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Ultrasonography of pleural effusion: the quantification of minimal detectable volume

Alan Šustić[1], Igor Medved[2], Dražen Kovač[3], Nikola Ivaniš[4], Darko Ekl[2], Ognjen Šimić[2]

[1]Dept. of Anaesthesiology and ICU, [2]Dept. of Surgery, [3]Dept. of Pathology, University Hospital Rijeka, Croatia, [4]Private ultrasound laboratory, Rijeka, Croatia

Background. *The aim of this study was to establish a minimal volume of free thoracic fluid in the pleural space of the supine cadaver detectable by ultrasonography.*
Material and methods. *A prospective study with an experimental model on 20 cadavers (10 male, 10 female; age 66 ±11 yr.; height 172 ±9 cm; weight 75 ±12.6 kg; body surface area (BSA) 1.87 ±0.2 m^2) was used. Each cadaver was punctured bilaterally in 5th or 6th intercostal space at the medioclavicular line with venous cannula infusing in NaCl 0,9% solution at randomised speed in the chest. During the procedure the laterodorsal part of the thoracic wall next to the pulmonal base and phrenicocostal sinus was ultrasonographically scanned. At the moment of the visualisation of anechogenic line pertaining to the free fluid between dorsal thoracic wall and lungs, the installation was stopped and the amount of injected fluid verified.*
Results*. Minimal, by ultrasonography detectable amount of free fluid in the right pleural space was 223±52 ml with the significant positive correlation to height ($r = 0.69$; $p < 0.001$), weight ($r = 0.68$; $p < 0.01$) and the BSA ($r = 0.71$; $p < 0.001$) of cadaver. Detectable volume in the left pleural space was notably smaller than contra lateral, namely 172±53 ml also with a significant correlation to the cadaver's height ($r = 0.55$; $p < 0.05$), weight ($r = 0.59$; $p < 0.01$) and BSA ($r = 0.60$; $p < 0.01$).*
Conclusions. *The authors affirm that ultrasonographically detectable quantity of free fluid in the chest positively correlates with height, weight and BSA of cadavers, and that the measured amount in the supine position is approximately 223 ml for the right space versus 172 ml for the left pleural space.*

Key words: pleural effusion, ultrasonography, quantification.

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Correspondence to: Alan Šustić, M.D., Ph.D., Dept. of Anaesthesiology and ICU, Clinical Hospital Rijeka, T. Strižića 3, Rijeka 51000, Croatia. Phone: + 385 51 21 84 07; Fax: + 385 51 21 84 07, E-mail: alan.sustic@mamed.medri.hr

Introduction

The diagnosis of pleural effusion in critically ill patients frequently presents a serious problem. Transportation risks, the uncoordinated co-operation and difficulties in adequate positioning of those patients in the intensive care unit (ICU) make radiological methods often inadequate or unperformable.[1,2] Ultrasonography provides a rapid, convenient, economic and bedside method for detecting pleural effusion in supine patients.[3-6] Meanwhile, there are no data in the pertinent literature, which could suggest what the minimal is, by ultrasonography detectable fluid volume in the pleural space. The aim of our study was to establish the smallest, by ultrasonography visible amounts of fluid in the cadaver (human body) in the supine position.

Materials and methods

An experimental model with 20 cadavers (10 male and 10 female; age 66 ±11 yr.; height 172 ±9 cm; weight 75 ±12.6 kg; body surface area (BSA) 1.87 ± 0.2 m^2) was used. Each cadaver was punctured bilaterally in 5^{th} or 6^{th} intercostal space at the medioclavicular line with venous cannula (1.5 mm x 44 mm; maximal possible flow of 142 ml/min) infusing in the pleural space NaCl 0.9% solution at randomised speed. During the whole procedure the laterodorsal part of the thoracic wall next to the pulmonal base and phrenicocostal sinus was ultrasonographically scanned. The lungs of the cadavers were not insuflated. At the moment of the first visualisation of anechogenic line pertaining to the free fluid between the dorsal thoracic wall and lungs, the installation was stopped and the amount of injected fluid verified. All cadavers were examined in the supine position by the same physician using portable scanner Hitachi 405 EUB with a 3.5/5 MHz narrow convex transducer (Hitachi Medical Corporation, Tokyo, Japan). The ultrasonographer was not previously informed about the chosen velocity of infusion flow and the volume infused. Average minimal detectable quantity of fluid in the left and right hemi thorax was compared and correlated with height, weight and BSA of each cadaver. A statistical method was Mann-Whitney U test and Pearson's moment of correlation.

