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Chest ultrasound compared with chest X-ray in detecting postoperative pulmonary complications following cardiac surgery: a prospective observational study.

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Abstract
introduction Patients who underwent cardiacsurgery were usually subjected to daily chest X-rays. The ability to detect postoperative pulmonary complications using chest X-rays is limited, and this technique requires radiation exposure and consumes time.Unlike chest ultrasounography that became an invaluable diagnostic tool facilitating facilitating more accurate diagnosis of postoperative pulmonary complications. In addition, lung ultrasound is a bedside technique. . This study aims to analyze the agreement between chest X-ray and chest ultrasound.
ResultsThis is an observational prospectivecohort study. 109 adult patients who underwent cardiac surgery were included. 109 patients had a chest X-ray and chest ultrasound follow-up on day 0, 66 patients had chest ultrasound and 64 chest X-ray on day 2, and 41 patients had chest ultrasound ans 44 patients had chest X-ray on day 3.In the present study the use of CXR as an Index Test For detection of Atelectasis against Ultrasound: There was a minimal agreement ¤=0.224, 95% CI: 0.126-0.322, p<.001, with 4-15% of data that are reliable, For CRX detection of Pulmonary edema against LUS, there was a weak agreement (¤=0.560, 95% CI: 0.413-0.707, p<.001), with 15-35% of data that are reliable. Regrading detection of Consolidation, there was no agreement (¤=0.044, 95% CI: -0.061-0.141, p=.156), with 0.00-4.00% of data that are reliable. Pneumothorax detection had a weak agreement (¤=0.434, 95% CI: 0.026-0.841, p<.001). While CXR detection of Pleural effusion against LUS had a moderate agreement (¤=0.625, 95% CI: 0.523-0.726, p<.001).
ConclusionFollowing cardiac surgery, lung ultrasonography found PPCs more often and sooner than chest X-ray. Our findings provide support for the idea that post-cardiothoracic surgery, ultrasonography of the lungs may serve as the principal imaging tool for the detection of PPCs, improving the quality of decision-making at the bedside. We need to find out how many PPCs are in these individuals by using lung ultrasonography as our main imaging tool.

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Introduction

Thoracic ultrasonography (lung and pleural) can diagnose different chest diseases like pneumothorax, pleural effusion, pulmonary edema, pulmonary embolism, pneumonia, interstitial processes, and the assessment of patients on mechanical ventilatory support. It is easy to use, rapid and reliable. (1)

Lung ultrasound is performed by the treating physician at the time and place of the clinical assessment and can provide a rapid, noninvasive assessment of the respiratory state without exposing patient or staff to ionizing radiation and without requiring transportation of the patient.(2)

Postoperative pulmonary complications are among the most frequent problems in perioperative care. There development depends on patient's initial clinical condition, anesthetic technique, method of mechanical ventilation, and type and technique of the surgical procedure.(3)

lung ultrasound can be used to detect postoperative pulmonary complications (respiratory infection, respiratory failure, atelectasis, pulmonary oedema, consolidation, pneumothorax, and pleural effusion) at an earlier timepoint than chest X-ray following cardiothoracic surgery enhancing bedside decision making. In addition, lung ultrasound can be used to evaluate the efficacy of therapies initiated for postoperative pulmonary complications, since lung ultrasound offers an accurate and easily reproducible bedside evaluation.(4)

Real-time thoracic ultrasonography can guide thoracentesis and percutaneous needle biopsy for thoracic lesions adjacent to the chest wall make them safe and easy procedures with higher diagnostic rate and reduced complications. (5, 6)Lung ultrasonography is superior to clinical examination and chest X-ray in diagnosis of acute respiratory pathology after cardiothoracic surgery in intensive care. Also, lung ultrasound may be useful before cardiothoracic surgery and after discharge from intensive care as in perioperative care, missed pathology can result in poor outcomes and delayed recovery. (7)

Patients and methods

An observational prospective cohort study was conducted on patients who underwent cardiacsurgeries in the Cardiothoracic Surgery Department at Kafrelsheikh Hospital from November 2022, to November 2023. The study was approved by the local ethical committee of the Kafrelsheikh Faculty of Medicine. Patient were not included if there was no investigator available, the researcher was notavailable or the patient refused the examination. Patients who had all of their CXR and lung ultrasounds upon their admission to surgical ICU on day 0, day 2 and day 3 postoperatively.

