The Effects of Low Tidal Volume and Ventilation on the Lungs in the Postoperative Period during Cardio Pulmonary Bypass in the Heart Surgery

Kalp Cerrahisinde Kardiyopulmoner Bypass Sırasında Düşük Tidal Volüme ile Ventilasyonun Postoperatif Dönemde Akciğer Üzerine Etkileri

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Abstract

The occurrence of respiratory problems in patients after the open heart surgery still continues to be a problem, which disturbs the comfort of surgery in the postoperative period. In this study, we aimed to prevent the sequestration, which might occur in the lungs within the continuous ventilation of the lungs that are disconnected as a routine during the cardiopulmonary bypass (CPB) under the low tidal volume; also aimed to reduce the edema in the lung tissue during the postoperative period and present these results along with the literature. For this purpose, 40 coronary artery bypass surgery patients are examined as two groups (Group 1, Group 2), which are planned under elective conditions as consecutive.40 patients who underwent coronary artery bypass surgery were divided into two groups and examined. 20 patients (group 1; 13 males, 7 females; average age is 58±8), who were normally disconnected during CPB; and 20 other patients, who are ventilated with low tidal volume during CPB (group 2; 12 males, 8 females; average age is 60±5) are taken into the study. Attention paid to not to have differences in preoperative characteristics of the patients. Lung ventilator modes, arterial blood gas levels, extubation times, preoperative pulmonary function tests (PFT) ve the postoperative day 7th and 1st month PFT's of both groups are compared. There are some significant differences between the patients of group 1 and group 2 as follows; the average partial oxygen (PO2) amount in arterial blood gases during the intensive care period with 40% oxygen after the surgery at the 2nd hour SMIV mode are 105±10 mmHg and 120 ± 20 mmHg respectively; SO2 values are 92±4 and 94±4 respectively; the average intubation times are 5,3 ±0,4 hours and 4,2 ±0,3 hours respectively; and oxygen saturations of service are 83% ± 5 and 90% ± 3 respectively for the 1st group and the 2nd group.When the ventilation of the lung with low tidal volume during the CPB is compared with the disconnection method applied normally; we conclude that the first method protects the lung functions better than the second one. It was seen in the light of our study; the pulmonary functions are better after the ventilation with low tidal volume, and respiratory complications are less likely to be detected.

Key words: Tidal volume, ventilation, cardiopulmonary bypass, postoperative period.

Özet

Açık kalp cerrahisi sonrası hastalarda solunum problemlerinin ortaya çıkması, halen postoperatif dönemde cerrahi konforu bozan bir problem olarak devam etmektedir. Bu çalışmamızda kardiyopulmoner bypass (KPB) esnasında rutin olarak dekonnekte edilen akciğerlerin düşük tidal volüm altında sürekli ventilasyonu ile akciğerde oluşabilecek sekestrasyonun önlenmesini ve postoperatif dönemde akciğer dokusundaki ödemi azaltmayı ve bunu literatür eşliğinde sunmayı amaçladık. Bu amaçla ardışık olarak elektif şartlarda planlı 40 koroner arter bypass cerrahisi hastasını iki gruba (Grup 1, Grup 2) ayırarak inceledik.Koroner arter bypass cerrahisi yapılan 40 hasta iki gruba ayrılarak incelendi. KPB esnasında; normalde dekonnekte edilen (grup 1) 20 hasta (13 erkek, 7 kadın; ortalama yaş 58±8) ve düşük tidal volüm ile ventile edilen (grup 2) 20 hasta (12 erkek, 8 kadın; ortalama yaş 60±5) çalışmaya alındı. Hastaların preoperatif özellikleri açısından farklılık olmamasına özen gösterildi. İki grubun operasyon sonrası akciğer ventilatör modları, arteriyel kan gazları düzeyleri, ekstübasyon zamanları, preoperatif solunum fonksiyon testleri (SFT) ve postoperatif 7. gün ve 1.ay SFT karşılaştırıldı. Operasyondan sonra hastaların 2. saat SMIV modunda %40 oksijenle yoğun bakımda arteriyel kan gazlarındaki parsiyel oksijen (PO_2) miktarı ortalama değerleri grup 1'de 105±10 mmHg, grup 2'de 120 ± 20 mmHg, SO_2 değerleri sırasıyla 92±4 ve 94±4 entübasyon zamanları ortalama grup 1'de 5,3 ±0,4 saat, grup 2'de 4,2 ±0,3 saat, servis oksijen satürasyon takiplerinde grup 1'de ortalama %83 ± 5, grup 2'deki hastalarda %90 ± 3 olacak şekilde anlamlı derecede farklı çıkmıştır.KPB esnasında akciğerin düşük tidal volüm ile ventilasyonunun normalde uygulanan dekonneksiyon metoduyla karşılaştırıldığında akciğer fonksiyonlarını daha iyi koruduğu görüşündeyiz. Çalışmamız ışığında görüldü ki düşük tidal volüm ile ventilasyon sonrasında solunum fonksiyonları daha iyi olmakta ve solunumsal komplikasyonlara daha az rastlanmaktadır.

