04-10 Acute medicine and critical illness

10 Acute medicine and critical illness

174 • ACUTE MEDICINE AND CRITICAL ILLNESS Clinical examination in critical care Airway Is the airway patent? Is the end-tidal CO_2 trace normal? Are there any signs of airway obstruction? A B Circulation Is the physiology normal (heart rate, blood pressure, peripheral temperature, lactate, urine output)? How much support is required (inotrope,vasopressor)? C D E Glucose What is the glucose level? Is insulin being administered? G G D

Haematology What are the haemoglobin/ platelet levels? Are there any signs of bleeding? H

Infection What is the temperature? Review recent infective markers and trend What antibiotics are being given and what is the duration of treatment? I

Enteral/exposure Feeding regime Stool frequency Abdominal tenderness/bowel sounds present? Disability Level of responsiveness Delirium screen Pupillary responses Doses of sedative drugs F Fluids, electrolytes and renal system What is the fluid balance? Urine volume and colour? Is there any oedema? Review the renal biochemistry and electrolyte levels Breathing Is the physiology normal (SpO_2, respiratory rate, tidal volume)? What is the level of support? Are there any abnormal signs on chest examination? Review the ventilator settings, arterial blood gases and recent chest X-ray F E C B A

Bedside physiological data commonly monitored in an intensive care unit setting. Monitoring Electrocardiography Heart rate, rhythm and QRS morphology Arterial line trace Size of the area under the curve is proportional to stroke volume Narrow peaks suggest low stroke volume as shown here Oxygen saturation Saturation of haemoglobin measured by plethysmography (SpO_2). Gives an indication of adequacy of oxygenation, and the quality of tissue perfusion can also be inferred – a flat trace suggests poor peripheral perfusion Central venous pressure trace A non-specific guide to volume status and right ventricular function. Increased values in fluid overload and right ventricular failure Capnography Numerical value of end-tidal CO_2 ($ETCO_2$) is less than arterial PCO_2 ($PaCO_2$) by a variable amount. Shape of trace can signify airway displacement/obstruction, bronchospasm or a low cardiac output (as shown below) kPa mmHg Time (secs)

Normal Steep 'upstroke' in early expiration Bronchospasm Shallow 'upstroke' in early expiration Partial obstruction/displacement of airway device Decreasing cardiac output Decreasing size of $ETCO_2$ waveform No ventilation (from any cause) Basic principles • Uses the different red and infrared absorption profiles of oxyhaemoglobin and deoxyhaemoglobin to estimate arterial oxyhaemoglobin saturation (SaO_2) • Only pulsatile absorption is measured • A poor trace correlates with poor perfusion Sources of error • Carboxyhaemoglobin – absorption profile is the same as oxyhaemoglobin: falsely elevated SpO_2 • Methaemoglobinaemia – SpO_2 will tend towards 85% • Ambient light/poor application of probe/ severe tricuspid regurgitation (pulsatile venous flow): falsely depressed SpO_2 • Reduced accuracy below 80% saturation • Hyperbilirubinaemia does not affect SpO_2 Plethysmography (SpO_2)

 is required. The requirement for admission is determined by many factors, including the severity of illness, the patient's physiological reserve, the need for urgent investigations, the nature of proposed treatments and the patient's social circumstances. In many cases, it is clear early in the assessment process that a patient requires admission. In such cases, a move into a medical receiving unit – often termed a medical admissions unit (MAU) or acute medical unit (AMU) – should be facilitated as soon as the initial assessment has been completed and urgent investigations and/or treatments have been instigated. In hospitals where such units do not exist, patients will need to be moved to a downstream ward once treatment has been commenced and they have been deemed sufficiently stable. Following the initial assessment, it may be possible to discharge stable patients home with a plan for early follow-up (such as a rapid-access specialist clinic appointment). Ambulatory care In some hospitals, it is increasingly possible for patient care to be coordinated in an ambulatory setting, negating the need for a patient to remain in hospital overnight. In the context of acute medicine, ambulatory care can be employed for conditions that are perceived by either the patient or the referring practitioner as requiring prompt clinical assessment by a competent decisionmaker with access to appropriate diagnostic resources. The patient may return on several occasions for investigation, observation, consultation or treatment. Some presentations, such as a unilateral swollen leg (p. 186), lend themselves to this type of management (Box 10.1). If indicated, a Doppler ultrasound can be arranged, and patients with confirmed deep vein thromboses can be anticoagulated on an outpatient basis. Successful ambulatory care requires careful patient selection; while many patients may cherish the opportunity to sleep at home, others may find frequent trips to hospital or clinic too difficult due to frailty, poor mobility or transport difficulties. Presenting problems in acute medicine Chest pain Chest pain is a common symptom in patients presenting to hospital. The differential diagnosis is wide (Box 10.2), and a Hospital medicine is becoming ever more specialised and people are living longer while accruing increasing numbers of chronic disease diagnoses. Rather than diminishing the role of the generalist, these factors paradoxically create a need for experts in the undifferentiated presentation. In the UK such physicians are known as ‘general physicians’, while in the US they are referred to as ‘hospitalists’. Acute illness can present in a large variety of ways, depending on the nature of the illness, the underlying health of the individual, and their cultural and religious background. The skills of prompt diagnosis formation and provision of appropriate treatment rely on the integration of information from all the available sources, along with careful consideration of underlying chronic health problems. Patients who deteriorate while in hospital make up a small but important cohort. If they are well managed, in-hospital cardiac arrest rates will be low. This can be achieved through the combined effects of prompt resuscitation and appropriate end-of-life decision-making. Early recognition of deterioration by ward teams and initial management by health-care professionals operating within a functioning rapid response system are the central tenets of any system designed to improve the outcomes of deteriorating ward patients. Intensive care medicine has developed into a prominent specialty, central to the safe functioning of a modern acute hospital. Scientific endeavour has resulted in a much better understanding of the molecular pathophysiology of processes such as sepsis and acute respiratory distress syndrome, which account for much premature death worldwide. Acute medicine Acute medicine is the part of general medicine that is concerned with the immediate and early management of medical patients who require urgent care. As a specialty, it is closely aligned with emergency medicine and intensive care medicine, but is firmly rooted within general medicine. Acute physicians manage the adult medical take and lead the development of acute care pathways that aim to reduce variability, improve care and cut down hospital admissions. The decision to admit to hospital Every patient presenting to hospital should be assessed by a clinician who is able to determine whether or not admission 10.1 Groups of patients who are potentially suitable for ambulatory care Group Example(s) Quality and safety issues Diagnostic exclusion group Chest pain – possible myocardial infarction; breathlessness – possible pulmonary embolism Even when a specific condition has been excluded, there is still a need to explain the patient’s symptoms through the diagnostic process Low-risk stratification group Non-variceal upper gastrointestinal bleed with low Blatchford score (p. 780); communityacquired pneumonia with low CURB-65 score (p. 583) Appropriate treatment plans should be in place Specific procedure group Replacement of percutaneous endoscopic gastrostomy (PEG) tube; drainage of pleural effusion/ascites The key to implementation is how ambulatory care for this group of patients can be delivered when they present out of hours Outpatient group with supporting infrastructure Deep vein thrombosis (DVT); cellulitis These are distinct from the conditions listed above because the infrastructure required to manage them is quite different

10.2 Differential diagnosis of chest pain Central Cardiac • Myocardial ischaemia (angina) • Myocardial infarction • Myocarditis • Pericarditis • Mitral valve prolapse syndrome Aortic • Aortic dissection • Aortic aneurysm Oesophageal • Oesophagitis • Oesophageal spasm • Mallory–Weiss syndrome • Oesophageal perforation (Boerhaave's syndrome) Pulmonary embolus Mediastinal • Malignancy Anxiety/emotion1 Peripheral Lungs/pleura • Pulmonary infarct • Pneumonia • Pneumothorax • Malignancy • Tuberculosis • Connective tissue disorders Musculoskeletal2 • Osteoarthritis • Rib fracture/injury • Acute vertebral fracture • Costochondritis (Tietze's syndrome) • Intercostal muscle injury • Epidemic myalgia (Bornholm disease) Neurological • Prolapsed intervertebral disc • Herpes zoster • Thoracic outlet syndrome 1May also cause peripheral chest pain. 2Can sometimes cause central chest pain. Characteristics Pleurisy, a sharp or 'catching' chest pain aggravated by deep breathing or coughing, is indicative of respiratory pathology, particularly pulmonary infection or infarction. However, the pain associated with myocarditis or pericarditis is often also described as 'sharp' and may 'catch' during inspiration, coughing or lying flat. It typically varies in intensity with movement and the phase of respiration. A malignant tumour invading the chest wall or ribs can cause gnawing, continuous local pain. The pain of myocardial ischaemia is typically dull, constricting, choking or 'heavy', and is usually described as squeezing, crushing, burning or aching. Patients often emphasise that it is a discomfort rather than a pain. Angina occurs during (not after) exertion and is promptly relieved (in less than 5 minutes) by rest. It may also be precipitated or exacerbated by emotion but tends to occur more readily during exertion, after a large meal or in a cold wind. In crescendo or unstable angina, similar pain may be precipitated by minimal exertion or at rest. The increase in venous return or preload induced by lying down may also be sufficient to provoke pain in vulnerable patients (decubitus angina). Patients with reversible airways obstruction, such as asthma, may also describe exertional chest tightness that is relieved by rest. This may be difficult to distinguish from myocardial ischaemia. Bronchospasm may be associated with wheeze, atopy and cough (p. 556). Musculoskeletal chest pain is variable in site and intensity but does not usually fall into any of the patterns described above. The pain may vary with posture or movement of the upper body, or be associated with a specific movement (bending, stretching, turning). Many minor soft tissue injuries are related to everyday activities, such as driving, manual work and sport. Onset The pain associated with myocardial infarction (MI) typically takes several minutes or even longer to develop to its maximal intensity; similarly, angina builds up gradually in proportion to the intensity of exertion. Pain that occurs after, rather than during, exertion is usually musculoskeletal or psychological in origin. The pain of aortic dissection (severe and 'tearing'), massive pulmonary embolism (PE) or pneumothorax is usually very sudden in onset. Other causes of chest pain tend to develop more gradually, over hours or even days. Associated features The pain of MI, massive PE or aortic dissection is often accompanied by autonomic disturbance, including sweating, nausea and vomiting. Some patients describe a feeling of impending death, referred to as 'angor animi'. Breathlessness, due to pulmonary congestion arising from transient ischaemic left ventricular dysfunction, is often a prominent feature of myocardial ischemia. Breathlessness may also accompany any of the respiratory causes of chest pain and can be associated with cough, wheeze or other respiratory symptoms. Patients with myocarditis or pericarditis may describe a prodromal viral illness. Gastrointestinal disorders, such as gastro-oesophageal reflux or peptic ulceration, may present with chest pain that is hard to distinguish from myocardial ischaemia; it may even be precipitated by exercise and be relieved by nitrates. However, it is usually possible to elicit a history relating chest pain to supine posture or eating, drinking or oesophageal reflux. The pain of gastro-oesophageal reflux often radiates to the interscapular region and dysphagia may be present. Severe chest pain arising after retching or vomiting, or following oesophageal instrumentation, should raise the possibility of oesophageal perforation. detailed history and thorough clinical examination are paramount to ensure that the subsequent investigative pathway is appropriate. Presentation Chest ‘pain’ is clearly a subjective phenomenon and may be described by patients in a variety of different ways. Whether the patient describes ‘pain’, ‘discomfort’ or ‘pressure’ in the chest, there are some key features that must be elicited from the history. Site and radiation Pain secondary to myocardial ischaemia is typically located in the centre of the chest. It may radiate to the neck, jaw, and upper or even lower arms. Occasionally, it may be experienced only at the sites of radiation or in the back. The pain of myocarditis or pericarditis is characteristically felt retrosternally, to the left of the sternum, or in the left or right shoulder. The severe pain of aortic dissection is typically central with radiation through to the back. Central chest pain may also occur with tumours affecting the mediastinum, oesophageal disease (p. 791) or disease of the thoracic aorta (p. 505). Pain situated over the left anterior chest and radiating laterally is unlikely to be due to cardiac ischaemia and may have many causes, including pleural or lung disorders, musculoskeletal problems or anxiety. Rarely, sharp, left-sided chest pain that is suggestive of a musculoskeletal problem may be a feature of mitral valve prolapse (p. 520).

 side. Local tenderness of the chest wall is likely to indicate musculoskeletal pain but can also be found in pulmonary infarction. Subdiaphragmatic inflammatory pathology, such as a liver abscess, cholecystitis or ascending cholangitis, can mimic pneumonia by causing fever, pleuritic chest pain and a small sympathetic pleural effusion, usually on the right. Likewise, acute pancreatitis can present with thoracic symptoms, and an amylase or lipase level should be requested where appropriate. It is imperative that the abdomen is examined routinely in all patients presenting with pleuritic chest pain. Initial investigations Chest X-ray, ECG and biomarkers (e.g. troponin, D-dimer) play a pivotal role in the evaluation of chest pain. However, indiscriminate ordering of such investigations may result in diagnostic confusion and over-investigation. The choice of investigation(s) is intimately linked to the history and examination findings. A chest X-ray and 12-lead ECG should be performed in the vast majority of patients presenting to hospital with chest pain. Pregnancy is not a contraindication to chest X-ray, but particular consideration should be given to whether the additional diagnostic information justifies breast irradiation. The chest X-ray may confirm the suspected diagnosis, particularly in the case of pneumonia. Small pneumothoraces are easily missed, as are rib fractures or small metastatic deposits, and all should be considered individually during chest X-ray review. A widened mediastinum suggests acute aortic dissection but a normal chest X-ray does not exclude the diagnosis. Provided it has been more than 1 hour since the onset of pain, chest X-ray in oesophageal rupture may reveal subcutaneous emphysema, pneumomediastinum or a pleural effusion. Patients with a history compatible with myocardial ischaemia require an urgent 12-lead ECG. Acute chest pain with ECG changes indicating a ST segment elevation myocardial infarction (STEMI) suggests that the patient is likely to benefit from immediate reperfusion therapy. Specific information relating to cocaine or amphetamine use should be sought, particularly in younger

Anxiety-induced chest pain may be associated with breathlessness (without hypoxaemia), throat tightness, perioral tingling and other evidence of emotional distress. It is important to remember, however, that chest pain itself can be an extremely frightening experience, and so psychological and organic features often coexist. Anxiety may amplify the effects of organic disease and a confusing clinical picture may result. A detailed and clear history is key to narrowing the differential diagnosis of chest pain. Figure 10.1 shows how certain features of the history, particularly when combined, can tip the balance of evidence towards or away from ischaemic cardiac chest pain. Clinical assessment Cardiorespiratory examination may detect clinical signs that help guide ongoing investigation. Patients with a history compatible with myocardial ischaemia should have a 12-lead electrocardiogram (ECG) performed while clinical examination proceeds. Ongoing chest pain with clinical features of shock or pulmonary oedema, or ECG evidence of ventricular arrhythmia or complete heart block should prompt urgent cardiology review and referral to a higher level of care. Chest pain that is accompanied by clinical evidence of increased intracardiac pressure (especially a raised jugular venous pressure) increases the likelihood of myocardial ischaemia or massive PE. The legs should be examined for clinical evidence of deep vein thrombosis. A large pneumothorax should be evident on clinical examination, with absent breath sounds and a hyper-resonant percussion note on the affected side. Other unilateral chest signs, such as bronchial breathing or crackles, are most likely to indicate a respiratory tract infection, and a chest X-ray should be expedited. Pericarditis may be accompanied by a pericardial friction rub. In aortic dissection, syncope or neurological deficit may occur. Examination may reveal asymmetrical pulses, features of undiagnosed Marfan's syndrome (p. 508) or a new early diastolic murmur representing aortic regurgitation. Any disease process involving the pleura may restrict rib movement and a pleural rub may be audible on the affected Fig. 10.1 Identifying ischaemic cardiac pain: the 'balance' of evidence. Ischaemic cardiac chest pain Non-cardiac chest pain Relieving factors Respiratory, gastrointestinal, locomotor or psychological Rest Quick response to nitrates Precipitation Spontaneous, not related to exertion, provoked by posture, respiration or palpation Precipitated by exertion and/or emotion Character Sharp, stabbing, catching Tight, squeezing, choking Radiation Other or no radiation Jaw/neck/shoulder/arm (occasionally back) Location Peripheral, localised Central, diffuse Associated features Not relieved by rest Slow or no response to nitrates Breathlessness

differential diagnosis list to chronic exertional breathlessness. The presence of associated cardiovascular (chest pain, palpitations, sweating and nausea) or respiratory symptoms (cough, wheeze, haemoptysis, stridor) can narrow the differential diagnosis yet further. A previous history of left ventricular dysfunction, asthma or exacerbations of chronic obstructive pulmonary disease (COPD) is important. In the severely ill patient, it may be necessary to obtain the history from accompanying witnesses. In children, the possibility of inhalation of a foreign body (Fig. 10.2) or acute epiglottitis should always be considered. There is often more than one underlying diagnosis; a thorough assessment should continue, even after a possible diagnosis has been reached, particularly if the severity of symptoms does not seem to be adequately explained. The causes of acute severe breathlessness are covered here; chronic exertional dyspnoea is discussed further on page 557. Clinical assessment Airway obstruction, anaphylaxis and tension pneumothorax require immediate identification and treatment. If any of these is suspected, treatment should not be delayed while additional investigations are performed, and anaesthetic support is likely to be required. In the absence of an immediately life-threatening cause, the following should be assessed and documented: • level of consciousness • degree of central cyanosis • work of breathing (rate, depth, pattern, use of accessory muscles) • adequacy of oxygenation (SpO2) patients. In the context of a compatible history, an ECG showing ischaemic changes that do not meet STEMI criteria should prompt regular repeat ECGs and treatment for non-ST segment elevation myocardial infarction (NSTEMI)/unstable angina. Measurement of serum troponin concentration on admission is often helpful in cases where there is diagnostic doubt, but a negative result should always prompt a repeat sample 6–12 hours after maximal pain. Acute coronary syndrome may be diagnosed with confidence in patients with a convincing history of ischaemic pain (Fig. 10.1) and either ECG evidence of ischaemia or an elevated serum troponin. If an elevated serum troponin is found in a patient who has an atypical history or is at low risk of ischaemic heart disease, then alternative causes of raised troponin should be considered (Box 10.3). Further management of acute coronary syndromes is discussed on page 498. In the absence of convincing ECG evidence of myocardial ischaemia, other life-threatening causes of chest pain, such as aortic dissection, massive PE and oesophageal rupture, should be considered. Suspicion of aortic dissection (background of hypertension, trauma, pregnancy or previous aortic surgery) should prompt urgent thoracic computed tomography (CT) or transoesophageal echocardiography. An ECG in the context of massive PE most commonly reveals only a sinus tachycardia, but may show new right axis deviation, right bundle branch block or a dominant R wave in V1. The classical finding of S1Q3T3 (a deep S wave in lead I, with a Q wave and T wave inversion in lead III) is rare. If massive PE is suspected and the patient is haemodynamically unstable, a transthoracic echocardiogram, to seek evidence of right heart strain and exclude alternative diagnoses such as tamponade, is extremely useful. If the patient is deemed to be at low risk of PE, a D-dimer test can be informative, as a negative result effectively excludes the diagnosis. The D-dimer test should be performed only if there is clinical suspicion of PE, as false-positive results can lead to unnecessary investigations. If the D-dimer is positive, there is high clinical suspicion, or there is other convincing evidence of PE (such as features of right heart strain on the ECG), prompt imaging should be arranged (p. 619 and Fig. 17.67). Acute breathlessness In acute breathlessness, the history, along with a rapid but careful examination, will usually suggest a diagnosis that can be confirmed by routine investigations including chest X-ray, 12-lead ECG and arterial blood gas (ABG) sampling. Presentation A key feature of the history is the speed of onset of breathlessness. Acute severe breathlessness (over minutes or hours) has a distinct Fig. 10.2 Inhaled foreign body. A Chest X-ray showing a tooth lodged in a main bronchus. B Bronchoscopic appearance of inhaled foreign body (tooth) with a covering mucous film. A B 10.3 Causes of elevated serum troponin other than acute coronary syndrome Cardiorespiratory causes • Pulmonary embolism • Acute pulmonary oedema • Tachyarrhythmias • Myocarditis/myopericarditis • Aortic dissection • Cardiac trauma • Cardiac surgery/ablation Non-cardiorespiratory causes • Prolonged hypotension • Severe sepsis • Severe burns • Stroke • Subarachnoid haemorrhage • End-stage renal failure