All patients admitted to the SICU were either intubated and were sedated following cardiac surgery or extubated following thoracic surgery according to local protocol. Then, followed by administration of supplemental oxygen via nasal cannula. Monitoring with pulse oximetry, heart rate, electrocardiography, invasive blood pressure and CXR performed according to standard clinical practice.

Lung ultrasonography done before or immediately after chest x-ray with blindness to the clinical details and chest x-ray findings and not knowing about the diagnostic and treatment plans of patients.

Postoperative pulmonary complications were defined as previously described : respiratory infection; respiratory failure,pleural effusion; atelectasis; pneumothorax; and bronchospasm, A distinction was made between PPCs and clinically-relevant PPCs, defined as a PPC requiring treatment, as determined by the treating physician. We considered someclinically-relevant treatments for PPCs as : high flow oxygen therapy; recruitment manoeuvres; continuous positive airway pressure (CPAP); re-intubation; bronchoscopy; bronchodilators; chest tubes placement; and the use of diuretics and/or antibiotics, in addition to local antibiotic protocols for cardiothoracic surgery. Diagnosis of clinically-relevant PPCs takes into consideration physical examination, patientl monitoring, laboratory results and CXR.Clinically relevant PPCs were considered the reference standard as diagnostic accuracy of CXR alone is debated and is therefore an imperfect reference standard for lung ultrasound. The diagnostic accuracy of the reference standard was improved by using a composite reference standard, including multiple tests, one of which was CXR.

We determined the BLUE profile for each BLUE point and BLUE profile per hemithorax as follows: A; B; A'; B' or C-profile. A-profile means predominantly A-lines . B-profile means predominantly multiple (> 2) anterior diffuse B-lines. A' or B' means the corresponding BLUE profile with absence of, or abolished lung sliding. C-profile means anterior alveolar consolidation. Furthermore, we determined the postero-lateral alveolar and/or pleural syndrome (PLAPS) on each side at the lateral subposterior ultrasound examination and scored this as positive or negative.

A recent scanning protocol suggests a four zones division of each hemithorax named Volpicelli's zones. All zones on each hemithorax must be scanned to obtain a complete examination and each thoracic zone should be scanned individually

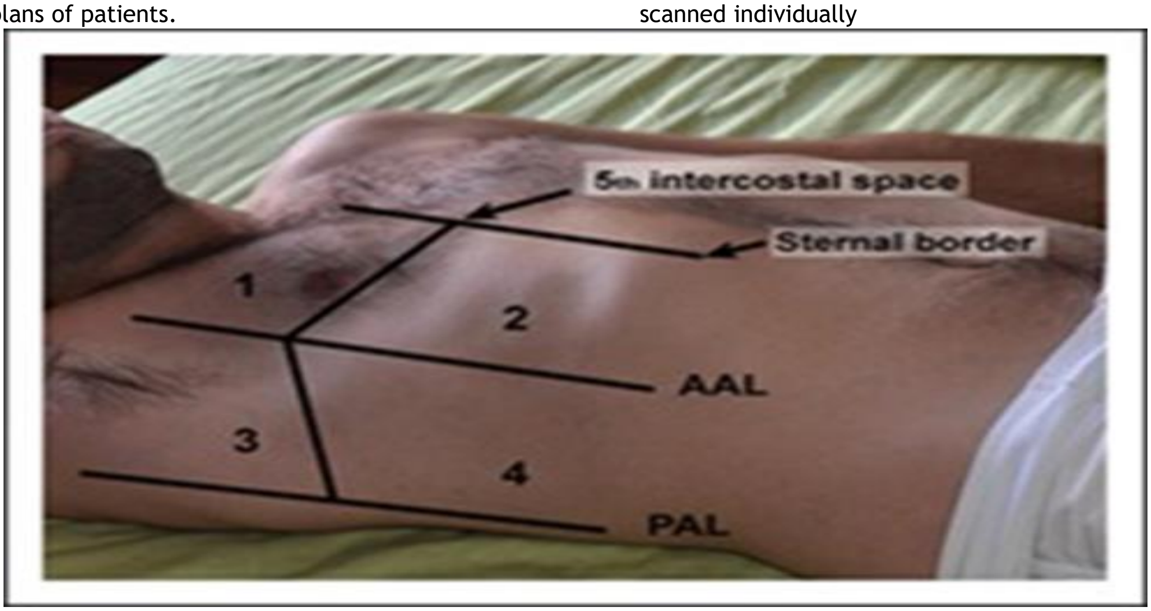

Fig. 1: The four Volpicelli's zones. AAL, anterior axillary line; PAL, posterior axillary line

RESULTS

The study included 109 who underwent cardiac surgery and met inclusion and exclusion criteria.

