

# Assessing the Predictive Role of Lung Ultrasound for Intensive Care Unit Length of Stay Following Adult Cardiac Surgery: A Prospective Observational Investigation

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## ABSTRACT

**Background:** In the realm of pediatric cardiac surgery, the lung ultrasound score has proven to be a valuable predictor of extended intensive care unit (ICU) stays. This study endeavors to extend this knowledge to the realm of adult cardiac surgeries by examining the lung ultrasound score's role in forecasting the duration of postoperative ICU stays in adult patients.

**Methods:** Data were gathered from 191 adult patients who were admitted to the ICU following elective cardiac surgery. Lung ultrasound examinations were conducted 12 hours after ICU admission, wherein six distinct lung areas on each side were assessed and scored. The primary objective was to establish the relationship between the total lung ultrasound (LUS) score and the length of ICU stay in days.

**Results:** A robust correlation was discovered between the total LUS score and prolonged ICU stays (lasting more than 3 days). Patients with shorter ICU stays exhibited a median LUS score of 3 and an interquartile range (IQR) of 3, while patients with prolonged ICU stays had a median LUS score of 6.5 and an IQR of 8, with a p-value less than 0.001. Furthermore, the total LUS score retained significance when analyzed as a continuous variable alongside other predictors in a multivariate logistic regression model, showing an adjusted odds ratio of 1.66 and a p-value of <0.001.

**Conclusion:** The postoperative total lung ultrasound score following cardiac surgery proves to be a valuable tool in predicting prolonged intensive care and hospital stays. This study demonstrates a robust correlation

between the LUS score and the duration of ICU stays, emphasizing its potential as a reliable prognostic indicator for postoperative outcomes in cardiac surgery patients.

**Keywords:** Lung ultrasound score; Intensive care unit (ICU); Cardiac surgery; Hospital stay.

## INTRODUCTION

The duration of critical care stay following adult cardiac surgeries has long been a topic of debate in the medical community. Numerous factors have been explored as potential predictors of outcomes in open-heart surgery, including established metrics such as The Society of Thoracic Surgeons (STS) risk score and the EuroSCORE II, alongside considerations of preoperative clinical condition, associated chronic diseases, surgery type, age, duration of cardiopulmonary bypass, Brain Natriuretic Peptide (BNP), and cystatin-C [1,2].

In recent years, there has been a growing interest in the application of lung ultrasound in critical care management, owing to its ease of use, bedside applicability, cost-effectiveness, noninvasiveness, and lack of radiation exposure. This interest has extended to cardiac surgery, encompassing both adult and pediatric cases [3].

A Lung Ultrasound Scan (LUS) can effectively diagnose conditions such as pneumothorax, pulmonary edema, pleural effusions, and consolidation [4]. Furthermore, it enhances the clinical evaluation of shock and cardiorespiratory failure, with the lung component becoming integral to the overall patient assessment [3]. LUS has been correlated with the severity of Acute Respiratory Distress Syndrome (ARDS) and has been predictive of mortality [5]. It offers reliable dynamic monitoring of regional lung aeration changes, especially in scenarios like prone positioning, Positive End-Expiratory Pressure (PEEP) application, and fluid loading [6]. Notably, a lung ultrasound score exceeding 13, measured after a successful spontaneous breathing trial during mechanical ventilation weaning, serves as a predictive marker for extubation failure [7].

While a recent study has introduced a novel postoperative lung ultrasound score focusing on B lines (indicative of subpleural interstitial edema in various lung regions) to predict critical care duration after pediatric cardiac surgeries [2], the application of such a scoring system in adult cardiac surgeries has been notably absent in the literature.

In light of the high risk of postoperative pulmonary complications associated with adult cardiac surgeries, we formulated a hypothesis: that the lung ultrasound score could serve as a reliable predictor of postoperative ICU stay duration in this patient population. Consequently, the present study aims to assess the role of the lung ultrasound score in forecasting the length of postoperative ICU stays following adult cardiac surgeries [8].

## MATERIALS AND METHODS

### Study Design and Participants

This prospective observational study was conducted at Fayoum University Hospital between August 2020 and March 2022, adhering to the Declaration of Helsinki principles [9]. Ethical approval was obtained from the Fayoum University Hospital Ethical Review Board (D 230), and participants provided informed consent. The study, registered on ClinicalTrials.gov (NCT04499027), followed CONSORT guidelines.

A total of 191 adult patients (aged above 18 years) undergoing elective cardiac surgery (valve replacement or adult congenital procedures via median sternotomy) were included. Exclusion criteria comprised inadequate acoustic windows, emergency surgeries, thoracic deformities, or preexisting pulmonary conditions [10].

