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ORIGINAL PAPER

# The Influence of Cardiopulmonary By-pass on Respiratory Function in Patients Who Underwent Coronary Disease Surgery

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**Aim:** The study is designed to show influence of cardiopulmonary by-pass (CPB) on respiratory function in patients who underwent cardiac surgery. **Patients and methods:** With respect on operative technique the patients were divided into two groups consisted of 40 patients, who underwent with or without CPB. On the bases of the hemodynamic measurements and counting alveolar arterial oxygen difference (A-a)DO2, saturation of mixed venous blood (SvO2), direct intrapulmonary shunt (V/Q) and hypoxemic score ($PaO_2$/FiO2) preoperative and postoperative respiratory function in these patients is assumed**.** There were one preoperative and four postoperative measurements. **Results and discussion:** Statistically significant difference is found between the examined groups between mean values of alveolar arterial oxygen difference (A-a)DO2 in three postoperative measurements (p=0,035, p=0,015 and p=0,011), direct intrapulmonary shunt (V/Q) in four postoperative measurements (p=0,037, p=0,023, p=0,014 and p=0,04), saturation of mixed venous blood ($SvO_2$) in four postoperative measurements (p=0,01, p=0,023, p=0,020 and p=0,020) and hypoxemic score ($PaO_2/FO_2$) in four postoperative measurements (p=0,018, p=0,028, p=0,017 and p=0,038). The comparative analyses of parameters of respiratory function in both groups showed increased degree of acute lung injury (ALI) in group of patients underwent CPB. C**onclusion:** Early discovering parameters of acute lung injury in early postoperative period in patients underwent cardiac surgery with cardiopulmonary by-pass can prevent development of postoperative complications and duration of hospitalization. Key words: cardiopulmonary by-pass, respiratory function, acute lung injury.

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## 1. INTRODUCTION

The technique of extracorporeal circulation during coronary artery bypass grafting demands using cardiopulmonary by-pass (CPB), the system which starting immune response, inflammation reactions and systemic effects like pulmonary dysfunction is as well (1). Open heart surgery using CPB due cardiopulmonary bloodstream follows a high degree of acute lung injury (ALI) and if is not detected early, can lead to acute respiratory distress syndrome (ARDS), whose mortality is greater than 50% (2, 3, 4)**.** There is report that lung injury (ALI) develops in almost all patients in whom CPB was used and is verified by the analysis of the alveolar-arterial oxygen difference, hypoxemic score and pulmonary shunt. The basic characteristics of ALI are indistinguishable clinical course in the initial phase, irrespective etiology. Early identification of origin ALI in patients after coronary artery bypass surgery using CPB helps in understanding and addressing this major medical problem in order to prevent fatal postoperative complications.

## 2. MATERIAL AND METHODS

We retrospectively reviewed the clinical data of 80 consecutive patients who underwent coronary artery by-pass surgery between January and December 2009 et Clinic for Cardiovascular Disease, University Clinical Center Tuzla. This study was approved by Institutional Review Board of the hospital.

The study did not include patients who had surgery over the past year, patients with chronic obstructive pulmonary disease (COPD), patients with allergic changes that could lead to changes respiratory functions as well as patients with preoperative inotropic support for low-volume heart syndrome (LCO). In all the patients, using standard preoperative preparation, thermo hemodilution Swan-Ganz catheter was placed to follow respiratory and hemodynamic parameters for the saturation of mixed venous blood (SvO2). Samples of arterial blood gas analysis were taken from a catheter placed in the radial artery by Seldinger's technique. The values of mixed venous blood saturation (SvO2) is given by taking blood samples from the peak pulmonary artery catheter placed in the arterial pulmonary whose referential values are 66-78%. Analyses were performed on the ABL apparatus. Patients were anaesthetized according to standard anesthesiology protocol for the cardio surgical patients. FiO2 during surgery was 70%, and 40 % in the postoperative period on a respirator. The following parameters were measured: partial pressure of oxygen and carbon dioxide in arterial blood oxygen, saturation of arterial blood and mixed venous oxygen saturation of blood hemoglobin. Based on these parameters, values of hypoxemia score (PaO2/FiO2), right-left shunt (Qs/Qt) and alveolar-arterial oxygen difference (A-a)DO2 were calculated and than the degree of acute lung injury is verified (5).

