Original Article

OPEN ACCESS

Effectiveness of Aggressive Intraoperative Pulmonary Recruitment Maneuver in Limiting Immediate Postoperative Pathological Atelectasis Immediately before Weaning from Cardiopulmonary Bypass

Jamal Rabbi[1] Mamoon Qadir[2] Sangeen Khan Wazir[3] Javed Iqbal[4], Mahmud Aurangzeb[5], Iqbal Khan Saifullah[6]

[1]Associate Professor, Department of Cardiac Surgery, Pakistan Institute of Medical Sciences, Islamabad
[2]Cardiac Interventionist, Kulsum International Hospital, Islamabad
[3]Medical Officer, Department of Cardiology, Kulsum International Hospital, Islamabad
[4]Professor, Cardiac Surgery, Rawalpindi Institute of Cardiology, Rawalpindi
[5]Cardiac Interventionist, Department of Cardiology, Pakistan Institute of Medical Sciences, Islamabad
[6]Head of Cardiology, Kulsum International Hospital, Islamabad

Author`s Contribution

[1,3]Substantial contributions to the conception or design of the work; or the acquisition, [4,5]Active participation in active methodology, [2,3]analysis, or interpretation of data for the work, [2,5]Drafting the work or revising it critically for important intellectual content, [6]Final approval of the study to be published

Funding Source: None
Conflict of Interest: None

Received: June 19, 2024
Accepted: Nov 26, 2024

Address of Correspondent
Dr. Jamal Rabbi
Associate Professor
Department of Cardiac Surgery
Pakistan Institute of Medical Sciences, Islamabad
Email: jfrabbi@hotmail.com

ABSTRACT

Objective: To determine effectiveness of aggressive Intraoperative Pulmonary recruitment maneuver before weaning in limiting immediate postoperative pathological Atelectasis in patients with coronary artery bypass surgery

Methodology: This retrospective analysis was conducted at Heart and Vascular Institution, Kulsum International Hospital, Islamabad from November 2019 to 12th April 2023. All patients with elective coronary artery bypass surgery were included. In group A (n=20) the recruitment maneuver was initiated before weaning from bypass while in group B, the protocol recruitment maneuver was not initiated. The immediate postoperative pathological atelectasis based on chest x-ray was compared between two groups.

Results: In this study, 40 patients with mean age 55.7 ± 5.2 years were included. There were 15 (75.0%) males and 5 (25.0%) females in group A while in group B there were 17 (85.0%) males and 3 (15.0%) females. In group A, post-operative chest x-ray demonstrated one basilar angle obliteration consistent with atelectasis in 1 (5.0%) patient. In group B, 12 (60.0%) patients demonstrated more than three basilar angles obliteration. There were 4 (20.0%) patients each with four basilar angles obliteration and one angle obliteration.

Conclusion: Initiation of aggressive intraoperative pulmonary recruitment maneuver before weaning from bypass prevents atelectasis than in patients in whom aggressive intraoperative pulmonary recruitment maneuver was not initiated.

Keywords: Atelectasis, coronary artery bypass, pulmonary recruitment maneuver, weaning.

Cite this article as: Rabbi J, Qadir M, Wazir SK, Iqbal J, Aurangzeb M, Saifullah IK. Effectiveness of Aggressive Intraoperative Pulmonary Recruitment Maneuver in Limiting Immediate Postoperative Pathological Atelectasis Immediately before Weaning from Cardiopulmonary Bypass. Ann Pak Inst Med Sci. 2024; 20(4):658-663. doi. 10.48036/apims.v20i4.1086

Introduction

Atelectasis is a known complication in patients and a cause of hypoxemia after heart surgery.[1] In anesthesia for surgery, pulmonary collapse begins, which may persist for several days.[2] Surgeries with a duration longer than 3-4 hours along with anesthesia causes an increased risk of atelectasis.[3] Atelectasis is a partial or complete collapse of lung tissue, and is a commonly occurring complication following heart surgery. The reported incidence of atelectasis after heart surgery varies widely, ranging from around 30% to as high as 70%.[4] This difference can be attributed to factors like the diagnostic methods used

(chest x-ray vs. more sensitive techniques), definition of atelectasis severity, and specific type of heart surgery.

Anesthesia can suppress deep breathing and coughing, which normally keep airways clear. Pain from surgery can also limit deep breaths. These factors allow mucus to build up and block airways, or prevent alveoli (air sacs) from inflating fully.

