doi: 10.30934/kusbed.794055 **e-ISSN:** 2149-8571

Kocaeli Üniversitesi Sağlık Bilimleri Dergisi

Özgün Araştırma / Original Article

http://dergipark.gov.tr/kusbed

LOW TIDAL VOLUME VENTILATION IN OPEN HEART SURGERY: WHICH TIDAL VOLUME IS BETTER 8 ML/KG OR 6 ML/KG?

AÇIK KALP CERRAHİSİNDE DÜŞÜK TİDAL VOLÜM VENTİLASYON: 8 ML/KG VE 6 ML/KG TİDAL VOLÜMDEN HANGİSİ DAHA İYİ?

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Geliş Tarihi / Received: 12.09.2020 **Kabul Tarihi / Accepted:** 12.12.2020 **Yayım Tarihi / Published:** 05.01.2021

Abstract

Objective: To compare the outcomes of 6m/kg vs. 8 ml/kg tidal volume in the lung protective ventilation - low tidal volume strategy in coronary artery bypass grafting operation.
Methods: Thirty-two patients enrolled in a randomized, single-center, prospective study were divided into two groups. The outcomes of 6m/kg vs. 8 ml/kg were compared. Arterial blood pressures, heart rate, central venous pressure, expired tidal volume, respiratory frequency, the alveolar minute ventilation, the inspiratory time, static compliance, peak airway pressure, plateau pressure, driving pressure, arterial blood gas data and $PaCO_2$-$EtCO_2$ difference were recorded at T_1 (15 min. prior to CPB), T_2 (15 min. following the termination of cardio pulmonary bypass), and T_3 times (at the end of the surgery). PaO_2/FiO_2 ratio was recorded at T_1, T_2 and T_3 and 6th (T_4) and 12th hours (T_5) after extubation.
Results: In Group 6ml/kg, extubation time and length of stay in the intensive care unit were significantly longer (p<0.001, p=0.001, respectively). Discharge times were similar in both groups. In group 6ml/kg, $PaCO_2$ was high at all times (T_1, T_2, T_3; p=0.002, p=0.004, p=0.001, respectively), Hemodynamic changes had a similar course in both groups, in Group 6ml/kg. The PaO_2/FiO_2 ratio was significantly higher in Group 8ml/kg at T_2 (p=0.009) and similar at other times.
Conclusion: Mechanical ventilation with a low tidal volume strategy with 8 ml/kg has more favorable outcomes by considering the shorter extubation time and length of stay in the intensive care unit comparing with 6 ml/kg.

Keywords: *Open heart surgery, cardiac anesthesia, low tidal volume ventilation*

Öz

Amaç: Koroner arter baypas greftleme operasyonunda düşük tidal hacim stratejisi ile akciğer koruyucu ventilasyonda 6ml/kg ile 8 ml/kg tidal hacim sonuçlarını karşılaştırması amaçlanmıştır.
Yöntem: Randomize, tek merkezli, prospektif çalışmaya alınan ardışık 32 hasta, iki eşit gruba ayrıldı. 6ml/kg ve 8ml/kg tidal volüm ile ventilasyonun sonuçları karşılaştırıldı. Arterial kan basınçları, kalp hızı, santral venöz basınç, ekspirasyon tidal hacimi, solunum frekansı, alveolar dakika ventilasyonu, inspirasyon süresi, statik kompliyans, pik hava yolu basıncı, plato basıncı, sürüm basıncı, arter kan gazı verileri ve $PaCO_2$-$EtCO_2$ farkı T_1 (CPB'den 15 dak. önce), T_2 (kardiyopulmoner baypasın sonlandırılmasından 15 dak. sonra) ve T_3 (ameliyatın sonunda) zamanlarında kaydedildi. PaO_2/FiO_2 oranı ekstübasyon sonrası T_1, T_2 ve T_3 ile 6. (T_4) ve 12. saatte (T_5) kaydedildi.
Bulgular: Grup 6 ml/kg'da ekstübasyon süresi ve yoğun bakımda kalış süresi anlamlı olarak daha uzundu (sırasıyla p<0,001, p=0,001). Taburculuk süreleri her iki grupta benzerdi. Grup 6ml/kg'da $PaCO_2$ daha yüksekti (sırasıyla T_1, T_2, T_3; p=0,002, p=0,004, p=0,001). Hemodinamik değişiklikler her iki grupta da benzer seyretti. PaO_2 / FiO_2 oranı Grup 8 ml/kg'da T_2'de anlamlı olarak daha yüksek (p=0,009) ve diğer zamanlarda benzerdi.
Sonuç: 8 ml/kg düşük tidal hacim stratejisi ile mekanik ventilasyon, 6 ml/kg ile karşılaştırıldığında daha kısa ekstübasyon süresi ve yoğun bakımda kalış süresi dikkate alındığında daha olumlu sonuçlara sahiptir.

