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Research Article / Araştırma

# Interstitial Edema After Cardiopulmonary Bypass in Patients Undergone Cardiac Surgery Patients: Evaluation Through Lung Ultrasonography

## *Açık Kalp Cerrahisi Geçiren Hastalarda Kardiyopulmoner Baypas Sonrası İnterstisyel Ödem: Akciğer Ultrasonografisi ile Değerlendirilmesi*

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## ABSTRACT

**Objectives:** Primary target of the study was identifying pulmonary interstitial edema (IE) with lung ultrasonography after open-heart surgery and searching the reasons of edema.

**Methods:** At the end of the surgery, patients divided in two groups: Group Control: No IE and lung ultrasound (LUS) Score <17. Group IE: IE, LUS score ≥17. All clinical, hemodynamic data, and LUS score were recorded at the beginning (t0), at the end of surgery ($t_1$), at post-operative 4th h ($t_2$), 24th ($t_3$), and 48th h ($t_4$).

**Results:** The mean LUS score of Group IE (n=32, 58%) was 20.8±4.3 and those of patients in Group C mean LUS skore ($t_1$) of 16.2±3.7 (n=23, %42) points at the end of the surgery ($t_1$). In Group IE, serum lactate level was higher than control group (respectively, 2.0±0.8, 1.6±0.8, p=0.04, p<0.02). There was statistically significant positive correlation between LUS scores at the postoperatively 4th h ($t_2$) and central venous pressure (CVP) at the beginning ($t_0$) (r=0.27 p=0.04). There was significantly positive correlation between LUS scores ($t_2$) at the postoperatively 4th h and duration of stay in intensive care unit (ICU) (r=0.35 p<0.01). There was negative correlation between CVP at the beginning (t0) and the pump balance during cardiopulmonary by-pass (r=0.29 p=0.03).

**Conclusion:** The values of CVP, post-operative serum lactate levels, and the length of stay in ICU are found higher in patients with pulmonary IE.

## ÖZ

**Amaç:** Çalışmanın birincil amacı, açık kalp cerrahisi sonrası interstisyel ödemi akciğer ultrasonografisi ile saptamak ve nedenlerini araştırmaktır.

**Yöntem:** Cerrahinin sonunda olgular iki gruba ayrıldı; grup kontrol (C) ve grup interstisyel ödem (İÖ). Grup C: İnterstisyel ödem yok, akciğer ultrasonografi (LUS) skoru <17; Grup İÖ: İnterstisyel ödem var, LUS skoru ≥17. Klinik, hemodinamik veriler ve LUS skorları başlangıçta ($t_0$), cerrahinin sonunda ($t_1$), cerrahi sonrası dördüncü saatte (t2), 24. saatte ($t_3$) ve 48. saatte (t4) kaydedildi.

**Bulgular:** Ortalama LUS skoru, cerrahinin sonunda ($t_1$), grup İÖ'de (n=32, %58) 20,8±4,3, grup C'de (n=23, %42) ise 16,2±3,7 idi. Serum laktat seviyesi, grup İÖ'de grup C'dekilerden anlamlı olarak daha yüksekti (sırasıyla, 2,0±0,8, 1,6±0,8, p=0,04, p<0,02). Postoperatif dördüncü saatte ($t_2$) LUS skorları ile başlangıçtaki santral venöz basınç (t0) değerleri arasında istatistiksel olarak anlamlı pozitif korelasyon vardı (r=0,27, p=0,04). Postoperatif dördüncü saatte ($t_2$) LUS skorları ile yoğun bakımda kalış süresi arasında istatistiksel olarak anlamlı pozitif korelasyon vardı (r=0,35, p<0,01). Başlangıçtaki santral venöz basınç ($t_0$) ile kardiyopulmoner baypas sırasındaki sıvı dengesi arasında istatistiksel olarak anlamlı negatif korelasyon bulundu (r=0,29, p=0,03).

**Sonuç:** İnterstisyel ödemli hastalarda başlangıçta santral venöz basınç, laktat değerleri ve yoğun bakımda kalma süreleri daha yüksekti. İnters-

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**ABSTRACT**

The patients with IE had more negative fluid balance in cardiopulmonary bypass (CPB). The presence of diabetes and renal failure, type of surgery, ejection fraction, duration of cross-clamp and CPB did not associated with pulmonary edema in this study. Evaluation of pulmonary IE by lung US method after open heart surgery is valuable in terms of being able to be applied at the bedside, being non-invasive, and providing information about fluid balance.

