Original Article

Cardiopulmonary Bypass and Continuous Low Tidal Volume

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ABSTRACT

Objective: is to compare the effects of low tidal volume ventilation versus no-ventilation in terms of reducing pulmonary dysfunction during cardiopulmonary bypass (CPB) in patients undergoing conventional coronary artery bypass graft (CABG) surgery.

Study Design: Randomized controlled trial study

Place and Duration of Study: This study was conducted at the Dow University of Health Sciences from June 2021 to June 2022.

Materials and Methods: A total of 62 patients who were planned to for cardiac pulmonary bypass graft surgery were enrolled and randomized in two groups. Group A ventilation group was managed with low tidal volume ventilation 3 ml/kg, 12 breaths/min respiratory rate and 5 cmHg PEEP. In group B non-ventilation group ventilation was arrested.

Results: The mean PaO_2/FiO_2 Ratio after intubation of Group A and Group B was 340.91±23.89 and 348.79±24.65, respectively. (p=0.207). The mean PaO_2/FiO_2 Ratio after 1 hour of CPB and PaO_2/FiO_2 Ratio after hours of CPB of Group A was greater than Group B, (p<0.001). Whereas, the A-a oxygen ($O_{2)}$ gradient after 1 hour of cardiopulmonary bypass CPB (kPa) and A-a oxygen ($O_{2)}$ gradient after 4 hour of cardiopulmonary bypass CPB (kPa) of Group A was less than Group B, (p<0.001). The mean ventilation time of Group A and Group B was 5.61±0.86 hours and 7.77±0.98 hours, respectively. (p<0.001). While, ICU stay and hospital stay of both the groups was almost same, (P>0.050).

Conclusion: In cardiac surgery patients especially cardiopulmonary bypass low tidal volume ventilation is associated with reduce risk of complications and better oxygenation during cardiopulmonary bypass.

Key Words: Low tidal volume, Pulmonary dysfunction, Ventilation, Cardiopulmonary Arrest, cardiopulmonary graft surgery.

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INTRODUCTION

In cardiac surgery cardiopulmonary bypass (CPB) is a useful technique that works on non beating heart[1]. During surgical procedure patient's oxygenation, circulation and temperature is maintained with CPB that provides bloodless field to the surgeon[2].

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CPB named because of bypass of lungs and heart by directing blood direct in aorta from right atrium. But this bypass procedure also associated with post-operative pulmonary complications[3]. Post-operative pulmonary dysfunction is most common among complications of open heart surgery that may lead to minor respiratory complications to acute respiratory distress syndrome[4].

After cardiac surgery mortality rate of ARDS varies from 40% to 90% [5]. Ventilation arrest after establishing CPB can have negative effects on lung function and increase the risk of complications such as retained bronchial sections, atelectasis, and pulmonary edema. Strategies to prevent or minimize pulmonary complications after cardiac surgery include early mobilization, incentive spirometry, chest physiotherapy, and avoiding overuse of sedatives and pain medications that may impair breathing[6]. This is due to the lack of ventilation and oxygenation to the lungs during the arrest, which can lead to decreased lung compliance and an increase in arterial venous shunt[7].

Additionally, the lack of ventilation can interfere with the surgical procedure by causing lung movements. To mitigate these risks, alternative methods of ventilation may be used during CPB, such as low tidal volume ventilation or intermittent positive pressure ventilation[8]. Different techniques like continuous or intermittent positive pressure ventilation, different vital capacity maneuvers and low tidal volume ventilation have been shown to be beneficial in reduction of the incidence of post-operative pulmonary dysfunction after cardiac surgery[9,10].

Limited literature is available to justify the role of both techniques in reduction of pulmonary dysfunction and complications. Our study will be a good addition in literature of anesthesia and cardiac surgery to understand the science of cardiothoracic anesthesia.

MATERIALS AND METHODS

This randomized control trial was conducted at Dow University of Health Sciences using non-probability consecutive sampling. The sample size was calculated using an online sample size calculator and the following statistics: Confidence interval of 95% and a power of study of 80%. After 4 hours of cardiopulmonary bypass CPB, the A-a oxygen (O2) gradient was found to be 19.37 ± 2.05 kPa in the ventilated group and 20.81 ± 1.94 kPa in the non-ventilated group.