Anahtar kelimeler: Tidal volüme, ventilasyon, kardiyopulmoner bypass, postoperatif dönem.

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Introduction

Heart surgery, abdominal surgery and thoracic surgery affect the lung functions in the early and late postoperative period. The most important factor in this period affecting the respiratory physiotherapies of the patients is the pains after surgery. After CPB, atelectasis especially in the lower zone of the lung and imbalances of ventilation/perfusion after a global edema are observed; and as a result of this, deterioration in gas exchange occurs. Today, it is shown that the lung functions after coronary bypass surgery are significantly preserved, while making the surgery with the beating heart without entering the CPB [1].

During the open heart surgery, even adequate amount of perfusion is provided for other organs, it is not possible for the lungs. During the surgery, the sequestration of blood cells is observed in the parenchymal tissue, because the input and output of blood into the lung is very limited for approximately 100 minutes or more.
It is known that the most affected organ from CPB is parenchymal tissue of the lungs and it is called as “shock lung or pump lung”, because the impact is very similar with the endotoxemia and hemorrhagic shocks [2]. Especially, when the duration of the surgery exceeds 140 minutes; chymotrypsin secreted from neutrophils sequestrated in the lung, proinflammatory cytokines secreted by the pulmonary macrophage and monocytes cause edema and atelectasis development in the lung [3]. Ground-glass opacity is observed in the telegraphy of the patients, who have shock lungs. Treatment is generally carried out as a treatment of edema.

Surfactant production is declining due to the decreasing number of type II pneumocytes cells in the lungs after CPB, which result in susceptibility to the atelectasis. Surfactant is a substance that reduces surface tension in the lung under normal conditions. As a result of further reduction of the surfactant, distress respiratory syndrome is observed. In addition, systemic edema is observed in the entire body due to the decreased amount of albumin, which sticks to the surface area of the lines and the denatured proteins, which occur due to the warming process right after a systematic cooling. In light of all these data, some dysfunctions occur in the lungs of the patients, and due to these problems, morbidity and mortalities like hospital stay durations, pulmonary infection, sepsis and death are increasing.

In this study, we aimed to reduce the lung damages and lung edema, which might occur due to the disconnecting during CPB, by ventilating the lungs with low tidal ventilation constantly.

Materials and Methods

40 patients, who underwent isolated coronary artery bypass surgery in the Department of Cardiovascular Surgery, were studied in two separate groups. Those patients, who had valve pathology, additional surgical procedures, myocardial infarction in the last four months, received intra-aortic balloon support and support treatment during preoperative period, an emergency operation performed, ischemic cerebral event depending on carotid disease, renal dysfunction and chronic obstructive pulmonary disease were excluded from the study. 20 patients (group 1; 13 males, 7 females; average age is 58±8), who were normally disconnected during CPB; and 20 other patients, who are ventilated with low tidal volume during CPB (group 2; 12 males, 8 females; average age is 60±5) are taken into the study. Attention paid to not to have differences in preoperative characteristics of the patients. After the surgery, the lung ventilator modes, arterial blood gas levels, extubation durations, postoperative 3^{rd}, 5^{th} and pulmonary function tests performed after 15^{th}, 30^{th} days and 2^{nd} month of being discharged are recorded for the patients of both groups.
The patients are connected to ventilation with inhaling end-tidal carbondioxide ($ETCO_2$) 30-35 mmHg in the mixture of tidal volume 10 ml/kg and 50% O_2 air, after being intubated by giving them 1-2 µg/kg fentanyl, 3-5 mg/kg thiopental sodium and 0.1mg/kg pancuronium in the induction of anesthesia.