**Keywords:** Cardiopulmonary bypass, interstitial edema, lung ultrasonography

**ÖZ**

tisyel ödemli hastalar, kardiyopulmoner baypasta sıvı dengesinde daha negatif olan hastalardı. Diyabet, renal yetmezliğin varlığı, cerrahinin tipi, ejeksiyon fraksiyonu, kros-klemp süresi ve kardiyopulmoner baypas süresi, bu çalışmada pulmoner ödemle birlikte değildi. İnterstisyel akciğer ödeminin kalp cerrahisi sonrası akciğer ultrasonografi yöntemi ile değerlendirilmesi yatak başında uygulanabilmesi, noninvaziv olması ve sıvı dengesi hakkında bilgi sağlaması açısından değerlidir.

**Anahtar sözcükler:** Akciğer ultrasonografisi, interstisyel ödem, kardiyopulmoner baypas,

## Introduction

The incidence of interstitial edema (IE) after cardiac surgery is about between 14% and 40%. Interstitial pulmonary edema means the increased extravascular fluid and is undesirable due to it disrupts tissue perfusion and oxygenation in the body. Inflammatory response syndrome due to extracorporal circulation, hemodilution, and cardioplegia solutions during cardiopulmonary bypass (CPB) causes by affecting alveola-capillary permeability.[1,2] Volume over loading to maintain preload after cardiac surgery in period of intensive care unit (ICU) may cause pulmonary edema, and also the restriction of fluid intake. Avoiding of volume overload may lead low cardiac output syndrome and may increase the need for inotropic support. Therefore, monitoring pulmonary edema at the bedside with real-time and non-invasive lung ultrasonography (lung ultrasound [LUS]) method helps to guide fluid therapy and reveals the cause of respiratory disorders earlier than clinical signs.[2,3]

There are many reasons for appeared IPE after CPB. Age, diabetes mellitus, chronic obstructive pulmonary disease, and chronic renal failure have been reported as independent risk factors for the development of IE.[4]

LUS is a non-invasive, easy, and practical method for bedside application. It has been reported as an alternative to many invasive methods in the recognition of IE.[5-10] In cardiac surgery ICU, ultrasound lung comet scores are positively correlated with pulmonary artery wedge pressure values[6] and radiological X-ray[5,7-11] for indicating the presence of extravascular lung water extravascular lung water (EVLW).

The primary aim of this study was to find the incidence of post-operative IE after open heart surgery by lung ultrasonography method. The secondary aim was to determine relevant factors associated with pulmonary edema (diabetes, renal failure, type of surgery, ejection fraction, duration of cross-clamp and CPB, and fluid balance in CPB) for IE.

## Methods

After obtaining approval from the Local Ethics Committee of our hospital (20478486-050.04.04), and providing the informed consent, patients over the age of 18 who will undergo elective coronary artery bypass graft surgery (CABG) or valve surgery were included in the study. Patients undergoing CABG without CPB, who had pneumonectomy, with massive pleural effusion and had higher than ≥17 LUS score at the beginning ($t_0$) which was not enrolled in study. Cases who died in the early post-operative period were excluded from the study. All cases were routinely monitored using invasive methods (electrocardiography, arterial pressure, and central venous pressure [CVP]) for cardiac surgery. Anesthetic induction was performed using midazolam (0.05-0.1 mg/kg), fentanyl (2-5 mg/kg), and rocuronium (0.6-1 mg/kg). General anesthesia was maintained with sevoflurane (1.0-2.0%), fentanyl (20-30 mg/kg as total dose for each patient), and midazolam (2-4 mg/h). Rocuronium was used for providing muscle relaxation. Mechanical ventilation was performed with a tidal volume of 6-8 mL/kg at a rate of 10-12 times/min, which was adjusted to maintain the end-tidal carbon dioxide level between 35 and 40 mmHg. After induction of anesthesia, transesophageal echocardiography probe was inserted in patient (Vivid S5GEHealthcare, Wauwatosa, WI).

Extracorporeal circulation is maintained with roller pump and moderate hypothermia (32-34°C). Cardiac protection was achieved with 4:1 cold blood cardioplegia. In cases where enough urine output could not be achieved (<0.5 ml. $kg^1$/15 min), 10 mg furosemide was administered. During CPB, the hematocrit (Hct) level was targeted at 21-24%. In addition, retrograde autologous priming, cell saver, and ultrafiltration methods were used in indicated cases for blood preservation.

