Section I
Chapter 1

Specific features of critical care medicine

Recognition of critical illness

Edwin Mitchell

Initial assessment and resuscitation

General considerations

- Critical illness, simply defined, is a state where death is likely or imminent. All of us will experience a critical illness by definition, but the aim of intensive care is to identify patients whose critical illness pathway can be altered and steered away from a fatal outcome.
- Over the past decade, it has become clearer that intervening earlier in a patient's critical illness may lead to improved survival. Even when life-prolonging treatment is no longer in the patient's best interests, acknowledging a patient is critically ill and in the terminal phase of their illness allows appropriate palliative care to be given.
- Critical illnesses are characterized by the failure of organ systems, and it is the signs of these organ failures that the initial assessment hopes to identify. Commonly, organ systems fail in sequence over time leading to multi-organ failure, and resuscitation aims to limit this. Mortality is proportional to the number of failed organs, duration of dysfunction and severity of organ failure.
- In contrast to the treatment of many routine medical conditions, where definitive treatment is based on a thorough assessment of the patient, the assessment of the critically ill patient typically occurs simultaneously with treatment due to clinical urgency.

Assessment

- The initial assessment of the critically ill patient should begin with a brief, targeted history and an appraisal of the patient's vital signs to identify life-threatening abnormalities that merit immediate attention. Signs suggesting severe illness are listed in Table 1.1.
- Most physicians are familiar with the 'ABCDE' (Airway, Breathing, Circulation, Disability, Exposure) approach to patient assessment taught on Advanced Life Support™, Advanced Trauma Life Support™ and other nationally recognized courses. This approach is speedy, thorough and adaptable, compared to the traditional medical 'clerking'.
- The principle behind the ABCDE approach is that problems are prioritized according to the severity of threat posed. Serious physiological derangements should be dealt with at each stage before moving on to assess the next step. For example, an obstructed airway should be identified and cleared before assessing breathing and measuring blood pressure.
- In reality, information is gathered in a non-linear fashion, but it is helpful to have a clear guideline within which to work. With adequate staff training and numbers, it should be possible to deal simultaneously with multiple problems.
- Common signs of organ failure should be sought, and bedside monitoring equipment (such as pulse oximetry, automated blood pressure measurement devices and thermometers) may augment the clinical examination. Near-patient testing, using equipment such as the Haemacue™, and arterial blood gas sampling can provide useful and rapid information regarding the oxygenation of the patient and common derangements in acid–base status and haemoglobin.

Resuscitation

- The purpose of resuscitation is to restore or establish effective oxygen delivery to the tissues, in particular those of the vital organs – brain, heart,

Core Topics in Critical Care Medicine, eds. Fang Gao Smith and Joyce Yeung. Published by Cambridge University Press.

Table 1.1 Signs suggestive of critical illness

- Obstructed/threatened airway
- Respiratory rate >25 breaths/min or <8 breaths/min
- Oxygen saturations <90% on air
- Heart rate >120 bpm or <40 bpm
- Systolic blood pressure <90 mmHg
- Capillary refill >3 seconds
- Urine output <0.5 ml/kg per hour more than last 4 hours
- Glasgow coma score <15 or status epilepticus or patient not fully alert

kidneys, liver and gut. Oxygen delivery depends on adequate oxygen uptake from the lungs, an adequate cardiac output to deliver the oxygen to the tissues and an adequate haemoglobin concentration to carry the oxygen.

- These goals of resuscitation are usually achieved by the use of supplemental oxygen, fluid or red blood cell transfusion, inotropic support or antibiotics as needed. In certain circumstances, such as penetrating trauma, a surgical approach to limiting life-threatening bleeding is considered to be a part of the resuscitation process.
- Resuscitation should begin as soon as the need for it has been identified. There is now evidence showing that early intervention (within a few hours of admission) limits the degree of organ dysfunction and improves survival. Waiting until the patient reaches the intensive care unit may be too long a delay if further deterioration in the patient's condition is to be prevented.
- In some situations, such as head injury, even single episodes of hypotension or hypoxia are associated with worsened outcomes.
- Early and complete resuscitation is associated with improved outcomes.

