

ORIGINAL RESEARCH

CARDIOTHORACIC ANESTHESIA

Lung ultrasound compared with CT chest in diagnosing postoperative pulmonary complications following cardiothoracic surgery

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ABSTRACT

Objective: This study aimed to compare the detection of postoperative pulmonary complications using lung ultrasound (LUS) versus computed tomography (CT) and assessed the association of risk factors with these complications.

Methodology: This prospective comparative study was conducted in the Critical Care Department at Kasr Alainy Hospital, Cairo University. It included 89 patients over 18 years old who underwent cardiac surgeries and were suspected of developing postoperative pulmonary complications (PPCs).

Results: The most frequent final diagnoses on both CT and LUS were unilateral pleural effusion and pneumothorax (20.2% each). LUS detected bilateral pleural effusions more often than CT (7.8% vs. 6.7%), while CT identified unilateral consolidation with subsegmental collapse more frequently than LUS (4.5% vs. 3.4%). Overall, LUS and CT showed 93.3% matching and 6.7% mismatching in detecting PPCs post-cardiothoracic surgery, indicating good compatibility.

Conclusion: LUS is a fast, radiation-free imaging method for real-time evaluation of PPCs after cardiothoracic surgery, making it a valuable tool for postoperative monitoring.

Keywords: Cardiothoracic Surgery; CT Chest; Ultrasound; Postoperative Pulmonary Complications

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1. INTRODUCTION

Pulmonary complications are common after cardiac surgery, including pneumonia, pulmonary embolism,

prolonged ventilation (>24h), and pleural effusions requiring drainage, which are reportable to the Society of Thoracic Surgeons^[1].

Given the close interdependence between the heart and lungs, meticulous pulmonary support and monitoring are essential post-cardiac surgery. Cardiothoracic intensivists must remain vigilant to address the unique pulmonary challenges encountered in these patients.²

Bedside lung ultrasound, a highly sensitive and specific imaging modality, is increasingly used in the ICU for diagnosing pulmonary pathology without radiation exposure.³ It generates distinctive artefacts through interactions between fluid, air, and pleurae, helping differentiate various pathological processes.⁴

This study aimed to compare the detection of postoperative pulmonary complications using lung ultrasound (LUS) versus computed tomography (CT) and assessed the association of risk factors with these complications.

2. METHODOLOGY

This observational, comparative study at Cairo University's Critical Care Department evaluated lung ultrasound for detecting post-cardiac surgery pulmonary complications, comparing it to CT as the gold standard while avoiding transport risks. This study included 89 patients who underwent various cardiac surgeries between October 2021 and July 2023 upon ICU admission at Kasr Alaliny Hospital's Cardiothoracic Department. Approved by Cairo University's Faculty of Medicine Ethics Committee (MD-419-2021), written informed consent was obtained.

We included adult patients (≥ 18 years) who underwent cardiothoracic surgery with suspected postoperative pulmonary complications. Exclusion criteria: preoperative lung pathology or age < 18 .

All ICU patients were intubated, sedated post-surgery, and extubated per protocol. Monitoring included vitals, ECG, invasive blood pressure, lab tests (CBC, coagulation, kidney, liver), and infection markers (PCT, CRP, cultures) per standard practice.

2.1. Lung Ultrasonography

Lung ultrasound (LUS) was routinely performed by a trained research team member ($n = 3$), including one investigator and an ICU fellow. It was conducted at admission (POD 0) and daily on PODs 1–3, though limited researcher availability prevented consistent daily scans.

A CX50 ultrasound machine (Koninklijke Philips NV) was used with both a cardiac phased array (1–5 MHz) and a linear vascular probe (> 10 MHz), selected based on preference. Lung sliding was assessed using the vascular probe, and LUS views followed the BLUE

protocol. The BLUE profile for each point and hemithorax (BLUE 1 and 2) was classified as A, B, A', B', or C. (Figure 1).

In lung ultrasound (LUS), key assessment points include the anterior (upper BLUE) and anteromedial (lower BLUE) regions, along with the posterior PLAPS point. The A profile is characterized by multiple A lines, indicating normal lung aeration, whereas the B profile shows more than two diffuse B lines, suggestive of interstitial syndrome. Variants A and B represent the respective A or B profiles with absent or abolished lung sliding. The C profile indicates anterior alveolar consolidation, and the PLAPS point is evaluated for posterolateral alveolar or pleural involvement, including consolidation or pleural effusion.

A hypoechoic subpleural focal image may indicate consolidated lung tissue. Atelectasis was diagnosed based on LUS findings, and differentiation from pneumonia included clinical markers like fever, leukocyte count, and CRP. Final conclusions followed the bedside LUS protocol in cardiothoracic patients.