Demographic Data	
Age (years)	
▪ n	109
▪ Min. – Max.	19.00 – 74.00
▪ Mean ± SD	50.14 ± 12.09
▪ SEM	1.20
▪ 95% CI of the mean	47.59 – 52.36
▪ Median	51.00
▪ 95% CI of the mean	49.00 – 55.00
▪ Percentile 25th – Percentile 75th	43.00 – 59.00
Sex	
▪ Male	64 (58.72%)
▪ Female	45 (41.28%)
BMI (kg/m²)	
▪ n	109
▪ Min. – Max.	12.56 – 31.83
▪ Mean ± SD	26.21 ± 2.64
▪ SEM	0.25
▪ 95% CI of the mean	25.71 – 26.71
▪ Median	26.03
▪ 95% CI of the mean	25.66 – 26.84
▪ Percentile 25th – Percentile 75th	24.97 – 27.38
Weight status	
▪ Underweight	2 (1.83%)
▪ Normal	27 (24.77%)
▪ Overweight	72 (66.06%)
▪ Obese class I	8 (7.34%)

Table 1 The demographic and clinical data of the studied participants
n: Number of patients
Min-Max: Minimum – Maximum
SD.: Standard Deviation
SEM: Standard Error of Mean
CI: Confidence interval

Type Of Surgery	n (%)
• CABG	48 (44.04%)
• Mitral Valve Replacement	35 (32.11%)
• Aortic Valve Replacement	26 (23.85%)
• Tricuspid Valve Repair	18 (16.51%)
• Redo Mitral Valve Replacement	3 (2.75%)
• Bentall	2 (1.83%)
• ASD Closure	6 (5.50%)
• Left Atrial Myxoma Removal	3 (2.75%)
• Coarctation Of Aorta Repair	1 (0.92%)
Total	109 (100.00%)

Table 2 Type of cardiac surgery and operative

		Ultrasonography		
		Positive	**Negative**	**Total**
Chest X-ray	**Positive**	104 (49.29%) TP.	5 (2.37%) FP	109 (51.66%)
	Negative	75 (35.55%) FN.	27 (12.80%) TN	102 (48.34%)
	Total	179	32	211

		(84.83%)	(15.17%)	(100.0%)
Kappa **Standard error** **95% CI** ***p*-value**		0.224 0.050 0.126-0.322 <.001*		

Table 3 agreement betweenChest X-rayand Ultrasonography for detection of Atelectasis

The true positive was 104/211 (49.29%), the true negative was 27 (12.80%), the false negative was 75 (35.55%) and the false positive was 5 (2.37%). There was a minimal agreement (¤=0.224, 95% CI: 0.126-0.322, p<.001), with 4-15% of data that are reliable. The specific Negative agreement was 40.30%, and the specific Positive agreement was 72.22%.

		Ultrasonography		
		Positive	**Negative**	**Total**
Chest X-ray	**Positive**	22 (10.43%) TP.	4 (1.90%) FP.	26 (12.32%)
	Negative	22 (10.43%) FN	163 (77.25%) TN	185 (87.68%)
	Total	44 (20.85%)	167 (79.15%)	211 (100.0%)
Kappa **Standard error** **95% CI** ***p*-value**		0.560 0.075 0.413-0.707 <.001*		

Table 4 agreement between Chest X-ray and Ultrasonography for detection of Pulmonary edema

The true positive was 22/211 (10.43%), the true negative was 163/211 (77.25%), the false negative was 22/211 (10.43%) and the false positive was 4/211 (1.90%). There was a weak agreement (¤=0.560, 95% CI: 0.413-0.707, p<.001), with 15-35% of data that are reliable. The specific Negative agreement was 92.61% and the specific Positive agreement was 62.86%.