Calculated sample size is 62 patients and 31 patients in each group. Patients of age 20-60 years**, b**oth gender, patients planned to undergo conventional CABG surgery were included in study. Pulmonary dysfunction was measured in terms of ventilation time, development of pulmonary edema, atelactesis and pleural effusion, Group I (ventilated): patients were maintained at 3 ml per kg tidal volume, Twelve breath per minute breath rate, and Peak End Expiratory Pressure of 5 cmH_2O, Group II (Non ventilated): ventilation was stopped during CPB.

Off pump surgery patients, insulin dependent diabetes mellitus, other valvular procedures, obese patients, below 30% ejection fraction, below 40% forced vital capacity and any pulmonary complication before surgery were not enrolled. Hospital ethical committee reviewed the all legal aspects of study and allowed its proceeding. Patients consent was also obtained. Simple random sampling was done to complete randomization of patients and categorized as group A ventilation group that was operated by low tidal ventilation (PEEP 5 cmH_2O, 3 ml/kg tidal volume along with 12 breath/minutes respiratory rate. No ventilation was given in group B during cardiopulmonary bypass.

Two large bore cannulas were inserted on dorsal sides of both hands. Anesthesia was induced with inj Kinz, midazolam and muscle relaxant atracurium and maintenance was attained with fentanyl, propofol and inhalational anesthetic isoflurane.

Invasive monitoring of pulse oximetry and blood pressure was attached. Activated clotting time (ACT) was maintained above 480 sec during the CPB. Blood cardioplegic solution of potassium was used for cardiac arrest. In group I continuous ventilation with low tidal volume was started after aortic cross clamping and in group II ventilation was stopped till removal of clamp.

It is important to note that moderate systemic cooling during surgery (32 degree centigrade) was achieved and the patient was revert to 37 degree centigrade before moving away from CPB. The time duration of bypass and cross-clamp were also recorded. Arterial blood samples were taken after intubation for investigation of arterial blood gases, as well as after one and four hours of CPB. A chest radiograph was taken on the 4th post-operative day to rule out any pulmonary complications (pleural effusion and edema). It is important to monitor all of these factors to ensure the patient's recovery is going smoothly.

Data analysis was done by SPSS updated version 23. Mean values and their SD was calculated for data available in continuous number form like age, BMI, ICU stay, hospital stay, mechanical ventilation time and extubation time. Frequency and percentages was calculated for categorical data like, gender, groups, pleural effusion and pulmonary edema. P value below 0.05 was taken significant after applying significance test.

RESULTS

Overall, 62 patients were included in our study, both male and female. The study patients equally divided into two groups as ventilation group (Group A) and non-ventilation group (Group B). No significant difference was found between demographics and operative characteristics of both the groups, ($p>0.050$). (Table No. 1).

The mean PaO_2/FiO_2 Ratio after intubation of Group A and Group B was 340.91±23.89 and 348.79±24.65, respectively. ($p=0.207$). The mean PaO_2/FiO_2 Ratio after 1 hour of CPB and PaO_2/FiO_2 Ratio after hours of CPB of Group A was greater than Group B, ($p<0.001$). Oxygen gradient (A-a O_2) one hour after CPB (kPa) and 4 hour of Group A was less than Group B, ($p<0.001$).

Table No. 1: Demographic and operative measures

Characteristic	Group A n=31	Group B n=31	p-value
Sex			
Male	20 (64.5)	21 (67.7)	0.788
Female	11 (35.5)	10 (32.3)	
Age (years)	49.22±6.54	52.68±6.41	0.051
Smoking status	9 (29.0)	6 (19.4)	0.374
Pre-op EF	53.74±5.16	54.45±5.56	0.605
Bypass time (min)	121±11.21	123±13.24	0.578
X-clamp time (min)	67.25±5.81	65.96±6.14	0.398

Op=operation, EF=ejection fraction, x-clamp=cross clamp

The mean ventilation time of Group A and Group B was 5.61±0.86 hours and 7.77±0.98 hours, respectively. ($p<0.001$). While, ICU stay and hospital stay of both the groups was almost same, ($P>0.050$). (Table No. 2).

Incidence of atelectasis in group A on fourth day after surgery was observed in 8 patients 25.8% and in group B it was observed in 10 patients 32.3% ($p=0.576$). The incidence of pleural effusion of Group A and Group B was 6 (19.4%) and 5 (16.1%), respectively. ($p=0.740$). Pulmonary edema was 4 (12.9%) in Group A and 3 (9.7%) in Group B, ($p=0.688$). (Figure No. 1).

