Effect of different lung ventilatory patterns during and after Cardiopulmonary bypass on oxygenation parameters after cardiac surgery in adults. A comparative study

A Thesis

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A comparative study

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Abstract:

Background: CPB is not the only stage in which lung injury might occur. Ventilation strategies before and after CPB also cause problems. Alveolar over-distention and reduced lung recruitment are involved in lung injury during general anesthesia in cardiac surgeries. Protective lung ventilation is a common practice during general anesthesia and includes positive end expiratory pressure (PEEP), recruitment maneuvers and the use of FiO2 levels not greater than 80%.

Aim of the work: The aim of the study is to compare the effect of application of continuous positive airway pressure (C-PAP) ventilation during cardiopulmonary bypass and application of positive end expiratory pressure (PEEP) after cardiopulmonary bypass (CPB) per se or followed by lung recruitment (RM) in the intensive care unit (ICU) on arterial oxygenation after cardiopulmonary bypass.

Patients and Method: After obtaining approval from the medical ethical committee, this study will be conducted in Cardiothoracic Academy of Ain Shams University and Ain Shams University specialized hospitals. The study included 66 patients divided into three equal groups.

Conclusion: The application of alveolar recruitment strategy showed short term improvement in the arterial oxygenation and ventilation perfusion mismatch in patients undergoing CABG using CPB. Further studies are needed to determine if this beneficial effect of recruitment maneuvers could be further prolonged and produce more lasting clinical effects.

Keywords: PEEP: Positive end expiratory pressure; PaO2/FiO2: Ratio between partial pressure of arterial oxygen and fraction of inspired oxygen; RMs: Recruitment maneuvers

List of abbreviations:

ARDS	: Adult respiratory distress syndrome
BMI	: Body mass index
CABG	: Coronary artery bypass grafting
COPD	: Chronic obstructive pulmonary disease
C-PAP	: Continuous positive airway pressure
CPB	: Cardiopulmonary bypass
DVT	: Deep venous thrombosis
HR	: Hour
IABP	: Intra-aortic balloon pump
ICU	: Intensive care unit
IL-6	: Interleukin 6
IL-8	: Interleukin 8
MIN	: Minute
NO	: Nitrous oxide
PaO_2/FiO_2	: Ratio between partial pressure of arterial oxygen and fraction of inspired oxygen
PCWP	: Pulmonary capillary wedge pressure
PE	: Pulmonary embolism
PEEP	: Positive end expiratory pressure
RMs	: Recruitment maneuvers
ROS	: Reactive oxygen species
RV	: Right ventricle
SECS	: seconds
SIRS	: Systemic inflammatory response syndrome
TNF	: Tumor necrosis factor
TRALI	: Transfusion related lung injury
VAP	: Ventilator associated pneumonia
VCM	: Vital capacity maneuvers
VILI	: Ventilator induced lung injury
VQ	: Ventilation/perfusion

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Introduction

Pulmonary complications are common after cardiac surgery. They prolong the duration of hospital stay, contribute to postoperative morbidity, and increase mortality. Pulmonary complications after cardiac surgery recorded incidence of 25% of all cardiac surgeries **(*Apostolakis et al., 2010).***

These problems range from postoperative pulmonary complications such as atelectasis, pneumonia, pleural effusion and diaphragm dysfunction to severe forms of acute respiratory distress syndrome which cause great effect of morbidity and mortality. Also these problems affect the pulmonary vascular bed and gas exchange mainly postoperative causing deterioration in arterial oxygenation ***(Ibañez et al., 2016).***

Impairment of gas exchange is reflected by reduction in oxygenation and ratio between partial pressure of arterial oxygen and fraction of inspired oxygen (PaO2/FiO2) which called ***"hypoxic index"*** after cardiac surgery associated with poor hospital outcome.PaO2/FiO2 (hypoxic index) value of 300 or less indicates reduced efficiancy in alveolar-capillary membrane performance ***(Esteve et al., 2014).***

