Different Ventilatory Modes During One Lung Anesthesia

An Essay

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By

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بسم الله الرحمن الرحيم

وَأَنْزَلَ اللهُ عَلَيْكَ
الْكِتَابَ والْحِكْمَةَ
وَعَلَّمَكَ مَا لَمْ
تَكُنْ تَعْلَمُ وَكَانَ
فَضْلُ اللهِ عَلَيْكَ
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List of Abbreviations

Abb.	Full term
ALI	Acute lung injury
ARDS	Acute respiratory distress syndrome
BB	Bronchial blocker
CO_2	Carbon dioxide
COPD	Chronic obstructive pulmonary disease
CPAP	Continuous positive airway pressure
CT scan	Computed tomography scan
DLT	Double lumen tube
$ETCO_2$	End tidal CO_2
ETT	Endotracheal tube
FBO	Fiberoptic bronchoscope
FiO_2	Fraction of inspired oxygen
FRC	Functional residual capacity
HFJV	High-frequency jet ventilation
HPV	Hypoxic pulmonary vasoconstriction
ICU	Intensive care unit
ID	Internal diameter
LIP	Lower inflection point
mm Hg	Millimeter Mercury
N_2O	Nitrous oxide
NO	Nitric oxide
OD	Outer diameter
OLV	One lung ventilation
$PaCO_2$	Arterial Carbon Dioxide tension
PAO_2	Alveolar partial pressure of O_2
PaO_2	Arterial Oxygen tension
PCV	Pressure-controlled ventilation
PEEP	Positive end-expiratory pressure
PvO_2	Mixed venous Oxygen tension
PVR	Pulmonary vascular resistance

List of Abbreviations (Cont…)

Abb.	Full term
RUL .... :	The right upper lobe
SLT .... :	Single lumen endobronchial tubes
TTE .... :	Tracheal tube exchanger
V/Q matching .. :	Ventilation-perfusion matching
V_A .... :	Alveolar ventilation
VATS................ :	Video-assisted thoracoscopic surgery
VCV.................. :	Volume-controlled ventilation
V_D .... :	Dead space
V_T .... :	Tidal volume

INTRODUCTION

Thoracic surgery represents a unique set of physiological problems for the anesthesiologist that requires special consideration. These include physiological derangements caused by placing the patient with one side down (lateral decubitus position), opening the chest (open pneumothorax), and the need for one lung ventilation ***(Morgan et al., 2006).***

There are a number of recognized indications for one lung ventilation. In practice, the most common indications for lung separation are: Surgical exposure (lung separation), prevention of contamination to the contralateral lung from bleeding, pus or saline lavage (lung isolation), and during differential lung ventilation for continuity of airway gas exchange such as with bronchopleural fistula ***(Campos, 2008).***

Advances in surgical techniques for thoracic, cardiac, or esophageal surgery have led to an increased use of lung separation techniques. A bronchial blocker, a double lumen endotracheal tube (DLT) or an endobronchial tube is used ***(Campos, 2007).***

Pressure-controlled ventilation (PCV) has been suggested to reduce peak airway pressure (P_{peak}) and intrapulmonary shunt during one-lung ventilation (OLV) when compared with volume-controlled ventilation (VCV) ***(Lohser, 2008)***.

Overcoming hypoxemia is a battle for thoracic anesthesiologists. What is the best ventilatory strategy to improve oxygenation while minimizing lung injury during one-lung ventilation? Different strategies have been used to improve hypoxemia during one lung ventilation. Lung isolation devices coupled with fiberoptic endoscopy have reduced the incidence of significant hypoxaemia during one lung ventilation. Positive End Expiratory Pressure (PEEP) is reported to reduce atelectasis in the ventilated lung and thus improve oxygenation ***(Kozian et al., 2010).***

In addition to thoracic surgery complications, there are different unfavorable outcomes resulting from one lung ventilation. Airway trauma, high inflation pressure and cardiovascular disturbances are the most common challenges ***(Anesthesiology Clinics of North America, 2005)***.

