Oncology
and Radiotherapy©
18(8) 2024: 001-006 • RESEARCH ARTICLE

A study on the assessment of the degree of pleural effusion following surgery with ultrasonography in patients having cardiac surgery

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ABSTRACT

Aim: The aim of this research was to create a useful, simpler formula to assist in the treatment of Pleural Effusion (PE), a common postoperative complication. Serial chest ultrasonography examinations at the bedside can be performed with no radiation risk and are more sensitive and reliable than Chest X-Rays (CXRs) in the identification of PE.

Objective: In our prospective observational analysis, 170 patients who underwent heart surgery and had basal pleural opacity on a CXR were included. Postoperative Day (POD) 5.7 ± 3.1 chest ultrasonography revealed effusion, which was verified. Inclusion criteria for subsequent thoracentesis were not protocol-driven but instead simply based on clinical considerations. Dyspnea, Peripheral Oxygen Saturation (SpO_2) values of ≤ 90%, and the maximum distance between the diaphragm's midpoint and the visceral pleura (DG 25 mm) were important inclusion criteria.

Results: The PE volume was around 450 ml, as determined by the abbreviated formula: V (ml) = [16×D (mm)], 140 individuals (82%) were reduced using a 14-G needle. Without any difficulties, success rate for getting fluid was 100%. The calculated and drained pleural effusions are quite accurate.

Conclusion: Thoracentesis decisions for postoperative patients may be made easily and inexpensively with the help of simple measurements of pleural effusion. The formula elucidated in this study might be useful to oncologists to apply for cancer patients where fluid accumulation is very common, especially in lung cancers on its first priority as breast, ovarian mesothelioma, and others.

Keywords: postoperative complication, Pleural Effusion (PE), ultrasonography, thoracentesis, Chest X-Rays (CXRs), cancers

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Word count: 3642 **Tables:** 02 **Figures:** 06 **References:** 18

Received: 14 August, 2024, Manuscript No. OAR-24-146035
Editor Assigned: 17 August, 2024, Pre-QC No. OAR-24-146035(PQ)
Reviewed: 01 September, 2024, QC No. OAR-24-146035(Q)
Revised: 08 September, 2024, Manuscript No. OAR-24-146035(R)
Published: 16 September, 2024, Invoice No. J-146035

INTRODUCTION

After Cardiac Surgical Procedures (CSP), PE is a frequent consequence. Large levels of PE in heart surgery postoperative patients may delay healing and lengthen hospital stays owing toward dyspnea. Nevertheless, the unfavorable characteristics of big PE are simply illustrated to emphasize the clinical importance [1]. There is a slight chance of emphysema developing, and other complications, including delayed lung volume, atelectasis, and the threat of pneumonia, and a possible link to arrhythmias. PE should have an optimal postoperative course with sufficient care if it is identified and quantified early. In the first 30 days following surgery, little over 6% of patients develop clinically severe PE. Studies, however, have mostly concentrated on patients who have undergone CABG surgery. In 65%-89% of patients, PE was reported after CABG. Most PEs is left-sided, insignificant, and spontaneously resolve. After CABG, a small percentage of patients may develop LPE [2]. IMA harvesting or diaphragm dysfunction is the two causes of perioperative effusions, which are often self-limited. Post cardiac injury syndrome is typically to blame for early effusions. Although late effusions might have a variety of origins, a trapped lung is the likely culprit in persistent effusions [3]. The majority of PE was unilateral, tiny, and left-sided; it didn't need to be treated. Patients with enlarged cardiac chambers or atelectasis did not have a greater incidence of effusion, and chest tubes were not shown to be a factor either. Moreover, postoperative morbidity has not been affected by pleurotomy. There was no change in PE frequency or grade between the usage of IMA+SVG and SVG. Additional findings indicated that the IMA and SVG groups in PPCs differed [4].

Compared to a CXR, chest sonography provides more accurate and sensitive identification of pleural effusions. Without any radiation risk, chest sonography may be performed repeatedly at the bedside. A lower incidence of problems was seen with thoracentesis carried out under ultrasonography. Unnecessary thoracentesis can be avoided if a patient's CXRs indicate an effusion that is not supported by an ultrasound. While thinking about pleural drainage, the suspected fluid volume is crucial. The advantages of a pleural puncture for a modest quantity of fluid should be balanced against the risks of bleeding or pneumothorax, especially in patients taking oral anticoagulants or in thrombogenic individuals. Few studies have been written about the management of PE in patients recovering from heart surgery who are breathing on their own. Hence, a quick approach to determine the effusion volume might be useful when choosing between treatment choices.

