Intraoperative Lung Recruitment Maneuvers and Its Outcomes

Essay

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BY

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List of Abbreviations

RM	Recruitment Maneuver
ARM	Alveolar Recruitment Maneuver
VT	Tidal Volume
IRV	Inspiratory Reserve Volume
ERV	Expiratory Reserve Volume
IC	Inspiratory Capacity
TLC	Total Lung Capacity
FRC	Functional Residual Capacity
RV	Reserve Volume
VC	Vital Capacity
P-V curve	Pressure - Volume Curve
PIP	Peak Inspiratory Pressure
PaO_2	Partial Pressure of Oxygen
PEEP	Positive End Expiratory Pressure
CPAP	Continuous Positive Airway Pressure
VILI	Ventilator Induced Lung Injury
ARDS	Adult Respiratory Distress Syndrome
IL	Interleukin
TNF	Tumor Necrosis Factor
Crs	Respiratory System Compliance
Ccw	Chest Wall Compliance
Cl	Lung Compliance
Pex	End Expiratory Alveolar Pressure
Ps	Static or plateau Pressure
LIP	Lower Inflection Point
UIP	Upper Inflection Point

WOB	Work of Breathing
Pavg	Average Inspiratory Pressure
Ti	Inspiratory Time
Paw	Airway Pressure
HbF	**:** Fetal Hemoglobin
CaO_2	Oxygen Content of Arterial Blood
$CcCO_2$	Capillary Oxygen Content
CvO_2	Mixed Venous Blood Oxygen Content
QT	Total Blood Moving Through the System
PRM	Prolonged Recruitment Maneuver
MRS	Maximal Recruitment Strategy
CT	Computed Tomography
PA	Alveolar Oxygen Tension
IP	Inductive Plethysmography
MO	Morbidly Obese
CPB	CardioPulmonary Bypass
ECC	Extra-corporeal Circulation
OLA	Open Lung Approach

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Introduction

Recruitment is a dynamic physiological process that refers to the reopening of previously gasless lung units ***(Richard et al, 2004).***

General anesthesia, even in the lung-healthy subject, causes an increase in intrapulmonary shunt, which may impair oxygenation. The magnitude of shunt is correlated with the formation of pulmonary atelectasis. Atelectasis appears within minutes after the induction of anesthesia in 85%–90% of all patients. The amount of atelectasis is larger in obese patients or when a high fraction of inspired oxygen (FiO_2) is used ***(Marco et al, 2003).***

Atelectasis occurs in the dependent parts of the lungs of most patients who are anesthetized. Development of atelectasis is associated with decreased lung compliance, impairment of oxygenation, increased pulmonary vascular resistance, development of lung injury and postoperative infection. The adverse effects of atelectasis persist into the postoperative period and can impact patient recovery ***and*** hence the need for measures to be taken to avoid atelectasis formation and reverse it if it had already been produced ***(Maceiras, 2005).***

Although intraoperative lung atelectasis is almost inevitable, special groups of patients are known to be affected more than others; for instance,in infants, morbidly obese patients, laparoscopic surgeriesand cardiac surgeries, etc ***(Maceiars& Kavanagh, 2005).***

Anesthesia providers may employ a variety of ventilation strategies to prevent or reverse the pulmonary changes induced by general anesthesia. Some commonly employed techniques include recruitment maneuvers (RMs); for example,positive end-expiratory pressure (PEEP), intervals of large tidal volume ventilation (>15 mls/kg), intermittent “sigh breaths”, and sequential increases in PEEP ***(Talleyetal, 2012).***

Recruitment maneuver denotes the dynamic process of an intentional transient increase in transpulmonary pressure aimed at opening unstable airless alveoli, which has also been termed alveolar recruitment maneuver. The rationale for recruitment maneuvers is to open the atelectatic alveoli, thus increasing endexpiratory lung volume, improving gas exchange, and attenuating VILI (Ventilator Induced Lung Injury) ***(Paolo etal, 2010).***

Alveolar Recruitment Maneuvers has no specific counterindications, but their exclusion criteria are hemodynamic instability, pneumothorax, pneumomediastinum and subcutaneous emphysema, recent lung biopsy and resections. High inspiratory pressures may induce complications, such as hemodynamic changes and risk of barotrauma. Sustained airway pressure has hemodynamic repercussions (decreased venous return and increased left ventricle afterload during maneuver) and exposes lung to higher risk of barotrauma. Hypotension with fast improvement after maneuver interruption is more frequent in hypovolemic patients ***(Gonçalves&Cicarelli, 2005).***

Since postoperative pulmonary complications are a major contributor to the overall risk of surgery, so, strategies that will help prevent these complications would improve the quality of medical care and decrease hospital costs ***(Shanderetal, 2011).***

Chapter One :

Pathophysiology Of Atelectasis

Chapter 1

Pathophysiology of Atelectasis

Anatomical and Physiological Considerations of the Respiratory System

An adult person usually breathes about 6 liters of air per minute at rest, yet, the volume varies with changes in demand, e.g. exercise, because the lungs; with a surface area exposed to air of 28 m^2(300 sq. ft.) at rest and up to 93 m^2(1,000 sq. ft.) during a deep breath, is able to adapt to increasing demand by increasing its surface area available for gaseous exchange, within limits.