**1st Intrapulmonary shunt (Qs / Qt) = CcO2-CaO2/CcO2-CvO2**

- CcO2 = aerobic content of the blood leaving the alveoli = (1.34 x Hgb x 1.0) + (PaO2 x 0.0031),
- PaO2 = FiO2 x (BP-PH2O)-(PaCO2/RQ) pressure of oxygen in the alveoli,
- BP = barometric pressure,
- PH2O = pressure water vapor,
- R/Q = respiratory quotient,
- CaO2 = (1.34 x Hgbx SaO2) + (PaO2 x 0.0031) the oxygen content of blood leaving the heart,
- CvO2 = (1.34 x Hgbx SvO2) + (PvO2 x 0.0031) the oxygen content of blood returning to heart.

**2nd Alveolar-arterial oxygen difference (A-a)$DO_2$**

- (A-a) DO2 = PaO2-PaO2,
- PaO2 = FiO2 * (760mmHg–47mmHg)–(PaCO2 / 0.8),
- PaO2 = partial pressure of oxygen in arterial blood,
- PaO2 = partial pressure of oxygen in the alveoli,
- 0.8-respiratory coefficient,
- Normal is about 2.5 kPa increases with age and with increasing inspiratory concentrations of oxygen. (A-a)DO2 = 2.5 + 0.21 *year..

**The criteria that we took for the existence of ALI are:**

- (A-a)DO2 > 300% of predicted values (6),
- PaO2/FiO2 ≤ 39.9 kPa acute onset ALI,
- PaO2/FiO2 ≤ 26.6 kPa acute onset of ARDS (7),
- Sudden drop SvO2 <20% or more indicates a change (8).

**Measurements**:

- I measurements: after anaesthesia induction,
- II measurement: 1 hour after surgery,
- III measurement: 4 hours after surgery,
- IV measurement: 8 hours after surgery,
- V measurement: 24 hours after surgery,

**Statistical analysis**

The SPSS statistical software for Windows (SPSS, Inc., Chicago, IL) was used for data analysis. Data are expressed as the median value and range or the mean ± standard deviation appropriate. Data from groups were compared with Student t-test. A *p*-value less than 0.05 was considered as significant in all of the tests.

## 3. RESULTS

In a prospective study 80 patients who underwent revascularization, were analyzed, 40 patients had surgery using cardiopulmonary bypass and 40 patients had surgery without cardiopulmonary bypass. There were 70 male patients or 87.5%, with mean age 54.45 ± 10.91 (range of 46-75) and 10 female patients or 12.5% with mean age 62,16±11,37 (range 56-76) with overall mean age 58,30±11,06 and range 46-76 years.

Table 1 shows the distribution of middle values of arterial blood O2 pressure. Statistically significant difference was found in all postoperative measurements, with lower values in the group of patients underwent CPB's.

Table 2 shows the middle arterial blood oxygen saturation (SpO2). Middle values of SpO2 were lower in the CPB group in all postoperative measurements with no statistically significant differences compared to the control group patients.

Table 3 shows statistically significant differences in middle values of (A-a)DO2 was observed in the third, fourth and fifth postoperative measurements. Middle values of (A-a)DO2 are above the reference CPB group.