2.2. Lung CT

CT chest scans were performed on all ICU patients a few days post-admission, using a Siemens 16-slice CT, once their condition allowed transfer per local protocol. A blinded radiologist assessed the images, retrieved from the electronic patient data system. Axial, coronal, sagittal, and 3D reformatted images were obtained with 3–5 mm slices (routine) and 1.25 mm slices (detailed exams). Scanning parameters included 140 kV, 100 mAs, and 0.5 sec per rotation.

Patients lay supine, holding their breath to prevent motion artifacts. The scanner's gantry housed rotating x-ray components, while a separate workstation processed images. The CT scan itself took under 30 seconds, but the full process lasted ~30 minutes. A radiologist analyzed the images and provided an official report.

2.3. Statistical Analysis

Data were collected, coded, revised, and entered into RStudio v2.3.2. Qualitative data were presented as numbers and percentages, while quantitative data were summarized using means, standard deviations, and ranges for parametric distributions, and medians with IQR for non-parametric distributions. Normality was tested using the Shapiro test.

3. RESULTS

The results included descriptive, comparative, and analytical data. Demographic analysis revealed mean age of 56.9 ± 8.1 years, with 74.2% males. Mean BMI

Table 1: Comparison between complicated and non-complicated patients regarding demographic characteristics, comorbidities and lung ultrasound BLUE profiles				
Variable		Complicated group (n = 60)	Non-Complicated group (n = 29)	P-value
Age (years)		57.4 ± 8.7	55.9 ± 6.9	0.337
Gender	Female	16 (26.7)	7 (24.1)	0.09
	Male	44 (73.3)	22 (75.9)	
BMI (kg/m ²)		29.3 ± 2.7	25.7 ± 2.1	< 0.001*
Electivity	Elective	9 (15.0)	27 (93.1)	< 0.001*
	Urgent	51 (85.0)	2 (6.9)	
Hypertension		27 (45.0)	15 (51.7)	0.712
Diabetes Mellitus (DM)		19 (31.7)	12 (41.4)	0.507
Obesity		33 (55.0)	13 (44.8)	0.5
Dyslipidemia		32 (53.3)	4 (13.8)	0.001*
Smoker		24 (40.0)	12 (41.4)	0.99
Lung Ultrasound BLUE Profiles				
Normal profile with batwing/seashore sign		20 (33.3)	13 (44.8)	
A profile with PLAPS, A/B profile & C profile		5 (8.3)	1 (3.4)	
A profile with shred sign		2 (3.3)	1 (3.4)	
A profile with sinusoid sign		18 (30.0)	7 (24.1)	
A profile with lung pointing		12 (20.0)	4 (13.8)	
A profile with stratosphere sign		1 (1.7)	1 (3.4)	
A/B profile		1 (1.7)	1 (3.4)	
C profile		1 (1.7)	1 (3.4)	

Bold/asterisk () highlights statistically significant differences (P < 0.05), Data given as mean ± SD or n (%)*

Table 2: Comparative analysis of postoperative complications with predictors (laboratory, clinical, and univariate regression)					
Parameter	Complicated (n = 60)	Non-complicated (n = 29)	P-value	Univariate odds ratio (95% CI)	P-value (Regression)
Ejection Fraction	53.1 ± 5.3	52.8 ± 5.2	0.868	–	–
CRP	60.3 ± 56.0	5.2 ± 1.0	< 0.001*	0.27 (0.05–0.55)	0.028*
PCT (µg/L)	5.9 ± 6.0	0.0 ± 0.0	< 0.001*	0.00 (NA–0.00)	0.233
APACHI Score	10.6 ± 5.4	5.4 ± 1.6	< 0.001*	0.57 (0.42–0.72)	< 0.001*
BMI	–	–	–	0.54 (0.39–0.69)	< 0.001*
Electivity	–	–	–	Ref. / 0.01 (0.00–0.05)	< 0.001*
Dyslipidemia	No/Yes	–	–	Ref. / 0.14 (0.04–0.41)	0.001*
Bypass time	–	–	–	0.89 (0.81–0.95)	0.004*

Comparison: Left columns show lab/clinical differences between groups, Regression: Right columns display univariate predictors of complications. Missing values (–) indicate parameters not compared directly but analyzed via regression.

was $28.1 \pm 3 \text{ kg/m}^2$, and 59.6% of cases were urgent. Patients were stratified into complicated (n = 60) and non-complicated (n = 29) groups. Comorbidities included HTN, DM, obesity, dyslipidemia, and smoking. HTN prevalence was similar between groups (45.0% vs. 51.7%, P = 0.712) (Table 1).