### Anesthetic Technique

Patients underwent standard preoperative evaluations. Anesthesia was induced using midazolam, fentanyl, propofol, and atracurium. Patients were intubated, mechanically ventilated, and monitored. Cardiopulmonary bypass (CPB) was established, and anesthesia was maintained with isoflurane, atracurium infusion, and propofol during CPB [11,12]. After CPB cessation and sternal closure, patients were transferred to the intensive care unit (ICU) while intubated and monitored.

### ICU Management

Extubation criteria included patient alertness, hemodynamic stability, absence of active bleeding, warm extremities, minimal inotropic support, and satisfactory arterial blood gas parameters. ICU discharge depended on several factors, including oxygen saturation, cardiac stability, absence of major bleeding, and stable vital signs.

### Lung Ultrasound Scan (LUS)

At 12 hours postoperatively, all patients underwent LUS examinations using a convex ultrasound probe. A radiologist assessed six lung areas, scoring each based on B-lines (0 to 3) indicative of lung aeration status. The total LUS score was calculated by summing individual quadrant scores [13].

### Measured Parameters and Statistical Analysis

The Primary outcome was the correlation between postoperative LUS score and ICU stay duration (considered prolonged if >3 days). Secondary outcomes included baseline characteristics, Euro SCORE II, individual lung area scores, extubation time, hospital length of stay (>7 days indicating prolonged stay), and in-hospital mortality. Descriptive statistics and appropriate tests (t-tests, Mann-Whitney tests, Chi-Square tests) were used for comparisons. Multiple logistic regressions were employed, and nomograms were created for predictive models. ROC curves were generated and compared using appropriate software.

Statistical significance was set at  $p < 0.05$ . IBM SPSS 28, Stata version 16, and MedCalc version 20 were used for analysis and visualization.

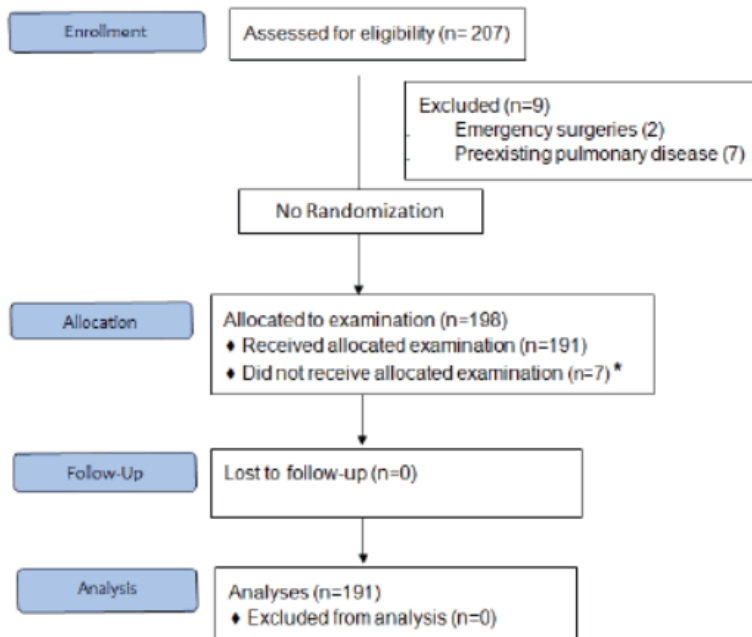
## RESULTS

Initially, 207 patients were evaluated for eligibility according to the study's criteria. Nine patients were excluded, with two undergoing emergency surgeries and seven having preexisting pulmonary diseases. The remaining 198 patients were scheduled for examination. However, out of these, 191 patients successfully underwent the planned ultrasound examination. Unfortunately, seven patients were unable to receive the examination: one patient passed away during surgery, two succumbed early in the intensive care unit before the ultrasound assessment, and four had inadequate acoustic windows (see Figure 1).

Summarizes the characteristics of the study participants. Of the patients, 48.7% experienced short stays in the intensive care unit (ICU) lasting three days or less, while 51.3% had extended ICU stays lasting more than three days. Similarly, 48.2% of patients had brief hospitalizations lasting seven days or less, whereas 51.8% had prolonged hospital stays exceeding seven days. Concerning extubation time, 36.1% underwent early extubation within six hours, while 63.9% experienced late extubation, occurring after six hours. The mean total Lung Ultrasound Score (LUS) for patients included in the study was  $5.45 \pm 4.9$ .

