Learning objectives

On completion of this chapter the reader should be able to:

- understand how to assess and handle a critically ill patient
- implement measures to minimize oxygen consumption
- formulate a treatment plan to increase volume and clear secretions, while integrating rehabilitation throughout
- identify and manage emergencies that may arise
- understand the teamwork and application of an on call service

The major long-term complication for Intensive Care Unit (ICU) patients is deconditioning, which underlines the importance of early rehabilitation, leading to lower mortality and reduced readmission rates (Vollman 2013). Outcomes of physiotherapy combined with occupational therapy are less delirium, shorter time on mechanical ventilation (MV) and increased return to independent function at discharge (Piriyapatsom et al. 2013). This is reinforced by the findings of Hanekom et al. (2012) that a specialist physiotherapist allocated to the ICU improves patient outcomes. As well as deconditioning, physiotherapy has been shown to reduce sputum retention, atelectasis, need for intubation, weaning failure (Gosselink et al. 2008) and brain dysfunction (Girard 2012). The more frequent the treatments, the shorter is the average patient’s length of stay (Castro et al. 2013).

ASSESSMENT

Modifications to the assessment described in Chapter 2 are below.

Notes and charts

Blood sugar, lactate, white cell count and urea/electrolytes can affect treatment. The implications of abnormal values are in Ch.2 and the Glossary, with some ICU examples.
1. Low or high potassium levels predispose to arrhythmias, as does low magnesium (Parikh 2012), contraindicating most forms of physiotherapy.

2. Low albumin is common in ICU patients because of fluid and membrane permeability problems, leading to metabolic alkalosis and systemic and pulmonary oedema (Ch.2).

3. *Neutropaenia* can be caused by malnutrition, immune deficiency or anti-cancer drugs, leaving a patient vulnerable to infection.

4. Anaemia is found in up to 95% of patients, compromising oxygen delivery (Kocsi *et al* 2012) and mobilization.

5. Impaired clotting occurs with disseminated intravascular coagulation (p.504), or, less drastically, if a patient is on anticoagulants. This increases the risk of bleeding with suction. Conversely, increased clotting raises the likelihood of deep vein thrombosis, as indicated by elevated levels of *prothrombin* (Aleman *et al* 2013) or platelets (Zakai *et al* 2013).

The notes also identify patients who are dependent on tobacco or alcohol. This is not a time for cold turkey and patients should be given nicotine replacement (Cartin-Ceba 2011) or medication for alcohol withdrawal (Sarff & Gold 2010). Increased morbidity is associated with unmanaged withdrawal from tobacco (Lucidarme 2010) or alcohol (Carlson *et al* 2012).

A typical chart is shown in App.C. Increased core temperature indicates that the patient is consuming extra oxygen. Peripheral temperature is normally 2° lower than core temperature, but if the difference is more than 5°, poor circulatory function is implicated. The chart may incorporate scales for mobility (Kasotakis *et al* 2012), sedation, delirium (Porter & McClure 2013), thirst (Puntillo 2013), *agitation* (Chanques 2006) and *sleep* (Bourne *et al* 2008). There is no reliable means of assessing awareness, so it is assumed that patients can hear and understand. A rough test for comprehension is to ask patients to poke out their tongue, which most paralyzed patients are physically able to do.

Routine pain assessment leads to shorter length of stay in the ICU (Paulus *et al* 2013). Scales have been validated for ventilated (Piriyapatsom *et al* 2013), and non-ventilated patients (Azzam & Alam 2013). *Multimodal analgesia* is advised (Payen *et al* 2013), especially as uncontrolled pain may impair quality of life even after discharge (Payen & Chanques 2012).
Breathlessness can be measured by two standardized questions (Karampela et al 2002):

- Are you feeling short of breath right now?
- Is your shortness of breath mild, moderate or severe?

Breathlessness may be due to patient-ventilator synchrony (Branson et al 2013) or it may reflect anxiety.

Blood pressure (BP) should be checked on the chart for its response to turning or previous sessions of manual hyperinflation (MH). If BP is low, unstable or sags on inspiration, or if mean arterial pressure (MAP) is <80 mmHg, the patient may be unable to maintain cardiac output during turning or manual hyperinflation (MH). A drop in systolic BP by more than 40 suggests sepsis (Sevransky 2010).

Electrolyte and haematocrit concentration are decreased with fluid excess and increased with fluid loss. Fluid status is disturbed by diuretics, diabetes, vomiting, diarrhoea, heart or kidney failure, burns, ascites or large open wounds. Hydration is difficult to assess clinically because oedema or overhydration can coexist with intravascular depletion in critically ill people, so reliance is best placed on the fluid balance chart and nurse report.

Signs of hypovolaemia or reduced cardiac output are:

- \( \uparrow \) heart rate (HR)
- \( \uparrow \) respiratory rate (RR)
- \( \downarrow \) systolic BP
- \( \downarrow \) urine output
- dizziness with position change
- sweating
- confusion or altered consciousness.

Hypovolaemia alone is distinguished by:

- \( \downarrow \) peripheral temperature (usually the first sign)
- dark coloured urine
- \( \downarrow \) vascular pressures (Ch.17)
- \( \downarrow \) pulse pressure.

Decreased cardiac output alone is distinguished by:

- pallor
- cold extremities.
**PRACTICE TIP**
Obtain a blank ICU chart and go through it with colleagues

**The patient**

*An inability to report symptom distress is not synonymous with an inability to experience suffering.*

Campbell 2010

Is the patient conscious, confused, agitated, sedated, paralyzed or in pain? What channels of communication are available? Paralysis, whether pathological or pharmacological, indicates the importance of clarity in communication because patients may be trying to make sense of sounds and sensations but cannot give feedback. Agitation may be due to lack of information, the endotracheal tube, fear, awkward positioning, abdominal distension or stress.

However unconscious a patient appears, it is worth remembering the ‘unconscious’ victim of the 7/7 London bombings who later reported that he had heard paramedics pass him by with the comment that he could not be saved.

Thirst is reported by 70% of patients (Arai 2013). Puntillo et al (2010) identified thirst as the second most intense symptom, but it is not routinely assessed, partly because half the nurses in this study did not perceive that mechanically ventilated patients could be thirsty.

Table 18.1 shows that unrelieved and distressing symptoms are present for the majority of critically ill patients. Breathlessness was found to be the most distressing symptom.

<table>
<thead>
<tr>
<th>Table 18.1</th>
<th>Prevalence of symptoms reported by ICU patients (Puntillo et al/2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptom</strong></td>
<td><strong>Percent of patients</strong></td>
</tr>
<tr>
<td>Fatigue</td>
<td>74.7</td>
</tr>
<tr>
<td>Thirst</td>
<td>70.8</td>
</tr>
<tr>
<td>Anxiety</td>
<td>57.9</td>
</tr>
<tr>
<td>Restlessness</td>
<td>49.0</td>
</tr>
<tr>
<td>Hunger</td>
<td>44.8</td>
</tr>
<tr>
<td>Breathlessness</td>
<td>43.9</td>
</tr>
</tbody>
</table>
Other points to note are the following:

1. Accessory muscle activity suggests excess work of breathing (WOB), while laboured breathing may indicate an obstructed airway.

2. A distended abdomen is common, for example Mostafa (2000) found that 83.3% of patients were constipated for a median of 6 days, which reduced lung volume and contributed to weaning failure.

3. Lines and tubes, especially femoral lines, haemofiltration lines, pacing wires, chest drains and lines in the feet, should be kept in view throughout treatment.

4. Muscle atrophy may be masked by limb oedema.

5. A wheeze-like sound at the mouth may indicate air leaking around the cuff of the tracheal tube.

6. If manual hyperinflation is to be undertaken, breath sounds can be heard more clearly when the bag is squeezed, and sometimes crackles can be elicited with a sharp release on expiration.

7. An acoustic secretion detector is available which can identify secretions (Lucchini et al 2011).

8. Absent or reduced breath sounds over the left lung may indicate right lung intubation (Fig 18.1).

<table>
<thead>
<tr>
<th>Pain</th>
<th>40.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sadness</td>
<td>33.9</td>
</tr>
<tr>
<td>Fear</td>
<td>32.8</td>
</tr>
<tr>
<td>Confusion</td>
<td>26.6</td>
</tr>
</tbody>
</table>

Fig 18.1
The ETT has passed into the R main bronchus and beyond the RUL bronchus, leading to absorption of gas in the non-ventilated RUL and atelectasis. The left lung would also have collapsed if the ETT had not been removed. ETT: endotracheal tube, RUL: right upper lobe
Monitors

Monitors should be observed before and during treatment. The arterial line allows continuous monitoring of BP and blood gases. SpO₂ levels must be maintained throughout, low levels being a risk factor for subsequent cognitive dysfunction (Modrykamien 2012).

Ventilator

The charts indicate ventilator settings and trends in the patient's response, while the ventilator screen shows events in real time. Interaction between patient and ventilator are represented as waveforms (Ch.17). Erratic readings may indicate a patient fighting the ventilator or coughing, confirmed by observation of the patient. A high level of positive end-expiratory pressure (PEEP) means that patients are at risk of severe hypoxaemia if they are disconnected from the ventilator. A sawtooth pattern on the expiratory portion of the waveform indicates excess secretions (Fig 18.2).

Fig 18.2
Expiratory sawtooth pattern on pressure and flow waveforms, suggesting a need for suction (Branson 2007)

In volume control ventilation, airway pressure provides the following information:

1. Peak pressure is normally 20 cmH₂O above the PEEP level.
2. Peak pressure below normal is usually due to a leak in the circuit.
3. End-expiratory pressure below the baseline suggests excess WOB.
4. Oscillations in airway pressure signify spontaneous breaths between ventilator breaths.
5. Values >30 cmH$_2$O above PEEP may be due to airflow obstruction, stiff lungs, pulmonary oedema, pneumothorax, obstruction by upper airway secretions, a kinked tube or clenched teeth (Fig 18.3).

**Fig 18.3**
Reasons for increased peak airway pressure in patients on volume-control ventilation. ARDS: acute respiratory distress syndrome

Alveolar pressure is more negative than airway pressure during patient triggering and more positive during a positive pressure breath.

**Imaging**

Portable x-rays are taken with the patient supine or sitting up as they are able. A supine or slumped position causes a pleural effusion to lose its clear boundary and appear as a generalized opacity with no air bronchogram, but a CT scan may clarify its presence (App D). Pleural effusions are common because of fluid imbalance or leaky membranes, the lung floating on top of the pleural fluid (Maslove et al 2013).

Pneumothoraces are also more difficult to identify on a supine than an upright film because the classic apicolateral location is less common and sometimes the boundary between air and lung is lost.

Close scrutiny of the x-ray is required:
- after unexpected loss of consciousness, in case of aspiration
- after trauma or cardiopulmonary resuscitation, in case of rib or sternal fracture
- after neck line insertion, in case of haemothorax or an apical pneumothorax
• after intubation.

