Literature Review

Calculation of Pleural Fluid Estimation Using Ultrasonography

Adityo Wibowo*, Mia Elhidsi, Agus Dwi Susanto

Department of Pulmonology and Respiratory Medicine Faculty of Medicine, Universitas Indonesia, Persahabatan National Respiratory Referral Hospital, Jakarta

Corresponding Author:
Aditya Wibowo | Department of Pulmonology and Respiratory Medicine Faculty of Medicine, Universitas Universitas Indonesia, Persahabatan National Respiratory Referral Hospital, Jakarta | aditpulmo@gmail.com

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Abstract

Pleural effusion is an abnormal accumulation of fluid in the pleural space due to an imbalance in increased pleural fluid production and decreased absorption. An ultrasound device can be used to guide the procedure to evacuate the pleural effusion fluid, increasing the procedure's accuracy and lowering the risk of complications. Several calculation methods can be used to calculate the volume of fluid in both an upright sitting position and a supine position. Ultrasound is nearly 100% more accurate than chest X-ray in detecting pleural fluid.

Keywords: pleural effusion, ultrasound, diagnostic

INTRODUCTION

Pleural effusion is an abnormal accumulation of fluid in the pleural space caused by increased pleural fluid production and decreased absorption. Pleural effusion is a secondary effect of other diseases, with an estimated incidence of 320 cases per 100,000 people worldwide. Data collected at Kariadi Hospital Semarang in 2002 discovered an incidence of 12 cases with various different causes.[1,2]

Another study at H. Adam Malik General Hospital Medan in 2011 found a total of 136 cases, and Persahabatan Hospital Jakarta found 229 cases of pleural effusion within three years of research. According to the most recent research at Sanglah Hospital Denpasar, there were approximately 107 cases of pleural effusion caused by infectious and non-infectious diseases.[1,2]

The evacuation of pleural effusion can be guided using ultrasound (USG) as a supplementary assessment to reduce the incidence of complications by 70-80%. Complications can range from minor to fatal, such as bleeding, tearing of the the intrathoracic organs, and pneumothorax.[3,4]

Calculating the estimated effusion volume is also useful for determining whether fluid evacuation should be done through a puncture, a chest tube, or simply through the use of medications.[3,4] To determine the quantity of pleural fluid, several published calculating techniques may be used.[5,6]

OVERVIEW OF THORACIC ULTRASOUND IN PLEURAL EFFUSION

Ultrasound is generally more sensitive than chest X-ray in detecting pleural fluid. When compared to an upright chest X-ray, the minimal amount of fluid that can be detected by ultrasound is 100 percent more accurate, with a fluid amount of only 5 ml. The benefits of using ultrasound include the fact that it does not emit radiation and that it allows the patient to be examined while still in bed. Another important function of ultrasound is to serve as a guide in performing punctures, biopsies, and markers in order to create a pleuroscopy pathway.[4–6]

Pleural effusion images on ultrasound can be classified into several types, including anechoic effusion, which appears as a black image on the screen because it lacks certain components, or simple effusion. An echogenic effusion, on the other hand, produces a floating reflected image as well as a gray or white screen image. This image represents the amount of protein, fibrin, blood, or pus that moves with each heartbeat. The last is complicated effusions, which are recognizable as fibrin threads that form bonds and cause fluid to collect in distinct sacs.[7,8]

On thoracic ultrasound, normal lung features range from three main points that appear on examination, namely lung sliding, lung pulse, and curtain effect. The friction between the parietal and visceral pleura causes lung sliding. Loss of the lung sliding feature is common in cases of pneumothorax, post-pleurodesis, or malignancy infiltrating the lung. A lung pulse is a rhythmic movement of the visceral pleura caused by motions from the beating heart, which is more noticeable in a collapsed lung. While the image of a healthy diaphragm appears as a white line that limits the thoracic cavity and abdominal organs in normal lungs, breathing movements cause the lungs to move up and down, covering the boundaries of the diaphragm line as if it were a curtain, a phenomenon called the "curtain effect".[7]

There are two methods for performing ultrasound in effusion examinations: brightness mode (B-mode) and motion mode (M-mode). Brightness mode, also known as B-mode, is a type of thoracic ultrasound examination that looks at the sound waves produced by the probe and reflected back by the organs in the thoracic cavity. The M-mode examination is a method for observing the movement of an organ in the thoracic cavity that has been adjusted for time. It is commonly used in cases of pneumothorax.[9,10]