 onset of atrial fibrillation in a patient with mitral stenosis. In such cases, the classic mid-diastolic rumbling murmur with pre-systolic accentuation may be heard. Patients sometimes describe chest tightness as ‘breathlessness’. However, myocardial ischaemia may also induce true breathlessness by provoking transient left ventricular dysfunction. When breathlessness is the dominant or sole feature of myocardial ischaemia, it is known as ‘angina equivalent’. A history of chest tightness or close correlation with exercise should be sought. Initial investigations As shown in Box 10.4, amalgamation of a clear history and thorough clinical examination with chest X-ray, ECG and ABG findings will usually indicate the primary cause of breathlessness. If bronchospasm is suspected, measurement of peak expiratory flow will assist in the assessment of severity and should be performed whenever possible. An ABG will often provide additional information to SpO_2 measurement alone, particularly if there is clinical evidence (drowsiness, delirium, asterixis) or a strong likelihood of hypercapnia. An acute rise in $PaCO_2$ will increase the HCO_3^- by only a small amount, resulting in inadequate buffering and acidaemia. Renal compensation and a large rise in HCO_3^- will take at least 12 hours. In acute type II respiratory failure (p. 565), the rate of rise of $PaCO_2$ is a better indicator of severity than the absolute value. An ABG is essential in the context of smoke inhalation to measure carboxyhaemoglobin level, and is central to the identification of metabolic acidosis or the diagnosis of psychogenic hyperventilation (Box 10.4). If 'angina equivalent' is suspected, • ability to speak (in single words or sentences) • cardiovascular status (heart rate and rhythm, blood pressure (BP) and peripheral perfusion). Pulmonary oedema is suggested by a raised jugular venous pressure and bi-basal crackles or diffuse wheeze, while asthma or COPD is characterised by wheeze and prolonged expiration. A hyper-resonant hemithorax with absent breath sounds raises the possibility of pneumothorax, while severe breathlessness with normal breath sounds may indicate PE. Leg swelling may suggest cardiac failure or, if asymmetrical, venous thrombosis. The presence of wheeze is not always indicative of bronchospasm. In acute left heart failure, an increase in the left ventricular diastolic pressure causes the pressure in the left atrium, pulmonary veins and pulmonary capillaries to rise. When the hydrostatic pressure of the pulmonary capillaries exceeds the oncotic pressure of plasma (about 25–30 mmHg), fluid moves from the capillaries into the interstitium. This stimulates respiration through a series of autonomic reflexes, producing rapid, shallow respiration, and congestion of the bronchial mucosa may cause wheeze (sometimes known as cardiac asthma). Sitting upright or standing may provide some relief by helping to reduce congestion at the apices of the lungs. The patient may be unable to speak and is typically distressed, agitated, sweaty and pale. Respiration is rapid, with recruitment of accessory muscles, coughing and wheezing. Sputum may be profuse, frothy and blood-streaked or pink. Extensive crepitations and rhonchi are usually audible in the chest and there may also be signs of right heart failure. Any arrhythmia may cause breathlessness, but usually does so only if the heart is structurally abnormal, such as with the 10.4 Clinical features in acute breathlessness Condition History Signs Chest X-ray ABG ECG Pulmonary oedema Chest pain, palpitations, orthopnoea, cardiac history* Central cyanosis, ↑JVP, sweating, cool extremities, basal crackles* Cardiomegaly, oedema/pleural effusions* ↓PaO_2 ↓$PaCO_2$ Sinus tachycardia, ischaemia*, arrhythmia Massive pulmonary embolus Risk factors, chest pain, pleurisy, syncope*, dizziness* Central cyanosis, ↑JVP*, absence of signs in the lung*, shock (tachycardia, hypotension) Often normal Prominent hilar vessels, oligaemic lung fields* ↓PaO_2 ↓$PaCO_2$ Sinus tachycardia, RBBB, S1Q3T3 pattern ↑T(V1–V4) Acute severe asthma History of asthma, asthma medications, wheeze* Tachycardia, pulsus paradoxus, cyanosis (late), →JVP*, ↓peak flow, wheeze* Hyperinflation only (unless complicated by pneumothorax)* ↓PaO_2 ↓$PaCO_2$ (↑$PaCO_2$ in extremis) Sinus tachycardia (bradycardia in extremis) Acute exacerbation of COPD Previous episodes*, smoker. If in type II respiratory failure, may be drowsy Cyanosis, hyperinflation*, signs of CO_2 retention (flapping tremor, bounding pulses)* Hyperinflation*, bullae, complicating pneumothorax ↓ or ↓↓PaO_2 ↑$PaCO_2$ in type II failure ± ↑H^+, ↑HCO_3^- in chronic type II failure Normal, or signs of right ventricular strain Pneumonia Prodromal illness*, fever*, rigors*, pleurisy* Fever, delirium, pleural rub*, consolidation*, cyanosis (if severe) Pneumonic consolidation* ↓PaO_2 ↓$PaCO_2$ (↑ in extremis) Tachycardia Metabolic acidosis Evidence of diabetes mellitus or renal disease, aspirin or ethylene glycol overdose Fetor (ketones), hyperventilation without heart or lung signs*, dehydration*, air hunger Normal PaO_2 normal ↓↓$PaCO_2$, ↑H^+ ↓HCO_3^- Psychogenic Previous episodes, digital or perioral dysaesthesia No cyanosis, no heart or lung signs, carpopedal spasm Normal PaO_2 normal* ↓↓$PaCO_2$, ↓H^+* *Valuable discriminatory feature. (ABG = arterial blood gas; COPD = chronic obstructive pulmonary disease; JVP = jugular venous pressure; RBBB = right bundle branch block)

Presentation The history from the patient and a witness is the key to establishing a diagnosis. The terms used for describing the symptoms associated with syncope vary so much among patients that they should not be taken for granted. Some patients use the term 'blackout' to describe a purely visual symptom, rather than loss of consciousness. Some may understand 'dizziness' to mean an abnormal perception of movement (vertigo), some will consider this a feeling of faintness, and others will regard it as unsteadiness. The clinician thus needs to elucidate the exact nature of the symptoms that the patient experiences. The potential differential diagnoses of syncope and presyncope, on the basis of the symptoms described, is shown in Figure 10.3. The history should always be supplemented by a direct eyewitness account if available. Careful history with corroboration will usually establish whether there has been full consciousness, altered consciousness, vertigo, transient amnesia or something else. Attention should be paid to potential triggers (e.g. medication, micturition, exertion, prolonged standing), the patient's appearance (e.g. colour, seizure activity), the duration of the episode, and the speed of recovery (Box 10.6). Cardiac syncope is usually sudden but can be associated with premonitory lightheadedness, palpitation or chest discomfort. The blackout is usually brief and recovery rapid. Exercise-induced syncope can be the presenting feature of a number of serious pathologies (such as hypertrophic obstructive cardiomyopathy or exercise-induced arrhythmia) and always requires further investigation. Neurocardiogenic syncope will often be associated with a situational trigger (such as pain or emotion), and the patient may experience flushing, nausea, malaise and clamminess for several minutes afterwards. Recovery is usually quick and without subsequent delirium, provided the patient has assumed a supine position. There is often some brief stiffening and limb-twitching, which requires differentiation from seizure-like movements. It is rare for syncope to cause injury or to cause amnesia after regaining awareness. Patients with seizures do not exhibit pallor, may have abnormal movements, usually take more than 5 minutes to recover and are often confused. Aspects of the history that can help to differentiate seizure from syncope are shown in Box 10.7. A diagnosis of psychogenic blackout (also known as nonepileptic seizure, pseudoseizure or psychogenic seizure) may be suggested by specific emotional triggers, dramatic movements objective evidence of myocardial ischaemia from stress testing may help to establish the diagnosis. Syncope/presyncope The term 'syncope' refers to sudden loss of consciousness due to reduced cerebral perfusion. 'Presyncope' refers to lightheadedness, in which the individual thinks he or she may 'black out'. Dizziness and presyncope are particularly common in old age (Box 10.5). Symptoms are disabling, undermine confidence and independence, and can affect a person's ability to work or to drive. There are three principal mechanisms that underlie recurrent presyncope or syncope: • cardiac syncope due to mechanical cardiac dysfunction or arrhythmia • neurocardiogenic syncope (also known as vasovagal or reflex syncope), in which an abnormal autonomic reflex causes bradycardia and/or hypotension • postural hypotension, in which physiological peripheral vasoconstriction on standing is impaired, leading to hypotension. There are, however, other causes of loss of consciousness, and differentiating syncope from seizure is a particular challenge. Psychogenic blackouts (also known as non-epileptic seizures or pseudoseizures) also need to be considered in the differential diagnosis. 10.5 Dizziness in old age • Prevalence: common, affecting up to 30% of people aged

> 65 years. • Symptoms: most frequently described as a combination of unsteadiness and lightheadedness. • Most common causes: postural hypotension and cardiovascular disease. Many patients have more than one underlying cause. • Arrhythmia: can present with lightheadedness either at rest or on activity. • Anxiety: frequently associated with dizziness but rarely the only cause. • Falls: multidisciplinary workup is required if dizziness is associated with falls. 10.6 Typical features of cardiac syncope, neurocardiogenic syncope and seizures Cardiac syncope Neurocardiogenic syncope Seizures Premonitory symptoms Often none Lightheadedness Palpitation Chest pain Breathlessness Nausea Lightheadedness Sweating Delirium Hyperexcitability Olfactory hallucinations 'Aura' Unconscious period Extreme 'death-like' pallor Pallor Prolonged (> 1 min) unconsciousness Motor seizure activity* Tongue-biting Urinary incontinence Recovery Rapid (< 1 min) Flushing Slow Nausea Lightheadedness Prolonged delirium (> 5 mins) Headache Focal neurological signs *N.B. Cardiac syncope can also cause convulsions by inducing cerebral anoxia.

182 • ACUTE MEDICINE AND CRITICAL ILLNESS 10.7 How to differentiate seizures from syncope Seizure Syncope Aura (e.g. olfactory) + − Cyanosis + − Lateral tongue-biting + −/+ Post-ictal delirium + − Post-ictal amnesia + − Post-ictal headache + − Rapid recovery − + Fig. 10.3 The differential diagnosis of syncope and presyncope. Labyrinthine dysfunction • Infection • 'Vestibular neuronitis' • Benign positional vertigo • Ménière's disease • Ischaemia/infarction • Trauma • Perilymph fistula • Other (e.g. drugs, otosclerosis) Central vestibular dysfunction • 'Physiological' (visual– vestibular mismatch) • Demyelination • Migraine • Posterior fossa mass lesion • Vertebro-basilar ischaemia • Other (e.g. disorders of cranio-vertebral junction) • Ataxia • Weakness • Loss of joint position sense • Gait dyspraxia • Joint disease • Visual disturbance • Fear of falling (Chs 24 and 25) Impaired cerebral perfusion Cardiac disease • Arrhythmia • Left ventricular dysfunction • Aortic stenosis • Hypertrophic obstructive cardiomyopathy Other causes • Vasovagal syncope • Postural hypotension • Micturition syncope • Cough syncope • Carotid sinus sensitivity • Hypoglycaemia (Ch. 20) • Anxiety* • Hyperventilation • Post-concussive syndrome • Panic attack • Non-epileptic attack • Epileptic seizure Presyncope (reduced cerebral perfusion) Syncope (loss of cerebral perfusion) Sensation of movement? (vertigo) Loss of balance? Lightheaded? Other description Funny turn or blackout

- Anxiety is the most common cause of dizziness in those under 65 years Loss of consciousness ('blackout') or vocalisation, or by very prolonged duration (hours). A history of rotational vertigo is suggestive of a labyrinthine or vestibular disorder (p. 1086). Postural hypotension is normally obvious from the history, with presyncope or, less commonly, syncope occurring within a few seconds of standing. The history should include enquiry about predisposing medications (diuretics, vasodilators, antidepressants) and conditions (such as diabetes mellitus and Parkinson's disease). Clinical assessment Examination of the patient may be entirely normal, but may reveal clinical signs that favour one form of syncope. The systolic murmurs of aortic stenosis or hypertrophic obstructive

cardiomyopathy are important findings, particularly if paired with a history of lightheadedness or syncope on exertion. BP taken when supine and then after 1 and 3 minutes of standing may, when combined with symptoms, provide robust evidence of symptomatic postural hypotension. Clinical suspicion of hypersensitive carotid sinus syndrome (sensitivity of carotid baroreceptors to external pressure such as a tight collar) should prompt monitoring of the ECG and BP during carotid sinus pressure, provided there is no carotid bruit or history of cerebrovascular disease. A positive cardio-inhibitory response is defined as a sinus pause of 3 seconds or more; a positive vasodepressor response is defined as a fall in systolic BP of more than 50 mmHg. Carotid sinus pressure will produce positive findings in about 10% of elderly individuals, but fewer than 25% of these experience spontaneous syncope. Symptoms should not, therefore, be attributed to hypersensitive carotid sinus syndrome unless they are reproduced by carotid sinus pressure. Initial investigations A 12-lead ECG is essential in all patients presenting with syncope or presyncope. Lightheadedness may occur with many arrhythmias, but blackouts (Stokes–Adams attacks, p. 477) are usually due to profound bradycardia or malignant ventricular tachyarrhythmias. The ECG may show evidence of conducting system disease (e.g. sinus bradycardia, atrioventricular block, bundle branch block), which would predispose a patient to bradycardia, but the key to establishing a diagnosis is to obtain an ECG recording while symptoms are present. Since minor rhythm disturbances are common, especially in the elderly, symptoms must occur at the same time as a recorded arrhythmia before a diagnosis can be made. Ambulatory ECG recordings are helpful only if symptoms occur several times per week. Patient-activated ECG recorders are useful for examining the rhythm in patients with recurrent dizziness but are not helpful in assessing sudden blackouts. When these investigations fail to establish a cause in patients with presyncope or syncope, an implantable ECG recorder can be sited subcutaneously over the upper left chest. This device continuously records the cardiac rhythm and will activate automatically if extreme bradycardia or tachycardia occurs. The ECG memory can also be tagged by the patient, using a hand-held activator as a form of 'symptom diary'. Stored ECGs can be accessed by the implanting centre, using a telemetry device in a clinic, or using a home monitoring system via an online link. Head-up tilt-table testing is a provocation test used to establish the diagnosis of vasovagal syncope. It involves positioning the patient supine on a padded table that is then tilted to an angle of 60–70° for up to 45 minutes, while the ECG and BP responses are monitored. A positive test is characterised by bradycardia (cardio-inhibitory response) and/or hypotension (vasodepressor response), associated with typical symptoms. Delirium Delirium is a syndrome of transient, reversible cognitive dysfunction that is more common in old age. It is associated with high rates of mortality, complications and institutionalisation, and with longer lengths of stay. The recognised risk factors for delirium are shown in Box 10.8. Presentation Delirium manifests as a disturbance of arousal with global impairment of mental function, causing drowsiness with 10.8 Risk factors for delirium Predisposing factors • Old age • Dementia • Frailty • Sensory impairment • Polypharmacy • Renal impairment Precipitating factors • Intercurrent illness • Surgery • Change of environment or ward • Sensory deprivation (e.g. darkness) or overload (e.g. noise) • Medications (e.g. opioids, psychotropics) • Dehydration • Pain • Constipation • Urinary catheterisation • Acute urinary retention • Hypoxia • Fever • Alcohol withdrawal 10.9 How to make a diagnosis of delirium: the 4AT

1. Alertness This includes patients who may be markedly drowsy (e.g. difficult to rouse and/or obviously sleepy during assessment) or agitated/ hyperactive. Observe the patient. If asleep, attempt to wake with speech or gentle touch on shoulder. Ask the patient to state their name and address to assist rating: • Normal (fully alert, but not agitated, throughout assessment)

• Mild sleepiness for <10 secs after waking, then normal

• Clearly abnormal

2. AMT4 Age, date of birth, place (name of the hospital or building), current year: • No mistakes

• 1 mistake

• ≥2 mistakes/untestable

3. Attention Say to the patient: ‘Please tell me the months of the year in backwards order, starting at December.’ To assist initial understanding, one prompt of ‘What is the month before December?’ is permitted: • Achieves ≥7 months correctly

• Starts but scores < 7 months/refuses to start

• Untestable (cannot start because unwell, drowsy, inattentive)

4. Acute change or fluctuating course Evidence of significant change or fluctuation in: alertness, cognition, other mental function (e.g. paranoia, hallucinations) arising over the last 2 weeks and still evident in last 24 hrs: • No

• Yes

Total 4AT score (maximum possible score 12) ≥4: possible delirium ± cognitive impairment 1–3: possible cognitive impairment 0: delirium or severe cognitive impairment unlikely (but delirium still possible if information in 4 incomplete) (AMT4 = Abbreviated Mental Test 4) disorientation, perceptual errors and muddled thinking. The three broad subtypes of delirium – hypoactive, hyperactive and mixed – can be differentiated on the basis of psychomotor changes. Patients with hyperactive delirium are often agitated and restless, whereas hypoactive delirium can present as lethargy and sedation, and is frequently misdiagnosed as depression or dementia. Fluctuation is typical and delirium is often worse at

184 • ACUTE MEDICINE AND CRITICAL ILLNESS • pyrexia and any signs of infection in the chest, skin, abdomen or urine (on dipstick testing) • oxygen saturation and signs of CO_2 retention • signs of alcohol withdrawal or psychoactive drug use, such as tremor or sweating • any focal neurological