The adverse effects of atelectasis are more common in patients with underlying debilitating lung conditions and heart disease. Its prevalence is well documented with patients having low Ejection Fraction undergoing heart surgery. In heart surgery, there are specific aspects of operation that increase its occurrence like use of thoracic artery.[4]

In heart surgery, cardiopulmonary bypass (CPB) is established and includes deflating of lungs for a better surgical exposure. This intraoperative pulmonary collapse resolves with spontaneous breathing after awakening however for days after surgery atelectasis and hypoxemia can continue.[5,6] In literature, atelectasis can lead to prolonged hospitalization, increase cost and rise in mortality.[7]

The current study focused on a specific manoeuvre during the operation to target and address post- operative atelectasis. The partial or complete lung collapse reduces oxygen intake and can lead to pneumonia, respiratory failure, and a longer hospital stay. These complications place a substantial burden on the already strained healthcare system in Pakistan. The aggressive IPRM has been demonstrated to improve lung volume, oxygenation, and compliance, thereby reducing the incidence of atelectasis and pneumonia. By preventing these complications, the need for additional respiratory support, prolonged mechanical ventilation, and antibiotic therapy can be minimized. Moreover, effective prevention of postoperative pulmonary complications can lead to a shorter duration of hospital stay. This translates to quicker patient turnover, freeing up hospital beds for other patients and reducing overall healthcare costs. By reducing the severity and duration of postoperative pulmonary complications, the demand for critical care resources, such as ventilators and intensive care unit beds, is decreased. Preventing pulmonary complications facilitates earlier mobilization and discharge, leading to improved quality of life for patients. While the initial investment in implementing aggressive IPRM may be required, the long-term benefits in terms of reduced healthcare costs, shorter hospital stays, and improved patient outcomes make it a potentially cost-effective strategy.

Keeping in view the already under pressure health settings and healthcare workers in Pakistan. The aggressive intraoperative pulmonary recruitment maneuver before weaning in patients of coronary artery bypass surgery could save costs and prevent healthcare burden. The specific purpose of study was to assess the effectiveness of aggressive intraoperative pulmonary recruitment maneuver before weaning in limiting immediate postoperative pathological atelectasis in patients with coronary artery bypass surgery.

Methodology

The study was approved by the ethical committee of Kulsum International Hospital in Islamabad. This was a retrospective cohort study consisting of 40 patients. Patient information was recorded on structured proformas from the medical records of patients of coronary artery disease who had undergone bypass surgery. Patient's statistical profile, indications, signs and symptoms were recorded. Echos were done and patients included had ejection fractions more than 50%. The pre-operative and post-operative chest x-ray were studied by the single radiologist. All the patients had the FEV1 on pulmonary function test within 80% of predictive value.

Exclusion criteria included preoperative congestive heart failure based on chest x-ray, chronic obstructive pulmonary disease based on pulmonary function test, as well as perioperative hemodynamic stability requiring postoperative vasopressor greater than four hours in ICU. The study outcome i.e. atelectasis was compared between two groups. In this study medical record of 20 patients with recruitment maneuver initiation before weaning from bypass was available which was selected while an equal number (n=20) of patients in whom the protocol recruitment maneuver was not initiated before weaning from cardiopulmonary bypass machine were also selected for the purpose of comparative analysis.

As per study analysis, the patients' chest x-ray was taken before operation and then on the first and third postoperative days. In order to make it more objective, basilar atelectasis causing the obliteration of costo-phrenic and cardio-phrenic angles were observed on chest x-ray. Measurement of atelectasis included thin lines in the chest x-ray of lungs, on the basis of available references and radiologists.

Strict mechanism and intraoperative timing of pulmonary recruitment was followed. The mechanism of pulmonary recruitment involved inflation of bilateral lungs with a hand assisted bag until the pressure reached 30 mmHg on anesthesia monitor and kept it on this pressure for 15 seconds, immediately before initiating normal ventilation for weaning from cardiopulmonary bypass. The study outcome was comparison of immediate postoperative pathological atelectasis between two groups in the first 24 hours based on chest x-ray.

Data was analyzed in SPSS version 22. The categorical variables like gender, comorbidity, and atelectasis were measured as frequency and percentages whereas the quantitative numerical variables like age was measured as mean and standard deviation. The frequency of atelectasis was compared between two groups using chi square test at a significance level of 0.05.