Monitoring the progress of resuscitation

At present, there are only limited ways in which the function of individual tissue beds can be assessed. Assessing the adequacy of resuscitation is usually based on either global markers of oxygen supply and utilization (such as the normalizaton of mixed venous oxygen saturations and lactate concentration), or the clinical responses of the affected organs – urine output from the kidneys for example. Whilst resuscitation is ongoing, invasive monitors such as an arterial cannula, a central venous cannula and a urinary catheter may be placed, but these additional monitors should not detract from the clinical monitoring of the patient.

Table 1.2 Suggested goals to be achieved within 6 hours of presentation for the resuscitation of septic shock refractory to fluid therapy (after Rivers *et al.*)

- Mean arterial pressure >65 mmHg
- Central venous pressure 8–12 mmHg
- Urine output >0.5 ml/kg per hour
- Central venous oxygen saturation >70%

- Resuscitation must be tailored to the individual patient. There are now data to suggest appropriate goals or parameters for resuscitation in certain clinical states, notably sepsis (Table 1.2), acute head injury and penetrating trauma.
- Over-enthusiastic attempts at resuscitation can lead to problems with fluid overload, worsening haemorrhage through dilution of clotting factors, or rapid electrolyte shifts leading to cerebral oedema.
- The importance of early assessment by adequately trained staff, with regular review of clinical progress, cannot be over-emphasized.

Once resuscitation is under way and the patient is stabilized, it is appropriate to begin an in-depth assessment of the patient. This means taking a more complete history, making a thorough examination and ordering clinical investigations as indicated. This phase of the process aims to establish an underlying diagnosis and guide definitive treatment. If deterioration occurs over this time, the cycle of assessment and resuscitation should begin again.

Physiology monitoring systems

Physiology monitoring systems are systems that allow the integration of easily obtained and measured physiological variables into a single score or code that triggers a particular action or care pathway (see also Chapter 5: Scoring systems and outcome).

- The commonly measured physiological variables are heart rate, blood pressure, respiratory rate, temperature, urine output and consciousness level, and these can be assessed at the bedside.
- Action may be triggered by a single abnormality or by an aggregate score. Aggregate scoring systems are generally preferred as they may also allow a graded response depending on the score.
- Physiological Scoring Systems (PSS) developed from the recognition that critically ill patients, and

Table 1.3 Advantages and disadvantages of Physiological Scoring Systems

Advantages	Disadvantages
• Rapid assessment • Facilitates communication between healthcare workers • Empowers staff • Reduces time from deterioration to action	• Poor sensitivity (may not identify all critically ill patients) • Not validated in target populations • May not be appropriate for all patients (chronic health conditions, terminally ill, children, etc.) • Scores may not be calculated correctly

in particular patients who suffered cardiac arrests, often had long periods (hours) of deterioration before the 'crisis' or medical emergency occurred.

- PSS scores are often termed 'track and trigger' scores; they aim to identify and monitor patients whose clinical state is worsening over time, and then trigger an appropriate clinical response.
- The Department of Health has recognized the need for the early identification of critically ill patients and recommends the use of track and trigger systems in all acute hospitals in the UK. The current recommendation is to use PSS to assess every patient at least every 12 hours or more frequently if they are at risk of deterioration.
- PSS may have variable sensitivity and specificity for predicting hospital mortality, cardiac arrest and admission to critical care. Triggering scores may need to be set locally to maximize the benefits from these scoring systems. Typically, these scoring systems are not very sensitive but have high negative predictive power for the outcomes mentioned above. Advantages and disadvantages of PSS are summarized in Table 1.3.

Medical emergency team and outreach

It has been recognized that intensive care units will never have the capacity for all the patients that may benefit from some degree of critical care provision. The concept of 'critical care without walls' is that patients' critical care needs may be met irrespective of their geographical location within the hospital.