		Ultrasonography		
		Positive	**Negative**	**Total**
Chest X-ray	**Positive**	1 (0.47%) TP.	1 (0.47%) FP.	2 (0.95%)
	Negative	30 (14.22%) FN	179 (84.83%) TN	209 (99.05%)
	Total	31 (14.69%)	180 (85.31%)	211 (100.0%)
Kappa **Standard error** **95% CI** ***p*-value**		0.044 0.052 -0.061-0.141 .156 NS.		

Table 5 agreement between Chest X-ray and Ultrasonography for detection of Consolidation

The true positive was 1/211 (0.47%), the true negative was 179/211 (84.83%), the false negative was 30/211 (14.22%) and the false positive was 1/211 (0.47%).

There was no agreement (¤=0.044, 95% CI: -0.061-0.141, *p*=.156), with 0.00-4.00% of data that are reliable. The specific Negative agreement was 92.03% and the specific Positive agreement was 6.06%.

		Ultrasonography		
		Positive	**Negative**	**Total**
Chest X-ray	**Positive**	2 (0.95%) TP.	1 (0.47%) FP.	3 (1.42%)
	Negative	4 (1.90%) FN	204 (96.68%) TN	208 (98.58%)

	Total	6 (2.84%)	205 (97.16%)	211 (100.0%)
Kappa **Standard error** **95% CI** ***p*-value**		0.434 0.208 0.026-0.841 <.001*		

Table 6 agreement between Chest X-ray and Ultrasonography for detection of Pneumothorax

The true positive was 2/211 (0.95%), the true negative was 204/211 (96.68%), the false negative was 4/211 (1.90%) and the false positive was 1/211 (0.47%).

There was a weak agreement (¤=0.434, 95% CI: 0.026-0.841, *p*<.001), with 15-35% of data that are reliable. The specific Negative agreement was 98.79% and the specific Positive agreement was 44.44%.

		Ultrasonography		
		Positive	**Negative**	**Total**
Chest X-ray	**Positive**	77 (36.49%) TP.	6 (2.84%) FP.	83 (39.37%)
	Negative	34 (16.11%) FN.	94 (44.55%) TN	128 (60.66%)
	Total	111 (52.61%)	100 (47.39%)	211 (100.0%)
Kappa **Standard error** **95% CI** ***p*-value**		0.625 0.052 0.523-0.726 <.001*		

Table 7 agreement between Chest X-ray and Ultrasonographyfor detection of Pleural effusion

The true positive was 77/211 (36.49%), the true negative was 94/211 (44.55%), the false negative was 34/211 (16.11%) and the false positive was 6/211 (2.84%).

There was a moderate agreement (¤=0.625, 95% CI: 0.523-0.726, *p*<.001), with 35.00-63.00% of data that are reliable. The specific Negative agreement was 82.46% and the specific Positive agreement was 79.38%.

Clinical Significance	**n (%)**
Day (0) (n=109)	
- Total clinically- relevant PPCs	12(11.00%)
- Pulmonary edema	2 (1.83%)
- Bronchospasm	5 (4.59%)
- Atelectasis	7 (6.42%)
Day (2) (n=66)	
- Total clinically- relevant PPCs	8(12.12%)
- Pulmonary edema	5 (7.57%)
- Bronchospasm	2 (3.03%)
- Pneumonia	1 (1.51%)
- Atelectasis	3 (4.54%)
Day (3) (n=41)	
- Total clinically- relevant PPCs	9(21.95%)
- Pulmonary edema	7 (17.07%)
- Bronchospasm	1 (2.43%)
- Pneumonia	1 (2.43%)
- Pneumothorax	1 (2.43%)

Table 8 clinical Significance in the Cardiac Surgery studied group

Day (0) : Total clinically- relevant PPCs was 12/109 (11.00%), pulmonary edema was 2/109 (1.83%), bronchospasm was 5/109 (4.59%), and Atelectasis was 7/109 (6.42).

Day (2) : Total clinically- relevant PPCs 8/66 (12.12%) , pulmonary edema was 5/66 (7.57%), bronchospasm was 2/66 (3.03%), pneumonia was 1/66 (1.51%), and Atelectasis was 3/66 (4.54%).

