# Lung Protection during Cardiac Surgery

*Essay*

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بسم الله الرحمن الرحيم

وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ

صدق الله العظيم

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# Contents

# List of Abbreviations

| | | |
|---|---|---|
| **ALI** | : | Acute lung injury |
| **ARDS** | : | Acute respiratory distress syndrome |
| **BAL** | : | Bronchoalveolar lavage |
| **BIS** | : | Bispectral index |
| **BMI** | : | Body mass index |
| **BPAP** | : | Bilevel positive airway pressure |
| **CABG** | : | Coronary Artery Bypass Grafting |
| **COPD** | : | Chronic obstructive pulmonary disease |
| **CPAP** | : | Continuous positive airway pressure |
| **CPB** | : | Cardiopulmonary bypass |
| **FEV** | : | Forced expiratory volume |
| **FiO2** | : | Fraction of inspired oxygen |
| **FRC** | : | Functional residual capacity |
| **FVC** | : | Forced vital capacity |
| **ICU** | : | Intensive care unit |
| **LV** | : | Left ventricle |
| **NO** | : | Nitric oxide |
| **OPCAB** | : | Off-Pump Coronary Artery Bypass |
| **OSAS** | : | Obstructive sleep apnea syndrome |
| **PA** | : | Alveolar pressure |
| **Pa** | : | Pulmonary arterial pressure |
| **PAH** | : | Pulmonary arterial hypertension |

| | | |
|---|---|---|
| **PaO2** | : | Partial pressure of oxygen in arterial blood |
| **PCV** | : | Pressure controlled ventilation |
| **PEEP** | : | With positive end expiratory pressure |
| **PP** | : | Prone position |
| **PPCs** | : | Postoperative pulmonary complications |
| **Pv** | : | Pulmonary venous pressure |
| **RAP** | : | Retrograde autologous priming |
| **REM** | : | Rapid eye movement |
| **RV** | : | Right ventricle |
| **SIRS** | : | Systemic inflammatory response syndrome |
| **t-PA** | : | Tissue plasminogen activator |
| **TRALI** | : | Transfusion related acute lung injury |
| ***V*A/*Q*** | : | Ventilation-perfusion ratio |
| **VCV** | : | Volume controlled ventilation |
| **VILI** | : | Ventilation induced lung injury |
| **6MWT** | : | 6-min walk test |

# Introduction

Despite the improvement in the cardiopulmonary bypass (CPB) techniques as well as the postoperative intensive care, impaired pulmonary function is a well documented (by enormous experimental and clinical evidence) complication of cardiopulmonary bypass, resulting in increased morbidity and mortality ***(Apostolakis et al., 2009).***

Preoperative preparation and evaluation, monitoring, induction, and maintenance of anesthesia for patients requiring CPB for heart surgery remains a vital and incredibly important aspect of anesthetic management. Planning for maintenance of anesthetic depth, neuromuscular relaxation, and prevention of awareness during CPB is important during the pre-bypass period. Paralysis is vital to prevent shivering during cooling and rewarming, which will increase myocardial oxygen consumption. In the time prior to initiation of bypass as well as the maintenance of bypass and separation periods, episodes of transient or prolonged hypotension due to either surgical necessity or patient hemodynamic instability may place patients at risk for awareness. Processed EEG as in use of the bispectral index (BIS) during anesthesia for cardiac surgery has been shown to help prevent awareness and guide use of anesthetic medications and agents ***(Serfontein, 2010).***

Impaired pulmonary function is a well-documented and fairly common complication, occurring in about 25% of patients after CPB for cardiac surgery; in the most severe cases acute respiratory distress syndrome results and contributes to significant postoperative morbidity and mortality ***(Mack et al., 2004).***

Methods to reduce hemodilution and improve the oncotic pressure may help reduce this interstitial edema. Use of blood cardioplegia and hemofiltration may accomplish this as well as retrograde autologous priming (RAP) of the CPB circuit. RAP involves removal of some of the crystalloid CPB circuit prime with the patient’s own circulating blood after venous and arterial cannulae have been inserted for bypass. A study by Hwang and colleagues showed that patients who underwent RAP prior to bypass had significantly higher hematocrit as well as cerebral oxygenation saturation levels during the bypass period. This statistically significant increase in hematocrit did not extend into the postoperative period although a trend toward increase in hematocrit persisted ***(Hwang et al., 2011).***

# Aim of the work

In this study we will focus on different modalities for preoperative lung assessment and to protect the lung intraoperatively and postoperatively during the cardiac surgery.

# Anatomy and Physiological Consideration

Accurate knowledge of anatomy and physiology of the respiratory tract is important not only in the field of pulmonology but also in anaesthesiology and critical care. About 70-80% of the morbidity and mortality occurring in the perioperative period is associated with some form of respiratory dysfunction. General anaesthesia and paralysis are associated with alterations in the respiratory function ***(Drain, 1996).***

Dynamic anatomical changes and physiological alteration happening during anaesthesia make it imperative for an anaesthesiologist to have sound knowledge of the respiratory system and apply it for safe and smooth conduct of anaesthesia. Such knowledge has influence on clinical practice of airway management, lung isolation during anaesthesia, management of cases with respiratory disorders, respiratory endoluminal procedures and surgeries, optimising ventilator strategies in perioperative period and designing airway devices ***(Hughes et al., 2008).***