Table No. 2: Clinical characteristics of both the groups

Characteristic	Group A n=31	Group B n=31	p-value
PaO_2/FiO_2 Ratio after intubation	340.91± 23.89	348.79±24.65	0.207
PaO_2/FiO_2 Ratio after 1 hour of CPB	326.67± 7.54	294.99±7.92	<0.001
PaO_2/FiO_2 Ratio after hours of CPB	300.69± 5.51	285.51±4.62	<0.001
A-a O_2 gradient after intubation (kPa)	18.98± 2.19	18.68±2.76	0.641
1 hour post CPB A-a oxygen gradient	22.08± 1.88	28.01±2.96	<0.001
4 hours post CPB A-a oxygen gradient	20.12± 1.11	22.48±1.21	<0.001
Ventilation time (hours)	5.61±0.86	7.77±0.98	<0.001
ICU Stay(hours)	33.99± 6.26	34.68±5.11	0.636
Hospital Stay (days)	7.91± 0.82	7.68±1.32	0.367

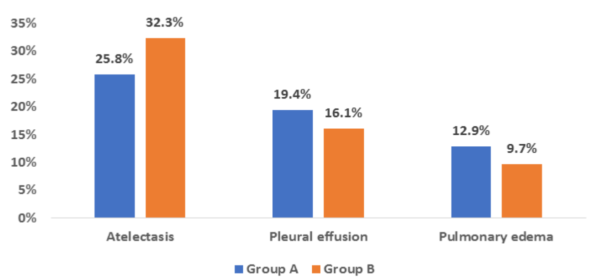

Figure No. 1: Comparison of postoperation chest complications seen on chest radiograph after 4 days of surgery.

DISCUSSION

Pulmonary dysfunction is a common complication of CPB during cardiac surgery. While advancements in CPB techniques and post-op care have improved patient outcomes, the risk of pulmonary dysfunction remains[11]. This dysfunction can be caused by various factors, such as inflammation, fluid overload, and prolonged ventilation. Monitoring pulmonary function closely during and after CPB is crucial for reducing the risk of complications and improving patient outcomes[12].

Numerous modifications have been made in management guidelines to reduce incidence pulmonary dysfunction during cardiopulmonary bypass[13]. These modifications include change in vital capacity method, which help to expand the lungs and improve oxygenation, as well as continuous ventilation with low tidal volume and continuous positive airway pressure (CPAP). These techniques can help to maintain adequate ventilation and oxygenation during surgery, reducing the risk of post-operative complications[14].

The studies conducted by Furqan et al[10] and Salama AM et al[15] show that ventilation has a positive effect on the postoperative respiratory function of patients. The PaO2/FiO2 ratio, which is an indicator of oxygenation, was higher in the ventilation group compared to the non-ventilation group. The A-a O2 gradient, which is an indicator of the efficiency of gas exchange, was also found to be significantly lower in the ventilation group. The studies suggest that low tidal volume ventilation is associated with better respiratory function in the immediate postoperative period.

Dasgupta et al[16] compared patients of cardiopulmonary bypass on their ventilation status, one group was not ventilated on CPB and other was ventilated on LTV, at the end of study observation was made in favor of LTV as complication in post-operative period were not significant or potentially fatal.

The study conducted by Alavi et al[17] revealed that the low tidal volume group had improved oxygen saturation and a decreased alveolar arterial oxygen gradient. This finding suggests that low tidal volume ventilation may benefit patients by improving oxygenation and reducing the gradient between alveolar and arterial oxygen levels. It is important to note that this study was conducted in a specific population, and further research is needed to determine the generalizability of these results to other patient populations.

Some other studies conducted by Davoudi et al[18] and Gur Ak et al[19] also reported similar findings that low tidal volume ventilation is more effective in reducing post-operative complications and A-a O2 gradient improvements as compared to non-ventilation patients. Difference regarding pulmonary edema, atelectasis and pleural effusion was not significant.

CONCLUSION

In cardiac surgery patients especially cardiopulmonary bypass low tidal volume ventilation is associated with reduce risk of complications and better oxygenation during cardiopulmonary bypass.

Author's Contribution:

Concept & Design of Study:	Hira Asad
Drafting:	Hamid Mehmood, Shahid Hussain
Data Analysis:	Rashid Hussain, Muhammad Arshed, Imran Ali.
Revisiting Critically:	Hira Asad, Hamid Mehmood
Final Approval of version:	Hira Asad

Conflict of Interest: The study has no conflict of interest to declare by any author.

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