maintain a euvoelaemic state.

Patients with AKI can have a normal urine output (prognostically favourable), be polyuric (which tends to occur in the resolving stages of AKI) or be oligo-anuric. The latter carries the worst prognosis and managing these patients is often quite challenging, because they require very frequent assessments of their fluid status. If they are clinically euvoelaemic, a 'watch and wait' strategy often has to be adopted until the patient either improves or deteriorates.

Investigations

A urine dipstick offers useful information. If more than one plus of protein is detected, send a urinary polymerase chain reaction (PCR) spot urine test. If a renal cause for the AKI is suspected, it is advisable to send a nephritic screen, complement levels, an auto-antibody screen and a myeloma screen in elderly patients. In this patient group, seek advice from a nephrologist early.

According to *NICE* Guideline 169, an urgent renal ultrasound (i.e. within 6 hours) should be performed in the following cases:

- Suspected renal obstruction
- Suspected pyonephrosis
- Patients with oligo-anuria
- Renal transplant patients



REMEMBER

If the cause of the AKI is thought to be pre-renal, patients do not necessarily require an ultrasound scan (USS) provided they are clinically improving.

Management

Treat the underlying cause

Specific management of each condition is required, which is beyond the scope of this book.

Treat the current fluid status

The *KDIGO* Guideline (2012) recommends a balanced crystalloid, such as Hartmann's or Plasmalyte, as the first-line fluid. Both fluids are alkalising and have 'buffering' effects, which is desirable as most AKI patients frequently have a degree of metabolic acidosis and also often lose bicarbonate in the urine. Plasmalyte has the advantage that it contains less chloride than Hartmann's. There is some evidence that hyperchloraemia is an independent predictor of mortality and leads to worse patient outcomes, which is why it should be avoided.

Normal saline contains a lot of chloride (154 mmol/L) and should ideally be avoided, unless the patient has severe hyperkalaemia.

1.26% sodium bicarbonate may be an appropriate fluid to administer in AKI patients who are fluid-depleted, have a metabolic acidosis with

concomitant hyperkalaemia and a low intrinsic bicarbonate level on their blood gas. It is advisable to seek senior input in these cases.

Criteria for emergency renal replacement therapy are as follows:

- Symptomatic uraemia
- Fluid overload refractory to loop diuretics, glyceryl trinitrate (GTN), morphine and continuous positive airway pressure (CPAP)/Optiflow
- A persistent severe metabolic acidosis
- Refractory severe hyperkalaemia

Review of implemented treatment

Patients with renal pathology will require regular review of their renal function via urine output and U+Es.

Special considerations – fluid management in patients with renal pathology

Fluid therapy in chronic renal failure

Clinical evaluation of volume status is vital in this patient group. Dialysis patients are usually on a fluid restriction regime and their management should always be discussed with their primary dialysis centre. The same rule applies to patients with a renal transplant. If there is clinical evidence of organ underperfusion, small aliquots of IVF may be appropriate. Balanced crystalloids should be the first-line choice. Monitor potassium and avoid hyperkalaemia.

Rhabdomyolysis

Rhabdomyolysis leads to release of myoglobin from muscle tissue. Under certain conditions, for example in volume depletion and acidic urine, myoglobin can precipitate with the body's intrinsic Tamm–Horsfall protein in the renal tubules and cause/exacerbate AKI. Early aggressive IVF therapy is the most important aspect of treatment and is required to 'flush the kidneys', increase estimated glomerular filtration rate (eGFR), minimise the nephrotoxic effects of myoglobin and aid its elimination from the body.

The treatment goal is to achieve 'high ins and outs', i.e. aggressive fluid therapy with a high urine output.

There is some evidence that urine alkalinisation may prevent precipitation of myoglobin and hence prevent AKI – pay particular attention

to the urinary pH on a urine dipstick. If it is less than 6.50 (i.e. acidic), use intravenous 1.26% sodium bicarbonate to alkalinise the urine, aiming for a urinary pH of greater than 6.50. Maintain this therapy until the myoglobinuria has resolved (as evidenced by clear urine and a urine dipstick negative for blood).

Monitor the patient's U+Es, including calcium, as well as the creatine kinase (CK).

Radiological contrast and IV fluids

Patients who require investigations involving iodinated contrast agents and who either have established AKI or are at risk of contrast-induced nephropathy (same risk factors as for AKI) should have renoprotective measures instituted prior to their investigation. Unless the patient is hypervolaemic, current evidence supports intravenous prehydration with normal saline or 1.26% sodium bicarbonate to ensure a euvoalaemic state before any contrast is administered. There is also some weak evidence that oral N-acetylcysteine may help prevent contrast-induced nephropathy.

It is advisable to familiarise yourself with your hospital's trust policy and to inform the radiology department that a patient has or is at risk of AKI. Iso- or low-osmolar agents with lower iodine contents are often selected in these cases.

You should also consider temporarily stopping any nephrotoxic drugs, particularly if the patient has significantly impaired renal function or chronic renal failure with an eGFR of less than 60 mL/min/1.73 m².

Post contrast exposure, the patient's renal function should be monitored for up to 5 days.

Diarrhoea and vomiting

Background physiology: GI causes of fluid depletion

Absorption and secretion of water occur throughout the intestine in normal circumstances. Diarrhoea results from disruption to the water and electrolyte transport in the small intestine. Intestinal transport mechanisms underpin the management of diarrhoea through oral fluid therapy and feeding.

A healthy adult imbibes approximately 2.5 L of fluid each day. Secretions including saliva, gastric and pancreatic juices plus bile add

approximately 6.5 L. This amounts to 9 L of fluid that enter the small intestine every day.

In the small intestine, water and electrolytes are simultaneously absorbed by the villi and secreted by the epithelial crypts. Hence, there is two-way flow of water and electrolytes between the intestinal lumen and the circulation. In health, fluid absorption exceeds secretion with a net result of fluid absorption.

In normal circumstances, more than 90% of fluid is reabsorbed in the small intestine. Approximately 1 L enters the large intestine where further reabsorption takes place. Usually only 100–200 mL of water is lost in solid stools.

Decreased absorption or increased secretion in the small bowel leads to an increase in the amount of fluid entering the large bowel. When this exceeds the limited absorptive capacity of the large bowel, then diarrhoea occurs.

Absorption of water and electrolytes

- Water is absorbed down the osmotic gradient created when solutes, especially sodium, are absorbed from the gut lumen by the villous epithelial cells.
- Sodium can be absorbed directly, linked to chloride, glucose or amino acid absorption or exchanged for hydrogen ions.
- Addition of glucose to an electrolyte solution can increase sodium absorption threefold.
- Sodium is then transported out of the epithelial cells by Na^+K^+ -ATPase ion pumps which transfer sodium to the extracellular fluid (ECF), increasing the osmolality.
- Water and other electrolytes then follow passively down the concentration gradient from bowel lumen through intercellular channels into the ECF.

Diarrhoea

Diarrhoea is defined by the World Health Organisation as having three or more loose or liquid stools per day, or as passing more stools than is normal for that person.

Diarrhoea is a common cause of death in the developing world. It is a relatively rare cause of death in the developed world but nevertheless

left untreated and without fluid rehydration it can lead to serious morbidity. Those patients at extremes of age are at particularly high risk.

Diarrhoea types

Secretory:

- Abnormal secretion of water and electrolytes into the small bowel
- Impaired sodium absorption in the villi
- Chloride secretion continues or increases
- Net fluid secretion
- May be result of effects of bacterial toxins or viruses on bowel mucosa

Osmotic:

Presence of poorly absorbed, osmotically active substance in gut lumen causes water and salts to move rapidly across the small bowel epithelium to maintain osmotic balance.

- Can occur when lactase deficiency or glucose malabsorption is present.
- If the gut contents are hypertonic, then electrolytes and water will pass down their osmotic gradient into the gut lumen from the ECF causing diarrhoea and loss of body water.

Secretory diarrhoea is more common but intestinal infections can cause diarrhoea by both mechanisms.

Diarrhoea results in loss of water and electrolytes such as sodium, chloride, potassium and bicarbonate. There may be additional water and electrolytes lost in vomitus and through increased insensible losses due to pyrexia. These losses lead to the following:

- Dehydration (loss of water and sodium chloride)
- Metabolic acidosis due to bicarbonate loss
- Potassium depletion

Dehydration can lead to decreased blood volume (hypovolaemia), cardiovascular collapse and death if severe cases are not treated

promptly. Dehydration can be classified into the following three types:

- Isotonic
- Hypertonic (hypernatraemic)
- Hypotonic (hyponatraemic)

History

Current medical problem

There are many causes of diarrhoea including the following:

- Bacterial infection, e.g. *Salmonella*, *Shigella*, *Campylobacter*, *Escherichia coli*, *Clostridium difficile*
- Viral infection, e.g. rotavirus, norovirus
- Inflammatory bowel disease
- Drugs, e.g. antibiotics, chemotherapeutic agents
- Gut ischaemia
- Appendicitis
- Food allergy/intolerance, e.g. coeliac disease

Current fluid status

Patients will generally have fluid depletion due to excess fluid loss, with varying degrees of dehydration (see 'Examination' section that follows).

Examination

Patients will be generally unwell, with nonspecific signs and symptoms of GI upset. Abdominal pain may be present, rarely with tenderness on examination. Assessment of dehydration is very important as it can cause severe morbidity.

Dehydration with 5% body weight loss

- Thirst
- Decreased skin turgor
- Tachycardia
- Dry mucous membranes/cracked lips
- Sunken eyes
- Sunken anterior fontanelle in infants
- Oliguria

Severe dehydration with 10% body weight loss

- Hypotension
- Anuria
- Cool extremities
- Reduced conscious level
- Signs of hypovolaemic shock

>10% body weight loss

- Circulatory collapse and death

Investigations

Blood tests

- Full blood count (FBC): White blood cells (WBC) may be raised, haemoglobin (Hb) might be raised in severe dehydration.
- U+Es: Hypokalaemia and hyponatraemia, urea is raised in dehydration and creatinine may be raised due to AKI caused by dehydration (pre-renal).

ECG

If electrolyte imbalance is severe, e.g. hypokalaemia-associated changes.

Stool samples

Send stool samples to isolate the causative agent.

Management

Treat the underlying cause

Patients should be isolated until the causal agent is identified and treated. Once the causal agent is treated or removed, stools usually return to normal.

Appropriate antibacterial or antiparasitic medications should be used to target the specific cause. If there is need for antibiotics, usually targeted anaerobic antibiotics guided by microbiology will be used. Some antibiotics can actually cause severe diarrhoea and colitis, such as ciprofloxacin.

Management of diarrhoeal dehydration should focus on rapidly correcting fluid and electrolyte deficits – ‘rehydration therapy’ – and then replacing further fluid and electrolyte loss until the diarrhoea resolves.

Fluid losses can be replaced orally or intravenously, the intravenous route usually being reserved for initial rehydration of severe cases, see the following.

*Treat current fluid status***Oral rehydration therapy:**

Intestinal absorption of sodium is enhanced by the active absorption of certain molecules like glucose. This glucose-linked sodium absorption can be applied to rehydrate patients using oral rehydration salt solutions. Water and other electrolytes follow sodium down the osmotic gradient and rehydration occurs. This is effective fluid replacement in most patients with secretory diarrhoea.

Oral rehydration therapy may be unsuccessful in the following:

- Patients with great stool loss, e.g. >15 mL/kg/hr
- Patients with glucose malabsorption
- Patients with severe unremitting vomiting

In cases of severe dehydration where life is endangered, initial rehydration must be achieved rapidly and this requires intravenous infusion of water and electrolytes. The intravenous route is also warranted where patients are unable to drink or have paralytic ileus.

IVF can rapidly restore blood volume and correct shock. A number of IVF are available but all are deficient in some of the electrolytes required to restore the deficits caused by acute diarrhoeal dehydration. Even where intravenous rehydration is required in the initial treatment of dehydration, oral fluid replacement should be co-instituted at the earliest opportunity.

IVF rehydration therapy:

There are many intravenous solutions available and in extreme situations; even intravenous coconut water has been successfully utilised!

Hartmann's solution, also known as Ringer's lactate solution, is the best readily available IVF option. Hartmann's is isotonic with blood and contains 130 mmol/L of sodium and 28 mmol/L lactate, which is metabolised to bicarbonate that can correct acidosis. Hartmann's contains no glucose and only low concentrations of potassium but these can be provided through additional intake of oral rehydration salts when appropriate. Hartmann's solution can be used universally to correct dehydration secondary to diarrhoea and in all patient age groups.

It should be noted that 5% plain dextrose solution is not a suitable intravenous solution as it does not contain any electrolytes, correct acidosis or effectively treat hypovolaemia.

Review of the implemented treatment

Treatment should be reviewed after implementation; monitor the patient closely for warning signs of fluid overload or continued dehydration. Special attention to electrolytes is needed to ensure the losses have been replaced and normal values are not exceeded. Thus, all patients receiving electrolyte replacement therapy need regular serial blood tests.

Special considerations

The following guideline should be considered when treating children:

- Diarrhoea and vomiting caused by gastroenteritis in under-fives: diagnosis and management *NICE* guidelines [CG84], published date: April 2009

Vomiting

Vomiting is a reflex action where stomach contents are forcefully ejected through the mouth. It is mediated by the vomiting centre, which resides centrally in the reticular formation of the medulla and receives impulses from the chemoreceptor trigger zone, heart, GI tract, abdominal organs and peritoneum via sympathetic nerves and the vagus nerve. The act of vomiting is coordinated via motor impulses through the cranial nerves to the upper GI tract and through spinal nerves to the abdominal muscles and diaphragm.

History

Current medical problem

There are many causes of prolonged vomiting such as the following:

- Chemotherapy-related
- Drug-related, e.g. opiates, antibiotics
- Infection-related/gastroenteritis: viral or bacterial
- Pyloric stenosis
- Small bowel obstruction
- Mesenteric ischaemia
- Pancreatitis
- Raised intracranial pressure, e.g. brain tumour
- Poisoning
- Pregnancy: Hyperemesis gravidarum

GI causes:

- Gastroenteritis, bacterial or viral
- Gastritis
- Food poisoning
- Gastroesophageal reflux disease (GORD)
- Pyloric stenosis
- Bowel obstruction
- Peritonitis
- Paralytic ileus
- Pancreatitis

Drugs:

- Opiates/opioids
- Chemotherapeutic agents
- Antibiotics

Central nervous system causes:

- Ménière's disease
- Concussion
- Migraine
- Brain tumours
- Benign intracranial hypertension and hydrocephalus

Metabolic causes:

- Hypercalcaemia
- Uraemia
- Adrenal insufficiency
- Hypo/hyperglycaemia

Pregnancy:

- Hyperemesis gravidarum

Current fluid status

Prolonged vomiting can result in dehydration and potential electrolyte imbalance. Vomiting of gastric contents leads to direct hydrochloric

acid loss (protons/ H^+ and chloride ions/ Cl^-). Parietal cells in the stomach produce more hydrochloric acid (HCl) and in doing so they secrete bicarbonate ions into the bloodstream. This occurrence is known as the alkaline tide. This increases the blood pH. Combined, this results in hypochloreaemic metabolic alkalosis (low chloride and high bicarbonate levels with a raised blood pH). Hypokalaemia and hyponatraemia may also be present.

Examination and investigation

Dehydration in vomiting will present in the same way as in diarrhoea; see the aforementioned section for signs, symptoms and investigations of dehydration.

Management

Treat underlying cause

- The underlying cause and duration of vomiting should be elucidated and treated.
- The sequelae and complications of nausea and vomiting (e.g. fluid depletion, hypokalaemia, and metabolic alkalosis) should be identified and corrected.
- Targeted treatment should be provided, when possible (e.g. surgery for bowel obstruction).

Treat current fluid status

The fluid replacement treatment of dehydration secondary to prolonged vomiting begins with an assessment of the extent of dehydration and measurement of serum electrolytes. These findings will guide the required fluid management.

In less severe cases, rehydration can still be achieved via the oral route with oral rehydration salt solutions.

The classical cause of hypochloreaemic metabolic alkalosis is pyloric stenosis in infants. It should be noted that this is classified as a medical as opposed to a surgical emergency and it is essential that fluid and electrolyte loss be corrected prior to any operation proceeding. In these cases, initial replacement is with 0.9% normal saline along with dextrose and subsequently, potassium supplementation.

Successful fluid resuscitation has been achieved when the patient is well perfused and serum electrolytes have returned to normal values with particular attention paid to chloride and bicarbonate levels.

Review of the implemented treatment

Same as for diarrhoea, as mentioned previously.

Burns**History***Current medical problem*

Burns or adverse drug reactions such as toxic epidermal necrolysis (TEN). It is important that the 24-hour period be determined as commencing from the time of the burn and not the time of presentation.

Current fluid status

Burns can result in massive fluid loss as the skin usually acts as a barrier without which intracellular and interstitial fluid can evaporate. Thus, patients suffering with burns will usually exhibit fluid depletion.

Examination

An assessment of burn surface area (BSA) can be made using the rule of nines and is carried out with the patient fully exposed. Care should be taken to minimise exposure time during assessment as burns patients can become hypothermic very quickly.

The rule of nines divides the body into areas which are given a percentage of total body surface. The following body areas are presumed to account for 9% of BSA each: head, arm, chest and abdomen. The following body areas are presumed to account for 18% of BSA each: back and leg. Calculation of total BSA can be made by estimating the extent of burns across different body parts and then adding them together.

Most emergency departments will also have a Lund–Browder chart which can be used to make a quick assessment of burn area.

The most commonly used formula in the United Kingdom to predict total fluid requirement (in the first 24 hours) is the Parkland formula (see ‘Management’ section).

Investigations*Bloods*

- FBC: ↑Hb due to fluid depletion and Hb concentration
- U+Es: ↑K released from damaged cells. ↑Creatinine, ↑urea caused by pre-renal AKI in cases of insufficient fluid resuscitation
- Arterial blood gas (ABG): ↑lactate, ↑base excess and metabolic aci-

dosis due to hypovolaemia and hypoperfusion

Management

Treat the underlying cause

Management of burns is a specialist subject and will not be covered here. Essentially, it consists of ensuring the burns remain clean and no suprainfection develops, minimising heat loss and allowing healing to develop. A large amount of fluid can be lost through burns and appropriate fluid management is crucial.

Treat the current fluid status

Fluid management in burns rests on initial resuscitation and subsequent calculation of replacement fluids based on the patient's percentage burn surface area (BSA).

The Parkland formula can be used, where total replacement fluid is a product of weight and BSA multiplied by 4 mL (fluid required in 24 hours = $BSA \times \text{weight [kg]} \times 4 \text{ mL}$).

Resuscitation should involve rapid clinical assessment of the patient's fluid status including blood pressure (BP), heart rate (HR) and capillary refill time (CRT). Be sure to assess both injured and non-injured limbs since the burn itself can affect assessment of perfusion.

Large bore intravenous access should be inserted and resuscitation commenced with warmed Hartmann's solution. The presence of shock necessitates a search for another cause (trauma or bleeding) since significant hypovolaemia is unlikely to be due to the burn injury alone.

A urinary catheter should be inserted aiming for a urine output of at least 0.5 mL/kg/hr in adults and 1 mL/kg/hr in children. If this is not achieved then resuscitation fluids should be increased.

