Int J Clin Exp Med 2019;12(6):7426-7433
www.ijcem.com /ISSN:1940-5901/IJCEM0090874

Original Article

The assessment of the effect of low tidal volume ventilation on postoperative respiratory functions during cardiopulmonary bypass in heart surgery

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Received January 5, 2019; Accepted April 11, 2019; Epub June 15, 2019; Published June 30, 2019

Abstract: Introduction: A deterioration in pulmonary functions leads to increased morbidity and mortality as well as an extended postoperative hospital stay. This study intends to contribute to the literature by examining the effect of low tidal volume ventilation on postoperative pulmonary functions and, therefore, on early extubation during cardiopulmonary bypass pumping in patients subject to open-heart surgery. Materials and method: The study was performed retrospectively with patients who underwent coronary artery bypass surgery by two different surgical teams in our clinic between 1 March 2014 and 1 March 2017 after approval of the Ethics Committee according to the Helsinki Declaration rules. The 50 patients in group 1 were randomly selected from the surgical team who preferred low tidal ventilation during cardiopulmonary bypass (CPB). The 50 patients in group 2 were randomly selected from among the patients operated on by the surgical team that did not ventilate the lungs during CPB. Results: No statistical differences were found between the groups in terms of age, gender, ejection fraction, or the EuroSCORE (European System for Cardiac Operative Risk Evaluation). The comparison of the preoperative respiratory function test data did not show any differences between the groups. It was found out that the extubation and intensive care durations of Group 1 were shorter and statistically significant (the extubation durations were 7.92±2.19 hours, 8.70±2.36 hours, p=0.021, and the intensive care durations were 54.62±12.35 hours, 60.62±12.36 hours p=0.016, respectively). Conclusion: As a result, it is inferred that the deterioration of pulmonary functions in heart surgery had a negative effect on postoperative hemodynamic instability. We believe that low tidal ventilation during cardiopulmonary bypass has a positive aspect for a patient's postoperative respiratory functions. We also believe that leaving a ventilator early helps patients to stay in the intensive care unit for a shorter period of time and to require a decreased CPAP.

Keywords: Cardiopulmonary bypass, mechanical ventilation weaning, respiratory failure

Introduction

While cardiovascular diseases accounted for 10% of all deaths at the beginning of 20th century, this rate has gradually gone up [1]. Consequently, open-heart surgeries also increased due to cardiovascular diseases. Pulmonary dysfunction in the postoperative period as a consequence of open-heart surgeries with cardiopulmonary bypass (CPB) poses a serious risk for patients [2, 3].

Postoperative pulmonary dysfunction can occur as a side effect of general anaesthesia and mechanical ventilation and may arise due to extended CPB duration, hypothermia, inflammatory process activation, increased extravascular pulmonary fluid, and atelectasis [4, 5]. Furthermore, atelectasis, which may develop in basal pulmonary segments, can create a risk of pulmonary infections [4, 5]. The deterioration in pulmonary functions leads to increased morbidity and mortality as well as extended postoperative hospital stays [4-6]. Current economic conditions, high hospital costs, and insufficient capacity in hospitals which we face highlights the importance of early discharge and early postoperative recovery. Early intubation is one of the most significant conditions in this respect [7-9].

Non-ventilation of the lungs is a preferred application since there is no blood in pulmonary circulation, and lungs treated with mechanical ventilation raise surgical difficulties surgery during CPB in open-heart surgery. However, it is also known that the collapse of the lungs during CPB leads to the development of atelectatic areas [10]. Since post-CPB pulmonary dysfunction due to atelectasis is a frequent problem encountered in intensive care units, there are also other applications for ventilation in the CPB process, such as low tidal high-frequency and the open lung approach where proper PEEP is applied.

In our clinic, the ventilation preferences of CPB patients were routinely different in patients who underwent bypass surgery in the two different surgical teams. This study intends to contribute to the literature by examining the effect of low tidal volume ventilation on postoperative pulmonary functions and, therefore, on early extubation during cardiopulmonary bypass pumping in patients subject to open-heart surgery.