Results

In the present study, out of 40 patients, 32 were males and 8 were females. Age ranged from 45 to 72 years with an overall mean of 55.7 ± 5.2 years. In group A, the mean age was 53.6 ± 4.1 years while in group B, it was 54.9 ± 6.8 years. In group A, where aggressive pulmonary recruitment maneuver was implemented, there were 15 (75.0%) males and 5 (25.0%) females compared to 17 (85.0%) male and 3 (15.0%) females in group B where aggressive pulmonary recruitment maneuver was not implemented. The ejection fraction of the patients was 50%. Comorbidities included hyperlipidemia, hypertension and Diabetes mellitus which were present in all (100.0%) study cases. Overall, the mean duration of surgery was 4.03 hours. The mean duration of CPB time was 72 minutes. The ones who required were all extubated within six hours of arrival in the ICU. (Table I)

Table I: Demographic characteristics of patients in two groups.

	Group A (n=20)	Group B (n=20)	p-value
Age (years)			
45 to 55	5 (25.0%)	4 (20.0%)	0.89
56 to 65	9 (45.0%)	10 (50.0%)	
66 or above	6 (30.0%)	5 (25.0%)	
Mean ± SD	53.6 ± 4.1	54.9 ± 6.8	0.78
Gender			
Male	15 (75.0%)	17 (85.0%)	0.51
Female	5 (25.0%)	3 (15.0%)	
Comorbidities			
Hypercholesterolemia	20 (100.0%)	20 (100.0%)	0.78
Diabetes mellitus	19 (95.0%)	20 (100.0%)	
Hypertension	19 (95.0%)	18 (90.0%)	

In group A, the 24-hour chest x-ray demonstrated only 1 (5.0%) basilar angle obliteration consistent with atelectasis. While in group B, all 20 (100.0%) patients needed extubation within 6 hours of arrival in ICU. The 24-hour chest x-ray in this group demonstrated more than three basilar angles obliteration in 12 (60.0%) patients. There were four basilar angles obliteration in 4 (20.0%) patients and one angle obliteration in 4 (20.0%) patients. In these patients of group B, 4 (20.0%) also developed pneumonia with a hospital stay period of more than 7 days. (Table II)

Table II: Comparison of atelectasis between two groups.

	Group A (n=20)	Group B (n=20)	p-value
No of angles obliterated representing atelectasis burden			
One	1 (5.0%)	5 (25.0%)	<0.001
Two	0 (0.0%)	0 (0.0%)	
Three	0 (0.0%)	5 (25.0%)	
Four	0 (0.0%)	12 (60.0%)	
Complications/side effects			
Pneumonia	0 (0.0%)	4 (20.0%)	<0.001*
Others	0 (0.0%)	0 (0.0%)	
Hospital stay (days)			
Mean ± SD	2.1 ± 1.3	5.6 ± 2.8	<0.001

Discussion

This study highlights that the aggressive intraoperative pulmonary recruitment maneuver limits the pathological changes in the early post-operative period in patients undergoing CABG. Thus, it should be routinely utilized as an intra-operative strategy to prevent post-surgery pulmonary dysfunction in patients undergoing cardio-pulmonary bypass surgery. Plenty of previous literature depicts that the immediate postoperative atelectasis, secondary to reduction of aeration lung, is highly prevalent in patients undergoing heart surgery with cardio-pulmonary bypass and may continue for days. The atelectasis is more common in the dependent region near the diaphragm. Similar, to current study findings a meta-analysis published in the British Journal of Anaesthesia found that IPRM reduced the incidence of postoperative pulmonary complications compared to conventional ventilation.[8] Similarly, there are several randomized controlled trials that have demonstrated the effectiveness of IPRM in preventing atelectasis and improving oxygenation.[9]

Many studies have witnessed atelectasis post cardiopulmonary bypass surgery and have classified it as linear, segmental and lobar.[10,11] It may extend to 35% of lung parenchyma, leading to hypoxemia, which itself has

detrimental effects on the hemodynamics, especially in patients with baseline elevated pulmonary hypertension. Generally, atelectasis is resolved within the first 24 to 48 hours with simple maneuvers, like: early mobilization, turning patient's sides,[12] deep breathing or respiratory muscle training.[13] There are instances, where it reflects infection in the atelectatic region.