Table 4 shows the distribution of middle values intrapulmonary shunt (Qs/Qt). Intrapulmonary shunt in the postoperative period showed increased mean values with statistically significant differences in CPB group of pa-

| Measurement Patients | I | II | III | VI | V |
|---|---|---|---|---|---|
| with CPB n=40 | 31.34±6.54 | 14.49±2.87 | 15.8±4.43 | 13.65±3.41 | 13.51±4.43 |
| without CPB n=40 | 30.56±4,12 | 19.86±5.05 | 20.35±4.28 | 22.13±4.3 | 19.69±3.35 |
| p<0.05 | p=0.055 | p =0.037 | p=0.023 | p=0.014 | p=0.04 |

Table 1. Distribution of arterial blood PaO2 (kPa) values

| Measurement Patients | I | II | III | VI | V |
|---|---|---|---|---|---|
| with CPB n=40 | 99.29±0.50 | 97.03±2.01 | 97.28±2.10 | 97.00±2.39 | 96.72±2.60 |
| without CPB n=40 | 99.17±0.48 | 98.19±1.26 | 98.30±1.36 | 98.54±0.92 | 98.28±1.20 |
| p<0.05 | p=0.13 | p =0.050 | p=0.059 | p=0.055 | p=0.057 |

Table 2. Distribution of SpO2 (%) values

| Measurement Patients | I | II | III | VI | V |
|---|---|---|---|---|---|
| with CPB n=40 | 29.38±8.12 | 16.53±4.93 | 8.16±3.11 | 7.86±2.99 | 8.02±2.86 |
| without CPB n=40 | 28.68±5.51 | 13.42±3.46 | 5.22±1.89 | 4.35±1.70 | 3.71±1.28 |
| p<0.05 | p=0.051 | p=0.05 | p=0.035 | p=0.015 | p=0.011 |

Table 3. Distribution of (A-a) DO2 (kPa) values

| Measurement Patients | I | II | III | VI | V |
|---|---|---|---|---|---|
| with CPB n=40 | 13.67 ±3.77 | 5.57±2.51 | 4.79±2.46 | 4.62±1.97 | 4.25±1.34 |
| without CPB n=40 | 12.95±3.65 | 5.96±2.77 | 2.79±1.70 | 2.59±1.01 | 2.44±1.23 |
| p<0.05 | p=0.055 | p =0.037 | p=0.023 | p=0.014 | p=0.04 |

Table 4. Distribution of Qs/Qt (%) values

| Measurement Patients | I | II | III | VI | V |
|---|---|---|---|---|---|
| with CPB n=40 | 49.44 ± 9.87 | 37.14±11.47 | 51.75±14.12 | 45.19±14.94 | 42.05 ± 10.48 |
| without CPB n=40 | 49.22 ± 5.42 | 49.71 ± 8.75 | 66.17 ± 14.47 | 64.78±15.10 | 59.87 ± 12.64 |
| p<0.05 | p=0.08 | p =0.018 | p=0.028 | p=0.017 | p=0.038 |

Table 5. Distribution of PaO2/FiO2 values

| Measurement Patients | I | II | III | VI | V |
|---|---|---|---|---|---|
| with CPB n=40 | 74.77±5.36 | 54.55±7.87 | 55.83±6.78 | 56.30±6.10 | 52,.92±6.85 |
| without CPB n=40 | 74.19±5.84 | 65.21±7.11 | 63.21±6.30 | 63.18±6.00 | 60.76±7.04 |
| p<0.05 | p=0.216 | p =0.01 | p=0.023 | p=0.020 | p=0.020 |

Table 6. Distribution of values SvO2(%)

tients in II (p = 0.037), III (0.023), IV (0.014), V (0.04).

In Table 5 we see the numerically expressed values, the distribution medium hypoxemic score (PaO2/FiO2) in both groups of patients with statistically significant differences in all postoperative measurements. Values hypoxemic scores were significantly lower in the CPB group of patients.

Decreased middle SvO2 were found in the group of patients underwent CPB, and with a statistically significant difference in the II, III, IV and V of the postoperative measurement.

