



Effects of Ventilatory Mode on Intraoperative and Postoperative Hypoxemia During One-Lung Ventilation in Thoracic Surgery

Essay

*Submitted for partial fulfillment of master degree
in Anesthesiology*

By

Peter Naiem Abd-El Massiah Ibraheem

M.B.B.Ch, Faculty of Medicine, Ain Shams University

Supervised by

Prof. Dr/Raouf Ramzy Gadalla

**Professor of Anesthesia and Intensive Care
Faculty of Medicine – Ain Shams University**

Dr/Adel Mikhail Fahmy

**Assistant professor of Anesthesia and Intensive Care
Faculty of Medicine – Ain Shams University**

Dr/Sahar Mohamed Talaat Taha Ahmed

**Lecturer of Anesthesia and Intensive Care
Faculty of Medicine – Ain Shams University**

**Faculty of Medicine
Ain Shams University**

2010

List of tables

<i>Number</i>	<i>Table</i>	<i>Page</i>
Table 1.1	Selected perioperative modifiers of HPV	12
Table 2.1	Conversion measurements of tracheal widths based on chest radiograph and bronchial diameter measurements based on CT scan chest and the predicted left DLT size	36
Table 2.2	Selection of double-lumen tube size based on adult patients' sex and height	36
Table 2.3	Comparative diameters of single- and double-lumen tubes	50
Table 2.4	The characteristics of the independent bronchial blockers	63
Table 2.5	Options for lung isolation	65
Table 3.1	Fluid management for pulmonary resection surgery	67
Table 3.2	suggested ventilation parameters for one-lung ventilation	85

List of Abbreviations

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
H ₂ O ₂	:	Hydrogen peroxide
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 ₂ O	:	Nitrous oxide
NO	:	Nitric oxide
OD	:	Outer diameter

List of Abbreviations (Cont.)

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
Redox	: Reduction oxidation
ROS	: Reactive Oxygen species
RUL	: The right upper lobe
<i>SLT</i>	: <i>Single lumen endobronchial tubes</i>
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

List of figures

<i>Number</i>	<i>Figure</i>	<i>Page</i>
Figure1.1	The effect of gravity on alveolar compliance in the upright position	4
Figure 1.2	Homeostatic Oxygen-Sensing System	6
Figure1.3	The molecular basis for HPV	8
Figure 1.4	Pulmonary blood flow distribution	15
Figure 1.5	The consequence of asymmetry in branching	16
Figure 1.6	A bronchial cast showing the asymmetric branching structure typical of both airway and vascular branching in the lung	17
Figure 1.7	A method of quantifying asymmetry of branching	19
Figure 1.8	Pulmonary vascular resistance vs lung volume	19
Figure 1.9	Proper positioning for a lateral thoracotomy	23
Figure1.10	The effect of the lateral decubitus position on lung compliance	24
Figure1.11	The effect of anesthesia on lung compliance in the lateral decubitus position	25
Figure 1.12	Positional changes of ventilation as they relate to the pressure–volume curve.	26
Figure 2.1	Diagram of the tracheobronchial tree	31
Figure2.2	Diagram of the original Carlens red rubber DLT	33
Figure 2.3	Left-sided double-lumen endobronchial tube	34
Figure 2.4	Right –sided DLT	38
Figure 2.5	Algorithm for determining the	40

	position for a left-sided DLT	
Figure 2.6	Blind method for placement of a left-sided double-lumen endobronchial tube	41
Figure 2.7	Fiberoptic visualization confirming correct position of a left-sided DLT	42
Figure 2.8	Malpositioned left-sided DLT	47
Figure 2.9	Diagram of three different designs of disposable right-sided double-lumen tubes	49
Figure 2.10	The three different designs of left double-lumen tubes studied with tracheal and bronchial cuffs inflated	50
Figure 2.11	Photographs of the bronchial cuffs of three designs of right double-lumen tube	50
Figure 2.12	Univent bronchial blocker system	54
Figure 2.13	Univent tube placement	56
Figure 2.14	Fogarty embolectomy catheter has been passed through a 7-mm-ID endotracheal tube beside a 4-mm diameter fiberoptic bronchoscope	58
Figure 2.15	Arndt bronchial blocker	61
Figure 2.16	Placement of the Arndt bronchial blocker	61
Figure 3.1	The relationship between pulmonary vascular resistance (PVR) and lung volume	68
Figure3.2	Patient position may affect the perfusion of the ventilated lung	73
Figure3.3	Effect of applied positive end-expiratory pressure (PEEP) on total PEEP and oxygenation during one-lung ventilation (OLV)	84

الملخص

لسنوات عديدة ، كان يعتبر نقص التأكسج فى الشرايين أثناء التهوية الرئوية الأحادية المشكلة الأكثر أهمية بالنسبة لطبيب التخدير. فى الوقت الحاضر هناك اهتمام متزايد إزاء الآثار المترتبة للوسائط المختلفة لأجهزة التنفس الصناعي فى اختيار طريقة مثلى تنفسية أو متغير التحكم الأمثل للتهوية أثناء التهوية الرئوية الأحادية.