Once the total fluid requirement for the first 24 hours has been calculated, any fluid that has already been administered should be subtracted from this amount.

The remaining volume should then be divided in half. This is the amount that should be delivered within the first 8 hours; the remainder should be given over the following 16 hours.

Review of the implemented treatment

It is important to re-assess your patient frequently to judge the adequacy of resuscitation. Accurate fluid assessment may not be possible due to insensible losses from the burns area, therefore base your

assessment on other signs and symptoms that might indicate fluid depletion: thirst, cardiovascular parameters, urine output.

Special considerations

Hypovolaemia is rarely due to the burn alone. Be sure to look for other sources of blood loss or trauma.

Guidelines

- Review the Parkland diagram for assessment of burns.

Electrolytes

- Regular monitoring of electrolytes is needed as both water and salts are lost from the burns.

FLUID OVERLOAD

Background physiology: Cardiology causes for fluid overload

Management of fluid status in patients with cardiovascular disease must take into account the extent of underlying disease and the immediate management of life-threatening conditions. Use the ABCDE method (see Chapter 3), addressing any emergency situations first.

Background

Cardiac failure arises when the heart's work as a pump becomes inadequate in supplying the cell's metabolic requirements. There are many causes of heart failure (HF), ischemic heart disease (IHD) being the most common one, resulting in decreased cardiac output. Cardiac output is influenced by: preload (volume of blood going into the right side of the heart), afterload (pressure against which the left side of the heart contracts), myocardial contractility and HR.

Here are some examples:

- Myocardial infarction (MI) will cause a decrease in contractility due to infarcted myocardium being replaced by inflexible scar tissue.
- Hypertension (HTN) will lead to an increase in systemic vascular resistance, resulting in increased work of the heart.
- Valvular disease: aortic stenosis increases afterload, whereas aortic regurgitation increases preload.
- Conduction problems, such as arrhythmias and heart blocks, affect HR.

Congestive cardiac failure

This condition describes failure of both the right and left sides of the heart, often as a result of failure of one side eventually impacting on the other. The heart pumps inadequately so that excess fluid accumulates in the vascular tree, which eventually seeps out into the interstitium and causes oedema.



REMEMBER

Mean Arterial Pressure = Cardiac Output \times Systemic Vascular Resistance

Cardiac Output = HR \times Stroke Volume

Decreased cardiac output will in turn trigger:

- Increased autonomic sympathetic activity.
- The alpha-1 receptors will increase peripheral vasoconstriction and reduce venous compliance, leading to a rise in systemic vascular resistance.
- The beta receptors will increase cardiac rate and contractility, which will put more strain on the heart.
- The Renin–angiotensin–aldosterone system (RAAS) is activated and increases the sodium and water content of the body, increasing the blood volume, leading to a rise in both preload and afterload.
- ADH levels rise, causing water retention which increases the blood volume and preload.

The body's response to HF is the same as in massive haemorrhage, and results in increased blood volume, afterload, preload, cardiac rate and contractility, which in turn worsens the HF.

History

Current fluid status

Symptoms of left ventricular failure:

- Shortness of breath (SOB), orthopnoea, paroxysmal nocturnal dyspnoea (PND), cough (pink frothy sputum), nocturia, tiredness, weakness.

Symptoms of right ventricular failure:

- Increasing leg swelling, increasing abdominal girth, nausea, anorexia.

Current fluid status

- Increased extracellular fluid volume (ECFV): Fluid overload.

Sodium content

- Normal: increased sodium = increased water (so this is a sodium regulation problem, e.g. RAAS).
- Reduced (hyponatraemia): increased sodium < increased water (so this is a water and sodium regulation problem, e.g. inappropriate ADH activation).

Tonicity

- Increased due to raised sodium levels
- Increased due to glucose in hyperglycaemia, diabetic ketoacidosis (DKA)

Past medical history

Possible cardiovascular disease: MI, angina, atrial fibrillation (AF), CCF, CKD, HTN.

Medication

- Anti-hypertensives
- Diuretics
- Beta-blockers
- ACE inhibitors
- Electrolyte supplement

Examination

Signs of left ventricular failure:

- Any signs of fluid in the lungs: third and fourth heart sounds, tachycardia, tachypnoea, wheeze, increased respiratory rate, cold peripheries, muscle wasting.

Signs of right ventricular failure:

- Any sign of excess fluid in the periphery: peripheral/sacral oedema, ascites, facial engorgement, raised jugular venous pressure (JVP).

Investigations*Bloods*

- FBC: ↓Hb will put extra strain on the heart.
- U+Es: ↑creatinine, ↑urea, ↑K due to diuretics, CKD, AKI

- Liver profile: ↑alanine aminotransferase (ALT) + alkaline phosphatase (ALP) in right-sided failure indicates hepatic congestion.
↓Albumin (oedema)
- Cardiac enzymes: Troponin to assess for MI, brain natriuretic peptide (BNP) is the biomarker of HF; >100 ng/L is diagnostic.
- ABG: Respiratory failure due to pulmonary oedema, acidosis due to renal failure or ↑K, raised anion gap due to secondary causes such as hyperglycaemia or alcohol.

ECG

AF, ischaemia, MI new/old, conduction abnormality, dysrhythmias.

Imaging

- Chest radiograph: Signs of fluid overload: cardiomegaly, upper lobe diversion, alveolar oedema, interstitial oedema and pleural effusion.
- Echocardiogram: An ejection fraction (EF) of less than 54% indicates left ventricular systolic failure but note that EF can be greater than 54% in diastolic failure, where the essential problem is ‘stiffness’ of the heart muscle.
- Ultrasound: Right-sided HF can be indicated by cardiac cirrhosis/free fluid around the liver and congested hepatic veins. Inferior vena cava assessment can also give information about the systemic vascular resistance and preload.

Management

In this situation, it is important to optimise the patient’s preload, without exacerbating fluid overload (remember the Frank–Starling mechanism). Cautious small fluid boluses, generally with a balanced crystalloid, should be delivered if the patient is deemed volume-deplete. Endpoints of resuscitation, such as BP, HR and urine output response, should be reviewed 10–15 minutes after administration of a fluid challenge.

Fluid: These patients will not usually require supplementation with IV fluids, but if IV fluids are needed, use *a balanced crystalloid*.

Treat the underlying cause

- Manage underlying cause of HF, e.g. valve disease, dysrhythmias, ischaemia.

- Manage exacerbating factors: infection, anaemia, HTN, thyroid disease.
- Medication review: nonsteroidal anti-inflammatory drugs (NSAIDs) contribute to fluid retention, verapamil is negatively inotropic, beta-blockers, although indicated in chronic HF, can exacerbate acute CCF. Consider omitting other anti-hypertensives if diuretics or a GTN-infusion will be used.

Treat fluid overload

Acute pulmonary oedema

- 100% oxygen via a non-rebreathe mask.
- Furosemide 20–120-mg IV stat (depending on the patient's body size, larger patients need more diuretic).
- GTN spray two puffs sublingually, if no improvement and SBP >90 mmHg, consider starting a GTN infusion.
- Morphine 2.5–10-mg IV slowly (dose depends on the patient's body size).
- Patients may require non-invasive ventilation (NIV)/CPAP if they are not responding to the aforementioned measures.
- Diuretic therapy can be helpful, but remember to review the patient's sodium and potassium levels before initiating.

Special considerations

Differential diagnoses

Chronic obstructive pulmonary disease (COPD), pulmonary embolism (PE).

Guidelines

- Framingham criteria for CCF.
- New York Health Association classification of HF.
- *NICE guideline 108 for the treatment of chronic CCF*: Use of ACE inhibitors, beta-blockers, mineralocorticoid receptor agonists such as Spironolactone or Eplerenone, digoxin, vasodilators such as a nitrate, hydralazine or calcium-channel blocker. More specialised treatments for HF include ultrafiltration (in diuretic-resistance), device therapy (biventricular pacing and ventricular assist devices) and heart transplantation.



REMEMBER

Furosemide is a loop diuretic; it can cause hypokalaemia and hypernatraemia, by way of its action on the Na/K/CL co-transporter pump system in the ascending limb of nephrons. Patients on diuretics require regular monitoring of their U+Es.

Review treatment

- Patients will require regular/continuous monitoring (BP, ECG, saturations) until they are stabilised; consider HDU care.
- Patients with decompensated HF and AKI will often require invasive haemodynamic monitoring and therefore HDU care. Getting the fluid balance right in this particular group of patients is one of the most challenging situations to be encountered in medicine!
- Continuous BP monitoring, titrate GTN to ensure systolic BP >100 mmHg.
- Urine output monitoring, strict fluid balance chart. Patients will often require fluid restriction.
- Dietary sodium restriction.
- Daily weights, as changes will represent fluid level alteration.
- Repeat U+Es with diuretic use to ensure there is no evolving electrolyte abnormality or worsening renal function.
- Serial ECGs.
- Rate-control if the patient is in fast AF. Digoxin is the drug of choice in this situation. Beta-blockers should be avoided/temporarily discontinued in acute HF.
- If the patient is tachypnoeic or saturations are <90% despite high-flow oxygen consider NIV, CPAP or Optiflow. Senior support is required.
- If the patient becomes shocked and systolic BP <85 mmHg consider vasoactive support with continuous ECG and BP monitoring, senior support and HDU care are required.
- If the acute HF develops in the context of an acute coronary syndrome, percutaneous coronary intervention may be required urgently. Discuss with a tertiary centre.

Liver disease

Chronic liver disease and cirrhosis

Cirrhosis is the condition where healthy liver cells are replaced by scar tissue and one of its most common complications is ascites (the accumulation of fluid in the peritoneal cavity).

Ascites

It is thought that peripheral arterial vasodilatation leads to an under-filled circulatory system, thereby activating the RAAS via its baroreceptors. This leads to sympathetic nervous system (SNS) and non-osmotic release of antidiuretic hormone (ADH) and results in sodium and water retention. As the liver disease worsens this results in fluid retention and ascites.

Hepatorenal syndrome

This is a type of functional renal failure due to low cardiac output and poor renal perfusion. It is managed using drugs that restore renal blood flow through peripheral arterial vasoconstriction, renal vasodilatation and plasma volume expansion (see more detail in the section ‘Complex Fluid States’).

History

Current medical problem

Patients with liver disease can present either with acute liver failure (see ‘Special Considerations’ section that follows) or as exacerbation of chronic liver disease either in compensated or decompensated state. The worsening hepatic function could be the natural progression of liver disease or due to another concurrent medical problem. Liver disease is very complex and it is beyond the scope of this book to cover the aetiology and management of liver disease.

The following sections on History, Examination, Investigation and Management are also applicable for the HRS Syndrome section and are repeated in that section with specific focus on HRS.

Current fluid status

Ask about the acute presentation; ask in particular about the following:

- Duration of any symptoms
- Nausea, vomiting, fatigue, weakness

- Decreased urine production
- Jaundice with dark urine
- Symptoms of ascites: Abdominal swelling, dyspnoea
- Symptoms of bacterial peritonitis: Signs of infection with abdominal pain/tenderness with ascites
- Confusion and altered sleep/wake cycle (symptoms of hepatic encephalopathy)

Past medical history

- Known chronic liver disease.
- Current or recent viral or alcoholic hepatitis.
- Past episodes of ascites/spontaneous bacterial peritonitis.
- Family history of liver problems.
- Alcohol: Ask about alcohol intake, current and historical. In particular, are they currently abstinent and if so, for how long?

Examination

Assess for signs of chronic liver disease such as palmar erythema, spider naevi, caput medusae, altered pattern of body hair ('hairless man'), gynaecomastia and decompensation (jaundice, ascites).

Check for a liver flap (asterixis) and confusion which are suggestive of encephalopathy.

Fluid status

- Assessing fluid status in patients with ascites can be challenging. Remember that these patients can be intravascularly deplete.
- Pay particular attention to the JVP; check CRT and monitor the urine output to assess this.
- They may also have fluid overload due to renal dysfunction and/or excess IV fluid therapy.

Investigations

All patients with acute liver failure and ascites need an urgent ascitic tap to rule out spontaneous bacterial peritonitis

Bloods

- FBC: Macrocytic anaemia.
- U+Es: Creatinine can be elevated, sodium <130 mmol/L suggests HRS.
- Clotting: Be aware that while many liver patients will have deranged clotting screens, they are in fact in a coagulopathic state so may require thromboprophylaxis.
- Liver function tests (LFTs): A full liver screen should be carried out if the aetiology of the liver disease is not known.
- Serum lactate (levels over 3 mmol/L signify poor prognosis).
- Blood glucose at least 2-hourly.

Sepsis is a common precipitant of decompensated chronic liver disease so ensure a full septic screen is sent.

Imaging

- Abdominal USS with portal and hepatic vein Dopplers to look at liver architecture and look for signs of portal HTN/thrombus and also to characterise small volume ascites.
- Chest x-ray (CXR) may show raised diaphragm (splinting from ascites).

Fluid assessment

- Urinary catheter
- Consider use of a cardiac output monitor

Management*Treat underlying cause*

Supportive therapy whilst liver function recovers: Ensure bowels opened at least twice a day to prevent encephalopathy, give lactulose to promote NH_4 excretion in the bowel and ensure adequate nutritional support.

Ascitic drains (with IV albumin cover to prevent post-paracentesis circulatory problems) will reduce discomfort in tense ascites. Shunt placement can also be considered in order to redistribute fluid.

The definitive treatment is a liver transplant, where indicated.

Treat the current fluid status

Restricting water intake:

ADH release results in water retention and consequent dilutional hyponatraemia. However, there is no evidence that water restriction in cirrhotic patients improves hyponatraemia.

Sodium restriction:

This is often done through dietary restriction.

Diuretics:

Spironolactone is commonly used and has been shown to be more efficacious than salt restriction alone.

Review of the implemented treatment

Patients with liver disease need frequent review as their fluid status can fluctuate.

Special considerations

Acute liver disease

Patients with abnormal LFTs and coagulopathy should ideally be admitted to an HDU for close monitoring.

These patients may require significant fluid resuscitation in the acute period. There is often a tendency by practitioners to avoid sodium-containing fluid (as per the management of chronic liver disease) but in these patients this can often lead to cerebral oedema and subsequent seizures. Vasoactive support may also be required.

COMPLEX FLUID STATES

Hepato-renal syndrome

HRS is a state of renal failure and fluid shifts in the context of advanced liver disease. It occurs in about 4% of patients with decompensated cirrhosis, and in about 30% of patients with cirrhosis and spontaneous bacterial peritonitis.

It is thought to be caused by a severe reduction in renal perfusion, the pathogenesis of which is not fully understood but is likely a result of a combination of the following:

- Splanchnic vasodilatation reducing the effective arterial blood volume and thus MAP and renal perfusion

- Over-activation of the RAS and synthesis of vasoactive mediators causing renal vasoconstriction affecting both renal perfusion and glomerular microcirculatory dynamics
- Impaired cardiac function due to cirrhotic cardiomyopathy.

There are two types of HRS:

Type 1: Characterised by a rapid decline in renal function (a doubling of serum creatinine in less than 2 weeks), which is usually triggered by a precipitating event such as infection or an alcoholic hepatitis precipitating decompensation of liver disease. It is usually associated with a coagulopathy and marked jaundice.

Type 2: This is a steady and progressive decline in renal function which is associated with refractory ascites and sodium retention (due to a dysfunctional renin–angiotensin system in chronic liver disease).

History

Current medical problem

There is no one specific test that can establish HRS. The major diagnostic criteria (all of which must be present) are as follows:

- Advanced acute or chronic liver disease with failure
- Raised serum creatinine (typically $>200 \mu\text{mol/L}$), or reduced creatinine clearance
- No sustained improvement with fluid resuscitation
- Proteinuria $<0.5 \text{ g/day}$
- Normal renal tract ultrasound
- Other causes of renal impairment excluded (e.g. hypovolaemia, sepsis, membranous glomerulonephritis [which could be secondary to hepatitis B]), renal tubular abnormalities, obstruction, use of radio-contrast agents

Type 1 HRS and severe type 2 HRS are serious, life-threatening conditions. Seek senior advice and get specialist input early.

Current fluid status

Ask about the acute presentation, the following in particular:

- Duration of any symptoms
- Nausea, vomiting, fatigue, weakness

- Decreased urine production
- Jaundice with dark urine
- Symptoms of ascites: Abdominal swelling, dyspnoea
- Symptoms of bacterial peritonitis: Signs of infection with abdominal pain/tenderness with ascites
- Confusion and altered sleep/wake cycle (symptoms of hepatic encephalopathy)

Past medical history

- Known chronic liver disease.
- Current or recent viral or alcoholic hepatitis.
- Past episodes of ascites/spontaneous bacterial peritonitis.
- Family history of liver/kidney problems.
- *Alcohol*: ask about alcohol intake, current and historical. In particular, are they currently abstinent and if so, for how long?

Medications

Ask about and check the chart for any nephrotoxic agents such as the following:

- Aminoglycoside antibiotics
- NSAIDs
- Antiviral agents (e.g. interferon in Hepatitis C)
- Diuretics
- ACE inhibitors and angiotensin blockers

Examination

Patients will typically have a low BP and bounding pulse. Look for signs of chronic liver disease such as palmar erythema, spider naevi, caput medusae, altered pattern of body hair ('hairless man'), gynaecomastia and decompensation (jaundice, ascites).

Check for a liver flap (asterixis) and confusion which are suggestive of encephalopathy.

Fluid status

- Assessing fluid status in patients with ascites can be challenging. Remember that these patients can be intravascularly depleted.

- Pay particular attention to the JVP; check CRT and monitor the urine output to assess this.
- They may also have fluid overload due to renal dysfunction and/or excess IV fluid therapy.

Investigations

All patients with acute liver failure and ascites need an urgent ascitic tap to rule out spontaneous bacterial peritonitis.

Bloods

- Bloods including FBC, U+Es, LFTs and clotting.
- Creatinine will be elevated.
- Sodium <130 mmol/L suggests HRS.
- Be aware that while many liver patients will have deranged clotting screens, they are in fact in a coagulopathic state so may require thromboprophylaxis.

Sepsis is a common precipitant of decompensated chronic liver disease so ensure a full septic screen is sent.

- A full liver screen should be carried out if the aetiology of the liver disease is not known.

Urine dipstick: testing for proteinuria and haematuria – marked proteinuria and haematuria indicate renal parenchymal disease rather than HRS. Renal biopsy may be required if HRS is still strongly suspected in these cases.

Imaging

- Renal USS to rule out obstruction
- Abdominal USS with portal and hepatic vein Dopplers to look at liver architecture and look for signs of portal HTN/thrombus and also to characterise small volume ascites
- CXR may show raised diaphragm (splinting from ascites)

Management

Treat underlying cause

- HRS will rarely recover unless liver function does: The goal of treatment is to support the liver and perfuse the kidneys.

- Supportive therapy whilst liver function recovers: Ensure bowels opened at least twice a day to prevent encephalopathy, give lactulose to promote NH_4 excretion in the bowel and ensure adequate nutritional support.
- Ascitic drains (with IV albumin cover to prevent post-paracentesis circulatory problems) will reduce discomfort in tense ascites.
- Stop nephrotoxic drugs including diuretics.
- The definitive treatment is a liver transplant, where indicated.

