Audit Report

OPEN ACCESS

An audit to evaluate the quantification of pleural effusions using thoracic ultrasonography in ICU

Sobia Mazhar

Department of Radiology, Jinnah Burn & Reconstructive Surgery Center, Lahore

Funding Source: None
Conflict of Interest: None
Received: September 26, 2019
Accepted: January 23, 2020

Address of Correspondent
Dr. Sobia Mazhar
Consultant Radiologist
Department of Radiology, Jinnah Burn & Reconstructive Surgery Center, Lahore
E-mail: drsobiamshahid@gmail.com

ABSTRACT

Objective: To develop a practical method of estimating the volume of pleural effusions with ultrasonography in ICU setting at a tertiary care hospital.

Methodology: A clinical audit study was conducted at the Department of Radiology, Jinnah Burn & Reconstructive Surgery Center, Lahore, from December 2018 to August 2019. Scans of 21 patients who underwent ultrasonography for quantification of pleural effusions in the ICU in December 2018 were studied retrospectively to assess the parameters being followed in the first audit.

Results: In the first audit, it was ascertained that the pleural effusion was being quantified into mild, moderate and severe based on subjective values. The method of quantification used was the same for supine and erect patients. The separation between two pleura was measures in mm and aspirated effusion in ml. A positive correlation was noted between these two measurements. The re-audit performed 6 months later showed improvement with 100% compliance to standards.

Conclusion: The first audit revealed that the qualitative method was being used solely. In qualitative analysis the effusion was classified according to the length of the transducer. It was termed minimal if it only covered the costophrenic angle; mild if it was limited in one transducer length, moderate if it involved two transducer length and massive in case it was larger than the two lengths. However, the exact amount of effusion cannot be ascertained by this method. Hence, the quantitative method was employed which gives an accurate estimation of the effusion.

Key Words: Clinical audit. Ultrasonographic quantification of pleural effusions. Volumetry. Thoracocentesis. Volume estimation.

Cite this article as: *Mazhar S. An audit to evaluate the quantification of pleural effusions using thoracic ultrasonography in ICU. Ann Pak Inst Med Sci. 2019; 15(4): 191-194.*

Introduction

Approximately 1-10 ml of fluid is normally present in the pleural space.[1] The fluid is being constantly produced and reabsorbed. This amount is maintained by a balance between the oncotic and hydrostatic pressures between the visceral and parietal pleural surfaces.[2] The disruption in this balance results in the accumulation of fluid in the cavity. Thoracic imaging is regularly performed in the critically ill patients in the ICU.[3] Radiograph is the first investigation performed. But there is growing used of ultrasound to provide a point of care imaging.[4] Thoracic ultrasound (TUS) has similar diagnostic accuracy to CT in accurately diagnosing pleural effusions, consolidations, pulmonary edema, and pneumothorax.[5] Although CT is the gold standard in the detection of effusions, it has the disadvantages of higher cost, radiation exposure and limited round the clock availability[6]. The purpose of this clinical audit is to determine the best method of quantification of pleural effusions using TUS and to standardize the technique.

Pleural effusion is a collection of fluid within the pleural cavity. Essentially it represents a pathological process that signifies either excess production or inadequate reabsorption. TUS image of pleural effusion depends on its chemical nature. This fluid could be transudative or exudative.[7] The ultrasound image of a simple pleural effusion is characterized by an echo-free space between the visceral and parietal pleura. A simple effusion is mostly transudative.[8] The ultrasound image of a complex pleural effusion is characterized by any of or a combination of debris, septations, heterogeneous echogenicity and loculations.[9] Homogenously echogenic effusions are mostly due to hemothorax or empyema.[10]

Quantification of fluid in the pleural cavity is an important step in its management.[11] Sonographic volumetry of pleural effusion involves a qualitative and quantitative approach.[12]

Table 1: Qualitative Ultrasound quantification of pleural effusion.

Qualitative Quantification	TUS visualization
Minimal	Costophrenic angle
Mild	Range, one probe
Moderate	Range, two probes
Massive	Range, three or more probes

Quantitative approach includes 4 formulae, 2 in supine position Balik & Eibenberger; and 2 in erect posture Geocke 1 & Geocke. [22]

The Balik formula[1-2]: The patient lies supine, the transducer is perpendicular to the dorsolateral chest wall and measurements are taken at maximum inspiration in mid-axillary line. Radiologist measures the maximum distance (in millimeters) between the visceral and parietal pleura. The formula is

Pleural effusion volume (ml) = (measured distance) x 20

The Eibenberger formula[1-2]: The patient lies supine; transducer is placed perpendicular to the chest wall and measurements were taken at maximum inspiration. Radiologist measures the maximum distance (in centimeters) between the lung and posterior chest wall. The formula is

Pleural effusion volume (ml) = (47.6 x distance) – 837

The Goecke 1 formula[1-2]: The patient is in erect position with the transducer on the dorsolateral chest wall, the index marker is directed cephalad (a longitudinal orientation) with distance measurements (cm) taken at end-expiration. One caliper is placed in the near field in the costophrenic angle, the subsequent caliper is placed in the far field at the lung base, constituting a maximum distance between lung and diaphragm. The formula is