Patients were divided in to two groups according to LUS scores at the end of the operation ($t_1$) to evaluate IE after CPBs. Group Control (n=23): No IE and LUS Score <17 and Group IE (n=32): IE and LUS score ≥17.[12]

LUS was performed at the beginning ($t_0$), 5 min after anesthesia induction), at the end of surgery, before transport to the ICU ($t_1$), at the 4$^{th}$ h ($t_2$), 24$^{th}$ h ($t_3$), and at the 48$^{th}$ ($t_4$) h in the ICU.

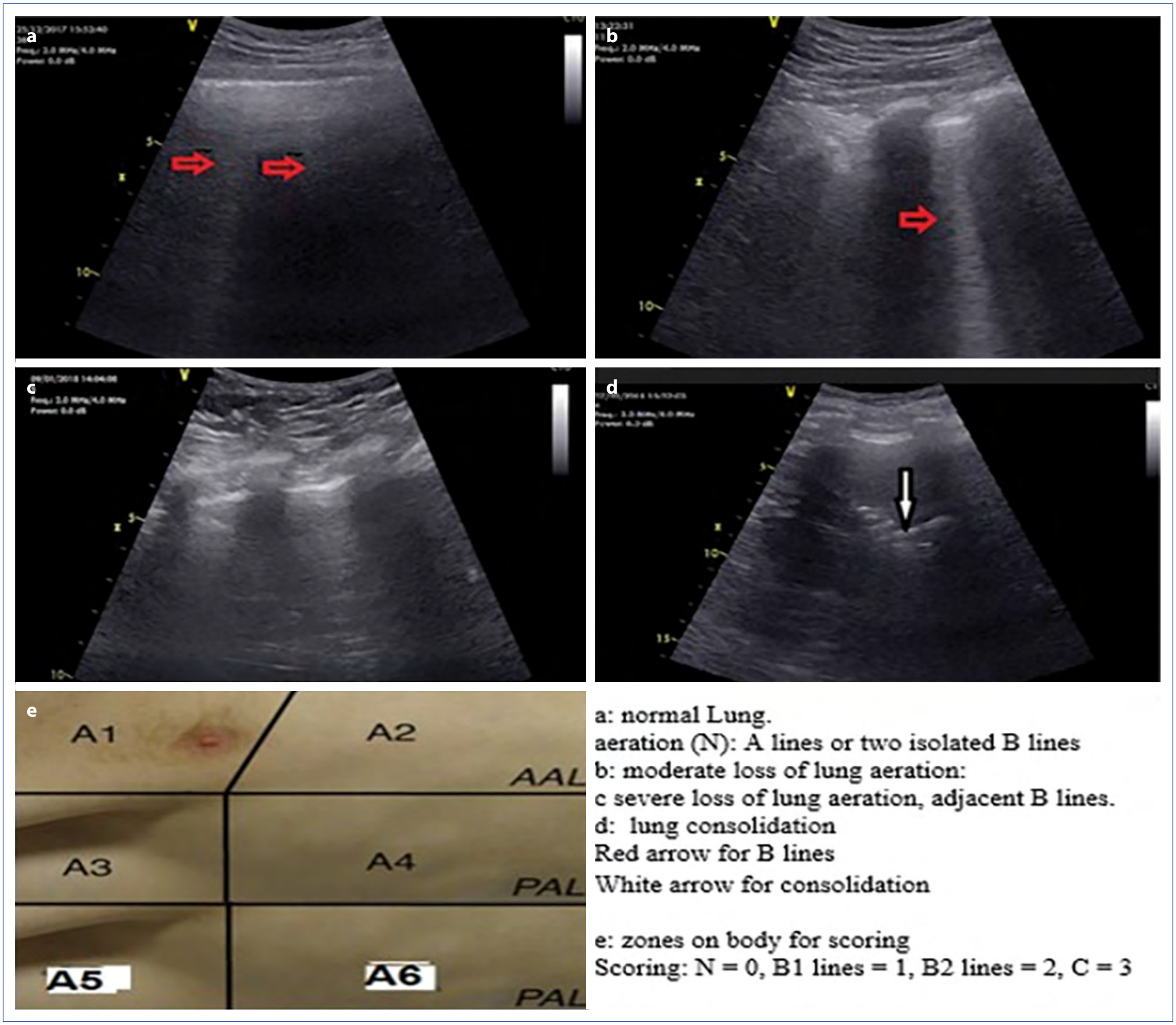


**Figure 1.** Four different ultrasounds examples from normal lung to lung consolidation for calculating lung ultrasound score, and sample areas for scoring. **(a)** Normal lung; **(b)** Moderate loss of lung aeration, **(c)** Severe loss of lung aeration, **(d)** Lung consolidation, **(e)** Zones on chest and scoring.

