

Postoperative respiratory complications

Almost 5 million hospital admissions lead to surgical care every year in England alone. It is estimated that 3.4% will develop a postoperative respiratory complication (Smetana et al, 2006), although the incidence ranges from 2–19% and is likely to be significantly higher in at-risk groups. When severe, these complications profoundly influence length of stay, morbidity and mortality. This article looks at identifying, preventing and treating postoperative respiratory complications, and gives practical tips for providing the best perioperative care for surgical patients.

What are postoperative respiratory complications?

Definitions of postoperative complications vary, which may explain the variation in incidence. Mild symptoms include sore throat, cough and dyspnoea, while severe complications include prolonged mechanical ventilation and life-threatening hypoxaemia, sepsis and pneumonia. The most important and morbid postoperative respiratory complications are atelectasis, pneumonia, respiratory failure (requiring mechanical ventilation on intensive care), exacerbation of underlying chronic lung disease and pulmonary thromboembolism. It is likely that many of these complications go undetected by clinicians.

Causes

Insult of surgery and anaesthesia

The insult of surgery itself predisposes to postoperative respiratory complications. Lung

mechanics are altered in patients undergoing surgery. When lying flat and under general anaesthetic, functional residual capacity (that volume remaining in the lung after passive expiration) may be reduced by up to 1.5 litres (Hedenstierna and Edmark, 2005). Loss of muscle tone promotes a reduction in lung volume and ventilation–perfusion matching is altered, especially in basal lung regions. This leads to atelectasis and alveolar collapse.

Under normal circumstances the functional residual capacity is greater than the closing capacity (that volume at which the small airways close during expiration), but general anaesthesia and the lying flat position decrease functional residual capacity such that small airways may close during normal tidal ventilation. This worsens the effects of hypoxaemia, atelectasis and ventilation–perfusion mismatch. Atelectatic changes that occur during surgery and anaesthesia often

persist into the postoperative period. To varying degrees, atelectasis is likely to affect almost all patients undergoing surgery and general anaesthesia.

Anaesthetic, patient and surgical factors will influence the risk of a patient developing postoperative respiratory complications (Tables 1–3). Looking at these risk factors, it is relatively easy to identify those patients who are most likely to be ‘at risk’ of these complications. Most commonly these are patients with several risk factors.

How to identify the at-risk patient

Preoperatively, at-risk patients may be identified by the type of surgery they are undergoing, their comorbidities and at consultant-led anaesthetic preassessment clinics. Preoperative scoring tools, lung function tests and, for high risk patient groups, cardiopulmonary exercise testing are useful in

Table 1. Anaesthetic causes of postoperative respiratory complications

Anaesthetic factors	Effects
Pain	Shallow breathing, hypoventilation, ventilation/perfusion mismatch worsens, poor cough
Sedatives with long half-lives	Sedative effects of hypoventilation and respiratory depression, e.g. benzodiazepines
Opioids	Respiratory depression (in excess) but beneficial analgesic effects if facilitating deep inspiration
Postoperative mechanical ventilation	Mechanical ventilation via endotracheal tube or tracheostomy allows micro-aspiration of oral and gastric secretions into lower airways, which can lead to ventilator-associated pneumonia
Epidurals and central neuraxial blockade	High motor block may cause respiratory compromise. When used as sole anaesthetic, improved ventilation/perfusion matching and reduced atelectasis
Nerve blocks	May cause respiratory compromise, e.g. phrenic nerve involvement, may avoid need for general anaesthetic, reducing atelectasis
Fluid overload	Positive fluid balance worsens ventilation/perfusion matching
Emergency surgery	Unfasted patients, risk of aspiration
Type of anaesthetic agent	No difference between intravenous or inhalational agents, ketamine alone reduces atelectasis
Residual drug in cannula, e.g. neuromuscular blocker	Can lead to sudden respiratory arrest when cannula next flushed

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stratifying risk and planning for postoperative levels of care. The concept of pre-habilitation is gaining favour, using exercise training to improve patients' cardiorespiratory fitness before surgery, reducing postoperative mortality (Jones et al, 2007).

Preoperative risk assessment tools

A number of preoperative risk assessment tools are helpful in stratifying risk. These typically require information about the patient's comorbidities in addition to the type and severity of surgery, and provide a mortality score for the patient. Most often expressed as a percentage, this is a useful means of quantifying risks of surgery when communicating risks to the patient and other health-care professionals.