Pleural effusion volume (ml) = distance (cm) x 90

Geocke 2 formula [1-2]: The patient is in an erect posture. Two distances are measured. The craniocaudal extent of the effusion at the dorsolateral chest wall (X) and then the distance between the lung base and the mid-diaphragm(LDD) in cm. The formula is

$$EV= (X+LDD) \times 70$$

Once quantification has been done, the decision is taken for pleural space intervention and justification made that the benefits of the procedure out way the potential complications. Pleural space intervention can be performed by either thoracocentesis, tunneled pleural catheter insertion or chest drain insertion.[18] Thoracentesis is indicated for the symptomatic treatment of large pleural effusions or the treatment of empyemas.[13] It is also indicated for pleural effusions of any size that require diagnostic analysis. There are no absolute contraindications for Thoracentesis.[14] Relative contraindications are uncorrected bleeding diathesis and chest well cellulitis at the site of puncture.[15] Typically, a diagnostic Thoracentesis is a small volume single 20 to 30 ml syringe which is sent for pathology analysis. A therapeutic thoracocentesis is a large volume of fluid. Removal of 400-500 ml of pleural fluid is often sufficient to alleviate shortness of breath. The recommended limit of a single session is 1000-1500 ml to avoid re-expansion pulmonary edema.[16] A fluid collection that is infected should be drained to eliminate the source of infection and the reservoir of infection.[17]

Tunneled pleural catheters (TPCs) have become an important tool I the management of chronic, recurrent, symptomatic and malignant pleural effusions.[19]

Indications for chest drain insertion include pneumothorax, hemothorax, empyemas and pleural effusions.[20]

Complications of pleural space interventions include the development of pneumothorax, hemothorax, re expansion pulmonary edema, organ laceration, uncontrolled bleeding and infection.[21-22]

Methodology

In the first audit, 21 ICU patients were retrospectively studied while in the second audit 29 adult ICU patients were taken in the study who were referred for USG guided drainage. Patients with only simple pleural effusions were included in the study. We used the 3–5 MHz curvilinear probe to view the pleural effusion and the surrounding landmarks. These included visualizing the lung within the pleural effusion, the diaphragm and liver on the right side and the diaphragm and spleen on the left side.

Table I: Relationship between pleural separation and aspirated effusion

Separation in mm	Aspirated volume ml
14	200
18	400
19	420
25	300
26	330
27	501
29	600
30	600
32	600
35	620
38	710
39	630
41	655
43	610
44	800
44	720
48	810
49	440
49	1080
51	900
51	890
51	1300
57	990
62	1400
65	1700
68	1600
72	1000
74	1800
75	1350

E-Saote machine was used for this purpose. We measured pleural effusions by first qualitative analysis, then using the Balik formula for supine patients and Geocke 2 formula for erect patients. A previous study[11] concluded that these formulae yielded the best estimates, with a Pearson correlation coefficient (r) of 0.87 and 0.92 respectively. All the cases were completely aspirated under USG guidance and terminated when no fluid could be further aspirated. The volume was measured in calibrated containers. Statistical correlation between the pleural separation on USG and aspirated fluid were done online. (Table I)

Results

In the second audit cycle, a total of 29 patients were evaluated. Five patients had bilateral effusions. Remaining 24 had unilateral effusions. The mean pleural space separation was 31.26 mm; with 83 mm being maximum and 12 mm being minimum separation. The mean of aspirated fluid was 773.6 ml; with 2200 ml being maximum and 220 ml being minimum values. Calculations revealed accurate correlation between the estimated pleural space separation and the drained effusion volume. ($r = 0.8565$, $r^2 + 0.7336$), P- value is <0.00001 which is significant. (Table II)

Discussion

The chest x-ray is usually the first imaging approach regarding a pleural effusion. The PA view shows the effusion as either blunting of the CP angle, or it may form a meniscus in case of moderate effusion. A large effusion may opacify the entire hemi thorax and shift mediastinum to the contralateral side. Other patterns of effusion like lamellar, encysted or sub pulmonary are also evident. Supine radiograph is relatively insensitive in the

Table II: Comparison between first and second audit and compliance.

Parameters	Calculations	First Audit % of patients (n=21)		Calculations	Second Audit % of patients (n=29)	
Patient position						
ERECT	6	28.57		9	31.03	
SUPINE	15	71.42		20	68.9	
Acquisition time End inspiration	8	38.09		29	100	
Qualitative measurement	Minimal	2	9.52	Minimal	1	3.4
	Mild	8	38.09	Mild	5	17.24
	Moderate	7	33.3	Moderate	11	37.93
	Massive	4	19.04	Massive	12	41.37
Quantitative measurement Baliks formula Geocke 2 formula						
	0	0		20	100	
	0	0		9	100	

detection of the pleural fluid and often underestimates the amount of fluid.[3] CP angle is often not blunted and radiograph may demonstrate a hazy veil like opacification due to layering of the fluid.

In comparison with CXR, TUS thoracic ultrasonography (TUS) has higher accuracy in detecting plural effusions, detecting as little as 3 ml. It has a sensitivity of 100 % for detecting pleural effusion[4]. TUS can be used under several different situations: to determine the presence or absence of pleural fluid, to identify the appropriate location for thoracocentesis, to identify loculated effusions and to distinguish fluid from thickening.

CT is more sensitive than both conventional CXR and ultrasound.[5] It can detect 10 ml of fluid in the pleural space. However, it is expensive, adds to radiation burden and might not be readily available to ICU patients.[19]

Conclusion

Bedside TUS is by far the best method to detect small effusions, the internal structure of the pleural collections and for interventional procedures**.** The best method to do that in erect patients is by using a qualitative assessment followed by Geocke 2 formula. The best method for supine patients is qualitative assessment followed by Baliks formula.

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