signs. Certain psychiatric conditions, such as depressive pseudodementia and dissociative disorder, can easily be mistaken for delirium. Mental state examination is necessary to seek evidence of associated mood disorder, hallucinations, delusions or behavioural abnormalities. Examination should also include cognitive testing with a tool such as the Mini-Mental State Examination (MMSE) or the Montreal Cognitive Assessment (MoCA) (p. 1181). Investigations and management Common causes of delirium, along with appropriate investigative pathways, are shown in Figure 10.4. Alongside investigation and treatment of underlying causes, delirium and disorientation should be minimised by a well-lit and quiet environment, with hearing aids and glasses readily available. Good nursing is needed to preserve orientation, prevent pressure sores and falls, and maintain hydration, nutrition and continence. Sedatives may worsen delirium and should be used as a last resort. Resolution of delirium, particularly in the elderly, may be slow and incomplete. Many patients fail to recover to their pre-morbid level of cognition. night, when delirious patients can present significant management difficulties. Emotional disturbance (anxiety, irritability or depression) is common. History-taking from a delirious patient is frequently impossible, and every effort should be made to obtain a collateral history from a close friend or relative. As delirium is particularly common in patients with dementia, the collateral history should ask specifically about onset and course of delirium, along with any functional consequences in comparison to the patient's norm. Clinical assessment In order to manage delirium effectively, the first step is to make a diagnosis. Tools such as the 4AT (Box 10.9) or the Confusion Assessment Method (CAM) can be used to detect delirium and differentiate it from dementia; such screening tools should be applied to all older patients admitted to hospital. Once a diagnosis of delirium has been established, attempts should be made to identify all of the reversible precipitating factors. Symptoms suggestive of a physical illness, such as an infection or stroke, should be elicited. An accurate drug and alcohol history is required, especially to ascertain whether any drugs have been recently stopped or started (see Fig. 10.4 for commonly implicated drugs). Although not always possible in its entirety, a full physical examination of all delirious patients should be attempted, noting in particular: Fig. 10.4 Common causes and investigation of delirium. All investigations are performed routinely, except those in italics. *Tend to present over weeks to months rather than hours to days. The chest X-ray shows right mid- and lower zone consolidation. The CT scan shows a subdural haematoma. (COPD = chronic obstructive pulmonary disease; CRP = C-reactive protein; MI = myocardial infarction; SSRI = selective serotonin re-uptake inhibitor; UTI = urinary tract infection) Infection Metabolic disturbance Toxic insult Acute neurological conditions Pain, hypoxia Pneumonia UTI Skin: cellulitis, abscess Gram-negative sepsis Full blood count, CRP Chest X-ray Urinalysis and culture Others as appropriate: sputum, blood cultures, wound swabs Digoxin level if prescribed Urea and electrolytes Plasma calcium Capillary blood and plasma glucose Liver function tests Thyroid function tests B12 and folate CT brain: only when intracranial lesion is suspected (focal neurological signs, recent fall or head injury) or no other physical cause of delirium is identified Lumbar puncture: only if meningitis or encephalitis is suspected Pulse oximetry (arterial blood gases if low) Chest X-ray ECG Acute renal impairment Hyponatraemia/hypernatraemia Hypercalcaemia Hypoglycaemia Hepatic encephalopathy Thiamin deficiency Hypothyroidism* B12 deficiency* Any drug but particularly • Anticholinergics • Digoxin • Opiates • Psychotropics • High-dose glucocorticoids Withdrawal of alcohol, opiate, SSRI or benzodiazepine Acute stroke Subdural haematoma Encephalitis or meningitis Seizure (post-ictal) Space-occupying lesion, e.g. tumour Pulmonary embolism Pneumonia Pulmonary oedema COPD exacerbation Acute MI photophobia/phonophobia, may support a diagnosis of migraine but others, such as progressive focal symptoms or constitutional upset like weight loss, may suggest a more sinister cause. The headache of cerebral venous thrombosis may be ‘throbbing’ or ‘band-like’ and associated with nausea, vomiting or hemiparesis. Raised intracranial pressure (ICP) headache tends to be worse in the morning and when lying flat or coughing, and associated with nausea and/or vomiting. A description of neck stiffness along with headache and photophobia should raise the suspicion of meningitis (Box 10.12), although this may present in atypical ways in immunosuppressed, alcoholic or pregnant patients. The behaviour of the patient during headache is often instructive; migraine patients typically retire to bed to sleep in a dark room, whereas cluster headache often induces agitated and restless behaviour. The pain of a subarachnoid haemorrhage frequently causes significant distress. Headache duration is also important to elicit; headaches that have been present for months or years are almost never sinister, whereas new-onset headache, especially in the elderly, is more of a concern. In a patient over 60 years with head pain localised to one or both temples, scalp tenderness or jaw claudication, temporal arteritis (p. 1042) should be considered. Clinical assessment An assessment of conscious level (using the Glasgow Coma Scale (GCS); Fig. 10.5) should be performed early and constantly reassessed. A decreased conscious level suggests raised ICP and urgent CT scanning (with airway protection if necessary) is indicated. A full neurological examination may provide clues as to the pathology involved; for example, brainstem signs in the context of acute-onset occipital headache may indicate vertebrobasilar dissection. Neurological signs may, however, be ‘falsely localising’, as in large subarachnoid haemorrhage or bacterial meningitis. Care should be taken to examine for other evidence of meningitis such as a rash (not always petechial), fever or signs of shock. Unilateral headache with agitation, ipsilateral lacrimation, facial sweating and conjunctival injection is typical of cluster headache. Conjunctival injection may also be seen in acute glaucoma, accompanied by peri- or retro-orbital pain, clouding of the cornea, decreased visual acuity and, often, systemic upset. Temporal headaches in patients over 60 should prompt examination for enlarged or tender temporal arteries and palpation of temporal pulses (often absent in temporal arteritis). Visual acuity should be assessed promptly, as visual loss is an important complication of temporal arteritis. Initial investigations If there is any alteration of conscious level, focal neurological signs, new-onset seizures or a history of head injury, then CT scanning of the head is indicated. The urgency of scanning will depend on the clinical picture and trajectory but in many circumstances 10.10 Primary and secondary headache syndromes Primary headache syndromes • Migraine (with or without aura) • Tension-type headache • Trigeminal autonomic cephalalgia (including cluster headache) • Primary stabbing/coughing/exertional/sex-related headache • Thunderclap headache • New daily persistent headache syndrome Secondary causes of headache • Medication overuse headache (chronic daily headache) • Intracranial bleeding (subdural haematoma, subarachnoid or intracerebral haemorrhage) • Raised intracranial pressure (brain tumour, idiopathic intracranial hypertension) • Infection (meningitis, encephalitis, brain abscess) • Inflammatory disease (temporal arteritis, other vasculitis, arthritis) • Referred pain from other structures (orbit, temporomandibular joint, neck) Headache Headache is common and causes considerable worry amongst both patients and clinicians, but rarely represents sinister disease. The causes may be divided into primary or secondary, with primary headache syndromes being vastly more common (Box 10.10). Presentation The primary purpose of the history and clinical examination in patients presenting with headache is to identify the small minority of patients with serious underlying pathology. Key features of the history include the temporal evolution of a headache; a headache that reached maximal intensity immediately or within 5 minutes of onset requires rapid assessment for possible subarachnoid haemorrhage. Other ‘red flag’ symptoms are shown in Box 10.11. It is important to establish whether the headache comes and goes, with periods of no headache in between (usually migraine), or whether it is present all or almost all of the time. Associated features, such as preceding visual symptoms, nausea/vomiting or 10.11 ‘Red flag’ symptoms in headache Symptom Possible explanation Sudden onset (maximal immediately or within 5 mins) Subarachnoid haemorrhage Cerebral venous sinus thrombosis Pituitary apoplexy Meningitis Focal neurological symptoms (other than for typically migrainous) Intracranial mass lesion: Vascular Neoplastic Infection Constitutional symptoms: Weight loss General malaise Pyrexia Meningism Rash Meningitis Encephalitis Neoplasm (lymphoma or metastases) Inflammation (vasculitis) Raised intracranial pressure (worse on waking/lying down, associated vomiting) Intracranial mass lesion New onset aged > 60 years Temporal arteritis 10.12 Identification of bacterial meningitis In patients presenting with headache, identification of those with bacterial meningitis is a top priority to facilitate rapid antibiotic treatment. In almost all cases there will be one of the following features: • meningism (neck stiffness, photophobia, positive Kernig’s sign) • fever > 38°C • signs of shock (tachycardia, hypotension, elevated serum lactate) • rash (not always petechial)

 after headache onset, to look for evidence of xanthochromia. It is increasingly accepted, however, that a negative CT scan within 6 hours of headache onset has such a high degree of sensitivity for excluding subarachnoid haemorrhage that an LP is not necessary. In such circumstances, a CT angiogram should be considered to exclude other pathology, such as arterial dissection. Many headaches require prompt involvement of specialists. Features of acute glaucoma, for example, require immediate ophthalmological review for measurement of intraocular pressures. Suspected temporal arteritis with an erythrocyte sedimentation rate (ESR) of

> 50 mm/hr should prompt immediate glucocorticoid therapy and rheumatological referral (see p. 1042 for management). Features of raised ICP in the absence of a mass lesion on neuroimaging may indicate idiopathic intracranial hypertension; CSF opening pressure is likely to be informative. Unilateral leg swelling Most leg swelling is caused by oedema, the accumulation of fluid within the interstitial space. There are three explanatory mechanisms for development of oedema that are described in Box 10.13. Unilateral swelling usually indicates a localised pathology in either the venous or the lymphatic system, while bilateral oedema often represents generalised fluid overload combined with the effects of gravity. However, all causes of unilateral leg swelling may present bilaterally, and generalised fluid overload may present with asymmetrical (and therefore apparently unilateral) oedema. Fluid overload may be the result of cardiac failure, pulmonary hypertension (even in the absence of right ventricular failure), renal failure, hypoalbuminaemia or drugs (calcium channel blockers, glucocorticoids, mineralocorticoids, non-steroidal anti-inflammatory drugs (NSAIDs) and others); see Box 16.14 (p. 463) for other causes. The remainder of this section focuses on the causes of ‘unilateral’ oedema. Presentation Any patient who presents with unilateral leg swelling should be assessed with the possibility of deep vein thrombosis (DVT) in mind. The pain and swelling of a

DVT is often fairly gradual in onset, over hours or even days. Sudden-onset pain in the posterior aspect of the leg is more consistent with gastrocnemius muscle tear (which may be traumatic or spontaneous) or a ruptured Baker's cyst. Leg swelling and pain associated with paraesthesia or paresis, or in the context of lower limb injury or reduced conscious level, should always prompt concern regarding the possibility of compartment syndrome (Box 10.14). Clinical assessment Lower limb DVT characteristically starts in the distal veins, causing an increase in temperature of the limb and dilatation of the superficial veins. Often, however, symptoms and signs are minimal. will be immediately required. Intracranial haemorrhage or a space-occupying lesion with mass effect should prompt urgent neurosurgical referral. If bacterial meningitis is suspected (Box 10.12), cerebrospinal fluid (CSF) analysis is required to make a definite diagnosis. Antibiotics should not be delayed for lumbar puncture (LP), which needs to be preceded by CT scanning only if raised ICP is suspected. In cases of thunderclap headache (peak intensity within 5 minutes and lasting over an hour), a normal CT scan should be followed by an LP performed more than 12 hours Fig. 10.5 Assessment of the Glasgow Coma Scale (GCS) score in an obtunded patient. Avoid using a sternal rub, as it causes bruising. Hello, Mr XXX. Can you open your eyes, please? Score best eyes/ motor/verbal response Trapezius pinch Score response looking at arms for localisation/ flexion/abnormal flexion Pressure on supra-orbital ridge Score response Firm nail-bed pressure Score if withdrawal present or any eye/verbal response No response No response No response 10.13 Mechanisms of oedema There are three explanatory mechanisms for the development of oedema that may occur in isolation or combination: • increased hydrostatic pressure in the venous system due to increased intravascular volume or venous obstruction • decreased oncotic pressure secondary to a decrease in the plasma proteins that retain fluid within the circulation • obstruction to lymphatic drainage ('lymphoedema')

10.14 Identification of compartment syndrome • Compartment syndrome classically occurs following extrinsic compression of a limb due to trauma or reduced conscious level (especially when caused by drugs or alcohol) • It usually presents with a tense, firm and exquisitely painful limb • The pain is characteristically exacerbated by passive muscle stretching or squeezing the compartment • Altered sensation may be evident distally • Absent peripheral pulses are a late sign and their presence does not exclude the diagnosis • Clinical suspicion of compartment syndrome should prompt measurement of creatine kinase and urgent surgical review Cellulitis is usually characterised by erythema and skin warmth localised to a well-demarcated area of the leg and may be associated with an obvious source of entry of infection (e.g. leg ulcer or insect bite). The patient may be febrile and systemically unwell. Superficial thrombophlebitis is more localised; erythema and tenderness occur along the course of a firm, palpable vein. Examination of any patient presenting with leg swelling should include assessment for malignancy (evidence of weight loss, a palpable mass or lymphadenopathy). Malignancy is a risk factor for DVT, but pelvic or lower abdominal masses can also produce leg swelling by compressing the pelvic veins or lymphatics. Early lymphoedema is indistinguishable from other causes of oedema. More chronic lymphoedema is firm and non-pitting, often with thickening of the overlying skin, which may develop a 'cobblestone' appearance. Chronic venous insufficiency is a cause of long-standing oedema that, particularly when combined with another cause of leg swelling, may acutely worsen. Characteristic skin changes (haemosiderin deposition, hair loss, varicose eczema, ulceration) and prominent varicosities are common, and sometimes cause diagnostic confusion with cellulitis. See Box 10.14 for the examination findings associated with compartment syndrome. Initial investigations Clinical criteria can be used to rank patients according to their likelihood of DVT, by using scoring systems such as the Wells score (Box 10.15). Figure 10.6 gives an algorithm for investigation of suspected DVT based on initial Wells score. In patients with a low ('unlikely') pre-test probability of DVT, D-dimer levels can be measured; if these are normal, further investigation for DVT is unnecessary. In those with a moderate or high ('likely') probability of DVT or with elevated D-dimer levels, objective diagnosis of DVT should be obtained using appropriate imaging, usually a Doppler ultrasound scan. The investigative pathway for DVT, therefore, differs according to the pre-test probability (p. 11) of DVT. For low-probability DVT, the negative predictive value of the D-dimer test (the most important parameter in this context) is over 99%; if the test is negative, the clinician can discharge the patient with confidence. In patients with a high probability of DVT, the negative predictive value of a D-dimer test falls to somewhere in the region of 97–98%. While this may initially appear to be a high figure, to discharge 2 or 3 patients in every 100 incorrectly would generally be considered an unacceptable error rate. Hence, with the exception of pregnancy (Box 10.16), a combination of clinical probability and blood test results should be used in the diagnosis of venous thromboembolism. If cellulitis is suspected, serum inflammatory markers, skin swabs and blood cultures should be sent, ideally before antibiotics 10.15 Predicting the pre-test probability of deep vein thrombosis (DVT) using the Wells score* Clinical characteristic Score Previous documented DVT

Active cancer (patient receiving treatment for cancer within previous 6 months or currently receiving palliative treatment)

Paralysis, paresis or recent plaster immobilisation of lower extremities

Recently bedridden for ≥ 3 days, or major surgery within previous 4 weeks

Localised tenderness along distribution of deep venous system

Entire leg swollen

Calf swelling at least 3 cm larger than that on asymptomatic side (measured 10 cm below tibial tuberosity)

Pitting oedema confined to symptomatic leg

Collateral superficial veins (non-varicose)

Alternative diagnosis at least as likely as DVT –2 Clinical probability Total score DVT low probability < 1 DVT moderate probability 1–2 DVT high probability

> 2 From Wells PS. Evaluation of D-dimer in the diagnosis of suspected deep-vein thrombosis. N Engl J Med 2003; 349:1227; copyright © 2003 Massachusetts Medical Society. *A dichotomised revised Wells score, which classifies patients as ‘unlikely’ or ‘likely’, may also be used. Fig. 10.6 Investigation of suspected deep vein thrombosis. Pre-test probability is calculated in Box 10.15. See also page 11. Pre-test probability (see Box 10.15) Low D-dimer −ve D-dimer +ve +ve +ve −ve −ve Probability low, or moderate with −ve D-dimer Probability high, or moderate with +ve D-dimer Repeat compression ultrasound in 7 days Treat Exclude Compression ultrasound Moderate or high are given. Ruptured Baker’s cyst and calf muscle tear can both be readily diagnosed on ultrasound. If pelvic or lower abdominal malignancy is suspected, a prostate-specific antigen (PSA) level should be measured in males and appropriate imaging with ultrasound (transabdominal or transvaginal) or CT should be undertaken.

 Fig. 10.7 Identifying and responding to physiological deterioration. A An example of an early warning score chart. (NEWS = National Early Warning Score; V/P/U = Verbal/Pain/Unresponsive) NEWS Key

Sp02 Date: Time: ≥25 21–24 12–20 9–11 ≤8 Default Chronic Hypoxia ≥91 ≥39° 38° 37° 36° ≤35°

> 140

Regular Y/N Alert V/P/U New confusion Unrecordable ≥88 94–95 Medical signature required to use scale for patients with Chronic Hypoxia Sign 92–93 86–87 ≤91 ≤85 Unrecordable % or litres Inspired 02 Temperature NEWS SCORE uses Systolic BP If manual BP mark as M Heart Rate Conscious Level Respiratory Rate A Identification and assessment of deterioration Early warning scores and the role of the medical emergency team There are many systems that have been developed with the aim of rapidly identifying and managing physiological deterioration. These are referred to as ‘rapid response systems’. One popular example of a rapid response system is a medical emergency team (MET). A MET system operates on the basis that when a patient meets certain physiological criteria, the team is alerted. The team is expected to make a rapid assessment and institute immediate management. This may include escalation to critical care or, following liaison with the parent clinical team, ongoing ward-based care. The trigger for a ‘MET’ call may be a single parameter – such as a low BP or tachycardia – or may consist of a composite early warning score. Early warning score systems function by the observer allocating a value between 0 and 3 for abnormalities in respiratory rate, SpO_2, temperature, BP, heart rate, neurological response and urine output (Fig. 10.7). The values are summed and the composite score gives an indication of the severity of physiological derangement. Early warning systems can be automated into an electronic format that calculates the score and even alerts the responsible clinician(s) by email or text message. There are advantages and disadvantages to having a separate MET system, compared with allowing the responsible clinical team to manage deterioration, and to having a composite score or a single parameter detection system. These are outlined in Box 10.17. Immediate assessment of the deteriorating patient An approach to assessment of the deteriorating patient can be summarised by the mnemonic ‘C-A-B-C-D-E’. C – Control of obvious problem For example, if the patient has ventricular tachycardia on the monitor or significant blood loss is apparent, immediate action is required. A and B – Airway and breathing If the patient is talking in full sentences, then the airway is clear and breathing is adequate. A rapid history should be obtained while the initial assessment is undertaken. Breathing should be assessed with a focused respiratory examination. Oxygen saturations and ABGs should be checked early (p. 190). 10.16 Swollen legs in pregnancy • Benign swollen legs: common in pregnancy; this is usually benign. • DVT: pregnancy is a significant risk factor, however. • D-dimer: should not be measured in pregnancy; it has not been validated in this group. • Imaging: should be arranged on the basis of clinical suspicion alone, and the threshold for undertaking a definite diagnostic test should be low.

• Inform registered nurse • Registered nurse assessment using ABCDE • Review frequency of observations • Inform Nurse in Charge • If ongoing concern, escalate to Medical Team • Continue routine NEWS monitoring with every set of observations Minimum 12 hourly/4 hourly in admission areas Frequency of Observations NEWS Score Total 0* Total 1–4* Total 7* or more Total 5–6* or 3 in one parameter *Regardless of NEWS always escalate if concerned about a patient’s condition Clinical Response Minimum 4 hourly Consider Structured Response Tool Consider Fluid Balance Chart Increase frequency to a minimum of 1 hourly Start Structured Response Tool Start Fluid Balance Chart Continuous monitoring of vital signs Start Structured Response Tool Start Fluid Balance Chart • Registered nurse assessment • Inform Nurse in Charge • Escalate to Medical Team as per local escalation • Urgent medical assessment • Management plan to be discussed with Senior Trainee or above • Consider level of monitoring required in relation to clinical care • Registered nurse to assess immediately • Inform Nurse in Charge • Request immediate assessment by Senior Trainee or above • Case to be discussed with supervising Consultant • If appropriate contact Critical Care for review B B Responses to physiological deterioration. A and B, From Royal College of Physicians. National Early Warning Score (NEWS): standardising the assessment of acute-illness severity in the NHS. Report of a working party. London: RCP, 2012. Fig. 10.7, cont’d 10.17 Advantages and disadvantages of different rapid response systems System Advantages Disadvantages Single parameter trigger High sensitivity. Probably picks up subclinical deterioration and allows optimisation Low specificity. Much time will be spent with patients who are not deteriorating Composite early warning scoring system, e.g. NEWS or MEWS score Combines good sensitivity with improved specificity May miss single parameter deterioration that is still significant, e.g. a drop of 2 GCS points may not trigger an alert MET system Brings expertise in deteriorating patients immediately to the bedside Expensive to have well-trained individuals who are free from other clinical duties. May deskill the ward-based teams in acute care. May not have expertise in highly specific areas of medicine Clinical team review Patient is seen by clinicians familiar with the patient and condition Clinical team may be busy with other urgent duties. There may not be expertise in acute care within the ward-based team (GCS = Glasgow Coma Scale; MET = Medical Emergency Team; MEWS = Modified Early Warning Score; NEWS = National Early Warning Score) C – Circulation A focused cardiovascular examination should include heart rate and rhythm, jugular venous pressure, evidence of bleeding, signs of shock and abnormal heart sounds. The carotid pulse should be palpated in the collapsed or unconscious patient, but peripheral pulses also should be checked in conscious patients. The radial, brachial, foot and femoral pulses may disappear as shock progresses, and this indicates the severity of circulatory compromise. D – Disability Conscious level should be assessed using the GCS (see Fig. 10.5 and Box 10.24, pp. 186 and 194). A brief neurological examination looking for focal signs should be performed. Capillary blood glucose should always be measured to exclude hypoglycaemia or severe hyperglycaemia. E – Exposure and evidence 'Exposure' indicates the need for targeted clinical examination of the remaining body systems, particularly the abdomen and lower limbs. 'Evidence' may be gathered via a collateral history from other health-care professionals or family members, recent investigations, prescriptions or monitoring charts. Selecting the appropriate location for ongoing management Any patient who will gain benefit from a critical care area should be admitted. Such patients generally fall into two groups: those with organ dysfunction severe enough to require organ support and those in whom the disease process is clearly setting them on a downward trajectory and in whom early, aggressive management may alter the outcome. Whether an individual patient should be