Medical emergency teams (METs) and critical care outreach (CCO) aim to redress the mismatch between the patient's needs when they are critically ill and the resources available on a normal ward, in terms of manpower, skills, and equipment.

- At present there is no clear consensus in the literature about the exact composition and role of these teams, nor their nomenclature.
- Currently there is emphasis in teaching critical care skills to all hospital doctors via courses such as ALERT™ (Acute Life threatening Events – Recognition and Treatment) and CCRISP™ (Care of the Critically Ill Surgical Patient).
- METs are usually understood to be physician-led. The team might typically consist of the duty medical registrar and intensive care registrar, a senior nurse and a variable number of other junior doctors.
- METs are often formed from people who do not usually work together, coming together as a team only when the clinical need dictates. The MET has an obligation to arrive quickly, to contain the necessary skill mix in its members, to document the extent of its involvement accurately, and to liaise with the team responsible for the patient's usual treatment.
- METs are summoned to critically ill patients who have been identified either by a scoring system as outlined above, because they have attracted a particular diagnosis (e.g. status epilepticus), or because of general concerns that the nursing staff have about a patient.
- METs have been shown to reduce the numbers of unexpected cardiac arrests in hospital in some observational studies, but the exact level of benefit is controversial. In some hospitals METs have replaced the traditional cardiac arrest team.

Critical care outreach (CCO) teams are typically nurse-led, and have a variety of roles compared to the MET, depending on local policy (Fig. 1.1). The nurses in CCO are typically senior nurses who have been recruited from an intensive care, coronary care or acute medical background. CCO nurses are often employed full-time in this role and may perform additional duties, such as following up patients on discharge from the intensive care unit, acute pain services, tracheostomy care and providing non-invasive ventilation advice.

Fig. 1.1 Critical care outreach (CCO) teams often carry portable equipment to help stabilize patients in places outside of critical care areas.

- When summoned to a critically ill patient, CCO will typically make an assessment and refer directly to intensive care services, or make suggestions to the parent medical team according to the requirements of the patients.
- At present, not all CCO are staffed to provide a round-the-clock service and thus patients still often rely on junior medical staff to provide their care out of hours.

In the UK, CCO is the most frequently used model, following on from Department of Health recommendations made in the late 1990s. Their explicit purpose is to avert ITU admissions, support discharge from ITU and to share critical care skills with the rest of the hospital. Other countries, most notably Australia, have pioneered the MET model since 1990. In some hospitals both systems run side by side. Currently the systems are in a state of flux. The rapid introduction of MET/CCO systems in most hospitals has made the assessment of its impact on patient survival difficult. It is also difficult to assess how many patients at any one time need the input of a MET/CCO, and the implications that this may have for resource allocation. At the time of writing, most of the available data suggest that the MET is under-utilized.

Referral to critical care team

Critical care can offer:

- organ support technologies
- high nurse : patient ratio
- intensive/invasive monitoring
- specialist expertise in managing the critically ill

Patients who need these services should be referred to the critical care team.

Intensive care units exist to support patients whose clinical needs outstrip the resources/manpower which can be safely provided on the general wards. The patient must also generally be in a position to benefit from the treatment, rather than simply to prolong the process of dying from an underlying condition. Chronological age alone is a poor indicator of survival from a critical illness; chronic health problems and functional limitations due to these are better predictors. There should be a discussion with the patient (if possible), or their family, to explain the proposed treatment and to seek their consent for escalating management.

Most critical care facilities operate a 'closed' policy, in which the referring team temporarily devolves care to the intensive care team. The latter is led by a clinician trained in intensive care. There is evidence that this approach leads to reduced lengths of stay and increased survival rates in patients. As part of this strategy, all referrals to intensive care should be passed through the duty intensive care consultant. The referring team still has an important role to play as definitive management of a condition (e.g. surgery) is still often provided by them.