Treat current fluid status

- Hypovolaemia requires correction with crystalloids/albumin or blood products. Albumin may have specific immunomodulatory effects.
- Once the patient is euvolaemic, fluid restriction to 1–1.5 L/day should be instituted to prevent dilutional hyponatraemia.

Review treatment

- Fluid balance must be scrupulously monitored and these patients require daily blood tests.
- Have a low threshold for ITU referral. These patients may require haemodynamic monitoring and vasoactive support to maintain perfusion.
- If they are not improving then they may need haemodialysis or filtration while liver function recovers, or as a bridge to transplant.
- Transjugular intrahepatic portosystemic shunt (TIPSS) has been shown in some small studies to have short-term benefits.

Special considerations

A variety of other treatments including N-acetylcysteine, misoprostol and ACE inhibitors have not been shown to have any benefit in HRS.

Electrolytes

Remember hyponatraemia is common and may be exacerbated by overzealous use of IVFs. Hyperkalaemia in HRS may be refractory to treatment and require dialysis.

OTHER IMPORTANT PRESENTATIONS

Fluids at the end of life

This is a difficult issue, and one that causes much heartache for relatives and health care teams alike. Seek advice from your palliative care teams. One of the main concerns raised by relatives of dying patients about the Liverpool Care Pathway was early withdrawal of nutrition and IVF. Hence, new guidance of the Leadership Alliance for Care of Dying People suggests continuing both unless the patient is deemed to be imminently dying.

Siting IV cannulas in dying patients can be challenging and the data shows little benefit for fluids at the end of life. In these cases, it is often appropriate to administer fluids subcutaneously via a butterfly syringe, usually a litre of saline over 24 hours.

Fluids in elderly patients

The principles of fluid therapy in older patients remains the same as in all patients; however, there are a few considerations to be borne in mind.

In particular, a low oral intake or swallowing difficulties are not an indication for IV fluid replacement, with all the attendant risks. Has the patient been assessed by dieticians and a speech and language therapist? What is the long-term plan for nutrition and hydration?

These patients may well have a degree of cardiac or renal impairment and this may not be formally diagnosed, so care is required when prescribing fluids – do not give large volumes without rechecking the patient's fluid status.

Older, frail patients may have a low body weight and fluids should be prescribed appropriately. Three litres of saline in 24 hours in a 40-kg patient is probably not beneficial!

A chronic low-grade hyponatraemia is relatively common in the elderly. Do not be tempted to over-investigate.

CONCLUSION

In this chapter, we have covered the fluid management of common medical presentations by dividing them according to the pathological fluid status they would cause. We have outlined the common causes,

specific examinations and investigation findings that you should focus on. The 'Management' section was divided into general treatment (which, at most, consists only of an outline) and specific fluid management. For full medical management of the conditions, as mentioned before, please seek senior help and other core medical texts (for examples see the 'Further Reading' section). We hope that the 'Fluid Management' sections have highlighted the approach to fluid prescribing and management and have armed you with tools to select the appropriate IVF, with particular attention to matching the electrolyte content of the IVF, for specific medical conditions.

The scope of this book is finite and we have focused on the common medical conditions. We have not covered all possible topics, such as endocrine pathologies (apart from diabetes mellitus in a case about DKA). We hope the examples covered here will provide you with the tools to adequately assess and treat your patients.

Developing a good knowledge and understanding of fluid therapies is crucial to becoming a skilled physician. Always consider your plans for fluid management carefully and take every opportunity to learn from complex cases.

CASE 4.1 – RE-FEEDING SYNDROME

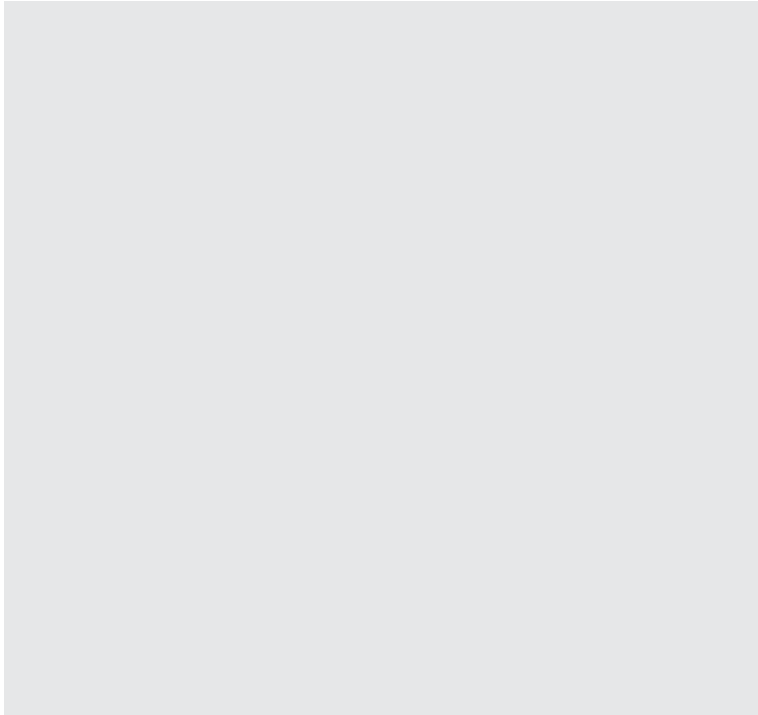
A 45-year-old cachectic man with a history of alcohol excess was admitted with seizures. The patient is being treated for alcohol withdrawal and commenced on a regime of chlorthalidone, multivitamins and energy drinks by the ward doctor.

After 2 days, blood tests show hypophosphataemia, hypokalaemia and hypomagnesaemia.

What is the likely diagnosis?

Re-feeding syndrome

Re-feeding syndrome was initially discovered in Japanese prisoners of war after World War II. After a prolonged period of malnutrition the body's main energy source becomes ketone bodies rather than glucose/carbohydrates and the body becomes depleted in macro- and micronutrients, including electrolytes. Initiation of sudden and full enteral or parenteral nutrition leads to an increase



in metabolic rate and switch back to glucose-based metabolism, with an increase of insulin secretion.

This anabolic state and increased insulin levels result in an increased need for phosphate (required for ATP synthesis). This results in fluid and electrolyte shifts.

Hallmarks of the syndrome are as follows:

- Hypophosphataemia
- Hypomagnesaemia
- Vitamin deficiencies
- Hypokalaemia
- Volume overload

Management

- The dietitian should review the patient daily. They normally recommend a slow build-up to the full caloric requirements over a few days.
- Daily monitoring of U+Es, including phosphate and magnesium.
- Replace electrolytes (enterally and IV).
- If the patient is showing signs and symptoms of re-feeding syndrome: Slow the rate of feeding, check U+Es regularly, replace electrolyte deficiencies, involve a dietitian, review for signs of fluid overload.

CASE 4.2 – HYPERCALCAEMIA

An 82-year-old man with known prostate cancer is admitted to hospital with lower back pain, constipation and confusion. His blood tests show the following:

Urea 20 mmol/L

Creatinine 120 mmol/L

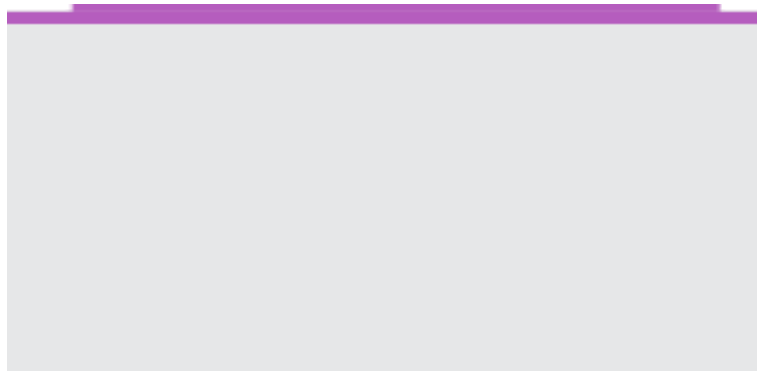
Potassium 4.5 mmol/L

Calcium 3.8 mmol/L

What is the main abnormality and what is the most likely underlying diagnosis?

Hypercalcaemia

- In this particular case, the patient's severe hypercalcaemia is most likely secondary to bony metastases.
- Generally, the two most common causes of hypercalcaemia are primary hyperparathyroidism and malignancy.



Hallmarks

- ‘Stones, bones, abdominal groans and psychic moans’
- Renal: nephrogenic diabetes insipidus
- GI tract: constipation, pancreatitis, nausea, anorexia
- Psychiatric: confusion, agitation, depression

Investigations

- Back imaging (lumbar x-ray/CT/MRI)
- Prostate-specific antigen (PSA)

Management

The most important part of the management is aggressive rehydration with Plasmalyte or normal saline. Hartmann’s solution can also be used but be aware that it contains 2 mmol/L of calcium. Make sure there is an accurate fluid chart available. Consider a bisphosphonate like Pamidronate, but only once the patient is clinically euvolaemic. Treat the underlying cause and consider referral to a specialist team, in this case oncology, for consideration of radiotherapy ± anti-hormonal treatment.

A 28-year-old man with known type 1 diabetes mellitus presents with a 2-day history of gastroenteritis. The patient appears very unwell, tachypnoeic RR 40 breaths/min, BP 95/45 mmHg, HR 110 beats/min, CRT 5 seconds.

What is the most likely underlying diagnosis?

Diabetic ketoacidosis

Hallmarks of the syndrome are:

1. Acidosis: venous pH <7.3 OR bicarbonate <15 mmol/L
2. Hyperglycaemia: capillary glucose >11 mmol/L
3. Presence of ketones: capillary ketones >3 mmol/L OR urine ketones minimum ++

Management

General management of DKA according to the Joint British Diabetes Societies Inpatient Care Group:

- Immediate management: Start normal saline with potassium.
- Fixed rate intravenous insulin infusion (FRIII) after IVF has been commenced. Correct blood glucose slowly at a rate

not exceeding 3 mmol/L/hr to avoid large osmotic shifts (see Chapter 2).

- FRIII is 50 units actrapid insulin in 50-mL normal saline delivered at 0.1 units/kg/hr (equivalent to 0.1 mL/kg/hr)
- The aim is to clear the blood of ketones, aiming for a fall in blood ketone levels of at least 0.5 mmol/hr.
- Particular attention should be paid to potassium levels which should be kept within normal range (no potassium replacement in IVF, only for serum values of potassium >5.5 mmol/L).
- Hypoglycaemia should be avoided.

Fluid management

Normal saline with premixed potassium is recommended on the ward (as per *National Prescribing Service* guidelines), as per national guidelines for treatment of DKA. In a high-dependency setting, Hartmann's solution is often used. There is currently no convincing evidence suggesting that normal saline is superior to Hartmann's in these patients. The main advantage of normal saline is that potassium can easily be added. As the acidosis corrects, shifts of potassium will occur. In most hospitals, these patients are looked after in a high-dependency setting which allows close monitoring of vital signs, fluid balance and electrolytes.

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Chapter 5

Fluid therapy management in surgical patients

INTRODUCTION

Surgery induces a stress response in human beings; our normal physiology becomes altered, including the fluid and electrolyte equilibrium. Surgical procedures require considerable planning and individualised management before, during and after. Before elective surgery, patients with chronic medical conditions often receive multidisciplinary support to ensure their care is optimised, problems are anticipated and contingency plans are made.

As a junior doctor in a surgical specialty, one is likely to be involved in a pre-assessment clinic, which provides an opportunity to plan for any special requirement the patient may have. For instance, insulin-dependent diabetics may require admission to hospital the day before their procedure, so that a sliding scale can be used to maintain their metabolism while they remain nil-by-mouth (NBM).

During the peri-operative period, the goal is to carefully replace maintenance requirements, insensible losses and extra output like post-operative vomiting. Always consider whether intravenous fluid (IVF) therapy is still required, is the patient's oral intake adequate?

This chapter guides you through the management of fluid balance in patients in the pre- and post-operative periods, addressing special points to consider in certain surgical procedures.

PRE-OPERATIVE FLUID STATUS MANAGEMENT

In some cases, surgical patients are admitted as emergencies, where there is less time for pre-operative assessment and surgery is unavoidable. It is important to focus on resuscitating the patient in these situations (see Chapter 3 for guidance).

Assess the patient's estimated fluid and electrolyte requirements from their history, examination, observations and test results.

History

1. **Planned surgical procedure:** An awareness of the site and extent of surgery will help you predict the patient's likely post-op fluid requirements. Is the procedure likely to be lengthy, increasing the duration of disruption to their usual physiology? For example, a large amount of fluid evaporates from an open abdomen (10–15 mL/kg/hr), so patients having a laparotomy will require extra fluid replacement.
2. **Current fluid status:** Patient's fluid intake and causes of extra fluid losses – do they balance? Ask what the usual fluid intake is like. Do they avoid drinking water? Do they have a fluid restriction (e.g. in renal failure)? Is the daily total intake of fluid adequate? Do they already depend on enteral feeding methods (nasogastric/jejunal)?

Knowing how often the patient passes urine/self-catheterises/empties their in-dwelling catheter bag/stoma bag will give an estimate of the fluid output.

Positive (+) fluid balance describes more recorded input than output, whilst negative (–) fluid balance describes more recorded fluid output than input. Determine whether the patient tends towards a positive or negative fluid balance in their routine life before surgery.



REMEMBER

Normal fluid balance

Approximate fluid intake of 70-kg adult:

- 1500-mL liquid
- 750-mL food
- 250-mL product of metabolism
- 2500-mL total

Normal output:

- 1500-mL urine
- 100-mL faeces
- 900-mL insensible loss
- 2500-mL total

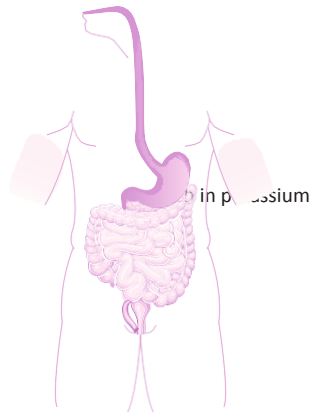
Insensible loss is the unmeasurable volume of pure water lost per day, up to 1200 mL at rest, via the skin and lungs.

Tachypnoea, temperature and metabolic rate may increase this level. Loss through sweating is normally negligible but can be greatly increased in, for example, sepsis or hot environments.

3. **Past medical history:** Ask pertinent questions to help guide your pre-operative fluid prescribing; are there any existing conditions that will necessitate cautious prescribing? Do they have a medical condition affecting their body's ability to respond adequately to fluid deficit or excess? Focus on the following:
 - a. Cardiovascular – Ischaemic heart disease (IHD) and heart failure (HF) will (in varying degrees) affect the heart's ability to pump blood around the body. Be cautious when prescribing fluid, as decreased cardiac output might result in excess fluid outside the intravascular space.
 - b. Renal – Depending on the extent and cause of acute kidney injury (AKI) a patient may require extra fluids, or conversely, require dialysis. Chronic kidney disease (CKD) of varying severity will affect how the body excretes fluids and electrolytes, and hence the quantity and type of fluid required. Patients with end-stage renal failure may not produce urine and may instead require dialysis for offloading of their excess fluid. They may therefore have strict daily fluid input restrictions;

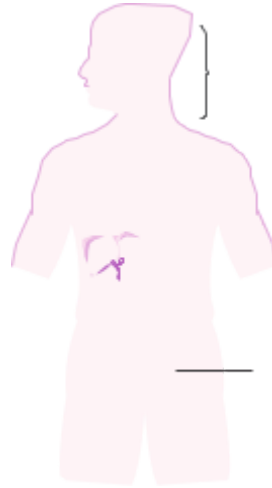
volume and type of IVF given peri-operatively should be tailored to this.

- c. Hepatic – Decompensated liver disease may affect sodium and water distribution, so caution should be applied when prescribing fluids, especially sodium-containing fluids like crystalloids.
- d. Gastrointestinal (GI) – Excretion from the GI tract can result in large fluid and electrolyte depletion (especially potassium and sodium), thus high stoma output, diarrhoea and vomiting all require regular electrolyte investigation and aggressive fluid replacement (see Figure 5.1). Compare Table 5.1 with Table 2.1 in Chapter 2. For instance, in a patient with



Stomach:
 Acidic mainly H⁺, K⁺, Cl⁻
 Low Na⁺ 50 mmol/L
 Low HCO₃⁻

High Na⁺ 130–140 mmol/L
 Lower Cl⁻ 60–95 mmol/L = High HCO₃



Hypotonic salivary secretions

Stomach: Isotonic
 up to 2500 mL in 24 hr
 Bowels:
 Alkaline

Small bowel: Isotonic
 to
 1500 mL in 24 hr in a recent ileostomy
 Large bowel:
 Hypotonic when low amounts of fluid
 Isotonic when high amounts of fluid
 More than 2000 mL/24 hr lost in diarrhoea

Figure 5.1 Composition of fluids secreted in the GI tract.

Table 5.1 Daily volume and electrolyte composition of gastrointestinal fluids

| | Volume (mL) | Sodium (mmol/L) | Potassium (mmol/L) | Chloride (mmol/L) | H ⁺ (mmol/L) | HCO ₃ ⁻ (mmol/L) |
|-------------|----------------|--------------------|-----------------------|----------------------|----------------------------|---|
| Gastric | 2500 | 30–80 | 5–20 | 100–150 | 40–60 | – |
| Biliary | 500 | 130 | 10 | 100 | – | 30–50 |
| Pancreatic | 1000 | 130 | 10 | 75 | – | 70–110 |
| Small bowel | 5000 | 130 | 10 | 90–130 | – | 20–40 |

Source: British National Formulary. <https://www.evidence.nhs.uk/formulary/bnf/current/1-gastro-intestinal-system/16-laxatives/165-bowel-cleansing-preparations/macrogols/klean-prep>. Accessed in September 2015.

copious bilious vomiting, around 130 mmol/L of Na⁺ is lost in bile daily; this will need replacing with an IVF with a similar sodium content. Hartmann's (131 mmol/L) or 0.9% normal saline (154 mmol/L) can be administered, rather than 5% dextrose, which contains no sodium.

4. **Medication:** Take particular note of medications that affect the function of the heart, kidneys and hormonal control of fluid and electrolyte balance. Some of these medications may need to be omitted or optimised before elective surgery; consult the *British National Formulary* (BNF), a clinical pharmacology text or a senior if you are unsure. The following are common medications in the elderly population and the effects that will influence your management:
 - a. Angiotensin-converting enzyme (ACE) inhibitors – Renal impairment, first-dose hypotension.
 - b. Beta-blockers – Can cause decreased cardiac output.
 - c. Thiazide diuretics – Can cause hypokalaemia, hyponatraemia, oliguria, hyperglycaemia, hypercalcaemia.
 - d. Loop diuretics – Hypokalaemia, hyponatraemia, hyperglycaemia, hypocalcaemia and dehydration.
 - e. Potassium-sparing diuretics – Can cause hyperkalaemia, hyponatraemia, water depletion.
 - f. Calcium-channel blockers – Can cause ankle oedema.
 - g. Some stimulant laxatives – Can cause dehydration and electro-

lyte imbalances.

- h. Electrolyte supplements – E.g. potassium supplements will increase serum potassium levels.

Examination

Look for clues that suggest decompensation from chronic disease; are there signs of worsening HF for instance, and is there a new-onset arrhythmia?