 Analysis of an arterial blood sample is especially helpful in narrowing the differential diagnosis and confirming clinical suspicion of severity. The 'base excess' provides rapid quantification of the component of disease that is metabolic in origin. A base excess lower than −2 mEq/L (or, put another way, a 'base deficit' of more than 2 mEq/L) is likely to represent a metabolic acidosis. A simple rule of thumb is that a lactate of more than 4 mmol/L or a base deficit of more than 10 mEq/L should cause concern and trigger escalation to a higher level of care. In addition to clinical examination, chest radiography and bedside ultrasound can help to distinguish the cause of poor air entry; consolidation and effusion can be readily identified and a significant pneumothorax can be excluded (as shown in Fig. 10.8). Hypoxaemia Pathophysiology Low arterial partial pressure of oxygen (PaO_2) is termed hypoxaemia. It is a common presenting feature of deterioration. Hypoxia is defined as an inadequate amount of oxygen in tissues (or the inability of cells to use the available oxygen for cellular respiration). Hypoxia may be due to hypoxaemia, or may be secondary to impaired cardiac output, the presence of inadequate or dysfunctional haemoglobin, or intracellular dysfunction (such as in cyanide poisoning, where oxygen utilisation at the cellular level is impaired). Over 97% of oxygen carried in the blood is bound to haemoglobin. The haemoglobin–oxygen dissociation curve delineates the relationship between the percentage saturation of haemoglobin with oxygen (SO_2) and the partial pressure (PO_2) of oxygen in the blood. A shift in the curve will influence the uptake and release of oxygen by the haemoglobin molecule. As capillary PCO_2 rises, the curve moves to the right, increasing the offloading of oxygen in the tissues (the Bohr effect). This increases capillary PO_2 and hence cellular oxygen supply. Shifts of the oxyhaemoglobin dissociation curve can have significant implications in certain disease processes (Fig. 10.9). admitted to the intensive care or high-dependency unit (ICU/ HDU) will depend on local arrangements. A useful tool to assist with the decision regarding location is the 'level of care' required (Box 10.18). Many intensive care units are a mix of level 2 and level 3 beds, which streamlines the admission process. Common presentations of deterioration As patients become critically unwell, they usually manifest physiological derangement. The principle underpinning critical care is the simultaneous assessment of illness severity and the stabilisation of life-threatening physiological abnormalities. The goal is to prevent deterioration and effect improvements, as the diagnosis is established and treatment of the underlying disease process is initiated. It can be useful to consider the physiological changes as a starting point to help delineate urgent investigations and supportive treatment, which should proceed alongside the search for a definitive diagnosis. Tachypnoea Pathophysiology A raised respiratory rate (tachypnoea) is the earliest and most sensitive sign of clinical deterioration. Tachypnoea may be primary (i.e. a problem within the respiratory system) or secondary to pathology elsewhere in the body. Cardiopulmonary causes of tachypnoea have been covered on page 179. Secondary tachypnoea is usually due to a metabolic acidosis, most commonly observed in the context of sepsis, haemorrhage, ketoacidosis or visceral ischaemia. More detailed information on metabolic acidosis can be found on page 364. Assessment and management A simple assessment of a patient's clinical status and basic physiology will usually indicate whether urgent intervention is required. In the examination, attention should be paid to the adequacy of chest expansion, air entry and the presence of added sounds such as wheeze. 10.18 Levels of care and the corresponding admission criteria for intensive care unit (ICU) and high-dependency unit (HDU) Level of care Criteria Appropriate location

Patients requiring/likely to require endotracheal intubation and invasive mechanical ventilatory support Patients requiring support of two or more organ systems (e.g. inotropes and haemofiltration) Patients with chronic impairment of one or more organ systems (e.g. COPD or severe ischaemic heart disease) who require support for acute reversible failure of another organ ICU

Patients requiring detailed observation or monitoring that cannot be provided at ward level: Direct arterial BP monitoring CVP monitoring Fluid balance Neurological observations, regular GCS recording Patients requiring support for a single failing organ system, excluding invasive ventilatory support (IPPV): Non-invasive respiratory support (p. 202) Moderate inotropic or vasopressor support Renal replacement therapy in an otherwise stable patient Step-down from intensive care requiring additional monitoring or single organ support HDU

Patients in whom frequent but intermittent observations and medical review are sufficient General ward setting (BP = blood pressure; COPD = chronic obstructive pulmonary disease; CVP = central venous pressure; GCS = Glasgow Coma Scale; IPPV = intermittent positive pressure ventilation)

with acute stroke, those with MI and those who chronically retain CO_2. Adverse effects of hyperoxia include: • free radical-induced tissue damage • less efficient buffering of carbon dioxide by oxyhaemoglobin (compared to deoxyhaemoglobin) • less efficient ventilation–perfusion matching in lung units (due to loss of hypoxic vasoconstriction of under-ventilated lung units) • decreased hypoxic respiratory drive in individuals with chronic hypercapnia. When attempting to determine the cause of hypoxaemia, it is useful to consider whether the primary physiological mechanism is a type of shunt, or one of the many causes of ventilation–perfusion mismatch, such as alveolar or central hypoventilation (Fig. 10.10). A classification of common causes of hypoxaemia in hospitalised patients is shown in Box 10.20. In reality, the observed physiological abnormality may represent a combination of inter-related processes, such as severe pulmonary oedema leading to exhaustion, which in turn causes hypoventilation. Evaluation of risk factors, history and examination will help to differentiate the likely aetiology and guide specific management. Further management of respiratory failure is discussed on page 202. Tachycardia Pathophysiology A heart rate of > 110 beats/min in an adult should always be considered abnormal and not attributed to anxiety until other causes have been excluded. Intrinsic cardiac causes (atrial fibrillation (AF), atrial flutter, supraventricular tachycardia and Due to the shape of the curve, a small drop in arterial PO2 (PaO2) below 8 kPa (60 mmHg) will cause a marked fall in SaO2. Relative hypoxaemia refers to the comparison between the observed PaO2 and that which might be expected for a given fraction of inspired oxygen (FiO2). With the patient breathing air, PaO2 of 12–14 kPa (90–105 mmHg) would be expected; with the patient breathing 100% oxygen, a PaO2 of > 60 kPa (450 mmHg) would be normal. Assessment and management Oxygen therapy should be titrated to avoid hyperoxia (too high a PaO2; Box 10.19). Hyperoxia is theoretically harmful via a number of mechanisms. This has a clinically significant effect in patients Fig. 10.8 Using ultrasound to rule out an anterior pneumothorax. A Probe position and orientation. B and C Two-dimensional (2D) ultrasound images. D and E M-mode ultrasound images. Key: (1) Intercostal muscle. (2) Rib. (3) Normal bright pleural line –'shimmering appearance' of sliding pleura. (4) Lung. (5) Absent 'shimmering' in pneumothorax and lung not visible. (6) Normal – 'sea shore' sign excludes pneumothorax at that location. The 'sea shore' is represented by the bright granular line with lung (sea) deeper to the bright line. (7) Absent granular pleural line and a repeating linear pattern or 'barcode' sign suggest the presence of pneumothorax. Normal (no pneumothorax) Normal (no pneumothorax)

3 4 B D C A E Abnormal (pneumothorax cannot be excluded) Abnormal (pneumothorax cannot be excluded) Fig. 10.9 The haemoglobin–oxygen dissociation curve and the effect of CO2 on oxygen saturations. In pulmonary embolism, compensatory hyperventilation often occurs. PaCO2 decreases, shifting the oxyhaemoglobin saturation curve to the left (green line). Therefore, despite a low PaO2 (8 kPa/60 mmHg), the saturation reading is 93%. = 6.0 kPa = 45 mmHg PO2 (kPa or mmHg) Haemoglobin saturation (SO2) % = 4.1 kPa = 31 mmHg kPa mmHg P75 P50

9 10 11 12 13 14

10.19 Prescribing oxygen in critical illness • Oxygen should be prescribed to achieve a target saturation of 94–98% for most critically unwell patients. • 88–92% is a more appropriate target range for those at risk of hypercapnic respiratory failure.

192 • ACUTE MEDICINE AND CRITICAL ILLNESS Hypovolaemia should not be missed. Concealed bleeding (e.g. into the pleura, gastrointestinal tract or retroperitoneum) may not be apparent initially and assessment of haemoglobin in an acute haemorrhage, when < 30 mL/kg of fluid has been administered, can be misleadingly high. Sepsis and other hyper-metabolic conditions may present with a tachycardia that is accompanied by tachypnoea, peripheral vasodilatation and a raised temperature. Other organ dysfunction should be noted from a brief general examination and salient points from the history. Assessment and management The management of a tachycardic patient should focus on treating the cause. Treating the rate alone with beta-blockade in an unwell or deteriorating patient should be done only under specialist guidance, in controlled conditions, and when a clear evaluation of the risk–benefit ratio has been undertaken. The recognition and management of primary cardiac dysrhythmias are discussed on page 468. The most appropriate method of rate control in AF depends primarily on the degree of haemodynamic compromise. An intravenous loading dose of amiodarone is well tolerated and efficacious in the majority of critically ill patients with AF and a very rapid ventricular rate. There are thromboembolic concerns regarding

chemical cardioversion of AF of unknown duration. However, in deteriorating patients, the low incidence of embolic events makes this concern of secondary importance to achieving haemodynamic stability. Digoxin continues to have a role in the treatment of AF in critically unwell but haemodynamically stable patients, when ventricular dysrhythmias) are less common in the general inpatient population than secondary causes of tachycardia. A cardiac monitor or 12-lead ECG early in the examination will help both determine severity (heart rate > 160 beats/min should prompt urgent escalation to a higher level of care) and narrow the differential diagnosis. AF with a rapid ventricular response should usually be regarded as secondary to another insult (mostly commonly, infection) until other diagnoses have been excluded. Fig. 10.10 Theoretical mechanisms of hypoxaemia. A Normal physiology. B Shunt caused by alveolar filling, e.g. in pneumonia or alveolar haemorrhage. The mixture of oxygenated and deoxygenated blood causes arterial desaturation. C Shunt caused by interstitial pathology, e.g. pulmonary oedema or fibrosis. Interstitial thickening causes inadequate transfer of oxygen from the alveolus to the blood, leading to shunting and arterial desaturation. Because minute volume is usually maintained, this causes type I respiratory failure. D Ventilation–perfusion (V/Q) mismatch caused by alveolar hypoventilation, e.g. in chronic obstructive pulmonary disease (COPD)/asthma. Alveoli are under-ventilated relative to perfusion. Alveolar PO_2 falls and PCO_2 rises, causing type II respiratory failure. E V/Q mismatch caused by central hypoventilation, e.g. in neuromuscular disease or narcotic use. The alveoli are relatively over-perfused, causing type II respiratory failure. F V/Q mismatch caused by a perfusion defect, e.g. a small pulmonary embolism. Pulmonary blood flow is diverted to other alveoli, causing them to be relatively over-perfused and thus reducing alveolar PO_2. Minute volume is increased, so PCO_2 is not elevated. Terminal bronchus Alveolus Alveolus filled with blood/secretions or collapsed. Blood will pass this alveolus without becoming oxygenated Pulmonary vein SO_2 98% Pulmonary artery SO_2 75% Pulmonary vein SO_2 98% SO_2 75% SO_2 75% SO_2 98% A B SO_2 90% SO_2 75% SO_2 90% Interstitium thickened by fluid, inflammatory exudate or cells SO_2 75% SO_2 98% C D SO_2 75% SO_2 75% SO_2 94% SO_2 90% ↓[O_2] ↑[CO_2] ↓[O_2] ↑[CO_2] ↓[O_2] ↓[CO_2] SO_2 75% SO_2 90% E F 10.20 Common causes of hypoxaemia in hospitalised patients Hypoxaemia due to shunt • Lung collapse • Consolidation/alveolar haemorrhage • Interstitial oedema or interstitial infiltration (e.g. fibrosis) • Silent aspiration of gastric contents Hypoxaemia due to ventilation–perfusion mismatch • Pulmonary embolism • Acute exacerbation of asthma • COPD (with high minute volume) Hypoxaemia from hypoventilation • Effects of opiates • Severe COPD (with low minute volume) • Neuromuscular disease/general weakness from other illness (COPD = chronic obstructive pulmonary disease)

early identification. If shock is suspected, resuscitation

should be commenced (p. 204). Hypotensive patients who do not have any evidence of shock are still at significant risk of organ dysfunction. Hypotension should serve as a ‘red flag’ that there may be serious underlying pathology. Organ failure occurs despite normal or elevated oxygen delivery, so a full assessment of the patient is indicated. A review of the drug chart is essential, as many inpatients will be on antihypertensive medications that are contributing to hypotension. Non-cardiac medications may also have a negative influence on BP; for example, some drugs used for urine outflow tract obstruction, such as tamsulosin, have an αadrenoceptor-blocking effect. Hypertension Pathophysiology High BP (hypertension) is common and is usually benign in a critical care context. However, it can be the presenting feature of a number of serious disease processes. Furthermore, acute hypertension can result in an acute rise in vascular tone that increases left ventricular end-systolic pressure (afterload). The left ventricle may be unable to eject blood against the increased aortic pressure, and acute pulmonary oedema can result (referred to as ‘flash’ pulmonary oedema.) Assessment and management Before treating an acute rise in BP, it is worth considering a few important diagnoses that may impact on the immediate management: • Intracranial event. Ischaemia of the brainstem (commonly via a pressure effect) will cause acute increases in BP. A neurological examination and CT scan of the head should be considered. • Fluid overload. Once the capacity of the venous blood reservoir becomes saturated, increases in fluid volume will lead to increases in BP. This can occur in younger patients without the onset of peripheral oedema and originate from myocardial dysfunction or impaired renal clearance. • Underlying medical problems. A brief search for a history of renal disease, spinal injury and less common metabolic causes such as phaeochromocytoma can be worthwhile. In women of child-bearing age, pregnancy-induced its inotropic properties can be helpful. Electrical cardioversion is reserved for dysrhythmias with extremely high heart rates, following failure of pharmacological management, and/or for those of ventricular origin. It is rarely successful in dysrhythmias secondary to systemic illness.

Hypotension

Pathophysiology Low BP (hypotension) should always be defined in relation to a patient’s usual BP. The calculation of mean arterial pressure (MAP) is shown in Box 10.21; it unifies the systolic and diastolic BPs into a single reference value. A MAP of > 65 mmHg will maintain renal perfusion in the majority of patients, although a MAP of up to 80 mmHg may be required in patients with chronic hypertension. Assessment and management The first stage of assessment is to decide if the hypotension is physiological or pathological. The MAP is useful as, despite low systolic pressures, it is rare to see a physiological

MAP of < 65 mmHg. Urine output is particularly useful in the determination of the desirable MAP for an individual patient; oliguria suggests that measures to increase the MAP should be sought (p. 204). If the hypotension is pathological, an assessment of severity should look at whether it is causing physiological harm to the patient (i.e. the

patient is shocked). Shock
Shock means ‘circulatory failure’. It can be defined as a level of oxygen delivery (DO2) that fails to meet the metabolic requirements of the tissues (Box 10.22). Hypotension is a common presentation of shock but the terms are not synonymous. Patients can be hypotensive but not shocked, and oxygen

delivery can be critically low in the context of a ‘normal’ BP. Along with the signs of low cardiac output (Box 10.23), objective markers of inadequate tissue oxygen delivery, such as increasing base deficit, elevated blood lactate and reduced urine output, can aid 10.21 Calculation of mean arterial pressure (MAP) MAP Diastolic blood pressure

systolic diastolic

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− ( )

At normal heart rates, the heart, on average, spends two-thirds of the cycle in diastole. The MAP reflects this by weighting the value towards the diastolic blood pressure *Oxygen is almost exclusively bound to haemoglobin; only tiny amounts are dissolved in blood at atmospheric pressure. 10.22 Oxygen content and delivery • Oxygen content of blood = *Haemoglobin level × oxygen saturation × constant • Cardiac output = Heart rate × stroke volume • Stroke volume is dependent on cardiac filling (preload) and contractility • In shock, the most productive measures to improve oxygen delivery are optimising the haemoglobin level and the cardiac output 10.23 Hypotension in relation to cardiac output: clinical signs and possible causes High cardiac output Low cardiac output Signs Warm hands Pulsatile head movement High-volume/strong pulse Low venous pressure Cold/clammy peripheries Peripheral cyanosis Raised venous pressure Causes Sepsis Allergy Drug overdose (e.g. antihypertensive) Acidosis (e.g. diabetic ketoacidosis) Thyrotoxicosis Beri-beri Bleeding Aortic stenosis and failed compensation Dysrhythmia Obstructive (pulmonary embolism/tamponade/ dynamic hyperinflation as in severe asthma) Chronic heart failure

 aspiration or obstruction), but a motor score of less than 5 would suggest significant risk. Coma is defined as a persisting state of deep unconsciousness. In practice, this means a sustained GCS of 8 or less. There are many causes of coma (Box 10.26), including neurological (structural or non-structural brain disease) and non-neurological (e.g. type II respiratory failure) ones. The mode of onset of coma and any precipitating event is crucial to establishing the cause, and should be obtained from witnesses. Failure to obtain an adequate history for patients in coma is a common cause of diagnostic delay. Once the patient is stable from a cardiorespiratory perspective, examination should include accurate assessment of conscious level and a thorough general medical examination, looking for clues such as needle tracks indicating drug abuse, rashes, fever and focal signs of infection, including neck stiffness or evidence of head injury. Focal neurological signs may suggest a structural explanation (stroke or tumour) or may be falsely localising (for example, 6th nerve palsy can occur as a consequence of raised intracerebral pressure). It is vital to exclude non-neurological causes of coma. Sodium and glucose should be measured urgently as part of the initial assessment, as acute hyponatraemia (p. 358) and hypoglycaemia (p. 738) are easily corrected and can cause irreversible brain injury if missed. hypertension and pre-eclampsia must always be considered. • Primary cardiac problems. Myocardial ischaemia, acute heart failure and aortic dissection can all present with hypertension. • Drug-related problems. Most commonly, these involve a missed antihypertensive medication, but sympathomimetic drugs such as cocaine and amphetamines can be implicated. The management of hypertension is discussed further on page 510. Decreased conscious level Assessment A reduction in conscious level should prompt an urgent assessment of the patient, a search for the likely cause and an evaluation of the risk of airway loss. The GCS was developed to risk-stratify head injury, but it has become the most widely recognised assessment tool for conscious level (see

Box 10.24 for breakdown of GCS assessment, Box 10.25 for how to communicate the findings and Fig. 10.5 for how to assess GCS). While disorders that affect language or limb function (e.g. left hemisphere stroke, locked-in syndrome) may reduce its usefulness, evaluation of the GCS usually provides helpful prognostic information, and serial recordings can plot improvement or deterioration. It is not possible to define a total score below which a patient is unlikely to be able to protect the airway (from 10.25 How to communicate conscious level to other health-care professionals • It is best to state the physical response along with the numerical score • For example, 'a patient who doesn't open his eyes, withdraws to pain and makes groaning noises, having a GCS of E1, M4, V2, making a total of 7' is preferable to 'a male with a GCS of 7' *Record the best score observed. When the patient is intubated, there can be no verbal response. The suffix 'T' should replace the verbal component of the score, and the remainder of the score is therefore a maximum of 10. 10.24 Glasgow Coma Scale (GCS)* Eye-opening (E) • Spontaneous

• To speech

• To pain

• Nil

Best motor response (M) • Obeys commands

• Localises to painful stimulus

• Flexion to painful stimulus or withdraws hand from pain

• Abnormal flexion (internal rotation of shoulder, flexion of wrist)

• Extensor response (external rotation of shoulder, extension of wrist)

• Nil

Verbal response (V) • Orientated

• Confused conversation

• Inappropriate words

• Incomprehensible sounds

• Nil

Coma score = E + M + V Always present GCS as breakdown, not a sum score (unless 3 or 15) • Minimum sum

• Maximum sum

10.26 Causes of coma Metabolic disturbance • Drug overdose • Diabetes mellitus: Hypoglycaemia Ketoacidosis Hyperosmolar coma • Hyponatraemia • Uraemia • Hepatic failure (hyperammonaemia) • Inborn errors of metabolism causing hyperammonaemia • Hyperammonaemia on refeeding following profound anorexia • Respiratory failure • Hypothermia • Hypothyroidism Trauma • Cerebral contusion • Extradural haematoma • Subdural haematoma • Diffuse axonal injury Vascular disease • Subarachnoid haemorrhage • Brainstem infarction/ haemorrhage • Intracerebral haemorrhage • Cerebral venous sinus thrombosis Infections • Meningitis • Encephalitis • Cerebral abscess • Systemic sepsis Others • Epilepsy • Brain tumour • Functional (‘pseudo-coma’)

Further investigations should be guided by the clinical presentation and examination findings; a sudden onset suggests a vascular cause. An early CT scan of the brain may demonstrate any gross pathology but if a brainstem stroke is suspected (Fig. 10.11), a CT angiogram of the circle of Willis will provide more useful information, as a non-contrast CT is frequently negative in this context. If there are features suggestive of cerebral venous thrombosis, such as thrombophilia or sinus infection, a CT venogram should be performed. Meningitis or encephalitis may be suggested by the history, signs of infection or subtle radiological findings. If these diagnoses are considered, it is best to commence treatment with broad-spectrum antibiotics and antivirals while awaiting more definitive diagnostic information. Other drug, metabolic and hepatic causes of reduced conscious level are dealt with in the relevant chapters. An ammonia level (sent on ice) can narrow the differential diagnosis to a metabolic or hepatic cause if there is diagnostic doubt; levels > 100 μmol/L (140 μg/dL) are significantly abnormal. Psychiatric conditions such as catatonic depression or neurological conditions such as the autoimmune encephalitides can cause a reduced level of consciousness, but they are diagnoses of exclusion and will require specialist input. Management Moving an unconscious patient into the recovery position is best for airway protection while preparations are made for escalation to a higher level of care. The decision regarding intubation for airway protection is always difficult. Length of stay in intensive care is significantly reduced if there is no secondary organ Fig. 10.11 Hyperacute changes in conscious state are commonly of vascular origin. CT of the brain is unlikely to identify many vascular causes but a CT angiogram of the circle of Willis is a high-yield investigation in this context. A Non-contrast CT of the head showing hyperdense thrombus in the basilar artery (arrow). This is a specific, but not sensitive, sign. B CT angiogram of the circle of Willis demonstrating thrombosis in the basilar artery (arrow). This has better sensitivity for acute vascular occlusion. B A dysfunction. Therefore, early intubation and the prevention of lung injury constitute the safer option if there is any doubt about a patient’s ability to protect the airway from obstruction or aspiration. Decreased urine output/deteriorating renal function Assessment A urine output of 0.5 mL/kg/hr is a commonly quoted, though admittedly arbitrary target. Although some patients can produce urine volumes below this level with no change in their renal biochemistry, such low volumes should alert the clinician to the possibility of suboptimal renal perfusion. Oliguria in association with hypotension or an increase in serum creatinine level (even if small) should prompt examination for the underlying cause. Pre-renal causes predominate in the general inpatient population, so optimising the MAP by administration of intravenous fluids (and possibly vasopressors) is the first priority. In the majority of inpatients there is no role for high volumes (i.e.