Two models were developed to investigate the association between extended Intensive Care Unit (ICU) stay and other factors. In the first model, the total Lung Ultrasound Score (LUS) was treated as a continuous variable. The variables included in this model, apart from LUS, were associated with higher odds of prolonged ICU stays, yielding a Pseudo R<sup>2</sup> value of 0.58. In the second model, the total LUS score was transformed into a binary variable (LUS > 4, LUS < 4), and the same variables from the first model were included. Interestingly,

the performance of these two models, as measured by the area under the curve, did not significantly differ (p-value = 0.609), indicating their comparable accuracy in predicting extended ICU stays.



**Figure 1:** Consort flow diagram of the study population.

For hospital length of stay (LOS), multiple logistic regressions were used. Initially, variables showing significance in univariate analysis were included in the model. The first model used the total LUS score as a continuous variable along with age, Euro SCORE II, ICU lactate (12 h), and the occurrence of complications. The second model utilized the total LUS score as a binary variable (LUS > 4, LUS < 4) in combination with age, Euro SCORE II, ICU lactate (12 h), and complications. Similar to the ICU stay models, there was no statistically significant difference in the performance of these two models, as evidenced by the p-value > 0.999. Both models exhibited an area under the curve of 0.932 (95% CI: 0.866, 0.963), signifying their equivalent predictive accuracy for prolonged hospital stays.

## DISCUSSION

In our study, we observed a robust correlation between the Lung Ultrasound Score (LUS) total score and the duration of intensive care stay. Notably, the total LUS score remained significant when analyzed as a continuous variable alongside other predictors in the multivariate logistic regression model. Higher LUS scores were associated with prolonged intensive care stay and increased mortality among our patients.

Our findings regarding LUS examination align with Cantiontti et al.'s results in pediatric cardiac surgery, where the LUS score demonstrated predictive value when incorporated into conventional risk models. Furthermore, both studies noted an association between LUS and extubation time [2].

Previous studies by Stein et al. and Haase-Fielitz et al. have linked fluid overload to prolonged intensive care stays and higher mortality rates. Our study indirectly assessed fluid overload through the total LUS score, which relies on lung B-lines, reinforcing the connection between fluid status and outcomes [11,12].

Our study also found a significant correlation between LUS scores and prolonged critical care stays for individual lung quadrants. While Cantiontti [2] emphasized the importance of anterior lung quadrants, our findings revealed correlations across all quadrants. Discrepancies could stem from age group differences and

the timing of ultrasound examinations, emphasizing the need for standardized protocols in future studies.

In our analysis, advanced age, higher Euro SCORE II, elevated ICU lactate levels at 12 hours, prolonged Cardiopulmonary Bypass time (CPB time), multiple inotropic support, delayed extubation time, and major intensive care complications were significantly associated with extended ICU stays. EuroSCORE II emerged as a strong predictor, consistent with studies by Ranjan et al., Wang et al., and Meadows et al. Furthermore, increased age and higher inotropic support were noted in previous research, emphasizing their impact on ICU stay duration [13].

The correlation between lactate levels and ICU stay duration resonates with studies by Haanschoten et al. and Radovic et al. Elevated blood lactate after cardiac surgery has been linked to adverse outcomes, including acute kidney injury and mortality. However, the timing of lactate measurement may influence its predictive value, as demonstrated by our findings and those of Evans et al. [11-15].

Increased CPB time was another significant predictor in our study, aligning with research by Salis et al. and Nissinen et al. Meadows et al.'s findings on Euro SCORE's predictability emphasize the importance of considering intraoperative and early postoperative variables, as we did in our model.

While other models, such as those proposed by Rotar et al. and De Cocker et al., provide valuable insights, the discrepancies in findings underscore the complexity of predicting ICU stay after cardiac surgery. Factors like sample size, patient selection, and variable inclusion contribute to these variations. In our study, specific limitations, including the exclusion of certain chest diseases and limited types of surgeries, may have influenced our results. Future studies should encompass diverse patient populations and surgery types to enhance the generalizability of findings. Additionally, analyzing mechanical ventilation-related factors could provide further insights into the interplay between ventilation strategies and LUS scores.

## CONCLUSION

Our study highlights the significant correlation between the Lung Ultrasound Score and the duration of intensive care stays after adult cardiac surgeries. Utilizing LUS scores as a predictive tool offers valuable insights into patient outcomes. Further research incorporating diverse patient cohorts and exploring the impact of mechanical ventilation parameters could enhance the predictive accuracy of LUS in the context of cardiac surgery recovery.

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