Weigh the patient to help you establish a baseline estimate of fluid composition; this mostly represents interstitial oedema. During their hospital stay, weighing the patient with the same scales at the same time of day gives an indication of acute hydration status. Maintain a cumulative chart to allow comparison.

Table 5.2 summarises the signs and symptoms associated with altered fluid balance in the pre-operative patient.

In pre-assessment clinics, be sure to pay attention to the blood pressure (BP), heart rate (HR), respiratory rate (RR) and oxygen saturation.

Table 5.2 Signs and symptoms of altered fluid balance in the pre-operative patient

| System | Fluid depletion | Fluid overload |
|----------------|--|--|
| Cardiovascular | <ul style="list-style-type: none"> • Tachycardia • Hypotension • Capillary refill time >2 seconds • Decreased skin turgor • Dry mucu | <ul style="list-style-type: none"> • Pulmonary rales • Respiratory rate >20 breaths/min |

Renal

- Decreased urine output <0.5 mL/kg/hr
- Concentrated urine

- Hypertension
- Added heart sounds
- Raised jugular venous pressure (JVP)
- Peripheral/sacral pitting oedema

- Oxygen saturation <92%
- Respiratory rate >20 breaths/min
- Bibasal crackles
- Wheeze
- Cyanosis
- Increased urine output >0.5 mL/kg/hr
- Clear urine

Gastrointestinal

- Loose stool
- High stomach output
- Vomiting
- Bowel obstruction

(Continued)

Table 5.2 (Continued) Signs and symptoms of altered fluid balance in the pre-operative patient

| System | Fluid depletion | Fluid overload |
|--------------|--|---|
| Endocrine | <ul style="list-style-type: none"> Blood sugar ≥ 11 mmol/L Ketonuria | |
| Neurological | <ul style="list-style-type: none"> Low Glasgow Coma Scale (GCS) < 8 | <ul style="list-style-type: none"> Low GCS < 8 Comatose |
| | <ul style="list-style-type: none"> Comatose | |

If there are abnormal results, their ability to cope with major surgery and fluid and electrolyte balance post-operatively may be affected. Decide if the patient needs a different medication regimen or specialist input before proceeding with surgery.

Investigations

By arranging the appropriate investigations, you play a crucial role in optimising the patient for surgery and recovery; for instance, a simple blood test could reveal that the patient's condition has led to hypokalaemia, easily corrected with oral supplementation in the days before surgery.

- Blood tests:** Especially important are up-to-date measurements and review of the patient's urea, electrolytes, liver function tests (LFTs) and haemoglobin (Hb). For instance, a woman with heavy periods may become severely anaemic while awaiting a hysterectomy; she may need a pre-operative red blood cell transfusion (see Chapter 6).

Urea and creatinine are often assessed together, to help determine current renal function. These need to be closely monitored if a patient has known chronic renal impairment; persistently abnormal levels may necessitate dialysis in the peri-operative period.

Normal urea 2.5–8.0 mmol/L.

- Normal creatinine 64–104 $\mu\text{mol/L}$ (males) and 49–90 $\mu\text{mol/L}$ (females).
- a. Raised urea can be caused by sepsis and GI bleeding (high-protein load).
 - b. Raised urea disproportionate to, or without raised creatinine can be caused by hypovolaemia leading to pre-renal failure. Rises in both can be caused by chronic kidney failure.
 - c. Estimated glomerular filtration rate (eGFR) may also be useful.

2. **Electrocardiogram:** Essential for assessment of any current cardiac ischaemia or rhythm abnormality: Fluid therapy will depend on the extent and cause of the problem. Where possible look at previous electrocardiograms (ECGs) and compare for any signs of atrial fibrillation, myocardial infarction or dysrhythmias.
3. **Imaging:** Useful to help determine if there is abnormal fluid distribution, such as chest x-ray (CXR) findings in the case of pulmonary oedema. Furthermore, imaging allows investigation into the clinical cause of abnormal fluid distribution, such as a cardiac or renal abnormality.
 - a. Radiographs – CXR for any signs of fluid overload
 - b. Echocardiogram – Left ventricular ejection fraction (LVEF), ventricular enlargement, dysfunctional pumping
 - c. Ultrasound scan – Renal hydronephrosis, small kidneys, and renal cysts/carcinoma
 - d. Computed tomography (CT) – CT of the abdomen for bowel obstruction and perforation and CT of the chest for chronic pleural effusions and empyema

Management

In elective surgery, the *Enhanced Recovery Programme* aims to minimise the body's stress response to anaesthesia and surgery, reducing post-operative recovery time. This method is now widely used across many surgical specialties and central to its ethos is the management of fluid balance and fasting times, to help avoid dehydration and malnutrition.

Treat the underlying cause

In a surgical specialty, the appropriate management choice may vary according to the patient's clinical status, i.e. patients who are initially managed conservatively may show worsening of their symptoms and therefore need urgent surgical management instead. In bowel obstruction for instance, nasogastric (NG) tube drainage or decompression at sigmoidoscopy may be required to relieve fluid and electrolyte loss via vomiting.

Treat the current fluid status

As part of the *Enhanced Recovery Programme*, surgical patients are often given one or two clear, carbohydrate-rich drinks (Preload®) before midnight and another drink 2–3 hours before surgery to help

ease symptoms of fasting and hunger. They are also thought to contribute to a quicker return to normal bowel function and minimise loss of body mass via anaerobic metabolism. Diabetic patients should be given these drinks along with their usual medications.

A fluid balance chart should be maintained by nursing staff, especially in unwell patients, in whom you should also consider placing a urinary catheter. If recorded accurately, these measures will be invaluable in helping you, the junior doctor, to detect when there is an imbalance in a patient's fluid input and output. Does the rate of the infusion need to be altered? Perhaps sips of clear fluids are adequate now?

Daily replacement of maintenance fluid and electrolytes whilst a patient is fasting does not usually exceed 3 L and this should be reduced to 2–2.5 L in those who are frail, elderly, malnourished or have existing renal or cardiac impairment. Calculations for obese patients ($\text{BMI} >40 \text{ kg/m}^2$) should be based on their ideal and not actual body weight.



When a patient is NBM, the following symptoms and signs

may develop:

- Dehydration
- Nausea and vomiting
- Electrolyte imbalance
- Hypoglycaemia
- Malnutrition

Aim to match their background maintenance requirements: 25–30 mL/kg/day of water, up to 40 mL/kg/day in healthy young adults **and** approximately 1 mmol/kg/day of potassium, sodium and chloride.

Don't ever forget the glucose! Approximately 50–100 g/day is required to limit starvation ketosis.

Alternating 1-L Hartmann's and 5% dextrose infusions over the fasted period in a healthy person is usually sufficient, but adjust the rate according to individual need. Previous teaching of '1 salty, 2 sweet' is now outdated.

Isotonic IVFs like 0.9% normal saline provide adequate water and electrolytes, but no glucose. In cases where prolonged pre-operative starvation occurs, the body will need more balanced solutions to avoid hyperchloraemic acidosis and hypoglycaemia. Maintenance requirements can be met by providing water, sodium and potassium, as is found in Hartmann's solution or Plasmalyte. The brain, renal medulla and red cells can get energy from stored sugar or protein from muscle breakdown, but these are unsustainable in prolonged starvation. Hypotonic solutions like 5% dextrose can be used intermittently to provide glucose (but not electrolytes) in prolonged starvation.

Excessive losses from gastric aspiration or vomiting should be treated pre-operatively with a balanced crystalloid solution that contains potassium, such as Hartmann's solution, Ringer's solution or Plasmalyte. Losses from diarrhoea/ileostomy/small bowel fistula/ileus/obstruction should be replaced volume-for-volume with Hartmann's or Ringer's lactate type of solutions.

Patients can take the following before being anaesthetised (check with a senior or the anaesthetist on your surgical list if unsure. Local guidelines may provide similar information):

Adult: Water up to 2 hours before anaesthesia (encourage moistened mouth swabs). Food up to 6 hours before.

Child: Water and clear fluids up to 2 hours before anaesthesia. Breast milk up to 4 hours before. Formula/cow's milk or solids up to 6 hours before.

Review the implemented treatment

Although the pre-operative patient is now in the ward, awaiting surgery, it is not good practice to simply prescribe a litre of a generic infusion and leave them to it! You must monitor them closely for warning signs of fluid overload, dehydration, altered consciousness or other adverse outcome.

Sick surgical inpatients must have regular blood tests; review the urea, creatinine, electrolyte and Hb levels on a flowchart if possible. Cumulative analysis helps you pick up abnormal trends much more quickly. Encourage the nursing staff to use the hospital's *Early warning chart* to record all observations and alert you if the system triggers.

For example, if a patient's BP suddenly drops to 80/50 mmHg and remains low despite the nurse repositioning them, do not hesitate to

switch the infusing crystalloid for a 500- or 250-mL challenge of an intravascular volume-expanding colloid like *Volplex*. Stay with the patient until you notice sustained improvement in the observations and urine output, think about possible causes of the sudden change and address them. Causes of such sudden changes could include sepsis or hypovolaemia.

Special considerations

Some operations require special preparation for the patient; for instance, low fibre and then bowel preparations are used to empty the bowels before a colonoscopy or colonic surgery. Commonly administered bowel preparations include oral sodium phosphate and *Klean-Prep*. These are designed to minimise dehydration but have the additional effect of inducing GI electrolyte losses and fluid imbalance. The high sodium and phosphate content makes these solutions hyperosmolar; they cause water to be retained in the intestinal lumen, leading to peristalsis and colonic emptying. *Klean-Prep* contains large macrogol molecules which remain in the bowel lumen, exerting an osmotic effect that keeps water within the lumen, softening stool and making it easier to pass. To achieve this, bowel preparation sachets are mixed with large volumes of water, up to 4 L over split doses. In the elderly, frail or in those with renal or HF, this volume is reduced to around 2 L in total, to avoid interstitial oedema.

Bowel preparations have the added side effect of inducing dehydration, hyponatraemia and hypokalaemia. Check the patient's electrolyte levels and fluid balance after bowel preparation is used; correct with titrated volumes of intravenous 0.9% normal saline or balanced crystalloid (Hartmann's or Plasmalyte) as necessary.

In *chronic renal failure*, there is associated electrolyte imbalance and reduced diuresis, hence the importance of estimating the patient's usual urine output and checking the electrolytes pre-operatively. Aim to balance the fluids to at least match the usual urine output and avoid blind addition of potassium, as hyperkalaemia can develop. In a healthy person, at least 400 mL of daily urine clearance is required to maintain normal function; in a person with renal failure, much less urine is produced. Avoid using arteriovenous (AV) fistulas, cephalic and subclavian veins to administer fluids or take blood samples as these need to be protected for dialysis.

KLEAN-PREP

Each sachet of Klean-Prep contains the following active ingredients:

| | |
|--|------------|
| Macrogol 3350 | 59.00 |
| Anhydrous sodium sulphate | 0 g |
| Sodium bicarbonate | 5.685 g |
| Sodium chloride | 1.685 g |
| Potassium chloride | 1.46 g |
| The content of electrolyte ions per sachet when made up to 1 L with water is as follows: | 0.74 |
| Sodium | 25 g |
| Sulphate | 125 mmol/L |
| Chloride | 40 mmol/L |
| Bicarbonate | 35 mmol/L |
| Potassium | 20 mmol/L |

Source: British National Formulary.
<https://www.evidence.nhs.uk/formulary/>

[bnf/current/1-gastro-intestinal-system/motile-drugs/165-bowel-cleaning-preparations/macrogols/klean-prep](https://www.evidence.nhs.uk/formulary/bnf/current/1-gastro-intestinal-system/motile-drugs/165-bowel-cleaning-preparations/macrogols/klean-prep). Accessed September 2015. With permission.

INTRA-OPERATIVE FLUID BALANCE

During surgery higher volumes of fluid are lost as a result of fluid compartment shift in response to surgical trauma. Extracellular fluid from the intravascular space moves to the interstitial space producing oedema of the bowel wall and mesentery, along with oedema of subcutaneous tissue and muscle. Evaporative loss is also increased, especially during open abdominal surgery. Estimates for intra-operative fluid replacement are as follows:

- 2–5 mL/kg/hr for superficial or peripheral surgeries
- 5–10 mL/kg/hr for open abdominal or thoracic surgeries
- 10–15 mL/kg/hr for major open abdominal surgery

During surgery, further fluid loss comes from loss of blood, mechanical ventilation (respiratory tract) and evaporation from skin in those who are pyrexial. An added aid to assessment of intra-operative fluid status

is the oesophageal Doppler, now widely used to achieve ‘goal-directed’ fluid therapy. This term relates to using restrictive amounts of IVF and advanced haemodynamic monitoring to maintain euvolaemia rather than hypervolaemia as previously taught. There is some evidence that goal-directed fluid therapy helps to maintain tissue perfusion and reduce complication rates and post-operative hospital stay (see GIFTASUP in the ‘Further reading’ section at the end of this chapter). Also lookout for outcomes of the ongoing RELIEF trial (large multi-centre analysis of restrictive versus liberal fluid therapy in major abdominal surgery).

As a junior doctor looking after the post-surgical patient, it is useful to review the anaesthetic chart to determine how the patient’s fluid balance was managed intra-operatively. For instance, intra-operatively, a patient with obstructive jaundice should have had judicious fluid replacement and diuretics to help prevent AKI secondary to hepatorenal syndrome. This will have an influence on how you manage the patient’s fluid balance immediately after surgery.

POST-OPERATIVE FLUID STATUS MANAGEMENT

Patients are at risk of complications associated with their operation directly (haemorrhage) or indirectly (infection, thrombosis), early signs of which can be detected by the vigilant junior doctor. The first 24 hours post-surgery are crucial, as oral intake is limited and the body has higher requirements to help it re-adjust.

Antidiuretic hormone (ADH) and renin–angiotensin–aldosterone system products are released after surgery, leading to water retention. Stress hormones including cortisol, adrenaline and glucagon as well as inflammatory mediators are released, increasing vascular permeability and interstitial fluid retention. Physiological organ functions are impaired, including renal clearance of excess electrolytes. In addition, potassium is released by damaged tissues; it accumulates if renal perfusion and therefore urine output is impaired, leading to the risk of arrhythmias. Potassium supplementation is often not required in the first 24 hours after surgery for this reason.

Post-operatively, if surgery was straightforward, patients should only need IVF therapy for a short period until they are able to resume a normal diet (encouraged within 24 hours if on an *Enhanced Recovery Programme*). Other reasons for giving post-operative IVF include to manage hypovolaemia, avoid renal failure, and to minimise

hypotension secondary to regional anaesthesia and analgesia. In those who require IVF for maintenance in the immediate post-operative period, choose a solution that has lower sodium and at as low a volume as possible. This is because the body is already holding on to sodium and water as a physiological response to the stress of surgery. Consider administering 4% dextrose/0.18% normal saline for this reason.

In the situation where the patient is unlikely to resume a normal diet within 5–7 days, e.g. bowel rest in colostomy formation, nutritional support will be required. This could be via the enteral route (NG, nasojejunal, percutaneous endoscopic gastrostomy tubes) or central/peripheral total parenteral nutrition.

History

Ask about: Ability to eat and drink. Are they only tolerating sips of water or more?

- Vomiting: Frequency and amount. NG drain output.
- Urinary output: Frequency, colour and amount.
- Bowel movements: Flatus, diarrhoea, stoma output if relevant.
- Wound drain output: Volume and character.

Loss of water through the GI tract is increased in diarrhoea and when there is an ileostomy, as there is no colonic water reabsorption. A basic knowledge of the procedure the patient has had is essential in helping you anticipate the likely post-operative course/recovery of the patient.

1. **Current fluid status:** Positive (+) fluid balance describes more recorded input than output, whilst negative (-) fluid balance describes more recorded fluid output than input.
2. **Past medical history:** If the patient is conscious, ask about any existing conditions that will necessitate cautious prescribing? Do they have a medical condition which will affect their body's ability to respond adequately to fluid deficit or excess? Review the medical notes if you do not already know the patient, looking for cardiovascular, renal and GI conditions in particular (review the History section under the 'Pre-Operative Fluid Status Management' section of this chapter).
3. **Medication:** In the immediate post-operative period, patients may not be alert/stable enough to take their usual medications and they are exposed to new drugs such as analgesics, diuretics and anti-emetics. Take particular note of medications that

affect the function of the heart, kidneys and hormonal control of fluid and electrolyte balance. For example, do not blindly restart diuretics or nonsteroidal anti-inflammatory (NSAIDs) without an examination and check of the renal function, as this may lead to AKI.

Examination

Look for clues that suggest that the patient is not coping with the insult of anaesthesia and surgery, or is developing a complication. Are they able to maintain perfusion? Do they have difficulty breathing? Is there a new onset of confusion?

If possible, weigh the patient daily for added information on fluid balance, and maintain a cumulative chart to allow comparison, especially in cardiac patients. Check for signs of fluid overload. Is there pitting oedema? Crepitations/crackles on lung auscultation?

As well as conducting a systematic examination as for the pre-operative patient, look for clues about altered fluid balance in the post-operative patient:

- Skin colour and turgor. Does the patient appear pale/mottled? Do the peripheries feel warm or cold?
- Inspect the urinary catheter. Does urine appear concentrated/diluted? Is there bloodstaining or frank haematuria? What is the volume of urine within the bag? How often has it been emptied?
- Inspect the wound drain(s) if present. Haemoserous fluid or frank blood? Is the fluid leaking out of the drain insertion site? What is the total volume drained since insertion?
- Inspect and palpate the surgical site looking for signs of ongoing bleeding: tense, tender abdomen, widespread bruising across the lower back, swollen joints.
- Inspect the NG tube/stoma bag if present; what are the contents like? Volume drained?

Investigations

Most patients do not need investigations during their hospital stay after an operation; however, if there is deviation from the expected recovery course (as suggested by the history and examination), appropriate investigations such as radiographs, ultrasound, CT, ECG and echocardiogram become useful.

Blood tests: Especially important are an up-to-date measurement of the patient's Hb, urea, electrolyte and LFT levels. Surgery alters the body's bio- chemical and hormonal balance; fluids and electrolytes shift, and stroke volume, microvascular blood flow and tissue oxygen delivery is altered.

- Check the full blood count (FBC) within 12–24 hours if dealing with a major surgical procedure such as a gastrectomy, colectomy or hysterectomy. If the patient shows signs of being unwell, serial FBC checks 6 hours apart are useful to determine whether further intervention such as transfusion (replace lost blood) or return to theatre (stem ongoing bleeding) are required. Hemocue can be used as a simple bedside test to determine if there has been a drop in Hb.

Management

Post-operatively, most patients are in a fluid-depleted state, owing to pre- operative starvation, vomiting, and intra-operative blood and insensible fluid loss. The focus of management is to replace this deficit within the first 24 hours (may require up to 4–5 L) and then return to maintenance levels (2–3 L/day) if they still require IVF. Aim to avoid fluid overload by also checking that their normal body weight is maintained and overall fluid balance is near zero. In a more monitored setting, lactate, mean arterial pressure (MAP) and urine output are used as measures of adequate fluid repletion and maintenance; aim for MAP ≥ 65 mmHg, urine output ≥ 0.5 mL/kg/hr and if available, central venous oxygen saturation of 70%.

