Post-operative Pulmonary Complications in the Adult Patient – Causes, Effects and Therapeutic Strategies

a report by
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Guiding the surgical patient safely and efficiently through the post-operative course is a goal shared by the entire healthcare team. Unfortunately, post-operative pulmonary complications (PPC) frequently defeat this objective. Clinically important PPC not only contribute to increased morbidity and mortality; they are a major factor in driving up total medical expenditures – especially in terms of intensive care unit utilisation. The most common PPC – atelectasis and bronchopulmonary infections – are related directly to ineffective clearance of airway secretions. Too often, patients with clinically significant excess or retained airway mucus are caught in a vicious cycle of respiratory decline.

Although the imperative for intervention is well understood, practical options for secretion management are not. Traditional methods including chest physiotherapy (CPT) and other technique-dependent technologies are supported empirically and by clinical trials. Unfortunately, effectiveness shown in controlled trials is rarely replicated in the 'real world' conditions of acute care medicine.

The challenges of PPC may be better met using technique-independent modalities for mobilising pulmonary secretions. Such modalities include high-frequency chest wall oscillation (HFCWO) and continuous lateral rotational therapy (CLRT). HFCWO, established for more than a decade as standard of care for chronic illness patients, is gaining rapid acceptance in the acute care setting. Likewise, clinical studies and positive outcomes increasingly support CLRT for high-risk patients. Because they simplify therapy and are reliably consistent, both are worth considering.

Patient Identification – Pre-operative Pulmonary Assessment

Virtually all patients undergoing major surgical procedures experience measurable physiological alterations in lung function. Pathophysiological changes occur routinely in the post-operative period. Patients undergoing thoracic and upper abdominal procedures typically show lung changes that may persist for two weeks or more. Arterial hypoxaemia, diminished pulmonary function tests (PFTs) and some degree of atelectasis are the rule. Overwhelmingly, those changes are transitory and recovery is uneventful. The challenge is to identify patients at significant risk for adverse events and poor outcomes.

PPCs range from simple atelectasis to fatal adult (acute) respiratory distress syndrome (ARDS). Risk factors are complex and multifactorial. A number of schema facilitate identification and ranking of high-risk patients. They include the Lawrence, Goldman and Charlston risk indices. Such tools permit PPC risk assessment by implementing a calculus that assigns relative values to each of a number of variables. Those variables are categorised broadly as procedure-related factors and patient-related factors and are weighted according to reliable data.

Procedure-related Factors

Upper abdominal surgery encourages a restrictive physiology and diminished vital capacity. Explanations for diminished pulmonary function following thoracic procedures are more complex and likely involve an interplay of factors including:

- inhibitory effects of inhaled anaesthetics on hypoxic pulmonary vasoconstriction;
- the diminution of the hypoxic and hypercapnic ventilatory drives that occurs when intravenous (IV) narcotics are used for induction; and
- further, as a result of an alteration in the shape and motion of the diaphragm and chest wall, a 20% decrease in functional residual capacity (FRC) is observed routinely in cardiothoracic cases. Post-operative inhibition of the diaphragm is reported to persist for up to four weeks.

Radiographic evidence of post-operative atelectasis is present in the majority of cardiothoracic surgical patients. The high incidence is attributed to factors including:

- operative and cardiopulmonary bypass time;

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- violation of the pleural space;
- maintenance of low body temperature; and
- to various traumas associated with the procedure(s) themselves.

Recent studies suggest that, as a consequence of surgically induced pulmonary ischaemia, the release of surfactant may be altered, thus encouraging atelectasis.

Duration and Effects of Anaesthesia

The pulmonary effects of anaesthesia have been studied extensively. Individual responses are idiosyncratic and anaesthesia-related complications are often difficult to anticipate. In general, the effects of surgical anaesthetics include:

- alterations in lung volume related to supine position;
- impairment of respiratory muscle function;
- alterations in lung mechanics related to gas exchange and hypoxic pulmonary vasoreactivity; and
- impairment of mucociliary clearance mechanisms.