## Anatomy of respiratory system

The respiratory system, functionally, can be separated in two zones; conducting zones (nose to bronchioles) form a path for conduction of the inhaled gases and respiratory zone (alveolar duct to alveoli) where the gas exchange takes place. Anatomically, respiratory tract is divided into upper (organ outside thorax -nose, pharynx and larynx) and lower respiratory tract (organ within thorax -trachea, bronchi, bronchioles, alveolar duct and alveoli). The discussion is mainly concentrated on the lower respiratory tract and the related physiology. Nose and nasal cavity are divided into two halves by the nasal septum. The lateral wall of the nose consists of three turbinates or conchae (superior, middle and inferior). The passage inferior to inferior turbinate is preferred passage for nasotracheal intubation ***(Ahmed-Nusrath et al., 2008).***

The pharynx is a tube-like passage that connects the posterior nasal and oral cavities to the larynx and oesophagus. It is divided into nasopharynx, oropharynx and laryngopharynx. Increase in soft tissue within bony enclosure of pharynx or decrease in bony enclosure size would result in anatomical imbalance and cause limitation of space available for airway ***(Watanabe et al., 2002).***

Excessive soft tissue (obesity) in fix bony enclosure leads to compromised pharyngeal passage. There are three narrowest portions of pharynx; passage posterior to the soft palate (retro palatal space), passage posterior to the tongue (retroglossal space) and passage posterior to epiglottis (retroepiglotic space). There is significant reduction of these spaces with sedation and anaesthesia which would lead to upper airway obstruction ***(Shorten et al., 1994).***

## Anatomical factors which compromises pharyngeal patency

Tensor palatine retracts the soft palate away from the posterior pharyngeal wall, thereby maintaining retro palatal patency. The genioglossus moves the tongue anteriorly to open the retroglossal space. Hyoid muscles (geniohyoid, sternohyoid and thyrohyoid) make the hyoid move anteriorly and stabilise the retroepiglotic laryngopharynx. Excessive fat deposition around these muscles would result in inefficient contraction of pharyngeal dilator muscles. This would lead to pharyngeal airway obstruction during sedation and anaesthesia ***(Benumof et al., 2002).***

## Anatomical imbalance of oropharyngeal soft tissue

Enlarged tongue (in the case of acromegaly or obesity) in normal bony enclosure of oropharynx or a smaller bony enclosure (receding mandible) of oropharynx would be unable to accommodate the tongue into oropharynx and thus shift the tongue into hypopharynx (laryngopharynx). Hypo pharyngeal tongue decreases laryngopharyngeal airway patency. This is one reason for obstructive sleep apnoea and difficult mask ventilation during anaesthesia ***(Chou et al., 2001).***

## Tracheobronchial tree

It is a complex system that transports gases from the trachea down to the acini, the gas exchange units of the lung. It is partitioned into 23 generations of dichotomous branching, extending from trachea (generation 0) to the last order of terminal bronchioles (generation 23). At each generation, each airway is being divided into two smaller daughter airways) ***(Weibel, 1963).***

### Trachea and right/left main bronchus

The trachea is a hollow conduit for gases and bronchial secretions. It extends from the level of C6 (cricoid cartilage) to the carina, approximately located at the level ofT4-T5. In adults, its length is approximately 11-13 cm, with 2-4 cm being extra-thoracic. The trachea has 16 to 22 horseshoe bands (c-shaped) of cartilages. The posterior tracheal wall lacks cartilage and is supported by the trachealis muscle. Depending on the level of inspiration, the posterior wall of the trachea becomes flat, convex or slightly concave ***(Minnich et al., 2007).***

The posterior wall of the trachea either flattens or bows slightly forward during expiration. In normal subjects, there is up to 35% reduction in antero-posteior tracheal lumen in forced expiration, whereas the transverse diameter decreases only by 13%. The trachea is generally midline in position, often displaced slightly to the right and posteriorly as it approaches carina. The angle of the tracheal bifurcation is called as the carinal/subcarinal angle, which is measured commonly as 73° (35-90°) ***(Chunder et al., 2015).***

The trachea divides at carina into the right and left main bronchus. The distance of the carina from the teeth varies markedly with change in neck position from flexion to extension (tracheal length variation is ± 2 cm), body position and position of diaphragm ***(Cherng et al., 2002).***

This explains the change in position of endotracheal tube during change in position of patient or flexion - extension of neck. The right main stem bronchus has a more direct downward course, is shorter than the left and begins to ramify earlier than the left main bronchus. This leads to higher chances of right endobronchial intubation. The right main stem bronchus divides into (secondary bronchi) right upper lobe bronchus and bronchus intermedius which further divides into right middle and lower lobe bronchus. The left bronchus passes inferolaterally at a greater angle from the vertical axis than the right bronchus. The left main stem bronchus divides into (secondary bronchi) the left upper and lower lobe bronchi ***(Minnich et al., 2007).***

## Tracheobronchial anatomical variations

Tracheobronchial tree exhibits a wide range of variations and its prevalence is 4%. The most common main bronchus anomalies are the tracheal bronchus and the accessory cardiac bronchus. Knowledge of tracheobronchial variants is important for clinical aspect in pre-operative evaluation in view of intubation, lung isolation techniques and other endo-bronchial procedures ***(Abakay et al., 2011).***