Al-Azhar Med. J.(Medicine). *Vol. 50(2), April, 2021, 1459 - 1466*
DOI: 10.12816/amj.2021.158632
https://amj.journals.ekb.eg/article_158632.html

COMPARATIVE STUDY OF DIFFERENT FORMULAE OF ULTRASONOGRAPHIC QUANTIFICATION OF THE AMOUNT OF PLEURAL EFFUSION

By

Mohamed Sabri Ahmed Amin, Abo-Bakr Helal Al-Asmar and Houssam El-Din Hassanin Abd El-Naby

Department of Chest, Faculty of medicine, Al-Azhar University, Cairo, Egypt

Corresponding author: Mohamed Sabri Ahmed Amin, **Mobile:** (+20)01016427899,

E-mail: mohamed.sabri.1992@gmail.com

ABSTRACT

Background: Pleural effusion may be a result of a primary pulmonary illness. It also can be the pleural manifestation of numerous of diseases that primarily affect other organs. Quantification of pleural effusion is of great value in clinical practice, as it usually guides the plan of management. Chest ultrasound (U/S) is one of the helpful non-invasive means in estimating pleural fluid volume.

Objective: To correlate the U/S estimated volumes of pleural fluid calculated by studied formulae, with the actual effusion volume, and to identify the most accurate formula in quantifying the pleural fluid volume.

Patients and Methods: This prospective cross-sectional study was carried out in the department of Chest, Bab Al-sha'reia University Hospital, during the period from October 2019 to September 2020, and included forty patients with clinical and radiological diagnosis of pleural effusion. Ultrasound estimation of the amount of pleural effusion was done using 4 different formulae, followed by full pleural drainage through either simple aspiration or tube thoracostomy. Lastly, the ultrasonographically estimated fluid volumes were then compared to the actually drained fluid volume.

Results: The supine formulae showed excellent correlation with the drained pleural fluid volume, with Pearson correlation coefficient(r) = 0.9607 and 0.9602 for Eibenberger and Balik formulae respectively (p-value <0.0001). On the other side, the erect formulae were found to have reasonable correlations with the drained volume, with r= 0.4017 (p-value= 0.0102) and 0.5729 (p-value <0.0001) for Goecke1 and Goecke 2 respectively. All studied formulae failed to quantify the pleural effusion volume accurately when comparing its estimated volume to the actually drained fluid volume.

Conclusion: The 4 studied formulae had good correlations with the actually drained volume. However, supine formulae were better than erect formulae.

Key words: Pleural effusion; Ultrasonographic; Quantification.

INTRODUCTION

Approximately 1-10 mL of fluid are normally present in the pleural space, maintained by the balance between the hydrostatic and oncotic forces in the visceral and parietal pleural vessels and extensive lymphatic drainage *(Light, 2013)*.

The use of ultrasonography (U/S) in examining the pleural space has become a standard practice worldwide *(Mercer et al., 2017)*. Physicians show a rising interest about examining the pleural space using U/S, which has a positive impact on patient's overall care, as there are many advantages of U/S over other radiological investigations *(Lichtenstein, 2017)*.

Ultrasonographically, pleural effusion volume can be estimated quantitatively or qualitatively. Qualitative estimations classify effusion as minimal, moderate or massive, while a quantitative approach involves the use of various formulae *(Cerquitella et al., 2016)*.

Many ultrasound-based formulae were put for pleural effusion volume estimation, but the ideal one should be simple, accurate and easily performed *(Ibitoye et al., 2018)*.

The present work aimed to correlate the U/S estimated volumes of pleural fluid calculated by studied formulae, with the actual effusion volume.

PATIENTS AND METHODS

This prospective cross-sectional study was carried out at Chest Department, Al-Azhar University Hospitals, Cairo, Egypt, during the period from October 2019 to September 2020. It included forty patients diagnosed clinically and radiologically as pleural effusion.