تمثل جراحة الصدر مجموعة فريدة من المشاكل الفسيولوجية لطبيب التخدير التي تتطلب اهتماما خاصا. وتشمل هذه التغيرات الفسيولوجية الناجمة عن وضع المريض فى الوضع الجانبي، وفتح صدره (استرواح الصدر المفتوح) ، والحاجة إلى التهوية الرئوية الاحادية.

إن فهم الاعتبارات الفسيولوجية المتعلقة بهذا الخلل الحادث يقدم فكرة مهمة للتعامل مع التهوية الرئوية الأحادية وبالتالي التوقع والوقاية والعلاج من نقص التأكسج المتعلق بهذا النوع من الجراحات

لقد تم إدخال التهوية الرئوية الاحادية والعزل الرئوى لأول مرة من قبل كارلينز فى الخمسينات من القرن الماضي عن طريق تصميمه لأنبوب تجويف مزدوج بخطاف . فى وقت لاحق تم تعديل تصميم الأنبوب ذو التجويف المزدوج وأدخلت تقنيات أخرى أحدث لعزل الرئة وأصبح استخدام منظار الألياف الضوئية حجر الزاوية فى تقنيات العزل الرئوى.

هذا التقدم الكبير فى تقنيات عزل الرئة يعطى طبيب التخدير خيارات متعددة لاختيار أفضل طريقة تناسب المريض ويعتبر الكثيرون أن هذا التقدم هو واحد من التفسيرات لخفض نسبة حدوث نقص التأكسج فى الدم المرتبط بهذا النوع من العمليات فى الآونة الأخيرة.

ان واحدة من الجوانب المهمة التي بحاجة إلى سيطرة جيدة خلال التهوية الرئوية الاحادية هى وضبط اجهزة التنفس الصناعي.لوقت طويل استخدمت تقنية

الحجم الرئوى المعتاد بحجم أكبر (١٠ - ١٢ مل/كج) ولكن استراتيجيات حديثة بدأت فى الظهور.

إن خفض الحجم الرئوى المعتاد الى (٥ - ٦ مل/كج) مع تطبيق الضغط الإيجابى فى آخر الزفير يعطى نتائج أفضل و أيضا " وضع الضغط المتحكم فيه " أفضل من "وضع الحجم المتحكم فيه" فى المرضى الذين يعانون من مرض الانسداد الرئوى المزمن الشديد والأمراض الفقاعية وأمراض الرئة المقيدة عند حدوث تقلبات كبيرة فى الضغط داخل الممر الهوائى وخاصة عند الافاقة والذى يكون غير مرغوب فيه.

وعلى الرغم من إبداء اهتمام كبير للتحكم فى التنفس الصناعى من خلال الرئة المستهوية إلا أن من المهم النظر فى المعاملة الانتقائية فى الرئة الغير المستهوية (لتحسين نسبة التأكسج بالدم بعدة وسائل).

Contents

	<i>Page</i>
List of Abbreviations	-
List of Tables	-
List of Figures.....	-
Introduction.....	1
Physiological Considerations during Anesthesia for Thoracic Surgery	3
Lung Isolation Techniques	28
Ventilatory Mode during One Lung Ventilation and its Effect In Prevention and Treatment Of Hypoxemia	66
Summary	98
References	100
Arabic Summary	- -

Acknowledgements

*Really I can hardly find the words to express my gratitude to **Prof. Dr. Raouf Ramzy Gadalla** Professor of anesthesia and intensive care, faculty of medicine, Ain Shams University, for his supervision, continuous help, encouragement throughout this work, and tremendous effort he has done in the meticulous revision of the whole work. It is a great honor to work under his guidance and supervision.*

*I am also indebted to **Prof. Dr Adel Mikhail Fahmy** Assistant professor of anesthesia and intensive care, faculty of medicine, Ain Shams University for his guidance, continuous assistance and sincere supervision of this work,*

*I would like also to express my sincere appreciation and gratitude to **Dr. Sahar Mohammed Talaat** lecturer of anesthesia and intensive care, faculty of medicine, Ain Shams University, for her continuous directions and support throughout the whole work,*

And at last, thanks to God who gives me all love and care as father to his beloved son

Peter Naiem

Cairo, 2010

Introduction

Indications and techniques for thoracic surgery have continually evolved since its origins. Common indications are no longer restricted to complications of tuberculosis and suppurative pneumonitis but now include thoracic malignancies (mainly of the lungs and esophagus), chest trauma, esophageal disease, and mediastinal tumours. Anesthetic techniques for separating the ventilation to each lung have allowed the refinement of surgical techniques **(Morgan et al., 2006)**.

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)**.

During thoracic surgery, when the anesthetized patient is moved from the supine to the lateral decubitus position, significant alterations in the matching of ventilation and perfusion occur. The changes in ventilation and lung perfusion follow and are essential for the understanding of the perturbations seen with OLV **(Dunn, 2000)**.