The sitting position measurement method must be performed in an upright position forming a 90-degree angle. The probe's position should form a longitudinal line along the chest wall. The fluid was measured on the dorsolateral side of the intercostal space while the probe was upright. The examination is performed at maximum inspiration, and images for measurement are recorded while the patient holds his breath. The probe's position should not be flat or at an angle, as this will cause the liquid's size to appear larger.[4]

CALCULATION OF PLEURAL FLUID VOLUME IN SITTING POSITION

The fluid measurement method for the sitting position is ideally placed in the posterior axillary line. At the end of expiration, an overall ultrasound examination was performed in the posterior axillary line with a convex probe of 3-5 MHz. The distance between the visceral pleura and the chest wall (image 1B) and the distance between the lung base and the apex of the cupula diaphragm were used as parameter values (image 1C). The probe will be moved up and down from the intercostal space as a marker of the initial location of the detected pleural effusion.[11]

The formula for calculating fluid volume in an upright sitting position can be done using the Goecke 1 formula: $EV = H \times 90$. The estimated volume of effusion fluid (EV) was obtained from calculating the chest wall craniocaudal distance on the screen in centimeters (cm) multiplied by 90 as a constant (image 1B). The second formula that is most often used is Goecke 2: $EV= (H+D) \times 70$, which is the estimated effusion fluid (EV) resulting from the calculation of the chest wall craniocaudal distance on the screen in cm plus the lung's basal distance to the diaphragm's center (D) multiplied by 70 as a constant (image 1C). According to a study of 42 patients, the estimated amount of fluid compared to the drained fluid was closest to the Goecke 2, with a correlation coefficient of around 0.87.[4,11,12]

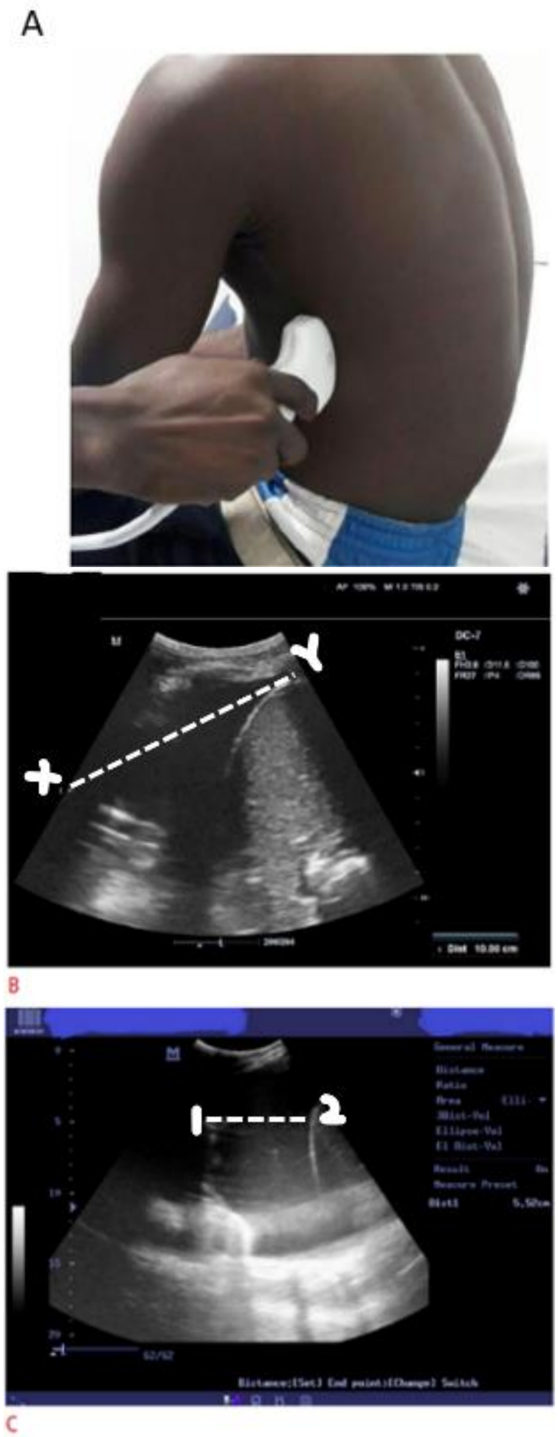

Image 1A: Patient in an upright sitting position and how to place the probe. 1B and 1C: Distance measurement of pleural effusion. **Goecke 1**: the distance between **(X)** the visceral pleura and **(Y)** the chest wall and **Goecke 2:** the distance between the base of the lung (1) and the apex of the cupula of the diaphragm/mid diaphragm (2).[4]