Anahtar Kelimeler: *Açık kalp cerrahisi, kardiyak anestezi, düşük tidal volum ventilasyon*

Introduction

Postoperative pulmonary dysfunction is the most important complication encountered following cardiac surgery, and the most common of these complications is atelectasis.[1]The utilisation of cardiopulmonary bypass (CPB), increases the use of blood products, and can result with large volume shifts and acute respiratory distress syndrome (ARDS).[2] Management ofmechanical ventilation during intraoperative period is crucial to prevent the development of postoperative pulmonary dysfunction.[3] Mechanical ventilation with low tidal volume (LTV) contributes to the development of postoperative pulmonary dysfunction by causing atelectasis and increasing atelectasis-induced lung damage, while a high tidal volume (HTV) strategy can result with postoperative pulmonary dysfunctionby increasing the release of inflammatory mediators.[4-6] In cardiac surgery, lung protective ventilation with LTV,a strategy which is adopted from the therapy of ARDS patients, is preferred; however, there is no clear consensus on this in practice.[7, 8] The amount of tidal volume meant by LTV is also not elucidated. Zochios et al.[8] defined LTV as 6-8 ml/kg of predicted body weight (PBW). The safety of a tidal volume of 6ml/kg and its administration to all patients is investigated.[9] Anatomically, this volume may make sense since normal physiological tidal volume (TV) for humans is approximately 6 mL/kg.[10] Given that oxygen and carbon dioxide pressures, lung perfusion, alveolar surface area, wall thicknesses and hemoglobin level are normal, the alveolar minute ventilation (MV_{Alv}) is equal to the difference between the TV and the dead space volume (DV) multiplied by the minute respiratory frequency (RF): MV_{Alv} = [(VT-VD)xRF]. In a 70kg person with normal lung function MV_{Alv} for 6ml/kg TV is calculated as MV_{Alv}= [(6ml/kg-2ml/kg)x(10-35/min)] = 2.8-9.8 L/min. Meanwhile calculating MV_{Alv} for 8 ml/kg for the same body weight results with 4.2-14.7L/min.[11,12] According to the above mentioned formula, amechanical ventilation with 6ml/kg is expected to result in higher $PaCO_2$ levels compared to 8ml/kg, which requires higher RF to provide normocapnia. Increased RF sets the ground for auto-PEEP and, shortening the inspiration time (T_i) to prevent auto-PEEP in turn leads to the development of hypoxemia. Development of auto-PEEP may also impair hemodynamic balance, which may be harmful for patients undergoing open heart surgery.[11,13] On the other hand, preventive effect of hypercapnia on lung damage should not be overlooked.[14] Furthermore, hypercapnia enhances cardiac contractility, heart rate (HR) and cardiac output, reduces systemic vascular resistance and improves oxygen delivery to tissues by shifting the oxyhemoglobin dissociation curve to the right.[15] We aimed to compare 6 ml/kg and 8 ml/kg TV with regard to respiratory and hemodynamic parameters in patients who had no lung disease and were scheduled for on-pump coronary artery bypass graft (CABG) surgery. We assumed that ventilation with 6ml/kg might lead to hypercapnia, respiratory acidosis, and that increased RF rates would negatively affect hemodynamics. Our primary outcomes were comparison of their effects on arterial blood gases (ABG), hemodynamic effects and respiratory mechanics. Our secondary outcomes included comparison of extubation time, length of stay in the intensive care unit (ICU), and time to discharge.