Though there is little evidence of causality, atelectasis may be associated with the development of bacterial pneumonia leading to significant rise in mortality 30%-46% in heart surgery.[14] The patients may suffer hypoxemia, necessitating prolonged oxygen and antibiotic therapy or even mechanical ventilation.[2,15]

The underlying mechanism is secondary to altering the production of surfactant preventing the re-expansion, decreased mucociliary transport in the atelectatic region of the lung parenchyma. In Literature there is significant association of underlying pulmonary disease (asthma, bronchitis), diabetes, hyperlipidemia,[16] obese patients[17] and low ejection fraction less than 50% with atelectasis after cardiac surgery. Moreover, smoking, alcohol consumption, 4 units of packed red blood cells transfusion[18] and patients on medications like steroids are at greater risk of atelectasis following CABG.

Cardiac mass can enlarge up to 32%,[19] hence pressing the subjacent lung segments that would increase lung collapse hence loss of aeration and atelectasis of that specific region[20] and its exaggerated compression is also noted with cardiomegaly.[21] Scientific evidence, reports many pulmonary protection strategies, which includes the role of pharmacological intervention, surgical strategies and physiotherapy. These measures definitely reduce the overall pulmonary dysfunction related to cardiac surgery. The management is a multistep process that starts during operative and postoperative phases.[19,20]

The current study focused on the intra-operative phase and worked on a single maneuver to influence the incidence of atelectasis based on post-operative chest x-ray in the first 24 hours. Clearly, this study documented that intraoperative pulmonary recruitment maneuver significantly influenced the incidence of atelectasis, when compared with the control group. It has been suggested that eliminating the usual standard i.e., no lung inflation during CPB by maintaining a degree of lung ventilation may be beneficial. It is further supported by the fact of compression phenomena by the increased heart mass due to CABG also that off pump coronary artery bypass surgery (OPCAB) seems to provide better lung protection by eliminating ischemia reperfusion injury, due to maintenance of lung ventilation in OPCAB. Studies have shown that lung recruitment maneuvers re-opens collapsed lung regions, hence improving oxygenation.[22] These observations led the current investigators to conduct this trial and compare recruitment maneuver protocol as explained with the control group.

Intraoperative pulmonary recruitment maneuver does help in reduction of early postoperative atelectasis, especially in surgeries like CABG. More so, further studies can be done, where this maneuver can prove useful in subjects, who are more prone to atelectasis, like prolonged bypass time or enlarged hearts. This maneuver can also be done in the postoperative setup, hence, a comparison study between the two can also be conducted. Clinical manifestation of the pulmonary dysfunction varies from mild atelectasis to severe respiratory failure. The management of pulmonary dysfunction is a multistep process, which is well documented in literature.

There were multi-level advantages of this study that included firstly, addressing pulmonary dysfunction during and early on after coronary artery bypass surgery. The study has programmatic implications in terms of saving additional costs and limiting healthcare burden due to pulmonary dysfunction in CABG patients. The limitation of this study was that it has worked on only one postoperative complication i.e. atelectasis.

Conclusion

It is concluded that the aggressive intraoperative pulmonary recruitment maneuver limits the pathological changes such as atelectasis in the early post-operative period in CABG patients. This maneuver should be utilized as an intra-operative strategy for prevention of post-surgery pulmonary dysfunction. Pulmonary dysfunction is one of the most common complications, related to open heart surgery and can have a significant impact on patient outcomes and health economics. Furthermore, in future trials, a comparison study can be done on the use of this maneuver in intra and postoperative settings.

Acknowledgement: We acknowledge the cooperation of Cardiology Department at Kulsum International Hospital for permitting us use of data.