> 30 mL/kg) of intravenous fluid if the MAP is normal. Exceptions to this rule include patients with clinical dehydration or high fluid losses such as in burns, diabetes emergencies (pp. 735 and

’38. and diabetes insipidus (p. 687), where fluid management should be guided by local protocols. Diagnosis and management Further assessment and management of oliguria are explained on page 391. Two other important causes of renal failure in the inpatient population are abdominal compartment syndrome and rhabdomyolysis. Abdominal compartment syndrome Abdominal compartment syndrome occurs when raised pressure within the abdomen reduces perfusion to the abdominal organs. It is most commonly seen in surgical patients, but can occur in medical conditions with extreme fluid retention such as liver cirrhosis. When it is suspected, intra-abdominal pressure can be monitored via a pressure transducer connected to a urinary catheter (following instillation of 25 mL of 0.9% saline into the bladder). Values over 20 mmHg suggest abdominal compartment syndrome is present. Urgent measures should be taken to reduce the pressure, such as decompression of the stomach, bladder and peritoneum if ascites is present. If conservative measures fail, a laparostomy should be considered. Rhabdomyolysis Rhabdomyolysis occurs when there is an injury to a large volume of skeletal muscle, usually because a single limb or muscle compartment has been ischaemic for a prolonged period. It can also occur following trauma and crush injury or after over-exertion of muscles. Over-exertion can occur after intense physical exercise or as part of a medical condition that causes widespread muscular activity, such as malignant hyperpyrexia or neuroleptic malignant syndrome. A creatine kinase (CK) level of > 1000 U/L is highly suggestive, although it can rise to tens of thousands in severe cases. Management should focus on identification and correction of the underlying cause and support for multi-organ dysfunction. Forced alkaline diuresis (using intravenous bicarbonate infusion and furosemide) can be used to maintain a good flow of less acidic fluid within the renal tubules and reduce myoglobin precipitation.

 non-infective processes, such as pancreatitis, burns, trauma, major surgery and drug reactions, can cause alarmins to be released and initiate the process of systemic inflammation. Propagation of the inflammatory response Once activated, immune cells such as macrophages release the inflammatory cytokines interleukin-2 (IL-2), IL-6 and tumour necrosis factor alpha, which, in turn, activate neutrophils. Activated neutrophils express adhesion factors and release various other inflammatory and toxic substances; the net effects are vasodilatation (via activation of inducible nitric oxide synthase enzymes) and damage to the endothelium. Neutrophils migrate into the interstitial space; fluid and plasma proteins will also leak through the damaged endothelium, leading to oedema and intravascular fluid depletion. Activation of the coagulation system Damaged endothelium triggers the coagulation cascade (via tissue factor, factor VII, and reduced activity of proteins C and S) and thrombus forms within the microvasculature. A vicious circle of endothelial injury, intravascular coagulation and microvascular occlusion develops, causing more tissue damage and further release of inflammatory mediators. In severe sepsis, intravascular coagulation can become widespread. This is referred to as disseminated intravascular coagulation (DIC) and usually heralds the onset of multi-organ failure.

Specific aspects of the diagnosis and management of DIC are discussed on page 978. Organ damage from sepsis Any and all organs may be injured by severe sepsis. The pathological mechanisms are shown in Figure 10.12. Lactate physiology Lactate is an excellent biomarker for the severity of sepsis. Hyperlactataemia (serum lactate > 2.4 mmol/L or 22 mg/dL) is used as a marker of severity. Figure 10.13 explains the physiology of hyperlactataemia; it is caused by all types of shock and therefore is not specific to sepsis. A lactate level of

> 8 mmol/L (>73 mg/dL) is associated with an extremely high mortality and should trigger immediate escalation. Measures to optimise oxygen delivery should be sought, and the adequacy of resuscitation measured by lactate clearance. The anti-inflammatory cascade As the inflammatory state develops, a compensatory antiinflammatory system is activated involving the release of antiinflammatory cytokines such as IL-4 and IL-10 from immune cells. While such mechanisms are necessary to keep the inflammatory response in check, they may lead to a period of immunosuppression after the initial septic episode. Patients recovering from severe sepsis are prone to developing secondary infections due to a combination of this immunosuppression and the presence of indwelling devices. Management The most important action is to consider sepsis as the cause of a patient's deterioration. Aligned to this is the requirement to consider other diagnoses that could be causing the presentation, such as haemorrhage, PE, anaphylaxis or a low cardiac output state. Resuscitation in sepsis General resuscitative measures are discussed on page 204. Early resuscitation can be aided by following the requirements of the *From the Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). 10.27 Definitions of sepsis and septic shock* Sepsis Patients with suspected infection who have 2 or more of: • Hypotension – systolic blood pressure < 100 mmHg • Altered mental status – Glasgow Coma Scale score ≤ 14 • Tachypnoea – respiratory rate ≥ 22 breaths/min Sepsis can also be diagnosed by suspected infection and an increase of ≥ 2 points on the Sequential Organ Failure Assessment (SOFA) score (p. 214) Septic shock A subset of sepsis with underlying circulatory or cellular/metabolic abnormalities associated with a substantially increased mortality: • Sepsis and both of (after fluid resuscitation):

1. Persistent hypotension requiring vasopressors to maintain a MAP

> 65 mmHg

2. Serum lactate > 2 mmol/L (18 mg/dL) Disorders causing critical illness Sepsis and the systemic inflammatory response Sepsis is one of the most common causes of multi-organ failure. Sepsis requires the presence of infection with a resultant systemic inflammatory state; organ dysfunction occurs from a combination of the two processes. The definition of sepsis has undergone various iterations and there is still a lack of consensus as to the

exact wording that best reflects this complex, multisystem process (Box 10.27). Aetiology and pathogenesis To understand how an infection can lead to progressive multiorgan failure, it is essential to have a grasp of the pathophysiology. Initiation of the inflammatory response The process begins with infection in one part of the body that triggers a localised inflammatory response. Appropriate source control and a competent immune system will, in most cases, contain the infection at this stage. However, if certain factors are present, the infection may become systemic. The causative factors are not fully elucidated but probably include: • a genetic predisposition to sepsis • a large microbiological load • high virulence of the organism • delay in source control (either surgical or antimicrobial) • resistance of the organism to treatment • patient factors (immune status, nutrition, frailty). Mediators are released from damaged cells (called 'alarmins') and these, coupled with direct stimulation of immune cells by the molecular patterns of the microorganism, trigger the inflammatory response. An example of such direct stimulation is that of lipopolysaccharide, which is found on the surface of Gram-negative bacteria. It strongly stimulates an immune response and is commonly used in research settings to initiate a septic cascade. Viral and fungal infections can cause a syndrome that is clinically indistinguishable from bacterial sepsis. Likewise, numerous

crystalloid. Early intubation is recommended in severe cases to facilitate further management and reduce oxygen demand. Appropriate antibiotics should be administered as early as possible (Box 10.29). The antibiotic choice will depend on local patterns of resistance, patient risk factors and the likely source of infection. Information on likely organisms and appropriate antibiotics can be found on pages 117 and 226. Microbiological samples (such as blood cultures, urine or CSF) should be taken, but this should not delay antibiotic administration, if obtaining samples is difficult. Early source control Source control requires an accurate diagnosis; urgent investigations should be performed as soon as physiological stability has been established. A CT scan of the chest and abdomen with contrast is a high-yield test in this context. Specific points in the history should be reviewed, such as risk factors for human immunodeficiency virus (HIV), contacts with tuberculosis and underlying immune status. Immunocompromised patients will be susceptible to a far broader spectrum of infectious microorganisms (p. 223). 'Sepsis Six' (Box 10.28). Red cell transfusion should be used to target a haemoglobin concentration of 70–90 g/L (7–9 g/dL). Albumin 4% can be used as colloid solution and has the theoretical benefit of remaining in the intravascular space for longer than Fig. 10.12 Pathophysiology of organ damage in sepsis. Macrovascular. Severe hypovolaemia, vasodilatation or septic cardiomyopathy can reduce oxygen delivery, causing tissue hypoxia. Paradoxically, most patients with sepsis have an increased cardiac output and oxygen delivery. Microvascular. Tissue injury can occur from hypoxia secondary to microvascular injury and thrombosis. Damaged epithelium permits neutrophils, proteins and fluid to leak out. Shunting. Organs fail in sepsis despite supranormal blood flow. It is likely that arteriovenous shunt pathways exist within vascular beds; these shunts open up in septic shock. Cellular. Cells are damaged by a number of mechanisms in sepsis: (1) direct injury by microorganisms; (2) injury from toxins produced by immune cells, e.g. oxygen free radicals; (3) mitochondrial injury causing cytopathic hypoxia – cells are unable to metabolise oxygen; (4) apoptosis – if the cell injury is sufficient, capsase enzymes are activated within the nucleus and programmed cell death occurs; (5) hypoxia from micro- and macrovascular pathology. Arterioles M A C R O V A S C U L A R Capillaries

Mitochondria Neutrophil Bacteria Nucleus Neutrophil Arteriovenous shunt Venules Microemboli M I C R O V A S C U L A R C E L L U L A R Fig. 10.13 Physiology of hyperlactataemia. Inadequate oxygen delivery Tissue hypoxia e.g. Ischaemic gut Shock (from any cause) Drugs e.g. Adrenaline (epinephrine) Salbutamol Excess muscle activity e.g. Extreme exercise Seizure Anaerobic metabolism Excess production Inadequate clearance β2-adrenoceptor stimulation High lactate Excess tissue production Hepatic failure Congenital enzyme deficiencies (rare) Other causes: Metformin Thiamin deficiency Haematological malignancy Drugs, e.g. antiretrovirals *International recommendations for the immediate management of suspected sepsis from the Surviving Sepsis Campaign (all to be delivered within 1 hr of the initial diagnosis of sepsis). 10.28 The 'Sepsis Six'*

1. Deliver high-flow oxygen
2. Take blood cultures
3. Administer intravenous antibiotics
4. Measure serum lactate and send full blood count
5. Start intravenous fluid replacement
6. Commence accurate measurement of urine output 10.29 Early administration of antibiotics in suspected sepsis • Broad-spectrum antibiotics should be administered as soon as possible after sepsis is suspected • Every hour of delayed treatment is associated with a 5–10% increase in mortality

 Acute respiratory distress syndrome Aetiology and pathogenesis Acute respiratory distress syndrome (ARDS) is a diffuse neutrophilic alveolitis caused by a range of conditions and characterised by bilateral radiographic infiltrates and hypoxaemia (Box 10.32). Activated neutrophils are sequestered into the lungs and capillary permeability is increased, with damage to cells within the alveoli. The pathophysiology is part of the inflammatory spectrum described in 'Sepsis' above, and the triggers are similar: infective and non-infective inflammatory processes. These processes result in exudation and accumulation of protein-rich cellular fluid within alveoli and the formation of characteristic 'hyaline membranes'. Local release of cytokines and chemokines by activated macrophages and neutrophils results in progressive recruitment of inflammatory cells. Secondary effects include loss of surfactant and impaired surfactant production. The net effect is alveolar collapse and reduced lung compliance, most marked in dependent regions of the lung (mainly dorsal in supine patients). The affected airspaces become fluid-filled and can no longer contribute to ventilation, resulting in hypoxaemia (due to increased pulmonary shunt) and hypercapnia (due to inadequate ventilation in some areas of the lung): that is, ventilation–perfusion mismatch. Diagnosis and management ARDS can be difficult to distinguish from fluid overload or cardiac failure. Classic chest X-ray and CT appearances are shown in Figures 10.14 and 10.15, respectively. Occasionally, conditions may present in a similar way to ARDS but respond to alternative treatments; an example of this might be a glucocorticoidresponsive interstitial pneumonia (p. 605). Management of ARDS is supportive, including use of lung-protective mechanical ventilation, inducing a negative fluid balance and treating the underlying cause. Establishing the severity of ARDS (Box 10.33) is useful, as severe disease will require more proactive management such as prone positioning or extracorporeal membrane oxygenation (ECMO; p. 204). Noradrenaline (norepinephrine) for refractory hypotension Central venous access should be established early in the resuscitation process and a noradrenaline infusion commenced. If there is severe hypotension, it is not necessary to wait until 30 mL/kg of fluid has been administered before commencing noradrenaline; early vasopressor use may improve the outcome from acute kidney injury. Measurement of central and mixed venous oxygen saturations may provide additional prognostic information (Box 10.30). Other therapies for refractory hypotension Refractory hypotension is due to either inadequate cardiac output or inadequate systemic vascular resistance (vasoplegia). When vasoplegia is suspected, it may be necessary to add vasopressin (antidiuretic hormone, ADH). This is a potent vasoconstrictor that may be used to augment noradrenaline (norepinephrine) in achieving an acceptable MAP. Intravenous glucocorticoids are also commonly used in refractory hypotension. There is little evidence that they improve the overall outcome, but they do lead to a more rapid reversal of the shocked state. There is a small increased risk of secondary infection following glucocorticoid use. Septic cardiomyopathy The myocardium can be affected by the septic process, presenting as either acute left or right ventricular dysfunction. A bedside echocardiogram is particularly useful to confirm the diagnosis, as ECG changes are usually non-specific. Dobutamine or adrenaline (epinephrine) can be used to augment cardiac output, and intravenous calcium should be replaced if ionised calcium is low. Other interventions such as intravenous bicarbonate in profound metabolic acidosis, high-volume haemofiltration/haemodialysis and extracorporeal support are sometimes used, but currently lack evidence of benefit. Review of the underlying pathology While sepsis is the most common cause of acute systemic inflammation, up to 20% of patients initially treated for sepsis will have a non-infectious cause: that is, a sepsis mimic (Box 10.31). These conditions should be considered where the clinical picture is not typical, no source of sepsis can be found, or the inflammatory response seems excessive in the context of local infection. Early reconsideration of the diagnosis of sepsis is crucial, as many of the ‘sepsis mimics’ offer a finite time window for specific intervention, after which irreversible organ damage will have occurred. 10.31 Sepsis mimics • Pancreatitis • Drug reactions • Widespread vasculitis – catastrophic antiphospholipid syndrome, Goodpasture’s syndrome • Autoimmune diseases – inflammatory bowel disease, rheumatoid arthritis, systemic lupus erythematosus • Malignancy – carcinoid syndrome • Haematological conditions – haemophagocytic syndrome, diffuse lymphoma, thrombotic thrombocytopenic purpura 10.32 Berlin definition of ARDS • Onset within 1 week of a known clinical insult, or new or worsening respiratory symptoms • Bilateral opacities on chest X-ray, not fully explained by effusions, lobar/lung collapse or nodules • Respiratory failure not fully explained by cardiac failure or fluid overload. Objective assessment (e.g. by echocardiography) must exclude hydrostatic oedema if no risk factor is present • Impaired oxygenation (see Box 10.33) 10.30 Central and mixed venous oxygen saturations • Saturation of venous blood sampled from the right atrium or superior vena cava (central) or pulmonary artery (mixed venous) • Both values reflect the balance of supply and demand of oxygen to the tissues • Mixed venous oxygen saturation is a measure of whole-body supply and demand of oxygen; central venous oxygen saturation measures the supply and demand of oxygen from the upper body. Normal mixed venous oxygen saturation is 70%. Lower values than this suggest inadequate oxygen delivery • Central venous oxygen saturation is more variable, depending on whether the patient is awake or anaesthetised, but a value of 70% is considered normal • Where cytopathic hypoxia occurs, oxygen extraction is impaired and the central and mixed venous oxygen saturations may be > 80%. This is often a poor prognostic sign

infarction and rupture of the septum) and acute mitral regurgitation (due to infarction or rupture of the papillary muscles). Severe myocardial systolic dysfunction causes a fall in cardiac output, BP and coronary perfusion pressure. Diastolic dysfunction causes a rise in left ventricular end-diastolic pressure, pulmonary congestion and oedema, leading to hypoxaemia that worsens myocardial ischaemia. This is further exacerbated by peripheral vasoconstriction. These factors combine to create the ‘downward spiral’ of cardiogenic shock (Fig. 10.17). Hypotension, oliguria, delirium and cold, clammy peripheries are the manifestations of a low cardiac output, whereas breathlessness, hypoxaemia, cyanosis and inspiratory crackles at the lung bases are typical features of pulmonary oedema. If necessary, a Swan–Ganz catheter can be used to measure the pulmonary artery pressures and cardiac output (p. 206). These findings can be used to categorise patients with acute MI into four haemodynamic subsets (Box 10.34) and titrate therapy accordingly. In cardiogenic shock associated with acute MI, immediate percutaneous coronary intervention should be performed (p. 491). The viable myocardium surrounding a fresh infarct may contract poorly for a few days and then recover. This phenomenon is known as myocardial stunning and means that acute heart failure Fig. 10.14 Chest X-ray in acute respiratory distress syndrome (ARDS). Note bilateral lung infiltrates, pneumomediastinum, pneumothoraces with bilateral chest drains, surgical emphysema, and fractures of the ribs, right clavicle and left scapula. Fig. 10.15 CT scan of the thorax in a patient with severe ARDS. Note the pathology is mainly in the dorsal (dependent) parts of the lung. 10.33 Determining the severity of ARDS Severity of hypoxaemia is calculated using a Pa/FiO_2 ratio. This is a number calculated by using the PaO_2 from an arterial blood gas measurement divided by the fraction of inspired oxygen (FiO_2, expressed as a fraction). For example, a patient with a PaO_2 of 10 kPa (75 mmHg) on 50% oxygen, i.e. FiO_2 of 0.5, would have a Pa/FiO_2 ratio of 20 kPa (150 mmHg). This would be defined as moderately severe ARDS, if the other Berlin criteria were met (see Box 10.32). All measurements should be taken on a minimum of 5 cmH_2O of PEEP or CPAP. • Mild: 40–26.6 kPa (300–200 mmHg) • Moderate: 26.6–13.3 kPa (200–100 mmHg) • Severe: ≤ 13.3 kPa (≤ 100 mmHg) (CPAP = continuous positive airway pressure; PEEP = positive end-expiratory pressure) 10.34 Acute myocardial infarction: haemodynamic subsets Cardiac output Pulmonary oedema No Yes Normal Good prognosis and requires no treatment for heart failure Due to moderate left ventricular dysfunction. Treat with vasodilators and diuretics Low Due to right ventricular dysfunction or concomitant hypovolaemia. Give fluid challenge and consider pulmonary artery catheter to guide therapy Extensive myocardial infarction and poor prognosis. Consider intra-aortic balloon pump, vasodilators, diuretics and inotropes Acute circulatory failure (cardiogenic shock) Definition and aetiology Cardiogenic shock is defined as hypoperfusion due to inadequate cardiac output or, more technically, a cardiac index of < 2.2 L/min/ m^2 (see Box 10.42). While cardiogenic shock is the final common pathway of many disease processes (e.g. sepsis, anaphylaxis, haemorrhage), the important primary causes of acute heart failure or cardiogenic shock (Fig. 10.16) are described here. Myocardial infarction In the majority of cases, cardiogenic shock following acute MI is due to left ventricular dysfunction. However, it may also be due to infarction of the right ventricle, or a variety of mechanical complications, including tamponade (due to infarction and rupture of the free wall), an acquired ventricular septal defect (due to