Copeland et al (1991) initially designed the POSSUM (Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity) scoring system to evaluate morbidity and mortality in general surgical patients. This was subsequently modified by Prytherch et al (1988) to P-POSSUM (Portsmouth- Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity) and is perhaps the most commonly used and validated preoperative risk assessment tool used in the UK. An algorithm-based calculator uses 12 physiological and six operative parameters, including patient's age, sex, comorbid disease, urgency and type of surgery and anticipated blood loss. This provides a mortality score (i.e. a percentage risk of death).

Arozullah et al (2001) devised a postoperative pneumonia risk index to identify patients at risk for postoperative pneumonia following major non-cardiac surgery. Variables include type of surgery age, functional status, weight loss, chronic obstructive pulmonary disease, general anaesthesia, impaired sensorium, cerebrovascular accident, blood urea nitrogen level, transfusion, emergency surgery, long-term steroid use, smoking and alcohol use. Patients are divided into five risk classes, those with the highest scores are most at risk. The original study showed postoperative pneumonia rates were 0.2% among those with 0–15 risk points and 15.3% for those with more than 55 risk points.

Quantifiably understanding the risks of surgery translates into mindful allocation of additional resources and optimal planning before surgery to minimize risks. This might mean additional preoperative tests, optimization of comorbid conditions, smoking cessation and exercise prehabilitation. Perioperatively, less invasive surgery may be an option, as well as considering regional anaesthesia techniques, thus reducing the risks of postoperative respiratory complications associated with general anaesthesia.

Table 2. Patient causes of postoperative respiratory complications

Patient factors	Effects
Underlying lung disease, e.g. COPD	Dysfunction lung units, reduced gas exchange. Severe COPD (FEV1 <40% predicted) has six times more complications
Asthma	Well-controlled asthma – no increase in complications. Suboptimal control associated with complications
Smoking	Two-fold increase in complications in current smokers. Very recent cessation also associated with complications; impaired ciliary function
American Society of Anesthesiologists classification	Independent risk factor. Poor functional status and sarcopenia associated with worse outcomes
Concurrent chest infection	Likely to worsen with mechanical ventilation. Increased A-a gradient and risks of hypoxaemia and shunt
Obstructive sleep apnoea/ chronic hypoventilation	Increased complications. Associated with obesity. Caution with opioids and respiratory depression
Immobility	Increased risk of thromboembolic disease
Old age	Independent risk factor. Increased alveolar collapse
Obesity (body mass index > 30 kg/m ²)	Literature not convincing that obesity alone is independent risk factor. Complications more likely in presence of pulmonary hypertension and cor pulmonale
Heart failure	Reduced delivery of oxygen, hypoxaemia and ventilation/perfusion mismatch
Neurological impairment, e.g. deficit from cerebrovascular accident	Increased risk of respiratory failure, pneumonia and aspiration

COPD = chronic obstructive pulmonary disease; FEV1= volume that has been exhaled at the end of the first second of forced expiration

Table 3. Surgical causes of postoperative respiratory complications

Surgical factors	Effects
Type of surgery	More common in major surgery, e.g. cardiac bypass, major abdominal and vascular. Less common in minimally invasive and laparoscopic surgery
Diaphragmatic and intercostal muscle involvement	Compromised respiratory muscle activity and hypoventilation
One-lung ventilation (thoracic and upper gastrointestinal surgery)	Atelectasis of deflated lung, barotrauma when reinflating lung
Prolonged surgery (> 4 hours)	Increased incidence of need for prolonged ventilation, fluid shifts and transfusion/blood loss
Blood loss and transfusion requirement	Transfusion causes inflammatory cascade and risk of acute lung injury
Thyroid, head and neck surgery	Haematoma or compression cause of airway obstruction
Patient position	Prone – better ventilation/perfusion matching; lateral – more atelectasis in lower lung; steep head down – atelectasis

Immediately after surgery, higher levels of postoperative care are often recommended for higher risk patients, and can be requested ahead of surgery. In resource-stretched settings, planning for which patients will benefit most from higher levels of postoperative care is fundamental to efficient management of bed occupancy, staffing and scheduling of surgical lists. The Royal College of Anaesthetists (2015) has endorsed and is promoting perioperative medicine across the UK. This concept is one of cohesiveness and teamwork. A multidisciplinary group works together to support the needs of higher risk surgical patients, who will benefit from the expertise of a variety of specialty doctors and health-care workers whose aims are to ensure safety, swifter recovery and fewer complications for patients.