Methods

After obtaining the local ethics committee approval (KÜ GOKAEK 2018/68, Clinical trials.gov identifier: NCT03651817) and written consent of the patients, 32 patients planned to undergo elective CABG were included in the study. Exclusion criteria were as follows: redo cases, patients with major obstructive or restrictive pulmonary disease (defined as 70% of predicted values for pulmonary function test variables of volume and flow), pulmonary hypertension (pulmonary artery pressure>35mmHg in preoperative transthoracic echocardiography), poor ventricular function (Ejection fraction<35%), renal failure (serum creatinine>1,8mg/dl) anemia (Hb<10gr/dl), morbid obesity (Body Mass Index>35kg/m^2), re-exploration and smoking history up to 2 months ago. Patients were premedicated with intravenous (iv) midazolam before being transferred to the operating room. 5L/min oxygen was given via face mask, heart rate (HR) was determined by 5-channel electrocardiography, standard peripheral oxygen saturation (SpO_2) and noninvasive blood pressure monitoring were performed. Radial artery cannulation was performed from the non-dominant hand following local anesthesia with lidocaine. After anesthesia induction with 0.05-0.1mg/kg midazolam, 5-10 µg/kg fentanyl, 0.1mg/kg rocuronium and 2-3mg/kg thiopental, male patients were intubated with an 8.0mm internal diameter (ID) endotracheal tube (ETT), and female patients were intubated with a 7.5mm ID ETT. A central venous pressure (CVP) catheter was placed preferably into the right internal jugular vein.

Study protocol: Half of the patients recieved volume controlled mechanical ventilation with rectangular flow waveform (6-ml/kg PBW (Group 6ml/kg) and the other half with 8-ml/kg PBW (Group 8ml/kg) after intubation.[16] Randomization was provided using the sequentially numbered opaque sealed envelope technique.[17] Both groups were set to have an Inspiratory/Expiratory ratio of 1/2, plateau time as 20% of inspiratory time (T_i), and a PEEP of 5 cmH_2O. All patients were ventilated with the same anesthesia device (Draeger, Primus, Draeger Medical AG & Co, Germany). In both groups, the respiratory rate (RR) was initially started as 10/min. RF was adjusted so that the end-tidal carbondioxide ($EtCO_2$) values were between 30-35mmHg. Oxygen concentration was increased when SpO_2 dropped below 97 percent. Anesthesia was maintained with 40% oxygen and 60% air mixture, desflurane (0.5-1.0 MAC) inhalation and remifentanyl infusion (0.2-0.3µg/kg/min). Intraoperative additional analgesia was provided using iv bolus fentanyl.

CABG was performed through a median sternotomy with heparinization under CPB using aortic and two-stage atriovenous cannulation. CPB was initiated using a membrane oxygenator with a non-pulsatile flow rate of 2.2 to 2.4 L/min/m^2 and a mean arterial pressure (MAP) of 50 to 80 mmHg. Moderate systemic hypothermia around 30ºC was induced during CPB. Arterial oxygen tension (PaO_2) was kept at 90-150 mmHg, arterial carbon dioxide tension at 35-40 mmHg and venous oxygen saturation ($ScvO_2$)>70% during the CPB period. Myocardial protection was achieved with antegrade hyperkalemic blood cardioplegia. The lungs were not ventilated during the CPB and connected to the Bain circuit with a basal oxygen flow of 200 ml/min. Total vital capacity maneuver (TVCM) was applied to all patients

before separation from CPB. TVCM was performed by inflating the lungs to 40 cm H_2O and holding this pressure for 15 seconds immediately before termination of CPB. The same mechanical ventilation strategy was continued after CPB. Balanced electrolyte solution (Isolyte S) was preferred primarily for fluid replacement. Fluid, blood and blood product transfusion was performed according to our routine clinical practice based on vasopressor and inotropic requirements, MAP, CVP, lactate values, venous oxygen saturation, hematocrit values (Htc<24%), NIRS levels and urine output are measured. At the end of the surgery, patients were transferred to the cardiovascular surgery intensive care unit. The same ventilation protocol was continued until patients were extubated.