A fluid balance chart should be maintained by nursing staff, especially in unwell patients, who should also have a urinary catheter. If recorded accurately, these measures will be invaluable in helping you, the junior doctor, to detect when there is an imbalance in a patient's fluid input and output. Does the rate of the infusion need to be altered? Perhaps sips of clear fluids are adequate now? Watch out for signs of re-feeding syndrome when the patient starts to take solid food after a prolonged period of reliance on IVF (see Case 1 in Chapter 4).

Isotonic IVF like 0.9% normal saline risks hypernatraemia/hyperchloraemia. Hyperchloraemia has the effect of reduced splanchnic and renal blood flow, as well as exacerbation of the inflammatory response in sepsis. Hartmann's provides adequate water and electrolytes and acts as an alkaline buffer in acidosis (sepsis, hypovolaemia). However, as hypovolaemia is common post-operatively, colloids like *Volpex* may be required to maintain intravascular volume and therefore cardiac stroke volume and tissue

perfusion to also aid healing.



When a patient is NBM, the following symptoms and signs may develop:

- Dehydration
- Nausea and vomiting
- Electrolyte imbalance
- Hypoglycaemia
- Malnutrition

Aim to replace the depleted fluid volume and electrolytes at a rate of around 1.5 mL/kg/hr, adjusted according to clinical status.

Then aim to match their background maintenance requirements:

25–30 mL/kg/day of water in the elderly, up to 40 mL/kg/day in

healthy young adults and approximately 1 mmol/kg/day of potassium, sodium and chloride.

Don't ever forget the glucose! Approximately 50–100 g/day is required to limit starvation ketosis.

Alternating 1-L Hartmann's and 5% dextrose infusions over the post-operative NBM period in a healthy person is usually sufficient, but adjust the rate according to individual need.

Consider administering 4% dextrose/0.18% normal saline in the immediate post-operative period.

Peri-operative blood loss of large volumes, i.e. greater than 500 mL, may need to be replaced with transfusion of red blood cells/fresh frozen plasma, etc. if the patient remains symptomatic despite volume replacement with colloids or balanced crystalloids. The patient should be counselled appropriately and steps taken to ensure safe transfusion.

The brain, renal medulla and red cells can get energy from stored sugar or protein from muscle breakdown, but these are unsustainable. Hypotonic solutions like 5% dextrose provide sugar but not electrolytes; they drive water into the intracellular space, increasing the risk of iatrogenic hyponatraemia and peripheral oedema if used for

prolonged periods. A solution of 4% dextrose/0.18% normal saline is a more appropriate post-operative fluid as this corrects sodium and water depletion. Most water moves down its osmotic gradient into the intracellular space, glucose also moves into the cell and the sodium mainly remains in the extracellular space.

Review the implemented treatment

You must monitor the patient closely for warning signs of fluid overload, dehydration, altered consciousness or other adverse outcome.

Post-operative inpatients whose recovery is not straightforward must have regular blood tests; review the urea, creatinine, electrolyte and Hb levels on a flowchart if possible. Cumulative analysis helps you pick up abnormal trends much more quickly. Encourage the nursing staff to use the hospital's *Early warning chart* to record all observations and alert you if the system triggers. Cumulative analysis of blood results and fluid balance charts helps you adjust your choice of IVF and flow rate, and eventually stop therapy altogether.

As mentioned previously, if a patient's BP suddenly drops to 80/50 mmHg and remains low despite the nurse repositioning them, do not hesitate to switch the infusing crystalloid for a 500- or 250-mL challenge of an intravascular volume-expanding colloid like *Volplex*. Stay with the patient until you notice sustained improvement in their observations, think about possible causes of the sudden change and address them. Perhaps there is ongoing intra-abdominal bleeding. Look for other signs, re-examine the patient and call for additional support from team members early on.

If a blood transfusion was required, have you checked an FBC and clotting profile 6 hours or more after completion? Do you need the support of a specialist nurse/dietician? Is the patient now stable enough to return to a normal diet and be discharged home?

Serial blood gases may display a rising lactate level, a subtle sign of worsening hypoperfusion.

Special considerations

Paralytic ileus is a post-operative problem which usually resolves within 48 hours. Manipulation of the bowel, sympathetic system action and potassium depletion contribute to its development. It features abdominal distension, vomiting, constipation and

absence of intestinal movements. Loss of large volumes of fluid, electrolytes (especially potassium) and protein into the gut lumen occurs (third-space losses), which should be carefully replaced. If the patient remains NBM, they may require an NG tube draining gastric fluids and a urinary catheter. IVF (0.9% normal saline with 20–40-mmol potassium chloride or Hartmann's solution), gut motility agents (e.g. metoclopramide) and analgesia are the mainstay of treatment (drip and suck). Be sure to monitor the fluid balance and daily serum electrolyte levels, adjusting the volume and type of IVF given accordingly.

Ascitic drainage carries a risk of hypovolaemia, hypoalbuminaemia and electrolyte disturbances ($\text{\$K}^+$, $\text{\$Na}^+$). Minimise these risks and detect by draining no more than 500–1000 mL/hr, maintaining a strict input/output fluid balance chart and checking observations at least every 4 hours. Aim to correct signs of hypovolaemia quickly, with a colloid (malignant ascites) or human albumin solution (from haematology, in portal-hypertensive ascites).

Irrigating solutions are used in endoscopic operations like transurethral resection of the prostate/bladder tumours, transcervical resection of the endometrium, cystoscopy and arthroscopy. The aim is to help distend the operative field and wash away debris. Solutions used alongside monopolar electrocautery contain one or two solutes; glycine (amino acid), mannitol (glucose isomer) and sorbitol (fructose and sucrose). Solutions used alongside bipolar electrocautery or in the absence of electricity contain electrolytes; sterile water or normal saline.

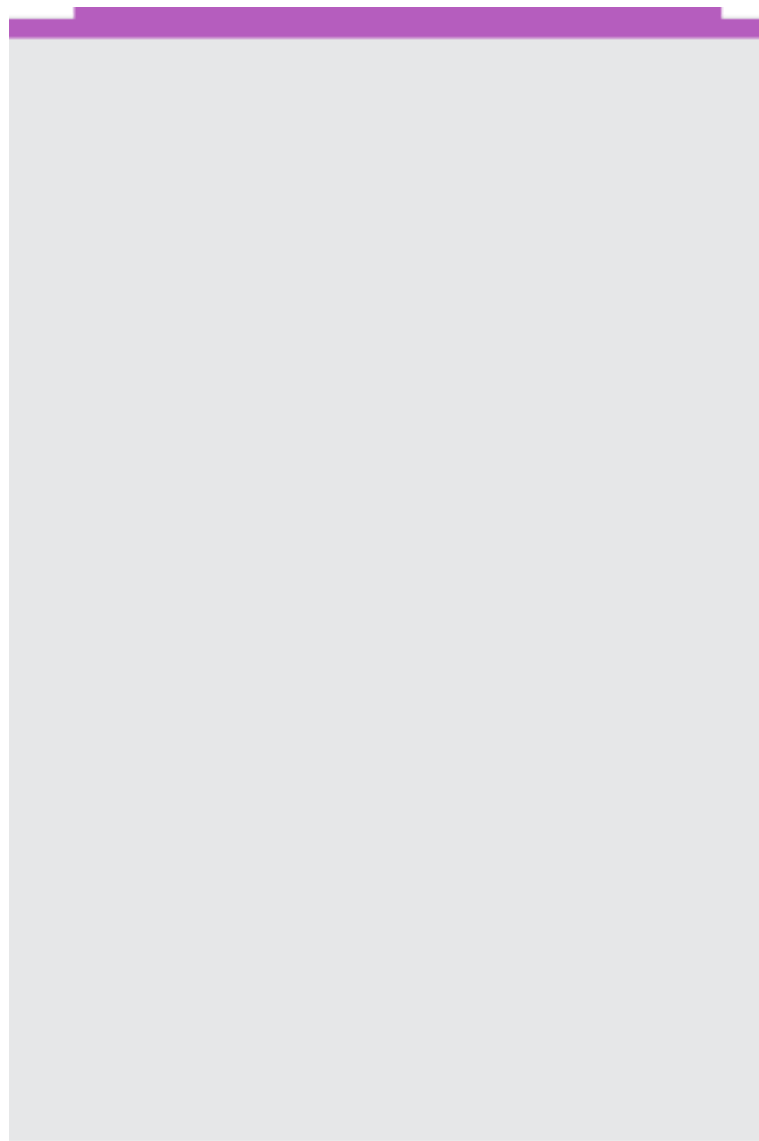
There is a risk of absorption of irrigating fluid into the vascular system and then body tissues, leading to a collection of symptoms known as 'transurethral syndrome' – hyponatraemia, hyperkalaemia, cerebral oedema, renal failure, and/or bradycardia and hypotension progressing to pulmonary oedema. Although rare, this occurs more with use of glycine, in transurethral resection of the prostate (TURP) and transcervical resection of the endometrium (TCRE), up to 3-L absorption in some reported cases. Treatment is supportive and involves fluid restriction, diuretics and observation. Correct the hyponatraemia (<120 mmol/L) slowly with hypertonic saline (7.5%) at a rate of 1 mmol/L/hr to achieve a serum sodium level of 130 mmol/L.

Ileostomies are used to manage conditions such as large bowel obstruction, malignancy or inflammatory bowel disease. As previously mentioned, the small bowel secretes a high volume of fluid (approximately 5000 mL) rich in sodium, chloride, potassium and enzymes in the healthy state. In those with ileostomies, this may be more pronounced, especially when first sited. The absorption of certain vitamins and minerals can also be diminished. Maintain a strict fluid input–output chart whilst the patient is in hospital and check electrolyte levels and renal function daily. If the patient is constantly in negative fluid balance, they will require large volumes of oral or IVF replacement, and in some cases, anti-motility agents and soluble fibre supplements to bulk up the ileostomy output. Select an IVF such as Hartmann's or Plasmalyte, which both have adequate sodium and potassium levels. Continue to monitor response to fluids and titrate volume and selection of fluid according to this.

CONCLUSION

Surgery produces a physiological stress response in the human body. As a junior doctor, you can help the patient prepare for this disruption to normal function and reduce the risk of morbidity and mortality peri-operatively. Starting at admission or in the pre-assessment clinic, use your history-taking and examination skills to determine if your patient has pre-existing risk factors such as cardiopulmonary disease, renal failure or coagulation disorders. Use the *Enhanced Recovery Programme* protocol to guide your management. Aim to match the body's maintenance fluid requirements in the pre-operative NBM period (25–30 mL/kg/day of water, up to 40 mL/kg/day in healthy young adults and approximately 1 mmol/kg/day of potassium, sodium and chloride).

Intra-operatively, match maintenance requirements and aim to replace lost fluid volume from the surgical procedure. The patient may be hypovolaemic and hypotensive after surgery, requiring larger volumes of IVF. 4% dextrose/0.18% normal saline is a reasonable choice in the immediate post-operative period; switch to balanced crystalloids or colloids depending on the patient's response. Once the patient tolerates sips of water, stop IVF therapy. Familiarise yourself with the common surgical procedures conducted in your particular specialty, so that you can understand why certain procedures may need slightly different fluid therapy regimes.



A 72-year-old man is referred to the surgical assessment ward with a 2-day history of worsening 'pain at the breastbone'. This did not resolve with simple painkillers and he has now

started vomiting, with an associated fever. He states that he had a procedure to remove gallstones recently; you check his discharge letter and discover that this was an endoscopic retrograde cholangiopancreatography (ERCP) done 2 weeks previously. Otherwise, he has no chronic medical conditions nor does he take any regular medications.

Airway: Patent. He is able to complete full sentences, but he winces during conversation.

Breathing: He prefers to sit upright, with his arms braced against the examination couch. No abnormal breath sounds auscultated. RR 26 breaths/min. Oxygen saturation 94% on air.

Circulation: Clammy, cool peripheries, capillary refill time (CRT) 4 seconds. HR 100 bpm. BP 110/70. Some difficulty establishing a patent cannula, but a 16G cannula is eventually sited and blood taken for arterial blood gas (ABG) and FBC, urea and electrolytes (U+Es), LFTs, amylase, clotting profile and group and save sampling.

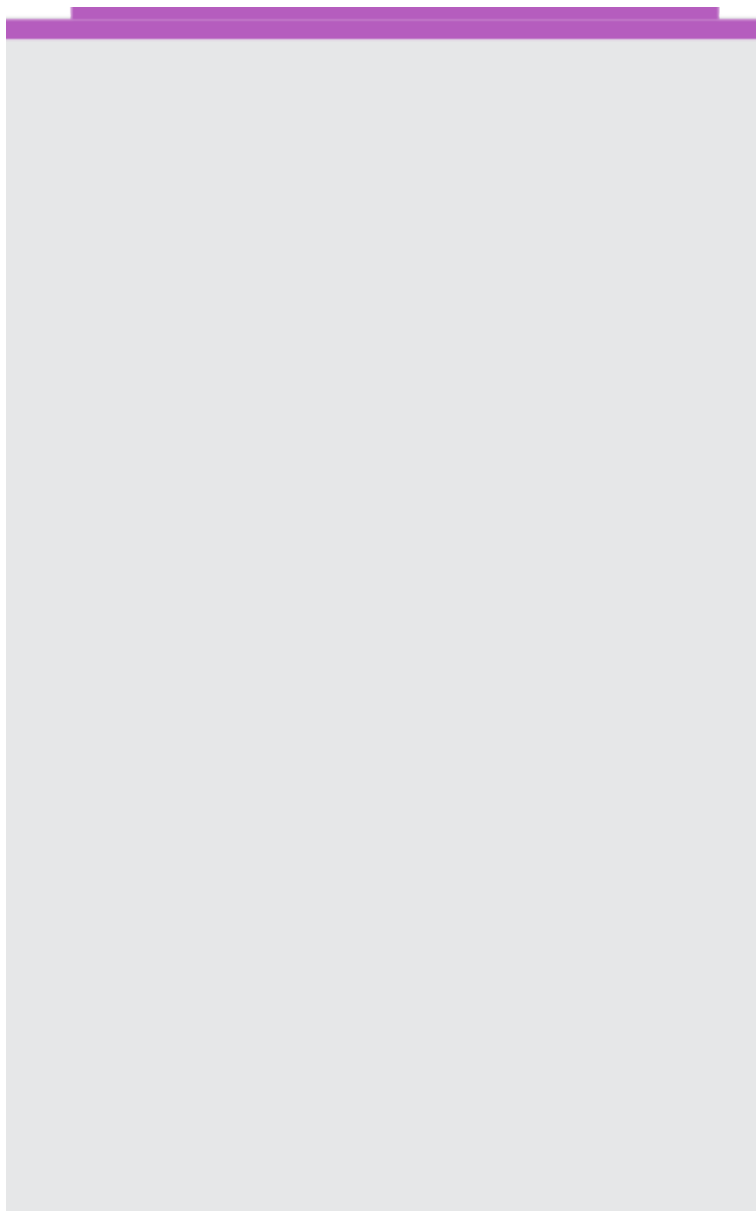
Disability: Glasgow Coma Scale (GCS) score 15/15. Capillary blood glucose level is 11.5 mmol/L. Urinalysis shows a trace of glucose and ketones.

Exposure: On inspection there is mild jaundice of the sclera, and mild abdominal distension. The abdomen is generally tender, but more so in the right upper quadrant. Digital rectal exam revealed no abnormalities.

What is the main abnormality and what is the most likely underlying diagnosis?

This patient presents with a variety of problems: abdominal pain following ERCP, vomiting, jaundice, hyperglycaemia, fever and signs of developing shock. Overall, the fact that his illness has developed soon after ERCP suggests acute pancreatitis. Diagnostic criteria for acute pancreatitis include the following:

- Sudden onset of persistent, severe epigastric or generalised abdominal pain radiating to the back.
- Elevation of serum lipase or amylase to more than three times the upper limit of normal.



- Features of pancreatic/peritoneal inflammation on imaging such as transabdominal ultrasound, CT or MRI. Imaging is only rec-

ommended if there is diagnostic uncertainty.

What are your priorities in treating this patient?

As this patient is already starting to show signs of severe pancreatitis and shock, he should be admitted to an acute surgical bed with regular checks of his BP, HR, RR, temperature and oxygen saturation. Resuscitation should include IVF therapy and supplemental oxygen to maintain his oxygen saturation at 94%–98%.

Hallmarks

- Severe acute abdominal pain, sometimes localised to the epigastrium.
- Markedly raised amylase or lipase or both, secondary to leakage from the inflamed pancreas into the systemic circulation.
- More commonly caused by gallstones or alcohol.
- Grey Turner's sign occurs late and rarely in the disease process; bruised appearance of the loins due to retroperitoneal tracking of bloodstained pancreatic juice.
- Severe pancreatitis features marked hypovolaemic shock; toxins from the inflamed pancreas and the body's inflammatory response make capillary walls leakier; water and sodium leak out of the intravascular space and into surrounding tissues. Tissue hypoperfusion and end-organ failure also feature.

Investigations

- ABG/venous blood gases (VBGs) provide information on acid–base status, tissue perfusion and electrolyte imbalance.
- Blood tests including LFTs, U+Es, amylase, FBC.
- ECG may show abnormalities secondary to electrolyte imbalance.
- Gallstones may cause obstruction of the ampulla of the pancreas or oedema of the pancreatic head; investigate/manage with ERCP or magnetic resonance cholangiopancreatography (MRCP) perhaps after the acute phase has settled.

Management

Supportive treatment includes analgesia, antibiotics, resting the pancreas by being NBM, and IVF replacement. To determine the severity of pancreatitis and therefore the management, use a scoring system such as Glasgow criteria or Acute Physiology and Chronic Health Evaluation II (APACHE II) score. A patient with a high

score has a more severe form of pancreatitis, with a higher risk of mortality, so they should be managed in an intensive care setting.

Hypovolaemia in pancreatitis can progress quickly to shock and cardiovascular collapse; fluid replacement, particularly within the first 24 hours has been shown to reduce mortality. A balanced crystalloid is ideal in the initial stages, but adjust the volume and choice of fluid in accordance with the patient's response to treatment. Maintain MAP at 65–85 mmHg, urine output >0.5 mL/kg/hr. Monitor the observations and blood glucose every hour; hyperglycaemia may need treatment if persistent. U+Es should be checked at least once a day to guide treatment.