Materials and method

The study was performed retrospectively with patients who underwent coronary artery bypass surgery by two different surgical teams in our clinic between 1 March 2014 and 1 March 2017 after approval of the Ethics Committee according to the Helsinki Declaration rules. The 50 patients in group 1 were randomly selected from the surgical team who preferred ventilation with low tidal volume during heart lung pumping (CPB). The 50 patients in group 2 were randomly selected from the patients operated on by the surgical team who did not ventilate the lungs during CPB.

The exclusion criteria

In both groups, patients under 18, those with a less than 40% ejection fraction, those with a less than 75% FEV1/FVC rate in a preoperative respiration test, those with a history of sleep apnea, those with a EUROscore above 7, and those with previous redo and emergent surgeries and renal and hepatic failures were not included in the assessment.

The demographical data, comorbidities, CPB, aorta cross clamp and operation durations, respiratory function test results, intraoperative and postoperative arterial blood gas values, preoperative and postoperative haemoglobin, hematocrit, urea and creatinine values, extubation and the intensive care unit and hospital stay durations of the patients were analyzed retrospectively from the hospital files and the hospital's automation system.

Routine bypass surgery procedure in our clinic

At our clinics, the patients to have open-heart surgery were asked to fill in and sign an informed consent after their preoperative preparations and were given 5 mg diazepam (orally) and premedications. In the operating room, the patients were applied electrocardiography at the D2 and V5 derivations, SpO_2 with a pulse oximeter, radial artery canulation on their non-dominant sides, and systemic arterial pressure monitorization. In their anaesthesia induction, they were given 3 mgr/kg propofol (propofol Fresenius flacon), 5 mcg/kg fentanyl (Talinat 10 mgr), 0.6 mgr/kg rocuronium (Myokron 50 mgr/5 ml), and applied intubation. They were also provided with fresh gas entry as 2 lt/min, tidal volume as 8-10 ml/kg, FiO_2 as 0.5, frequency as 10-12/Min and PEEP as 5 using an anaesthesia device (Dragger Primus, Germany). The patients were subjected to a central catheter in their internal jugular veins using the Seldinger method, and urea output was monitored with central venous pressure (CVP) follow-up. Furthermore, heat monitorization was also provided with a heat probe. For anaesthesia maintenance, 0.1-0.3 mg/kg rocuronium, sevoflurane (sevorane liquid 100% - 250 ml solution) inhalation and, at analgesic doses, and fentanyl were given. Before cardiopulmonary bypass, antifractionated heparin (heparin flacon 25000 IU/5 ml) was provided at anticoagulation 300 units/kg dose. The activated coagulation time (ACT) was measured for the anticoagulation evaluation. Also, the arterial blood gas was also measured simultaneously with ACT. Cardiopulmonary bypass was initiated as ACT reached beyond 450 seconds. Hemodynamic data, drug administration and ventilation settings (tidal volume, frequency, PEEP) applied to the anesthesia device were recorded on the anesthesia follow-up slip during the whole operation. Depending on the pref-

Table 1. A comparison of demographical data and preoperative cardiac risk factors

	Group I (n=50)	Group II (n=50)	p
Age (mean ± SD)	63.04±10.61	65.18±8.45	0.267
Male n (%)	32 (64%)	30 (60%)	0.680
Female n (%)	18 (36%)	20 (40%)	
EF (mean ± SD)	49.56±7.11	50.10±7.46	0.696
EUROSCORE (mean ± SD)	3.72±1.96	4.32±2.18	0.124
Hypertension n (%)	46 (92%)	50 (100%)	0.117
Diabetes mellitus n (%)	19 (38%)	20 (40%)	0.838
Cerebrovascular disease n (%)	4 (8%)	4 (8%)	1.00
Peripheric artery disease n (%)	8 (16%)	6 (12%)	0.564
Hyperlipidemia n (%)	12 (24%)	7 (14%)	0.202

EF: Ejection fraction, EUROSCORE: European System for Cardiac Operative Risk Evaluation.