Referral to the critical care team may occur via a variety of routes. The admission may be planned well in advance in the case of elective surgery, or anticipated and discussed with the ITU consultant in the case of emergency surgery. Acute medical admissions should be referred to the ITU consultant directly from the medical consultant, but in emergencies referral may be made via the MET/CCO. The patient is usually reviewed on the ward prior to admission in order to facilitate resuscitation and safe, timely transfer to critical care.

Key points

- Early recognition and treatment of the critically ill patient may improve outcome.
- Recognition of a critically ill patient by junior or inexperienced staff may be facilitated by a scoring system.
- Physiological scoring systems are widely used, but not always well validated.
- METs and CCOs aim to provide critical care skills rapidly to critically ill patients.
- Referrals to the critical care services may happen from any level, but the final decision to admit a

patient to a critical care bed should be made by an experienced critical care physician.

Further reading

- Bickell W, Wall M, Pepe P *et al.* (1994) Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. *N. Engl. J. Med.* **331**: 1105–9.
- Intensive Care Society (2003) *Evolution of Intensive Care*. www.ics.ac.uk/icmprof/downloads/icshistory.pdf
- Intensive Care Society (2008) *Levels of Critical Care for Adult Patients: Standards and Guidelines*. www.ics.ac.uk/downloads/Levels_of_Care_13012009.pdf
- National Institute for Clinical Excellence (2007) *Clinical Guideline CG59: Acutely Ill Patients in Hospital*. www nice.org.uk/guidance/index.jsp?action=byID&o=11810#summary
- Rivers E, Nguyen B, Havstad S *et al.* (2001) Early goal-directed therapy in the treatment of severe sepsis and septic shock. *N. Engl. J. Med.* **345**: 1368–77.

Chapter 2

Advanced airway management

Isma Quasim

Critically ill patients may need respiratory support as part of their treatment on the intensive care unit. The provision of respiratory support is a core function of the intensive care unit; internationally around a third of patients admitted to intensive care units receive some form of mechanical ventilation for more than 12 hours. Advanced airway skills form an essential part of the intensive care clinician's armoury and are invaluable in times of emergency.

This chapter will focus mainly on the aspects of advanced airway management used most commonly in critical care: intubation and extubation, tracheostomy, cricothyroidotomy and 'mini-tracheostomy'.

Intubation

Indications for intubation (Table 2.1)

Bag–valve-mask and non-invasive ventilation are two methods of providing short-term positive pressure ventilation or intermittent airway management. However, intubation is often necessary to provide more long-term and continuous positive pressure ventilation and/or to secure and protect the airway of patients with reduced level of consciousness.

Airway assessment

Studies have suggested that difficult intubation in patients for elective operative procedures occurs approximately in 1–3% of cases, and this incidence increases up to 10% in critical care patients. In anaesthesia, there are a number of methods and parameters of airway assessment used to predict potential difficult intubation. These include the modified Mallampati score, thyromental distance, inter-incisor distance and neck mobility. In addition, difficult intubation should be anticipated in patients with certain anatomical features (protruding teeth, morbid obesity, large breasts and short necks) or pathologies such as upper airway infection (e.g. epiglottitis, laryngitis), trauma, inhalational injury, tumour, cervical spine injury, previous upper airway operations or radiotherapy.

In critical care practice, given the relative urgency for intubation in sick or non-cooperative patients, full assessments are not always possible or practical. Some vital information can still be found on an anaesthetic chart such as preoperative assessment of the airway, the grade of laryngoscopic view and techniques of airway managements. Patients should be intubated by a clinician experienced in advanced airway management with difficult airway adjuncts available.

When dealing with sick patients on the ward, conditions in the ward setting are often unfavourable due to limited equipment and lack of assistance, making intubation more difficult. Ideally patients should be transferred to a safer environment such as the critical care unit, the anaesthetic room or the operating theatre where trained assistance is available.

Rapid sequence induction

Patients who present in emergency situations are assumed to have a full stomach and in the UK, it is recommended that a rapid sequence induction (RSI) is used in intubation. This is a technique that minimizes the risks of regurgitation and subsequent aspiration of gastric contents. The principles involved are:

(1) Patient should be on a bed that can be tilted if necessary. Mandatory monitoring should be commenced including ECG, pulse oximetry, blood pressure, end-tidal CO_2 monitoring.
(2) Preparation of all essential emergency drugs before the start of procedure.