Meg is a 42-year-old nulliparous woman currently undergoing investigations for abdominal bloating. She has had a negative

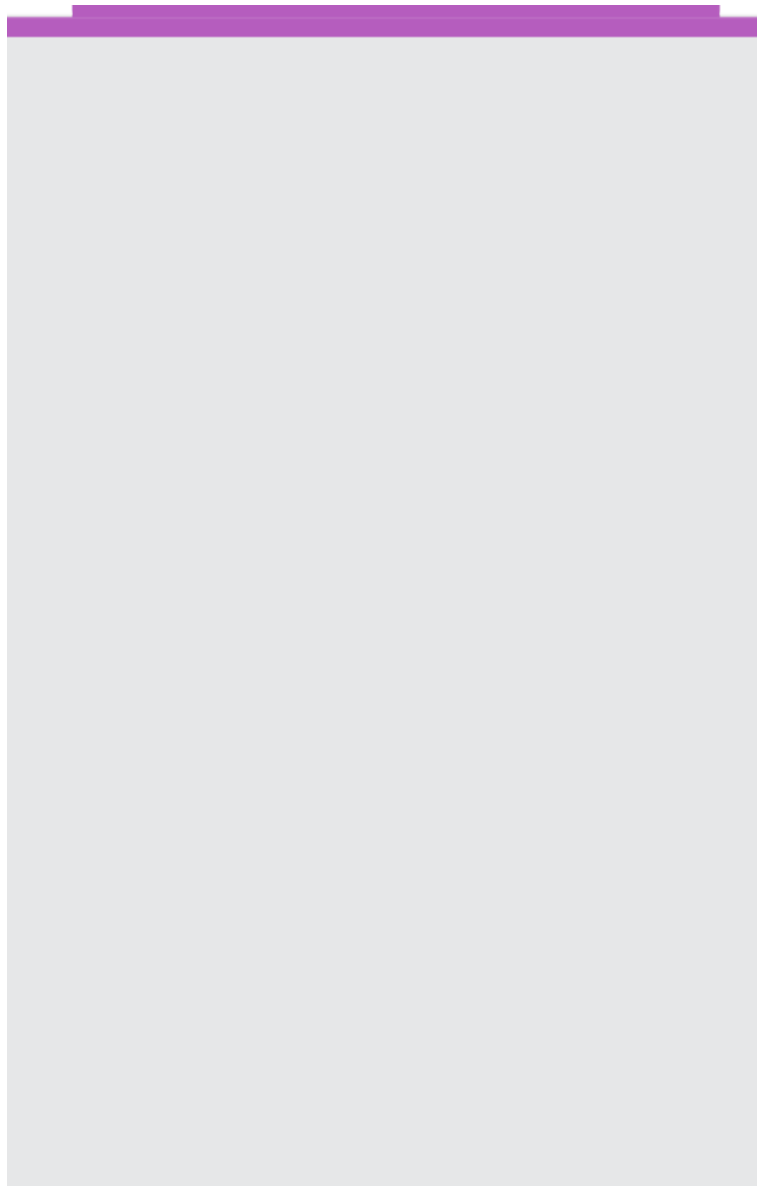
urine pregnancy test, her general practitioner (GP) has asked her to keep a food diary and she is awaiting a transabdominal ultrasound. She presents to the urgent care centre with a history of increasing abdominal pain and bloating, as well as a new onset of vomiting. Her observations are within normal limits; serum blood test results of note are as follows:

| | | |
|-----------------------------|----------------------------|-------------------------------|
| Hb 112 g/L | Na ⁺ 130 mmol/L | LFTs are within normal limits |
| WCC 11×10^9 | K ⁺ 4 mmol/L | |
| Neutrophils 4×10^9 | Creatinine 65 μ mol/L | |
| CRP 50 | Urea 10 mmol/L | |

On assessment, she is noted to have dry mucous membranes, reduced skin turgor and a tense, distended and generally tender abdomen. She vomits around 400 mL of bilious fluid during the consultation and she does not recall when she last passed urine.

What is the main abnormality and what is the most likely underlying diagnosis?

Gradual development of abdominal distension has developed into acute abdominal pain and vomiting. Meg is also showing signs of dehydration. An AXR in A&E is likely to confirm small bowel obstruction. Further investigations may be required to determine the exact cause of obstruction.



What are your priorities in treating this patient?

As Meg is in acute pain and showing signs of dehydration, she will

need resuscitation with IVF and analgesia. This warrants hospital admission and assessment by a member of the surgical on-call team. Once resuscitated, she will need further assessment to help determine whether surgical intervention is required or not; this may include decompression of dilated bowel, reducing intussusception or resecting ischaemic bowel.

Hallmarks

- Vomiting, cramping/paroxysmal abdominal pain, inability to pass stool or flatus
- Signs of dehydration including hypotension, tachycardia, reduced urine output
- Tinkling or reduced bowel sounds in mechanical obstruction

Investigations

- Blood tests have already been done. A lactate level would be a useful indicator of tissue perfusion and likelihood of infection.
- AXR/erect CXR may show dilated bowel loops, intra-abdominal mass, air under the diaphragm suggestive of bowel perforation.
- More detailed imaging via CT may be required to identify the underlying cause of obstruction.

Management

In small bowel obstruction, there is dilatation of bowel loops proximal to the point of obstruction and collapse of bowel distal to this point. Fluid accumulates within the bowel lumen, distending it. The bowel walls become oedematous, and their absorptive function is diminished. Vomiting leads to loss of sodium, chloride, potassium and hydrogen ions from the body, resulting in hypovolaemia and signs of hypotension.

An NG tube helps to drain and decompress the build-up of fluid; however, it is not always tolerated by conscious patients. The patient most often remains NBM to avoid aggravating the obstruction.

Replacement IVF therapy aims to replace lost intravascular fluid volume and electrolytes especially potassium. Like-for-like volume replacement with some additional volume to account for insensible losses is advised, especially as patients can lose a significant amount of fluid through vomiting. Hartmann's solution,

Ringer's lactate or 0.9% normal saline with added potassium chloride are advised. Titrate the volume given to the patient's responses: are BP, HR and urine output normalising? Are the serum potassium and sodium levels within normal limits?

Some patients improve with conservative management (drip and suck), gradually the vomiting and abdominal pain eases and they are able to tolerate oral intake again. Others may deteriorate into hypovolaemic shock and cardiac arrest, especially if there is sudden bowel perforation or ischaemia. Resuscitation and then surgical intervention may be required.

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Chapter 6

Blood products and transfusion

INTRODUCTION

As a junior doctor, you are expected to recognise clinical indicators for transfusion of blood components, counsel the patient and gain their consent for this. You will also prescribe, organise and sometimes over-see the administration of blood.

When assessing a patient who is being considered for transfusion, aim to determine what the cause of bleeding is. Is it chronic or acute? Is there an intrinsic problem with the production of cells or clotting factors? Is there over-coagulation requiring reversal? Ensure that you are taking steps to prevent further blood loss and/or anaemia, and resuscitate the patient if signs of shock are present. Once you have assessed the patient for signs and symptoms of anaemia, if you remain unsure about whether a transfusion is necessary, discuss with a senior member of your team or a haematologist. Always consider whether alternatives to extrinsic blood products are more suitable. In some cases, such as Jehovah's Witnesses and oncology patients, the risks of transfusion can outweigh the benefits. Alternatives include colloid fluid, iron replacement and autologous transfusion/cell saver techniques.

After you have determined that a patient would benefit from a transfusion, you must discuss the indication, process, risks and intended outcome with them if they are conscious. This should include sharing written information (local hospital or national leaflet) and

documenting verbal consent to proceed. If the patient is unconscious or if major trauma has occurred, you may not be able to converse with the patient, but act in their best interests and transfuse if necessary to save their life.

Transfused blood components contribute to the circulating fluid volume and can lead to transfusion-associated circulatory overload. It is therefore essential to consider the patient's individual attributes; weight, elderly age and concomitant medical problems such as heart failure (HF) and renal impairment. Consider whether a slower rate of administration is required, is a diuretic required after transfusion, and if so, at which stage? Check for signs of fluid overload during transfusion.

This chapter aims to revise the clinical assessment of acute anaemia, available blood products and their indications/cautions, common transfusion regimes, as well as special cases to consider.

ASSESSMENT

Symptoms of anaemia are commonly non-specific and in the case of chronic anaemia, can be absent. With a gradual decline in haemoglobin (Hb), the body is able to compensate and increase the oxygen-carrying capacity of blood; however, with acute blood loss patients tend to decompensate more quickly, developing hypovolaemia and symptoms such as dizziness, fatigue, irritability, palpitations and breathlessness. Quickly determine if the situation is an emergency; does the patient need immediate resuscitation? Enquire about symptoms, examine the patient, and review the observations and drug and fluid-balance charts. Conduct some simple investigations to help determine if management with transfusion is required and tailor this to your specific patient.

HISTORY

Current medical problem

Why is the patient in hospital? Have they had a surgical procedure recently? Did they collapse in the community? Are they elderly? Ask whether there has been recent obvious bleeding such as haemoptysis, haematemesis, melaena, haematuria, epistaxis or heavy vaginal bleeding.

Current fluid status

Consider the patient's fluid intake, output and causes of extra fluid losses: do they balance out?

Intake

Has their medical/surgical condition stopped them from drinking enough water? If so, have they had enough replacement for their age and size? Assess the quantity of input from the following:

1. Oral intake – All types of fluid
2. Intravenous fluids (IVFs) – Note types of fluids (crystalloids, colloids, blood) and electrolyte composition
3. Parenteral feeding – Note electrolyte composition
4. Enteral feeding via nasogastric tubes (NGT), nasojejunal tubes and percutaneous endoscopic gastrostomies (PEGs)

Output

Assess all routes of output and insensible losses a patient might have. It is especially important to assess whether there is ongoing blood loss; has the patient noted blood in their stool/urine/vomit/surgical drain/ wound site?

Signs and symptoms of fluid depletion can be vague, but put in context with the fluid balance chart, they should support your diagnosis. It is important to look at trends, as they will reveal the cause of fluid abnormality. For example, a patient may become progressively hypotensive due to ongoing blood loss and the observation chart will show a steady decline in blood pressure (BP), a rise in heart rate (HR) and altered respiratory rate (RR).

Hypovolaemia

- **Symptoms:** Thirst, oliguria/anuria, orthostatic hypotension, headache, lethargy, confusion, vomiting, diarrhoea.
- **Signs:** Decreased skin turgor, increased capillary refill time (CRT), cool peripheries, dry mucous membranes, tachycardia, weak thready pulse, tachypnoea, hypotension, increased RR, coma. These signs may not respond to fluid challenge, giving a clue to acute blood loss.

Table 6.1 Signs and symptoms of hypovolaemia by fluid compartment

| Compartment | Symptoms of hypovolaemia | |
|---------------|--------------------------|--|
| | | Signs of hypovolaemia |
| Intravascular | <i>Thirst, nausea</i> | <i>Tachycardia, hypotension</i> |
| Interstitial | <i>Thirst, nausea</i> | <i>No oedema, dry mucous membranes, poor skin turgor</i> |

Think about the different fluid compartments. Table 6.1 presents the signs and symptoms of hypovolaemia associated with each compartment.

Past medical history

A patient's history will guide blood component prescribing. Have they previously received blood transfusions? If so, which components and was there a reaction? They may now have antibodies that might mean obtaining compatible blood takes a longer time. Your history should outline conditions that could affect current fluid status and highlight any indications for cautious prescribing. Focus on the following:

- **Haematological** – Presence of haemoglobinopathies such as sickle cell disease, haemolytic diseases and clotting factor disorders such as haemophilia. Also ask about a known vascular malformation, which could predispose to bleeding.
 - Most patients with β -thalassaemia major require red cell transfusions every 4 weeks or so to maintain their HbA levels above 95 g/L; anaemia can occur if the patient's schedule of transfusion is not individualised. Sickle cell disease patients have chronic anaemia and require red cell transfusion in acute crises and to prevent long-term organ damage when HbS fractions rise.
 - Consider undiagnosed haemophilia or von Willebrand disease if there is a personal or family history of unprovoked bleeding; the patient will need tests for these conditions and recombinant activated factor VII, VIII or desmopressin (releases factor VIIIc and von Willebrand factor [vWF] from endothelial cells to treat or prevent bleeding).
- **Hypoalbuminaemia** – Associated with inflammatory conditions, liver failure, nephrotic syndrome, malignancy and chronic illness. Hypoalbuminaemia reduces colloid osmotic pressure, contributing to oedema. This also inhibits platelet aggregation, therefore inhibiting clotting and cessation of blood loss. Distribution and

metabolism

of protein-bound drugs such as warfarin is altered in hypoalbuminaemia, increasing the risk of overcoagulation and bleeding.

- **Cardiovascular** – Ischaemic heart disease (IHD) and HF will affect the heart's ability to pump blood around the body in varying degrees. There may be pre-existing fluid overload. Be cautious when prescribing blood, as decreased cardiac output might result in excess fluid outside the intravascular space (oedema).
- **Renal** – Depending on the extent and cause of acute kidney injury (AKI) a patient may require careful transfusion, or dialysis first. Chronic kidney disease (CKD) of varying degrees will affect how the body processes external fluids and blood, and hence, the quantity and rate at which blood components are administered may need to be reduced. Ask if the patient is receiving erythropoietin, which increases the rate of production of red blood cells (RBCs), thus helping to prevent anaemia.

Medication

Take particular note of medications that affect the function of coagulation, the heart, kidneys and hormonal control of fluid and electrolyte balance. Some of these medications may need to be omitted or optimised before elective surgery or during an emergency admission; consult the *British National Formulary* (BNF), a clinical pharmacology text or a senior if you are unsure. The following are common medications in the general population and the effects that will influence your management:

- **Anticoagulants** – e.g. warfarin, dabigatran, rivaroxaban, heparin. Concurrent illness/incorrect dosing/drug interaction/surgery can lead to bleeding which is difficult to control. Reversing the anticoagulant effect can be tricky and lead to long-term problems re-establishing anticoagulation.
- **Antiplatelet drugs/nonsteroidal anti-inflammatory drugs (NSAIDs)** – e.g. aspirin, ibuprofen, clopidogrel, prasugrel. Aspirin and clopidogrel irreversibly impair platelet activation and cross-linking, an effect that can take up to 7 days to stop. NSAIDs have a shorter half-life and a reversible effect on prostaglandin synthesis. These drugs can lead to bleeding, especially if there is an interaction with cytochrome P450 (CYP450) inhibitors.
- **Antifibrinolytics** – e.g. tranexamic acid. To help control acute bleeding, especially in massive haemorrhage, menorrhagia,

epistaxis and haemophilia. Can also be used in bleeding caused by over anticoagulation.

- **Steroids** – Used for a variety of conditions, can lead to side effects, which are more likely in higher doses. These include peptic/oesophageal ulcers, thromboembolism, congestive cardiac failure (CCF) and generalised fluid and electrolyte imbalances.
- **Potassium sparing diuretics** – e.g. spironolactone can cause hyperkalaemia, hyponatraemia and water depletion. Stored red cells release potassium which could contribute to existing hyperkalaemia.
- **Electrolyte supplements** – e.g. potassium supplements will increase serum potassium levels; consider stopping them if red cell transfusion is required.
- **ACE inhibitors** – Renal impairment, increasing the risk of fluid overload with transfusions.
- **Beta-blockers** – Can cause decreased cardiac output, which will affect tissue perfusion in the event of hypovolaemia secondary to bleeding.
- **Furosemide** – Loop diuretic which can be used to offload excess fluid in frail patients or those with HF. This is administered in between blood transfusions to help avoid volume overload.



Warfarin

In acute bleeding, especially if international normalised ratio (INR) >1.5 , stop warfarin, give 5 mg vitamin K intravenously and 25–50 IU/kg of four-factor prothrombin complex concentrate (e.g. Beriplex, Octaplex). Pre-operatively, stop warfarin 5 days beforehand, replace with low-molecular-weight heparin up to 24 hours before the procedure if high risk of thrombosis.

Direct thrombin inhibitors (Dabigatran) and direct factor Xa inhibitors (Rivaroxaban, Apixaban)

These newer oral anticoagulants also have the side effect of haemorrhage, but less so than with warfarin. No current antidotes, but relatively short half-life of 5–20 hours depending on renal function. Tranexamic acid and haemodialysis may help; seek haematology advice.

Heparin

Unfractionated heparin may be used to treat and prevent venous thrombosis, but has the side effects of haemorrhage and thrombocytopenia. The half-life of a continuous infusion is dependent on the dose and presence of renal impairment, varying from around 30 to 150 minutes. Therapeutic dosing requires 4–6 hourly clotting samples to determine the activated partial thromboplastin time (APTT) ratio (comparison of the APTT of the patient with that of normal pooled plasma). Stopping the infusion is usually sufficient to treat overdose, but rarely, reversal with protamine (protein that binds heparin, 1 mg for 100 IU heparin, maximum 50 mg) may be required.

Low-molecular-weight heparins, e.g. Enoxaparin, Tinzaparin, also treat and prevent venous thrombosis with the advantage of easier use, reduced need for monitoring and less effects on platelets. Since they have a longer half-life than the unfractionated form, stop prophylactic doses 12 hours before surgery and treatment doses 24 hours before. Protamine has less potency in reducing anticoagulant effects in the event of haemorrhage.

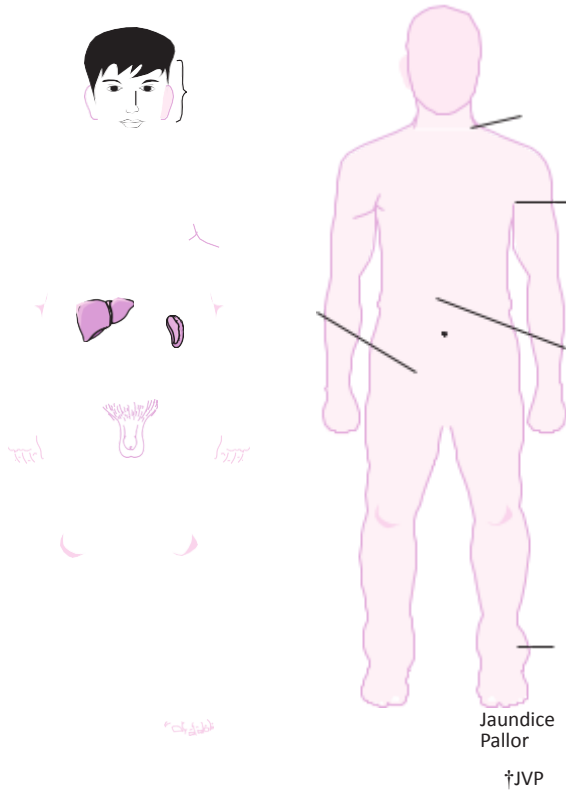
Examination

Look for clues that suggest trauma, ongoing bleeding or decompensation from chronic anaemia. Are there signs of worsening HF, for instance, and is there a new-onset arrhythmia? Assess the abdomen; is it tense, tender and becoming more distended over a short period of time (intra-abdominal bleeding)?

Use the ‘ABCDE’ approach to assess and manage the patient who has signs of hypovolaemic shock (see Chapter 3).

Late signs of bleeding such as bruising to the surrounding skin, flank (Grey Turner’s sign) or peri-umbilicus (Cullen’s sign) may be present. Signs of chronic anaemia include skin and conjunctival pallor, cheilosis, angular stomatitis, koilonychia and jaundice (see Figure 6.1).

Examine the orifices for clues about the source of bleeding, and inspect recent venepuncture/cannula/central line sites for bleeding; this could indicate disseminated intravascular coagulation (DIC). Also focus on the following signs outlined in Table 6.2.



Enlarged lymph nodes

Melaena Haematuria

Koilonychia

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Peripheral oedema

Figure 6.1 Signs of chronic anaemia.

Table 6.2 Signs of fluid depletion in ongoing bleeding

| System | Fluid depletion |
|----------------|--|
| Cardiovascular | <ul style="list-style-type: none">• Tachycardia?• Hypotension?• Capillary refill time (CRT) >2 seconds?• Decreased skin turgor?• Dry mucous membranes?• Postural drop in blood pressure? |
| Respiratory | <ul style="list-style-type: none">• Respiratory rate (RR) >20 breaths/min? |
| Renal | <ul style="list-style-type: none">• Decreased urine output <0.5 mL/kg/hr?• Concentrated urine? |
| Neurological | <ul style="list-style-type: none">• Low Glasgow Coma Scale (GCS) <8?• Comatose? Meningism? Retinal signs? (may be associated with CNS bleed) |

Most importantly, talk to the patient; determine if their airway is patent. Is their breathing pattern altered? Do they remain coherent or are they acutely confused, as can occur in haemorrhagic shock? You may need to abandon a full examination if you find abnormalities that require immediate resuscitation and additional help.