Chapter One
DEFINITION AND HISTORY OF ONE LUNG ANESTHESIA

One lung anesthesia is a technique in which one lung is separated from the other in ventilation during surgery ***(Cohen, 2000).***

Thoracic anesthesia encompasses a wide variety of diagnostic and therapeutic procedures involving the lungs, airways, and other intrathoracic structures. As the patient population presenting for noncardiac thoracic surgery has evolved, so have the anesthetic techniques to manage these patients ***(Licker et al., 2006).***

Thoracic surgery at the beginning of the past century was primarily for infectious indications (e.g., lung abscess, bronchiectasis, empyema). Although these cases still present for surgery in the postantibiotic era, afterwards the most common indications are related to malignancies (pulmonary, esophageal, and mediastinal). Fundamentals to anesthetic management for the majority of thoracic procedures are: lung isolation to facilitate surgical access within the thorax and management of one-lung anesthesia ***(Slinger and Johnston, 2005).***

Lung-isolation techniques are primarily designed to facilitate one lung ventilation (OLV) in patients undergoing cardiac, thoracic, mediastinal, vascular, esophageal, or orthopedic procedures involving the chest cavity.Lung isolation is also used to protect the lung from soiling by the contralateral lung in such cases as bronchopleural fistula, pulmonary hemorrhage, and whole-lung lavage. And, lung isolation can be used to provide differential patterns of ventilation in cases of unilateral reperfusion injury (after lung transplantation or pulmonary thromboendarterectomy) or in unilateral lung trauma ***(Licker et al., 2003).***

Prior to 1900, surgeons rarely ventured into the chest. Thoracotomy was a hazardous and an uncommon operation. Both tracheal and bronchial insufflation of anesthetic gas under pressure had been tried for thoracic work. Anesthesia had even been performed for successful thoracotomy, using a combination of a metal resuscitation tube and bellows ventilation with the Fell-O’Dwyer apparatus. None of these techniques were widely accepted at the time, although they all contained the roots of modern thoracic anesthesia ***(Benumof, 1983).***

The development of thoracic anesthesia and thoracic surgery was delayed more than 50 years after the introduction of ether because anesthesiologists could not manage patients during mask anesthesia with spontaneous ventilation and an open chest. These patients developed what was originally called the “pneumothorax syndrome***” (Mulot et al., 2002).***

In the early 1900s; several pioneers, such as the New Orleans surgeon Matas, advocated positive-pressure ventilation and a primitive form of endotracheal ventilation, which had been demonstrated to be safe in animal experiments, for thoracic anesthesia. Modern methods, incorporating OLV, have evolved from these experiments. Essentially, any anesthetic technique that provides safe and stable general anesthesia for major surgery can and has been used for lung resection. There is a major trend to the use of combined thoracic epidural and general anesthesia for thoracic surgery ***(Williams and Kay, 2000).***

The concept of endobronchial intubation had its roots in the late nineteenth century. Experimental physiology work on dogs published by Head in 1889 described endobronchial intubation using a long, cuffed metal bronchial tube, attached to a short tracheal tube. However, the first description of “closed endobronchial anesthesia”; or true one-lung anesthesia, came in 1932, from Joseph Gale and Ralph Waters of Madison, Wisconsin USA, as a direct extension of earlier cuffed endotracheal tube work ***(Domino et al., 1984).***

The development of double-lumen tubes (DLT) was a response to the fast growing capabilities in thoracic surgery, which required faster, surer and simpler lung separating methods. The Björk and Carlens DLT was first used during anesthesia in 1950. Next decades were followed by the introduction of different types of DLTs with variable capabilities ***(Slutsky, 1994).***

Chapter Two

ANATOMICAL ASPECTS

A) The Trachea:

The Trachea is a tube 13 cm long and 2.5 cm in diameter. It has a fibroblastic wall in which are embedded a series of C -shaped bars of hyaline cartilage that keep the lumen patent. The trachea extends in the neck from the lower end of cricoid cartilage at the level of 6^{th} cervical vertebra and it ends below in the thorax at level of the sternal angle (lower border of 4^{th} thoracic vertebra) by dividing into the right and the left main bronchi **(Fig. 1)** ***(Snell, 1995).***

The carina is the cartilage at the tracheal bifurcation, which is seen as a very obvious sagittal ridge when the trachea is inspected brochoscopically ***(Benumof, 1995).***

The trachea is supplied by the inferior thyroid artery(a branch of thyrocervical trunk) in the upper 2/3 and by bronchial arteries (two branches on the left side and one branch on the right side originating directly from the aorta) in the lower 1/3. The arteries run circumferentially and there are free anastomoses at the long axis of the trachea. The bronchial and inferior thyroid veins drain into the bronchocephalic vein which drains in the superior vena cava ***(Gray and Goss, 1995).***

The trachea is supplied by branches of vagus nerve whose activity mediates bronchoconstriction via muscarinic