Hemodynamic changes [systolic, diastolic and mean arterial pressures (SAP, DAP, MAP), HR and CVP], Expired TV (TV_{exp}), RF, MV_{Alv}, Ti, static compliance (C_{stat}), peak airway pressure (P_{peak}), plateau pressure (P_{plateu}), driving pressure (DP), Arterial blood gas (ABG) data and $PaCO_2$-$EtCO_2$ difference were recorded 15 min prior to CPB (T_1), 15 min following the termination of CPB (T_2), and at the end of the surgery (T_3). PaO_2/FiO_2 ratio was recorded at 6^{th} (T_4) and 12^{th} hours (T_5) after extubation in addition to T_1, T_2 and T_3. DP was calculated based on the $DP=PP_{lateau}$-PEEP formula. Extubation was performed according to mutual clinical protocols of cardiovascular surgery and cardiac anesthesiologist. Patients requiring reintubation or non-invasive mechanical ventilation support were recorded.

Statistical Analysis

In a previous study with patients undergoing open heart surgery, $PaCO_2$ was 35.62±3.5 mmHg before performing CPB in cases who underwent VCV with 8ml/kg PBW TV.[18] In this study, by calculating that $PaCO_2$ would increase at least 10% with 6 ml/kg TVV, the number of cases was calculated as 16 for each group with 80% power. All statistical analyses were performed using IBM SPSS for Windows version 20.0 (SPSS, Chicago, IL, USA). The Shapiro-Wilk's test was used to assess the assumption of normality. Continuous variables were presented depending on presence of normal distribution with either mean±standard deviation or (in case of no normal distribution) median (25^{th}-75^{th} percentile). Categorical variables were summarized as numbers (percentages). Comparisons of continuous variables between groups were carried out using the dependent samples t test/Mann-Whitney U test, whichever was appropriate. The changes in variables between time periods were analyzed by repeated measures ANOVA and Friedman's two-way ANOVA. Association between two categorical variables was examined by the Chi-square test. All statistical analyses were carried out with 5% significance and a two-sided *p*-value <0.05 was considered as statistically significant.

Results

None of the 32 patients included in the study required reintubation or non-invasive mechanical ventilation after being extubated, and there were no deaths. Preoperative and demographic characteristics were similar in both groups (Table 1). Surgical and anesthetic features are demonstrated in Table 2. In Group 6ml/kg, extubation time and length of stay in the ICU were significantly longer (p<0.001, p=0.001, respectively) whereas discharge times were similar in both groups (Table 2). In group 6ml/kg, $PaCO_2$ was high at all times (p=0.002, p=0.004, p=0.001, respectively), pH, PaO_2, lactate, hemoglobin and hematocrit levels were similar in both groups (Table 3). Hemodynamic changes had a similar course in both groups (Table 4). When respiratory mechanics were investigated, TV_{exp} was higher, RF was less, P_{peak}, $P_{plateau}$ and DP was higher, and Ti was longer in Group 1. C_{stat} was similar in both groups (Table 5). The PaO_2/FiO_2 ratio was significantly higher in Group 8ml/kg at T_2 (p=0.009) and similar at other times (Table 6).

Table 1. Demographics and preoperative features

	Group 8ml/kg n:16	**Group 6ml/kg n:16**	***p***
Age (year)	58,00±8,98	58,25±7,74	0,933
ASA II/IIIn((%)	7(43,8)/9(56,2)	7(43,8)/9(56,2)	1,000
Gender F/M n/(%)	4(25,00)/12(75,00)	3(18,8)/13(81,2)	1,000
Weight (kg)	82,25±9,27	79,00±9,32	0,331
Height (cm)	169,68±6,62	166,93±6,12	0,232
BMI (kg/m^2)	29,00(25,67-30,00)	28,45(27,08-29,37)	0,956
EF (%)	55,00(45,00-64,75)	55,00(50,00-60,00)	0,956
PBW (kg)	67,00(65,25-69,00)	65,50(65,00-67,00)	0,128
Heavy Smoking * n/(%)	9(56,30)	11(68,80)	0,715
Light Smoking** n/(%)	7(43,70)	5(31,20)	0,715
Comorbidity n/(%)			
Hypertension	8(61,53)	9/(64,28)	1,000
Diabetes Mellitus	3(23,07)	2(14,28)	1,000
COPD	2(15,38)	3(21,42)	1,000
Medication n/(%)			
Beta blocker	7(43,75)	6(37,50)	1,000
ACE inh	1(6,25)	2(12,50)	1,000
Bronchodilatator Agent	4(25,00)	3(18,75)	1,000
Antidiabetic Agents	2(12,50)	3(18,75)	1,000
Aspirin	2(12,50)	2(12,50)	1,000