Hardware is deliberately radiopaque. The tracheal (endotracheal or tracheostomy) tube is identified by its opaque line and should extend half-way down the trachea. If it is too long, unventilated areas collapse (Fig 18.1). If it is too short, it may become dislodged, and the patient's head should be moved as little as possible. A central venous line is usually traceable to the vena cava. A pulmonary artery catheter passes through the heart in a loop, with its tip in a branch of the pulmonary artery.

A clinical decision making tool for the ICU patient is in App.C.

**Fig 18.4** The ETT has passed into the R main bronchus and beyond the RUL bronchus, leading to absorption of gas in the non-ventilated RUL and atelectasis. The left lung would also have collapsed if the ETT had not been removed. ETT: endotracheal tube, RUL: right upper lobe

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**HANDLING PEOPLE WHO ARE CRITICALLY ILL**

'Who am I?  
Where am I?  
Why do I hurt so much?'

*Nursing Times, 1981*

**Minimising oxygen consumption**

'I heard a lot more than I think they think I heard.'

Jablonski, 1994
Preliminaries

‘Someone would come near me and would just be working and not saying anything to me. That would be frightening because I didn’t know what they were going to do next’

Parker et al, 1984

Patients are often scared, disorientated and sleep deprived. Medication may prevent the creation of new memories and they will often not remember information about previous treatments or even where they are. They need regular explanations about treatment, and even when unconscious or paralysed, they need advice before any physical touch, otherwise anxiety increases oxygen consumption ($\dot{V}$O$_2$).

Increased $F_{\text{I}O_2}$, fluids or medication may be required to maintain oxygenation while ensuring stable haemodynamics and minimum pain. If sedation is needed, a bolus of propofol before treatment is suitable because of its short recovery time. The traditional regime of percussion, vibrations and suction can, if done inappropriately, destabilise cardiac output, raise BP and HR, increase $\dot{V}$O$_2$ and reduce PaO$_2$ (Weissman 1993). However, Berney et al (2012) state that appropriate and sensitive physiotherapy create no greater metabolic demands than turning the patient into side-lying.

**KEY POINT**
Stress increases oxygen consumption and reduces motivation. Treatment is most effective in a motivated patient. Stress is therefore better prevented than treated.

Orientation

‘When the link to life seems tenuous, the immediate world is clung to desperately...I had a passionate need to make that corner of the world a home’

Moore, 1991

Most patients need a visible clock, calendar, family photographs and personal belongings in an area that they can control, if they are able. They also need information on progress, interpretation of noises and voices, attendance to alarms promptly, explanation of neighbours' alarms, their phone if they are able to talk, and treatment with the same physiotherapist before, during and
after admission to the ICU when feasible. We should enter the patient's space gently, introduce ourselves and explain our purpose.

Sleep and rest
Patients should not, if possible, be woken if asleep, especially when flickering eyelids indicate that they are in the REM phase of the sleep cycle, when tissue regeneration is at its maximum. Sleep is an essential component of rehabilitation in its function of resting muscles in order to benefit from exercise.

Family
If visitors are present, they can either be invited to stay or asked to leave during treatment, depending on the patient’s wish. The presence of relatives means that they can become involved in patient care and are reassured that physiotherapy is not distressing. However, if the patient’s wish cannot be ascertained, it is usually best that visitors are asked to leave.

Communication

‘Do not deny the patient their experience. The most helpful conversation I had was with a physician who acknowledged that I was in a ‘dark’ place... Immediately, I believed she knew I was suffering… I trusted this physician’
Hipp & Ely, 2012

The priority is to establish communication, including:

- clear and explicit explanations, repeated as necessary, including why physiotherapy is necessary, what it will feel like, how long it will last and instructions on how to ask for it to stop
- hearing aid or glasses if used, which reduces the incidence of delirium (Allen et al 2012)
- a speaking valve (Sutt 2017) or a speaking tracheostomy tube, which also facilitates protective expiration after swallowing to help prevent aspiration (Prigent et al 2012)
- referral to speech-language therapy (Radtke et al 2011) a lip-reading interpreter (Meltzer et al 2012) or translator, if required
- communication aids such as word or picture charts (Fig 21.7), smartphone (Fig 21.8), paper and clipboard, a magic slate or computer
systems (Koszalinski et al 2012)


Communication should be aimed at patients rather than over them. Chatting over patients can increase stress more than suction (Lynch 1978). One patient said 'it didn't matter what they talked about, so long as they talked to me' (Villaire 1995).

Anxious patients are not usually helped by being told to relax. The source of anxiety needs to be identified and information provided. If a patient wishes not to communicate, this should also be respected.

**Fig 21.7**

![Image](image1.png)

**Fig 21.8**

![Image](image2.png)
Helplessness

*What do you do when you can’t bear it? What are the alternatives?*  
Rollin, 1976

Helplessness can lead to depression, so the more helpless the patient, the more important is autonomy. Patients can choose whether they would like treatment now or later, if possible, and their preferred position to be left in, if this fits in with nursing needs. If they request, patients should be turned before the allotted time. They can have charge of the TV remote and radio channel, if available, and decide whether they would like to regain their day/night rhythm by being woken in the day or having a sleeping pill at night. Autonomy is particularly important in this situation of unequal power.

Anxiety is reduced by combining factual information with advice that enables patients to be proactive, as much as they are able. Depression is eased by allowing expression of emotion, encouraging independence, using imaginative interventions such as pet visitation schemes (Miracle *et al* 2009) and initiating rehabilitation from the start (Gosselink *et al* 2008). Clinicians also need to identify how much each patient would like to take their own decisions and how much they cede decision-making to staff (Kon *et al* 2016).

**Touch**

ICU patients are extra sensitive to human physical contact as a contrast to the cold clinical procedures to which they are subjected. Therapeutic touch reduces anxiety (Zare *et al* 2010), massage decreases stress (Waldmann 2009 p.71) and reflexology can lessen the need for sedation (Akin *et al* 2014). As always, it should be remembered that individuals and cultures vary and some dislike touch, particularly male-to-female touch.

**Handling unconscious or paralysed people**

*I was imprisoned and people were sitting on me and I just couldn’t get out, because I was restricted where I was and I couldn’t move*.

Darbyshire *et al* 2016
One study found that a third of handling procedures is accompanied by cardiac instability, desaturation or ventilatory distress (Jong et al 2013). Repositioning and suctioning have been identified as the two procedures causing the most pain in ventilated patients (Ayasrah 2016). Forewarning is always required, and a bolus of morphine often needed (Ahlers et al 2012).

**Turning**

*‘To be talked frankly through a complete procedure would help curb the deadly effects of uninformed anticipation’*

---

Brooks, 1990

The longer a patient has been immobile, the more sensitive their cardiovascular system is to position change. A lateral turn in a critically ill patient can cause haemodynamic instability (Shannan et al 2015) or reduce tissue oxygenation by 8-22%, with increased VO$_2$ bearing a greater responsibility than reduced oxygen delivery (DO$_2$) (Vollman 2013). A suggested sequence is the following:

1. Turn off continuous tube feed.
2. Inform the patient, then talk them through each step.
3. Ensure sufficient slack in lines and tubes.
4. Ensure that glide sheets are in place, the team is following the same manual handling protocol and an individual is responsible for the airway and vulnerable lines.
5. Ensure that the team is co-ordinated in relation to care of the skin and joints, e.g. protect heels from friction, avoid using the leg as a lever.
6. Suction oral secretions, as far as above the cuff, to minimise the risk of aspiration (Gentile & Siobal 2010).
7. Support the tracheal tube. Some patients like to hold an endotracheal tube briefly with their teeth during the turn.
8. Say clearly, so that the team and patient can hear, previously-agreed instructions e.g. ‘ready, steady, turn’.
9. Turn smoothly, ensuring that the shoulder joints and head are supported if the patient is paralysed, and that creases in the sheet
are smoothed out after the turn.

10. Check lines, patient comfort, monitors, joint positions, ensure there is no cuff leak.

11. Re-attach continuous tube feed


**Pressure area care**

Pressure sores distress patients and are avoidable. Risk factors are malnutrition, obesity, steroids, diabetes, advanced age, immobility, hypovolaemia and vasopressor drugs (Smit et al 2016).

Anything can be put on a pressure sore except the patient. Hospitals are full of concoctions, but better still is prevention by means of:

- adequate nutrition (Miller et al 2015), especially vitamin C and protein
- regular turning, without friction, and judicious positioning
- specialised beds
- keeping pressure areas dry.

A sacral pressure sore that has developed in supine does not preclude sitting out in a chair, so long as a pressure cushion is used and an upright position maintained to prevent pressure on the sacrum. A time limit should be set and there must be meticulous monitoring of the wound before and after.

**TECHNIQUES TO INCREASE LUNG VOLUME**

*No-one explained...all they said was not to worry about it*

Patient quoted by Thomson 1973

For spontaneously breathing patients, lung volume can be increased by the techniques in Chapter 6. For ventilated patients, the following modifications can be used.

**Positioning**

Positioning is the main physiotherapy intervention for critically ill patients, and may be the only treatment for some patients. Spending too long in supine
encourages basal atelectasis, especially of the left lower lobe because the heart compresses its bronchus (Khan et al. 2009b). Turning from supine to sidelying helps clear lower lobe atelectasis, reduce the risk of pneumonia, promote patient comfort, safeguard pressure areas and increase cardiac output (Thomas et al. 2007). If the patient is lying well forward (Berney et al. 2012), the abdominal contents are prevented from encroaching on lung volume.

Other effects of positioning have been documented:

1. Kinetic beds turn patients continually along a longitudinal axis and help prevent atelectasis (Ahrens et al. 2004).
2. As with spontaneously breathing patients, ventilated patients with unilateral lung pathology normally show optimal gas exchange when lying with the affected lung uppermost (Ng & Ong 2010).
3. Miette (2013) found two studies claiming that side-lying reduced bacterial colonization. This position also improves gas exchange, respiratory mechanics and secretion clearance, shortens duration of mechanical ventilation and, so long as the tracheal tube is kept horizontal, appears to reduce aspiration (Mauri et al. 2010).
4. With the patient horizontal, mucus may be prevented from flowing distally. Bassi et al. (2008) claim that the head-up position may act as a form of reverse postural drainage, facilitating colonization of the airways and possibly pneumonia.

Evidence for head-of-bed elevation is conflicted (Metheny 2013). Raising the head of the bed is said to prevent ventilator-associated pneumonia by minimizing gastroesophageal reflux (GOR), but the semi-recumbent position encourages pooling of secretions above the cuff, and one study which aimed at a head-up position of 45° found this to be achieved for only 15% of the time (Miette 2013). Unless the whole bed is tipped head-up, skin integrity is put at risk (Grap 2005) and head elevation tends to become the slumped position, with abdominal pressure restricting lung volume and, with enteral feeding, increasing GOR (Leng et al. 2011). Head of bed elevation to 45° may also reduce BP and oxygen delivery (Gocze et al. 2013) so monitoring must be continuous.

For patients who are cardiovascularly stable, a tilt table can be used to
gradually achieve an upright position. Neurological patients require particular attention to observation and haemodynamic monitoring during this process. When using a tilt table without a manual control, a hoist sling should be placed under the patient in case of malfunction, after checking that the legs of the hoist fit under the tilt table.