Lung ultrasound BLUE profiles revealed that in complicated patients, 20 (33.3%) had a normal profile with batwing/seashore sign, 5 (8.3%) had an A profile with PLAPS, A/B profile and C profile, 2 (3.3%) had an A profile with shred sign, 18 (30.0%) had an A profile with sinusoid sign, 12 (20.0%) had an A profile with lung pointing, 1 (1.7%) had an A profile with stratosphere sign, 1 (1.7%) had an A/B profile, and 1 (1.7%) had a C profile. In non-complicated patients, 13 (44.8%) had a normal profile with batwing/seashore sign, 1 (3.4%) had an A profile with PLAPS, A/B profile and C profile, 1

Table 4: Comparative postoperative pulmonary findings on CT and LUS

Complications	Lung CT	Lung Ultrasound	Notes
Pleural Effusion	36 (40.4)	34 (38.2)	Close agreement (~2.2% difference)
Pleural Thickening	13 (14.2)	11 (12.4)	Similar detection rates
Pneumothorax	18 (20.2)	18 (20.2)	Identical diagnosis
Lung Collapse	10 (11.2)	11 (12.4)	Minor difference (~1.2%)
Consolidation	14 (15.7)	11 (12.4)	Slightly higher on CT (~3.3%)
Interstitial Coarsening	4 (4.5)	-	Only detected by CT
Atelectasis	48 (53.9)	-	Only reported on CT

Data presented as n (%)

(3.4%) had an A profile with shred sign, 7 (24.1%) had an A profile with sinusoid sign, 4 (13.8%) had an A profile with lung pointing, 1 (3.4%) had an A profile with stratosphere sign, 1 (3.4%) had an A/B profile, and 1 (3.4%) had a C profile (Table 1).

Echocardiographic findings among 89 patients revealed that 6.7% had normal ejection fraction (EF), while 93.3% showed abnormal EF with varying degrees, including 62.9% with regional wall motion abnormalities (RWMA). Aortic conditions included aneurysm 3.4%, and dissection 4.5%, while valvular pathologies involved aortic regurgitation 41.6%, aortic stenosis 2.2%, mitral regurgitation 7.9%, and mitral stenosis 2.2%, with no significant EF difference between groups (53.1 ± 5.3 vs. 52.8 ± 5.2 , P = 0.83). Univariable analysis identified urgent surgery (OR: 0.01, P < 0.001), dyslipidemia (OR: 0.14, P = 0.001), CRP (OR: 0.27, P = 0.028), longer bypass time (OR: 0.89, P = 0.004), and higher APACHE scores (OR: 0.57, P < 0.001) as

Table 3: Hospital stay duration and clinical outcomes among studied cases (n = 89)

Variable	Value
Length of ICU stay (days)	5.2 ± 3.6
Mechanical Ventilation >24 hrs	20 (22.5)
Lung CT Result Positive	60 (67.4)
Lung Ultrasound Result Positive	54 (60.7)

Data presented as mean \pm SD or n (%)

risk factors for complications, whereas higher BMI was protective (OR: 0.54, P < 0.001) (Table 2).

Items of outcomes included APACHE II score, length of ICU stay, need of mechanical ventilator beyond 24 hours, lung CT results and lung U/S results. The

APACHE score ranged between (3.0 - 35.0), with a mean \pm SD (8.9 ± 5.1).

The length of hospital stay ranged from (1.0 to 2.0 days), with a mean of 5.2 ± 3.6 days and a median of 2

days. Regarding imaging findings, CT chest detected lung complications in 60 patients (67.4%), while 29 patients (32.6%) had no complications. Lung ultrasound (US) identified complications in 54 patients (60.7%), with 35 patients (39.3%) showing no complications (Table 4).

Table 5: Comparative accuracy and matching of LUS to CT for pulmonary complication detection

Parameter	Value	95% CI
Agreement		
Match	83 (93.3%)	-
Mismatch	6 (6.7%)	-
Performance		
Sensitivity	90%	0.79 - 0.96
Specificity	100%	0.88 - 1.00
PPV	100%	0.93 - 1.00
NPV	83%	0.66 - 0.93
Accuracy	93%	-
p-value	< 0.001*	-

Table 6: Comparative final findings in CT and LUS among all studied cases

	CT Positive (n = 60)	CT Negative (n = 29)	Total (n = 89)
US Positive	54 (60.7%)	0 (0%)	54
US Negative	6 (6.7%)	29 (32.6%)	35
Total	60	29	89

Among the 89 patients, pleural effusion was present in 36 (40.4%) and 34 (38.2%) cases across assessments, while pleural thickening was observed in 13 (14.2%) and 11 (12.4%) patients, respectively. Pneumothorax was consistently diagnosed in 18 patients (20.2%). Lung collapse varied slightly between 10 (11.2%) and 11 (12.4%) cases, and consolidation was reported in 14 (15.7%) and 11 (12.4%) patients. Additional findings included interstitial tissue coarsening in 4 patients (4.5%) and atelectasis in 48 (53.9%), though the latter was not mentioned in the second assessment (Table 5).