Microatelectasis, increasing venous admixture and shunting, is correlated to low lung volumes. Additionally, drugs used in anaesthesia adversely affect respiratory muscle function and promotes hypoxaemia by inhibiting pulmonary hypoxic vasoconstriction and increasing shunting. Duration of anaesthesia, especially in procedures lasting three or more hours, is strongly associated with subsequent development of PPC.

Peri-operative pulmonary pathophysiology following cardio/thoracic and upper abdominal surgery can be summarised as follows:

- reduction in vital capacity by 50% to 60%;
- reduction in functional residual capacity (FRC) by 30%;
- diaphragm dysfunction secondary to reflex inhibition after surgery;
- pain and splinting;
- atelectasis;
- pneumonia;
- impaired gas exchange;
- hypoxaemia;
- impaired cough function;
- impaired mucociliary clearance; and
- microaspiration.

Normal pulmonary physiology is also disrupted to varying degrees following head and neck surgical procedures, major orthopaedic procedures and surgery for trauma, especially spinal cord injury.

Patient-related Risk Factors

Patient-related factors known to increase risk for PPC include:

- significant systemic disease;
- significant smoking history;
- chronic lung disease
  - presence of wheeze,
  - productive cough,
  - chronic bronchitis;
- recent respiratory infection;
- obesity;
- advanced acquired immunodeficiency disease; and
- age.

Post-surgical Mucus Hypersecretion/Mucus Retention

Major thoracic and upper abdominal procedures are accompanied by transient physiological alterations that encourage mucus retention and airway obstruction. These alterations are intensified by presence of risk factors enumerated above and by placement of artificial airway and/or mechanical ventilation. They include:

- reduced cough function as a result of
  - reduced vital capacity,
  - supine position,
  - pain,
  - analgesia,
  - sedation,
  - endotracheal intubation;
- decreased regional ventilation;
- decreased ciliary transport;
- prolonged lobar dependence;

- abnormal mucus flow; and
- dehydration of secretions secondary to anaesthesia.

Clinical Relevance of Abnormal or Retained Airway Secretions

Robustly powered epidemiological studies demonstrate strong associations between excess/retained pulmonary mucus and morbidity, hospitalisations, mechanical ventilation dependence and mortality. The presence of excess mucus or retained mucus affects pulmonary function, pulmonary health and survival in several ways: Excess/retained secretions result in:

- diminished pulmonary function;
- airway obstruction;
- mucus plugging;
- impaired mucociliary clearance function;
- increased risk for infection;
- acute lobar collapse;
- respiratory failure;
- need for mechanical ventilatory support; and
- morbidity and mortality.

Risk Reduction

Pre-surgical pulmonary risk assessment is meaningless unless effective interventions for risk modification are implemented. The literature confirms that, in some at-risk patients, PPC may be avoided by proper preparation and by rigorous intra-operative and post-operative care. In others, PPC may be modified and resolved successfully by implementing well-established pre-operative, intra-operative and post-operative interventions including weight reduction, smoking cessation, aerobic conditioning, etc.

Airway Clearance Therapy

Some form of airway clearance therapy (ACT) is prescribed routinely to treat post-surgical patients with evidence of ineffective secretion control. This is especially true for patients with pre-existing pulmonary disease. Therapy is recommended both before and after thoracic and cardiovascular surgery to minimise pulmonary secretions, to maximise oxygenation and to re-expand atelectatic lung segments. Chest physiotherapy (CPT), the predicate form of ACT, is the subject of the largest number of studies and is most frequently cited in the literature. A series of randomised controlled trials published over that last half century demonstrate significant reductions in both atelectasis and PPC in CPT-treated abdominal cardiothoracic surgical and ventilator-dependent patients.

Treatment Options

A variety of airway clearance techniques demonstrate efficacy among selected patients in controlled conditions. However, daunting patient and procedure-related factors diminish their utility in the post-operative and ICU setting. Most critically ill or major surgery patients do not have the energy, lung capacity or respiratory muscle strength for techniques that depend on forced expiration or positive end-expiratory pressure devices. For such patients, alternatives are limited to CPT via percussion and postural drainage (P&PD), HFCWO and/or CLRT.

