

Review Article

## Prevention of Postoperative Pulmonary Complications-Multidisciplinary Approach

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### Abstract

Postoperative pulmonary complications (PPC) substantially increases the risk of morbidity, mortality, length of hospitalisation and has significant financial implications. Risks of postoperative pulmonary complications can be broadly divided into patient related, procedure related, anaesthesia related and postoperative care related. The prevention of PPC requires comprehensive multidisciplinary approach that include preoperative risk stratification and optimizations, intra-operative lung protective strategies, greater utilization of regional analgesia and avoidance of opioid analgesia, balancing intravenous fluid, minimising blood and blood product transfusion, fast tracking protocol for enhanced recovery, vigilance monitoring, physiotherapy and lung expansion manoeuvres including use of non-invasive ventilation in selected patients and other supportive care such as nutritional support, glycemic control, selective gastric drainage, thrombo-prophylaxis and early empirical antibiotic therapy in suspected infection and sepsis.

**Keywords:** Postoperative; Pulmonary complications; Acute lung injury; Lung protection; Multi-modal; Multidisciplinary

### Introduction

Postoperative pulmonary complication (PPC) accounts for substantial increase in morbidity and mortality following anaesthesia and surgery. PPC ranges from simple atelectasis to frank pneumonia to Acute Lung Injury (ALI) or Acute Respiratory Distress Syndrome (ARDS)<sup>[1-5]</sup>. ALI/ARDS are the extreme severe form of PPC which carries higher mortality, sometime exceeding 45% in certain surgical populations<sup>[4,5]</sup>. The peri-operative period is an important period where many clinical and therapeutic strategy can be applied as preventive approach to reduce PPC. Early diagnosis of at risk group and proper timely interventions can both reduce the incidences and severity of PPC.

This review is aimed at addressing some of the important issues or risk factors for PPC in adults and their prevention through evidence based interventions in peri-operative period.

### General Anaesthesia and Pulmonary Physiology

Induction of GA results in loss of respiratory muscle tone. The loss of supporting muscle tone promote the reduction in lung volume and onset of atelectasis; more than 90% patients under general anaesthesia developed some form of atelectasis and this atelectasis may persist beyond 24 hrs in more than 50% and may in some

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last up to week<sup>[6,7]</sup>. These effects are more evident in patients undergoing thoracic or upper abdominal surgery which can cause reduction in vital capacity by 50% and functional residual capacity (FRC) by 30%<sup>[8]</sup>. The development of atelectasis is the primary event in the pathogenesis of PPC such as hypoxaemia, pulmonary infection, postoperative ALI or ARDS<sup>[7-14]</sup>. Three types of atelectasis are described based on the mechanisms of atelectasis; compression, absorption and loss of surfactant atelectasis. General anaesthesia (GA) is implicated in the development of all the three types of atelectasis<sup>[6,10,11]</sup>.

Following upper abdominal and thoracic surgery, the respiratory mechanics changes, patients tend to breath small tidal volume with rapid rate to maintain the adequate minute ventilation (rapid shallow breathing) and poor coughing effort due to dynamic pain<sup>[8]</sup>. This altered breathing patterns in addition to the residual effects of anaesthesia, impaired mucociliary clearance and coughing contribute to the retention of secretion and postoperative pneumonia. These effects are complicated by patient co-existing general debility

or pulmonary illness or conditions such as smoking and acute physiological alteration in fluid electrolyte balance. Numerous studies and systemic reviews have been conducted to quantify the risk factors for predicting the PPC. Broadly these factors can be categorised into patient related factors, procedure related, anaesthesia related and postoperative care related.