The remainder of this research is structured as follows:

- Section 2 - literature review,
- Section 3 - Materials and methods
- Section 4 - results and discussion
- Section 5- conclusion

RELATED WORKS

The prospective research compared roentgenograms with thoracic surgeons' ultrasound evaluations for the identification of pneumothorax and PE following noncardiac thoracic surgery [5]. Before the removal of the chest tube and on the day of surgery, patients underwent two ultrasounds' scans. PE in patients having heart surgery should be evaluated to ascertain the effects of applying an additional early mobilization regimen and other variables. Using the extra early mobilization regimen did not result in a reduction in PE or the need for further therapies for PE drainage [6]. The ARISCAT score was used to determine whether a patient was at a high or intermediate risk of developing postoperative pulmonary complications throughout this prospective observational feasibility study [7]. These patients were all consecutive patients undergoing major abdominal surgery. Study's objective is to determine if personalized intraoperative lung ultrasound-guided PEEP reduces intraoperative partial PaO_2 and early postoperative pulmonary problems in obese patients having laparoscopic bariatric surgery [8]. Hypoxemia and PPCs are linked to morbidity and death. To diagnose PPCs in patients with hypoxemia following general anesthesia, the author set out to assess the viability and effectiveness of LUS and contrast the findings to those of thoracic CT [9].

To determine if patient-based intransitive ultrasound-guided recruitment techniques could shorten recovery times and reduce the risk of postoperative pulmonary complications was performed in the study [10]. The clinical data relating to the use of LUS during cardiac surgery's perioperative period and in critical care is presented in this narrative review [11]. The methods, diagnostic and prognostic accuracy of LUS are also described in this study. An overview of ongoing clinical studies reviewing the clinical effects of LUS is also included. Using LUS, investigate the effects of the iPEEPRM in children with CHDs. In children having cardiac surgery, iPEEPRM successfully decreased atelectasis and enhanced lung aeration, oxygenation, and CDyn/kg [12]. Study compares the diagnosis made using standard bedside CXR to the diagnostic made using LUS to determine the degree of agreement between the two modalities' diagnoses of various cardiovascular diseases in intensive care units [13]. Study's objective was to assess the effects of postoperative pulmonary dysfunction caused by pressure-volume-controlled central air-controlled breathing while undergoing cardiac failure whereas a clinical trial was not ventilated [14].

MATERIALS AND METHODS

Pleural effusions

Postoperative pleural effusions after heart surgery can have a wide variety of causes, thus they need to be treated with caution and extra attention. Determining the etiology frequently necessitates a thorough clinical history and pleural fluid study. An effusion's etiology heavily depends on timing. Early effusions are frequently hemorrhagic, neutrophil-predominant, and linked to operational trauma in the first 17 postoperative days. Low BMI, female gender, history of AF, history of heart failure, concomitant valve replacement, and anticoagulation history are all linked to effusions after CABG. In a CABG patient, postoperative PE (22.5% of patients) is the 2nd most frequent reason for readmission, and the requirement for thoracentesis is a bad prognostic indicator. PEs following heart surgery also frequently signifies a partial or full manifestation of post pericardiotomy syndrome. PE is the presenting symptom of sub-acute retained blood, with outflow resembling more liquefied pleural fluid than true blood. Retained blood syndrome is a continuum of problems that raises the risk of stroke (especially when intervention is needed), lengthens ICU stays, and prolongs the time of mechanical ventilation in CABG patients. Advanced age, low body weight, elective surgery, a lengthy CPB, a complicated procedure, the use of more than 5 bypass grafts, and perioperative antiplatelet medication are threat factors for postoperative bleeding in cardiac surgery patients. The estimated incidence ranges from 13.8% to 22.7%. There should always be a worry for pulmonary infection, which is covered next, in addition to pleural effusions and retained blood products.

Study participants

Data on 140 (82%) consecutive spontaneously breathing patients who also had thoracenteses under ultrasound guidance between 2021 and 2023 (47 females and 93 males) were prospectively gathered. Aortic valve implants (73% biological prostheses) were given to 89 (64%) patients while CABGs were performed on 51 (36%) patients. On PODs 1, 3, and 5, patients underwent standard CXRs, and on POD 5 for valve replacements, and echocardiograms. Neutralizing of the lateral costophrenic angle and opacification on CXR were both indicative of PE, which has been confirmed in every one of these participants after ultrasonography (Figure 1).