Preoperative tests

The National Institute for Clinical Excellence (2003) published guidance on the use of preoperative tests for patients, which is currently being revised and updated. The recommendations are 'look-up' tables, set out by surgery type (minor, intermediate and major), American Society of Anesthesiologists grade and comorbidities. Guidance is colour-coded in a similar way to traffic lights, recommending or refuting the need for a variety of tests. In the higher risk patient, lung function tests and arterial blood gas data may be of value in planning perioperative care, but are not routinely recommended preoperatively.

Basic spirometry measures the forced expiratory volume in 1 s (FEV₁) and forced vital capacity and a best value after optimal bronchodilator therapy is also used. Results are often compared to that predicted value for a 'normal' person (derived from population studies), giving a percentage of the predicted normal value. The ratio of FEV₁/forced vital capacity is commonly determined. Diffusion capacity is calculated by measuring the amount of carbon monoxide taken up by the patient in unit time. This provides a gross estimate of alveolar/capillary function and is not just a test of the diffusion of oxygen across the alveolar capillary membrane. Actual values or percentages of predicted 'normal' may be presented. Drawbacks of lung function tests such as spirometry are the limited information they provide when the body is stressed as they are performed at rest and with oxygen demands not reflective of the stress of surgery.

Older et al (1993) provided a compelling argument for the use of cardiopulmonary

exercise testing in the high-risk surgical population. Cardiopulmonary exercise testing allows objective quantification of the level at which end-organ oxygen demand exceeds delivery (Smith et al, 2009), and is increasingly used to aid patient risk stratification and counselling. An increasing number of anaesthetists and surgeons use results as a barometer for the allocation of higher levels of postoperative care (Huddart et al, 2013). The test involves maximal and submaximal treadmill or bicycle exercise with continuous electrocardiogram monitoring and breath-by-breath determination of oxygen uptake and carbon dioxide output, and spirometry. Maximal oxygen consumption (VO₂ peak), peak heart rate, exercise capacity, anaerobic threshold and respiratory gas exchange ratio can be calculated. VO₂ peak (ml/kg/min) is the highest oxygen consumption achieved at maximal work before stopping the test.

Cardiopulmonary exercise testing is valuable in distinguishing between differing causes of dyspnoea and evaluates functional status where other preoperative tests cannot. There is no 'magic number' at which surgery is deemed safe or unsafe, although anaerobic threshold (the level at which oxygen demand outstrips supply and muscle cells begin generating ATP anaerobically) is the most common cardiopulmonary exercise testing variable used in clinical practice. An anaerobic threshold of <11 ml/kg/min correlates with poorer outcomes and is a good yardstick for justifying higher levels of postoperative care (Older et al, 1999; Carlisle and Swart, 2007).

Arterial blood gases

Preoperative hypoxaemia (oxygen saturations <90% and desaturation >4% with exercise) is associated with an increased risk of complications. Hypercarbia (arterial PaCO₂ >6 kPa) does not appear to be an independent predictor of poor outcome, but an awareness of baseline values for patients with respiratory disease can be very valuable when deciding on techniques, analgesia, postoperative oxygen prescriptions and destination after surgery.

Importantly, none of these tests are perfect or solely prescriptive in determining the best option for a patient when trying to minimize postoperative respiratory complications – evaluation of the clinical picture is vital, with the patient at the centre of the equation. Until a truly individualized assessment of risk emerges, profiling the individual, results need to be carefully interpreted in context.

Smoking cessation

Preoperative smoking interventions including nicotine replacement therapy increase short-term smoking cessation and may reduce postoperative morbidity (Mastracci et al, 2011; Myers et al, 2011). The optimal preoperative intervention intensity remains unknown. A Cochrane review determining effects of preoperative smoking cessation showed that interventions that begin 4–8 weeks before surgery, include weekly counselling, with nicotine replacement therapy are more likely to have an impact on complications and on long-term smoking cessation (Thomsen et al, 2010).

Prevention better than cure

There is a raft of interventions that promote successful recovery after major surgery (Miller and Mythen, 2014). Lung protective ventilation – a combination of tidal volumes of 6–8 ml/kg (of ideal body weight), 6–8 cmH₂O positive end expiratory pressure and recruitment manoeuvres – reduced pulmonary complications in a study of at-risk patients undergoing major surgery (Futier et al, 2013). Physiotherapy for patients after surgery both prevents and ameliorates the effects of postoperative complications. Encouraging cough and deep breathing exercises improves ventilation–perfusion matching and mobilizes sputum, reducing infection, while early mobilization decreases the likelihood of thromboembolism.