ASA; American Society of Anesthesiologists, BMI; Body mass index, PBW; Predicted body weight, LVEF; Left ventricular ejection fraction, COPD; Chronic obstructive pulmonary disease
*Heavysmoking (≥30 cigarettes per day), **Lightsmoking (<30 cigarettes per day)

Table 2. Comparison of intraoperative data between the groups

	Group 8ml/kg n:16	**Group 6ml/kg n :16**	***p***
CC time (min)	58,50(45,50-90,75)	60,00(46,25-90,75)	0,867
CPB time (min)	105,50(94,75-128,25)	114,50(88,75-161,00)	0,590
Defibrillation(n)	5(31,30)	6(37,50)	1,000
Bilateral open pleura (n)	3(18,80)	2(12,50)	1,000
LIMA/ Saphenous vein/ Both (n)	5(31,30)/ 6(37,40)/ 5(31,30)	4(25,00)/ 7(43,80)/ 5(31,20)	1,000
Intraoperative (n)			
ES	14(87,50(/2(12,50)	14(87,50)/2(12,50)	1,000
TDP	3(18,80)/13(81,20)	6(37,50)/10(62,50)	0,433
TS	2(12,5)/14(87,50)	2(12,50)/14(87,50)	1,000
Inotropic support	11(68,80)	13(81,20)	0,685
Rocuronium dose (mg)	130,81±8,40	128,00±9,95	0,072
Fentanyl dose (mcg)	850,00(800,00-900,00)	850,00(800,00-900,00)	0,867
ET_{Desf} (MAC)	0,80(0,80-0,90)	0,80(0,70-0,80)	0,196
Anesthesia time (min)	275,00(243,75-326,25)	300,00(272,50-330,00)	0,224
Fluid balance (ml)	1144,37±298,28	1426,87±600,24	0,106
Transfusion of ES in ICU (n)	11(68,80)	12(75,00)	1,000
Extubation time (h)	6,50(5,12-9,00)	11,00(8,25-15,00)	0,000
Length of stay ICU (h)	4901(47,25-70,75)	70,00(70,00-97,50)	0,001
Leight of Hospital Stay (day)	8,50(7,25-10,50)	7,50(6,25-10,00)	0,539

CC; Cross Clamp, CPB; Cardiopulmonary Bypass, ICU; Intensive Care Unit, ES; Erythrocyt Suspension, FFP; Fresh Frosen Plasma, TS; Thrombocyte Suspension, LIMA; Left internal mammarian artery, MAC; Minimum Alveolar Concentration

Table 3. The data obtained from arterial blood gas analysis

	Group 8ml/kg n:16	**Group 6ml/kg n:16**	***p***
pH			
T_1	7,42±0,04	7,43±0,04	0,906
T_2	7,41(7,40-7,44)	7,42(7,38-7,45)	0,752
T_3	7,38±0,03	7,37±0,06	0,480
PaO_2 (mmHg)			
T_1	134,20±33,46	121,15±30,32	0,257
T_2	139,30±23,95	133,46±25,68	0,511
T_3	102,30(86,50-136,25)	98,30(83,05-128,00)	0,616
$PaCO_2$ (mmHg)			
T_1	33,50(32,92-35,52)	37,25(36,10-38,00)	**0,002**
T_2	34,93±2,00	38,14±3,57	**0,004**
T_3	35,60 (34,05-37,92)	38,90(37,17-40,42)	**0,001**
SaO_2 (%)			
T_1	98,75(97,40-99,20)	98,60(96,67-99,00)	0,270
T_2	98,74±0,54	98,45±0,62	0,160
T_3	98,10(96,25-98,87)	97,90(96,25-99,05)	0,724
Lactate (mmol/L)			
T_1	1,47(0,80-1,75)	1,02(0,62-1,40)	0,149
T_2	1,20(0,92-1,50)	0,95(0,62-1,27)	0,073
T_3	2,70±1,34	2,62±1,01	0,860
Hemoglobin (gr/dl)			
T_1	11,93±1,50	12,10±1,51	0,754
T_2	11,93±1,75	12,05±1,47	0,216
T_3	10,20(9,72-10,67)	9,95(9,25-10,75)	0,669
Hematocrit (%)			
T_1	36,76±4,51	37,36±4,57	0,714
T_2	34,72±5,22	37,26±4,21	0,140
T_3	31,55(30,07-33,05)	30,85(28,72-33,32)	0,669