## 4. DISCUSSION

The study showed that patients who underwent CPB have a higher incidence of ALI compared with patients without CPB. Murakami et al. suggested that one of possible causes is the immune response that triggers the termination of CPB and lung ventilation during CPB and reduces the production of surfactant, which may be one of the reason for hypoxia (9, 3). The strongest expression of lung imbalance is value of alveolar-arterial oxygen difference (A-a)DO2. Normal is 1 to 2.5kPa, increasing with age and the percentage of inhaled oxygen (10). The effect of high FiO2 to increase (A-a)DO2 value can be seen in the first measurement in both groups, regard that measurements are done after induction of general anesthesia with FiO2 0.7. In the first postoperative measurement we can saw the influence of mechanical ventilatory support for an increase in (A-a)DO2 value (11, 12). There was a decrease in alveolar-arterial oxygen difference during the stay of patients on the intensive care unit at the reference level, for patients who had no CPB, while the value of (A-a)DO2 in the group of patients operated using CPB remain at all times 300% or more above the reference values. Similar results were obtained by Birdi et al. which stated that the increase in (A-a)DO2 value is good indicator of lung damage in patients treated with the use of CPB's (13). Another important parameter values is low ALI hypoxemia scores PaO2/FiO2. All values ≤ 39.9 kPa indicate the existence of ALI (14). In patients who underwent CPB, we have a lower value in the second, third, fourth and fifth measurement with a statistically significant difference compared to the same measurements of other groups. Based on this we can conclude that there is a change in oxygenation that occurred in the group where is used CPB. Doyle et al. stated that values of intrapulmonary shunt fully follow changes in the hypoxic score and changes in the alveolo-arterial oxygen difference (15). Similar results were shown in our study. In both groups of patients, the value of Qs/Qt were within reference values but with no statistically significant differences in the four postoperative measurements, where we found other parameters of lung injury. Mean values intrapulmonary shunt are higher in the group of patients underwent CPB's. By measuring the saturation of mixed venous blood (SvO2), we followed the dynamics of lung injury. The fall of mean SvO2 value in postoperative measurements indicated pulmonary changes even in the earliest stages in patients treated with the use of CPB's (16). Starting mechanism of immune and inflammatory responses to non pulsate of blood flow is reasonably considered to leading to systemic effects of CPB followed the high incidence of systemic complications (1). Precisely measuring the saturation of mixed venous blood tells us that despite the normalization of the basic parameters, hypoxia of tissue is still there (17). Change may also be related to changes in CO2 level and can help us to make decisions in separating the patient from the respirator and the PEEP using. Wagner et al. suggest that measurement of arterial blood gas analysis selectively (SpO2, PO2) does not indicate the existence of changes in the lungs (18). In support, the values of SpO2, PaO2 in both groups did not differ from physiological values of any of them and have no statistically significant difference even hypoxic score in II measurement was 37.14 ± 11.47 and mean value of saturation (SpO2) in this measurement was within the normal values (97.03 ± 0.50). The value (A-a)DO2 in all postoperative measurements in the patients undrewent CPB indicates the existence of ALI, whereas the mean value of SpO2 within normal limits. Doyle (1986) stated that only the measurement of arterial blood gas parameters may not show changes related to ALI in the early stages and gave emphasis to the importance of measuring the value (A-a)DO2 in high-risk patients, which fully agrees with our results. In our research we have obtained, on the basis of the most important parameters measurements that follow lung injury, the conclusion that the frequency of ALI is higher in the group of patients who underwent CPB compared to patients without CPB.

## 5. CONCLUSION

Heart surgery by using CPB leads to acute lung injury, which is at an early stage, cannot be observed by measuring the standard gas analysis. Measurements of (A-a)DO2, hypoxemic score, saturation, mixed venous blood and pulmonary shunt are very important for ALI verification. The proper approach to the problem of treatment the patient during the postoperative treatment in the Intensive Care Units as well as new therapeutic guidelines can greatly reduce the CPB side-effects. The introduction of modern oxygenators and filter minimizes immune responses and lung damage. Proper strategy may prevent ARDS which mortality is still 50% or more. This study gives us the opportunity to observe at an early stage appearance of ALI. We can reduce the occurrence and consequences of ALI by the application of new therapeutic procedures, primarily in patients who underwent CPB.

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