Core Topics in Critical Care Medicine, eds. Fang Gao Smith and Joyce Yeung. Published by Cambridge University Press.

(3) Equipment needed should be checked prior to the procedure including two working Macintosh laryngoscopes, endotracheal tubes, laryngeal mask airways, working suction. Airway adjuncts such as oropharyngeal airways, longer laryngoscope blades, McCoy laryngoscope or bougie that might be required in an unexpectedly difficult intubation should also be available.

(4) Trained assistance familiar with the technique should be available.

(5) Preoxygenation with high flow 100% oxygen for 3–5 minutes to maximize oxygen reserves and prevent hypoxaemia until tracheal intubation is established.

(6) A rapidly acting intravenous induction agent such as thiopentone and suxamethonium should be used to achieve rapid muscle relaxation and tracheal intubation.

(7) Sellick's manoeuvre or cricoid pressure should be applied just before patient loses consciousness.

Table 2.1 Critical care indications for intubation

Indications	Examples
Provide long-term positive pressure ventilation	Respiratory failure
Protect the airway	Glasgow Coma Scores <8
Secure the airway	Airway obstruction, inadvertent or failed extubation

This involves digital pressure against the cricoid cartilage of the larynx, pushing it backwards (Fig. 2.1). This causes compression of the oesophagus between the cricoid cartilage and the C5/C6 vertebrae posteriorly, thus minimizing passive regurgitation of gastric contents (Fig. 2.2). Force applied should be 30 N to 40 N and should be maintained until the correct placement of endotracheal tube has been confirmed by auscultation and cuff inflated. It must be released during active vomiting, to reduce the risk of oesophageal rupture.

Induction agents

Most critical care units do not have fixed protocols for the drugs used to facilitate tracheal intubation, the choice of which can vary according to the personal experience, drugs availability and the patients' pre-admission conditions or co-morbidities.

The majority of anaesthetic induction agents are vasodilators and have cardiodepressant effects. The use of these induction agents can lead to a precipitous fall in blood pressure and cardiac output in dehydrated, septic or haemodynamically unstable patients. It is good practice to monitor patients' cardio-respiratory parameters closely including invasive blood pressure monitoring prior to induction and have fluid boluses and vasopressor drugs prepared and immediately available.

It is beyond the realm of this chapter to go into the pharmacology in depth but a few of the commonly

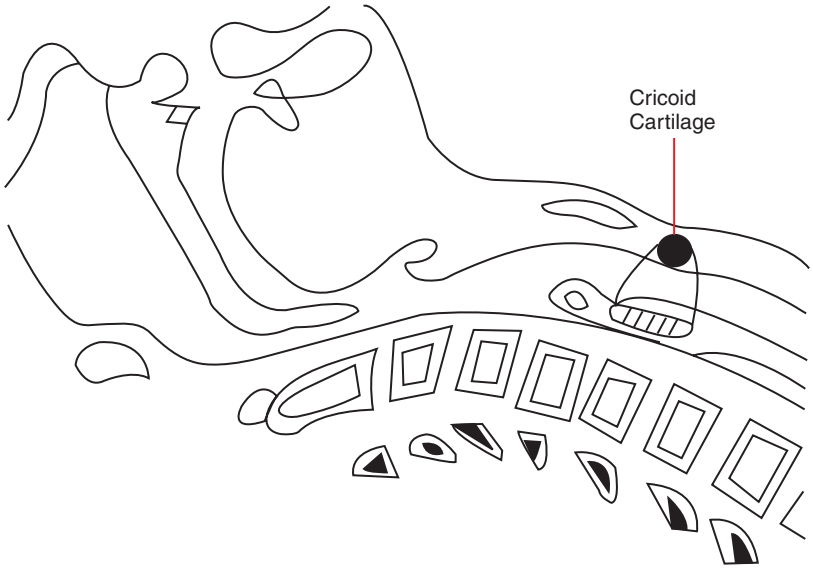

Fig. 2.1 Cricoid cartilage. (With permission of *Update in Anaesthesia*, Issue 2 (1992), Article 4: Cricoid pressure in Caesarean section.)