T_1; 15 min prior to cardiopulmonary bypass, T_2; 15 min following cardiopulmonary bypass, T_3; End of the surgery

Table 4. Hemodynamic data

	Group 8ml/kg n:16	**Group 6ml/kg n:16**	***p***
HR (Beat/min)			
T_1	65,00(60,00-69,50)	65,00(60,25-80,75)	0,809
T_2	74,80±13,02	75,37±16,56	0,916
T_3	92,80±20,32	96,18±17,09	0,615
SA (mmHg)			
T_1	105,00(96,25-128,50)	108,00(90,25-117,75)	0,402
T_2	102,12±15,27	95,06±9,24	0,124
T_3	110,81±13,18	112,31±12,49	0,743
DAP (mmHg)			
T_1	59,62±7,32	61,68±9,12	0,486
T_2	57,00(51,50-66,00)	56,00(49,75-60,00)	0,361
T_3	56,50(55,00-62,00)	58,00(53,50-61,00)	1,000
MAP(mmHg)			
T_1	74,50±9,45	75,00(65,00-81,75)	0,896
T_2	72,50(64,75-82,75)	67,00(62,25-71,00)	0,080
T_3	75,50(70,75-79,75)	74,50(68,25-81,50)	0,696
CVP (mmHg)			
T_1	9,31±3,89	9,31±3,13	1,000
T_2	8,56±2,70	8,62±1,66	0,938
T_3	8,93±2,17	8,87±3,40	0,951

HR; Heart rate, SAP; Systolic arterial pressure, DAP; Diastolic arterial pressure, CVP; Central venous pressure, T_1; 15 min prior to cardiopulmonary bypass, T_2; 15 min following cardiopulmonary bypass, T_3; End of the surgery

Table 5. Respiratory dynamics and ventilation parameters

	Group 8ml/kg n:16	**Group 6ml/kg n:16**	***p***
TV (ml)			
T_1	528,75±80,19	368,31±35,21	0,000
T_2	523,75±8,19	368,31±35,20	0,000
T_3	531,43±62,80	366,31±38,80	0,000
RR (breath/min)			0,005
T_1	12,00(12,00-12,00)	14,00(12,00-16,00)	0,000
T_2	12,12±1,85	16,25±2,72	0,000
T_3	13,37±1,89	19,25±3,25	
MV (ml/min)			
T_1	6,25±0,48	6,36±0,85	0,283
T_2	6,45(6,21-6,87)	6,00(4,85-7,62)	0,254
T_3	6,93±0,73	7,11±1,30	0,634
$EtCO_2$(mmHg)			
T_1	32,00(30,25-32,75)	32,00(30,50-35,00)	0,160
T_2	31,50(30,00-32,00)	31,00(30,00-32,75)	0,867
T_3	33,00(31,25-34,00)	32,00(31,00-34,75)	0,696
P_{peak} (cmH_20)			
T_1 (11,00-23,00)	19,56±2,09	15,18±1,97	0,000
T_2 (13,00-23,00)	20,43±1,54	16,12±2,47	0,000
T_3 (14,00-27,00)	21,12±3,07	18,25±2,84	0,001
$P_{plateau}$ (cmH_20)			
T_1 (10,00-20,00)	16,18±2,07	13,12±1,82	0,000
T_2 (7,00-22,00)	18,50(15,25-21,75)	14,00(12,25-14,75)	0,001
T_3 (11,00-24,00)	19,50(17,25-21,75)	14,00(14,00-15,00)	0,001
C_{static}(ml/cmH_20)			
T_1 (25,60-46,80)	33,95(30,26-37,15)	31,30(30,00-32,92)	0,160
T_2 (23,00-39,00)	30,69±4,00	30,92±3,53	0,864
T_3 (18,00-38,80)	31,59±3,92	29,86±5,86	0,336
DP (cmH_2O)			
T_1 (5,00-15,00)	11,06±1,98	8,18±1,79	0,000
T_2 (5,00-17,00)	13,37±3,15	8,62±1,70	0,000
T_3 (6,00-19,00)	14,50(12,00-16,75)	9,50(9,00-10,00)	0,000
Ti sec			
T_1	1,66(1,49-1,67)	1,42(1,25-1,66)	0,002
T_2	1,66(1,42-2,00)	1,25(1,11-1,42)	0,000
T_3	1,53±0,20	1,06±0,19	**<0,001**
$PaCO_2$-$EtCO_2$ (mmHg)	2,00(1,02-3,17)	2,65(1,92-7,12)	0,110
T_1	3,43±2,20	6,70±4,05	**0,009**
T_2	3,50(1,65-4,85)	5,80(4,47-7,70)	**0,000**
T_3			