Factors which may limit positioning are abnormal muscle tone, pain, neurological instability such as brain or spinal cord injury, fractures, pressure sores, unstable BP and some invasive support systems such as haemofiltration.

**Neurological facilitation of respiration**

Tidal volume \( (V_T) \) and minute volume can be increased by perioral stimulation or intercostal stretch (Ch.6).

**Deep breathing on the ventilator**

Most patients are on a mode of ventilation that incorporates spontaneous breathing and they may be able to take deep breaths voluntarily. Deep breathing is particularly successful when patients are motivated by watching the results of their endeavours on the \( V_T \) monitor.

**Mechanical aids**

High frequency percussive ventilation reportedly resolves atelectasis that is unresponsive to bronchoscopy, but clinically meaningful outcomes have not been proved (Kallet 2013).

**Manual hyperinflation**

\[ \text{It was by far the most frightening thing that happened to me.} \]

Patient quoted by Rowbotham (1990)

Manual hyperinflation delivers extra volume and oxygen to the lungs via a bag such as a rebreathe bag. Compared to positioning, which is accepted as preventive care for most ICU patients, manual hyperinflation is not used routinely because prophylaxis has not been substantiated, and it comes with
complications.

Terminology

- **Manual ventilation** means squeezing gas into a patient's lungs at $V_T$, e.g. when changing ventilator tubing
- **Manual hyperventilation** delivers rapid breaths, e.g. if the patient is breathless, hypoxaemic or hypercapnic
- **Manual hyperinflation** provides deep breaths in order to increase lung volume, e.g. when treating a person with atelectasis or sputum retention.

Physiotherapy is associated with manual hyperinflation (MH). The words 'bag-squeezing' or 'bagging' are also used, but not in front of patients as they can be misinterpreted, e.g. that the patient is to go into a body bag.

Effects

Benefits of MH are:

- reversal of atelectasis (*Berney et al 2012*)
- sputum clearance (*van Aswegen et al 2013*)
- improved oxygen levels (Fig 18.5) and, with suction, temporary improvement in lung compliance (*Choi & Jones 2005*).

Fig 18.5

(a) Improved gas exchange with MH (*Patman et al 2000*). $\text{PaO}_2: \text{FiO}_2$: oxygen tension in relation to inspired oxygen, **MH**: manual hyperinflation
**Complications**

The complications of MH are an exaggeration of the complications of mechanical ventilation (MV), particularly barotrauma and haemodynamic compromise.

BP may rise or fall, either of which may reduce cardiac output even in people with normal cardiac function (Anning et al 2003). Hypotension is caused by reduced venous return to the heart, and is more pronounced in patients who are hypovolaemic or vasodilated.

For patients on high PEEP, disconnection from the ventilator to attach the bag may not be offset by the benefits of the procedure. In this case, options are to use ventilator hyperinflation or to modify the technique as on p.462.

**Equipment**

A rebreathe Mapleson-C or Water’s bag (Fig.18.6a) is inflated with wall oxygen and comes in 1-3 litre sizes, the 2 litre being used for most adults. It incorporates an expiratory valve which is adjusted to deliver an accurate pressure to the patient, and its compliance allows the clinician to feel the ease of inflation.

Semi-rigid units, e.g. the self-inflating Ambu or Laerdal bag, use room air with added oxygen and were originally designed for resuscitation. The flow and pressure are not easily controlled and they are less responsive to techniques such as the end-inspiratory hold. They have a lower peak expiratory flow and do not appear to clear secretions as effectively as the Mapleson-C bag (van Aswegen et al 2013). It is also suggested that they are less able to improve respiratory mechanics than ventilator hyperinflation (Savian et al 2006). High pressures are avoided by a pressure release valve rather than controlled by the operator. Both bags can be used with a PEEP valve so that pressure is not lost during treatment (Fig 18.6b).
The gas delivered to the patient is usually 100% oxygen. This is safe for patients during the brief period of treatment, but for hypercapnic COPD patients who might be dependent on their hypoxic drive to breathe, and who are breathing spontaneously with no SIMV back-up, an air source and oxygen entrainment might be preferable, with continuous observation of the SpO$_2$ and, if available, end-tidal CO$_2$.

A heat-moisture exchanger (HME) incorporating a bacterial filter is added to the circuit to ameliorate the inrush of cold air that causes discomfort and sometimes bronchospasm.

**Technique**

The following method is suggested:

1. Ensure the patient's fluid and cardiovascular status are optimum.
2. Explain to the patient the purpose of the procedure and that it involves several deep breaths; ensure that they know how to
communicate if they want the procedure to stop, and obtain consent. Ask if they would like extra analgesia or sedation.

3. Ensure that a manometer and HME are connected to the circuit.
4. Position the patient well forward in side-lying (Fig. 18.7). In supine the bases are unlikely to be responsive to hyperinflation because positive pressure favours the more compliant non-dependent regions, especially in the larger right lung (van Aswegen et al. 2013). For patients who cannot turn, close attention to technique (especially nos. 10-11, below) may deliver some extra volume to the lung bases in supine. If a different lung region is to be targeted, it is best placed uppermost.

**Fig 18.7**  
Manual hyperinflation targeting the L lower lobe, which is being palpated to check for optimum expansion

5. Check monitors after the turn. MH should not be started until cardiovascular stability is assured in the new position.
6. Observe chest expansion.
7. Ensure that the patient is free of distractions or nursing interventions.
8. Connect the bag to the oxygen with a flow rate of 15 l/min, turn off the low-pressure alarm, turn the ventilator and humidifier to standby, disconnect the patient from the ventilator and connect
them to the bagging circuit.

9. Rest tubing on the sheet to avoid pulling on the tracheal tube, tell the patient when to expect ordinary breaths and when deep breaths. Using two hands, squeeze the bag a couple of times at $V_T$ to acclimatize the patient and to assess lung compliance.

10. Then give slow smooth deep breaths, adjusting the valve to increase pressure until expansion is greater than on MV. It is suggested that a breath at 150% of $V_T$ reverses the adverse effects of suction, and twice $V_T$ reverses atelectasis (Maxwell & Ellis 2002). Watch the manometer to ensure a safe and effective pressure (see next page). Slow inspiratory flow minimizes turbulence and the risk of alveolar damage (Silva et al 2012).

11. Hold maximum pressure at end-inspiration for one or two seconds in order to encourage the filling of poorly-ventilated alveoli, especially if atelectasis is the problem. This is similar to the plateau pressure in Fig.17.4a. Haemodynamically unstable patients should not receive this end-inspiratory hold, and are best given one deep breath interspersed with several tidal breaths, or if the patient is able, spontaneous breaths.

12. Release the bag sharply to simulate a huff, especially if sputum retention is the problem.

13. Ensure adequate time before the next inflation to avoid build up of intrinsic PEEP or cardiovascular instability, while watching the $SpO_2$ monitor.

14. Throughout, watch the chest for expansion, the face for distress and the abdomen for signs of unwanted active expiration. The more alert the patient, the greater is the need to co-ordinate with their breathing. Stop if the patient's facial expression or the monitors indicate distress, or if crackles indicate that secretions have been mobilized and suction is required. If crackles are heard or the patient coughs, give normal $V_T$ breaths until the patient is suctioned, to avoid pushing the secretions back down. If MH causes no change, stop after about 6 breaths for re-assessment.
15. Reset the ventilator, advise the patient and reconnect them to the ventilator. Observe chest movement and monitors, auscultate the chest.

16. Repeat the cycles until auscultation indicates that volume is restored or secretions cleared. If this is not achieved within 5-10 minutes of accurate MH, it is unlikely to occur in this session.

17. To maintain the benefits of MH, the side-lying position should be maintained afterwards, ensuring that the tracheal tube is kept horizontal, as long as this position is comfortable for the patient and convenient for nursing procedures.

**Pressures**

Each bed space should be supplied with its own manometer to ensure effective and safe pressures (Davies & Igo 2004) and to reduce complications (Hila & Ellis 2002). The following are guidelines:

1. For MH to be effective in normal lungs, inflation to 40 cmH₂O is required to reverse atelectasis (Novak et al 1987, Rothen et al 1999).

2. For MH to be safe in normal lungs, inflation to 50 cmH₂O is considered acceptable so long as PEEP is maintained to stabilize the alveoli (García-Fernández et al 2013), while two hyperinflations to a maximum 60 cmH₂O have been used safely by Khanna et al (2013).

3. For MH to be safe in diseased or damaged lungs, it is impossible to identify a maximum safe pressure. For people with acute respiratory distress syndrome (ARDS), Gattinoni et al (2002) claim that 45 cmH₂O is safe and Oczenski et al (2005) show no evidence of complications using continuous positive airway pressure (CPAP) at 50 cmH₂O for 30 secs, using the prone position to protect vulnerable lung regions. However few physiotherapists would risk using these pressures in people with such damaged lungs.

All the above studies had limitations, and efficacy should be monitored throughout, to ensure that the minimum effective pressure is used.
Contraindications

MH should be avoided with the following:

- extra-alveolar air, e.g. undrained pneumothorax, subcutaneous emphysema or bulla
- bronchospasm causing peak airway pressures above 40 cmH₂O, in particular with acute asthma.

Precautions and modifications

MH should be avoided or modified with the following:

- patients at risk of barotrauma, e.g. those with emphysema, fibrosis, pneumocystis pneumonia or ARDS
- rib fracture because a covert pneumothorax might be present; if MH is essential, the scan should be scrutinized or a radiologist's opinion sought
- pneumothorax with a chest drain
- air leak, as demonstrated by air bubbling through a chest drain bottle
- hyperinflated lungs with intrinsic PEEP; if MH is essential, a longer expiratory time may reduce the risk of further gas trapping
- bronchopleural fistula
- recent pneumonectomy because of the risk of a bronchopleural fistula; the fifth to 10th postoperative days are when the healing stump is most vulnerable
- BP that is low, high or unstable; if MH is essential in hypotensive patients, they should be maximally stabilized first and the technique should be brief, with prolonged expiration and no end-inspiratory hold, in order to facilitate venous return
- hypovolaemia; if MH is necessary, the above modifications are advised
- arrhythmias or frequent ectopics
- during renal dialysis if this destabilizes BP
- acute brain injury, especially if there is no intracranial pressure monitoring
- haemoptysis of unknown cause
- severe hypoxaemia with PEEP above 10 mmHg because disconnection of the patient from the ventilator entails loss of PEEP; if MH is essential, desaturation can be minimized by:
  - incorporating a PEEP valve in the circuit, though this may slow expiratory flow
  - manually preventing the bag fully deflating at end-expiration
  - increasing the flow rate, and increasing the speed of the procedure to prevent deflation and augment oxygenation, but only if the patient is haemodynamically stable
  - ventilator hyperinflation.