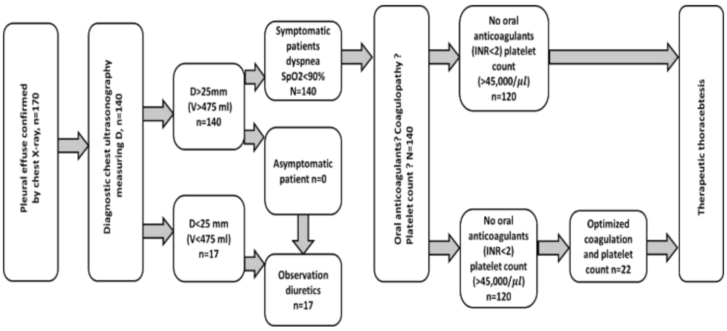
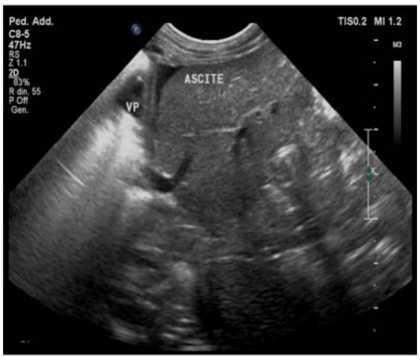


Fig. 1. A flowchart of patient selection and postoperative pleural effusion treatment

Pre-puncture ultrasonography was used to confirm effusion on POD 5.7 ± 3.1. Patients with coagulopathy by an INR and/or platelet count $<50\times10^2$/l or those taking oral anticoagulants, nonetheless they weren't exhausted, right away after an ultrasonography evaluation of the PE. Instead, if clinically tolerable, they were drained 12 hours later after achieving the desired INR value.

Major clinical criteria for thoracentesis included dyspnea and peripheral SpO_2 values ≤ 90% measured without the need for additional oxygen. Patients were seated whilst having an ultrasound examination. Mid-scapular line and cranial movement were made with the ultrasonic probe. When the intrapleural spacing decreased during inspiration, the visceral layer shifted throughout each respiratory cycle. Behind the pleural effusion, the lung looked to be either evacuated or congested. After freezing the pic-ture at end-expiration, the maximum Distance (D) between the diaphragm's midpoint and the Visceral pleura (V) was measured (Figure 2).



Longitudinal ultrasonography

Fig. 2. A significant effusion encircling the consolidated lung is visible in a longitudinal ultrasonographic scan

Before tapping, it was necessary to have a clear mental image of the diaphragm, liver, and spleen to prevent unintended penetration. To enroll the patient in the trial, an intrapleural distance of DG 25 mm was needed. Once the mid-scapular line had been established with the probe, a thoracentesis was carried out. To prevent pulmonary edema, all thoracenteses were therapeutic, with the pleural space being drained to a significant amount, but only to a maximum of 2200 ml. A pump device that was mounted on the 14-G CON during the thoracentesis allowed for aspiration of the PE. When there was no more fluid left to aspirate, the tap was closed while the *V* was noted. On post-puncture ultrasonography, every patient who had pleural fluid incompletely aspirated and exhibited an 18 mm separation of the pleural layers was disqualified from the research. All individuals who underwent thoracentesis were followed by a CXR.

Statistical analysis

The Graph Pad Prism, version 5.0, the program was employed to do the statistical study. Using Bartlett's test for equal variances, the distribution of the data was examined and found to be normal ($P<0.01$). The mean and SD are used to express the results. We used linear regression to explore the correlation among the volume of pleural fluid and D. In addition to calculating the SEE, the difference between both the expected and drained effusion quantities was employed to calculate the mean prediction error. There were said to be complications. Using covariance analyses, the results of the left and right pleural effusions were compared.

RESULTS AND DISCUSSION

A total of 170 PE patients were assessed. D<25, or failing to meet the inclusion criteria for thoracentesis, prevented 17 of the 170 patients included in this research from undergoing thoracentesis. If the criterion DG ≥ 25 mm with an estimated amount of PE of about 450 ml were satisfied, a total of 140 continuously ventilating patients (93 men and 47 women) were effectively drained with ultrasonography supervision. Under ultrasonography supervision, one tap was always sufficient; further tapping wasn't required. The mean BMI for patients was 28.22 kg/m^2 ± 2.92 kg/m^2 (range 23.47-36.78) and their median age was 56 (range 42 years-60 years). At the point of expiration, the diaphragm's median elevation measured (D_{pre}) was 45.4 mm ± 12.3 mm above the visceral pleura. $V_{drained}$ was 706.4 ml ± 218 ml (range 250 ml-1300 ml) in mean drained amount. The formula $V_{drained}$ (ml) $(15.10 \times D_{pre}) \pm 21.46$ was calculated first from the drained volume of pleural fluid using D_{pre}. The expected *V*, according to this procedure, was 705.5 ml ± 190.5 ml. There was a SP connection between D_{pre} and $V_{drained}$ established: $r=0.77$; $r^2=0.5929$; $p<0.001$ (Figure 3).