TV; Tidal volume, P_{peak}; Peak airway pressure, $P_{plateau}$; Plateau pressure, C_{static}; Static Compliance, DP; Driving Pressure, T_1; 15 min prior to cardiopulmonary bypass, T_2; 15 min following cardiopulmonary bypass, T_3; End of the surgery

Table 6. Oxygenation ratio intraoperatively and postoperatively

	Group 8ml/kg n:16	**Group 6ml/kg n:16**	***p***
PaO_2/FiO_2			
T_1	320,87±80,71	300,73±81,03	0,487
T_2	322,25±57,30	306,84±73,72	**0,009**
T_3	255,00(192,00-329,37)	219,10(149,00-309,37)	0,254
T_4	396,55±92,77	338,60±108,11	0,121
T_5	357,03±114,86	346,31±130,84	0,807

T_1; 15 min prior to cardiopulmonary bypass, T_2; 15 min following cardiopulmonary bypass, T_3; End of the surgery T_4; 6 h following extubation, T_5; 12 h following extubation

Discussion

In this study we compared two LTV strategies with 6ml/kg and 8 ml/kg in cardiac surgical patients undergoing on pump CABG. Mechanical ventilation with a LTV strategy with 8 ml /kg has more favorable outcomes by considering the shorter extubation time and length of stay in the ICU comparing with 6 ml/kg.

In the literature, the results of studies, in which LTV is used in cardiac surgery, differ. Some studies recommend [LTV6,8,19-23], while others report that it has limited benefits[24], and some studies report no advantage of LTV.[25] There may be several reasons for different outcomes such as what body weight was taken as a basis when calculating TV: actual, predicted or ideal body weight? Some studies does not mentioned this at all[19],[25] whereas some of them use ideal body weight.[24] In lung protective ventilation strategy, it is recommended to calculate TV based on PBW.[26,27] Another reason may be different main outcomes. In some of the studies, the main outcomes include postoperative airway pressures, lung compliance and arterial oxygenation values while in other studies, they include organ failure and length of stay in the ICU, and in some studies, main outcomes include investigating systemic and pulmonary inflammatory markers such as TNF_Alfa, IL-$_1$ and IL-$_8$.[19,20,22,24,25] On the other hand, confusion in terminology can lead to different interpretation of results. Namely, lung protective ventilation can also be applied without PEEP or recruitment maneuver (RM).[28] Open lung ventilation (OLV) involves RM and high PEEP administration.[29] Chaney et al.[19] do not mention RM in their study and Lellouche et al.[20] performed RM after weaning from CPB, Miranda et al.[22] applied RM after induction and during the postoperative ICU stay. Therefore, in the last two studies, patients were actually ventilated with the OLV strategy.[20,22]

The last factor that can lead to different results is the definition of LTV. According to some authors[19,22,24,25], LTV is defined as 6ml/kg, according to some others[6] as 8ml/kg, and for other researchers[20] it is defined as TV below 10ml/kg.