CPT – An Obsolete Option

CPT is an airway clearance technique based on the theory that percussion of various areas of the chest and back transmits shock waves through the chest wall, loosening secretions in the airways. Following percussion, the patient is strategically positioned so that the loosened secretions can drain into the upper airways, where they can be cleared using coughing and huffing techniques. To clear all segments of the lung, most textbooks specify repeating the procedure for each of nine to 12 specified postures.

The decision to use chest physical therapy requires assessment of the potential benefits versus potential risks and limitations. CPT depends heavily upon precise execution of technique and patient positioning. Few critically ill/post surgical patients can tolerate several daily CPT sessions requiring arduous physical manipulation and breathing techniques. Transient hypoxaemia associated with postural drainage and inducement of gastro oesophageal reflux pose additional risks. Nursing and respiratory therapist shortages may preclude choice of CPT. The demands of labour-intensive, physically demanding and time-consuming treatment schedules frequently cannot be met. Additionally, risk for injury to the care-giver is a growing concern.

Practical Alternatives – Technique-independent Therapy

Secretion management modalities including HFCWO and CLRT have few or none of the disadvantages and/or limitations associated with chest

physiotherapy (CPT) and other technique-dependent airway clearance modalities. Clinical research and practical experience indicate both safety and tolerance among most critical care/post-surgical patients. Thus, such therapies may be ideal for appropriate acute care/post-surgical patients.

HFCWO

- HFCWO, also called high-frequency chest compression (HFCC) technology, works on the principle that rapid compression and relaxation (oscillation) of the chest wall generates increased airflow velocities, thus creating brief changes in lung airflow patterns similar to coughing. The percussive effects of chest wall oscillation also thin sticky secretions, making them easier to clear. Therapy is administered by means of a simple inflatable chest wraparound unit attached by hoses to an air pulse generator. The vest inflates and deflates rapidly, gently compressing and releasing the chest wall five to 20 times per second. The oscillations can be adjusted to different frequencies and pressures. During therapy, oscillating compressive forces are distributed evenly over the thorax surrounding the area of the lungs. This extensive contact area results in a large total oscillating force applied to the thorax.

- HFCWO has been used safely and effectively in cardio-thoracic surgery patients and in stabilised trauma/spinal cord injury and ventilator patients. With appropriate care, patients with invasive or cumbersome equipment including chest tubes, external pacer wires, central venous lines, swan-ganz catheters, CPAP or BiPap, implanted pacemakers and cardiac defibrillators and sternal incisions closed with cable wire tolerate HFCWO therapy without adverse incidents.

CLRT

- Continuous lateral rotational therapy (CLRT), also called kinetic therapy (KT), is utilised increasingly to prevent pulmonary complications in immobilised patients. CLRT is based on the theory that regular turning will enhance draining of secretions from distal lung regions, thus preventing or reducing hypoxaemia, atelectasis, secretion pooling and subsequent pneumonia. Pulmonary benefits result from more homogeneous distribution of transalveolar pressures and tidal volume and in improved secretion mobilisation. CLRT beds rotate continuously from side to side sufficiently to elevate one lung above the other. With CLRT, patients are turned up to 200 times per day; standard nursing procedure specifies 12 daily turns. Some CLRT models include percussion and vibration features.

- CLRT has been used safely and effectively in critically ill patients including those with stroke or neurological injury, with stabilised trauma/spinal cord injury and in ventilated patients. The therapy is associated with prevention or improvement of atelectasis, reduced risk for nosocomial and ventilator-associated pneumonia and reduction in acute care days.

HFCWO and CLRT are strongly associated with treatment adherence. Nursing and respiratory care staff lack resources to meet the demanding requirements of CPT or patient-turning protocols. Because HFCWO and CLRT require minimal staff time and effort, they have the potential to optimise therapy.

Improving Outcomes for Post-surgical Patients

For patients judged to be at risk, prophylactic or therapeutic airway clearance therapy is necessary to prevent or modify risks imposed by routine complications of major surgery. Prompt patient identification and timely implementation of techniques to mobilise and clear retained airway secretions favours improved outcomes. HFCWO and CLRT do not have the disadvantages and limitations associated with traditional strategies including CPT and manual patient turning. Better patient outcomes, reductions in resource utilisation and lower healthcare costs benefit all. To help achieve these goals, strategies including HFCWO and CLRT merit serious consideration. ■

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