Application of LUS: The examinations were performed by same expert using an Convex Probe (GE 4c-RS, General Electric USA, Inc) equipped with convex probe 2-5 MHz. The investigator was unaware of clinical data of the patient. The ultrasonographic examinations were performed with patients in the near-to-supine (30° head up) position. Each chest wall was divided into 6 zones, and each zone was scored between 0 and 3 (total; range 0-36) (Fig. 1). Seventeen or more points of LUS scores were defined as IE[13] (Fig. 1).

## Perioperative Hemodynamic Management

Volume replacement was performed in line with the stroke volume index (SVI) and pleth variability index (PVI, Masimo Corp, Irvine, CA, USA). SV was measured by TEE intraoperatively and transthoracic echocardiography was performed after extubation in ICU. SVI and cardiac index (CI) were kept at normal range during the operation (respectively, 30-65 ml $m^2$ $beat^{-1}$ and 2.5-4.2 L $min^{-1}$ $m^2$). PVI was kept 12-14%. All cases were managed in accordance with the gold directed fluid therapy protocol, perioperatively.[14] If the patient was responsive to tilting the bed 30° of angle, 250 ml crystalloid (isolyt S) was performed intermittently until fluid unresponsiveness. If the patient was unresponsive to fluids and hemodynamic instability was continued, SVI, CI, and mean arterial pressure (MAP) were considered and inotropic and vasoconstrictor agents were infused.

**Table 1.** Characteristics of patients perioperatively

| Characteristics of patients | Total (n=55) | Group C (n=23) | Group IE (n=32) | p |
|---|---|---|---|---|
| Age (year) | 62±10.4 | 62±9 | 61±11 | 0.8* |
| BSA ($m^2$) | 1.8±0.2 | 1.6±0.3 | 1.9±0.1 | 0.4* |
| Euroscore | 1 (0-3) | 1 (0-3) | 1 (1-3) | 0.8** |
| LUS $t_0$e | 15±1.2 | 15.9±1.1 | 15.9±1.3 | 0.8* |
| EF $t_0$ (%) | 52±7 | 53±6 | 51±8 | 0.3* |
| Operation time (min) | 238±49 | 229±59 | 245±39 | 0.2* |
| CPB time (min) | 103±34 | 102±34 | 104±34 | 0.9* |
| CC time ($d_{min}$) | 74±32 | 71±32 | 76±33 | 0.5* |
| Ventilation time (hour) | 9 (6-16) | 8 (6-13) | 12 (8-19.5) | 0.2** |
| Lenght of ICU stay (day) | 2 (1-2) | 2 (1-2) | 2 (1-2) | 1.0** |
| Dopamine (ml/h) | 5 (3-5) | 4 (3-5) | 5 (3-5) | 0.4** |
| Dobutamine (ml/h) | 5 (3-5) | 5 (3-5) | 4 (3-5) | 0.4** |
| Steradin (ml/h) | 3 (0-8) | 4 (0.8) | 3 (0.8) | 0.5** |

*: Student t-test; **: Mann-Whitney U test. BSA: Body surface area; LUS: Lung ultrasound; EF: Ejection Fraction; CPB: Cardiopulmonary bypass; CC: Cross clemp; ICU: Intensive care unit.

## Collection of Data

At the same time intervals with LUS scoring, heart rate (HR), MAP, Hct, CVP, SVI, CI, partial arterial oxygen pressure/inspiratory oxygen fraction ratio ($PaO_2/FiO_2$), and lactate values were recorded. Cross clamp (CC) time, CPB time, duration of the operation, equilibrium status of the pump, amount of inotropes administered after CPB, perioperative amount of blood and blood products administered, the duration of stay in the ICU, and mechanical ventilation time were recorded.