Exclusion Criteria:

Patients with any of the following were totally excluded from the study; loculated/encysted effusions or empyema, very small effusions (<10 mm pleural separation by fluid on ultrasonography), inability to accommodate supine or full erect positions, thoracic deformities, diseases affecting diaphragmatic motility directly or indirectly, previous thoracic surgery, known bleeding tendency disorder, regular anti-coagulation or patients with international normalization ratio (INR) >2or platelets count <100000/mm^3 *(Müller et al., 2015)*,conditions interfering with good U/S window, e.g. subcutaneous emphysema, chest wall edema and morbid obesity and lastly those with incomplete fluid drainage on post-thoracentesis ultrasonography (>5 mm separation of the pleural layers).

Ethical clearance was granted by Al-Azhar Faculty of Medicine Ethics and Research Committee. Informed consents were obtained from all participants.

All subjects were submitted to the following; full history taking, thorough clinical examination, routine laboratory investigations (complete blood count, random blood sugar, liver function tests, kidney function tests and coagulation profile), plain chest X-ray (postero-anterior and lateral views), CT chest with or without IV contrast (if needed), chest U/S and complete thoracentesis.

Chest U/S:

The curvilinear transducer (2-6 MHz) of the ultrasound machine model (SonoScape - SS1 China) was used in the study. Ultrasonographic examination was first done while the patient is completely supine to obtain values (in millimeters) for the supine formulae. The chest was examined at the laterodorsal/ posterolateral part of the chest wall through the intercostal spaces. The transducer was oriented perpendicularly to the chest wall (sharp transverse scan). Measurements were taken at maximum inspiration, while the patient holding his/her breathe. The maximum perpendicular (interpleural) distance between the posterior surface of the lung and the posterior chest wall was recorded *(Ibitoye et al., 2018)*.

Patient sat in a fully erect position, and measurements (in centimeters) were taken for the erect formulae. The chest was examined at the laterodorsal/ posterolateral part of the chest wall through the intercostal spaces, with the transducer oriented longitudinally along the long axis of the chest. The craniocaudal extent (lateral height) of the effusion and the lung base to mid-diaphragm distance were measured at the end of expiration *(Ibitoye et al., 2018)*.

Each measurement was repeated for 3 times and the average value was obtained for statistical analysis. The estimated effusion volume was subsequently calculated for each studied formula as follows:

Supine Formulae:

- **Eibenberger: EV= 47.6X-837**

Where EV= estimated effusion volume (mL), X= maximum perpendicular distance between the pulmonary surface and the chest wall at maximal inspiration (mm) with the probe in the transverse position *(Mathis, 2011)*.

- **Balik: EV= 20X**

Where EV= estimated effusion volume (mL), X= maximum perpendicular distance between the pulmonary surface and chest wall at maximal inspiration (mm) with the probe in transverse position *(Mathis, 2011)*.

Erect Formulae:

- **Goecke 1: EV= 90X**

Where EV= estimated effusion volume (mL), X= craniocaudal extent of the effusion at the dorsolateral chest wall measured in erect position (cm) with the probe oriented longitudinally *(Mathis, 2011)*.

- **Goecke 2: EV= 70(X+LDD)**

Where EV= estimated effusion volume (mL), X= craniocaudal extent of the effusion at the dorsolateral chest wall measured in the erect position (cm), LDD= lung base to mid-diaphragm distance (subpulmonary height of the effusion) (cm), with the probe oriented longitudinally *(Mathis, 2011)*.

Thoracocentesis was then performed under ultrasound guidance, either through simple aspiration, or via insertion of a 28-Fr chest tube (Polymed, Argyle, India) into the mid-axillary line through the fourth or fifth intercostal spaces and connected to underwater seal drainage system. Total lung expansion and complete drainage was confirmed by plain chest radiography and U/S.

Statistical analysis:

Data were collected, coded, revised, verified and computerized. Statistical analysis of data was performed using Statistical Package for the Social Sciences (SPSS) version 15 (IBM, Corp, Chicago, IL, USA). Quantitative data were expressed as range, mean ± standard deviation (SD), while qualitative data were expressed as frequency and percentage.

P-values ≤0.05 were considered significant. Kruskalwallis test was used to compare two or more groups and to study whether samples originate from the same distribution or not. While Pearson Correlation Coefficient tests (r) was used to study the degrees of correlation.