Important factors of Postoperative pulmonary complications			
Patient related	Procedure Related	Anaesthesia Related	Postoperative
Age	Site of incision	Anaesthesia technique	Monitoring
Obesity	Thoracic/abdominal	Regional Vs GA	Postoperative Analgesia
Obstructive Sleep Apnea	Invasive surgery	Mechanical ventilation	Early mobilisation
Chronic Obstructive Pulmonary Disease /asthma	Duration of surgery	Fluid balance	Physiotherapy
Pulmonary Hypertension	Fluid and blood loss	Use of blood product	Lung expansion techniques
Interstitial lung diseases		Hyperoxia/hypoxia	Nutritional support
Respiratory Tract Infection		Analgesic technique	Selective naso-gastric Tube
Smoking/alcoholism			Thromboprophylaxis
General debility			Glycemic control
Immunity			Judicial Antibiotic use

### Patient Related Factors

Important patient related factors can be described as follow

#### Age

Elderly patients have decreased overall organ reserve, altered physiology of organs, and may have multiple associated co-morbid conditions. Studies have shown that age is an independent predictor of postoperative pulmonary complication<sup>[9,15,16]</sup>.

#### Obesity

Body Mass Index (BMI) above 35 is associated with many cardio-pulmonary changes such as sleep apnoea, atelectasis, obesity hypoventilation syndrome, pulmonary hypertension, cor-pulmonale and hypercapnic respiratory failure. Although the association of obesity and PPC is well known<sup>[17-19]</sup>, some studies failed to show the direct correlation between obesity and PPC<sup>[20-22]</sup>. Recent studies have shown that BMI above 35 is linearly associated with increasing PPC; but such correlation is not evident in patients with BMI less than 35<sup>[23,24]</sup>. There is 30% chances of developing PPC after abdominal surgery in patients with BMI of 40 and above<sup>[25]</sup>.

#### General Health and immunity

Poor functional status, general debilitated state, low albumin level, significant weight loss are also risk factors for PPC. Patients with immune compromised state are at risk for postoperative pneumonia and respiratory failure<sup>[15]</sup>.

#### Personal habit: Smoking and Alcohol

Smoking increases the risk of PPC more than 2 fold, and this risk remain elevated for up to 1 year even after cessa-

tion of smoking<sup>[15,26-28]</sup>. Abrupt cessation of smoking can inhibit coughing and retention of secretion which leads to small airway obstruction. Ideally smoking should be stopped 8 week prior to schedule surgery; less than 8 week abstinence may be associated with higher incidence of pulmonary complication than those who continued to smoke<sup>[29]</sup>. A systemic review concluded that smoking cessation should be pursued in most patients even if it is very close to time of surgery, but the longer the abstinence period, the greater reduction in risk of pulmonary complications<sup>[30]</sup>. Smoking and alcoholism often co-exist in many patients. Alcoholism as such is also one of the risk factor for PPC and this risk is additive with concomitant smoking<sup>[3,31]</sup>.

#### Obstructive sleep apnoea (OSA)

Patients with OSA have higher incidences of PPC in the form of desaturation, atelectasis, respiratory failure, ALI/ARDS requiring invasive ventilator support<sup>[26,32]</sup>. However, the incidence of severe PPC is relatively low irrespective of severity of OSA in patients already diagnosed pre-operatively<sup>[26]</sup>. It is the borderline patients or undiagnosed patients that pose a real threat. A recent survey by Auckley and Bolden has shown that significant number of surgical patients (24-41%) have undiagnosed OSA and are at risk of serious PPC during the peri-operative period<sup>[33]</sup>.

#### Pre-existing pulmonary pathology

**Obstructive lung diseases:** Patients with Chronic Obstructive Pulmonary Disease (COPD) and Bronchial Asthma have higher incidences PPC in the peri-operative period<sup>[28,33-35]</sup>. For obstructive airway diseases there is no absolute prohibitive value of pulmonary function test that is contraindicative for surgery. Patients, who are symptomatic, have poor cough, limited exercise capacity or have acute exacerbation should be optimised before elective surgery. Well controlled Bronchial Asthma does not appear to have increased risk, but sub-optimal control of asthma does pose a risk for pulmonary complications<sup>[35]</sup>. As preoperative strategy, smoking cessation, bronchodilator and steroid, hydration, antibiotic and chest physiotherapy may help to optimise the underlying conditions. Use of steroid in peri-operative period in patients with COPD is debatable<sup>[36-38]</sup>. Inspiratory muscles training for 2-4 weeks prior to surgery in high-risk operations such as abdominal aortic aneurysm repair, CABG have shown significant reduction in PPC<sup>[39,40]</sup>. A few studies have demonstrated that intense inpatient pulmonary rehabilitation program significantly improved exercise tolerance and operability (lung resection) in comparison to their baseline status<sup>[41-43]</sup>.