When switching from two-lung to one-lung ventilation shunt fraction increases, oxygenation is impaired and hypoxemia may occur. Hypoxemia during one-lung ventilation may be prevented by applying a ventilation strategy that avoids alveolar collapse while minimally impairing perfusion of the dependent lung (**Karzai and Schwarzkopf, 2009**).

Physiological Considerations During Anesthesia For Thoracic Surgery

Ventilation – perfusion matching

1. Lung ventilation

Pulmonary ventilation means the inflow and outflow of air between the atmosphere and the lung alveoli (**Guyton et al., 2006**).

Ventilation is measured as the sum of all exhaled gas volume in 1 min (minute ventilation).

The *tidal volume* is the volume of air inspired or expired with each normal breath; it amounts to about 500 milliliters in the adult male (**Guyton et al., 2006**).

Not all the inspired gas mixture reaches alveoli; some of it remains in the airways and is exhaled without being exchanged with alveolar gases. That part of the tidal volume (V_T) not participating in alveolar gas exchange is known as dead space (V_D). Alveolar ventilation (V_A) is the volume of inspired gases actually taking part in gas exchange in 1min.

$$V_A = \text{respiratory rate} \times (V_T - V_D)$$

Dead space is actually composed of gases in non-respiratory airways (**anatomic dead space**) as well as in alveoli that are not perfused (**alveolar dead space**). The sum

of the two is referred to as **physiological dead space**. In the upright position, dead space is normally about 150 ml for most adults (approximately 2 ml/kg) and is nearly all anatomic (**Morgan et al., 2006**).

Distribution of ventilation:

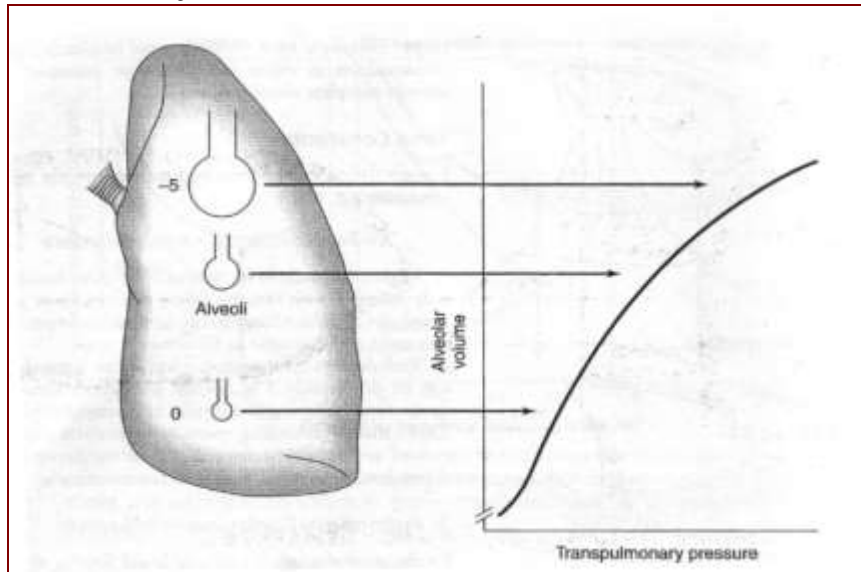


Fig. 1.1 The effect of gravity on alveolar compliance in the upright position (**Morgan et al., 2006**).

Regardless of body position, alveolar ventilation is unevenly distributed in the lungs. The right lung receives more ventilation than the left one (53% versus 47%), and dependent areas of both lungs tend to be better ventilated than do the upper areas because of a gravitationally induced gradient in intrapleural pressure (and necessarily transpulmonary pressure) (**Morgan et al., 2006**).

Pleural pressure decreases about 1 cm H₂O (becomes less negative) per 3 cm decrease in lung height. This difference places alveoli from different areas at different points on the pulmonary compliance curve (**Fig. 1.1**). Because of a higher transpulmonary pressure, alveoli in upper lung areas are near – maximally inflated and relatively noncompliant, and they undergo little more expansion during inspiration. In contrast, the smaller alveoli in dependent areas have a lower transpulmonary pressure, are more compliant, and undergo greater expansion during inspiration (**Morgan et al., 2006**).

2. Lung perfusion

Pulmonary blood flow serves three purposes. First, it delivers oxygen from the alveoli to the body, fueling metabolic oxygen demand. Second, it returns carbon dioxide to the alveoli for removal and exhalation. Third, it provides for left heart preload to support systemic cardiac output (**Lohser, 2008**).

The pulmonary vascular bed is a low resistance conduit and possesses significant recruitable territory. This allows pulmonary pressures to stay low, even when cardiac output is increased to 30 L/min because of exercise (**Lohser, 2008**).

The major determinants of the distribution of pulmonary blood flow include *hypoxic pulmonary vasoconstriction (HPV), gravity, and non gravitational factors*.