Table 2. A comparison of the groups' pulmonary function tests

	Group I (n=50)	Group II (n=50)	p
FEV1 (mean ± SD)	90.60±8.69	93.38±4.74	0.152
FVC (mean ± SD)	91.32±8.42	94.80±4.47	0.075
FEV1/FVC (mean ± SD)	92.30±8.14	95.52±5.95	0.060

erence of the surgical team in Group 1, when CPB was started, ventilation was continued with a tidal volume of 100 ml, frequency 30/min, peep 5 mm Hg. In Group 2, the respiratory tract of the patients was left open to the atmosphere according to the preference of the different surgical team. Each 100 Unit heparin dose was neutralized with 130 units of protamine (promin 5000 IU/5 ml) during the conclusion of the cardiopulmonary bypass. Again, a simultaneous arterial blood gas examination was carried out during ACT control after protamine. After leaving cardiopulmonary bypass, the patients were ventilated with FiO_2 50%, and 100% O_2 was applied until they were taken to the intensive care units. The monitored patients in the intensive care units were extubated gradually, decreasing FiO_2 by 80%, 60% and 50% under weaning conditions in compliance with blood gas monitoring. In our study, we wanted to compare the results of two different surgical teams in our clinic with two head ventilation applications during CPB.

The blood gas measurement points of the patients were determined as T1, T2, T3, T4 and T5. T1: Before Cardiopulmonary Bypass; T2: During Cardiopulmonary Bypass; T3: After Cardiopulmonary Bypass; T4: In Intensive Care Unit; T5: After Extubation.

Statistical methods

A Shapiro-Wilk test was used to determine whether the data complied with the normal distribution. Descriptive statistics (mean ± standard deviation) were given for the continuous variables. For the categorical variables, the descriptive statistics were indicated as the frequency and percentage (n (%)). In the comparison of the two independent groups, an independent samples *t*-test was used for the data that complied with the normal distribution, and a Mann Whitney U Test was used for those that did not. Pearson chi-square and Fisher exact tests were used for the comparison of categorical variables, and the results were given with n and percentage values. On the other hand, a sample *t*-Test was used for the data that complied with a normal distribution, but a Wilcoxon signed rank test was used for those that did not. The level of significance was accepted as $\alpha=0.05$. The statistical analyses were carried out using the IBM SPSS Statistics 21.0 program.

Results

This study was carried out on 100 patients, in total, of which 38 were females and 62 were males. No statistical differences were found in both of the groups in terms of age, gender, ejection fraction, or EUROscore (**Table 1**). The comparison of the preoperative respiratory function test data did not show any differences between the groups (**Table 2**). As indicated in **Table 3**, there was no difference among the operation, aorta cross clamp, or cardiopulmonary bypass durations of the patients. However, it was determined that the extubation and intensive care durations of Group 1 was shorter and statistically significant (the extubation durations were 7.92±2.19 hours, 8.70±2.36 hours, p=0.021, and the intensive care durations were 54.62±12.35 hours, 60.62±12.36 hours p=0.016,

Table 3. Intraoperative and postoperative durations of the groups

	Group I (n=50)	Group II (n=50)	p
Operation duration (min) (mean ± SD)	209.94±13.28	212.52±14.20	0.350
Cardiopulmonary bypass duration (min) (mean ± SD)	98.78±11.27	97.80±9.63	0.641
Aorta cross clamp duration (min) (mean ± SD)	77.64±9.55	75.70±9.32	0.431
Extubation duration (hours) (mean ± SD)	7.92±2.19	8.70±2.36	0.021
Intensive care duration (hours) (mean ± SD)	54.62±12.35	60.62±12.36	0.016
Hospital stay duration (days) (mean ± SD)	7.72±1.11	7.84±1.33	0.956

Table 4. Postoperative findings and complications

	Group I (n=50)	Group II (n=50)	p
Cerebrovascular event n (%)	1 (2%)	1 (2%)	1.00
Infection n (%)	1 (2%)	2 (4%)	1.00
Haemorrhage revision n (%)	4 (8%)	3 (6%)	1.00
CPAP requirement n (%)	4 (8%)	11 (22%)	0.050
Re-intubation n (%)	0	1 (2%)	1.00
Neurological complication n (%)	1 (2%)	0	1.00
Wound site revision n (%)	3 (6%)	0	0.242
Mortality n (%)	1 (2%)	2 (4%)	1.00

CPAP: Continuous Positive Airway Pressure.