**Pulmonary hypertension (PHT):** Pulmonary hypertension has been recognised as independent predictor of PPC after cardiac surgery<sup>[44-47]</sup>. Although, it is not included as independent risk factor in non-cardiac surgery, presence of pulmonary hypertension is associated with increased peri-operative cardiac and pulmonary complications<sup>[46-48]</sup>.

**Interstitial Lung disease (ILD):** ILD also pose increased risk for PPC. Thoracic surgery has been implicated in exacerbation of ILD. Low forced vital capacity, low diffusing capacity, ongoing exacerbation at the time of surgery and extent of surgical lung resection are linked with increased risk of postoperative

exacerbation<sup>[49,50]</sup>.

**Respiratory Tract Infection (RTI):** Recent or ongoing respiratory tract infection including bronchitis, pneumonia increases the risk of PPC. It is recommended to treat the underlying infection before proceeding with an elective surgery<sup>[51]</sup>.

### Procedure Related Risk Factors

#### Site of incision and duration of surgery

The surgical incision site and its distance from the diaphragm are inversely related to the PPC. So, according to incision site, aortic aneurysm repair carries the highest risk followed by thoracic and upper abdominal surgeries; whereas, the lower abdominal and peripheral surgeries were associated with low incidence of PPC. Surgery lasting longer than 3-4 hrs is associated with higher incidence of PPC (40%) in comparison to surgery lasting less than 2 hrs. (8%)<sup>[15]</sup>.

#### Invasiveness of surgical procedure

Minimally invasive surgery or laparoscopic technique are associated with less postoperative pain, early ambulation and reduced risk for PPC<sup>[15,52-54]</sup>.

#### Cardio-Thoracic surgery

Major cardio-thoracic surgeries are associated with both local trauma and systemic inflammation because of cardio-pulmonary bypass (CPB)<sup>[55,56]</sup>. PPC depends not only on the direct parenchymal damage due to manipulation or resection, but also on the pulmonary manifestation of systemic inflammatory response. Systemic inflammatory mediators cause damage to both capillary and alveolar endothelium disrupting the alveolar-capillary barrier, impairing gas exchange and causing extra-vascular fluid accumulation<sup>[57]</sup>. This extra-vascular water accumulation is the hallmark of ALI<sup>[58]</sup>. The main predictors of postoperative ALI in cardio-thoracic surgeries are pneumonectomy, excessive fluid loading, one lung ventilation, and cardiac surgery involving CPB<sup>[52,57,59-63]</sup>.

### Anaesthesia Related Risk Factors

Anaesthetist have a great role in the protection of injured lung and the prevention of normal lung from injury during the peri-operative period. Despite the advancement in surgical and anaesthetic techniques, the incidence of PPC is remarkable. Proper anaesthetic management can prevent or ameliorate most of these injuries.

#### Anaesthetic technique

There are inconsistent data regarding pulmonary complication with spinal/epidural anaesthesia in comparison to general anaesthesia<sup>[64-66]</sup>. Patients who received general anaesthesia combined with neuraxial block for postoperative analgesia, were found to have lower incidences of postoperative pneumonia and respiratory failure likely due to less use of opioid in postoperative period<sup>[67,68]</sup>. These results suggest that addition of regional anaesthesia rather than avoidance of general anaesthesia may be the key to reducing pulmonary complications.

### Type of anaesthetic drugs

Residual effects of long acting neuromuscular blocking drugs like pancuronium might remain in the immediate postoperative period, that can promote atelectasis and also increase the risk of aspiration. Short or intermediate acting muscle relaxant is preferred over long acting ones. Volatile anaesthetics may impair hypoxic pulmonary vasoconstriction causing ventilation-perfusion mismatch<sup>[69]</sup>.