Due to the accumulation of fluid in the lower part of the thoracic cavity, formulas calculated in an upright sitting position are considered to be a better parameter in calculating the pleural fluid. The problem is that the amount of fluid is occasionally calculated to be greater than the exact volume.[4,11,12]

The USTA method, which calculated the volume of pleural effusion in patients who had undergone cardiac surgery, was the next study to calculate the volume of pleural fluid using the upright sitting method. On postoperative days 1, 3, 5, and 7, patients will have routine chest X-rays, and images on examination of the lateral position will be confirmed by ultrasound in patients with obtuse costostophrenic angles. In this study, the distance between the height of the upper limit and the mid-scapula was measured in an upright sitting position. The formula for fluid volume (ml) = (15.06 x D) + 21.45 is obtained by the distance D (mm) measured at the end of expiration as the distance between the mid-height of the diaphragm and the visceral pleura in a collapsed lung.[13]

The value of a simplified equation is then calculated in this study by multiplying the distance D by 16, as the formula for the approximate amount of liquid. There was no significant difference between the average calculation of the estimated fluid before the puncture and the actual amount of fluid after the puncture. Patients who have been taking vitamin K derivative drugs for about 12 hours will be subjected to a fluid evacuation procedure if their INR values are close to normal (2.0). With fluid volumes greater than 1000 ml, this formula may overestimate the fluid amount due to lower lobe atelectasis. Because this study only included patients with a distance D greater than 30 mm, the approximate value for the amount of fluid less than 500 ml could not be calculated accurately.[13]

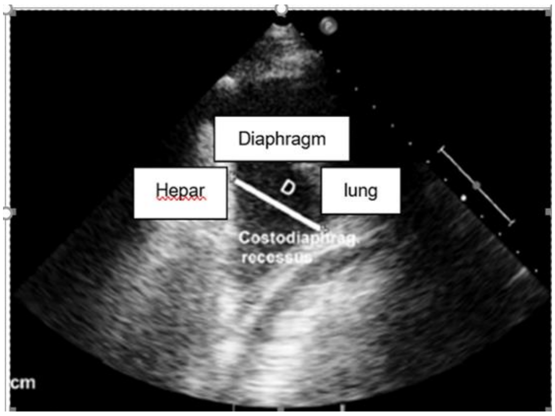

Image 2. Calculation of fluid volume using Usta method. D is the distance between the mid-diaphragm and the collapsed lung.[13]

CALCULATION OF PLEURAL FLUIDS VOLUME IN SUPINE POSITION

Fluid volume measurement can also be calculated in the supine position using several formulas. The first formula is Eibenberger: EV = (47.6 x (A)) - 837 which obtains an estimate of the volume of effusion in milliliters (ml) by measuring the perpendicular distance in millimeters (mm) of the lung surface to the posterior chest wall during maximum inspiration (image 3B) by placing the probe in a transverse position multiplied by 47.6 and the result is reduced by 837. The calculation of the pleural fluid volume in the supine position is often performed in patients who are unable to sit down properly. The free fluid will move towards the back and the lower side of the body, forming a sickle.[4,12,14]

The transverse ultrasound probe was placed in the posterior axillary line. According to studies, the predicted fluid volume on ultrasound has a significant correlation coefficient with a true figure of about 0.8 compared to a radiological reading of about 0.5. The effusion measured on an ultrasound screen at a depth of 20 mm has a mean value of around 380 ml and a standard deviation of 130 ml.[4,12,14]