Enhanced recovery pathways, whose central aims are early mobilization, early enteral nutrition and minimizing the stress response of surgery with minimally invasive techniques and multimodal analgesia, reduce complications (NHS Improving Quality, 2013). These patients benefit from the coordinated activity of a multidisciplinary team, including dieticians and physiotherapists who promote mobilization and return to normal function. The World Health Organization's Surgical Safety Checklist (Haynes et al, 2009) has standardized practice, improving compliance with important elements of a patient's care, such as antibiotic and thromboprophylaxis prescriptions, and reducing complications.

Early warning scores: early detection of complications in the postoperative period

Early detection, timeliness and competency of clinical response form a triad of

determinants of clinical outcome in people with acute illness. Early warning scores have been formally used in hospitals for over a decade, and are designed to highlight the deteriorating patient with acute illness and escalate appropriate review and management. The Royal College of Physicians (2012) has published a revised and standardized scoring system, known as the National Early Warning Score (NEWS). The NEWS scoring system reviews the patient's physiology in six areas: respiratory rate, oxygen saturations, temperature, systolic blood pressure, pulse rate and level of consciousness. A score is allocated for each area, the magnitude of the score reflecting how extreme the parameter varies from normal. An additional 2 points are added for patients requiring oxygen. The scoring system and NEWS observation chart can be downloaded free from www.rcplondon.ac.uk/national-early-warning-score.

When complications arise, prompt action, seeking help early and a stepwise approach safeguards patients from harm. Practical tips for preventing and managing postoperative respiratory complications include:

- Routine recording of defined physiological parameters for all patients
- Early referral to critical care outreach services
- Effective handover of patients at risk of respiratory complications
- Review drug charts for polypharmacy and medications that might increase risks of respiratory depression, e.g. sleeping tablets, opioids
- Prescribe supplementary oxygen for patients receiving epidurals, patient-controlled analgesia, opioids and at-risk groups
- Review drug charts for thromboprophylaxis prescriptions
- Nurse patients in appropriate areas
- Specialist staff and equipment to deal with emergencies on the ward
- Ensure patients with preexisting lung disease have routine medications prescribed
- Ensure patients with obstructive sleep apnoea who use home continuous positive airway pressure bring these devices into hospital and continue to use them
- High risk patients identified at preassessment should have a high dependency or intensive care unit bed booked postoperatively
- Opiate prescribing
- Physiotherapy.

Management of the acutely unwell patient with respiratory compromise

Management should follow a stepwise and methodical approach of assessment and treatment (*Figure 1*). A cause is not always immediately apparent. Seeking senior help early and following an ABCD schema (airway, breathing, circulation, disability) will invariably provide more clues and focus attention on immediately protecting the patient's airway and ensuring adequate oxygenation and ventilation.

Specific treatments for postoperative respiratory emergencies

Managing patients with respiratory complications will often require protecting and supporting airway, breathing and circulation, and appropriate escalation of care. When a particular cause is identified, there are a number of specific pharmacological and therapeutic treatments for respiratory complications (*Table 4*). Some will require support and expert help from senior clinicians, in areas where continuous monitoring is available (e.g. high dependency areas). Often, no specific cause will be found, and reasons

are multifactorial. Awareness of the signs and symptoms of a tiring, deteriorating hypoxic patient are fundamental to appropriately treating and escalating care.