RESULTS

Forty patients were included in this study. The ages of patients ranged from 28 to 86 years old, with a mean age of58.9 ± 13.4 years. Among the study population 57.5% were males and 42.5% were females. In 60% of the patients the pleural effusion was right-sided, while in 40% the pleural effusion was left-sided.

Dyspnea was the most predominant symptom, it existed in 95% of all patients, 62.5% were suffering from chest pain, 50% had cough, 20% gave history of toxic symptoms and only 5% were presented by both hemoptysis and pressure manifestations due to huge mediastinal mass.

When assessing co-morbidities among the study population, hypertension was the most frequent co-morbidity, being existed in 27.5%. Diabetes mellitus, ischemic heart disease and chronic obstructive pulmonary disease (COPD) equally occupied the second rank with 17.5% for each, chronic kidney disease came after and presented in 10% and lastly chronic liver disease in 7.5% of patients.

The supine formulae calculated results showed excellent (very high) correlations with the drained pleural fluid volume, with r= 0.9607 and 0.9602 for Eibenberger and Balik formulae respectively (p-value <0.0001). On the other side, the erect formulae estimated volumes were found to have reasonable (good) correlations with the drained volume, with r= 0.4017 (p-value= 0.0102) and 0.5729 (p-value <0.0001) for Goecke1 and Goecke 2 respectively **(Table 1)**.

Table (1): Correlations of estimated pleural fluid volumes calculated by studied formulaewith the actually drained fluid volume

Correlations / Formulae	(r)	p-value
Eibenberger vs Actual	**0.9607**	**<0.0001**
Balikvs Actual	**0.9602**	**<0.0001**
Goecke 1 vs Actual	**0.4017**	**0.0102**
Goecke 2 vs Actual	**0.5729**	**<0.0001**

(r): Pearson Correlation Coefficient, vs: versus.

The mean estimated pleural fluid volumes by the supine formulae were 2190.8 ± 860.4 and 1273.2 ± 360.8 mL for Eibenberger and Balik respectively, while those calculated using the erect formulae were 1066.8 ± 304.2 and 1371.4 ± 350.6 mL for Goecke1 and Goecke 2 respectively. There were statistically significant differences (p-values <0.0001) between all the means calculated by the formulae in one hand and the mean of actually drained pleural fluid volume (2322.5 ± 867.9 mL) in the other hand **(Table 2)**.

Table (2): Comparison of the estimated pleural fluid volumes calculated by studied formulaewith the actually drained fluid volume

Formula / Volume	Actual (N= 40)	Goecke1 (N= 40)	Goecke2 (N= 40)	Balik (N= 40)	Eibenberger (N= 40)	KW	P-value
Mean	2322.5	591.9	928.7	1273.2	2190.8	134.3	<0.001
±SD	867.9	168.3	220.9	360.8	860.4		

KW: Kruskal Wallis Test.

DISCUSSION

Many authors developed sonographic methods for the volumetric quantification of pleural effusions in either supine or erect positions *(Teichgräber and Hackbarth, 2018)*.

The current work studied the accuracy of four of these methods in comparison to the actually drained volume. These 4 formulae were chosen for evaluation because they can be performed easily and quickly, making them helpful in routine clinical applications *(Mathis, 2011)*.

The findings we get coincide with the strong correlation between Eibenberger and Balik formulae in one hand and the actually drained pleural fluid volume in the other hand obtained by Vetrugno and Bove *(Vetrugno and Bove, 2018)*.

On the other side, these results oppose those obtained by a recent study, in which the erect formulae were more correlated with the drained volume *(Ibitoye et al., 2018)*. Despite that, in the same study Balik and Eibenberger equations showed good correlation with the actually drained fluid volume.

The correlation coefficients of the supine formulae reported in the current study are higher than that recorded by the study of *(Usta et al., 2010)*, which included patients with post-operative pleural effusion secondary to cardiac surgery, and depended on a different modified equation (V= 16D), in which (V) is the totally drained pleural fluid volume and (D) is the maximum distance between lung base and the centre of the diaphragm while patient in supine position.