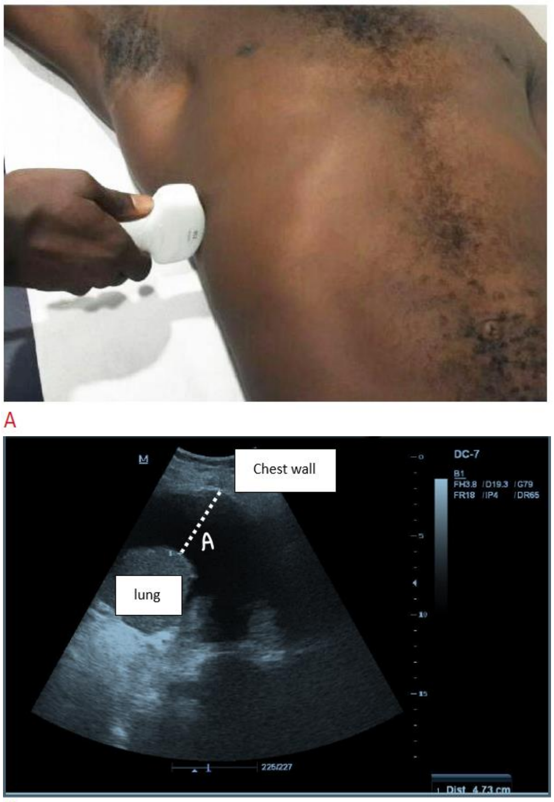

Image 3A**:** Patient in an supine position and how to place the probe. 3B**:** A line is a perpendicular distance between visceral pleura and parietal pleura in the chest wall.[4]

According to the formula calculation, an effusion depth of 40 mm yields an approximate volume of 1000 ml with a standard deviation of 330 ml. The predictive error value for ultrasound is estimated to be around 224 ml, as compared to 465 ml for chest X-ray. The ratio of the patient's thoracic cavity and the elevation of the diaphragm space affect this value, which can cause a deviation in the result.[4,12,14]

The Balik formula, EV = A x 20, is used to calculate the volume of pleural effusion by measuring the A value as the perpendicular distance between the lung surface (visceral pleura) and the chest wall (parietal pleura) at the end of expiration (in millimeters) multiplied by 20 by placing the probe in the transverse position. In comparison to the Einberger method, Balik's method is a relatively simple calculation. The correlation coefficient for both types of calculations is around 0.72.[15]

The study found that the values on the right and left sides of the chest differed significantly. Because the left side has a heart, the calculated volume of the left chest was closer to the actual volume after the fluid was removed. In the intensive care unit, Balik evaluated 81 patients. The study was limited to patients with pleural spaces greater than 10 mm, making the decision to take the fluid easier.[15]

Vignon had performed a study to determine the approximate fluid content of the pleural space. He had compared two methods for calculating pleural fluid volume. The first formula used (depth of pleural effusion) 2 x effusion height from upper to lower limit, and the second formula used (maximum cross-sectional area) x effusion height from upper to lower border. The research weaknesses were the difficulty in determining the size of the effusion and the small examination area in the intercostal space. This study also discovered a simple formula for calculating fluid volume by calculating that the effusion width greater than 45 mm in the right hemithorax and greater than 50 mm in the left hemithorax equals the actual amount of fluid, which is approximately >800 ml. The study's limitation is that it only collects pleural fluid from patients with an interpleural distance of 25 mm or greater, so fluid volume cannot be calculated in cases with smaller distances. In addition, no other examinations were used in this study to compare the estimated pleural fluid volume.[16]

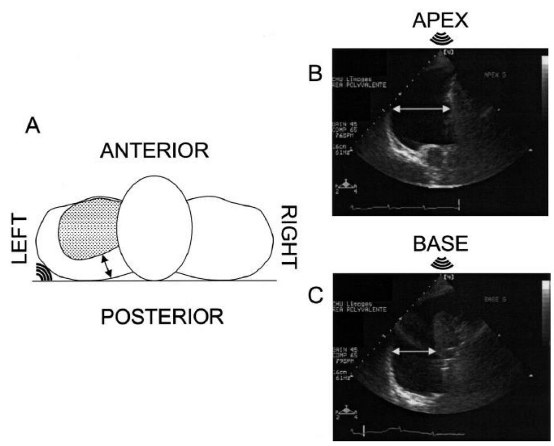

Image 4. Calculation of fluid volume by the Vignon method. (A) the patient at supine position with the probe placed on the right dorsolateral position, (B) The interpleural distance at the lung apex, (C) The interpleural distance at the lung bases (arrows distance was calculated at the end of expiration).[16]

The next calculation method for pleural effusion in the supine position is the Roch method, which is mostly performed on patients in intensive care. In this study, the ultrasound probe was attached to the posterior axillary line between the ninth and eleventh ribs to see the diaphragm, and then the probe was moved up to see the position of the fluid. The fluid was characterized by the appearance of an anechoic image above the diaphragm. The fluid image is limited by the parietal pleural layer on the surface and the visceral pleura on the inside. Identification of the lung image behind the fluid and breath movements will change the interpleural distance. The measurement of fluid volume will be carried out at the end of expiration and the measurement distance that is used as a benchmark is divided into three types, namely lung-diaphragm (LD), posterior chest-lung distance (PLD) and posterior chest-lung distance in the 5th intercostal space (PLD5).[17]