 should be treated intensively because overall cardiac function may subsequently improve. Acute massive pulmonary embolism Massive PE may complicate leg or pelvic vein thrombosis and usually presents with sudden collapse. The clinical features and treatment are discussed on page 619. Bedside echocardiography may demonstrate a small, under-filled, vigorous left ventricle with a dilated right ventricle; it is sometimes possible to see thrombus in the right ventricular outflow tract or main pulmonary artery. In practice, it can be difficult to distinguish massive PE from a right ventricular infarct on transthoracic echocardiogram. CT pulmonary angiography usually provides a definitive diagnosis. Acute valvular pathology, aortic dissection and cardiac tamponade These conditions should be considered in an undifferentiated presentation of shock. The diagnosis and management of these conditions is discussed on pages 514, 506 and 544. Post cardiac arrest The initial management of cardiac arrest is discussed on page 456. Following the return of spontaneous circulation (ROSC), the majority of cardiac arrest survivors will need a period of time in intensive care to achieve physiological stability, identify Fig. 10.16 Some common causes of cardiogenic shock. Aorta Cardiac tamponade PA RA RV LV LA Aorta Endocarditis of mitral valve PA RA RV LV LA Aorta Right ventricular infarct PA RA RV LV LA Aorta Pulmonary embolism PA RA RV LV LA Aorta Dysrhythmia caused by: Left ventricular damage Myocardial infarction Myocarditis PA RA RV LV LA Ventricular tachycardia Aorta PA RA RV LV LA Left ventricular infarct Fig. 10.17 The downward spiral of cardiogenic shock. Ventricular dysfunction Systolic Diastolic ↓ Cardiac output ↓ Blood pressure ↓ Coronary perfusion Further ischaemia ↑ Left ventricular diastolic pressure ↑ Pulmonary congestion Hypoxaemia

the most specific test to predict irrecoverable brain injury. This test is performed by administering an electrical impulse over a peripheral nerve and recording the electrical impulses measured by the scalp electrodes overlying the part of the brain expected to receive the impulse. Where this is not available, prognostication based on all other available information, along with the perceived wishes relating to the level of disability the individual would be prepared to accept, should allow a decision regarding ongoing treatment to be made. Where there is doubt, more time should be given to allow assessment of neurological recovery. Other causes of multi-organ failure As previously discussed, sepsis is the most common cause of multi-organ failure. However, multi-organ failure secondary to single organ dysfunction, such as cardiac failure, liver failure, renal failure or respiratory failure, is also common. The multisystem insult in these disease processes goes beyond the direct biochemical damage and tissue hypoxia caused by the primary organ dysfunction. It probably reflects cellular signalling pathways and the release of other systemic toxins by the failing organ, referred to as organ ‘crosstalk’. Multi-organ failure can also be caused by a physiological insult that damages a wide variety of cells in different organs, including toxins from extrinsic sources such as envenomation and intrinsic sources such as myoglobin in rhabdomyolysis (p. 195). Multi-organ failure can also be caused by profound physical injury to cells from processes such as nuclear radiation, heat exposure or blast trauma. Critical care medicine Decisions around intensive care admission Being a patient in intensive care is seldom a pleasant experience. The interventions are usually painful and the loss of liberties that are normally taken for granted can be devastating. While much of the unpleasant sensory and emotional experience can be modified with high-quality care and analgesia, there is a strong case that it can only be morally ‘right’ to admit a patient to intensive care if the end justifies the means. There must be a realistic hope that the patient will regain a quality of life that would be worth the pain and suffering that he or she will experience in intensive care. Few patients are able to comprehend fully what it means to be critically ill, so the physician should guide the process of determining who should be admitted to intensive care. Selecting the appropriate level of intervention for an individual patient can be very difficult. The decision-making process should involve an assessment of the likelihood of reversibility of the disease, the magnitude of the interventions required, the underlying level of frailty, and the personal beliefs and wishes of the patient (commonly expressed through their next of kin). As technology and science have improved, conditions that were previously regarded as terminal can now be supported and life can be considerably prolonged (Box 10.37). There have been several prominent examples of individuals who have received intensive care, but where an onlooker might have considered treatment to be futile owing to frailty, comorbidity or profound neurological injury. Such cases will, in part, shape the views and expectations of society, and it is unlikely that making decisions in this area will become any easier. Some suggested techniques to aid decision-making are listed in Box 10.38. 10.36 Prognostication after cardiac arrest: predictors of poor neurological recovery Coexisting problems • Multi-organ failure • Significant comorbidities Clinical • Persisting and generalised myoclonus • Absence of pupillary or corneal reflexes • Poor motor response (absent or extensor response) Biochemical • A neuron-specific enolase > 33 μg/L Imaging • CT showing loss of grey–white differentiation • Focal cause or consequence of cardiac arrest, e.g. subarachnoid haemorrhage Electrophysiology • EEG patterns may suggest brain injury, e.g. burst suppression • Somato-sensory evoked potentials – bilateral absence of the N20 spike (recorded from scalp electrodes from cutaneous electrical impulse over the median nerve) 10.35 Physiological targets following a return of spontaneous circulation (ROSC) • Temperature management. Facilitate maintenance of temperature at 36°C and avoidance of pyrexia by the use of a cooling blanket. This should be continued for 72 hrs. Muscle relaxants may be required to prevent shivering • Blood pressure management. Aim for a MAP of at least 70 mmHg and a systolic blood pressure of > 120 mmHg • Glucose control. Control the glucose to 6–10 mmol/L (108– 180 mg/dL) • Normal CO_2 (4.5–6 kPa, 33–45 mmHg) and oxygen saturation (94–98%). Avoid both hypoxaemia and hyperoxia and manage the underlying cause of the arrest, and optimise neurological recovery. Acute management A MAP of > 70 mmHg should be maintained to optimise cerebral perfusion. Shock is common following ROSC and is caused by a combination of the underlying condition leading to the arrest, myocardial stunning and a post-arrest vasodilated state. Support with inotropes, vasopressors and occasionally mechanical support from an intra-aortic balloon pump or venous–arterial ECMO (p. 207) may be required. Specific cardiac interventions and their indications are described in Chapter 16. Other physiological targets are listed in Box 10.35. Prognosis Predicting which patients will not recover from the brain injury sustained at the time of cardiac arrest is very difficult. Certain features suggest that the outcome will be poor: for example, the absence of pupillary and corneal reflexes, absence of a motor response and persistent myoclonic jerking. Tools to assist prognostication following cardiac arrest are shown in Box 10.36. The clinician should, where feasible, delay prognostication until a period of 72 hours of targeted temperature management has been completed. The bilateral absence of the ‘N20’ spike on the somato-sensory evoked potential is

 Respiratory support Non-invasive respiratory support Non-invasive respiratory support provides a bridge between simple oxygen delivery devices and invasive ventilation. It can be used in patients who are in respiratory distress but do not have an indication for invasive ventilation, or in those who are not suitable for intubation and ventilation for chronic health reasons. Patients must be cooperative, able to protect their airway, and have the strength to breathe spontaneously and cough effectively. Clinicians should avoid using non-invasive respiratory support to prolong the dying process in irreversible conditions such as end-stage lung disease. Likewise, a failure to respond to treatment or further deterioration should trigger a decision regarding intubation, as delayed invasive ventilation in this context is associated with worse outcome. High-flow nasal cannulae High-flow nasal cannulae (HFNCs) are devices that provide very high gas flows of fully humidified oxygen and air. They offer distinct advantages over non-invasive ventilation (NIV) in selected patients, mainly those with type I respiratory failure (particularly pneumonia) who have not reached an indication for invasive ventilation. They allow patient comfort and increased expectoration while providing some degree of positive end-expiratory pressure (PEEP) and a high oxygen concentration that can be titrated to the SO2. Continuous positive pressure ventilation Continuous positive pressure ventilation therapy involves the application of a continuous positive airway pressure (CPAP) throughout the patient’s breathing cycle, typically 5–10 cmH2O. It helps to recruit collapsed alveoli and can enhance clearance of alveolar fluid. It is particularly effective at treating pulmonary atelectasis (which may be post-operative) and pulmonary oedema. It uses a simpler device than NIV but otherwise offers no direct benefit over it. Non-invasive ventilation or bi-level ventilation NIV provides ventilatory support via a tight-fitting nasal or facial mask. It can be delivered by using a simple bi-level ventilation (BiPAP) turbine ventilator, or an intensive care ventilator. These machines can deliver pressure at a higher level (approximately 15–25 cmH2O) for inspiration and a lower pressure (usually 4–10 cmH2O) to allow expiration. Ventilation can be spontaneous (triggered by a patient’s breaths) or timed (occurring at a set frequency). Systems that synchronise with a patient’s efforts are better tolerated and tend to be more effective in respiratory failure. Timed breaths are used for patients with central apnoea. NIV is the first-line therapy in patients with type II respiratory failure secondary to an acute exacerbation of COPD because it reduces the work of breathing and offloads the diaphragm, allowing it to recover strength. It is also useful in pulmonary oedema, obesity hypoventilation syndromes and some neuromuscular disorders. It should be initiated early, especially when severe respiratory acidosis secondary to hypercapnia is present. NIV can also be used to support selected patients with hypercapnia secondary to pneumonia, or during weaning from invasive ventilation, but its effectiveness in these contexts is less certain; early intubation or re-intubation is probably more beneficial. Stabilisation and institution of organ support In order to stabilise a critically unwell patient, the primary problem should be corrected as quickly as possible: for example, source control in sepsis and control of the bleeding point in haemorrhage. Immediate resuscitation and prioritisation of the safety of the patient are clearly important, but there is only a limited role for ‘optimising’ the patient if such measures may significantly delay a definitive treatment, such as laparotomy for a perforated viscus. In some cases, the definitive treatment is not readily apparent or treatments take time to have their full effect. In these cases, adequate organ support to stabilise the patient while the treatment is given becomes the main goal of care. 10.38 Techniques to improve admission decision-making • Always act in the best interests of the patient: external influences are commonly present but these should be of only secondary importance • Maximise patient capacity: wherever possible, the patient should be involved in discussions of escalation and resuscitation status • Communicate openly and honestly with the next of kin: when communicating potential outcomes, it is best to use natural frequencies rather than percentages. For example, ‘If we had 100 patients with the same illness as your mother, only 10 would survive’ is easier for most people to understand than ‘there is a 90% chance of death’ • Reach mutual agreement with the next of kin: it is rare for there to be discord between clinicians and family, and in most cases the most appropriate course of action is clear • Seek additional opinions: other clinicians involved in the care of the patient will provide useful input. The premise should be to err on the side of escalation where the most appropriate course of action is unclear. Where there is an unresolvable difference in opinion, a mediation process or court ruling may be required to make the final decision. Thankfully, this is a very infrequent occurrence • Plan ahead: advance planning in chronic, progressive disease can make the decision easier. Some health facilities use an escalation form, which specifies the interventions that should be offered or are acceptable to the patient. This can be useful as the binary decision of for/not for resuscitation fails to account for the array of interventions that can be performed before cardiac arrest occurs 10.37 Critical illness in the context of congenital conditions • Longer survival: there are many congenital conditions that would, in the past, have been fatal in childhood, but now patients survive into adulthood. Decision-making can be difficult when the adolescent has impaired decision-making capacity. • Parental views: in such circumstances, the views of the parent or legal guardian become paramount. • Goals of care: often a detailed explanation of what is, and is not, achievable in intensive care allows the direction of care to be switched to palliative when life expectancy is poor and quality of life is severely impaired. • Decision-making: such conversations may require input from experts in the patient's congenital condition(s), and advanced decision-making regarding ICU admission should be encouraged whenever patients and families feel able to discuss such issues.

breathe spontaneously once it is safe to do so. The determination of what constitutes critical will depend on the status of each patient. For example, a patient with raised ICP will have a strong indication for normocapnia (because hypercapnia increases ICP). Unfortunately, achieving the minute volumes required to maintain normocapnia can, in itself, be harmful to the lungs (p. 204). Ventilator modes Following intubation, most patients have a period of paralysis from the muscle relaxation. Mandatory ventilation is, therefore, required for a variable period, depending on the severity of the lung injury, the underlying disease process and the general condition of the patient. Mandatory ventilation means that the ventilator will deliver set parameters (either a set tidal volume or a set inspiratory pressure), regardless of patient effort. A physician can choose to support additional patient effort in between mandatory breaths with pressure support. This requires sufficient patient effort to 'trigger' the ventilator to deliver a synchronised breath, in time with the patient's own ventilation. Other parameters that should be considered when using mechanical ventilation are shown in Figure 10.18. As a patient's illness resolves, or if the lung injury necessitating intubation is not severe, periods of spontaneous breathing with pressure support are commenced. While spontaneous breathing is preferable to mandatory ventilation modes, the shearing forces of patient effort can exacerbate lung injury in patients with severely damaged lungs. It is, therefore, important that a patient is permitted to breathe in a planned and controlled way. Intubation and intermittent positive pressure ventilation Taking control of the respiratory system in a critically ill patient is one of the most significant and risky periods in a patient's journey. Critical incidents are common because the patient is often deteriorating rapidly and is exhausted. The potential for cardiovascular collapse is further exacerbated by the negatively inotropic and vasodilating drugs used to induce anaesthesia, and the period of apnoea invoked to facilitate intubation (Box 10.39). The main aims of intermittent positive pressure ventilation (IPPV) are to avoid critical hypoxaemia and hypercapnia while minimising damage to the alveoli and encouraging the patient to 10.39 Optimising safety during intubation • Intervene early in the disease process (once it has become clear that the disease trajectory is downward) • Use a stable anaesthetic technique: low doses of sedative agents and rapidly acting paralytic agents • Remember that intubation should be performed by the most experienced operator available • Use techniques to optimise oxygenation and ventilation in the period around intubation, e.g. keeping non-invasive ventilation in situ for pre-oxygenation, leaving high-flow nasal cannulae on for the intubation process, and using a video-laryngoscope in an anticipated difficult intubation Fig. 10.18

Settings to be considered when commencing mechanical ventilation. Respiratory rate and minute volume Depend on the minute volume required to achieve the desired PCO_2, and whether the patient is breathing spontaneously. Rates are commonly 20–30 breaths/min Ventilator mode Mandatory, spontaneous, or mandatory with the ability to take spontaneous breaths (as shown here) FiO_2 Fraction of inspired oxygen. This is usually titrated to oxygen saturations targeting 92–95% Tidal volume Usual target is 6 mL/kg of predicted body weight (PBW) Positive end-expiratory pressure (PEEP) The pressure within the respiratory system during expiration, commonly 5–15 cmH_2O. Higher levels of PEEP often improve oxygenation but put strain on the right heart (as it makes it harder to pump blood through the pulmonary circulation) Plateau pressure Airway pressure during an inspiratory hold. Keeping plateau pressure as low as possible above PEEP is the most protective strategy for the lungs Pressure–time graph Volume–time graph Flow–time graph

 in the prone position for 12–24 hours and then rotated back to the supine position for a similar period. This cycle continues until there is evidence of resolving lung injury. Extracorporeal respiratory support Sometimes, despite optimal invasive ventilation, it is not possible to maintain adequate oxygenation or prevent a profound respiratory acidosis. When a patient has a reversible cause of respiratory failure (or is a potential lung transplant recipient) and facilities are available, extracorporeal respiratory support should be considered. Venous–venous extracorporeal membrane oxygenation In venous–venous extracorporeal membrane oxygenation (V V ECMO), large-bore central venous cannulae are inserted into the superior vena cava (SVC) and/or the inferior vena cava (IVC) via the femoral or jugular veins, and advanced under ultrasound or fluoroscopic guidance (Fig. 10.19). Venous blood is then pumped through a membrane oxygenator. This device has thousands of tiny silicone tubes with air/oxygen gas on the other side of the tubes (the membrane). This facilitates the passage of oxygen into the blood and diffusion of carbon dioxide across the membrane, where it is removed by a constant flow of gas (sweep gas). The oxygenated blood is then returned to the right atrium, from where it flows through the lungs as it would in the physiological state. This means that even if the lungs are contributing no oxygenation or carbon dioxide removal, a patient can remain well oxygenated and normocapnic. Extracorporeal carbon dioxide removal In some patients it is possible to maintain oxygenation but there is refractory hypercapnia. There are devices available that can remove carbon dioxide using a much lower blood flow rate than V V ECMO. Consequently, smaller venous cannulae, similar to those used in renal dialysis, can be sufficient to have a 'CO_2 dialysis' effect. This can be useful in patients in whom normocapnia is essential (such as those with a raised ICP), or those with refractory hypercapnia and adequate oxygenation. In addition, extracorporeal carbon dioxide removal can be used to reduce the required minute volume, which is a beneficial strategy for protecting the lungs against VILI or facilitating early extubation. Cardiovascular support Initial resuscitation A brief assessment can usually yield enough information to determine whether a patient is at significant risk of an imminent cardiac arrest. If the patient is obtunded and there is no palpable radial or brachial pulse, then treatment should proceed as described on page 457. In anaphylactic shock, or undifferentiated shock in a peri-arrest situation, a single dose of intramuscular adrenaline (epinephrine) 0.5 mg (0.5 mL of 1 : 1000) can be life-saving. If expertise is available, a small dose of intravenous adrenaline can delay cardiac arrest long enough to identify the cause of shock and institute other supportive measures; a suggested dose would be 50 µg (0.5 mL of 1 : 10 000). If haemorrhage is considered a possibility, a 'major haemorrhage' alert should be activated, facilitating rapid access to large volumes of blood and blood products. A classification of shock is shown in Box 10.40. Ventilator-induced lung injury

Every positive-pressure breath causes cyclical inflation of alveoli followed by deflation. The resultant damage to alveoli occurs via several possible mechanisms: • distending forces from the tidal volume, termed ‘volutrauma’ • the pressure used to inflate the lung, referred to as ‘barotrauma’ • alveoli collapsing at the end of expiration, called ‘atelectotrauma’ • the release of inflammatory cytokines in response to cyclical distension, called ‘biotrauma’. The threshold of injurious ventilation is unique to each patient. Moderate ventilator pressures and volumes used to ventilate healthy lungs may not cause ventilator-induced lung injury (VILI), but the same settings may cause significant VILI if delivered to a patient with lungs that are already damaged from another disease process. Strategies that may reduce the incidence and severity of VILI include: • Permissive hypercapnia. In the majority of patients who are ventilated for respiratory failure, it is preferable to tolerate moderate degrees of hypercapnia rather than strive for normal blood gases at the expense of VILI. For example, in a patient with isolated respiratory failure, a physician may choose to tolerate a $PaCO_2$ of up to 10 kPa (75 mmHg), provided the H^+ is < 63 nmol/L (pH > 7.2). • ‘Open lung’ ventilation. Maintaining a positive pressure within the airways at the end of expiration prevents atelectotrauma. Use of low tidal volumes, higher levels of PEEP (Fig. 10.18) and recruitment manœuvres (occasional short periods of sustained high airway pressures to open up alveoli that have collapsed) can reduce the incidence of VILI. • Paralysis. When respiratory failure is severe, patient effort may worsen VILI. An infusion of muscle relaxant can be used to moderate dyssynchrony with the ventilator. Advanced respiratory support Airway pressure release ventilation Airway pressure release ventilation (APRV) is a mode of ventilation that lengthens the inspiratory time to the extreme, with a very short period of time for expiration. It relies on spontaneous movement of the diaphragm from patient effort to facilitate the mixing of gas within the respiratory system during the long period in full inspiration, followed by a very short period of low pressure to allow passive expiration. It has not, however, been demonstrated to be superior to conventional modes of ventilation, but may have a role in moderate to severe ARDS. Prone positioning In ARDS, the posterior parts of the lung lose airspaces due to atelectasis and inflammatory exudate. By placing patients on their front, the pattern of fluid distribution within the lung changes, and ventilation–perfusion matching is improved. This is used to enhance oxygenation in moderate to severe ARDS, and may have some disease-modifying effects as the dependent areas of the lung are changed periodically. Although there are risks associated with nursing a patient in the prone position, it is becoming a widespread therapy. Patients are usually placed