Our main aim was to compare the potential benefits of the LTV values defined as 6 or 8ml/kg. $PaCO_2$ value was considered as the reference in sample size calculation since no similarly designed study was found in the literature. In our study, it is expected that $PaCO_2$ will be higher with use of 6 ml/kg TV. Despite the increase in $PaCO_2$, pH levels remained similar. The similarity of PaO_2, SaO_2 and lactate levels indicates that arterial and tissue oxygenation is similarly affected by both amounts of TV. The decrease of T_i as a result of increasing RF at 6ml/kg did not negatively impact oxygenation. The $PaCO_2$-$EtCO_2$ value was found to be significantly different between groups in T_2 and T_3. Normal $PaCO_2$-$EtCO_2$ difference is 2-5mmHg.[30] Chronic obstructive pulmonary disease, left heart failure, pulmonary embolism, the reverse Trendelenburg position, intrinsic lung disease, hypovolemia, and increased physiological dead space are among the causes for this difference. The increase in the $PaCO_2$-$EtCO_2$ difference at 6ml/kg can be explained by the increase in physiological dead space due to the inclusion of patients with intact lung function and similarity of hemodynamic data, the amount of inotropic agent used, the amount of blood and fluid replacement and the preoperative EF values in both groups. This is the result of elevated RF. Although the increase in $PaCO_2$-$EtCO_2$ difference showed increased ventilation and perfusion impairment, it was not reflected in ABG.

PaO_2/FiO_2 ratio was lower with 6ml/kg at 15 minutes following weaning from CPB. This suggests that minimal atelectatic areas developing during ventilation at 6ml/kg increase even more during CPB when ventilation ceases. Atelectatic areas caused an increase in ventilation–perfusion mismatching. The equalization of this ratio at the end of the surgery may be due to the opening of the atelectatic lung areas with the administration of RM during exit from the CPB.

Despite the elevation of arterial carbon dioxide level, increased respiratory rates and high airway pressures, similar hemodynamic responses were observed in both groups.

Although P_{peak} and $P_{plateau}$ were higher with 8ml/kg in our study, $P_{plateau}$ was below 30cm H_2O recommended for lung protective ventilation.[31] The $P_{plateau}$ median value with 8ml/kg TV was 19,50 cm H_2O (interquartile range: 17,25 to 21,75). Similarly, although DP is higher than the other group with 8ml/kg, this value is lower than the upper limit value (15 cmH_20) specified in the studies.[32] A similar course in compliance indicates that the lungs were ventilated in the safe ventilation zone in both groups. One of the important but unforeseen results of our study was the elongation of the extubation time with 6ml/kg. This may be due to more extensive atelectatic areas. The definitive diagnosis of this would have been possible with computed tomography of the thorax; however, this was not performed to avoid unnecessary radiation exposure. This can be considered as a limitation of our study. Although the duration of extubation and the length of stay in the ICU do not prolong time to discharge in our study, this result has a crucial importance by considering the correlation of postoperative pneumonia and intubation time.[33] Postoperative pneumonia is more common in cardiac surgery compared to other surgeries, and constitutes a major cause of morbidity and mortality.[34, 35] Since we did not predict the results related to extubation and length of stay in the ICU when we started our study, data on postoperative pneumonia was not followed, which may be another limitation of our study.

Conclusion

In conclusion, 6ml/kg and 8ml/kg mechanical ventilation similarly affected oxygenation and hemodynamics in CABG patients who do not have any lung disease. Airway pressures were higher with 8ml/kg, but below the recommended values for lung protective ventilation. Due to the fact that extubation time and length of stay in the ICU are shorter with 8ml/kg mechanical ventilation, it can be preferred in patients who are at a high risk of developing postoperative pneumonia. Our results are obtained from patients with normal lung functions. Lung disease and coronary artery disease are likely to coexist due to factors such as age, smoking and obesity. The results may be different in these patients. Further comparative studies are needed regarding this topic.

Aknowledgements

None

Declaration of Conflict of Interest

None

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