## Statistical Analysis

Statistics for Windows (v.12.5 StatSoft, Inc., Oklahoma City, USA) software was used for statistical evaluations. The distribution characteristics of the variables were determined by Shapiro-Wilks or Kolmogorov-Smirnov and Liliefors tests. Variables with normal distribution were expressed as mean±SD (standard deviation) and median (interquartile range) values were used as central distribution criteria. In comparison of two independent groups with nonparametric variables, Mann-Whitney U or Chi-square test, for parametric variables Student-t-test or one-way analysis of variance, for correlation analysis between variables, according to the distribution characteristics of the variable. Pearson product-moment or Spearman rank-order method were used. The statistical significance limit of "p" value was accepted as 0.05.

# Results

Sixty-three patients were included in the study, two patients who underwent coronary artery surgery without CPB, and one patient who died on the post-operative day 1 are excluded from the study.

Baseline characteristics are summarized in Tables 1 and 2. The mean LUS score of Group IE (n=32, 58%) was 20.8±4.3 points at the end of the surgery ($t_1$). This score of Group IE continued to be high the next days. The patients in Group C became also higher to over 17 LUS score at $t_2$, $t_3$ time intervals (from 16.2±2.7 to 19.2±3.7 and to 19.2±3.1). The highest mean LUS score of all patients was found at the postoperatively 4$^{th}$ h. The mean scores on the post-operative 2$^{nd}$ day in both groups were similar to those of post-operative day 1. Due to missing data belonging to day 2$^{th}$ ($t_4$), their data are shown in Table 2.

According to descriptive characteristics, any statistically significant difference was not found between groups as for age, body mass index, diabetes, renal failure, euroscore, operation time, duration of CPB, CC time, ventilation time, ICU stay, dopamine, dobutamine, and steradian infusions ($p>0.05$) Table 1.

Regarding clinical characteristics of the groups, any statistically significant difference was not found between the groups in terms of perioperative and post-operative HR, MAP, CVP, Hct, $PaO_2/FiO_2$, CI, and PVI parameters ($p>0.05$, Table 2). Perioperative lactate levels were statistically significantly higher in Group IE than those Group C (respectively, 2.0±0.8, 1.6±0.8, p=0.04). Perioperative requirements for erythrocyte (1.8±1.7 U vs. 1.5±1.9 U) fresh frozen plasma (2.8±1.5 vs. 2.9±1.8 U) and platelet apheresis (0.3±0.5 vs. 0.5±1.0 U) were similar between groups ($p>0.05$).

There was statistically significant positive correlation between Lung US scores at the post-operative 4$^{th}$ h ($t_2$) and CVP at the beginning ($t_0$), (r=0.27; p=0.04, Fig. 2). The higher LUS scores were observed in patients with the higher baseline central pressure values. A statistically significant

**Table 2.** Comparison of hemodynamic parameters between groups

| Hemodynamic parameters | $t_0$ | $t_1$ | $t_2$ | $t_3$ | p* |
|---|---|---|---|---|---|
| HR (beat/min$^{-1}$) | | | | | 0.7 |
| Group C | 73.2±15.7 | 86.4±10.1 | 88.8±15.6 | 86.3±14.0 | |
| Group IE | 76.4±20.2 | 87.4±21.2 | 92.9±17.6 | 88.4±16.1 | |
| MAP (mmHg$^1$) | | | | | 0.6 |
| Group C | 72.2±8.2 | 69.7±12.5 | 74.1±9.1 | 75.0±9.4 | |
| Group IE | 76.1±11.4 | 68.5±6.6 | 74.4±12.6 | 77.5±8.1 | |
| CVP (mmHg) | | | | | 0.9 |
| Group C | 5.0±3.3 | 5.8±2.6 | 6.8±2.8 | 6.1±1.9 | |
| Group IE | 6.0±4.5 | 7.2±4.1 | 6.6±2.6 | 6.0±2.1 | |
| Hct (%) | | | | | 0.4 |
| Group C | 40.3±3.9 | 26.0±3.5 | 29.2±4.0 | 28.1±3.0 | |
| Group IE | 38.2±5.4 | 26.0±4.0 | 29.2±4.7 | 29.1±3.0 | |
| $PaO_2/FiO_2$ | | | | | 0.1 |
| Group C | 251±118 | 302±125 | 369±129 | 265±108 | |
| Group IE | 239±106 | 273±98 | 298±112 | 241±86 | |
| Lactate (mmol/dL) | | | | | |
| Group C | 1.1±0.5 | 1.6±0.8 | 2.2±1.2 | 2.3±1.2 | 0.4 |
| Group IE | 1.0±0.5 | 2.0±0.8 | 2.6±1.3 | 2.3±1.1 | 0.02** |
| SVI (ml/beat/m$^2$) | | | | | |
| Group C | 33.8±11.7 | 28.5±11.4 | 31.7±10.3 | 33.8±10.9 | 0.1 |
| Group IE | 33.8±10.9 | 37.1±13.5 | 37.8±10.9 | 38.1±9.7 | 0.03** |
| CI (L/min/m$^2$) | | | | | 0.3 |
| Group C | 2.2±1.0 | 2.4±1.1 | 2.4±0.8 | 2.3±1.1 | |
| Group IE | 2.4±1.3 | 2.9±1.4 | 2.3±1.2 | 2.3±1.0 | |
| PVI (mmol/dL) | | | | | |
| Group C | 19.8±8.6 | 17.3±5.0 | 13.4±4.4 | 12.9±3.7 | 0.2 |
| Group IE | 18.6±7.0 | 16.8±6.6 | 15.5±5.6 | 14.1±4.4 | |
| LUS | | | | | |
| Group C (n=23) | 15.9±1.2 | 16.2±2.7 | 19.2±3.7 | 19.2±3.1 | |
| Group IE (n=32) | 15.9±1.1 | 20.8±4.3 | 23.7±3.7 | 20.8±3.3 | |