Fig. 10.19 Principles of extracorporeal membrane oxygenation (ECMO). A Basic ECMO circuit: venous–arterial (VA) and venous–venous (V V). B Example of a V V ECMO circuit. C Example of a VA ECMO circuit. Gas out Membrane oxygenator Controller console RPM

Pressures Saturations Flow Oxygenated blood returned to vein (V–V) or artery (V–A) Venous blood from patient (usually inferior vena cava) Centrifugal pump Venous ‘return’ cannula Superior vena cava Right atrium now full of oxygenated blood Tricuspid valve Right ventricle Inguinal ligament Femoral artery Access ECMO cannula Femoral vein Skin puncture site in proximal thigh From ECMO circuit To ECMO circuit Venous ‘return’ cannula Venous ‘access’ cannula Gas in A B Pulmonary vein (left) Pulmonary vein (right) Right atrium Proximal aorta Mitral valve Aortic valve Left ventricle Blood from ECMO circuit Blood from ‘normal’ circulation (native circulation) Where the two circulations meet depends on the native cardiac output; if very low, they will meet very proximally/at the aortic valve Oxygenated blood at high pressure will flow proximally up the aorta to perfuse organs Blood will also flow distally to perfuse the legs Arterial ‘return’ cannula Arterial ‘return’ cannula To ECMO circuit From ECMO circuit Venous ‘access’ cannula C

 agent: for example, in cardiogenic shock or shock associated with bradycardia. If there is evidence of low cardiac output, adrenaline (epinephrine) or dobutamine should be commenced. Both agents are equally effective, but dobutamine causes more vasodilatation and additional noradrenaline may be required to maintain an adequate MAP. Vasopressin is added if hypotension persists despite high doses of noradrenaline and cardiac output is thought to be adequate. In extreme situations it is acceptable to start infusions of inotropes through a well-sited, large-bore peripheral cannula, although central venous access and an arterial line (for monitoring) should be inserted as soon as possible. The actions of commonly used vasoactive drugs are summarised in Box 10.41. Advanced haemodynamic monitoring There are many different devices available to estimate cardiac output. Such devices employ a variety of mechanisms, including the Doppler effect of moving blood, changes in electrical impedance of the thorax, or the dilution of either an indicator substance or heat (thermodilution). The information is processed within the equipment, and often integrated with additional data, such as the arterial pressure waveform, to give an estimate of cardiac output and stroke volume. When the aetiology of shock is straightforward and the patient is responding as predicted to treatment, the value of devices that estimate cardiac output is limited. Portable echocardiography has the advantage of giving qualitative information – for example, demonstrating aortic stenosis or a regional wall motion abnormality – as well as quantitative information on stroke volume, but it requires technical expertise. Pulmonary artery (PA) catheters, sometimes referred to as Swan–Ganz catheters (Fig. 10.20), are invasive but provide useful information on pulmonary pressures, cardiac output, mixed venous oxygen saturations (see Box 10.30) and, by extrapolation, whether the cause of the shock is vasodilatation or pump failure. They can be helpful in complex cases, such as shock after cardiac surgery, or in patients with suspected pulmonary hypertension (Box 10.42). However, PA catheters are associated with some rare but serious complications, including lung infarction, PA rupture and thrombosis of the catheter itself. Such complications occur infrequently in centres that use PA catheters regularly; it should be stressed that a lack of familiarity within the wider clinical team is a relative contraindication to their use. Mechanical cardiovascular support When shock is so severe that it is not possible to maintain sufficient organ perfusion with fluids and inotropic support, it is Venous access for the administration of drugs and fluids is vital but often difficult in critically unwell patients. Wide-bore cannulae are required for rapid fluid administration. In extremis, the external jugular vein can be cannulated; it is often prominent in low cardiac output states and readily visible on the lateral aspect of the neck. Occluding the vein distally with finger pressure makes it easier to cannulate, but care must be taken to remain high in the neck to avoid causing a pneumothorax. Intra-osseous or central venous access can be established if there are no visible peripheral veins. Ultrasound can provide assistance for rapid and safe venous cannulation. Rapid infusion devices are widely available and should be used for the delivery of warmed, air-free fluid and blood products. Fluid and vasopressor use Resuscitation of the shocked patient should include a 10 mL/ kg fluid challenge. Using colloid or crystalloid is acceptable; starch solutions are associated with additional renal dysfunction and should be avoided. The fluid challenge can be repeated if shock persists, to a maximum total of 30 mL/ kg of fluid. However, commencing vasopressor therapy early in resuscitation is better than delaying until a large volume of fluid has been given. Amongst other beneficial effects, vasopressors induce venoconstriction, reducing the capacitance of the circulation and effectively mobilising more fluid into the circulation. If a patient remains shocked after 30 mL/kg of fluid has been administered, a re-evaluation of the likely cause is required, looking particularly for concealed haemorrhage or an obstructive pathology. A bedside echocardiogram is especially useful at this stage to evaluate cardiac output and exclude tamponade. Noradrenaline (norepinephrine) should be commenced as the first-line vasoactive agent in most cases, unless there is a strong indication to use a pure inotropic or chronotropic 10.40 Categories of shock Category Description Hypovolaemic Can be haemorrhagic or non-haemorrhagic in conditions such as hyperglycaemic hyperosmolar state (p. 738) and burns Cardiogenic See page 199 Obstructive Obstruction to blood flow around the circulation, e.g. major pulmonary embolism, cardiac tamponade, tension pneumothorax Septic See page 196 Anaphylactic Inappropriate vasodilatation triggered by an allergen (e.g. bee sting), often associated with endothelial disruption and capillary leak (p. 75) Neurogenic Caused by major brain or spinal injury, which disrupts brainstem and neurogenic vasomotor control. High cervical cord trauma may result in disruption of the sympathetic outflow tracts, leading to inappropriate bradycardia and hypotension. Guillain–Barré syndrome (p. 1140) can involve the autonomic nervous system, resulting in periods of severe hypo- or hypertension Others e.g. Drug-related such as calcium channel blocker overdose; Addisonian crisis 10.41 Actions of commonly used vasoactive agents Drug Action Vasoconstrictor Inotrope Chronotrope Adrenaline (epinephrine) ++ +++ ++ Noradrenaline (norepinephrine) ++++ + + Dobutamine – ++++ +++ Vasopressin +++++ No action – (reflex bradycardia)

in cardiogenic shock. There are risks associated with thrombosis formation on the balloon, mesenteric ischaemia and femoral artery pseudo-aneurysm following removal of the device. Venous–arterial extracorporeal membrane oxygenation Venous–arterial extracorporeal membrane oxygenation (VA ECMO) can be life-saving in profound cardiogenic shock and has even been used effectively in refractory cardiac arrest. The circuit and principles are very similar to those described in ‘V V ECMO’ above (see p. 204 and Fig. 10.19) with one important difference: oxygenated blood is returned to the arterial system (rather than into the right atrium). This means that the pump needs to generate sufficient pressure to allow blood to flow sometimes necessary to use an internal device to augment or replace the inadequate native cardiac output. Intra-aortic balloon pump An intra-aortic balloon counter-pulsation device is a long tube that is usually inserted into the femoral artery and fed proximally into the thoracic aorta. The basic principle is that a helium-filled balloon is able to inflate and deflate rapidly in time with the cardiac cycle. It is inflated in diastole, thus augmenting forward flow of blood to the abdominal organs and improving diastolic pressure proximal to the balloon, thereby optimising coronary perfusion. While the principle is appealing, and an intra-aortic balloon pump (IABP) is often effective in achieving predetermined physiological goals, this does not translate into improved survival Fig. 10.20 A pulmonary artery (Swan–Ganz) catheter. A There is a small balloon at the tip of the catheter and pressure can be measured through the central lumen. The catheter is inserted via an internal jugular, subclavian or femoral vein and advanced through the right heart until the tip lies in the pulmonary artery. When the balloon is deflated, the pulmonary artery pressure can be recorded. B Advancing the catheter with the balloon inflated will ‘wedge’ the catheter in the pulmonary artery. Blood cannot then flow past the balloon, so the tip of the catheter will now record the pressure transmitted from the pulmonary veins and left atrium (known as the pulmonary artery capillary wedge pressure), which provides an indirect measure of the left atrial pressure. (LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle)

mmHg Right ventricular pressure Wedge (left atrial) pressure Balloon inflated Balloon Right atrial pressure Pulmonary artery pressure A B Aorta RA RV LV LA Pulmonary artery 10.42 Interpreting haemodynamic data Variable Units Reference range Interpretation Cardiac output (CO) litres/minute (L/min) 4–8 L/min Low cardiac output suggests pump failure Cardiac index (CI) Cardiac output referenced to the size of the patient litres/minute/metre2 (L/min/m2) 2.5–4 L/min/m2 More useful than raw cardiac output alone, especially in smaller patients Central venous pressure (CVP) mmHg 0–6 mmHg Reflects right atrial pressure – a non-specific measurement of right ventricular (RV) function and volume status Low levels suggest good RV function or hypovolaemia Pulmonary artery systolic pressure (PA systolic) mmHg 15–30 mmHg Difficult to interpret in isolation Low levels suggest vasodilatation, hypovolaemia or right heart failure High levels are seen in many pathologies, e.g. left heart failure, primary pulmonary arterial hypertension (PAH), fluid overload Pulmonary artery diastolic pressure (PA diastolic) mmHg 5–15 mmHg As with PA systolic pressure, difficult to interpret in isolation Pulmonary artery capillary wedge pressure (PACWP) mmHg 2–10 mmHg (should be within a few mmHg of PA diastolic) Reasonable indication of left atrial pressure – raised in left heart failure and fluid overload Measurement is associated with injury to PA so should only be taken occasionally Transpulmonary gradient (PA diastolic – PACWP) mmHg 1–5 mmHg A high gradient suggests the pathology is in the pulmonary arteries, e.g. primary PAH

208 • ACUTE MEDICINE AND CRITICAL ILLNESS • Manage status epilepticus using antiepileptic agents such as levetiracetam, phenytoin and benzodiazepines. In refractory cases an infusion

of sodium thiopental or ketamine may be required. The aim of management in acute brain injury is to optimise cerebral oxygen delivery by maintaining normal arterial oxygen content and a cerebral perfusion pressure (CPP) of > 60 mmHg. Secondary insults to the brain, such as hypoxaemia, hyper-/ hypoglycaemia and prolonged seizures, must be avoided. ICP rises in acute brain injury as a result of haematoma, contusions, oedema or ischaemic swelling. Raised ICP causes damage to the brain in two ways: direct damage to the brainstem and motor tracts as a result of downward pressure and herniation through the tentorium cerebelli and foramen magnum, and indirect damage by reducing CPP. Cerebral blood flow is dependent on an adequate CPP. The CPP is determined by the formula: CPP MAP ICP

− ICP can be measured by pressure transducers that are inserted directly into the brain tissue. The normal upper limit for ICP is 15 mmHg and an upper acceptable limit of 20 mmHg is usually adopted in intensive care. Sustained pressures of > 30 mmHg are associated with a poor prognosis. Various strategies are used to control ICP: maintaining normocapnia, preventing any impedance to venous drainage from the head, giving osmotic agents such as mannitol and hypertonic saline, and using hypothermia and decompressive craniectomy. No single technique has been shown to improve outcome in severe intracranial hypertension. CPP should be maintained above 60 mmHg by ensuring adequate fluid replacement and, if necessary, by treating hypotension with a vasopressor such as noradrenaline (norepinephrine). Complex neurological monitoring must be combined with frequent clinical assessment of GCS, pupillary response to light, and focal neurological signs. Daily clinical management in intensive care Clinical review In intensive care, detailed clinical examination should be performed daily to identify changes to a patient’s condition and review the latest diagnostic information. Further focused clinical reviews are usually incorporated into twice-daily ward rounds. Each ward round offers an ideal opportunity to monitor and document compliance with relevant care bundles. A care bundle is a group of interventions that, when implemented concurrently, have provided evidence of clinical benefit. The mnemonic ‘FAST HUG’ provides a useful checklist of interventions that reduce intensive care complications: feeding, analgesia, sedation, thromboprophylaxis, head of bed elevation (to reduce the incidence of passive aspiration), ulcer prophylaxis and glucose control. Other key aspects of the daily review are outlined on page 174. The overarching aim of the review is to identify the issues that are impeding recovery from critical illness, and make alterations to address them. In addition, specific and realistic goals for each relevant organ system should be defined, facilitating the autonomous titration of therapy by the bedside critical care nurse. An example of daily goals may be: ‘Titrate the noradrenaline (norepinephrine) to achieve a MAP of 65 mmHg, aim for a negative fluid balance, titrate FiO_2 to achieve oxygen saturations through the systemic circulation. The sites of venous and arterial access can be either central (via a thoracotomy or sternotomy) or peripheral via cannulae in the IVC/SVC and the femoral/ subclavian artery. If the return cannula is peripherally sited (e.g. in the femoral artery), blood will flow back up the aorta from distal to proximal and perfuse the organs. The outcome depends on the avoidance of complications (primarily, bleeding at the cannula site, intracranial haematoma, air embolism, infection and thrombosis) and improvement of the underlying condition. Most causes of profound cardiogenic shock are unlikely to resolve, and the potential availability of a longer-term solution, such as cardiac transplantation or insertion of a ventricular assist device, is a prerequisite for commencing VA ECMO in most centres. Renal support Renal replacement therapy (RRT) is explained in detail on page 420. The key points relating to RRT in an intensive care context are: • Haemodynamic instability is common. Continuous therapies are widely believed to cause less haemodynamic instability than intermittent dialysis. However, many units use intermittent dialysis without significant problems. • Haemodialysis and haemofiltration are equally good. Although there are theoretical benefits to removing inflammatory cytokines with haemofiltration, this does not translate into improved survival. • Anticoagulation is usually achieved using citrate or heparin. Citrate has a better profile for anticoagulating the extracorporeal circuit without inducing an increased bleeding risk, but may accumulate in patients with profound multi-organ failure and should be avoided in very unstable individuals. • Most patients who survive intensive care will regain adequate renal function to live without long-term renal support. • A thorough investigation for reversible causes of renal dysfunction should always be undertaken in conjunction with instigation of renal support (see Fig. 15.18, p. 411). • Shock appears to reverse more rapidly when renal support is instituted. Commencing renal support soon after a patient develops renal ‘injury’ (when serum creatinine is more than two times higher than baseline) is probably beneficial in the context of septic shock. Neurological support A diverse range of neurological conditions require management in intensive care. These include the various causes of coma, spinal cord injury, peripheral neuromuscular disease and prolonged seizures. The goals of care in such cases are to: • Protect the airway, if necessary by endotracheal intubation. • Provide respiratory support to correct hypoxaemia and hypercapnia. • Treat circulatory problems, e.g. neurogenic pulmonary oedema in subarachnoid haemorrhage, autonomic disturbances in Guillain–Barré syndrome, and spinal shock following high spinal cord injuries. • Manage acute brain injury with control of ICP.

noise reduction, cessation of drugs known to precipitate delirium, and treatment of potential underlying causes such as thiamin replacement in patients at risk of Wernicke’s encephalopathy. Patients with agitated delirium that is refractory to verbal de-escalation should initially be managed with small doses of intramuscular antipsychotics, changed to the enteral route once control is established. Atypical antipsychotics such as olanzapine and quetiapine are more efficacious than traditional drugs such as haloperidol. Pharmacological interventions are not useful as prophylaxis or in hypoactive delirium. Additional information on diagnosis and management of delirium can be found on page 184. Weaning from respiratory support As the condition that necessitated ventilation resolves, respiratory support is gradually reduced: the process of ‘weaning’ from ventilation. Some approaches to weaning are described below. of 92–95% and titrate sedation to a RASS score of 0 to −1’ (Box 10.44). Sedation and analgesia Most patients require sedation and analgesia to ensure comfort, relieve anxiety and tolerate mechanical ventilation. Some conditions, such as critically high ICP or critical hypoxaemia, require deep sedation to reduce tissue oxygen requirements and protect the brain from the peaks in ICP associated with coughing or gagging. For the majority of patients, however, optimal sedation is an awake and lucid patient who is comfortable and able to tolerate an endotracheal tube (termed ‘tube tolerance’). Over-sedation is associated with longer ICU stays, a higher prevalence of delirium, prolonged requirement for mechanical ventilation, and an increased incidence of ICU-acquired infection. Box 10.43 compares the various agents used for sedation in intensive care. The key principles are that the patient should primarily receive analgesia, rather than anaesthesia, and caution should be used with drugs that accumulate in hepatic and renal dysfunction. Often a combination of drugs is used to achieve the optimal balance of sedation and analgesia. Sedation is monitored via clinical sedation scales that record responses to voice and physical stimulation. The Richmond Agitation–Sedation Scale (RASS) is the best-recognised tool (see Box 10.44 for details). Regular use of a scoring system to adjust sedation is associated with a shorter ICU stay. Many ICUs also have a daily ‘sedation break’, when all sedation is stopped in appropriate cases for a short period. This is commonly combined with a trial of spontaneous breathing aiming to shorten the duration of mechanical ventilation. Delirium in intensive care Delirium is discussed on page 183. It is extremely common in critically ill patients and often becomes apparent as sedation is reduced. Hypoactive delirium is far more common than hyperactive delirium, but is easily missed unless routine screening is undertaken. A widely used bedside assessment is the CAM-ICU score. The patient is requested to squeeze the examiner’s hand in response to instruction and questions, aiming to ascertain whether disordered thought or sensory inattention is present. Delirium of any type is associated with poorer outcome. Management is focused on non-pharmacological interventions such as early mobilisation, reinstatement of day–night routine, 10.44 Richmond Agitation–Sedation Scale (RASS) Score Term Description +4 Combative Overtly combative, violent or immediate danger to staff +3 Very agitated Pulls on/removes tubes or catheters, or aggressive to staff +2 Agitated Frequent non-purposeful movement or patient–ventilator dyssynchrony +1 Restless Anxious or apprehensive but no aggressive or vigorous movements

Alert and calm −1 Drowsy Not fully alert but sustained awakening (> 10 secs) with eye opening/contact to voice −2 Light sedation Brief awakening (<10 secs) with eye contact to voice −3 Moderate sedation Movement but no eye contact to voice −4 Deep sedation Movement to physical stimulation but no response to voice −5 Unrousable No response to voice or physical stimulation 10.43 Properties of sedative and analgesic agents used in ICU Drug Mode of action Advantages Disadvantages Propofol Intravenous anaesthetic Rapid onset and offset Large cumulative doses can cause multi-organ failure, especially in children – the ‘propofol infusion syndrome’ Alfentanil Potent opiate analgesic Rapid onset and offset High doses may be required Agitation may persist Morphine Opioid Analgesia Active metabolites and accumulation cause slow offset Midazolam Benzodiazepine sedative Can be used in children Active metabolites and accumulation cause slow offset Remifentanil Very potent opiate Analgesia and tube tolerance Respiratory depression – extreme caution in non-intubated patients Dexmedetomidine α2-adrenergic agonist Excellent tube tolerance Less delirium Can be used in awake patients Cost and availability