Conclusions

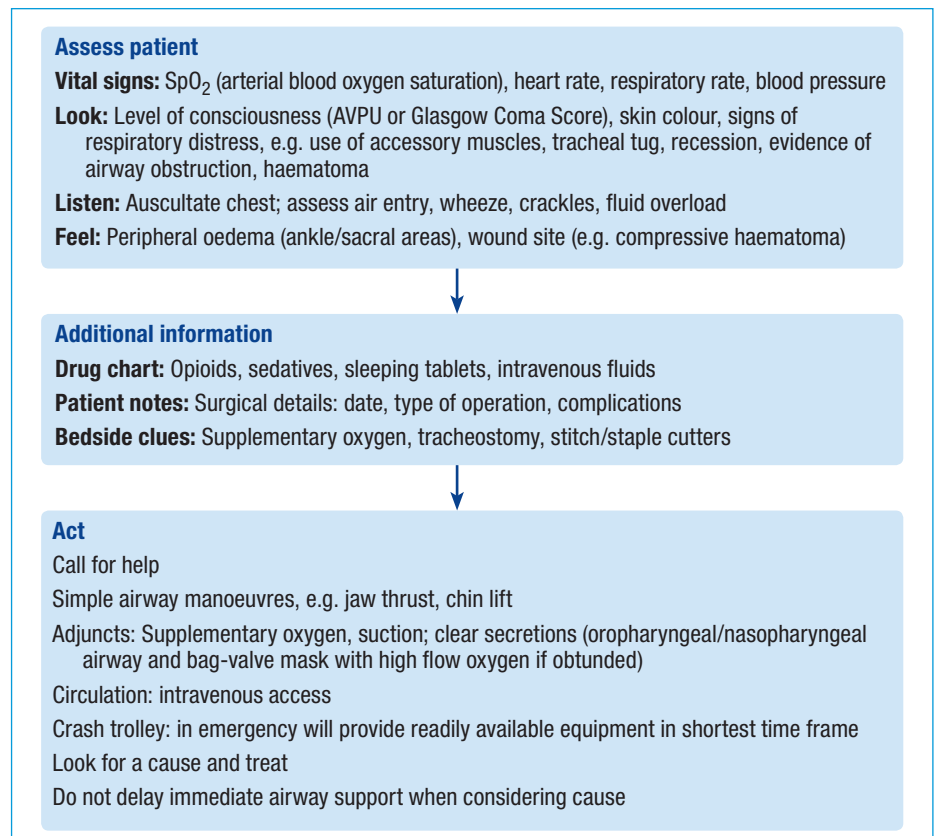
An awareness of the importance of recognizing and acting upon deterioration is fundamental to the care of all surgical patients. A report published by the National Institute for Health and Clinical Excellence (2007) demonstrated that when patients become acutely unwell in hospital, they may receive suboptimal care. This may be because their deterioration is not recognized, the severity of their condition underestimated, or an inappropriate response is triggered. **BJHM**

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Figure 1. Emergency management of the acutely unwell patient with respiratory compromise. AVPU = Alert; responsive to Verbal stimuli; responsive to Painful stimuli; and Unresponsive.



KEY POINTS

- Postoperative respiratory complications are common, occurring in up to 20% of all surgical patients.
- The most important and severe postoperative respiratory complications are pneumonia, respiratory failure, need for mechanical ventilation on intensive care and pulmonary thromboembolism.
- Patient, anaesthetic and surgical factors increase the risk of developing postoperative respiratory complications: look out for these when assessing patients.
- High-risk patients should be identified preoperatively, using tests such as lung function studies and cardiopulmonary exercise testing.
- Early warning risk scores identify the deteriorating patient and will expedite the escalation of care.
- Management should follow a stepwise A, B, C, D approach in addition to searching for and treating cause.

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Table 4. Specific treatments for postoperative respiratory complications

Precipitant or cause	Key features	Treatment
Opioid overdose	↓ Respiratory rate, small pupils	Oxygen, airway support, intravenous naloxone 200–400 µg
Benzodiazepine overdose	↓ Conscious level, ↓ respiratory rate	Oxygen, airway support, flumazenil, expert help (critical care/anaesthetist) 0.2 mg intravenous (total dose: 1 mg in 0.1–0.2 mg increments)
Expanding neck haematoma (e.g. post thyroid surgery)	Neck swelling, airway compromise	Stitch/staple cutters, release collection of blood. Urgent surgical and anaesthetic support. Transfer to operating theatre
Obstructive sleep apnoea (premorbid)	Desaturation, apnoeic episodes	Continuous positive airway pressure, nurse in high dependency or critical care area, avoid opioids where possible
Excessive intravenous fluids	Desaturation, pulmonary oedema, respiratory distress	Continuous positive airway pressure, nurse in critical care area, consider diuretic or opioids to offload
High motor blockade (epidural or central neuraxial blockade)	Sensory and motor blockade, poor respiratory effort, desaturation	Expert help (anaesthetist), sit patient up, stop epidural infusion, oxygen and airway support if needed
Residual drug in cannula, e.g. neuromuscular blocker	Sudden loss of consciousness, respiratory distress	Urgent expert help (anaesthetist), airway support. May require intubation
Chest infection/sepsis	Chest X-ray changes, consolidation/atelectasis, desaturation	Antimicrobials, supportive treatment: oxygen, escalation of care, continuous positive airway pressure
Pulmonary embolus	Different presentations such as tachycardia, dyspnoea, chest pain, collapse	Confirm diagnosis, haemodynamic and respiratory support. Expert help for thrombolysis, anticoagulation and other interventions
Vomiting and aspiration	Airway obstruction, choking, desaturation, chemical pneumonitis with chest X-ray changes	Expert help (anaesthetist), escalate

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