### Ventilator hyperinflation or recruitment manoeuvres

To reduce some of the complications of manual hyperinflation, alveolar recruitment can be aided by hyperinflation through the ventilator. The following have been described:

1. In volume control, $V_T$ is gradually increased until peak airway pressure reaches 40 cmH$_2$O, then six hyperinflation breaths are delivered before returning the ventilator to its previous settings. After 30 seconds rest, the process is repeated until the desired outcome is achieved, or complications such as patient distress or haemodynamic instability supervene. This can improve lung compliance and clear secretions, with the assumption that it would increase lung volume similarly to manual hyperinflation. The technique allows the flow pattern to be observed on the screen, to ensure full exhalation before the next breath is delivered, thus reducing the risk of intrinsic PEEP (Berney & Denehy 2002).

2. In pressure control, a stepwise increase in PEEP up to 15 cmH$_2$O and $V_T$ up to 18 ml/kg are administered until a peak inspiratory pressure of 40 cmH$_2$O is reached, then maintained for 10 cycles. This has shown improved oxygenation immediately after heart surgery, with stabilization of newly-recruited alveoli by ongoing PEEP (Claxton et al 2003).
3. The pressure and/or time of the positive pressure breath is increased, e.g. peak pressure of 45 cmH₂O and PEEP of 35 cmH₂O for one minute followed by PEEP of 10 cmH₂O (Halter 2003).

4. Inflation pressure is increased to 30–40 cmH₂O for 30–40 seconds, inspiratory pause is extended, three consecutive sighs are delivered at plateau pressure 45 cmH₂O, or PEEP raised to 40 cmH₂O with pressure control at 20 cmH₂O above this level for two mins followed by on-going PEEP at 25 cmH₂O (Hess & Bigatello 2002).

5. In SIMV, FiO₂ is increased to 1.0, inspiratory time adjusted to 3-5 secs, RR to 6-8 bpm and Vₜ to 15 ml/kg body weight, increasing at first by 150 ml per breath until a peak pressure of 40 cmH₂O is achieved. Four sets of 8 ventilator breaths per treatment are claimed to produce the same outcomes and safety profile as MH (Dennis et al 2012b).

6. Inflation pressure is increased to 40 cmH₂O for 10 secs (Hedenstierna 2012).

The benefits of these strategies are not sustained unless high PEEP is maintained (Hess & Bigatello 2002).

The following complications of ventilator hyperinflation have been identified:

- haemodynamic instability caused by sustained positive pressure, e.g. 20 sec inflations at 40 cmH₂O for 8 mins (Nunes et al 2004)
- alveolar overdistension caused by pressure support of 50 cmH₂O and PEEP levels above optimal compliance (Villagrà et al 2002),
- for patients with acute lung injury, desaturations, arrhythmias and air leaks following 40 cmH₂O of CPAP for 40 secs up to four times a day (Fan et al 2012)
- gas trapping, which can be prevented by ensuring that exhaled Vₜ is as long as inhaled Vₜ.

Recruitment without overdistension may be achieved by periodic ventilator deep inflations (Allen et al 2006). Slow moderate-pressure inflations appear to achieve the same benefit as vital capacity inflations, with less risk of complications (Lowhagen 2011) and thoracic tomography has been suggested for safety (Dueck 2006).
Recruitment manoeuvres were developed to maintain alveolar stability and offset the lost lung volume caused by lung protective ventilation strategies for ARDS (Ch.19), not primarily to expand collapsed lung units. Most studies do not report on whether complications were documented, and some of the pressures are alarmingly high for patients with damaged lungs. Their safety has been questioned (Hess 2002), particularly after 3-5 days into the course of ARDS, when the lungs are at their most fragile. Martin (2009) claims that they improve radiographic images of the lungs but not patient outcomes, begging the question as to whether these ‘open lungs’ are happy lungs or simply pretty lungs.

Manual hyperinflation, which is designed to clear secretions as well as increase volume, has been described as the treatment of choice for physiotherapists (Barker & Adams 2002). However, physiotherapists will probably use both, depending on the outcomes, and further research may tip the balance in favour of using the ventilator rather than a bag to reinflate lungs or clear secretions.

PRACTICE TIP
Set up a test lung with a spare ventilator, using a spontaneous mode with high flow, and display the pressure-volume loop. Practice hyperinflation through the ventilator and relate it to $V_T$ and the pressure attained with MH, including maintenance of manual PEEP. The screen can be frozen to identify details.

TECHNIQUES TO CLEAR SECRETIONS
The most effective interventions to clear thick secretions in intubated patients are hydration, humidification and mobilization (Halm 2008). For intubated people who cannot mobilize, regular turning will help keep secretions moving. Hydration in the ICU is normally aimed at optimum haemodynamic status rather than secretion clearance, but the physiotherapist can have a say on ward rounds. Other interventions are suction as required, and sometimes manual techniques or manual hyperinflation.

Humidification
Humidification is provided by a **hot water humidifier**, with temperature alarms set at maximum 37°C and minimum 30°C. An alternative is a **heat-moisture exchanger** (HME), which may be adequate for short term use in well hydrated patients who do not have excessive or thick secretions. Added to the information in Ch.8, the following arguments have been made about the two systems:

1. Compared to hot water humidification, HME’s are less able to increase mucociliary transport (Nakagawa *et al* 2004). They quadruple the risk of endotracheal tube (ETT) obstruction (Branson 2009) and increase the work of breathing such that Hilbert (2003) suggests the support level for patients on pressure support ventilation be increased by 8-15 cmH₂O.

2. HME’s increase dead space and reduce CO₂ clearance (AARC 2012) and allowance should be made for a drop in PaCO₂ when the device is removed (López *et al* 2000).

3. If mechanical ventilation (MV) is expected to last more than a few hours, a heated humidifier has been advised (Ryan *et al* 2002), although one of the authors of this study was employed by a humidifier company.

4. Lucato *et al* (2005) found that resistance increased within hours of applying an HME. They stated that patients with hypersecretory disease will need a hot water humidifier straight away.

5. In contrast, Branson (2007) suggests that a heated humidifier should be used from the outset only if intubation is expected to last >96 hours.

*Fig 18.8* shows the risk of ETT occlusion with different HME’s (p.228) and a hot water humidifier.
Saline nebulizers are loved by ICU bacteria. If they are indicated, attention should first be given as to why the humidification system is inadequate. A rather balmy scenario is to intersperse an HME with saline nebulizers.

**Postural drainage**

The side-to-side positioning applied to most patients is usually adequate for postural drainage and has demonstrated increased sputum yield during MH (Berney et al. 2012). A head-down tilt may be required (Berney 2004) but gravity is thought to have less of an effect on the movement of secretions than flow bias (Graf & Marini 2008), and the position is unwise for most patients on MV, especially if haemodynamics are compromised. Kinetic beds appear to reduce the incidence of pneumonia (Chung & Mueller 2011).

**Manual techniques**

Percussion or vibrations are not required routinely, and when combined with postural drainage have not been shown to reduce ventilator-associated pneumonia (VAP) or atelectasis (Branson 2007). Vibrations cause less airflow than MH, but manual techniques do not usually cause significant haemodynamic problems (Wong et al. 2006) and they may help to clear excessive or thick secretions.

Vibrations with MH may help reduce intrinsic PEEP by ensuring full exhalation before the next hyperinflation, and, when started just before termination of the end-inspiratory hold, they can increase lung volume (Shannon et al. 2010).

‘Rib cage compression’, which may have similar effects to rib-springing, can reduce lung volume, hinder gas exchange and may actually reduce sputum clearance (Unoki et al. 2004) though this may not occur if followed by strategies to restore volume.

**Flow bias**

Expiratory flow greater than 10% above inspiratory flow facilitates mucous
movement towards the mouth (Ntoumenopoulos et al. 2013). The physiotherapist can discuss ventilator settings with the intensivist if an extra boost to mucous clearance is required.

**Manual hyperinflation**

If not contraindicated, MH assists sputum clearance, with emphasis on rapid release to reinforce expiratory flow bias (van Aswegen et al. 2013).

**Mechanical aids**

Both bubble PEP (Jones et al. 2013c) and the Flutter (Chicayban 2011) can be slotted into the exhalation port. High frequency percussive ventilation may be used with both spontaneous and mechanical ventilation, and an insufflation-exsufflator can be connected to the tracheal tube to facilitate a cough, although disconnection from the ventilator limits its use (Kallet 2013).

**Suction**

*The coughing, gagging and choking spasms produced by the sink plunger technique were terrifying*  
Patient quoted by Day et al. (2002)

Suction stops the patient breathing and may cause pain (Paulus et al. 2013) but, so long as no ‘sink-plunger’ technique is employed, it is normally less harrowing than nasopharyngeal suction, especially if the patient is fully informed and talked through the process.

Secretions in peripheral airways are unlikely to contribute to airflow obstruction because of the number of alternative airways, but if stagnant they may contribute to infection. Secretions in the large airways, where there is less collateral ventilation, may interfere with gas exchange or cause plugging. Suction should be carried out when indicated and if secretions are accessible (AARC 2010).

**Complications**

Suction may cause:
• ↓ lung volume due to negative pressure and, with open suction, disconnection from the ventilator (Ntoumenopoulos 2013)

• ↑ oxygen demand (White et al 1990)

• hypoxaemia, arrhythmias and mucosal injury (Chang 2014 p.174)

• bronchospasm (AARC 2010)

• repeated inoculation of the lungs from the biofilm lining the tracheal tube, releasing up to 60,000 colonies of bacteria with each suction pass (Lewes 2002)

• bleeding (Maggiore et al 2013), due to clotting disorder, heparinization or suction that is rough, frequent or with dry airways

• bradycardia in certain patients, which can be attenuated by nebulized atropine (Brooks et al 2001).

Most complications can be reduced by preoxygenation, post-suction hyperinflation and optimal technique.

**Catheters**

The smallest effective catheter should be used, which must be no more than half the internal diameter of the tracheal tube, a larger size causing more mucosal damage than the suction pressure (AARC 2010). A size >12 FG tends to reduce PaO2 and tidal volume, and increase pulmonary artery pressure and PaCO2 (Almgren et al 2004).

A closed-circuit in-line catheter (Fig.18.9) is sealed in a protective sleeve and becomes part of the ventilator circuit. It brings the following advantages:

• no disconnection from the ventilator, leading to less desaturation, less volume loss (Maggiore 2003), less airway collapse, maintenance of PEEP and attenuation of pressure changes (Palazzo & Soni 2013)
• less risk of cross-infection, so long as the catheter is not changed every day (Lorente et al 2006).

Open suction requires disconnection of the patient from the ventilator but has advantages:
• less likelihood of the preserved PEEP blowing mucus back into the lungs, which could require compensation with higher suction pressures (Branson 2007)
• according to a meta-analysis, shorter time on MV and lower colonization rates (Siempos et al 2008)
• ability to use the rocking thumb technique (Ch.8) rather than obligatory use of intermittent suction to relieve pressure.

Although in-line catheters should reduce cross infection, there appears to be no difference in pneumonia or mortality for the patient (Subirana 2010).

![Fig.18.9](image)

Closed circuit catheter connected to the tracheal tube via a T-piece. The irrigation port allows the passage of saline for loosening secretions or cleaning the catheter.