Table 5. Comparison of the groups' lab results

	Group I (n=50)	Group II (n=50)	p
Preoperative HG (mean ± SD)	12.61±1.66	12.58±1.53	0.888
Postoperative HG (mean ± SD)	9.35±0.57	9.33±0.72	0.866
Preoperative HCT (mean ± SD)	38.58±4.85	37.80±4.72	0.317
Postoperative HCT (mean ± SD)	28.88±1.64	28.50±2.03	0.297
Preoperative BUN (mean ± SD)	17.38±4.54	17.80±4.86	0.740
Postoperative BUN (mean ± SD)	26.08±11.25	28.10±8.24	0.127
Preoperative Cr (mean ± SD)	0.94±0.23	1.00±0.41	0.850
Postoperative Cr (mean ± SD)	1.12±0.38	1.10±0.45	0.707

HG: Haemoglobin (g/dL), HCT: Hemotocrit (%), BUN: Blood Urea Nitrogen (mg/dL), Cr: Creatinine (mg/dl).

respectively). The hospital stay durations of the Group 1 patients were shorter than those of Group 2, but the difference was not significant (**Table 3**).

The patients in the two groups did not show any differences in the postoperative period in terms of cerebrovascular condition, infection, haemorrhage revision, wound site requirement, neurological complication and mortality, but the Group 2 patients had a statistically significant CPAP requirement (p=0.050) (**Table 4**). There was no difference in the preoperative and postoperative lab results of the groups (**Table 5**).

The comparisons of the partial arterial oxygen values of the patients demonstrated that the PaO_2 values of Group 1 patients at T2, T3, T4, and T5 were higher than the Group 2 patients (**Figure 1**). The $PaCO_2$ values of Group 2 at T2, T3, T4, and T5 were higher than Group 1 (**Figure 2**), but the pH values of the former were lower than the latter (**Figure 3**).

Discussion

As is the case with all surgical operations, the purpose of open-heart surgeries is to decrease morbidity and mortality and discharge patients in the most appropriate manner as well as to reduce costs. Thus, it becomes possible to provide service to more patients. All these distinguish the significance of early recovery. Early recovery may require various components, such as varying applications in surgery and anaesthesia, early extubation and mobilization, prophylactic treatment of possible complications, and aggressive treatment of developed ones. One of the most prominent issues of these components, that is, early extubation, helps patients to be less subject to cardiovascular and respiratory problems, which develop as side effects of intubation. In the postoperative period following heart surgery, providing early extubation on the condition that the hemodynamic and neurological conditions and postoperative haemorrhage and body heat of the patients are evaluated minimizes cardiac and respiratory complications [11].

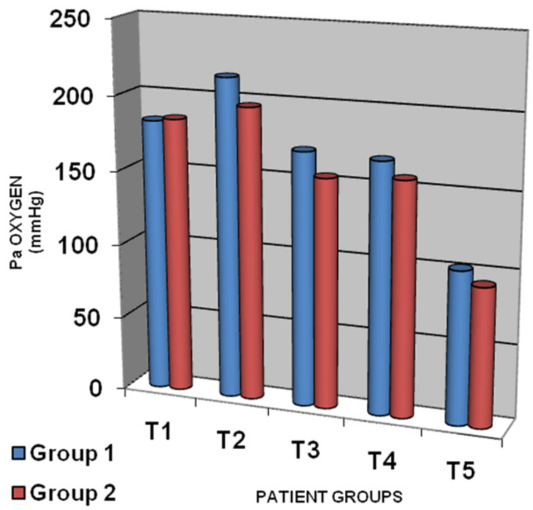

Figure 1. A comparison of the partial arterial oxygen values of both groups.