CPB is not the only stage in which lung injury might occur. Ventilation strategies before and after CPB also cause problems. Alveolar over-distention and reduced lung recruitment are involved in lung injury during general

anesthesia in cardiac surgeries. Protective lung ventilation is a common practice during general anesthesia and includes positive end expiratory pressure (PEEP), recruitment maneuvers and the use of FiO2 levels not greater than 80% ***(Ferrando et al., 2015).***

Recruitment maneuvers (RMs) have been proposed as an adjunct to mechanical ventilation to reverse alveolar derecruitment and improve pulmonary gas exchange.There are different methods to perform RM when using the conventional ICU ventilator. The three RM methods that are mostly used and investigated are sighs, sustained inflation, and extended sigh. There is no standardization of any of the above RM ***(Guerin et al., 2011).***

Aim of the study

The aim of the study is to compare the effect of application of continuous positive airway pressure (C-PAP) ventilation during cardiopulmonary bypass and application of positive end expiratory pressure (PEEP) after cardiopulmonary bypass (CPB) per se or followed by lung recruitment (RM) in the intensive care unit (ICU) on arterial oxygenation after cardiopulmonary bypass.

Different pulmonary complications occur after CPB

Generally there are multiple risk factors for early pulmonary dysfunction after Cardiothoracic Surgery:

Table(1):Perioperative risk factors for early pulmonary dysfunction after cardiothoracic surgery *(Jensen and Yang, 2007):*

Preoperative Variables	• Age ≥ 75 Years • Body mass index ≥ 30 kg/m2 • Mean pulmonary artery pressure ≥ 20 mmHg • Stroke volume index ≤ 30 mL/m2 • Low serum albumin • History of cerebrovascular disease • Emergency surgery • Total cardiopulmonary bypass time ≥ 140 min
Postoperative Variables	• Hematocrit (immediate postoperative) ≥ 30% • Mean systemic arterial pressure ≥ 90 mmHg • Cardiac index ≥ 3.0 L/min/m2
Pulmonary dysfunction associated with	• Postoperative increase in serum creatinine • Neurologic complications • Nosocomial infections • Prolonged mechanical ventilation • Length of stay in the cardiovascular ICU and hospital

Pulmonary complications after cardiac surgery include:

1- Atelectasis:

It is the most common pulmonary complication after cardiac surgery occurring in about 70% of cases. It is the collapse or closure of a lung alveoli resulting in reduced or absent gas exchange. It may affect part or all of a lung but the most common affected sites after cardiac surgeries are the basal one. During CPB, the lungs are not perfused and they are allowed to collapse to functional residual capacity (FRC). There are multiple risk factors trigger inducing of atelectasis including smoking, obesity and elderly ***(Canet et al., 2010).***

Causes of atelectasis after cardiac surgeries:

A-Intra-operative causes:

The induction of general anesthesia, manual compression of the left lower lobe during maneuvers to expose the posterior surface of the heart, manual compression of the right lung during cannulation of the inferior vena cava, manual compression of the lung during internal mammary artery dissection, apnea during CPB and the harvesting of internal mammary arteries results in atelectasis, which is increased by the creation of a pleurotomy ***(Badenes et al., 2015).***

B-Post-operative causes:

Poor postoperative coughing due to pain and weakness of respiratory muscles which lead to Lack of deep inspiration, pleural effusions, gastric distention and

increased interstitial lung water ***(Badenes R et al., 2015).***

Evidence by chest radiography:

Clinically significant atelectasis is generally visible on chest X-ray; findings can include lung opacification and/or loss of lung volume.

Post-surgical atelectasis will be bi-basal in pattern. Chest CT or bronchoscopy may be necessary if the cause of atelectasis is not clinically apparent.