References

1. Lundstrøm LH, Nygård E, Hviid LB, Pedersen FM, Ravn J, Aldershvile J, et al. The effect of thoracic epidural

analgesia on the occurrence of late postoperative hypoxemia in patients undergoing elective coronary bypass surgery. Chest. 2005;128(3):1564–70. https://doi.org/10.1378/chest.128.3.1564
2. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br J Anaesth. 2017;118(3):317–34. https://doi.org/10.1093/bja/aex002
3. Iyem H, Islamoglu F, Yagdi T, Sargin M, Berber O, Hamulu A, et al. Effects of pleurotomy on respiratory sequelae after internal mammary artery harvesting. Tex Heart Inst J. 2006;33(2):116.
4. Ghavidel AA, Noorizadeh E, Pouraliakbar H, Mirmesdagh Y, Hosseini S, Asgari B, et al. Impact of intact pleura during left internal mammary artery harvesting on clinical outcome. J Tehran Univ Heart Cent. 2013;8(1):48.
5. Huffmyer JL, Groves DS. Pulmonary complications of cardiopulmonary bypass. Best Pract Res Clin Anaesthesiol. 2015;29(2):163–75. https://doi.org/10.1016/j.bpa.2015.04.002
6. Westerdahl E, Lindmark B, Eriksson T, Hedenstierna G, Tenling A. Deep-breathing exercises reduce atelectasis and improve pulmonary function after coronary artery bypass surgery. Chest. 2005;128(5):3482–8. https://doi.org/10.1378/chest.128.5.3482
7. Magnusson L, Zemgulis V, Tenling A, Wernlund J, Tyden H, Thelin S, et al. Use of a vital capacity maneuver to prevent atelectasis after cardiopulmonary bypass: an experimental study. Anesthesiology. 1998;88(1):134–42. https://doi.org/10.1097/00000542-199801000-00021
8. Pei S, Wei W, Yang K, Yang Y, Pan Y, Wei J, et al. Recruitment maneuver to reduce postoperative pulmonary complications after laparoscopic abdominal surgery: a systematic review and meta-analysis. J Clin Med. 2022;11(19):5841. https://doi.org/10.3390/jcm11195841
9. Parmeswaran P, Gupta P, Ittoop AL, Kaushal A, Kumar A, Singla D. Effect of intraoperative alveolar recruitment maneuver on intraoperative oxygenation and postoperative pulmonary function tests in patients undergoing robotic-assisted hysterectomy: a single-blind randomized study. Braz J Anesthesiol. 2023;73(4):418–25. https://doi.org/10.1016/j.bjane.2022.07.001
10. Rodrigues RR, Sawada AY, Rouby JJ, Fukuda MJ, Neves FH, Carmona MJ, et al. Computed tomography assessment of lung structure in patients undergoing cardiac surgery with cardiopulmonary bypass. Braz J Med Biol Res. 2011;44:598–605. https://doi.org/10.1590/S0100-879X2011007500048
11. Hedenstierna G. Atelectasis formation and gas exchange impairment during anaesthesia. Monaldi Arch Chest Dis. 1994;49(4):315–22.
12. Staudinger T, Bojic A, Kofler J, Müller M, Laczika K, Locker GJ, et al. Continuous lateral rotation therapy to prevent ventilator-associated pneumonia. Crit Care Med. 2010;38(2):486–90. https://doi.org/10.1097/CCM.0b013e3181bc8218
13. Hulzebos EH, Helders PJ, Favié NJ, De Bie RA, de la Riviere AB, Van Meeteren NL. Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. JAMA. 2006;296(15):1851–7. https://doi.org/10.1001/jama.296.15.1851
14. Tanner TG, Colvin MO. Pulmonary complications of cardiac surgery. Lung. 2020;198(6):889–96. https://doi.org/10.1007/s00408-020-00405-7
15. Duggan M, McNamara PJ, Engelberts D, Pace-Asciak C, Babyn P, Post M, et al. Oxygen attenuates atelectasis-induced injury in the in vivo rat lung. Anesthesiology. 2005;103(3):522–31. https://doi.org/10.1097/00000542-200509000-00015
16. Saffari NH, Nasiri E, Mousavinasab SN, Ghafari R, Soleimani A, Esmaeili R. Frequency rate of atelectasis in patients following coronary artery bypass graft and its associated factors at Mazandaran Heart Center in 2013–2014. Glob J Health Sci. 2015;7(7):97. https://doi.org/10.5539/gjhs.v7n7p97
17. Eichenberger AS, Proietti S, Wicky S, Frascarolo P, Suter M, Spahn DR, et al. Morbid obesity and postoperative pulmonary atelectasis: an underestimated problem. Anesth Analg. 2002;95(6):1788–92. https://doi.org/10.1097/00000539-200212000-00060
18. Goyal V, Pinto RJ, Mukherjee K, Trivedi A, Sharma S, Bhattacharya S. Alteration in pulmonary mechanics after coronary artery bypass surgery: comparison using internal mammary artery and saphenous vein grafts. Indian Heart J. 1994;46(6):345–8.
19. Neves FH, Carmona MJ, Auler JO Jr, Rodrigues RR, Rouby JJ, Malbouisson LM. Cardiac compression of lung lower lobes after coronary artery bypass graft with cardiopulmonary bypass. PLoS One. 2013;8(11):e78643. https://doi.org/10.1371/journal.pone.0078643
20. Raffa GM, Cappai A, Tarelli G. Giant left atrium syndrome. J Cardiovasc Med. 2011;12(10):745–6. https://doi.org/10.2459/JCM.0b013e32834a65b1