*p: ANOVA; **p: Student's t-test; $t_1$ versus $t_2$ $t_0$: At the beginning; $t_1$: End of the surgery; $t_2$: Post-operative 4$^{th}$ h.; $t_3$: Post-operative 24$^{th}$ h. HR: Heart rate; MAP: Mean arterial pressure; Hct: Hematocrit; CVP: Central venous pressure; Hct: ??????; $PaO_2/FiO_2$: Partial pressure of oxygen/fraction of inspired oxygen; SVI: Stroke volume index; CI: cardiac index; PVI: Pleth variability index; LUS: Lung ultrasonography score.

negative correlation was found between baseline ($t_0$) CVP values and pump balance during CPBs (r=-0.29; p=0.03, Fig. 3). The patients who had higher CVP values at the start of CPB had higher negative pump balance at the termination of CPB. There was a statistically significant positive correlation between the post-operative 4$^{th}$ h ($t_2$) LUS scores of the patients and the length of stay in the ICU (r=0.35; p<0.01, Fig. 4). The higher the LUS scores of the patients, the longer the length of stay in the ICU.

## Discussion

In our study, we evaluated the incidence of pulmonary IE in the ICU soon after the surgery by lung ultrasonography in patients who underwent open heart surgery for CABG or valve surgery. It was found that the patients who had higher central pressure at the beginning had higher LUS scores in the ICU. As the LUS scores of the patients increased, the duration of stay in the ICU was prolonged. Perioperative lactate values of the group with IE were statistically higher than the control group.

In our study, lung US scores at the 4$^{th}$ h ($t_2$) statically significant correlated with baseline CVP values (Fig. 2). The patients who had the higher CVP showed the higher LUS score. Contrary, Enghard et al.[15] reported that LUS correlated with EVLW, but there was no correlation between CVP and lung US. Several reasons may deal with this difference. First, patient populations who enrolled in studies was different. While our patients had cardiac vulnerability and injured alveoli-capillary permeability due to cardio pulmonary bypass, their patients had challenge

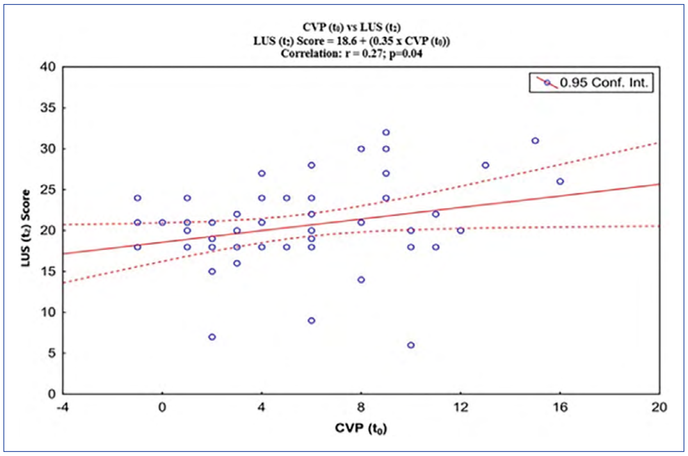


**Figure 2.** Correlation of between postoperative 4th h ($t_2$) lung ultrasound scores and central venous pressure at the beginning ($t_0$).