Investigations

By arranging the appropriate investigations, you play a crucial role in determining the cause of anaemia/bleeding, stopping bleeding, determining whether the patient requires a transfusion or other intervention and if so, ensuring that this is conducted safely. As you are not expected to request highly specialised tests when investigating anaemia, we will focus on the more common tests you will be expected to request and understand (see Table 6.3).

1. **Blood tests:** Especially important are an up-to-date measurement of the patient's full blood count (FBC), urea, electrolyte, liver function and clotting screen results. A blood film gives more information if aspects of the FBC result are abnormal. A Hemocue test gives a quick estimation of Hb level, as does an arterial blood gas (ABG), which may also show low oxygen saturation and mixed acidosis in haemorrhage. For instance, a patient with ongoing haemolysis may have a rising trend in unconjugated bilirubin. DIC would prolong APTT, raise INR and deplete platelet counts.

Clotting Screen Helps monitor effect of interventions such as anticoagulants. Useful in those at risk of developing DIC, e.g. massive haemorrhage, severe sepsis, burns. Consider repeated clotting screens in bleeding that is difficult to control (is DIC developing?). Screening for DIC consists of checking prothrombin time (PT), APTT, fibrinogen, fibrin split products, and platelet count. This is confirmed by elevated coagulation times, decreased platelet counts and fibrinogen, and the presence of fibrin split products (see Table 6.4).

Group and Save (G&S) samples should be collected, labelled by the bedside and checked with another health care professional to avoid transfusion errors. Laboratories analyse for ABO and rhesus D (RhD) grouping as well as common red cell antibodies. This information is stored so that specific blood components compatible with the patient can be prepared within 45 minutes of a subsequent request.

Table 6.3 Full blood count

| Parameter | Interpretation |
|---|--|
| Haemoglobin | — or § as anaemia advances. |
| Red blood cell (RBC) count | § in anaemia, haemolysis, massive transfusion. † to compensate for low oxygen levels, in plasma fluid loss and bone marrow dysfunction. |
| Reticulocyte count | † in acute or chronic blood loss, haemolytic anaemia. § in iron, B ₁₂ or folate deficiency, bone marrow failure, aplastic anaemia. |
| White blood cell (WBC) count | † in infection, inflammation, cancer. |
| Haematocrit/packed cell volume (PCV) | § in bone marrow failure, severe infections. |
| Mean corpuscular volume (MCV) | Same findings as RBC count. |
| | † in B ₁₂ or folate deficiency, liver disease. § in iron deficiency, thalassaemia, chronic disease. |
| Mean corpuscular haemoglobin (MCH) | May § in iron deficiency, thalassaemia, inflammation. |
| Mean corpuscular haemoglobin concentration (MCHC) | As in the previous row. |
| Red cell distribution width (RDW) | † due to variation in size and shape of RBCs in some forms of anaemia, e.g. iron or B ₁₂ deficiency. |
| Platelets | † in inflammation, bleeding, iron deficiency, splenectomy, cancer. § in disseminated intravascular coagulation (DIC), chronic bleeding, aplastic anaemia, Idiopathic Thrombocytopenic Purpura (ITP), splenomegaly, liver disease, many other causes. |
| Mean platelet volume | † when larger, younger, more reactive platelets are present, indicates high platelet destruction and turnover. § in impaired production of platelets. |

Crossmatch differs in that the patient's information is paired with a compatible stored blood component, a quicker process. This may be required in advance of a procedure if the patient has atypical antibodies and is at risk of requiring a transfusion.

Liver function and electrolyte tests In liver dysfunction, synthesis of proteins such as clotting factors is affected, leading to raised PT, and low albumin levels. Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) levels increase in hepatocellular damage. Bilirubin level is raised in high rates of

destruction of RBCs as

occurs in haemolytic anaemia and sickle cell crises. Urea elevated more than creatinine suggests bleeding from the gastrointestinal tract. Electrolyte disturbance can exacerbate abnormal fluid shift patterns in anaemia. Transfusion can lead to hypocalcaemia and hyperkalaemia; therefore serial tests of electrolyte levels should be used as a baseline and to monitor for these side effects when managing bleeding.

Additional blood tests that may be helpful in evaluating anaemia include the following:

- a. Haemoglobinopathy screen to help determine if a previously undiagnosed haemoglobinopathy such as sickle cell disease or β -thalassaemia is the cause of anaemia
- b. Iron studies
- c. Folate and B₁₂ levels
- d. Blood film
- e. Coombs test
- f. Clotting factor assay (factors II, V, VII, IX, X, XI, XII) and Protein C and S levels
- g. Antibody screening, e.g. to intrinsic factor in B₁₂ deficiency
- h. Virology tests, e.g. cytomegalovirus (CMV), Epstein–Barr virus (EBV)
- i. Bone marrow aspiration
- j. Toxicology screening

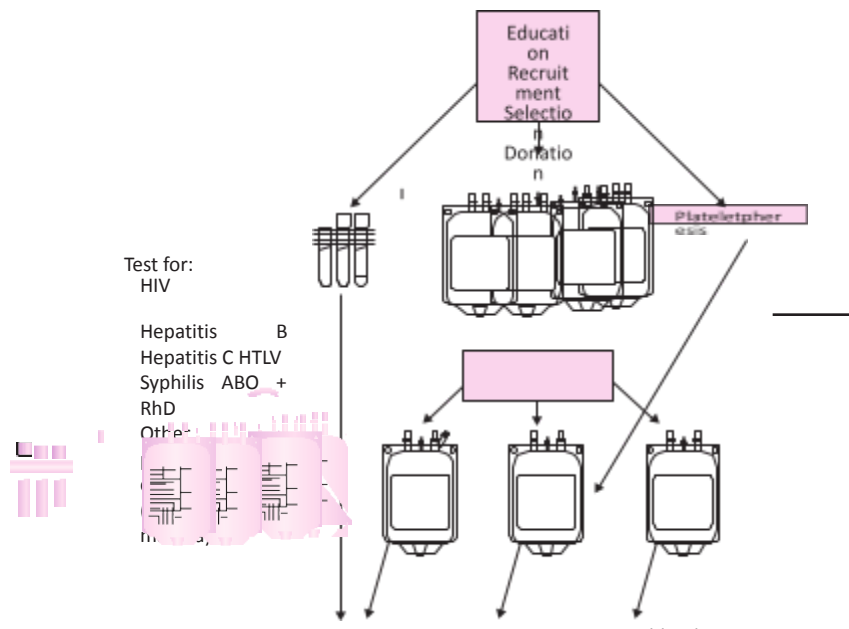
Table 6.4 Clotting screen results in coagulation disorders

| Disorder | Prothrombin time (PT) | | Platelet count | | Bleeding time |
|--|-----------------------|----|----------------|------|---------------|
| | †† | † | †† | † | |
| INR | | | | | |
| APTT | | | | | |
| Disseminated intravascular coagulation (DIC) | †† | † | †† | † | †† |
| Von Willebrand's | — | †† | — | — | † |
| Haemophilia | — | †† | — | — | — |
| Platelet defect | — | — | — | — | † |
| Liver disease | † | † | —/† | —/\$ | —/† |
| Heparin | † | †† | †† | — | — |
| Vitamin K | †† | † | † | — | — |

2. **Urine:** Gross haematuria warrants further assessment of the renal function/tract for stones, malignancy, benign prostatic hyperplasia or obstruction. Microscopic urinalysis may confirm the presence of RBCs/casts, seen in tubular or glomerular causes of bleeding; urine cytology provides more information. Albuminuria suggests renal impairment, especially if the albumin–creatinine ratio is also raised. Elevated urobilinogen/haemosiderin levels may indicate haemolysis.
3. **Electrocardiogram:** Essential for assessment of any current cardiac ischaemia or rhythm abnormality secondary to bleeding – blood component and fluid therapy will depend on the extent and cause of the problem. Where possible, look at previous ECGs and compare for any signs of atrial fibrillation, myocardial infarction or dysrhythmias.
4. **Imaging:** Useful to help determine if there is abnormal fluid distribution, such as chest x-ray (CXR) findings in pulmonary oedema. Furthermore, imaging allows investigation into the clinical cause of abnormal fluid distribution, such as transfusion-associated circulatory overload, or a cardiac or renal abnormality.
 - a. Radiographs – CXR for any signs of fluid overload, haemothorax
 - b. Echocardiogram – Left ventricular ejection fraction (LVEF), ventricular enlargement, dysfunctional pumping
 - c. Ultrasound scan – Ruptured abdominal aortic aneurysm (AAA), intra-abdominal or wound-site haematomas, splenic rupture, renal hydronephrosis
 - d. Computed tomography (CT) – CT of the head for intra-cranial bleed or of the abdomen for suspected leaking AAA, intra-abdominal collections. CT cystourethrogram in suspected bladder trauma/malignancy

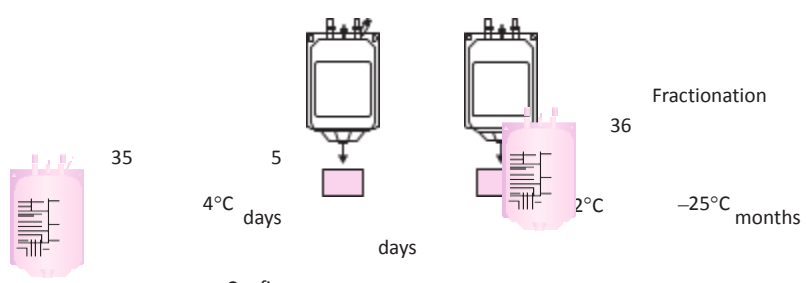
BLOOD COMPONENTS

Following rigorous screening, donor blood is processed into blood components such as red cell and platelet concentrates, fresh frozen plasma (FFP) and cryoprecipitate. Plasma from donor blood is processed and incorporated into blood plasma derivatives such as factors VIII and X, human albumin solution and immunoglobulins (Figure 6.2).



Pooled platelets

Fresh frozen plasma



Confirm

compatibility

NB: platelet shelf life can be extended to 7 days with use of bacterial screening

ative
s,

Figure 6.2 Production of blood components and blood derivatives. (From Derek N, *Handbook of Transfusion Medicine*, Norwich, UK: United Kingdom Blood Services, 2013. With permission.)

Whole blood

A unit of whole blood consists of around 405–495 mL of leucocyte-depleted blood with added citrate phosphate dextrose anticoagulant. This is no longer commonly used in the United Kingdom, due to the unnecessary risk of reactions to components of blood transfused. This maximises the ways in which donor blood can be split into different components and used to help as many people as possible.

Red cells

Indication: To restore oxygen-carrying capacity in severe anaemia or ongoing bleeding, where alternative treatments are ineffective or not appropriate.

Practical points: Plasma is removed from donated blood and replaced with an additive solution. A typical unit has a volume of 220–340 mL, raises Hb levels by around 10 g/L and can be stored for up to 35 days. Stored at 2°C–6°C, it must be started within 30 minutes of removal from the blood fridge and completed within 4 hours. Low viscosity allows a red cell unit to be squeezed in where necessary. Ideally, it should be crossmatched to a recent sample from the patient to avoid ABO incompatibility; in an emergency O RhD- negative blood can be used.

Irradiated red cells are used for patients at risk of transfusion-associated graft-versus-host disease, e.g. organ transplant patients on specific immunosuppressors. Gamma or x-rays are used within 14 days of receiving donated blood and the product must then be used within 14 days.

Washed red cells are used for patients with recurrent, severe allergic or febrile reactions and IgA-deficient patients with anti-IgA antibodies. Preparation involves removal of all but traces of plasma.



REMEMBER

Normal Hb values:

Men: 130–180 g/L Women: 110–150 g/L

Consider blood transfusion if the Hb is between/or <70–80 g/L and the patient is symptomatic. Quickly decide upon and arrange transfusion of red cells in case of massive haemorrhage. Assess your implemented treatment and decide whether further amounts or types of blood components are required.

A unit of red cells gives an increment of around 10 g/L, but this applies to a standard weight of 70–80 kg. The number of units prescribed should be less if the patient weighs less than this, to avoid fluid overload.

A transfused volume of 4 mL/kg will generally give an increment of 10 g/L. Low-weight adults and all children should have their transfusion prescribed in millilitres rather than units to avoid potential overload.

Platelets

Indication: Treatment or prevention of bleeding in those with thrombocytopenia or platelet dysfunction (could be secondary to massive haemorrhage).

Practical points: 200–300 mL/unit. Stored at 20°C–24°C for 5–7 days, must be kept agitated. Adult therapeutic dose is $>240 \times 10^9$ /unit. Platelet transfusions should be selected to be compatible with a patient's blood group, as platelets have ABO antigens on their surface. Produced in two ways; the majority by apheresis from a single donor or by pooling from four donors.

Irradiated platelets are used for the same indications as the irradiated red cells mentioned previously.

Platelets in additive solution are obtained by washing to remove plasma. Only available for use for 24 hours after this process. Used in those who have previously had severe allergic or febrile reactions to standard platelet transfusions.

Human leukocyte antigen (HLA)-selected platelets are used in those with HLA antibodies developed after previous transfusions.

Human platelet antigens (HPAs)-selected platelets are used for babies with neonatal alloimmune thrombocytopenia.

Fresh frozen plasma

Indication: Treatment of patients with bleeding in the presence of single or multiple clotting factor deficiency. No longer indicated for warfarin reversal; use prothrombin complex instead if required. Do not use as a plasma volume expander as there is the risk of a severe allergic reaction.

Practical points: Obtained from male donors only (reduces risk of transfusion-related acute lung injury [TRALI]). Around 250 mL/unit, adult dose requires at least 4 units, as amount of individual clotting factors per unit varies. Stored for up to 36 months at -25°C or below. Use immediately or within 24 hours of thawing if stored at 4°C . Use immediately or within 4 hours of thawing if stored at room temperature.

FFP can be processed via a solvent detergent pooling method to further inactivate microbes (including HIV) and standardise the levels of clotting factors in each pack. Methylene blue treatment of single donor FFP also further inactivates microbes and is preferred in some paediatric settings.

Cryoprecipitate

Indication: Initially developed for haemophilia treatment (factor VIII concentrate used instead nowadays), now mainly used as a more concentrated, lower infused volume source of fibrinogen than FFP.

Practical points: Made by thawing FFP at 4°C to produce a cryoglobulin rich in fibrinogen, factor VIII and vWF. Can also be produced from methylene blue processed FFP. Single donor pack (average 43 mL) or pool from five donors (average 189 mL). Stored for up to 36 months at -25°C or below. Use immediately or within 4 hours of thawing, cannot be re-refrigerated.

Granulocytes

Indication: Used in those with severe neutropenia with life-threatening bacterial or fungal infection. More commonly used in those with severe neutropenia after cytotoxic chemotherapy or bone marrow failure.

Practical points: Prepared from whole blood as buffy coats or by apheresis from individual donors. Irradiated before use and must be group compatible with the recipient. Must be approved by a senior haematologist. Stored at 20°C–24°C, should not be agitated. Stored for 24 hours only and should be administered over 1–2 hours. Daily infusions may be given until evidence of recovery occurs, if there is decline despite several consecutive transfusions or if a severe reaction occurs.

Individual buffy coats contain red cells and platelets in addition to granulocytes, reducing the need for concurrent platelet and red cell transfusions. Around 10 packs of 60 mL each are required to achieve a daily dose, 10–20 mL/kg in those weighing less than 30 kg.

Pooled buffy coats have lower volumes and less red cell and plasma content, with a reduced need for platelet and red cell transfusions. 10 donations are pooled into a pack volume of 200–250 mL with platelet additive solution. Two packs are required for a standard adult dose, 10–20 mL/kg in those weighing less than 30 kg.

Apheresis granulocytes are obtained from relatives or friends who are HLA-compatible with the recipient. These samples contain much higher numbers of granulocytes, as the donors receive granulocyte colony stimulating factor and steroids before sample collection.

A patient may require more than one type of blood product. This decision depends on the patient's symptoms, estimated amount of blood lost and the mechanism through which this has happened; see the section on 'Transfusion regimes' for more on this.

BLOOD PRODUCTS

The term blood products describes blood plasma derivatives manufactured from pooled plasma donations from countries with low risk of variant Creutzfeldt–Jakob disease. All products are subject to pathogen-inactivation processing steps to remove transfusion-transmitted viruses and other microbes.

Human albumin solution

Indication: Isotonic solution (3.5%–5.5%) used in acute or sub-acute loss of plasma volume as seen in burns and pancreatitis for example. Also used as a replacement fluid in plasma exchange therapy. Concentrated solution (20%) used in severe hypoalbuminaemia with low plasma volume and generalised oedema, e.g. in cirrhosis or nephrotic syndrome; aims to expand plasma volume despite salt and fluid intake restriction. Also used when large volumes of ascites are drained in patients with portal hypertension for example.

Practical points: Contains no blood group antibodies or clotting factors. Available in 50-mL, 100-mL or 500-mL preparations. Administer slowly in those with circulatory failure to avoid further overload. Prescribed as a medicinal product; see your local or national formulary for prescription details.

Clotting factor concentrates

Indication: Treatment or prophylaxis of bleeding in those with congenital or acquired coagulation disorders. Single factor concentrates are available for most congenital deficiencies, except for deficiencies of factors II and V. Discuss the appropriate choice of concentrate with a local senior haematologist on-call before prescribing or ordering.

Recombinant factor VIIIc is used in Haemophilia A, while **recombinant factor IX** is used in Haemophilia B. **Dried factor VIII fraction** contains varying amounts of vWF, and is used where a bleeding episode is not improved by desmopressin. It may also contain factors II, VII and X.

Recombinant factor VIIa (NovoSeven) is used in factor VII deficiency, haemophilia with inhibitors to factor VIII and IX and acquired haemophilia. It is also used in intracranial haemorrhage and diffuse alveolar haemorrhage and can be given in boluses during an acute bleeding episode.

Fibrinogen concentrate (factor I) is used in congenital or acquired (DIC, massive transfusion) hypofibrinogenaemia. **Dried factor XIII**

fraction (human fibrin-stabilising factor) is used in congenital factor XIII deficiency.

Prothrombin complex concentrate (e.g. Beriplex, Octaplex) contains factors II, VII, IX and X. Now used instead of FFP to reverse warfarin overdose in active or expected bleeding, at a dose of 25–50 IU/kg, under haematology guidance. Also used to treat coagulopathy secondary to liver disease.

Immunoglobulin solutions

Normal immunoglobulin is manufactured from normal plasma and contains antibodies to viruses such as hepatitis A, rubella and measles. It is given in intramuscular doses to those who may be susceptible to infection with these viruses. In high intravenous doses, normal immunoglobulin is used as a replacement in severe immunoglobulin deficiency and in autoimmune conditions such as idiopathic thrombocytopenic purpura (ITP). Normal immunoglobulin is contraindicated in those with IgA deficiency with a known IgA antibody because of the risk of life-threatening allergic reaction or anaphylaxis mediated by possible IgG anti-IgA antibodies.