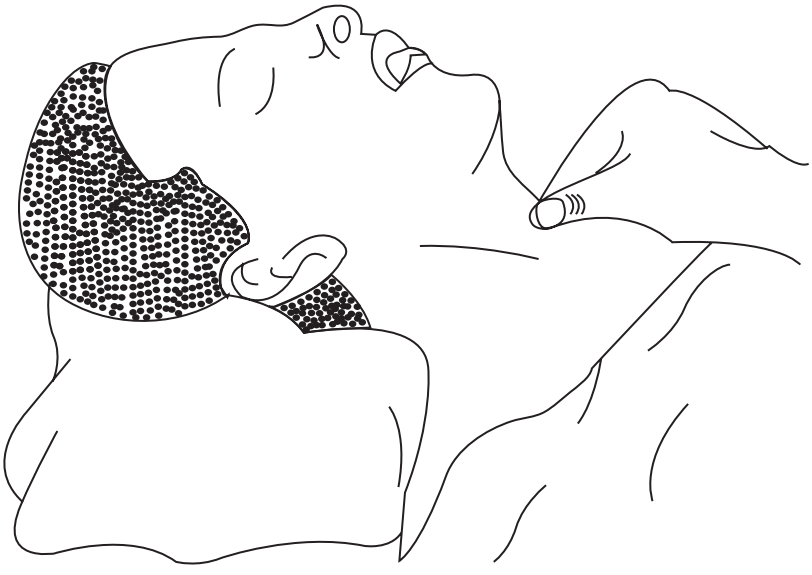

Fig. 2.2 Application of cricoid pressure. (With permission of *Update in Anaesthesia*, Issue 2 (1992), Article 4: Cricoid pressure in Caesarean section.)

used intravenous induction agents and muscle relaxants are outlined below:

Propofol – The induction dose is 1.5–2.5 mg/kg but this should be reduced in haemodynamically unstable patients as it can cause profound hypotension. It has the advantage of being able to be continued as an infusion for sedation and is a drug familiar to the majority of anaesthetists and intensivists.

Etomidate – The dose of 0.3 mg/kg causes less haemodynamic instability than propofol, and has been used as drug of choice for critically ill patients. Its use has declined as major concerns have been raised over adrenocortical suppression even when given as a single dose at induction.

Thiopentone – The classical induction agent used in RSI along with suxamethonium. It provides smooth rapid induction in a dose of 3–6 mg/kg but also produces dose-related cardiac depression. Its metabolism is slow and sedation can persist for many hours afterwards.

Muscle relaxants

In a RSI situation, only suxamethonium should be used and it is given immediately after the IV induction agent without bag-mask ventilation. In a situation in which it is safe and appropriate to use a longer-acting muscle relaxant as the primary agent, then hand ventilation must be checked prior to its administration to avoid the 'can't intubate, can't ventilate' scenario.

Suxamethonium – Suxamethonium is a depolarizing neuromuscular blocker and is the only available neuromuscular blocker with a rapid onset of effect and an ultra short duration of action of around 5 min. Given in a dose of 1–1.5 mg/kg it provides excellent intubating conditions within 60 sec but is contraindicated in conditions such as burns (>24 hours old), hyperkalaemia, malignant hyperpyrexia, myotonia and other neurological diseases. Suxamethonium is metabolized rapidly by plasma pseudocholinesterase and the duration of action is increased in patients who carry an atypical gene for this enzyme. In patients who are heterozygous for the atypical gene duration of action is increased by 50–100%; in patients who are homozygous for the atypical gene duration of action is increased to 4 hours.