A rough method of quantification was followed, and effusions were classified into small, moderate and large according to the number of intercostal spaces (ICSs) at which the effusion could be detected by the U/S probe starting from the costophrenic angle; small (one ICS), moderate (2-3 ICS) and large (≥4 ICSs). Small effusions were<500 mL, moderate effusions 500-1000 mL and large effusions >1000 mL *(Brockelsby et al., 2016)*.

Ibitoye et al., (2018) reported that Eibenberger formula the most accurate of the 4 studied formulae in predicting the volume of pleural effusion, with a non-significant difference between the volume of fluid calculated using Eibenberger formula and the actually drained fluid volume. Pleural fluid volumes calculated by other formulae showed a statistically significant under-estimation when compared with the truely drained volume.

In contrary to the current study, *Mathis, (2011)* reported an observation about considerable underestimation of the volume calculated using Eibenberger formula in relation to the real volume, especially in those with large thoracic cavities. Other limitations of Eibenberger formula include diaphragmatic elevation and the effect of the lung parenchymal status on the shape of the pleural fluid, i.e. poorly aerated/collapsed lower lobe will mostly displace underlying pleural fluid, thus yielding a smaller estimated volume than the actual volume.

Our results mismatch with those of a previous compartive study included 5 equations; (Goecke 1, Goecke 2 and Balik), in addition to another 2 equations; one of them is that moduled by *Usta et al. (2010)*, and the last one is a modification of Goecke 1 formula by replacing the factor 90 by 100 rendering it EV= 100X. This study concluded that Goecke 2 equation is the most accurate in estimating the volume of pleural fluid among the studied equations, with an intra-class correlation coefficient (ICC) equals 0.83, while the modified Goecke 1 formula (EV= 100X) is the simplest to calculate, with a nearby ICC (0.79). However, this disparity between their results and ours may be attributed to differences in the measurement landmarks used to derive sonographic estimates *(Hassan et al., 2017)*.

CONCLUSION

All studied formulae showed good correlations with the actually drained volume, but supine formulae were the best to do that.

REFERENCES

1. **Brockelsby C, Ahmed M and Gautam M (2016):** Pleural disease assessment and outcome (Pleural effusion size estimation: U/S, CXR or CT? Thorax; 3: A1-A288.
2. **Cerquitella M, Saccomandi P, Schena E, Silvestri S, Scarlata S and Giua R (2016):** Ultrasound estimation of pleural effusion in geriatric patients. In: IEEE International Symposium on Medical Measurements and Applications (MeMeA), 15-18.
3. **Hassan M, Rizk R, Essam H and Abouelnour A (2017):** Validation of equations for pleural effusion volume estimation by ultrasonography. J Ultrasound, 20: 267-271.
4. **Ibitoye BO, IdowuBM, Ogunrombi AB and Afolabi BI (2018):** Ultrasonographic quantification of pleural effusion: comparison of four formulae. Ultrasonography; 37(3): 254-260.
5. **Lichtenstein D (2017):** Novel approaches to ultrasonography of the lung and pleural space: where are we now? Breathe; 13: 100-111.
6. **Light RW (2013):** Pleural diseases. 6th ed.Pbl.Philadelphia, PA: Lippincott Williams &Wilkins., 126-129.
7. **Mathis G (2011):** Pleura. In: Mathis G, ed. Chest sonography. 3rd ed. Pbl.Heidelberg: Springer-Verlag., 30-32.
8. **Mercer RM, Psallidas I and Rahman NM (2017):** Ultrasound in the management of pleural disease. Expert Rev Respir Med.; 11: 323-331.
9. **Müller MC,Arbous MS and Spoelstra-de Man (2015):** Transfusion of fresh-frozen plasma in critically ill patients with a coagulopathy before invasive procedures: a randomized clinical trial (CME). Transfusion, 55(1): 26-35.
10. **Teichgräber UK and Hackbarth J (2018):** Sonographic bedside quantification of pleural effusion compared to compute tomography volumetry in ICU patients. Ultrasound Int Open, 4(4): E131-E135.
11. **Usta E, Mustafi M and Ziemer G (2010):** Ultrasound estimation of volume of postoperative pleural effusion in cardiac surgery patients. Interact CariovascThorac Surg.; 10: 204-207.
12. **Vetrugno L and Bove T (2018):** Lung ultrasound estimation of pleural effusion fluid and the importance of patient position. Ann. Intensive Care; 8: 125.