Direct signs of atelectasis include displacement of inter-lobar fissures and mobile structures within the thorax, over-inflation of the unaffected ipsilateral lobe or contralateral lung, and opacification of the collapsed lobe ***(McAlister et al., 2005).***

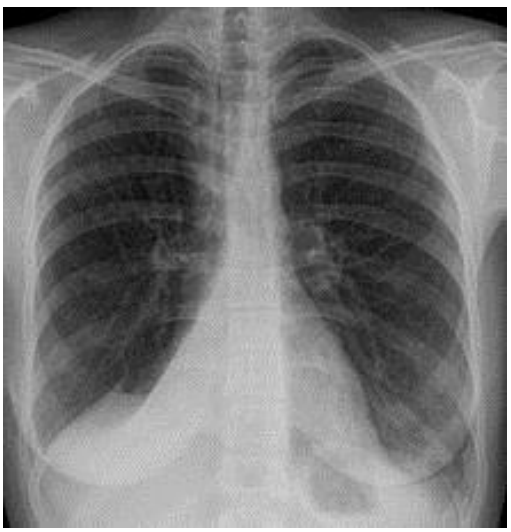

Fig.(1): Bilateral lower lobe atelectasis chest x-ray ***(McAlister et al., 2005).***

2- Pleural effusion:

It is the second most common post-operative pulmonary complication after cardiac surgery. The reported incidence after coronary artery bypass grafting (CABG) was 40% to 50% ***(Light et al., 2002).***

Causes of pleural effusion after cardiac surgery:

Post-operative bleeding, atelectasis, pneumonia, cardiogenic and non-cardiogenic pulmonary edema, pleurotomy performed to harvest internal mammary artery grafts, damage from topical cardiac hypothermia, disruption of pleural lymphatic drainage by internal mammary artery harvesting and leaking of fluid from the mediastinum ***(Labidi et al., 2009).***

Clinical manifestations:

Mostly pleural effusions after cardiac surgery are mild and asymptomatic but in few cases large bloody effusions occur and patients manifested with dyspnea but no chest pain or fever ***(Light, et al., 2002).***

Evidence by chest radiography:

There are five grades of pleural effusion determined by chest x-ray:

Table(2): grades of pleural effusion determined by chest x-ray *(Light et al., 2002).*

Grade of effusion	Characteristic of Chest x-ray
0	No pleural fluid present
1	Blunting of the costo-phrenic angle
2	More than blunting of the costo-phrenic angle but less than 25% of hemi-thorax occupied by pleural fluid
3	Pleural fluid occupying 25–50% of hemithorax
4	Pleural fluid occupying 51–75% of hemithorax
5	Pleural fluid occupying more than 75% of hemithorax

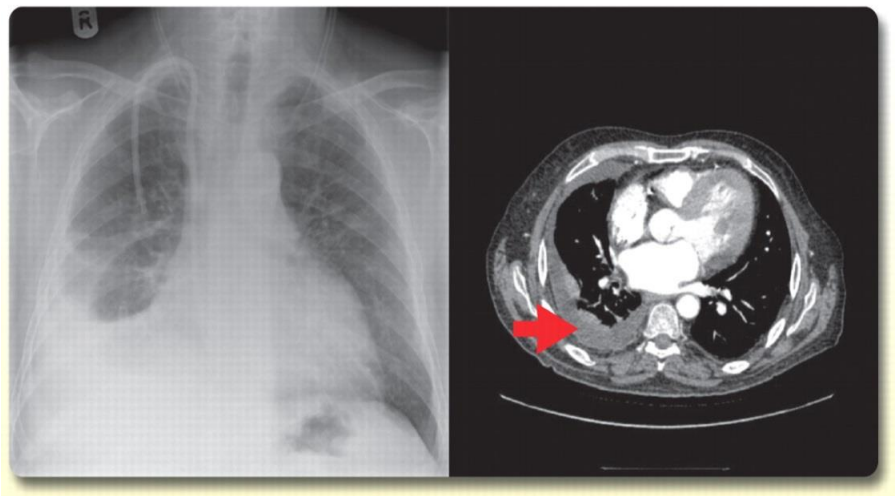

Fig.(2): pleural effusion chest x-ray and CT-scan ***(McGrath and Anderson., 2011).***