Central catheterization was performed to the patients via the right internal jugular vein after routine surgery preparations. The left internal mammarian artery (LİMA) and saphenous vein graft (SVG) were prepared by submerging median sternotomy with mediastinum simultaneously. 300U/kg heparin was prepared for the CPB. The CPB was entered after opening the pericardium and following the two stage cannulation of arterial and unicaval. All patients were provided with vent by the aortic venting

method. The cardiac arrest is created after 32^0C systemic hypothermia, antegrade blood cardio

plegia and aortic cross clamping. Patients in Group 1 were disconnected, while the patients of Group 2 were ventilated continuously. The maximum amount of ventilation was fixed to 250-300 ml, which is half of the total tidal volume; and it has been carefully watched out to not to interfere with the surgical field and not to damage the quality of anastomosis due to the low amount of given tidal. Anticoagulation was achieved by making ACT (Activated Clotting Time) measurements at 30 minute intervals and giving heparin to the pump if necessary. In both groups at 20 minutes intervals, cardioplegia solutions are repeatedly applied. The pump blood flow speed was carried out as 3-3.5 L/m^2/minute during the surgery, and the average arterial pressure was kept between 60-80 mmHg. The hematocrit values of the patients are maintained between 24% and 28 %. All proximal anastomoses of the patients were performed under cross clamp. Heparin was neutralized with protamine with a ratio of 1:1 at the end of the CPB. Preoperative and postoperative follow-ups are performed by the same anesthesia team for both groups.

Patients, in intensive care after the surgery, were heated with heating blankets. Heating blankets were removed when the temperature of patient's ear reached 37^0C. The ventilation modes, respiratory rates, tidal volumes and PEEP numbers are adjusted according to body mass index of the patients, in the intensive care unit, for both groups. Those patients, who have enough muscle power, PCO_2<45 mmHg, pH>7.33, PO_2>75 mmHg, is in the CPAB mode, have stable hemodynamic values, is receiving low-dose treatment support and have no drainage were extubated. Patients' blood gas follow-ups with blood glucose and electrolytes values are adjusted hourly in the first six hours after extubation, then every two hours for the next six hours period. Intra-aortic balloon pump was placed to a patient, who was having low cardiac output syndrome. All other patients were transferred to the services in postoperative 48 hours. All the patients, except the one who had intra-aortic balloon pump, were discharged on the day of postoperative 6^{th} after their service follow-ups. One patient from Group 2 was discharged on the day of postoperative 10^{th}.

Statistical Evaluation

SPSS analysis software was used for the statistical analyzes performed (SPSS for Windows, version SPSS Inc, Chicago). Student t test is used for quantitative data between groups, and chi-square test was used for qualitative data. Multiple Anova test was used for comparison of the differences between preoperative and postoperative values. Results were expressed as mean ± standard deviation. P <0.05 values were considered statistically significant.

Results

There were no statistically significant differences between both groups in terms of the preoperative FEV1, FVC, pO2 and pCO2 values, LIMA usage, anastomotic numbers, cross clamp durations, pleural opening and pericardial and pleural drain numbers (p < 0,05) (Table 1).

Table 1. Group a postoperative pulmonary function tests.

FEV 1 (ml)	2654 +- 752	2098 +_ 653	2456 +_ 632
FEV 1 %	105.58 +_ 16.22	79.54 +_18.65	99.01 +_ 19.62
FVC (ml)	3365 +_ 15.78	2485 +_ 456.45	2854 +_ 258.22
FVC %	104.32 +_ 18.4	80.11 +_ 18.98	99.78 +_15.78
FEV / FVC	85.14 +_ 9,56	87.50 +_ 7.87	84.12 +_ 8,25

The airway pressure of Group 1 is found significantly higher than Group 2 during the intubation follow-ups in the postoperative intensive care unit. The pressure in the airway in the early postoperative period is an indicator of edema and atelectasis in the bed. Oxygen saturation values and blood gases are recorded during the ventilation modes in the intensive care intubation follow-ups for all patients. The average saturation values of the patients in Group 1 were 5% higher than the patients in Group 2, and this difference was statistically significant (p > 0.05).

Pathology is detected in 40% of the patients (Group 1 % 25, Group 2 % 15) on the chest telegraphs, which was taken in the first day after the surgery. The most frequent pathology was atelectasis and ground glass appearance.

Atrial fibrillation is developed in 2 patients of Group 1 and 1 patient of Group 2 in the post-operative days 2 and 3. Atrial fibrillation is treated with the initiated medical treatment to the patients. In Group 2, intra-aortic balloon pump was placed to a patient, who had low cardiac output syndrome.

Patients were, followed up after the service, discharged in a healthy way. In the pulmonary function tests, which are made on the days of post-operative 15th and 30th as a part of the outpatient clinic controls, it is observed that the FEV1 and FVC values of the patients in Group 2 are higher than the average and this difference is found statistically significant.

In this study, we observed that perfusing the lungs during cardiopulmonary bypass with low tidal volume instead of making them disconnected, has a statistically important effect on the SFT parameters of especially postoperative early period and till the 2nd month following the discharge (Table 2).

Table 2. Group b postoperative pulmonary function tests.