**Preliminaries**

Pre-oxygenation is required for all patients (AARC 2010), the ‘100% oxygen’ button being the simplest method. Self-ventilating patients may find it helpful subjectively to hyperventilate beforehand. Indications, contraindications and technique for nasopharyngeal suction are in Ch.8, with modifications for intubated patients below.
**Technique for closed-circuit suction**

Each unit will have its own protocol, but some tips are that:

1. Extra gloves are not necessary.
2. The suction pressure is checked with the vacuum on, i.e. with the vacuum control valve unlocked.
3. If the MH bag is connected during suction, its valve must be kept open.
4. The T-piece should be supported throughout.

During catheter insertion, it is standard practice to avoid suction in order to minimize mucosal damage, although Lewis (2002) claims that greater risk is caused without suction due to bacteria being pushed further down the airways. Standard practice is advised until further research emerges.

During catheter withdrawal, some patients voluntarily hold their breath longer than necessary, in which case they can be told, once the catheter has been withdrawn back to the tracheal tube, that they can breathe again. Unlike with nasopharyngeal suction, it is not always clear to patients the point at which they can breathe.

The AARC (2010) claim that shallow suction, i.e. only as far as the end of the tracheal tube, reduces complications, but Ntoumenopoulos (2013) suggests but this is based on neonatal literature and may be counterproductive.

If more than one suction pass is necessary, oxygenation must return to baseline before repeat suction. Suction should be terminated if HR slows by 20 or increases by 40 bpm, if BP drops or arrhythmias develop. The final suction should be outside the endotracheal tube, with the patient’s permission, to reach secretions above the cuff, which helps prevent microaspiration and VAP (Hess 2002).

Difficulty passing the catheter may be due to kinking of the tracheal tube, herniation of the cuff over the end of the tube, or the patient biting the tube. Biting requires reassurance and sometimes insertion of a bite block or Guedel airway.

Vibrations are unnecessary during suction because, unless the patient is paralysed, the enforced coughing accompanying suction overrides outside
influences. Occasionally apical vibrations can be used to stimulate a cough.

**Modifications for open suction**

Open suction entails inserting a sterile catheter directly into the tracheal tube. Aseptic technique should be pristine: the catheter must not touch the rim of the tracheal tube on insertion and sterile gloves are mandatory. Boxed gloves are not sterile and Rossoff (1995) found that half were contaminated. The same catheter should not be used for repeat suction.

For access to the left main bronchus, Branson (2007) recommends turning the head to the right, or using an angled (coudé-tip) catheter with the tip directed towards the left main bronchus. These techniques are used by anaesthetists, but most physiotherapists do not find them necessary because they usually mobilize secretions sufficiently beforehand.

**Reducing hypoxaemia**

Returning the patient to the ventilator at normal settings between suction passes is not adequate to prevent desaturation, and the following are suggested:

1. Manual hyperventilation or hyperinflation helps reverse hypoxaemia and atelectasis respectively, if not contraindicated.

2. Pressing the ‘100% oxygen’ button whenever the patient is on the ventilator helps maintain oxygenation.

3. During closed suction, the triggering function of the ventilator can be used to deliver pressure-supported breaths at 40 cmH$_2$O (Maggiore 2003).

4. After suction, ventilator hyperinflation can be used, e.g. 30 seconds of peak inspiratory pressure at 35–40 cmH$_2$O and PEEP at 15 cmH$_2$O (Heinze et al 2011).

5. No more than 10 seconds should be spent with the patient unable to breathe. If longer is needed, this can be accommodated during open
suction by withdrawing the catheter sufficiently to prevent coughing, removing the thumb from the catheter port to release the vacuum, occluding the catheter mount opening (with the catheter still in situ), then giving the patient 100% oxygen by the bag or ventilator. Suction can be resumed when the patient has stabilized. This avoids unnecessary removal and reinsertion of the catheter, which increases the infection risk.

**Saline instillation**

The need for saline suggests that humidification is inadequate. If this has been corrected but secretions are still too thick to clear, normal saline can be instilled into the lungs. This can increase the yield of sputum (Schreuder & Jones 2004) and reduce VAP (Caruso et al 2008), possibly by rinsing out bacteria from the ETT or by stimulating a cough. However, other studies have shown an increased risk of infection, so it should only be done if essential (Roberts 2009).

There are some doubts about the mechanism of saline instillation because mucus does not incorporate water easily (Halm 2008). Its mode of action may be to physically dislodge encrusted secretions or to stimulate a cough.

The procedure should not be prolonged, otherwise gas exchange is compromised (Young-Ra 2002) and breathlessness can persist for up to 10 minutes (Halm 2008). The following is suggested:

1. Warm the saline, e.g. by always keeping saline in a pocket so that it is readily available at body temperature.

2. When opening the container, the open ends must not be touched even with gloved hands.

3. Advise the patient, then administer the saline slowly to prevent them feeling as if they are drowning.

4. No more than 5 ml at a time is advised (Bostick & Wendelgass 1987), but more can be used if accompanied by increased ventilator FiO\textsubscript{2} and if
interspersed with manual or ventilator hyperventilation to prevent desaturation.

5. If the aim is to loosen secretions (rather than dislodge debris at the end of the tracheal tube), the patient should be turned after instillation, so that the instilled side is uppermost for treatment. This can be coordinated with the patient’s regular turns to avoid unnecessary disruption. Suction performed after the turn, and if required after manual techniques, is then well timed to clear both secretions and saline.

Tips for open suction:
- do not allow the saline to splatter over the tracheostomy dressing, or indeed over anything
- if saline instillation does not clear the secretions, it can be delivered more distally by injecting it through the catheter.

Tip for closed-circuit suction:
- hold the T-piece upwards to help the passage of saline, unlock the vacuum control valve, advance the catheter, and inject saline through the side port just before inspiration so it is carried distally with the next breath.

Patients who are able can use the yankauer sucker to clear their mouth afterwards. They should not be turned or moved until stable.
Clinical reasoning

Don’t forget the ‘Limitations’ section in the literature. Fig 18.10 shows a ‘positive’ outcome from saline instillation, but the authors sensibly point out, in their Limitations paragraph, that the sputum weight included the saline.

Fig 18.10
Mean ‘sputum weight’ after suction with and without saline instillation (Hudak et al 1996)

EXERCISE AND REHABILITATION

Getting me out of bed has always made me feel like the team and I are working together, not against each other. This simple action helps ground me in the environment and helps my mind, which seems to work overtime to understand the stimuli that bombard it.

Patient quoted by Hipp & Ely (2012)

Increasing numbers of ICU patients now survive (Fan 2010), which has raised the profile of rehabilitation. Autonomy is at the heart of rehabilitation, and patients who are involved in their own care have found it easier to move on after discharge (Karlsson & Forsberg 2008). Rehabilitation should be initiated immediately (Mendez-Telle 2012), facilitated by nutritional supplements (Chambers 2009) and the concept of the ‘animated ICU’ in which sedation is minimized (Hall 2010).

Rehabilitation is recommended for a minimum 45 mins a day (Danbury
et al 2013). The importance of exercise is underlined by the detrimental effects of immobility (Ch.1) and the reported outcomes of ICU rehabilitation:

- brain protection by reducing delirium (Hopkins et al 2012)
- lung protection by modulating inflammation in the early phase of acute lung injury (Goncalves et al 2012)
- ↑ muscle strength, ↓ length of ICU stay (Renaud et al 2013)
- ↑ exercise tolerance and quality of life, ↓ dyspnoea, sedation and re-admission (Adler & Malone 2012)
- ↑ functional outcomes, ↓ days in hospital (Stiller 2012)
- ↑ respiratory muscle strength, sphincter control and ventilator-free time (Porta et al 2005)
- ↑ secretion clearance (Morris & Afifi 2010 p.228)
- ↓ ICU myopathy, systemic inflammation, insulin resistance and microvascular dysfunction (Fan 2010).

Early mobilization, in particular, has shown:

- ↓ lung and vascular complications (Clark et al 2013)
- ↓ delirium (Porter & McClure 2013)
- ↓ time on the ventilator, leading to ↓ atelectasis, pneumonia and the cognitive and functional limitation that can otherwise continue for years after discharge (Vollman 2013)
- ↓ ICU stay and ↑ percentage of patients discharged home (Engel et al 2013)
- ↓ morbidity and mortality (Hopkins et al 2012).

One obese patient had her pre-morbid exercise tolerance of 3 metres increased to 37 metres during her 9-day stay on the ICU (Korupolu et al 2010).

**Passive exercise**

Clavet et al (2008) found that a third of patients who spent more than 2 weeks in the ICU developed joint contractures sufficient to impair function. This can be prevented by passive movements, which also maintain sensory input and comfort, possibly preserve muscle architecture (Kress 2013) and, if done frequently, reduce the risk of myopathy (Renaud et al 2013). Inclusion of the shoulder joint brings a modest increase in minute volume (Loram & de Charmoy
Special attention is required for the Achilles tendon, hip joint, joints around the shoulder, two-joint muscles and, for long-term patients, the jaw and spine. Continuous passive motion reduces protein loss (Morris 2007), pain and muscle inflammation (Amidei 2013), and a stiff chest wall may respond to stretching exercises including manual rotation of the thorax in time with the ventilatory cycle (Leelarunggrayub et al 2009), while ensuring that the tracheal tube is stabilized.

A femoral catheter precludes all but minor hip flexion (Perm et al 2013). All ICU staff need advice on care of the joints, especially the shoulder, which is the most commonly reported joint affected by subsequent chronic pain (Battle et al 2013a). Patients with fractures, burns or altered muscle tone need input from specialist colleagues, and those with impaired circulation to the peripheries due to septic shock need multidisciplinary intervention. To prevent overstretch of flaccid anterior tibial muscles, a pillow at the end of the bed can be placed against a vertically-placed tray to maintain plantigrade.

There is some limited evidence of benefit from neuromuscular electrical stimulation (Williams & Flynn 2014) or functional electrical stimulation (Parry et al 2012). For affluent ICUs, whole-bed vibration helps stimulate neuromuscular activity (Ritzmann 2013).

**Active exercise**

---

*No modern ICU can match the body’s sophisticated system for delivery of biochemical compounds during exercise.*

---

Woodard & Berry (2001)

Exercise helps maintain conditioning and reduce inflammation (Winkelmann 2007). Benefit has been shown from resistive exercises (Gosselink et al 2008), functional exercises such as turning in bed or sitting over the edge of the bed (Chiang et al 2006), and Wii (Kho et al 2012). Specific effects include the following:

1. Arm strengthening for 20 minutes a day improves strength, mobility and dyspnoea (Porta et al 2005).
2. Inspiratory muscle training twice daily up to Borg score 6-8 can progress exercise tolerance and ADL (Chang et al 2005).


**KEY POINT**
Active little-and-often exercise is required for all patients who are willing and able

An exercise programme can be maintained for patients who are on inotropic support (Macauley 2012) but vigorous active exercise should be avoided because of limited cardiovascular reserve. Input from the dietician is advisable (NICE 2009), and patients, nurses and relatives will be motivated by an exercise diary to encourage progression (App B).