Specific immunoglobulins are obtained from selected donors with high plasma levels of antibodies to tetanus, hepatitis B, rabies, varicella zoster and anti-D for example.

TRANSFUSION REGIMES

After a thorough clinical assessment, a decision should be made about whether the transfusion of one or more blood components/products is appropriate, ensuring that the benefits outweigh the risk of harm. A recent crossmatch or G&S sample (some laboratories require a sample obtained within the previous 72 hours) should be used to prepare the right blood for the right patient.

Document the reason for transfusion, treatment target and the patient's consent in the clinical notes. Prescribe each unit to be administered and the duration of each unit; remember that in haemorrhage causing compromise, units should be administered 'stat' (over 5–10 minutes). Ensure that the patient has a working large bore peripheral cannula (at least green 18 gauge, with a flow rate of approximately 2.8 L/hr) or central venous catheter. IVF should not be given through the same infusion line as blood components, but through a different line or lumen

of a multi-lumen catheter. Calcium in, e.g. Gelofusin and Hartmann's solution antagonises the citrate anticoagulant in blood components and rarely, may allow clots to form if administered in the same infusion line.

The term 'goal-directed therapy' in relation to blood transfusions refers to the need to ensure that patients only receive the type and number of blood components/products that they require and avoid over-transfusion and associated adverse effects. Therapy should be restrictive rather than liberal. What is the target Hb level? How many units of red cells will be necessary to achieve this?

Remember that in rapid acute blood loss, the Hb level does not drop immediately. This only occurs with dilution over time as the body shifts fluid between compartments to compensate, or as IVF is administered. Think of a bucket of blood; part of this is emptied, the overall volume of blood in the bucket is reduced, but the concentration remains the same.

Major haemorrhage

Major haemorrhage protocol exists in hospitals to co-ordinate the response to a significant loss of blood volume, as can be seen in trauma or surgical patients. Apart from clinicians, the haematology laboratory and porters are alerted so that blood components can be prepared and transported to the patient without delay. Major haemorrhage may be identified when bleeding leads to signs of haemorrhagic shock (systolic BP <90 mmHg, HR >100 bpm etc.); the patient is likely to have lost 30%–40% of circulating blood volume by this stage. Major haemorrhage may also be defined as blood loss of more than 150 mL/min, or 50% of blood volume loss within 3 hours or more than one blood volume loss within 24 hours (>70 mL/kg).

Aim to site two large bore cannulas, taking samples for FBC, clotting profile, fibrinogen, U+Es, LFTs and G&S. Whilst waiting for blood to arrive, replace intravascular fluid volume with a warmed, balanced crystalloid (Hartmann's, Plasmalyte) or colloid (Volpex, Gelofusin) if profound hypotension occurs. Do not hesitate to administer O RhD-negative blood if there is ongoing bleeding whilst waiting for group-specific blood. Tranexamic acid as a bolus or infusion is also useful in limiting fibrinolysis in major haemorrhage.

Major haemorrhage protocol often consists of two or more packs of blood components in differing amounts. An example is set out below, check your local hospital guideline to determine what your protocol consists of.

- **Pack 1** – 4 units of RBCs
- **Pack 2** – 6 units of RBCs, 4 units of FFP, 1 pool of platelets. 2 pools of cryoprecipitate if fibrinogen level <1.5 g/L

Pack 1 is issued in the first wave and then pack 2 and subsequent repeats of pack 2 are issued following assessment of the patient's response, whether there is ongoing bleeding and upon advice from a senior haematologist. In some cases of major haemorrhage, massive transfusion and coagulopathy, transfusion of RBC, FFP and platelet units is advocated in a near 1:1:1 approach. This is because transfusion of large volumes of IVF and RBCs leads to dilutional coagulopathy; platelet, fibrinogen and other clotting factor levels fall, especially when insufficient levels of platelets or FFP are transfused. Consumptive coagulopathy occurs when platelets and clotting factors are used up in the physiological response to trauma. Increased fibrinolysis, hypothermia, hypoxia, acidosis and hypocalcaemia also contribute to coagulopathy in major haemorrhage.

Massive transfusion can lead to metabolic disturbances such as hypocalcaemia. The citrate anticoagulant in blood components can bind to ionised calcium, which can lead to clinical manifestations of hypocalcaemia (treat with calcium chloride or gluconate as necessary).



2–3 hours each.

In elderly patients or those with existing circulatory compromise such as heart failure, administer Furosemide 20–40-mg orally or intravenously after the second unit of red cells and then with each alternate unit thereafter.

Re-assess the patient within 2 hours of the initial transfusion. Has there been an adequate haemodynamic response? Have BP and HR returned to normal range? Urine output maintained at ≥ 0.5 mL/kg/hr?

Is there a need for further units of red blood cells? Are FFP, platelets or cryoprecipitate now indicated if there is ongoing bleeding or abnormal coagulation?

Consider instigating the major haemorrhage protocol if there is rapid ongoing blood loss or haemorrhagic shock develops.

As a minimum, monitoring of the patient receiving a blood transfusion should include temperature, pulse, BP and RR, with a baseline 0 minutes before the transfusion starts and then 15 minutes after this. Check these observations again within 60 minutes of completing each individual unit. If any symptoms of a reaction occur, check these observations again; if there is a significant change, consider stopping the transfusion and taking further action to stabilise the patient.

REVIEW THE IMPLEMENTED TREATMENT



REMEMBER

In patients who are actively bleeding, the platelet count should be maintained $>50 \times 10^9/L$, PT ratio >1.5 and fibrinogen >1.5 g/L. Hb level should be >70 g/L and >90 g/L in those with existing cardiovascular disease.

You must monitor the patient closely for warning signs of fluid overload, dehydration, electrolyte abnormalities (hypocalcaemia, hyperkalaemia), altered consciousness or other adverse outcome.

Complications of blood transfusions include immunological causes such as blood group incompatibility, haemolysis, graft-versus-host disease, transfusion-associated lung injury and urticaria. Non-immunological causes include transmission of infection, iron overload, electrolyte changes in massive transfusion and air embolism. Specifically, this text focuses on the identification and management of transfusion-associated circulatory overload.

Transfusion reaction screen

A reaction to the transfusion of blood products is classed as any that occurs within 24 hours of administration. Use the 'ABCDE' approach to assess and manage the patient, with the addition of adrenaline, hydro- cortisone, chlorphenamine and IVFs if severe anaphylaxis occurs.

Screening investigations should include the following:

- Baseline FBC, renal and liver function, urinalysis.
- G&S sample for repeat compatibility and antibody testing.
- Return the blood component to the lab for bacterial contamination and compatibility testing.

- Mast cell tryptase levels rise after a true severe anaphylactic reaction; levels should be checked as soon as possible after the event and then at 3 and 24 hours after. Most useful where symptoms of anaphylaxis may be masked, such as under anaesthesia.

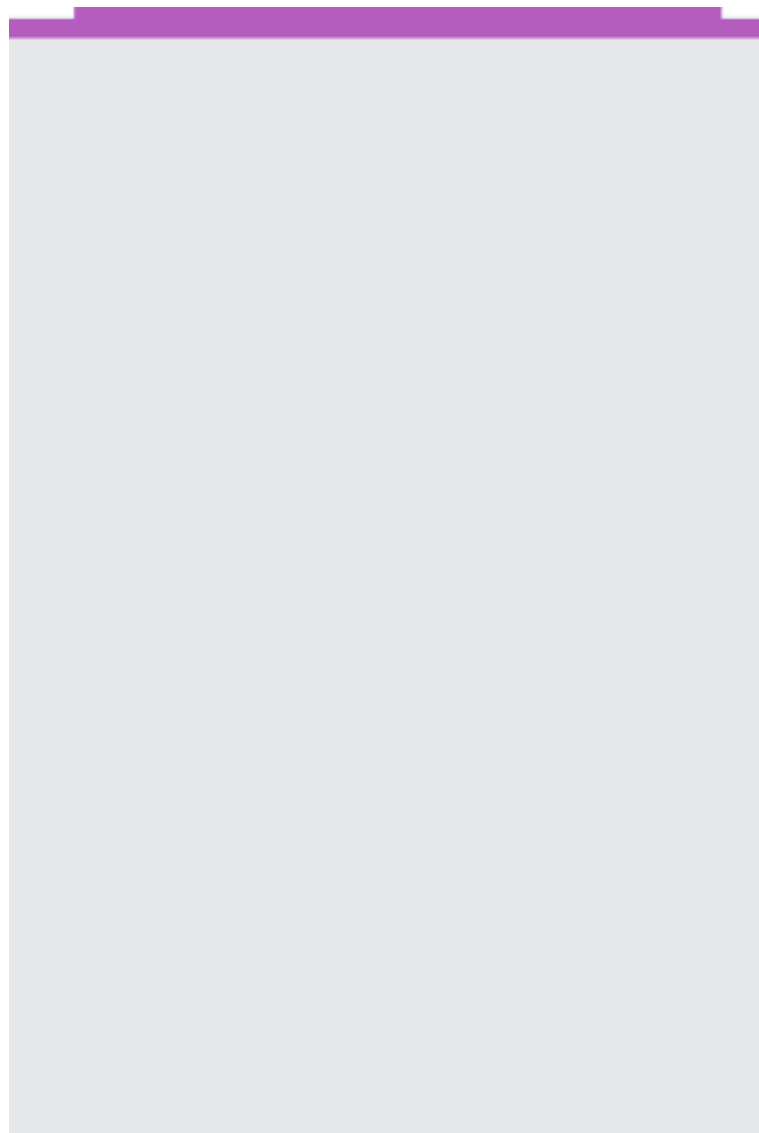
Transfusion associated circulatory

overload Transfusion associated circulatory overload (TACO) is acute or worsening pulmonary oedema within 6 hours of a blood transfusion. This is more common with RBC transfusions or transfusion of large volumes of blood components.

Features include tachycardia, hypertension, acute respiratory distress and positive fluid balance. Treatment involves stopping the transfusion and supportive management to move fluid from the pulmonary interstitium; oxygen, diuretics, close monitoring perhaps on a high dependency unit. The risk of TACO is reduced by careful clinical assessment before transfusion and calculating volumes to be transfused according to weight and in millilitres, not unit size. Close monitoring during transfusion can also help to identify TACO early.

CONCLUSION

Anaemia can be a life-threatening condition, especially if caused by acute haemorrhage. In assessing a patient for signs of acute anaemia or ongoing haemorrhage, take a detailed history, examine and conduct appropriate investigations. If there are signs of ongoing bleeding, address this quickly, instigating the local major haemorrhage protocol if necessary. Whole blood is no longer used to replace lost blood volume; different components such as RBCs, FFP and cryoprecipitate are used instead. This is done as 'goal-directed therapy', i.e. to maintain target Hb, PT, fibrinogen and platelet levels and avoid complications such as circulatory overload and metabolic disturbances. Blood products such as clotting factor concentrates and immunoglobulins are useful in managing congenital or acquired clotting disorders and immune-mediated conditions. Remember that senior members of your clinical team and haematologists are available for advice when managing patients who require blood components or blood products.



A 57-year-old man with known heavy alcohol intake and tobacco abuse presents to hospital complaining of lethargy and foul-smelling black tarry stool. His observations are as follows:

HR 120 bpm
BP 80/40 mmHg
CRT 5 seconds
RR 22 breaths/min
O₂ saturation 88% on room air
Temperature 36°C

On examination, no stigmata of chronic liver disease are found. He has rhinophyma and epigastric tenderness on palpation; he admits to taking ibuprofen for the previous few days. During the consultation, he vomits around 100 mL of fresh blood and becomes confused.

What is the main abnormality and what is the most likely underlying diagnosis?

This man is displaying signs of hypovolaemic shock secondary to recent upper GI bleeding. He is tachycardic, hypotensive, hypoxic, hypothermic and has a narrow pulse pressure.

Hallmarks

- Melaena, epigastric pain and haematemesis are signs of upper GI bleeding.
- Peptic ulcer disease and oesophageal varices are the most common causes of upper GI bleeding.
- Hypovolaemic shock features severe hypotension, narrow pulse pressure, tachycardia and reduced tissue perfusion secondary to reduced intravascular fluid volume.

Management

- Call for help, move the patient to a bay in the resuscitation area of A&E.
- Use the 'ABCDE' approach to initiate resuscitation.
- Maintain his airway and oxygen saturation at 88%–92% (tobacco abuse and admission saturation of 88% suggests hypercapnic respiratory drive).
- Site two large bore cannulae and administer 500 mL of warm balanced crystalloid (Hartmann's or Plasmalyte) via a pressure bag.

CASE 6.1 (continued)

- High dose intravenous proton-pump inhibitor such as pantoprazole.
- Review ABG/venous blood gas (VBG) and FBC results, arrange blood transfusion as necessary, using the major haemorrhage protocol if fresh bleeding continues.
- Consider thiamine and alcohol withdrawal regimes once he is stable.

Investigations

- Hemocue or VBG to get a quick Hb result.
- FBC, G&S, clotting profile. U+Es.
- Erect CXR – looking for signs of perforation (peritoneal bleed).
- Arrange urgent endoscopy to determine if gastric/oesophageal ulcers are present and to stem ongoing bleeding.
- Consider urinary catheterisation to help monitor urine output i.e. end-organ perfusion.

old woman is transferred to labour ward via ambulance because the placenta has not delivered and she is estimated to have lost around 500 mL of fresh blood from the vagina so far. The paramedics have sited a 'green' cannula and an infusion of Hartmann's is running through. She is quickly transferred to the labour ward theatre for removal of the retained placenta.

Upon transfer from the bed to the theatre table, a large pool of blood is noted on the incontinence pad she has been lying on. This pad is subsequently weighed, adding another 250 mL to the total estimated blood volume lost. After the spinal anaesthetic and removal of the placenta, there is a sudden gush of blood from the vagina, the sterile drapes and incontinence pads on the floor are soaked.

She states that she feels faint and can no longer hear clearly. The anaesthetist also notes that she appears pale and her observations are as follows:

HR 125 bpm

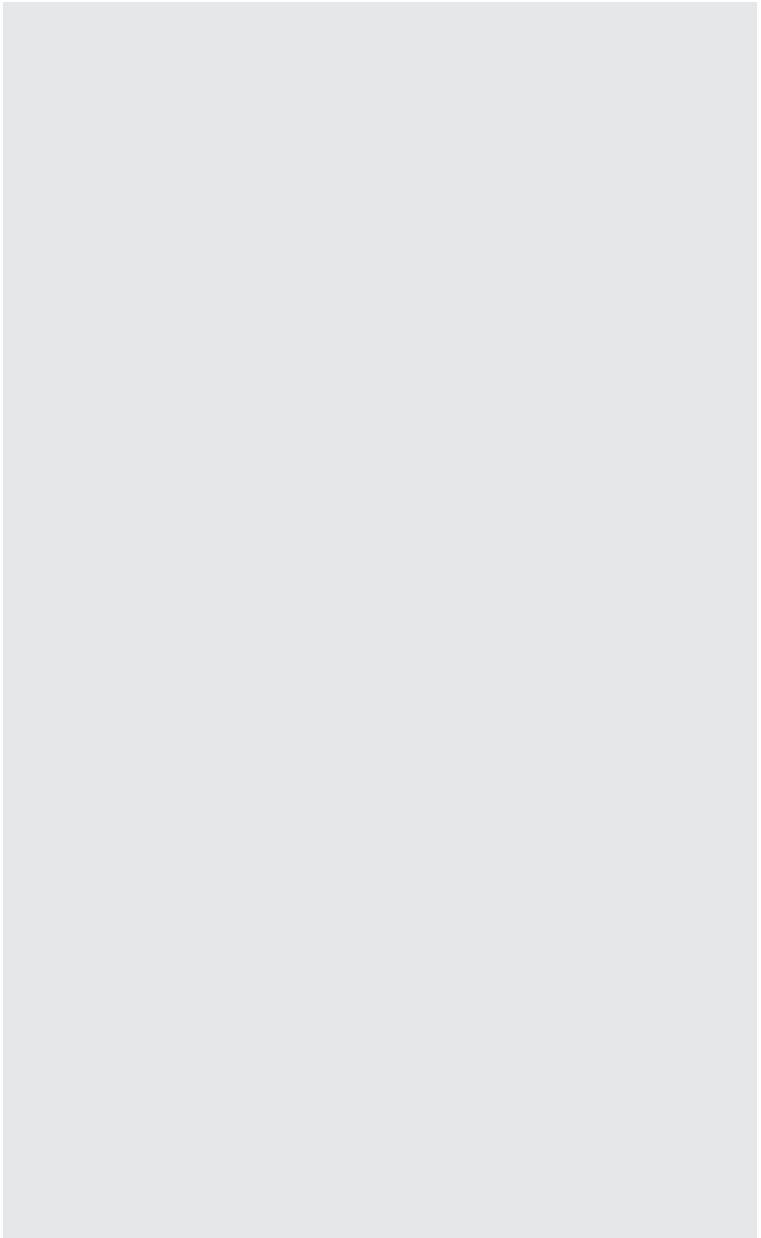
BP 80/52 mmHg

CRT 5 seconds

RR 26 breaths/min

O₂ saturation 92% on room air

Temperature 37°C



What is the most likely underlying diagnosis?

Haemorrhagic shock in massive obstetric haemorrhage secondary to a retained placenta and uterine atony.

Hallmarks

- Massive obstetric haemorrhage can be brisk or rapidly accumulate over a short period of time.
- Young people cope with a large loss in circulating blood volume for longer than those who are frail or have an existing cardiopulmonary disease.
- Fibrinolysis can be more marked than in other causes of massive haemorrhage.
- Hypotension, tachycardia and hypoxia are features of haemorrhagic shock.

Management

- Use the 'ABCDE' approach to resuscitate the patient.
- Administer oxygen at 15 L/min via a non-rebreath mask.
- Squeeze in 500 mL of a warm, balanced intravenous crystalloid through a pressure bag. Further fluid boluses may be required whilst awaiting blood.
- Estimate the total volume of blood lost, including weighing of the pads, drapes and blood clots. This will help decide whether the patient requires a certain number of RBC units only or a major haemorrhage protocol and therefore FFP, platelets and cryoprecipitate in addition.
- Aim to replace lost blood with transfused blood quickly; consider giving warmed O RhD-negative blood, which is kept in a fridge in most labour wards.
- Obstetric management includes bimanual uterine compression to help improve uterine tone, and pharmacological measures such as misoprostol, syntocinon and ergometrine.
- Continue the cycle of clinical and laboratory monitoring and administration of goal-directed blood component therapy until bleeding stops and the patient is stable.
- Seek senior obstetric and anaesthetic support with stabilising the patient. In some cases, patients need arterial and central venous lines and nursing in a high-dependency or intensive care setting so that their response to treatment can be closely monitored and adjusted.

CASE 6.2 (continued)

Investigations

- Point-of-care testing such as Hemocue, ABG/VBG provide rapid information about the patient's current status.
- Laboratory samples of blood for FBC, clotting profile, fibrinogen, U+Es and G&S should be sent as soon as possible after admission, to provide baseline information.
- Further laboratory blood samples help guide ongoing management. For example, Hb count may be below target despite massive transfusion.
- If further vaginal bleeding occurs after the initial phase, pelvic ultrasound may be required to investigate for further retained products of conception.

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