In humans; the ventilation involves movement of the chest wall to produce a pressure gradient that will permit flow and movement of gas. This can be accomplished by the respiratory muscles, by negative pressure ventilation (iron lung), or by positive pressure ventilation (mechanical ventilator). Measurements of respiratory mechanics allow a clinician to monitor closely the course of pulmonary disease. At the bedside, changes in these mechanics can occur abruptly (and prompt immediate action) or they may reveal slow trends in respiratory condition (and prompt initiation or discontinuation of mechanical ventilation) ***(Diaz-Mendoza et al., 2013).***

PULMONARY ANATOMY

Gross Anatomy

The Trachea is the cartilaginous and fibromuscular tube that extends from the inferior aspect of the cricoid cartilage (sixth cervical vertebra level) to the main carina (fifth thoracic vertebra level). Its length is 3 cm at birth and 10-12 cm in adults. The shape of the intrathoracic trachea changes during expiration as a result of invagination of the posterior wall, causing as much as a 30% reduction of the anteroposterior diameter ***(Diaz-Mendoza et al., 2013).***

Bronchi: The airways divide by dichotomous branching (Figure 1.1), with approximately 23 generations of branches from the trachea to the alveoli.

Bronchi are composed of cartilaginous and fibromuscular elements. The wall thickness is approximately proportional to the airway diameter on airways distal to the segmental branches.

There are 2 mainstem bronchi (right and left) and 3 lobar bronchi (right), with a total of 10 segmental bronchi; 2 lobar bronchi are found on the left, with a total of 8 segmental bronchi. Generally, the length and diameter of the central airways vary from right to left ***(Simoff et al, 2006)***

Figure 1.1: CT scan of chest (coronal view). Trachea, main carina, and right main stem bronchus with upper, middle, and lower lobe airways can be seen. Left main stem bronchus is also seen with upper lobe airway. Left lower lobe airway cannot be seen ***(Diaz-Mendoza et al, 2013).***

The Lungs: Some symmetry exists between the right and the left lung. Both lungs are divided into lobes. The gross functional subunits of each lung are called segments and have a close relation with the segmental bronchi. The right lung comprises 10 segments: 3 in the right upper lobe (apical, anterior and medial), 2 in the right middle lobe (medial and lateral), and 5 in the right lower lobe (superior, medial, anterior, lateral, and posterior). The left lung comprises 8 segments: 4 in the left upper lobe (apico-posterior, anterior, superior lingula, and inferior lingula) and 4 in the left lower lobe (superior, antero-medial, lateral, and posterior).

The lungs are covered by the visceral pleura, which is adjoining with the parietal pleura as it reflects from the lateral surfaces of the mediastinum. The visceral pleura forms invaginations into both lungs, which are called fissures. There are 2 complete fissures in the right lung and 1 complete fissure with an incomplete fissure in the left; these separate the different lung lobes ***(Diaz-Mendoza et al, 2013).***

Microscopic Anatomy

The trachea has multiple layers. The mucosa is composed of a ciliated pseudo-stratified columnar epithelium and numerous mucus-secreting goblet cells that rest on a basement membrane with a thin lamina propria. The submucosa contains seromucous glands. The adventitia contains the C shaped cartilaginous rings interconnected by connective tissue.

The epithelium of the bronchus is pseudo-stratified columnar ciliated epithelium, also with numerous goblet cells. The cartilage support is eventually lost at the bronchiolar level (0.5-1.0 mm diameter). The muscle layer becomes the dominant structure and is composed of smooth muscle and elastic fibers. At this level, the mucosa may be highly folded.

The terminal bronchioles are considered the respiratory zone of the lungs. They divide into respiratory bronchioles, which continue downstream as alveolar ducts that are completely lined with alveoli and alveolar sacs.

The epithelium of the respiratory bronchiole is primary cuboidal and may be ciliated; goblet cells are absent. The supporting thin layer is formed by collagenous and smooth muscle. Alveoli appear as small pockets that interrupt the main wall. The terminal portion of the respiratory duct gives rise to the alveolar sacs (composed of a variable number of alveoli). The interalveolar septum often contains 10-15 μ m openings (Pores of Kohn), between neighboring alveoli that help equalize air pressures among them ***(Diaz-Mendoza et al, 2013).***