Day (3) : Total clinically- relevant PPCs 9/41(21.95%), pulmonary edema was 7/41 (17.07%), bronchospasm was 1/41 (2.43%), pneumonia was 1/41 (2.43%), and pneumothorax was 1/41 (2.43%).

Time lag to do Thoracic Ultrasound and Chest X-ray in both studied groups:
Time lag to perform chest ultrasound (minutes) (5-19)With a median range 7
Time lag to perform chest x-ray (minutes) (40-180)With a median range 70

Procedure	Time Lag (min)	Median (range)
– Chest Ultrasound – Chest X-ray	(5-19) (40-180)	7 70

Table 9 Time lag to do Thoracic Ultrasound and Chest X-ray in both studied groups

Discussion

Pulmonary complications are common in cardiac surgery and significantly contribute to morbidity, extended hospital stays, and the need for repeated examinations. Routine and multiple CXRs (CXR) are typically performed to detect these complications, as they are the current standard for diagnostic imaging.[1,2] However, CXR exposes both healthcare workers and patients to ionizing radiation. Lung ultrasonography (LUS) is an alternative method that can be easily performed at the bedside. Recently, LUS has been gaining popularity as a non-invasive, radiation-free tool for diagnosing various pulmonary diseases.[2-6]

In this study, 211 chest ultrasound and chest X-ray examinations were done at different time points after surgery (day 0 on 109 patients, day 2 on 66 patients, day 3 on 41 patients) with the median age (46.5 years).Patients were not included if there was on investigator available to performs ultrasound examination, the researcher was not available ,the the patient refused to do the examination, patients cannot be assessed by chest ultrasounography due to technical issues, patients with non-elective surgery or patients with subcutanous emphysema.

In the current study, the age ranged from 19.00 to 74.00 years, with a mean±SD. of 50.14±12.09 years. Males represented 58.72%, and females were 41.28%. Notably, the study included a wide range of age.In the present study the use of CXR as an Index Test For detection of Atelectasis against Ultrasound: There was a minimal agreement ¤=0.224, 95% CI: 0.126-0.322, p<.001, with 4-15% of data that are reliable, For CRX detection of Pulmonary edema against LUS, there was a weak agreement (¤=0.560, 95% CI: 0.413-0.707, p<.001), with 15-35% of data that are reliable. Regrading detection of Consolidation, there was no agreement (¤=0.044, 95% CI: -0.061-0.141, p=.156), with 0.00-4.00% of data that are reliable. Pneumothorax detection had a weak agreement (¤=0.434, 95% CI: 0.026-0.841, p<.001). While CXR detection of Pleural effusion against LUS had a moderate agreement (¤=0.625, 95% CI: 0.523-0.726, p<.001).

Cantinotti et al. (2018),[8] reported that For pleural effusion, the agreement between chest X-ray (CXR) examinations and the reference standard lung ultrasound (LUS) was 76.1%. CXR had a sensitivity of 58.0% (95% CI: 46.3-69.6), a specificity of 82.1% (95% CI: 72.1-92.2), a positive predictive value of 76.2% (95% CI: 63.3-89.1), and a negative predictive value of 64.8% (95% CI: 53.7-75.9). For atelectasis, the agreement between CXR and the reference standard LUS was 64.5%. CXR had a sensitivity of 49.5% (95% CI: 39.6-59.3), a specificity of 83.3% (95% CI: 64.8-98.2), a positive predictive value of 89.2% (95% CI: 79.2-99.2), and a negative predictive value of 28.6% (95% CI: 18.0-39.2). Specifically, the diagnosis of isolated atelectasis on CXR was confirmed by LUS in 47% of cases. In the remaining cases, LUS either identified associated pleural effusion or revised the diagnosis to isolated pulmonary congestion.

In Volpicelli's study,[9] the use of LUS in cardiac surgery remains extremely limited, with only one paper reporting on a few pediatric clinical cases found in recent literature.Previous researches suggested that lung ultrasound not only facilitates prompt diagnosis of pulmonary complications but also might be used as a primary imaging technique to screen for complications after cardiac surgery.[10-11]Bajracharya et al (2020),[12] concluded that lung ultrasound is a viable alternative, offering a noninvasive, reliable, and accurate method for diagnosing common pulmonary complications in pediatric patients following cardiac surgery, compared to CXRs. This approach provides acceptable diagnostic accuracy while reducing exposure to ionizing radiation, as well as saving time and costs.