Rocuronium – A dose of around 0.6 mg/kg provides good intubating conditions within 2 min; however when given in a dose of 1–1.2 mg/kg it can facilitate intubation within 60 sec and can be used in a 'modified rapid sequence induction' when suxamethonium is contraindicated. It has duration of action of around 30 min.

Atracurium – The initial dose is 0.5 mg/kg and provides intubating conditions within 2 min. It is useful in patients with renal or hepatic impairment as it is broken down by spontaneous Hoffmann degradation. It has a short duration of action of around 20–25 min and if prolonged muscle relaxation is necessary it can be given by IV infusion at 0.5 mg/kg per hour.

See Table 2.2 for a summary of induction agents and muscle relaxants.

Inhalational induction

There will be instances when an inhalational induction may be the preferred method, e.g. upper airway

Table 2.2 Commonly used induction agents and muscle relaxants

Name	Main features	Doses	Indications	Cautions
Propofol	Rapid onset; unaffected by renal or hepatic disease	1.5–2.5 mg/kg	Intravenous induction agent Given by infusion for sedation Anticonvulsant	Vasodilatory and cardio-depressant
Etomidate	Rapid onset; less cardiodepressant.	0.3 mg/kg	Induction agent	Not for use in porphyria Adrenocortical suppression even after single dose
Thiopentone	Smooth rapid onset	3–6 mg/kg	Induction agent; anticonvulsant	Avoid in porphyria. Slow hepatic metabolism
Suxamethonium	Effective within 60 sec; lasts 3–5 min	1–1.5 mg/kg	Depolarizing muscle relaxant	Not for use in malignant hyperthermia and myotonia Caution in burns, renal failure, spinal cord injuries
Atracurium	Adequate muscle relaxation within 3 min; lasts 20–25 min. Safe for use in renal and hepatic failure	0.3–0.6 mg/kg	Non-depolarizing muscle relaxant	Histamine release may cause bronchospasm and hypotension
Rocuronium	Rapid onset if dose of 1–1.5 mg/kg used. Longer duration of action of 30–40 min	0.6 mg/kg gives adequate relaxation in 2 min	Non-depolarizing muscle relaxant	Intermediate risk of anaphylaxis

obstruction, burns or status asthmaticus, and sevoflurane is one of the most commonly used agents within the UK for this technique. Inhalational induction is usually carried out by an anaesthetist and requires an anaesthetic machine and circuit.

Endotracheal intubation

Endotracheal intubation is usually via the oral route but historically nasal intubation was common practice. The oral endotracheal tube avoids the risk of sinusitis and allows a tube with a larger internal diameter to be used, reducing the work of breathing. Nasal endotracheal tubes, on the other hand, are better tolerated in awake patients and are used in some paediatric critical care units.

During intubation, the patient should be fully monitored. Equal breath sounds should be auscultated to rule out oesophageal intubation but this is not always reliable. Capnography should be used to confirm tracheal intubation as recommended by the Royal College of Anaesthetists. Lightweight portable capnography devices are available when intubation is required to be performed outside of the critical care, operating theatre or anaesthetic room environment. Chest X-rays should be performed to confirm the position of the tip of the endotracheal tube to avoid inadvertent endobronchial intubation.

Difficult and failed intubation

In an unanticipated difficult intubation situation, oxygenation should be maintained with hand ventilation until appropriate help arrives. Clinicians experienced in advanced airway management should familiarize themselves with the failed intubation drill (Fig. 2.3). The Difficult Airway Society UK website (see *Further reading*) has the following management plans:

(1) Unanticipated difficult tracheal intubation during rapid sequence induction of anaesthesia.

(2) Rescue techniques for the 'can't intubate, can't ventilate' situation.