دراسة مقارنة لمختلف معادلات القياس الكمى لمقدار الانصباب البللورى باستخدام الموجات فوق الصوتية

محمد صبري أحمد أمين, أبو بكر هلال الأسمر, حسام الدين حسنين عبدالنبي

قسم الأمراض الصدرية, كلية الطب, جامعة الأزهر, القاهرة

E-mail: mohamed.sabri.1992@gmail.com

خلفية البحث: قد ينشأ الانصباب البللوري عن مرض رئوي أساسيّ, وقد يكون مظهراً بللورياً لعدد غفير من الأمراض التي تصيب الأعضاء الأخرى أوليًّاً. ويعد التقييم الكمِّي للانصباب البللوري ذو أهمية كبيرة في الممارسة الإكلينيية, نظراً لدوره في توجيه خطة المناجزة, كما تعتبر تقنية الموجات فوق الصوتية أحد الوسائل المجدية غير الباضعة لتحقيق ذلك.

هدف البحث: تحديد مدى الارتباط بين حجم السائل البللوري المقدَّر بواسطة تقنية الموجات فوق الصوتية باستخدام المعادلات محل الدراسة, والحجم الفعلي للانصباب البللوري المزاح, فضلاً عن تحديد المعادلة الأكثر دقة في التقدير الكمِّي لحجم السائل البللوري.

المرضى وطريقة البحث: أجريت هذه الدراسة المستعرِضة الاستباقية بقسم الأمراض الصدرية بمستشفى باب الشعرية الجامعي خلال الفترة من أكتوبر 2019 وحتى سبتمبر 2020, وشملت أربعين مريضاً, تم تشخيصهم إكلينيكياً وشُعاعياً كحالات انصباب بللوري, حيث تم تقدير كمية الانصباب البللوري بواسطة تقنية الموجات فوق الصوتية باستخدام أربع معادلات مختلفة, ثم تلا ذلك نزح السائل البللوري كلياً, عن طريق الشفط البسيط أو بتركيب أنبوب صدري. وأخيراً تمت مقارنة أحجام السائل البللوري المقدرة بواسطة المعادلات بالحجم المزاح فعليًّاً.

نتائج البحث: أظهرت الدراسة ارتباطاً مرتفعاً للغاية بين معادلتي وضعية الاستلقاء وحجم السائل البللوري المزاح, حيث بلغ معامل ارتباط (بيرسون) 0.9607 و0.9602 لمعادلتي (إيبينبرجر) و(باليك) على الترتيب. وعلى الجانب الأخر فقد أبدت معادلتا وضعية الجلوس المعتدل ارتباطاً مُقنِعاً مع حجم السائل

المـــــزاح, حيـــــث بلــــغ معامـــــل ارتبــــاط (بيرســـــون) 0.4017 و0.5729 لمعـــــادلتي (جويـــك1) و(جويـــك2) علـــى الترتيـــب. وقـــد أخفقـــت كـــل معـــادلات الدراســـة فـــي بلـــوغ التقيـــيم الكمِّـــي الـــدقيق لحجـــم الانصـــباب البللـــوري, باســـتثناء معادلـــة (إيبينبرجـــر) والتـــي تجلـــت عـــن فـــارق إحصـــائي غيـــر ذي أهميـــة عنـــد المقارنـــة بـــين حجـــم الســـائل المُقـــدَّر بواسطتها والحجم الفعلي للسائل المزاح (p= 0.4973).

الاســـتنتاج: أظهـــرت المعـــادلات الأربـــع ارتباطـــاً جيـــداً بحجـــم الســـائل المـــزاح, وإن كانـــت معادلتـــا وضـــعية الاســـتلقاء تتفوقـــان فـــي ذلـــك الارتبـــاط. تعـــد معادلـــة (إيبينبرجـــر) المعادلة الأمثل في التقدير الكمِّي لحجم السائل البللوري.

الكلمات الدالة: الانصباب البللورى, الموجات فوق الصوتية, التقدير الكمى.