In patients with heart and kidney diseases, who are at a high risk of fluid overload, LUS can be utilized to predict the development of adverse events during long-term follow-up. For instance, Gargani et al. (2015)[13] demonstrated that detecting >15 B-lines before discharge was strongly correlated with readmission during the 3- and 6-month follow-ups of patients admitted due to acute heart failure. Another study involving similar patients showed that detecting >30 B-lines was also associated with the risk of readmission.

Studies have shown that LUS not only improves outcomes, such as reducing the duration of mechanical ventilation and decreasing the incidence of postoperative desaturation events, but also provides prognostic value as an independent predictor for the length of stay in the intensive care unit.[14-17]

Furthermore, there was a noted diagnostic advantage for specific types of postoperative pulmonary complications, although not for all forms of pulmonary complications. While LUS improved diagnostic accuracy for pulmonary congestion compared to clinical examination and CXR alone, the low incidence of other pulmonary complications limited the study's ability to adequately compare different imaging approaches for detecting these complications.

In the recent issue of the Journal of Cardiothoracic and Vascular Anesthesia, Gothra et al.[18] conducted a study to evaluate whether adding LUS to the standard practice of clinical examination and CXR would lead to earlier or improved detection of PPCs in pediatric patients undergoing cardiac surgery with cardiopulmonary bypass.[18] The study included 100 children with acyanotic congenital cardiac lesions (left-to-right shunt), who were assessed preoperatively and at 12, 24, 48, and 72 hours after surgery. Ultimately, a total of 33 and 22 PPCs were observed in the early and late postoperative periods, respectively. The authors found that adding LUS to the standard practice of clinical examination and CXR significantly increased the detection of PPCs in the early postoperative period (i.e., at 12 and 24 hours postoperatively), but not in the late postoperative period (i.e., at 48 and 72 hours postoperatively).

Cantinotti et al. (2015) [8] have outlined the establishment of an institutional program where LUS is routinely conducted to assess common PPCs in pediatric patients following cardiac surgery. These complications include pleural effusions, anomalies in diaphragmatic excursion, and PNX. Investigators involved in this program aimed to reduce the the frequency of CXRs while enhancing diagnostic accuracy in identifying PPCs.

An important takeaway from Cantinotti et al. (2015 and 2018)[8,16] findings is that LUS should not be seen as a replacement for CXR. Instead, LUS and CXR should be regarded as complementary assessments to be used selectively based on the specific clinical context.[8,16]

Gothra et al. (2021)[18] indicated that LUS plays a complementary role alongside the standard practice of clinical examination and CXR, but it is currently not likely to replace this approach. While the investigators did not specifically assess whether LUS could replace CXR, their findings emphasized that the optimal benefit of LUS lies in the early detection of PPCs.

In addition, Gothra et al. (2021),[18] also assessed a secondary outcome, which involved correlating preoperative and postoperative LUS scores with the occurrence of PPCs. An independent investigator, not involved in patient care, evaluated six zones in each hemithorax and scored the LUS examination based on the number of B-lines observed in each zone.[19] These zones were defined by three longitudinal lines (parasternal, anterior axillary, posterior axillary) and two axial lines (above the diaphragm, 1 cm above the nipple). These findings supported other recent data showing that LUS provides not only diagnostic but also prognostic information in pediatric cardiac surgery patients.

Cantinotti et al. (2020),[16] demonstrated that the preoperative LUS scores exhibited a superior predictive ability for PPCs in the early postoperative period compared to the preoperative CXR score, although this difference did not persist beyond 24 hours. Multivariate analysis revealed that the preoperative LUS score was independently associated with PPCs and emerged as an independent predictor for PPCs, duration of mechanical ventilation, and length of stay in the intensive care unit.

As the authors suggested, future studies should focus on evaluating the impact of patient age on the effectiveness of LUS. Such studies could provide valuable insights into the optimal use of LUS in different age groups undergoing pediatric cardiac surgery.