**Mobilization**

*The notion that hospitalization, even in the ICU, mandates full bed rest is changing* Kress (2013)

An attempt should be made to stand all patients for whom it is safe (Box 18.1) as soon as they are responsive to verbal stimulation (Kress 2013). With careful management, observation and monitoring, patients can be mobilized with endotracheal tubes (Bahadur et al 2008), femoral catheters (Perm et al 2013), other central lines, vasoactive drugs, renal replacement therapy, or with acute lung injury or delirium (Vollman 2013). Solicitous attention to lines and tubes is required, and wheeled walkers with attachments to carry equipment are helpful.

The following complications of mobilization have been reported in a systematic review that included mechanically ventilated patients with central lines or on haemodialysis:

- ↓SpO₂ (the commonest adverse event)
- unstable BP
- falls
- loss of nasogastric tube
- loss of arterial line
- extubation

This list should not prevent mobilization but is a useful reminder of the vigilance required. Although a femoral line can be managed, some physiotherapists encourage their teams to site these elsewhere when possible.

Long term patients may be excited at the prospect of their much-awaited first expedition out of bed, and some are then disillusioned by the extent of their weakness and fatigue, especially if they have lost the comprehension as well as the ability to walk. One patient stated: ‘I didn’t know how to walk any more’ (Strahana & Brown 2005).

Prior to mobilization, the feed is stopped, and increased ventilatory support may be needed at first, with brief sessions to avoid fatigue. The head of the bed is raised before the patient sits up over the edge of the bed, from where they swing their legs. After lowering the bed until their feet reach the floor, the patient stands and their colour and monitors are kept under observation, especially pallor, dizziness, unstable cardiovascular status or reduced SpO₂. Standing without walking should be brief to prevent venous pooling. Some beds provide a chair position to facilitate mobility.

For patients able to go further than walking on the spot, mobile monitoring and either a rebreathe bag or a portable ventilator on a trolley can be used. Adventurous patients aim to exercise to 50-60% of maximal HR (Stiller 2007). The retinue should be followed closely by a wheelchair.

Getting dressed is a good morale booster, done in a separate session and with the help of the occupational therapist if required. Occupational therapy is recommended from the onset of MV (Pohlman et al 2010) and, when combined with early mobilization, leads to earlier functional independence (Hodgson et al 2012).

With these precautions, Leditschke et al (2012) were able to mobilize their patients on most days, and Nava (1998) showed how a little-and-often but intensive rehabilitation programme led to ‘dramatic improvements’ even in patients unable to wean (Nava 1998). Clark (1985) documents a patient
describing how visits outside helped to 'maintain my sanity'. The gym is also a useful destination, and even the pool for some patients.

For patients unable to stand, sitting in a chair helps to prevent hypovolaemia, redistribute skin pressure, maintain muscle length, assist orientation and load vertebrae to limit calcium loss and promote cartilage nutrition. Tipping chairs are useful for patients with orthostatic intolerance, and tilt tables can benefit those with low lung volume, muscle weakness, pressure sores and venous pooling (Chang et al 2004).

<table>
<thead>
<tr>
<th>System</th>
<th>Factors that may limit mobilization</th>
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<tbody>
<tr>
<td><strong>Cardiovascular</strong></td>
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<tr>
<td>MAP</td>
<td>&lt;65 mmHg</td>
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<td></td>
<td>&gt;20% recent variability</td>
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<tr>
<td>HR</td>
<td>&lt;40 or &gt;130 bpm</td>
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<td>Cardiac</td>
<td>Cardiac ischaemia, new MI, unstable ECG, unstable angina</td>
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<td></td>
<td>Arrhythmia requiring new drug</td>
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<td></td>
<td>Temporary pacemaker</td>
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<tr>
<td>Other</td>
<td></td>
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<tr>
<td>haemodynamic</td>
<td>Inotropes, vasoactive drugs especially new vasopressor, $\beta$-blockers</td>
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<tr>
<td></td>
<td>Bleeding, including oesophageal varices</td>
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<td>Platelet count &lt;20,000 mm$^3$</td>
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<td>PE or DVT not yet medically stable</td>
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<td></td>
<td>Orthostatic hypotension</td>
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<td><strong>Respiratory</strong></td>
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<tr>
<td>$SpO_2$</td>
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<td>$PaO_2/FiO_2$</td>
<td>&lt;300</td>
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<tr>
<td>RR</td>
<td>&lt;8 or &gt;35/minute</td>
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<tr>
<td>Ventilator</td>
<td>PEEP &gt;10 cmH$_2$O</td>
</tr>
<tr>
<td></td>
<td>Asynchrony with ventilator</td>
</tr>
<tr>
<td></td>
<td>Insecure airway</td>
</tr>
<tr>
<td></td>
<td>Pressure support &gt;20 cmH$_2$O or SIMV &gt;18 bpm</td>
</tr>
<tr>
<td></td>
<td>$FiO_2$ &gt;0.6</td>
</tr>
<tr>
<td><strong>Neurological</strong></td>
<td></td>
</tr>
<tr>
<td>Brain injury</td>
<td>Increased ICP or recent surgery</td>
</tr>
<tr>
<td>Spinal cord lesion</td>
<td>Unstable injury</td>
</tr>
<tr>
<td><strong>Orthopaedic</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unstable fracture</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limited ability to respond to commands</td>
</tr>
<tr>
<td></td>
<td>Haemoglobin &lt;7 g/100 ml or acute ↓ in Hb</td>
</tr>
<tr>
<td></td>
<td>Split skin graph, some vascular operations</td>
</tr>
<tr>
<td></td>
<td>Blood sugar &lt;3.5 mmol/L,</td>
</tr>
<tr>
<td></td>
<td>Recent eye surgery</td>
</tr>
<tr>
<td><strong>Contraindications, or factors indicating that activity should stop</strong></td>
<td></td>
</tr>
<tr>
<td>Request by patient to stop, or visible distress</td>
<td></td>
</tr>
<tr>
<td>Dizziness</td>
<td></td>
</tr>
<tr>
<td>New onset chest pain</td>
<td></td>
</tr>
<tr>
<td>Change in colour</td>
<td></td>
</tr>
<tr>
<td>↓ BP or HR</td>
<td></td>
</tr>
<tr>
<td>RR &gt;35/min sustained for &gt;60 secs</td>
<td></td>
</tr>
<tr>
<td>Change in heart rhythm</td>
<td></td>
</tr>
<tr>
<td>$SpO_2$ &lt;85%</td>
<td></td>
</tr>
</tbody>
</table>

*MAP: mean arterial pressure, MI: myocardial infarct, HR: heart rate, PE: pulmonary embolus, DVT: deep vein thrombosis, PEEP: positive end-expiratory pressure, SIMV: synchronised intermittent mandatory ventilation*
**End of treatment session**

After treatment, the following are suggested:

1. Check that all alarms have turned themselves back on.
2. Ensure the patient’s nurse knows that treatment is finished.
3. Ensure the call bell and other requirements are within reach of the patient.
4. Ensure that lines are in view.
5. Reassure the patient that they are not being left alone and that their lines are safe so that they do not feel inhibited from moving.
6. For a side-lying patient, check that their ear is not folded over.
7. Check any individual concerns, e.g. anxiety about facing a wall.
8. Tell the patient the time and ask if they need further information.
9. If a rest is required, liaise with the nurse about dimming the light and using eye shades.

**Transfer from the ICU**

*You’d gone from this hugely protective critical care to this sort of hit and miss uncoordinated service*  
Patient quoted by Field *et al* (2008)

For patients who have been under constant supervision, transfer to the ward is a vulnerable time as well as bringing relief at reaching a milestone. Pre-emptive strategies to minimize relocation stress include early identification of risk factors (*Williams et al* 2010), restoration of sleep patterns, information packs for the patient and family, phased reduction of bedside equipment, a visit from the patient’s named ward nurse, an exit interview and follow-up outreach (*Field et al* 2008). Patients may be surprised at being too weak to pick up their tablets or press the buzzer. Relocation management is particularly important for older patients, whose ICU mortality is the same as younger patients but post-ICU mortality higher (*Christensen 2013*).

Premature discharge from the ICU increases mortality (*Danbury et al* 2013), and risk stratification tools should be used (*Hosein et al* 2013). Night time
discharges should be documented as an adverse incident (NICE 2007).

When I was moved from intensive care to the general ward I felt as if my life support system had been ripped away

Moore (patient), 1991, p.12

Follow up

She had offered to peel the potatoes and managed 4 potatoes in 40 minutes, then had to have an hour’s rest before peeling the other four

Jones & Griffiths 2002, p.54

After discharge, longer-term patients require access to a multidisciplinary Follow-up Clinic (Danbury et al 2013). Physiotherapy input is aimed at musculoskeletal problems and on-going rehabilitation. Without follow-up, the time taken to return to the previous level of activities is typically 9-12 months (NICE 2009), with only half able to return to work (Pawlik 2012). Significant functional improvements can be achieved even for patients who are ventilator-dependent (Sobush et al 2012), and structuring rehabilitation on the ICF model helps prevent ‘post-intensive care syndrome’ (Iwashyna & Netzer 2012).

A dedicated gym class enables patients to find support from others who have been through a similar experience, support which neither professionals nor family can provide. For example, one young patient had not been able to come to terms with attempting to hit a nurse while hallucinating, despite reassurance from staff. ‘Oh that’s nothing to what I tried to do’ said a fellow patient on the neighbouring exercise bike, immediately lifting the burden from the young man.

‘Strikingly high’ rates of psychological morbidity have been found in ICU survivors (Wade et al 2012), including a 25-50% incidence of depression (Vest et al 2011). Anxiety and depression relate to delusional memories (Ringdal et al 2010), and cognitive and emotional difficulties are virtually ubiquitous (Hopkins 2009). Patients who have experienced a life-threatening episode benefit from debriefing (Mishra 2011) and may need help in constructing a narrative of events, facilitated by their ICU diary to help the transition from critical illness to normality (Perier 2013).

Patients may also feel that they have been given a second chance in
life and experience heightened spirituality (Papathanassoglou et al 2003), each day seeming more precious than before (Walton 2002). Follow-up give them the chance to process this.

Ongoing rehabilitation increases exercise tolerance, reduces anxiety and depression (McWilliams et al 2009), helps patients pace themselves and reduces problems of imbalance, fear of falling, panic attacks and physical, psychological and cognitive difficulties (Aitken 2010). Other complications can be identified such as visual problems due to hypotensive episodes, sexual dysfunction, chronic fatigue syndrome and polypharmacy (Waldmann 2009 p.70).

Late rehabilitation can also be successful. One patient described her continued dyspnoea years later, so she hired a trainer, ‘to brutalize me on the treadmill’, and fully recovered after 12 sessions (Misak 2011).

Home visits, telemedicine (Jackson et al 2012) and video teleconferencing can assist rehabilitation (Needham et al 2012) and a self-help rehabilitation manual aids physical recovery and can halve levels of depression (Jones & Skirrow 2003).

Feedback from follow up clinics helps to sensitize ICU staff to the patient experience. For example, a patient who had been described as an ICU success story told how she had experienced lying naked in bed while staff washed her and chatted to each other about their social lives. Every day for the past 3 years, she said, she ‘wished she was dead’ (Russell 1999).