Extubation/ weaning protocols

In 2000, a study investigated characteristics of conventional mechanical ventilation in 412 medical and surgical ICUs involving 1638 patients across North America, South America, Spain and Portugal. The study confirmed that there was similarity between countries for the primary indications for mechanical

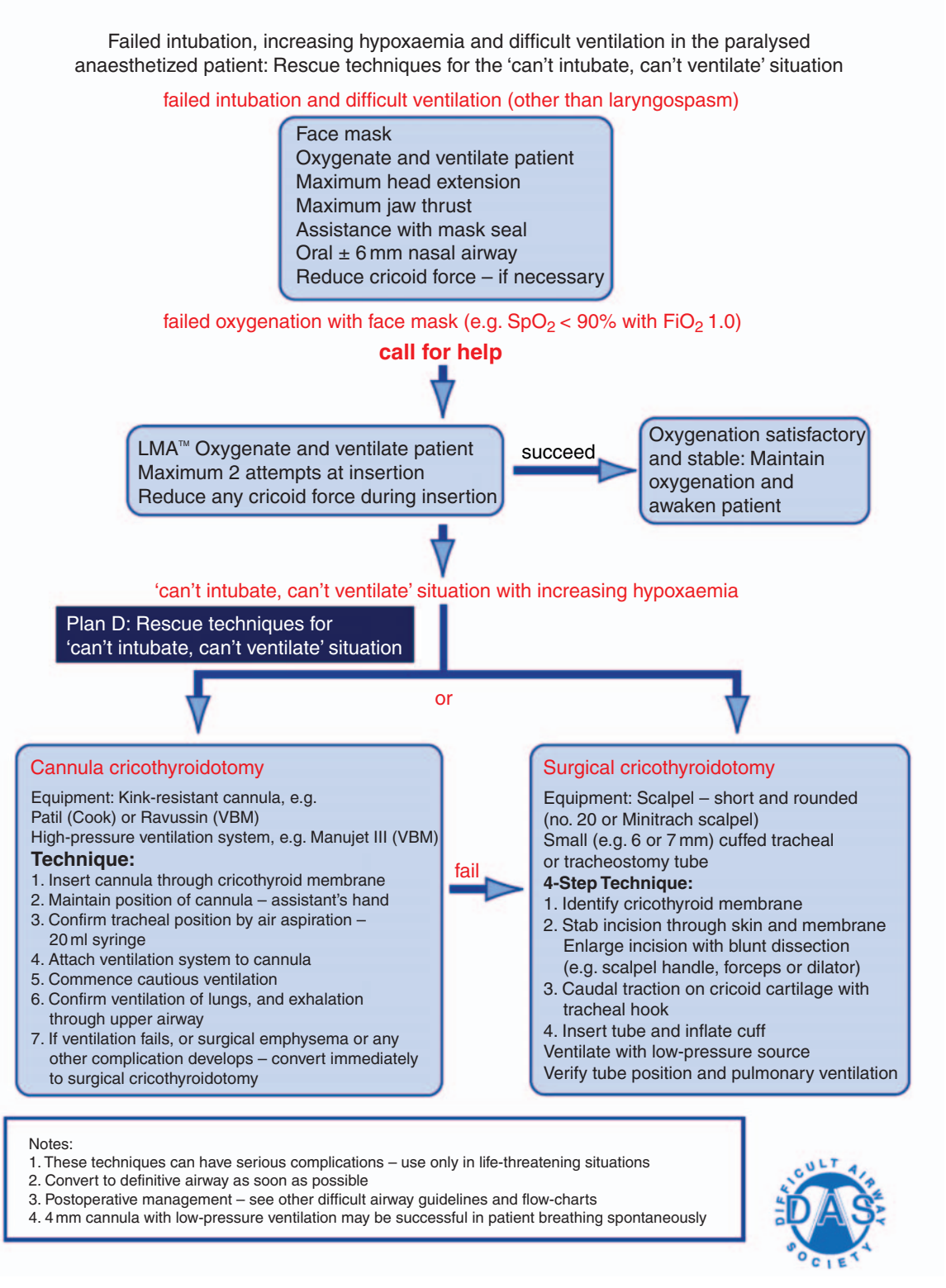

Fig. 2.3 Failed intubation algorithm. (With permission of Difficult Airway Society, UK.)