### Mechanical ventilation

The role of mechanical ventilation in the development on postoperative ALI has been debated for years. Aggressive mechanical ventilation has been recognised as one of the important risk factor for PPC<sup>[55,58,59]</sup>. Use of small tidal volume (6-8 ml/kg) might protect the lung from mechanical insult of ventilation while maintaining adequate gas exchange<sup>[58]</sup>. Alveolar hyperinflation with cyclic stretching in prolonged mechanical ventilation may trigger lung injury<sup>[56,70]</sup>. The duration of mechanical ventilation might also play important role in post ventilation lung injury<sup>[71-73]</sup>. Intraoperative lung protective strategy in the form of low tidal volume, use of judicious PEEP and recruitment maneuvers in intermediate to high-risk patients undergoing major abdominal surgery was associated with improved clinical outcome and reduced health care utilization<sup>[74]</sup>. Such benefit of short term lung protective strategy for low risk patients is doubtful<sup>[75]</sup>. Although some studies do suggest beneficial effects of low tidal volume lung protective ventilator strategy even for short duration procedure for healthy lungs<sup>[76-80]</sup>.

### One lung ventilation

Postoperative ALI after one lung ventilation in thoracic surgery is a distinctive entity. Four independent factors for primary ALI has been recognised. Intra-operative airway pressure, intravenous fluid replacement, pneumonectomy and preoperative alcohol abuse<sup>[53,81]</sup>.

### Transfusion related acute lung injury (TRALI)

Transfusion Related Acute Lung Injury (TRALI) can develop in the peri-operative period<sup>[82,83]</sup>. The diagnosis of TRALI is basically a diagnosis of exclusion. Bilateral ALI associated within 6 hrs. of blood or blood product transfusion after excluding the other possible causes of ALI suggest TRALI<sup>[84]</sup>. The patho-physiology of TRALI is not yet clearly defined. The accepted model being immunologic injury where leucoagglutinating antibodies in the transfused plasma binds to recipient neutrophils and are subsequently sequestered in the lung activating complements and other inflammatory mediators resulting in endothelial damage, capillary leakage leading into frank ALI. The second postulated mechanism is that some biologically active mediator in blanked blood interact with lung tissue<sup>[85-88]</sup>. A delayed form of TRALI has been recognised that developed 6-72 hours after transfusion and is more apparent in critically ill or multiple trauma patient and is associated with higher mortality rate<sup>[89]</sup>.

### Peri-operative fluid and ALI

Alteration in haemodynamic, metabolic, endocrine and immunological functions that occur perioperatively have considerable effects in fluid balance and distribution. These changes alter the capillary permeability and promote transfer

of intra-vascular fluid to the interstitial space, particularly the lung interstitial space that may progress from interstitial edema to frank pulmonary edema<sup>[90]</sup>. There is no universal or accepted definition of optimal, restrictive or liberal fluid therapy<sup>[91-94]</sup>. There is no clear agreement on the peri-operative fluid therapy. Direct association between liberal fluid administration and development of postoperative acute lung injury (ALI/ARDS) has been shown by many studies<sup>[94-98]</sup>.

### **Inhalation anaesthetics and lung protection**

Recent studies have shown that volatile agent has immune modulating effects and protect the lung by inhibiting the expression of pro-inflammatory mediators such as IL-8, IL-10, TNF etc<sup>[99-103]</sup>. These exciting works indicates that volatile agents might have a significant role in attenuating the lung injury from host of insults; however, considerable work is needed to define their role on the extent of lung protection.

### **Postoperative Strategy**

#### **Oxygen Therapy and PPC**

Oxygen is a two way sword. Both hypoxia and hyperoxia causes ischaemic re-perfusion type of injury<sup>[104,105]</sup>. The pulmonary changes that occur due to excess oxygen has been described as hyperoxic acute lung injury (HALI)<sup>[104-108]</sup>. The extent of lung injury in HALI depends on the duration and concentration of oxygen (above 50%), existing lung pathology, concomitant infection and use of mechanical ventilation<sup>[106]</sup>. With the present concept of lung protective strategy in the form of PEEP, low tidal volume, minimal Fio<sub>2</sub>, the problem of HALI has been substantially reduced in recent times. Unlike the normal healthy lung, the threshold for HALI may be lowered in injured or diseased lung.