Comparing Frequency of PPC detection with lung ultrasound versus CT showed 93.3% of cases (83/89) had concordant results, while 6.7% (6/89) were discordant. A detailed analysis revealed that among the 60 patients with positive CT scans, 54 (60.7% of total cohort) had corresponding positive ultrasound findings, while 6 (6.7%) showed false-negative ultrasound results. Notably, all 29 patients with negative CT scans (32.6% of total cohort) consistently demonstrated negative ultrasound findings, with no false-positive cases observed (Table 5 and 6).

4. DISCUSSION

The patients' ages in this study ranged from 27 to 72 years, with a mean of 56.9 ± 8.1 years. This aligns with Jakobson et al. (2022), who reported a mean age of 55.29 ± 18.05 years (range: 18–87) while evaluating LUS as an alternative to CXR in postoperative thoracic surgery care.⁵

Other studies comparing LUS and CXR for PPC detection showed variations in patient age. Elabdein et al. reported a lower mean age (40.14 ± 15.49 years), while Touw et al. found a higher mean (68 ± 10 years).^{6,7}

Males were more prevalent than females in this study (74.2% vs. 25.8%), consistent with findings from Jakobson et al. and Touw et al.^{5,7}

Men typically breathe with their diaphragm, while women rely more on thoracic breathing, which may explain the higher incidence of PPCs in men after cardiothoracic surgery due to restricted diaphragm movement.⁸

However, Sadeghi et al. identified female gender as a risk factor for PPCs post-cardiac surgery ($P = 0.0235$), attributing this to differences in surgical procedures, with men more frequently undergoing CABG and women undergoing valvular heart surgery.⁹

In this study, PPC patients had a BMI range of 23–35 kg/m², averaging 28.3 kg/m², indicating overweight predominance. This aligns with Touw et al, who reported a mean BMI of 27.5 ± 4.9 kg/m² in suspected PPC cases after cardiothoracic surgery.⁷

Similarly, Malík et al. found a mean BMI of 27.9 ± 5.4 kg/m² among 297 thoracic surgery patients with suspected PPCs.¹⁰ In contrast, Fan et al. reported a mean BMI of 24.5 ± 4.6 kg/m² in PPC cases post-cardiac surgery, finding no significant BMI-PPC association ($P = 0.841$).¹¹

Patients undergoing cardiac surgery often have multiple cardiovascular risk factors, including hypertension, diabetes, obesity, and dyslipidemia.⁶

Preoperative diabetes independently contributes to postoperative hyperglycemia, which worsens outcomes by increasing mechanical ventilation duration and multiorgan failure risk.¹² Karimi et al. found that preoperative diastolic hypertension raised postoperative mortality risk, while systolic hypertension had no significant effect.¹³ However, Sanders et al. argued that evidence is insufficient to link lower preoperative blood pressure with reduced perioperative complications.¹⁴

The EuroSCORE II model does not consider BMI a perioperative mortality risk, as obesity's impact on cardiac surgery remains debated.¹⁵ Some studies highlight an "obesity paradox," showing similar or lower morbidity and mortality rates in obese patients,¹⁶ Conversely, other research associates obesity with worse outcomes, such as prolonged ventilation and hospital stays after CABG.¹⁷

Obese patients have a higher risk of morbidity and mortality after coronary artery bypass grafting (CABG).¹⁸

Elevated LDL-C and non-HDL-C cholesterol levels are linked to increased postoperative risks, while rapid LDL-C reduction improves survival after acute coronary syndrome and CABG.¹⁹