For practical reasons, the following equations may be employed to determine the quantity of pleural fluid: V_{pre} (ml)$=16 \times D_{pre.}$ Mean calculated V_{pre} using the abbreviated equation, 726.4 ml ± 201.41 ml. The resulting method's standard error of estimation was 97.38 ml. The average validation loss of V_{pre} utilizing the developed pre-equation was −0.16 ml ± 97.05 ml, as well as the simple equation, was −21.2 ± 97.72. The remaining PE following thoracentesis was determined by ultrasonography testing to be $D_{post}=9.12$ mm ± 5.72 mm. D was included in the post-derived equation to get (V_{post} (ml)$=(15.02 \times D_{post} +21.39)$, which gave rise to Vpost=158.6 ml ± 108.28 ml. The result of adding Dpost to the abbreviated equation V_{pre} (ml)$=16 \times D_{pre}$ resulted in $V_{post}=146.19$ ml ± 92.28 ml.

There were no instances of hemorrhage or pneumothorax during the successful fluid retrieval under ultrasound supervision. Just 73% of drained pleural effusions were simply serious; the remainder was hemorrhagic-serous. Before and after thoracentesis, the average peripheral SpO_2 was 90.74% ± 1.28 and 98.38 ± 1.96, respectively. If merely treated using diuretics in an observation manner, patients would have had to stay in the hospital for 3 ± 1.7 (range 1-5) days longer. However, after thoracentesis, breathing improved as well as the patients might be released on POD 9-10.

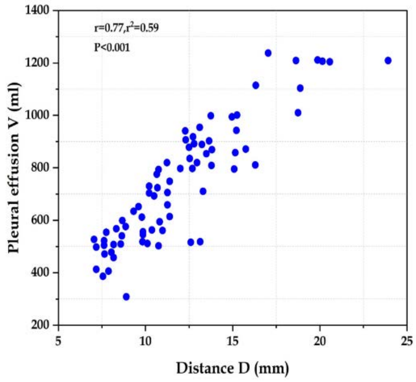


Fig. 3. Correlation between 140 thoracenteses and the observed distance D

More patients with PE were detected by ultrasonography than by CXR at the time of ICU admission. Pleural effusion, consolidation, pneumothorax, atelectasis, and pulmonary edema were shown to be PPCs. CXR and ultra-sonographic detection rates of PE on days 1, 2, and 3 are depicted in figure 4. Both groups saw a rise in the prevalence of PE throughout the postoperative period, with detection of 85% with 68% on day 2 and 75% and 53% on day 3 for ultrasonography and CXR. Table 1 depicts the outcomes of the study.

Tab. 1. Outcomes of the study

Metrics	Pleural Effusion		
	Day 1	Day 2	Day 3
Sensitivity (%)	42	25	50
Specificity (%)	85	87	83
PPV (%)	95	93	86
NPV (%)	17	14	82
Accuracy (%)	86	82	78

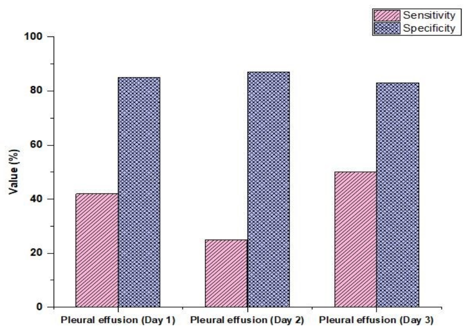


Fig. 4. Presence of postoperative PE based on ultrasonography and CXR

The diagnostic accuracy, specificity, NPV, sensitivity, and PPV of ultrasonography and CXR are depicted in figures 5 and 6, respectively (Table 2).