FEV 1 (ml)	2878 +_ 565	2235 +_ 765	2658 +_ 398
FEV 1 %	108 +_ 854	85 +_ 652	102.65 +_ 18.78
FVC (ml)	3578 +_ 18.78	2547 +_ 654.21	2978.45 +_ 369.47
FVC %	108.71 +_ 17.65	85.21 +_ 17.96	102.36 +_ 45.2
FEV/ FVC	88.14 +_ 8,32	89.54 +_ 7,32	88.14 +_ 7,99

Discussion

After cardiac surgery, having respiratory distress is a problem, which bothers the patients as well as the relatives of the patients and the surgeon, disturbs the comfort of the surgery and increases the hospital costs by extending the stay of the patients at the hospital. As a result of our study, we conclude that ventilation of the lungs with low tidal volume is better for the pulmonary functions during the CBP. The real issue what we aim to do here is; applying a technique to reduce the atelectasis and pulmonary edema in patients. There is a wide spectrum of work focusing on pulmonary functions after CPB in the literature.

Although the open heart surgery made with the heart-lung machine provides perfusion for the other organs, this is not a valid solution for the lungs. During the surgery, the sequestration of blood cells is observed in the parenchymal tissue, because the input and output of blood into the lung is very limited for approximately 100 minutes or more; and this might results in prolonged intubation time, pulmonary edema, atelectasis, postoperative pneumonia and morbidities like ARDS.

During CPB, the capillary pressure in the interstitial part of the lung reduces to a level, which is close to zero. There are four main factors that provide fluid passage from capillary membrane in a regular lung: capillary wedge pressure, interstitial fluid pressure, plasma colloid osmotic pressure and interstitial fluid osmotic pressure [4]**.** Pulmonary edema occurs due to the results of these aforementioned factors. Some pulmonary functions are worsening in the early and late period depending on applying median sternotomy to the patients, increased bronchial secretions, phrenic nerve damage during the surgery or temporal phrenic nerve paralysis based on external cold mediastinal implementation, not being able to cough due to the postoperative pain and the lack of breathing exercises [5-7].

According to a study conducted by Pasquina and his colleagues [8], after cardiac surgery, atelectasis is observed in the 65% of the patients, while a small amount of pulmonary edema with 21% and pneumonia with 3% respectively; and prophylactic respiratory physiotherapy performing is recommended to the patients in the preoperative period to get over these complications.

In a study made by Isabel et al [9], respiratory physiotherapy is conducted to the patients in the preoperative period and then the reduction of pulmonary complications is shown. We conducted pre-operative breathing exercises to all our patients with the help of tri-flow device.

During CPB, ascending aorta can be vented through the right superior pulmonary vein, pulmonary artery and left ventricular apex in order to decompress the heart and lungs. The purpose of this action is reducing the possible endothelial damage to the heart and the pulmonary edema. According to a study made by Haberal et al [10], the decompression made with pulmonary venting is better than the one made in accordance with aortic venting method in terms of pulmonary functions. The conducted study reduces edema by reducing blood flow to

the pulmonary laver. Our study helps blood, which goes to lung laver, to go to the left atrium which is the regular physiological way, by consistently low tidal ventilation.

During CPB, IL-6, IL-8, TNF-α are secreted from the macrophages and monocytes in the blood cells against the allografts (CPB mains) to protect the body. The same substances are secreted depending on the ischemia reperfusion damages and cause edema formation [11]. According to a study conducted by Nilsson et al [12] on porcine subjects, it is revealed that in cardiopulmonary bypass, the most affected organ during the complement activation is the lung and these effects are caused by direct and indirect effects of C5a. C5a are occurring especially against the foreign tissues like CPB lines, thus it is recommended by Nilsson et al to use heparin-coated lines.

In a study made by Singh et al [13], it is shown that partial pressure of oxygen is reaching the lowest values after CPB, which increases over the next few days and cannot reach preoperative values on day 8. In our study, we observed that in the patients, who were continuously ventilated with low tidal ventilation, oxygen saturation values of the patients are reaching the preoperative values on the postoperative day 5.
As seen in the literature, most of the studies are about reducing the pulmonary edema. In this study, we aimed to reduce the postoperative pulmonary edema by putting the sequestered blood in the lungs to the circulation through low tidal ventilation.

Conclusion

During cardiopulmonary bypass surgeries significantly damage occurs in the lungs. When the ventilation of lung with low tidal volume compared with the usual disconnection method of ventilation during CPB, we claim that the lung functions are better preserved by the first method. After ventilation with low tidal volume, the pulmonary functions are better and respiratory complications are observed less frequent. Although SFT gives similar results at the end of the first month, the aim of this study is providing a better undergo to the patients in the early postoperative period, which is a critical stage for the patients.

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