CVP: Central venous pressure; LUS: Lung ultrasound.

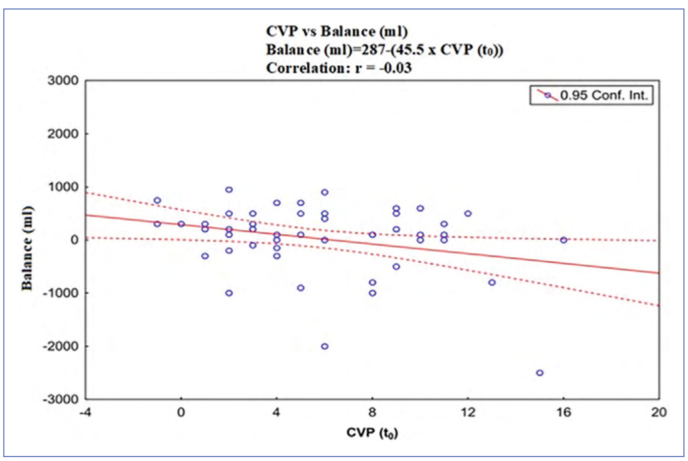


**Figure 3.** The correlation between central venous pressure at the beginning ($t_0$) and the pump balance during cardiopulmonary bypass.

CVP: Central venous pressure.

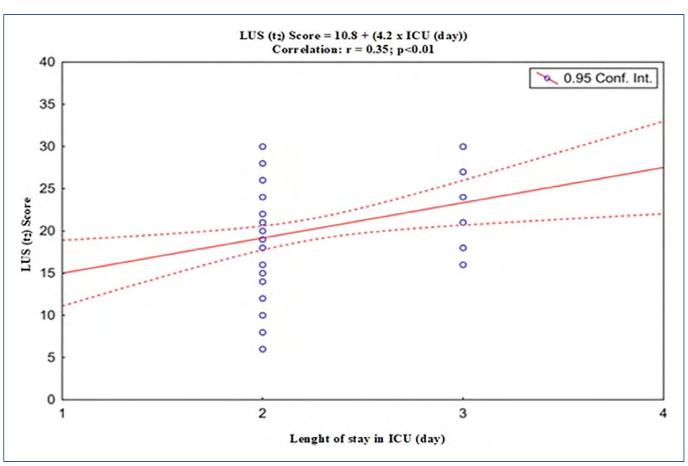


**Figure 4.** The correlation of between post-operative 4th h ($t_2$) lung ultrasound score and length of stay in intensive care unit.

LUS: Lung ultrasound; ICU: Intensive care unit.

general ICU. Thus, the effect of higher CVP levels on creating IE in our patients should be different from those in general ICU. Second, the patients who had higher CVP levels may have been right ventricle dysfunction at the beginning. If we had data of right ventricular function, we could more accurately interpret the relationship between CVP and LUS. Finally, the differences in cutoff values of LUS score were taken to detect IE. While Zhao et al.[13] found 16.5 LUS score as the cutoff value for identifying IE, Ciumanghel et al.[12] found 17 LUS score, in which we chose (respectively).

Although, there are meta-analyzes data supporting the superiority of dynamic fluid monitoring parameters than CVP,[16] CVP still maintains its place in the practice of fluid management in ICUs, especially where dynamic measurement devices cannot be used.

We also found that the patients who had higher central pressure before CPB ($t_0$) were more negative balance levels (r=-0.29; p=0.03, Fig. 2). Here, the perfusionist may have a role in practicing hemofiltration in these cases with high CVP. Thus, the patients with high central pressure values at the beginning ($t_0$) may be left in more negative balance according to CPB to avoid fluid load or overload due to cardiac failure.

In our study, a statistically significant positive correlation was found between the post-operative 1st day lung US and the duration of stay in the ICU (r=0.35; p<0.01, Fig. 3). As the LUS scores of the cases increase, their length of stay in the ICU also prolongs. Similarly, Tierney et al.[17] performed lung ultrasonography in 250 patients with acute respiratory distress in advanced ICUs and found that LUS showed a statistically significant positive correlation with mechanical ventilation time, duration of stay in ICU and mortality. Vitale et al.[7] also evaluated 20 pediatric patients with congenital heart disease by lung ultrasonography on post-CPB 0, 1, and 2 days in the postoperative ICU. As a result of the study, they found a statistically significant positive correlation between the post-operative 1st day lung US and the duration of stay in the mechanical ventilation and ICU. In our study, the mean length of stay in the ICU was 2.2±0.4 days. Respiratory problems, together with cardiac problems, are one of the main reasons that prolong the postoperative stay in ICUs.[4,18] In our study, no correlation was found between the duration of stay in the mechanical ventilation and the lung US. We think that this lack of correlation may be due to reasons of IE in patients after cardiac surgery.