#### **Postoperative analgesia**

Adequate postoperative analgesia provide better patient comfort, help in initiation of early ambulation and hence reduces risk of deep venous thrombosis (DVT) and also improved the performance of lung expansion manoeuvres. Studies using epidural analgesia after thoraco-abdominal surgeries reported reduced postoperative complication than patients managed with conventional opioid analgesics<sup>[109-112]</sup>. Para-vertebral analgesia are associated with similar analgesic efficacy with fewer pulmonary complications than epidural analgesia<sup>[113]</sup>, however, other studies favour epidural analgesia<sup>[114,115]</sup>. With the advancement in knowledge and techniques of ultrasonography guided needle placement, varieties of truncal blocks such as para-vertebral, intercostal, transverse abdominals plane, rectus sheath and ilio-inguinal/ilio-hypogastric can be easily and safely done. However there are limited studies comparing the truncal nerve block with established techniques<sup>[116]</sup>.

The current concept of management of acute postoperative pain is to use multi-modal approach in the form of combination of multiple drugs or techniques such as combining the regional analgesia, non-opioids, NSAIDs and adjuvants drugs complement each other and minimised side effects of a particular therapy<sup>[117-120]</sup>. Benefit of such approach may be more evident in high risk and elderly compromised patients<sup>[121]</sup>.

### **Fast tracking protocol/ enhanced recovery after surgery (ERAS) protocol**

The concept of fast tracking is a multi-modal multidisciplinary team approach from the preoperative to postoperative care. With the application of fast tracking or enhanced recovery after surgery protocol that involves team approach to provide early recovery following surgery to improved postoperative outcome including socio-economic benefits<sup>[122-125]</sup>.

#### **Selective Naso-gastric tube:**

Routine use of naso-gastric tube to decompress the stomach is associated with increased risk of pulmonary micro-aspiration and higher rate of pneumonia and atelectasis; it also delays the start of oral intake. Routine use of nasogastric tube in abdominal surgeries is no more indicated<sup>[126,127]</sup>.

#### **Pulmonary physiotherapy**

Patient with pulmonary disease and patient undergoing cardio-thoracic and upper abdominal procedure are at risk of PPC. Lung expansion and respiratory muscle training should ideally be started from the preoperative period and should be continued in the postoperative period as a part of comprehensive treatment<sup>[39-42,128,129]</sup>. Early use of chest physiotherapy in patients with surgery-associated critical illness may have significant impact on physical and functional outcome in addition to decreasing the length of ICU stay<sup>[130]</sup>.

#### **Other supportive care**

Proper monitoring in early postoperative period and identification of key events such as desaturation, bradycardia, nausea/vomiting, pain, which are some of the important parameters that are often implicated as predictors of subsequent pulmonary complications<sup>[131]</sup>. Prevention of thrombo-embolism<sup>[32,133]</sup>, proper nutritional support<sup>[134]</sup>, good glycemic control<sup>[135]</sup>, early recognition and management of infection or sepsis, optimization of fluid and electrolytes balance are important aspect of postoperative patient recovery and outcome.

### **Summary**

Varieties of PPC may develop in the postoperative period ranging from simple atelectasis to ALI/ARDS in extreme which carries a high mortality. Prevention of PPC is a multidisciplinary multimodal approach involving surgeon, physician, anaesthesiologist, nurse, physiotherapist, dietician etc. Factor implicated for postoperative ALI are grossly divided into patient related, procedure related, anaesthesia related and post procedural care.

PPC can be preventable to a large extent through multi modal approach. Preoperative identification and optimization of high risk preoperative conditions, emphasising for less invasive surgical approach, lung protective anaesthetist strategies, regional analgesia, applying fast tracking protocol and vigilance monitoring and active postoperative care involving multidisciplinary team are important factors in prevention and reduction of PPC.

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