The lung-diaphragm distance was taken on a longitudinal image with the probe placed on the chest wall at the posterior axillary line, then the distance between lung thickness and diaphragm was marked as the diaphragm lung distance (LD). The distance between the lung and the posterior chest wall at the lung bases was measured when the lower side of the lung was visible. The probe was placed 30 mm above it and the probe was rotated 90°.[17]

The image of the effusion was seen as a convex shape between the chest wall and the lung. The anteroposterior size between the lung and the lower posterior chest wall was marked as (PLD). The distance between the lung and the chest wall in the fifth intercostal space was measured by the transverse position, i.e., the anteroposterior thickness of the fluid in the chest wall to the lung was assessed as PLD5.[17]

Calculations with PLD and PLD5 have a significant correlation with the actual volume of the fluid between 0.56-0.68 while in the LD distance the value was only 0.24 because LD images would not always appear in patients even though the fluid volume was more than 1200 ml. This condition was mostly caused by the tendency of the fluid to occupy the lowest chest wall position in the posterior. PLD distance can be used to predict the amount of pleural fluid more than 500 ml if the distance was >5 cm with the positive predictive value >90%.[17]

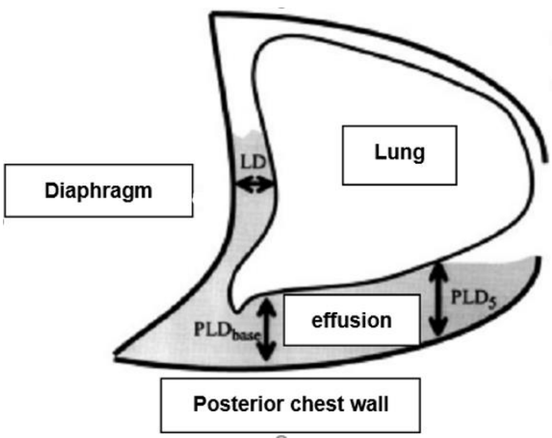

Image 5. Formula calculated by Roch method. LD: Lung-diaphragm; PLDbase: posterior chest-lung distance; PLD5: posterior chest-lung distance at 5th intercostal space.[17]

Pleural effusions in supine position can also be calculated by the formula found by Remerand et al This study found that the symptoms were not only due to the amount of fluid but also affected by the patient's height, weight, and the shape of the thoracic cavity. The measurement was made using the formula for the depth of the median (A) point multiplied by the height of the upper and lower limits of fluid (L), then the results were compared with the estimated fluid in the thorax CT scan image. The correlation value between the estimated fluid on ultrasound and the actual amount of fluid after the evacuation was about 0.84. This measurement method had some weaknesses. The first was the difference in fluid volume that can appear when the probe is placed in the different intercostal regions. The next problem was that this formula was difficult to calculate the volume of fluid in massive pleural effusion due to the scapula shadow, which would cause not all of the fluid to be seen on the monitor.[18]

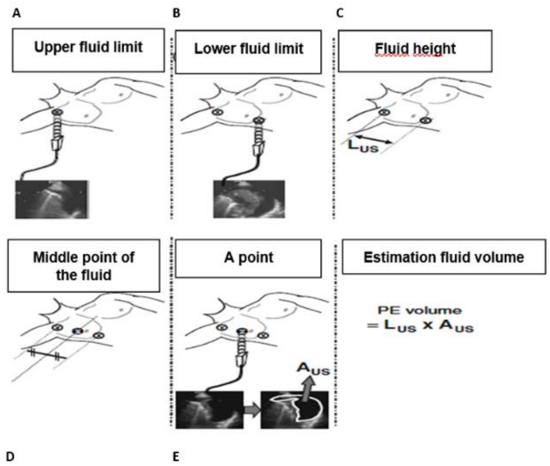

Image 6. Calculating fluid with the Remerand method. (A) and (B) the upper and lower limits of the liquid, (C) the location of Lus i.e. the distance between A and B. (D) and (E) the midpoint to determine the location of Aus. PE: pleural effusion, Lus: the height of the upper and lower limits of fluid, Aus: the area of the midpoint of the fluid that appears on the screen.[18]

CONCLUSION

Ultrasound is a valuable tool in detecting pleural effusion. Fluid volume measurement can be performed in an upright sitting position or a supine position. The Goecke calculation formula in upright sitting has the predictive value closest to the actual volume of the fluid. Calculation in the supine position using the

Balik method has the most accurate volume to calculate the pleural fluid volume.

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