Goals and exercise plans should be included in the discharge summary and sent to community physiotherapists and GPs, with copies to the patient.

Surviving critical illness is only the beginning Batt et al (2013)

**Physiotherapy outcomes**

Clinical outcomes include:

1. Auscultation
   - ↑ breath sounds, ↓ bronchial breathing, ↓ crackles.

2. Radiology
3. Observations
   - \( \uparrow \text{SpO}_2 \)
   - with pressure controlled ventilation: \( \uparrow \) tidal volume
   - with volume controlled ventilation: \( \downarrow \) airway pressure.

Functional outcome is aimed at a return to as near as possible the patient's pre-morbid life-style, to include cognition, ADL and contentment. For physical function, valid tools are the Chelsea Critical Care Physical Assessment Tool (Corner et al. 2013) and the Physical Function Test (Denehy et al. 2013).

\[ I \text{ suppose it's safe to say that I'm not the same person as before } \]

The key to the successful management of emergencies is informed anticipation and recognition. Physiotherapists are not immersed in life-threatening events every day, so it is advisable to review protocols regularly in order to maintain confidence and avoid the indecision that is often evident at the scene of an emergency. It is also useful to know if a patient has an advance directive declining a certain procedure, and if this has been changed subsequently (Loertscher et al. 2010).

Some emergencies are covered in the text:

- asphyxic asthma
- burns
- chest drains
- fat embolism
- laryngospasm
- shock
- tracheostomies.

Local protocol should take precedence over the information below.
**Cardiac arrest**
Cardiac arrest is cessation of heart function. It is the normal mechanism of the old-fashioned process of death, but is occasionally reversible. It is followed within seconds by loss of consciousness and then by loss of respiration.

**Anticipation**
Before starting work on any new ward, the first task is to locate the crash trolley. When seeing a new patient, the medical history will provide evidence of **DNAR** status and risky conditions such as ischaemic heart disease, severe respiratory disease, drug overdose, metabolic disturbance, arrhythmias or shock. Physiotherapists working in the community or out of reach of a crash trolley need to carry a pocket mask for mouth-to-mask ventilation. Teamwork is assisted by a cardiac arrest risk triage system (Churpek *et al* 2012).

**Recognition**
Warning signs are a change in breathing, colour, facial expression or mental function. Hypoventilation with altered consciousness is an ominous combination. The ECG then shows pulseless electrical activity, pulseless ventricular tachycardia, ventricular fibrillation or asystole.

After cessation of the heart beat:
- the ECG flatlines
- in 15 seconds, the patient loses consciousness
- in 30 seconds, the pupils dilate fully
- In 90–300 seconds, cerebral damage occurs (Papastylianou 2012), though the brain stem lasts longer.

The patient's colour may be pale, ashen or blue, depending on the cause. No carotid pulse can be felt in the groove between the larynx and sternomastoid muscle. Respiration may become gasping and then stop, unless respiratory arrest has been the primary event.

**Action**
The time between collapse and initiation of resuscitation is critical, and a false
alarm is better than a dead patient. If suspicions are raised by a change in consciousness and colour, call out to the patient, and if they are unresponsive, follow the basic life support stage of cardiopulmonary resuscitation (CPR) as in the Resuscitation Council (UK) algorithm (App C) and local training.

On arrival of the crash team, advanced life support may include defibrillation, during which staff should stand clear. When no longer needed, the physiotherapist can give attention to other patients who will be distressed at witnessing the event. Survival for in-hospital cardiac arrests is <20% (Chen et al 2013), with survival to discharge dropping to 7.6% (Moulaert et al 2011). Survivors may sustain hypoxic brain injury and require an ICF-based rehabilitation programme (Moulaert et al 2011).

Respiratory arrest
As cardiac arrest leads to respiratory arrest, so does respiratory arrest if not reversed lead to cardiac arrest.

Anticipation
Predisposing factors include exacerbation of COPD, airway obstruction (e.g. foreign body, smoke inhalation, swelling or bleeding from trauma) or aspiration. Warning signs are inability to speak, and violent respiratory efforts, laboured breathing or drowsiness.

Recognition
Respiratory arrest is indicated by absence of chest movement, loss of airflow from the mouth and nose, and sometimes cyanosis. This progresses to loss of consciousness.

Action
1. Call for help.
2. Establish a patent airway as for CPR. Sometimes just moving the head will open the airway. If there is no airflow, continue as below.
3. If a foreign body is the likely culprit and the victim is choking, attempt
to dislodge it from the throat by suction or by hand. The main causes are the tongue, vomit and blood. If unsuccessful, follow the Resuscitation Council (UK) choking algorithm (App C) and local training. If the patient is still not breathing, continue as below.

4. Ventilate by a bag-mask system, Laerdal face mask or mouth-to-mouth. Inspiration time is 1½ to 2 seconds. Repeat once every 6 seconds. Continue for 1 minute, then re-assess.

If cardiac arrest ensues, instigate full CPR. If breathing starts, turn the patient into the recovery position because vomiting is common as consciousness lightens. Further details are in the Resuscitation Council algorithms.

Seizure

Anticipation

The medical notes indicate whether a patient has a history of epilepsy. Other causes of fitting are brain injury, alcohol intoxication, or, in children, fever. Some patients sense an aura in advance.

Recognition

Seizures vary from transient loss of consciousness to major muscle activity, followed by drowsiness.

Action

1. Patients subject to seizures should have the bed kept low, side rails up and padded, and oxygen and suction available.

2. If there is advance warning, insert a Guedel airway, if the patient consents. Do not attempt this once the seizure is under way.

3. Protect the patient's head and body from injury. Loosen tight clothing around the neck if possible. Do not use restraints or hold the victim down. Keep in side-lying if possible.

4. Afterwards, ensure the patient is in the recovery position. Reassure them as consciousness returns. Request medical assessment.
Haemorrhage

Anticipation
Uncontrolled bleeding can follow surgery, arterial line disconnection or trauma.

Recognition
External bleeding is usually apparent. Internal bleeding is suspected if there are signs of severe hypovolaemia (p.451). BP and HR are the least reliable of these signs because BP can be maintained by vasoconstriction and HR is responsive to other variables. Bleeding into a closed space causes pain.

Action
1. Position the patient supine.
2. Apply pressure to the bleeding point if accessible.
3. Elevate the affected part if feasible.
4. Request assistance.
5. Explain to the patient what is happening.

Riha & Schreiber (2013) describe the medical management of severe bleeding.

Massive haemoptysis
Massive haemoptysis is >200ml blood loss over 24 hours or enough bleeding to be life-threatening because of hypotension or aspiration of blood.

Anticipation
Predisposing factors are lung cancer, bronchiectasis, abscess or TB.

Action
If the patient can protect their airway, they can sit up and expectorate the blood until bronchoscopy is ready. Other patients should be positioned with the head slightly down, and if the side of the haemorrhage is known, laid on the affected side to prevent aspiration into the healthy lung. Cough suppressants and sedatives should not be given. Patients with depressed consciousness or at risk of aspiration need intubation, suction and sometimes bronchial artery
Cardiac tamponade

Cardiac tamponade is accumulation of gas or fluid, usually blood, in the pericardium. The pericardium is not distensible in the short term and can only accommodate 100 ml fluid rapidly without affecting cardiac output, after which an additional 40 ml doubles pericardial pressure, compressing the heart and damming back blood into the systemic veins. If this increasing pressure is not relieved, cardiac arrest ensues.

Anticipation

Tamponade can occur in the first 24 hours after heart surgery. Other predisposing factors are trauma, dissecting aneurysm, infection or malignancy.

Recognition

Progressive compression of the heart leads to precipitate loss of cardiac output, and the following may be evident:

- ↓ BP, $\text{SvO}_2$ and urine output
- ↑ HR, CVP and PAWP
- CVP and PAWP approximately equal
- pulsus paradoxus
- distended neck veins
- enlarged heart on xray
- restlessness, fear or feelings of impending doom (Ikematsu 2012).

Action

Alert the doctor, who will aspirate the fluid (Gumrukcuoglu et al 2011) or take the patient to theatre.

Tension pneumothorax

Gas entering the pleural space on inspiration but unable to escape on expiration causes a tension pneumothorax. Cardiac arrest normally follows.
within 20 minutes.

**Anticipation**

In ventilated patients, pneumothoraces may be under tension at the following times:

- immediately after intubation, if inadvertent tube placement into the right main bronchus causes hyperinflation of the right lung
- in the hours following initiation of mechanical ventilation, when air is forced through a previously unknown leak in the pleura.

Predisposing factors are emphysema, and surgery or other trauma to the chest. Subcutaneous emphysema in the neck can be a warning sign.

**Recognition**

Tension pneumothorax is sufficiently rare to be sometimes mistaken for severe bronchospasm. Both of these conditions cause respiratory distress, wheeze, increased airway pressure and laboured breathing. The added features of a tension pneumothorax are:

- ↓ amplitude in ECG (often the first sign)
- unequal chest expansion
- hyperresonant percussion note on the affected side
- ↓ breath sounds on the affected side, or both sides if severe
- ↓ SpO₂
- cyanosis
- distended neck veins and ↑ CVP (unless the patient is hypovolaemic)
- displaced apex beat
- in self-ventilating patients, dyspnoea and tracheal deviation away from the affected side
- in ventilated patients, high airway pressure (in volume control ventilation), and expired minute volume less than preset minute volume
- ↓ BP, ↑ HR, progressing to cardiovascular collapse
- radiograph as in Fig 18.11.
L tension pneumothorax, as indicated by a black area devoid of lung markings on the patient's L, and mediastinal shift away from the affected side. The patient is intubated and has fractured ribs and subcutaneous emphysema on the L.

**Action**

Alert the doctor, who will insert a 14G cannula into the pleura at the second intercostal space in the mid-clavicular line to release the pressure. While waiting, an experienced physiotherapist can disconnect the patient from the ventilator, connect to a bag and manually ventilate with 100% oxygen, using high flow and low pressure. Otherwise $F_{O_2}$ through the ventilator should be maximized. Some patients may be able to breathe spontaneously, which will reduce the positive pressure in the chest. These decisions are usually taken by the team.

**Air embolism**

**Anticipation**

Air may enter the circulation after cardiac or neurosurgery, or occasionally from a pneumothorax or during insertion or removal of a pulmonary artery catheter or vascath.

**Recognition**

A large air embolus causes respiratory distress, palpitations, dizziness, weakness and pallor or cyanosis.
**Action**

Summon help. Place the patient head down in left-side-lying, which diverts air away from the pulmonary artery and pulmonary circulation. Give high-percentage oxygen. An embolus >100 ml may cause cardiac arrest, which requires cardiac compression with heavy and deep pressure to disperse air bubbles to peripheral segments of the pulmonary artery.

**Anaphylaxis**

Anaphylaxis often manifests as respiratory distress or, with anaphylactic shock, hypotension, occurring minutes to hours after exposure to an allergen. After summoning assistance, the patient should be positioned with legs raised, given high-percentage oxygen (Simons & Sheikh 2013) and asked to cough (Tomori 2013).