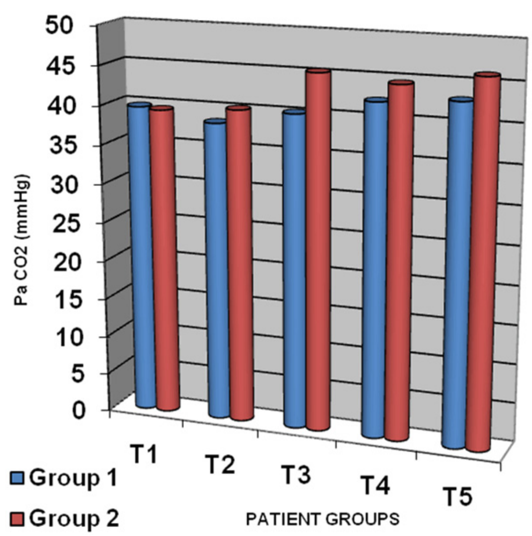

Figure 2. A comparison of the partial arterial carbon dioxide values of both groups.

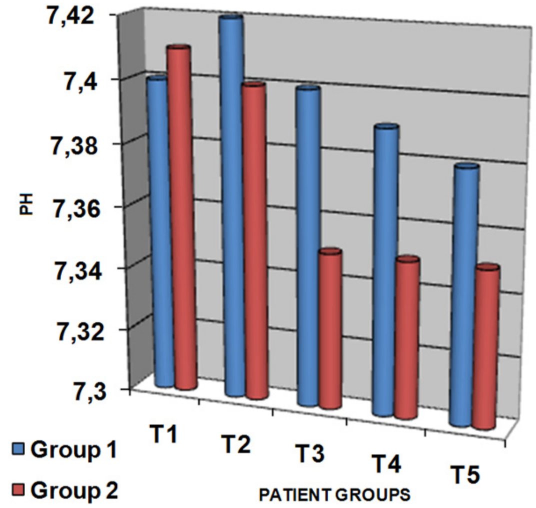

Figure 3. A comparison of the arterial PH values of both groups.

The cardiovascular problems that are posed by intubation appear as decreased cardiac output following airway and intrathoracic pressures due to alveolar distention, and as increased pulmonary vascular resistance and increased right ventricular load. Moreover, there are other complications incurred due to the endotracheal tube, such as extended intubation vocal cord dysfunction, larynx edema, and tracheal stenosis, and, due to mechanical ventilation such as barotrauma, volutrauma and increased infection risk [12]. Because of such complications, early extubation, the continuity of it and the non-reintubation of the patient in the postoperative period following open-heart surgery have always been important issues. Ozlem Ercen et al. carried out a study on extubation success and time using a rapid shallow breathing index for rapid extubation [13]. They inferred that the rapid shallow breathing index can be used reliably for extubation in patients to whom coronary artery bypass grafting was applied [13].

The use of non-invasive mechanical ventilation also provides corrections in the respiratory and cardiac parameters of patients who are extubated but develop respiratory insufficiency following heart surgery and can prevent reintubation and invasive mechanical ventilation complications [14]. In this study, the patients of both groups required non-invasive mechanical ventilations. However, the non-invasive requirement in Group 2, which was not ventilated during cardiopulmonary bypass, was found to be significantly high ($p=0.05$) (**Table 4**).

The problems that are observed during open-heart surgery do not appear only due to intubation and mechanical ventilation. There are also the respiratory effects of the systemic inflammatory response. These may arise as pulmonary edema, decreased lung compliance, or decreased functional residual capacity. Postoperative atelectasis is also a frequently occurring respiratory insufficiency and causes a significant obstacle before extubation. It may develop as a result of decreased functional residual capacity, postoperative pain, and the type and duration of surgery (the frequency increases in thoracic and upper abdominal surgeries) due to the anaesthetic agents provided. Furthermore, ventilation with high levels of oxygen can also contribute to the development of atelectasis. In a study conducted by Edmark et al., it was shown that decreased FiO_2 values during anaesthesia significantly decreases the development of atelectasis [15]. On the other hand, interrupting ventilation, which is frequently applied during the cardiopulmonary bypass processes of open-heart surgeries, can also contribute to the development of atelectasis in the postoperative period [16].