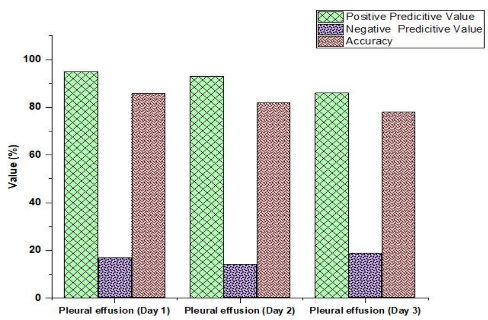


Fig. 5. Sensitivity and specificity of ultrasonography and CXR surgery

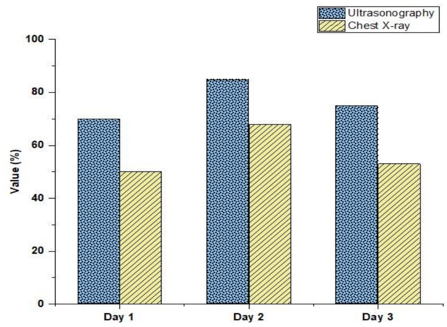


Fig. 6. Diagnostic accuracy of ultrasonography and CXR

Tab. 2. Comparison of ultrasonography and CXR

Pleural Effusion	Ultrasonography	CXRs
Day 1	70 (%)	58 (%)
Day 2	85 (%)	68 (%)
Day 3	75 (%)	53 (%)

DISCUSSION

They performed a longitudinal examination on 26 adult nonconsecutive patients who had heart surgery and had pleural effusion found by ultrasonography during the postoperative phase. The amount of pleural fluid drained and the volume measured by Balik's formula showed a significant positive connection. Furthermore, they discovered that, when compared to Light's criteria, the ultrasound-derived features of a drained PE exhibited adequate diagnostic reliability to distinguish between exudate and transudate [15].

Clinical results of patients undergoing heart surgery who had PE are presented in the study [16]. The results indicated a correlation between individuals identified with PE during cardiac surgery and unfavorable clinical results, which appeared to be unrelated to the intricacy of the procedure and coexisting conditions such as heart failure. The results encouraged investigators to assess new approaches and strategies for avoiding PEs to enhance results for heart surgery patients.

The results of postoperative heart surgery patients who were referred for outpatient treatment of a severe pleural effusion were presented in the study [17]. They discovered that antiplatelet and/or anticoagulant medication-assisted thoracentesis represented a relatively secure procedure when conducted on a postoperative heart surgery group that presented with symptomatic PE. They also found that the majority of PEs continues to be self-limited and that numerous individuals were manageable as outpatients.

To make the management of PE, a common postoperative complication, easier to handle, we set out to develop a realistic algorithm in the study that was just presented. It is well acknowledged that chest ultrasonography outperforms CXR in terms of sensitivity and accuracy in the detection of pleural effusions. Without any radiation danger, chest ultrasonography may be performed repeatedly at the bedside. Modern portable miniaturized advanced ultrasound systems enable doctors to quickly perform thoracentesis and rapid diagnostics at the patient's bedside, which is ideal in emergent circumstances. The benefit of utilizing ultrasonography to assess PE is obvious: by calculating the volume of pleural fluid using our streamlined formula V (ml) [16 × D (mm)], it is possible to determine whether or not thoracentesis is necessary. In this study, there were no complications; in particular, no pneumothoraxes were reported. The main benefit of thoracentesis performed using a 14-G needle is that it is much less invasive than using a formal chest tube, which both requires skin incisions. However, with the technique described in this study, patients are not immobilized after thoracentesis.

Additionally, it was suggested that for pleural separations under 18 mm, the relationship might not be as direct and clinically significant. The lower lobe extension process with significant effusions >1200 ml was a possible source of error for the amount underestimated since it may have provided varying volume architecture than what could have been measured. The thoracic cavity's dimensions influence sonographic measurement as well. The layer assessed by ultrasonography may result in an underestimating of the real volume of pleural fluid in tall persons with big thoraces. The examination method may also have an impact on the outcomes; the transducer must not be tilted or angled as this could produce that scan at an angle to the perpendicular direction. There could be significant intra- and interobserver variation in the ultrasonographic measurement, which would emphasize the need for some ultrasonography expertise.

Pleural effusion management in advanced cancer patients is a challenging task, especially a unique challenge for inpatient admission in the palliative medicine ward [18]. Considering various modalities of the treatments, like pharmacological, radiological, and chemotherapeutic interventions, the severity of tumor subsidence in terms of control without relapse is very important. Pleural metastasis stage consideration is very crucial, and the present study might be helpful to know the stage of advancement in different cancers.

CONCLUSION

Practical algorithms, like the one we described for managing postoperative pleural effusions, are useful for decision-making. Utilizing our streamlined approach, we could rapidly evaluate PE and make an efficient decision regarding thoracentesis timing and expense. Patients undergoing cardiac surgery can benefit from thoracentesis of PEs less than 450 ml; this secure procedure significantly speeds up breathing and postoperative recovery. As a result, after cardiothoracic surgery, ultrasonography detected more clinically significant PE and did so earlier than CXR.

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