**Ventilator malfunction or disconnection**

A stute eyes and ears pick up the slight hiss of an air leak, identify from an orchestra of alarms which is the offending malfunction, or notice the subtle change in a drowsy patient’s demeanour which signifies that something is amiss. Prevention includes reading the manufacturer’s handbook in order to understand the workings of the ventilator and distinguish what each alarm signifies.

**Alarms**

The most relevant alarms for the physiotherapist are the high and low pressure alarms, and those for BP, F\textsubscript{1}O\textsubscript{2} and the humidifier heater. The high pressure alarm is set at about 5-10 cmH\textsubscript{2}O higher than peak airway pressure and may be activated if there is:

- major atelectasis
- sputum retention in a large airway
- patient coughing or fighting the ventilator
- bronchospasm
- pneumothorax
- partial extubation
- right main bronchus intubation
- cuff herniation over the end of the tracheal tube
- patient biting the endotracheal tube (ETT).

If the patient bites the ETT, this requires dissuasion, a bite block or Guedel airway. For a displaced ETT, the doctor will deflate the cuff, reposition the tube, inflate the cuff, listen for equal breath sounds and request a check x-ray.

The low pressure alarm means that pressure has fallen more than 5-10 cmH₂O below the desired limit and indicates that there is a leak in the system, confirmed by reduced expired minute volume and airway pressure. A disconnected circuit should be reconnected after a quick alcohol wipe if it has touched anything. The patient’s condition should be checked, the cause determined, appropriate adjustments made and the nurse informed.

Alarms are fallible. Patient observation comes first.

**Arterial line or central line disconnection**

If a major line becomes disconnected at a junction, the patient requires reassurance because of the amount of blood loss, and the nurse may need assistance in reconnecting the line, while ensuring that no air is present in the line.

If a major line comes out of the patient, firm pressure to the site is required and the doctor informed so that it can be reinserted.

**Unplanned extubation**

Accidental endotracheal extubation can destabilize a patient haemodynamically and compromise ventilation. Prevention is assisted by the use of weaning protocols and avoiding restraints (Bouza et al 2007). If extubation occurs, call for help, apply oxygen, re-position the patient, if required, to assist breathing, and advise the patient to breathe steadily. Bag/mask ventilation may be required.
Patient problems causing distress include:

- subjective problems (Table 18.1)
- pneumothorax, pulmonary oedema, bronchospasm or mucous plug
- biting the tube.

Ventilator problems include:

- kink (high pressure alarm) or leak (low pressure alarm) in the circuit
- intrinsic PEEP
- inaccurate settings for flow rate, tidal volume, I:E ratio or trigger sensitivity.

Call for assistance, meanwhile check airway pressure/tidal volume and monitors. Ask the patient if they want more air. If the answer is a nod, or the patient is unable to respond, disconnect the patient from the ventilator, after informing them, and connect to the bag with oxygen. Either manually ventilate or allow the patient to self-ventilate through the bag with the valve open for minimal resistance and a high flow rate for comfort.

If distress continues, it is probably a patient-based problem, to be sorted with yes/no questions or suctioning the airway. Unilateral air entry raises suspicions of a malpositioned tracheal tube, pneumothorax or mucous
If manual ventilation resolves the distress, it is probably a ventilator problem, to be dealt with as follows:

- leaking tracheal tube cuff: inflate the cuff with air from a syringe, just enough to eliminate the leak, inform the nurse who will measure and record the cuff pressure
- tube disconnection: re-connect after cleaning the disconnected ends
- inability to identify problem: inform the nurse
- tracheal tube malfunction, bronchospasm, ventilator asynchrony unresolved by talking to the patient: inform the doctor.

**Fig 18.13  Flow chart to manage distress in a ventilated patient**
ON CALLS

A well managed on-call system can sustain many a sick patient through a difficult night. The key to success is education, so that all parties understand the scope and limitations of physiotherapy.

**Education of medical staff**

All levels of medical staff need information on the indications for out-of-hours physiotherapy, with particular attention to juniors starting a new rotation. Young doctors in a new environment can become anxious with an unfamiliar event and call out the physiotherapist unnecessarily, or not call when it is indicated. Education can be through informal talks, involvement in doctors' continuing education programmes and ensuring that the junior doctors' induction pack contains on-call information. Medical training hardly brushes the subject of physiotherapy and this is an educational opportunity to be grasped gladly.

**Education of nursing staff**

Nurses and physiotherapists work closely and have an understanding of each others' roles. Day-to-day exchange of information lays the foundation for cooperation, and this can be developed into teaching sessions so that nursing staff know when to advise doctors that the physiotherapist should be called.

**Education of physiotherapists**

Junior and non-respiratory senior staff need confidence in making respiratory decisions. Useful time can be spent going through equipment and practicing problem-solving with case studies. Competency tools are available (Thomas et al 2008) and several steps can be taken to facilitate a sound night's sleep for those on call:

- shadowing a senior colleague on a previous call-out
- time set aside the preceding afternoon for the on-call physiotherapist to see any borderline patients with the respiratory physiotherapist
• a respiratory physiotherapist available at the end of the phone for advice
• after a call out, discussing with a mentor the clinical reasoning and treatment of the patient
• a handout to include switchboard arrangements, location of equipment, bleep information and who is authorized to call out the physiotherapist (example in App C).

If called to the Emergency Department, it is advisable to check that the patient is not immersed in tests and investigations, and to identify when they will be available for treatment.

The interests of the patient and good relations with other disciplines can be fostered by the physiotherapist taking responsibility for pre-arranging call-outs when appropriate. The physiotherapist can also give advice over the phone.

Many departments organize evening physiotherapy shifts because there is evidence that this can prevent deterioration in patients after major surgery (Ntoumenopoulos & Greenwood 1996) and assist patients with excessive secretions (Wong 2000). Seven-day working has also improved clinical outcomes (Smith & Coup 2011).

An on call service is particularly helpful for patients with acute COPD (Babu et al 2010), and Box 18.2 provides suggestions for the alleviation of dyspnoea in these and other acutely unwell patients.

**Box 18.2  Management of the acutely breathless patient**

**Tips**
- avoid noise, bright lights and crowding
- do not enter the patient’s personal space until after introductions
- avoid chatter, be specific, talk gently and steadily
- offer questions with yes/no answers to minimize the patient’s need to speak
- identify the patient’s view of the cause of their dyspnoea
- relatives may have information on the patient’s coping strategies
- patients may find curtains claustrophobic or need the window open.

**Management of symptoms**
- Fatigue and SOB: rest, positioning and SOB techniques (Ch.7)
- Feeling out of control: identify patient’s own strategies, suggest others, ensure
autonomy
- Anxiety: identify cause, provide information
- Lack of sleep: liaise with team re. environment, check anxiety, check physical discomfort and positioning
- Pain: identify cause. If due to coughing, educate on selective cough facilitation and suppression (Ch.8) as and when appropriate, or wound support. If due to muscle tension, relieve by positioning and relaxation. Suggest or show massage to relatives
- Exhaustion: monitor PaCO$_2$ and pH to identify need for noninvasive ventilation.

Management of objective signs

\[
\begin{align*}
\text{PaCO}_2 & \\
\downarrow & \\
\text{low} & \text{high, with stable pH} & \text{rising, with low pH} \\
\text{i.e. baseline value} & & \\
\downarrow & \\
\text{normal response to SOB} & \text{normal response to advanced chronic disease} & \text{can be dangerous if due to exhaustion} \\
\downarrow & & \\
\text{normal SOB management} & \text{NIV (check x-ray)} & \\
\end{align*}
\]

if PaCO$_2$ is not available:
- monitor SpO$_2$ which is less sensitive to V$_E$ but will decrease if $\downarrow$ V$_E$ is severe,
- monitor symptoms of rising CO$_2$: headache, flapping tremor, warm hands.

\[
\begin{align*}
\text{Position} & \\
\downarrow & \\
\text{optimal} & \text{inefficient, alert patient} & \text{inefficient, exhausted patient} \\
\downarrow & & \\
\text{normal SOB management.} & \text{reposition (e.g. high-side-lying forward-lean-sitting).} & \text{prop up with pillows.} \\
\end{align*}
\]

Breathing

\[
\begin{align*}
\text{fast but stable} & \text{irregular, tense or asynchronous} \\
\downarrow & & \\
\end{align*}
\]
normal SOB                      encourage smooth, rhythmic, efficient breathing,
management                       or if patient is able, abdominal breathing

Management of secretions in a breathless patient

- Hydration
- Humidification (warm if bronchospasm)
- Slow rhythmic percussion
- AD or modified ACBT (without slowing RR)
- Cough suppression until secretions are accessible, then cough facilitation.


**CASE STUDY: Ms CM**

*Identify the problems of this 58 y.o. woman from Chichester who has been admitted for mechanical ventilation due to apnoea of unknown cause.*

**Background**
- Several admissions for mechanical ventilation.

**Nurse report**
- Patient needs regular reminders to breathe at night.

**Subjective**
- I hate this tube in my throat.
- Tired, not sleeping well.

**Objective**
- Intubated, on CPAP via the ventilator.
- Patient alert, in side-lying.
- Vital signs, $\text{SpO}_2$, auscultation and x-ray normal.

**Day 2**
- Diagnosed with Ondine's curse.

**Questions**
1. Does the patient have a problem with impaired oxygenation?
2. Does the patient have a problem with impaired ventilation?
3. Does the patient have a problem with her inspiratory muscles?
4. Does the patient have a problem with her respiratory pump?
5. Is the mode of ventilation suitable?
6. Goals?
7. Plan?

*Ondine’s curse*: apnoea caused by loss of automatic control of respiration, usually due
to defective chemoreceptor responsiveness secondary to neurological or other disorder.

**CLINICAL REASONING**

Re. intubated patients:
‘Although published guidelines recommend that these catheters be used once only when employing an open technique, this recommendation does not appear to be research based’.


**Response to case study**

1. No, SpO$_2$ is normal.
2. Yes, Ms M requires regular reminders to breathe at night.
3. No, she is not complaining of breathlessness and is able to breathe when prompted.
4. Yes, the diagnosis implicates the neurological component of her respiratory pump.
5. No, CPAP supports oxygenation, not ventilation. Ms M needs a mode that provides mandatory breaths at night for when she does not breathe, e.g. **SIMV**. No ventilation is required in the day when she can initiate breaths consciously.
6. Goals: maintain function while short and long term management is organized, then rehabilitate.
7. Plan:
   - Liaise with team re. mode of ventilation; suggest nocturnal **NIV**.
   - Check patient’s understanding of diagnosis and agree plan of action.
   - Mobilize patient fully as able while ventilated, then when weaned give clothes and advise on self-mobility.
   - Liaise with physiotherapist at referral centre to which patient will be sent for initiation of long term home nocturnal NIV.

Footnote – dolphins are also ‘conscious breathers’ and can only allow half of their brain to sleep at a time.

**Response to clinical reasoning**

If there is no research to justify a technique, then physiological reasoning is required. Re-inserting a used catheter is likely to introduce infection.