210 • ACUTE MEDICINE AND CRITICAL ILLNESS patients are important to identify, as emergency management in the event of a tracheostomy problem (blockage or displacement) must be through the tracheostomy site; access will not be possible via the upper airway. Nutrition It is crucial that

critically ill patients receive adequate calories, protein and essential vitamins and minerals. Calculation of exact requirements is complex and requires the expertise of a dietitian. It is, however, useful to make a rough estimation of requirements (p. 705). Under-feeding leads to muscle wasting and delayed recovery, while over-feeding can lead to biliary stasis, jaundice and steatosis. Enteral feeding is preferred where possible because it avoids the infective complications of total parenteral nutrition (TPN) and helps to maintain gut integrity. However, TPN is recommended for patients who are likely to have a sustained period without effective enteral feeding, or who are already malnourished. Caution must be taken to avoid the consequences of refeeding syndrome (p. 706). Other essential components of intensive care Survival after critical illness depends, to a large extent, on the prevention of medical complications during recovery from the primary insult. Thromboprophylaxis DVT, venous catheter-related thrombosis and PE are common in critically ill patients. Low-molecular-weight heparin (LMWH) should be administered to all patients, unless there is a contraindication. Often patients at highest risk of thrombosis, such as those with hepatic dysfunction or those who have suffered major trauma, have a relative contraindication to heparin. Such cases mandate daily evaluation of the risk–benefit ratio, and LMWH should be administered as soon as it is deemed safe to do so. Mechanical thromboprophylaxis, such as intermittent calf compression devices, are useful adjuvants in high-risk patients. Glucose control Hyperglycaemia is harmful in critical illness and may occur in people with pre-existing diabetes or undiagnosed diabetes, following administration of high-dose glucocorticoids, or as Spontaneous breathing trials A spontaneous breathing trial involves the removal of all respiratory support followed by close observation of how long the patient is able to breathe unassisted. The technique is particularly effective when linked to a reduction in sedation. PEEP and pressure support are reduced to low levels, or patients are disconnected from the ventilator and breathe oxygen or humidified air through the endotracheal tube. Signs of failure include rapid shallow breathing, hypoxaemia, rising $PaCO_2$, sweating and agitation. Patients who pass a spontaneous breathing trial are assessed for suitability of extubation (endotracheal tube removal). Progressive reduction in pressure support ventilation Progressive reduction in pressure support ventilation (PSV) is applied to each breath over a period of hours or days, according to patient response. Some ICU ventilators have software that allows the facility to wean the support provided automatically. A useful tool to guide the weaning process is the rapid shallow breathing index (RSBI). This composite score of a patient’s spontaneous respiratory rate and tidal volume (respiratory rate divided by tidal volume in litres) gives a numerical indication of how difficult the patient is finding breathing at that particular level of support. A RSBI value of > 100 suggests that a patient is working at a level that would be unsustainable for longer periods. Extubation It is not possible to predict whether a patient is ready to be extubated accurately; the timing relies heavily on clinical judgement. There are, however, some simple rules that can aid decision-making. Patients must have stable ABGs with resolution of hypoxaemia and hypercapnia despite minimal ventilator pressure support and a low FiO_2. Conscious level must be adequate to protect the airway, comply with physiotherapy, and cough. Furthermore, an assessment must be made as to whether the patient can sustain the required minute volume without ventilator support. This depends on the condition of patients’ lungs, their strength and other factors affecting the $PaCO_2$, such as temperature and metabolic rate. The need for re-intubation following extubation is associated with poorer outcome, but patients who are not given the opportunity to breathe without a ventilator will also be at increased risk of ventilator-associated complications such as pneumonia and myopathy. Tracheostomy A tracheostomy is a percutaneous tube passed into the trachea (usually between the first and second, or second and third tracheal rings) to facilitate longer-term ventilation. The advantages and disadvantages of tracheostomy insertion are listed in Box 10.45. When ventilation weaning has been unsuccessful, a tracheostomy provides a bridge between intubation and extubation; the patient can have increasing periods free of ventilator support but easily have support reinstated. A tracheostomy can be inserted percutaneously, using a bronchoscope in the trachea for guidance, or surgically under direct vision. Occasionally, a patient will have a tracheostomy in situ following a laryngectomy. Such 10.45 Advantages and disadvantages of tracheostomy Advantages • Patient comfort • Improved oral hygiene • Access for tracheal toilet • Ability to speak with cuff deflated and a speaking valve attached • Reduced equipment 'dead space' (the volume of tubing) • Earlier weaning and ICU discharge • Reduced sedation requirement • Reduced vocal cord damage Disadvantages • Immediate complications: hypoxaemia, haemorrhage • Tracheostomy site infection • Tracheal damage; late stenosis

function (and thus consciousness), but a lesion in the ventral pons (usually caused by infarction) results in complete paralysis. The term 'vegetative state' implies some retention of brainstem function and minimal cortical function, with loss of awareness of the environment. In contrast, 'minimally conscious state' implies that there is some degree of awareness and intact brainstem function. Confident distinction between these states is important and requires careful assessment, often over a period of time. Brain death is, by definition, irreversible but other states may offer hope for improvement. ICU-acquired weakness Weakness is common among survivors of critical illness. It is usually symmetrical, proximal and most marked in the lower limbs. Critical illness polyneuropathy and myopathy can occur simultaneously and, within the constraints of an altered sensorium, it can be impossible to distinguish the two conditions clinically. Risk factors for both processes include the severity of multi-organ failure, poor glycaemic control and the use of muscle relaxants and glucocorticoids. Critical illness polyneuropathy This is due to peripheral nerve axonal loss and characteristically presents as proximal muscle weakness with preserved sensation. a consequence of 'stress hyperglycaemia'. Hyperglycaemia is commonly managed by infusion of intravenous insulin titrated against a 'sliding scale'. Intensive management of hyperglycaemia with insulin can result in hypoglycaemia, which may also be harmful in critical illness. Therefore, a compromise is to titrate insulin to a blood glucose level of 6–10 mmol/L (108–180 mg/dL). Blood transfusion Many critically ill patients become anaemic due to reduced red cell production and red cell loss through bleeding and blood sampling. However, red cell transfusion carries inherent risks of immunosuppression, fluid overload, organ dysfunction from microemboli, and transfusion reactions. In stable patients, a haemoglobin level of 70 g/L (7 g/dL) is a safe compromise between optimisation of oxygen delivery and the risks of transfusion. This transfusion threshold should be adjusted upwards for situations where oxygen delivery is critical, such as in patients with active myocardial ischaemia. Peptic ulcer prophylaxis Stress ulceration during critical illness is a serious complication. Proton pump inhibitors or histamine-2 receptor antagonists are effective at reducing the incidence of ulceration. There is, however, a suggestion that the use of these agents, particularly in conjunction with antibiotics, may increase the incidence of nosocomial infection, especially with Clostridium difficile (p. 264). It is therefore common practice to stop ulcer prophylaxis once consistent absorption of enteral feed is established. Complications and outcomes of critical illness The majority of patients will survive their episode of critical illness. While some will return to full, active lives, there are many who have ongoing physical, emotional and psychological problems. Adverse neurological outcomes Brain injury Head injury, hypoxic–ischaemic injury and infective, inflammatory and vascular pathologies can all irreversibly injure the brain. If treatment is unsuccessful, patients will either die or be left with a degree of disability. In the latter situation, the provision of ongoing organ support will depend on the severity of the injury, the prognosis, and the wishes of the patient (usually expressed via relatives). Brain death is a state in which cortical and brainstem function is irreversibly lost. Diagnostic criteria for brain death vary between countries (Box 10.46); if satisfied, these criteria allow physicians to withdraw active treatment and discuss the potential for organ donation. Diagnosing brain death is complex and should be done only by physicians with appropriate expertise, as clinical differentiation from reduced consciousness can be challenging (Box 10.47). Where there is doubt – for example, in patients with coexisting spinal injury or localised brainstem pathology – additional investigations should be performed. The 'locked-in' syndrome, in which the patient is paralysed except for eye movements, requires preserved hemispheric 10.46 UK criteria for the diagnosis of brain death Preconditions for considering a diagnosis of brain death • The patient is deeply comatose:

a. There must be no suspicion that coma is due to depressant drugs, such as narcotics, hypnotics, tranquillisers

b. Hypothermia has been excluded – rectal temperature must exceed 35°C

c. There is no profound abnormality of serum electrolytes, acid–base balance or blood glucose concentrations, and any metabolic or endocrine cause of coma has been excluded • The patient is maintained on a ventilator because spontaneous respiration has been inadequate or has ceased. Drugs, including neuromuscular blocking agents, must have been excluded as a cause of the respiratory failure • The diagnosis of the disorder leading to brain death has been firmly established. There must be no doubt that the patient is suffering from irremediable structural brain damage Tests for confirming brain death • All brainstem reflexes are absent:

a. The pupils are fixed and unreactive to light

b. The corneal reflexes are absent

c. The vestibulo-ocular reflexes are absent – there is no eye movement following the injection of 20 mL of ice-cold water into each external auditory meatus in turn

d. There are no motor responses to adequate stimulation within the cranial nerve distribution

e. There is no gag reflex and no reflex response to a suction catheter in the trachea • No respiratory movement occurs when the patient is disconnected from the ventilator for long enough to allow the carbon dioxide tension to rise above the threshold for stimulating respiration ($PaCO_2$ must reach 6.7 kPa/50 mmHg) The diagnosis of brain death should be made by two doctors of a specified status and experience. The tests are usually repeated after a short interval to allow blood gases to normalise before brain death is finally confirmed

 Other long-term problems The experience of critical illness and the necessary invasive management can leave patients with profound psychological sequelae akin to the post-traumatic stress syndrome seen in many survivors of conflict. Specialist help is required in managing these issues. Sometimes recovering patients benefit from returning to the ICU to see the environment in a different way and gain a better understanding of the processes and procedures that haunt them. Long-term physical consequences are also common. Many diseases are not completely cured but follow a relapsing–remitting course; patients who have been critically ill with sepsis are far more likely than others in the general population to suffer from it again. Organ damage often persists and iatrogenic complications are common (e.g. damage to the vocal cords or tracheal stenosis from mucosal pressure caused by the cuff of the endotracheal tube). Intensive care follow-up clinics provide an excellent forum for addressing such issues, and for coordinating care involving a variety of medical specialties. The older patient Critically ill older patients present additional challenges following intensive care discharge (Box 10.48). As the ability to make a full recovery depends on frailty rather than chronological age, it can be helpful to use a validated frailty scoring system (p. 1306) to inform admission decision-making. Rehabilitation medicine has much to offer survivors of critical illness, and an early referral is beneficial when it is clear that a patient is likely to survive with significant morbidity. 10.47 Classification of brain death and reduced conscious states Diagnosis Features Investigation Prognosis Brain death See Box 10.46 Often not required if cranial imaging shows compatible cause and patient meets clinical criteria In diagnostic doubt: four-vessel angiogram (fluoroscopic or CT) of cerebral vessels or isotope scan of brain to demonstrate absence of cerebral blood flow Time of confirmed brain death is recorded as time of death Potential to donate organs – donation after brain death (DBD) donor Vegetative state (VS) 'Persistent VS' > 1 month 'Permanent VS' > 1 year No reaction to verbal stimuli Some reaction to noxious stimuli Sleep–wake cycles (periods of eye opening) Maintained respiratory drive Intact brainstem reflexes Occasional automatic movements (yawning, swallowing) Cranial imaging for primary cause Maintained cortical blood flow Poor. May be better with traumatic aetiology Minimally conscious state Some reaction to verbal stimuli Some reaction to noxious stimuli Spontaneous movements Intact brainstem reflexes EEG demonstrates reactivity Variable. Recovery of function more likely than in VS Locked-in syndrome Cortex is intact but bilateral motor tracts are damaged Can be partial or complete, i.e. some response to verbal stimuli (e.g. vertical eye movements to communicate) Variable brainstem reflexes No limb movement to noxious stimuli Imaging for primary cause – commonly MRI or CT will show brainstem or pontine infarction Variable and depends on cause – progress can continue over months to years It may also manifest as failure to wean from the ventilator secondary to respiratory muscle weakness. Electrophysiological studies of the affected nerves can be helpful, especially to rule out other potential causes such as Guillain–Barré syndrome. Conduction studies typically show reduced amplitude of transmitted voltage action potential with preserved velocity (compare with findings in Guillain–Barré syndrome; pp. 1076 and 1140). There are no specific treatments aside from resolution of the underlying cause and rehabilitation. Weakness may persist long into the convalescence stage of illness. In some cases, the clinical picture may be more in keeping with individual nerve involvement. This may be due to local pressure effects or part of a generalised picture. Great care must be taken to avoid pressure on high-risk areas such as the neck of the fibula where the common peroneal nerve navigates a superficial course. Nerve palsies such as foot drop can be permanent. Critical illness myopathy Although loss of muscle bulk is related to immobility and the catabolic state of critical illness, it is likely that microvascular and intracellular pathophysiological processes are also involved in critical illness myopathy. These processes result in loss of actin myofibrils and muscle weakness. Typically, the CK is normal or only mildly elevated. Like critical illness polyneuropathy, critical illness myopathy is usually a clinical diagnosis. Nerve conduction studies and electromyography may be suggestive of critical illness myopathy, and helpful in ruling out other pathology, but a muscle biopsy is required to confirm the diagnosis (p.

1076). It characteristically shows selective loss of the thick myofibrils and muscle necrosis. Management is conservative and the prognosis is good in ICU survivors.

patient continues to be ventilated. The practice of organ donation varies throughout the world but the principles remain the same. Organ donation specialists are contacted and they begin the process of establishing the suitability of any organs for transplantation and matching potential recipients. Many patients will have expressed their wishes through an organ donor registration scheme but agreement of family and next of kin is a moral (and sometimes legal) prerequisite. Once the organ retrieval theatre team have been assembled and all preliminary tests have been completed, the deceased patient is transferred to the operating theatre and the organs are sequentially removed. Donation after cardiac death If a patient does not meet brain death criteria but withdrawal of treatment has been agreed, donation of organs with residual function may be appropriate. This is termed ‘donation after cardiac death’ (DCD). If the patient dies within a short period following the commencement of ‘warm ischaemic time’ (the time to asystole following the onset of physiological derangement after the withdrawal of active treatment), then DCD can proceed. The deceased patient is transferred to an operating theatre and the agreed organs (often lungs, liver, kidney and pancreas) are retrieved. As heart valves and corneas can be retrieved later (within a longer time frame), tissue retrieval may occur in the mortuary. Postmortem examination or autopsy There are several indications to request a postmortem examination. A coroner (or legal equivalent) may initiate the process if a death is unexpected or violent, or has occurred under suspicious circumstances. The treating physician(s) may request one if they are unable to establish a cause of death or there is agreement that it may yield information of interest to the family or clinical team. The postmortem diagnosis is frequently at odds with the antemortem diagnosis and it is a very useful learning exercise to review the results with all those involved in the patient’s care. Discharge from intensive care Discharge is appropriate when the original indication for admission has resolved and the patient has sufficient physiological reserve to continue to recover without the facilities of intensive care. Many ICUs and HDUs function as combined units, allowing ‘step-down’ of patients to HDU care without changing the clinical team involved. Discharge from ICU is stressful for patients and families, and clear communication with the clinical team accepting responsibility is vital. Nursing ratios change from 1 : 1 (one nurse per patient) or 1 : 2 to much lower staffing levels. Discharges from ICU or HDU to standard wards should take place within normal working hours to ensure adequate medical and nursing support and detailed handover. Discharge outside normal working hours is associated with higher ICU re-admission rates and increased mortality. The receiving team should be provided with a written summary, including the information listed in Box 10.49. The ICU team should remain available for advice; many ICU teams provide an outreach service to supply advice and facilitate continuity of care. Critical care scoring systems Admission and discharge criteria vary between ICUs, so it is important to define the characteristics of the patients admitted in Withdrawal of active treatment and death in intensive care Futility The idea of futility is not new: Hippocrates stated that physicians should ‘refuse to treat those who are overmastered by their disease, realising that in such cases medicine is powerless’. In intensive care, where the concept of futility is often used as a criterion to limit or withdraw life-sustaining treatment, it is helpful to have a working definition on which families and physicians can agree. It is, therefore, reasonable to define futility in such circumstances as the point at which recovery to a quality of life that the patient would find acceptable has passed. The primary insult may be neurological (irreversible brain injury not meeting criteria for brain death), or multi-organ failure that is refractory to treatment. Death Whilst most patients prefer to die at home, many spend their final days in hospital. Chapter 34 details the medical, legal and ethical priorities that should guide patient management once the decision to withdraw active treatment has been made (p. 1354). The decision to shift the focus of care to palliation should not change its intensity; it is the over-arching objective that changes. Only interventions that will improve the quality of a patient's remaining life should be offered. In the ICU, it is often appropriate to continue infusions of sedatives and analgesics, as reducing or stopping them may cause unnecessary pain and agitation. Measures that were instituted to prolong life should be withdrawn (usually including cessation of inotropes and extubation) to allow the patient to die peacefully with their family and friends present. Organ donation Donation after brain death The diagnosis of brain death is discussed on page 211. Once brain death has been confirmed, consideration should be given to organ donation, termed 'donation after brain death' (DBD). Time of death is recorded as the time when the first series of brain death tests are undertaken, although the deceased 10.48 The critically ill older patient • ICU demography: increasing numbers of critically ill older patients are admitted to the ICU; more than 50% of patients in many general ICUs are over 65 years old. • Outcome: affected to some extent by age, as reflected in APACHE II (see Box 10.50), but age should not be used as the sole criterion for withholding or withdrawing ICU support. • Cardiopulmonary resuscitation (CPR): successful hospital discharge following in-hospital CPR is rare in patients over 70 years old in the presence of significant chronic disease. • Functional independence: tends to be lost during an ICU stay and prolonged rehabilitation may subsequently be necessary. • Specific problems: Skin fragility and ulceration Poor muscle strength: difficulty weaning from ventilator and mobilising Delirium: compounded by sedatives and analgesics High prevalence of underlying nutritional deficiency.

 into the management of patients with that diagnosis, in order to identify aspects of care that could be improved. Further information Websites criticalcarereviews.com Reviews and appraisal of ICU topics. emcrit.org Online podcasts and general information on emergency medicine and critical care. esicm.org European Society of Intensive Care Medicine: guidelines, recommendations, consensus conference reports. lifeinthefastlane.com Information on a range of intensive care and emergency medicine topics. survivingsepsis.org Surviving Sepsis website. order to assess the effects of the care provided on the outcomes achieved. Two systems are widely used to measure severity of illness (see Box 10.50 for further details): • APACHE II: Acute Physiology Assessment and Chronic Health Evaluation • SOFA score: Sequential Organ Failure Assessment tool. When combined with the admission diagnosis, scoring systems have been shown to correlate well with the risk of death in hospital. Such outcome predictions are useful at a population level but lack the specificity to be of use in decision-making for individual patients. This is in contrast to well-validated, disease-specific tools, such as the CURB-65 tool for pneumonia, which can be helpful in guiding individual management (see Fig. 17.32, p. 583). Predicted mortality figures by diagnosis have been calculated from large databases generated from a range of ICUs. These allow a particular unit to evaluate its performance compared to the reference ICUs by calculating standardised mortality ratios (SMRs) for each diagnostic group. A value of unity indicates the same performance as the reference ICUs, while a value below 1 indicates a better than predicted outcome. If a unit has a high SMR in a certain diagnostic category, it should prompt investigation 10.50 Comparison of APACHE II and SOFA scores APACHE II score • An assessment of admission characteristics (e.g. age and pre-existing organ dysfunction) and the maximum/minimum values of 12 routine physiological measurements during the first 24 hours of admission (e.g. temperature, blood pressure, GCS) that reflect the physiological impact of the illness • Composite score out of 71 • Higher scores are given to patients with more serious underlying diagnoses, medical history or physiological instability; higher mortality correlates with higher scores SOFA score • A score of 1–4 is allocated to six organ systems (respiratory, cardiovascular, liver, renal, coagulation and neurological) to represent the degree of organ dysfunction, e.g. platelet count

> 150 × 109/L scores 1 point, < 25 × 109/L scores 4 points • Composite score out of 24 • Higher scores are associated with increased mortality 10.49 How to write an ICU discharge summary: information to be included • Summary of diagnosis and progress in intensive care • Current medications and changes to regular medications with justifications • Antibiotic regime and suggested review dates • Results of positive microbiological tests • Positions of invasive devices and insertion dates • Escalation plan in the event of deterioration • Pending investigations and specialty consultations • If the physiology remains abnormal due to chronic disease, rapid response triggers should be adjusted accordingly

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