In this study, chronic diseases such as hypertension (47.2%), DM (34.8%), obesity (51.7%), and dyslipidemia (37.1%) were prevalent, aligning with previous findings.²⁰ A review of 2,477 cardiac surgeries (2011–2014) identified obesity, hypertension, and DM as the most

common chronic diseases, followed by peripheral arterial and lung diseases.²¹

Smoking has been linked to postoperative pulmonary complications (PPCs), while non-smoking has also been associated with PPC risk.^{9,22} Univariable analysis showed significant PPC risk factors, including urgent cases ($P < 0.001$), dyslipidemia ($P = 0.001$), CRP levels ($P = 0.028$), bypass time ($P = 0.004$), and APACHE score ($P < 0.001$). Higher BMI was protective ($P < 0.001$). Crawford et al. also noted age, estimated GFR, and comorbidities like lung disease and previous MI as PPC predictors.²¹ The most common surgeries performed were CABG (52.8%), valve surgery (29.2%), and combined procedures (10.1%).²¹ Tolsma et al. analyzed CXR indicators within 24 hours post-cardiac surgery, identifying CABG (59%), CABG with valve surgery (16%), and valve surgery (13%) as the most common procedures.²³

In our study, the mean bypass time was 78.3 ± 17.1 minutes, notably shorter than the 138 ± 61 minutes reported by Alsaddique et al. who examined post-cardiac surgery monitoring with LUS and ECHO.²⁴

The BLUE protocol enables rapid (<3 minutes) bedside identification of acute respiratory failure based on pathophysiology.²⁵ It differentiates conditions like pulmonary edema, embolism, pneumonia, asthma, COPD, and pneumothorax using specific LUS profiles.²⁶

Key LUS signs include the bat sign, lung sliding (seashore sign), A-line, quad sign, sinusoid sign (pleural effusion), fractal and tissue-like signs (consolidation), B-line and lung rockets (interstitial syndrome), and lung point (pneumothorax). Pneumonia and atelectasis are distinguished using the dynamic air bronchogram and lung pulse.²⁶

CT, the gold standard, demonstrated LUS sensitivity and specificity between 90%-100%, suggesting LUS as a viable bedside diagnostic tool for critically ill patients.²⁷

In our study, the most common US findings were a normal profile with the batwing/seashore sign (37.1%), followed by the A profile with the sinusoid sign (28.1%, pleural effusion) and the A profile with lung pointing (18.0%, pneumothorax). Less frequent findings suggesting consolidation included A profile with PLAPS, A/B profile, and C profile (6.7%), A profile with shred sign (3.3%), A profile with stratosphere sign (2.2%), A/B profile alone (2.2%), and C profile alone (2.2%).

The most common PPCs diagnosed by both CT and LUS were pleural effusion and pneumothorax, aligning with previous findings. Similarly, a study on 221 post-cardiac

surgery patients identified atelectasis and pleural effusion as the most frequent PPCs.²⁸

LUS demonstrated a sensitivity of 90%, specificity of 100%, accuracy of 93%, PPV of 100%, and NPP of 83% in detecting PPCs compared to CT. These results highlight LUS's high diagnostic accuracy post-cardiothoracic surgery. While many studies have shown LUS superiority over CXR in detecting PPCs, few have compared LUS directly to CT.²⁹⁻³¹

Our findings support prior research showing bedside LUS as an effective alternative to CXR and CT in critically ill patients, reducing unnecessary imaging.³² LUS offers rapid, non-invasive, and repeatable bedside assessment, aiding in both diagnosis and monitoring of PPCs. Repeated LUS imaging has been shown to influence PPC diagnosis and treatment.²⁴

The study's strength lies in comparing LUS to CT for thoracic pathologies.

5. LIMITATIONS

include a small sample size and lack of follow-up for monitoring treatment effectiveness. While pain was not assessed, LUS likely causes less discomfort than repositioning for a CT scan. Additionally, the study did not report mortality rates, as this was beyond its scope.⁸¹

6. CONCLUSION

Data indicates that pleural effusion and pneumothorax are the most common PPCs in ICU patients after cardiothoracic surgery. LUS BLUE profiles demonstrate high diagnostic accuracy in detecting PPCs in postoperative ICU patients, with sensitivity 90%, specificity 100%, PPV 100%, NPV 83%, and accuracy 93%. As a fast, radiation-free bedside tool, LUS is a reliable alternative for monitoring PPCs after cardiothoracic surgery.

7. Data availability

The numerical data generated during this research is available with the authors.

8. Conflict of interest

All authors declare that there was no conflict of interest.

9. Funding

The study utilized the hospital resources only, and no external or industry funding was involved.

10. Ethical approval

Ethical approval was obtained from the Faculty of Medicine, Cairo University (Code: MD-419-2021). The electronic survey included a statement: "Filling out this form means you agree to participate." The study followed the World Medical Association's Declaration of Helsinki, and written informed consent was obtained.

11. Authors' contribution

WOA, and MRZN. contributed to the development of the protocol, abstracted data.

WAR, and MHM. developed the original idea and the protocol, abstracted and analyzed data, wrote the manuscript, and is a guarantor.

DAA. prepared the manuscript.

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