Conclusion

Lung ultrasound is feasible in patients after cardiothoracic surgery, who are often considered less accessible to this imaging technique due to factors such as wound dressings and thoracic drain tubes.Lung ultrasound detected more clinically relevant PPCs and identified them earlier than CXR following cardiothoracic surgery. Our results suggest that lung ultrasound can be used as the primary imaging technique to detect PPCs after cardiothoracic surgery, enhancing bedside decision-making. The next step is to test lung ultrasound as the primary imaging technique in these patients and further quantify the extent of PPCs.So, lung ultrasound is highly valuable for diagnosing pulmonary complications after cardiothoracic surgery, especially considering the limitations of CXRs, particularly in ICU settings where patients are often examined in supine positions.

Limitations

Lung ultrasound was not studied as the primary imaging technique following cardiothoracic surgery and was not compared with CXR in a blinded, randomized controlled trial. As a result, possible variations in therapy initiated and the incidence rate of detection of clinically relevant PPCs using lung ultrasound compared to CXR could not be studied.

Additionally, the analysis of lung ultrasound (LUS) was conducted by qualified radiologists, while chest X-rays (CXR) were performed by different specialties, introducing potential sources of bias.

Lung ultrasound was performed by multiple investigators with varying levels of experience, reflecting daily clinical practice. Additionally, lung ultrasound demonstrated high inter-observer agreement, consistent with previously reported findings, and was completed more quickly than CXR.

Furthermore, previous studies have indicated that lung ultrasound diagnoses more pulmonary complications compared to CXR. The use of CXR as a reference standard, which may have inferior accuracy compared to LUS (the index test), complicates the interpretation of our results.

However, there are several technical limitations can impede the passage of ultrasound waves and affect the quality of imaging. Factors such as dressings, surgical wounds, chest tubes, varying degrees of subcutaneous emphysema which can prevent proper evaluation of the underlying pleura and lung parenchyma, and limited patient mobility can hinder ultrasound visualization. The hilum and deeper lung tissue are not easily assessed with LUS. LUS cannot assess the ventilated lung, and pathologic processes not reaching the pleura may go undetected. Therefore, atelectasis surrounded by aerated parenchyma would be missed by LUS.

However, LUS typically exhibits higher sensitivity than specificity. For example, B-lines might indicate inflammation, fibrosis, or fluid accumulation, necessitating interpretation alongside other findings and the patient's clinical status. Lastly, operator experience strongly influences LUS results, although multiple studies have reported good interobserver agreement and a relatively short learning curve.

The difference in positioning between lung ultrasound (LUS) and chest X-ray (CXR) indeed presents a limitation in your study. LUS examinations were performed with patients in both supine and lateral decubitus positions to scan different areas of the chest, while CXRs were only done in the supine position. This variation could introduce discrepancies in the imaging results.

There was a significant time lag between the performance of LUS, CXR, and CT scans. This delay, as illustrated by the example of pneumothorax, provides sufficient time for the condition to worsen, although the management of such life-threatening situations typically relies on clinical diagnosis without waiting for test results.

Additionally, applying the ultrasound probe to the posterior chest zone of bedridden, immobilized, intubated, or unconscious patients presented challenges, as it was often difficult to position the probe between the patient and the bed. This obstacle is similar to the difficulty encountered during positioning for X-ray imaging but is compounded by the higher risk associated with patient transfers compared to CT examinations.

Recommendations

We recommend using lung ultrasound (LUS) as a complementary tool for patients after cardiothoracic surgery. Our findings indicate that LUS is highly effective in diagnosing pulmonary complications in patients' post-cardiothoracic surgery, particularly given the limitations of chest X-rays (CXR) in ICU settings where patients are often examined only in supine positions. Future research should include multicenter studies with larger samples to investigate the cost-effectiveness and ease of implementation of LUS.

Authors' contributions:

Aya Mohammed Tolba Saleh: data collection, statistical analysis, and analysis of data. Mohamed Moustafa Abdelaal : administrative, technical, or material support and interpretation of data. Wael Mohamed El-feky : conception and design. Ahmed Ibrahim Mosa Ebeed:supervision. All authors read and approved the fnal manuscript.

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Availability of data and materials

The data underlying this article will be shared on reasonable request to the corresponding author.

Declarations

Ethics approval and consent to participate. The study was approved by the ethical committee of Kafrelsheikh University Faculty of Medicine.Written informed consent was obtained from all participants.

Consent for publication

A written consent was taken from every patient before enrollment in our study.

Competing interests

The authors declare that they have no competing interests.

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