In our study, any correlation was not found between lung US and PVI. The pleth variability index is a dynamic parameter to predict fluid responsiveness and changes in line with preload and also strongly correlated with pulse pressure. Since it is not operator-dependent, it is superior to echocardiography and ultrasonography (stroke volume, right ventricular end-diastolic volume, diameters of inferior, and superior vena cava, etc.). However, PVI was closely related to the perfusion index. It has a limited use in the evaluation of fluid response in cases with low perfusion index. Thus, to frequently observed changes in arterial compliance, including the use of vasopressors, vasodilators, cardiac dysfunction, and arrhythmias in cardiac surgery cases, PVI may be useful combined with other follow-up parameters in cardiac surgery cases.[19] We used PVI with other parameters, SVI, lactate, and urine output for GDFT implementation.

In our study, $PaO_2/FiO_2$ ratios did not show any difference between groups (Table 2). There was no correlation between post-operative lung US and $PaO_2/FiO_2$ values. On the other hand, Ciumanghel et al.[12] found a statistically significant negative correlation between LUS scores and $PaO_2/FiO_2$ in patients with acute renal failure monitored in the ICU. The cutoff value of 17 for the B-lines score, which guided in this study, was found for detecting a decrease in $PaO_2/FiO_2$ ratio under 300 in this study. Similarly Bilotta et al.[20] showed a decrease in $PaO_2/FiO_2$ ratio with the increase in the number of B-lines in the LUS in 45 patients treated in the neurology ICU. Zhao et al.[13] and Tierney et al.[17] found a positive correlation between lung US findings and lower $PaO_2/FiO_2$ ratios in patients with acute respiratory distress followed up in ICUs, as well. In our study, $PaO_2/FiO_2$ ratios in the group with IE were significantly lower than those control group, but significance was not showed between groups after surgery in early period (Table 2). In addition, the perioperative lactate, as an indicator of tissue dysoxia, in Group IE was also statistically significantly higher than those control group (Table 2). Despite the presence of IE, the lack of correlation with low $PaO_2/FiO_2$ may be attributed to the earlier occurrence of B-lines than deterioration of gas exchange[21] or to the low number of ours.

The assessment of the interstitial compartment by PiCCO or LiDCO is invasive, time-consuming and non-practical methods. Ultrasound is gaining popularity in ICUs and emergency rooms thanks to its bedside application and non-invasive nature. Moreover, earlier emergence of B-lines in lung ultrasonography than gas exchange deteriorations allows rapidly prevention, diagnosis, and treatment of IE.[21]

## Limitation

Our study has a few limitations. We described the IE in terms of LUS scores at the different time intervals and observed the course over time of LUS scores from baseline to post-operative 2$^{th}$ day in this pilot study. We saw that a patient in Group C can switch on Group IE on the next day, or *vice versa* (Table 2). This finding, in which we could not foresee, may be the reason why we could not find a difference between the two groups in terms of hemodynamic and intravascular volume status parameters. We plan to explore the cause of pulmonary edema after CPB with considering this condition in our following studies. Second, due to limited number of patients enrolled into the study, our correlation coefficients need to be confirmed by larger studies for evaluation of IE with lung US scores.

The values of CVP, post-operative serum lactate levels, and the length of stay in ICU are found higher in patients with pulmonary IE. The presence of diabetes and renal failure, type of surgery, ejection fraction, duration of cross-clamp, and CPB did not associated with pulmonary edema. The patients with IE had more negative fluid balance in CPB.

Evaluation of pulmonary IE postoperatively by LUS method after open heart surgery is valuable in terms of being able to be applied at the bedside, being non-invasive, and providing information about fluid balance.

### Disclosures

**Ethics Committee Approval:** The study was approved by The Manisa Celal Bayar University Faculty of Medicine Health Sciences Ethics Committee (Date: 20/12/2017, No: 20.478.486).

**Informed Consent:** Written informed consent was obtained from all patients.

**Peer-review:** Externally peer-reviewed.

**Conflict of Interest:** None declared.

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