There are studies which indicate that the follow-up of arterial blood gas values as well as hemodynamic parameters can be a significant indicator for patient observations concerning respiratory dysfunctions. The study carried out by Confalonieri et al. in 2005 analyzed the parameters that affected success in NIMV and found that the failure of NIMV and the requirement of intubation were likely to be 90% in case NIMV was applied for two hours and, following that, if the blood gas pH value of a patient was below 7.25 [17]. Esra Eker et al. examined the relation between the follow-up of artery blood gases and NIMV treatment applications during acute respiratory insufficiency extubated and developed subsequent to a heart surgery. They demonstrated that the positive changes in pH, $PaCO_2$ and PaO_2 values after a short time of application determine the success of NIMV application [14].

Loeckinger et al. compared the effects of various ventilation strategies during cardiopulmonary bypass on postoperative gas changes. Loeckinger et al. did not provide ventilation to a group of patients during bypass process while the other patients were given 10 cmH_2O CPAP. It was found out that the patients who were given 10 cmH_2O CPAP had better perfusion of lung fields and higher arterial oxygen pressure compared to the non-ventilated patients [10]. Both groups in the current study were also followed-up and compared in terms of arterial blood gas parameters. The patients ventilated with low tidal volume during cardiopulmonary bypass process (Group 1) had higher PaO_2 at the T2, T3, T4 and T5 points compared to the non-ventilated patients (**Figure 1**). The $PaCO_2$ values of the non-ventilated patients (Group 2) at the T2, T3, T4, and T5 points were higher than Group 1 (**Figure 2**), but the pH values of the former were lower than the latter. These values support the study carried out by Loeckinger et al. [10].

There are studies which have demonstrated that the applied mechanical ventilation methods can decrease both pulmonary dysfunction and inflammation which occur during cardiac surgery. One of these methods is the open lung approach. The open lung approach, which is applied by ventilating the lungs during a cardiopulmonary bypass process via low tidal volume, high frequency, and proper PEEP helps patients to have increased oxygenation and functional residual capacity as well as fewer adverse effects of the cardiopulmonary pump [10, 18]. Chaney et al. found that the patient group provided with a low tidal volume and high frequency during the cardiopulmonary process as a protective ventilation strategy had lower postoperative shunting and alveolo-arterial oxygen partial pressure differences compared to the control group (normal tidal volume and frequency) [19]. They also demonstrated that lung protective methods contribute to the efficiency of postoperative extubation [19]. The current study found out that Group 1 had lower extubation and intensive care unit stay durations compared to Group 2.

The intraaortic balloon pump requirement, the use of two or more inotropic agents, postoperative myocardial infarction, and haemodialysis need are among the independent risk factors that extend intensive care durations for patients subsequent to open-heart surgery. This period should be minimized with protective methods for myocardial and kidney functions during the intraoperative process [20]. There have been various studies that have examined whether protective lung ventilation strategies in an open lung approach during coronary artery surgery such as CPAP application have any impact on hemodynamic parameters by increasing left ventricular after-load. Loeckinger et al. observed that 10 cmH_2O CPAP applied during cardiopulmonary bypass had a negative effect on hemodynamic in the postoperative process [10]. In studies that were carried out on patients treated with a CABG operation, Dhyr T. et al. indicated that PEEP as applied subsequent to a pulmonary recruitment maneuver did not decrease cardiac output [21]. The current study did not find any difference between the groups in terms of hemodynamic parameters and inotropic requirement for the contraction of the heart.

The hemoglobin-hematocrit level is among the most important criteria for oxygen supply to tissues. Patients become subject to hemodilution during the cardiopulmonary bypass process of cardiovascular surgeries. This, in return, is a factor that affects the hematocrit level subsequent to cardiopulmonary bypass [22]. Furthermore, decreased urea output also reduces the hematocrit level based on hemodilution in open-heart surgeries. The haemoglobin levels and preoperative urea output of the patient groups of this study were found to be similar.

Conclusion

We found that the deterioration of pulmonary functions in heart surgery had a negative effect on postoperative hemodynamic instability. We believe that low tidal ventilation during cardiopulmonary bypass has a positive effect on a patient's postoperative respiratory functions. We also believe leaving a ventilator early helps patients to stay in intensive care units for a shorter period of time and to require decreased CPAP.

Disclosure of conflict of interest

None.

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