Results

Minimal, by ultrasonography detectable amount of free fluid in the right pleural space was 223 ± 52 ml (range: 105 - 295 ml) with significant positive correlation to height ($r = 0.6849$; $p < 0.001$), weight ($r = 0.6799$; $p < 0.01$) and the BSA (Figure 1) of cadaver ($r = 0.7075$; $p < 0.001$). Minimal detected volume in the left pleural space was notably smaller ($p < 0.001$) than contra lateral, namely 172 ±53 ml (range: 80 - 240 ml) also with a significant correlation to the cadaver's height ($r = 0.5532$; $p < 0.05$), weight ($r = 0.5886$; $p < 0.01$) and BSA ($r = 0.6042$; $p < 0.01$) (Figure 2).

Discussion

The clinical routine in the diagnosis of pleural effusions uses a conventional posterior to anterior (PA) chest radiography in the erect or high sitting position (≥45°) or a lateral decubitus radiography (LDR) where patients are in lying position. Both radiographic methods in standard hospital conditions have satisfac-

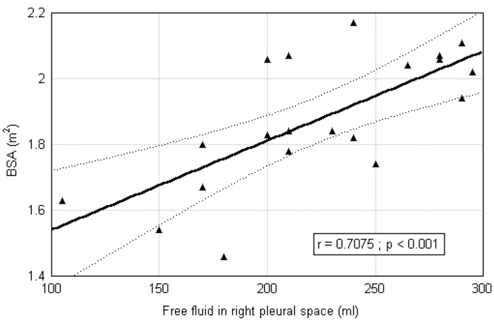

Figure 1. Correlation between the cadavers body surface area (BSA) and minimal, by ultrasonography detectable amount of free fluid in the right pleural space. Solid line: regression line; dotted lines, 95% confidence interval.

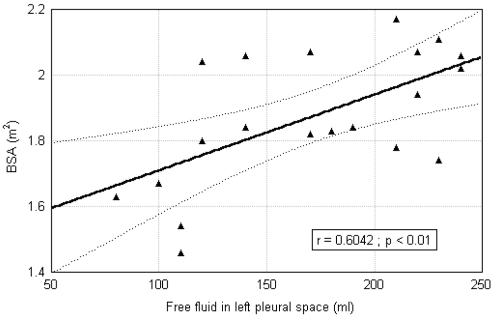

Figure 2. Correlation between the cadavers body surface area (BSA) and minimal, by ultrasonography detectable amount of free fluid in the left pleural space. Solid line: regression line; dotted lines, 95% confidence interval.

tory accuracy, however, in the ICU setting where the quality of radiograph is sub optimal and where adequate positioning of the patient is impossible, the sensitivity of those methods in the detection of minor effusions is not convincing.[1,2] A computed tomography is often used in the diagnosis of pleural effusions (quantitative and qualitative), but it is connected with the transport of patients from ICU and is not always available in all hospitals.[1,2]

Recently, ultrasonography has been recognised as a superior method in the diagnostics of pleural effusions in the supine position, particularly in critically ill ICU or trauma patients.[4-6]

In the presented study, average minimal, by ultrasonography detectable, fluid volume in the right pleural space was 223 ml, while the mean volume of fluid in the left pleural space was 172 ml. Such discrepancy is probably due to the position of cardiac massive, which is situated predominately in the left hemithorax. Classic anatomical studies confirm that the transversal diameter of the lung base is significantly smaller on the left side (7-9 cm left *vs.* 10-13 cm right); that the left lung is smaller than the right and consequently, the overall volume of the left hemithorax is smaller than the overall volume of the right hemithorax.[7] It follows that the required quantity of pleural fluid necessary for the ultrasonographic visualisation in the left thorax is much smaller than on the right side.

In the study a statistically significant correlation between the minimal detectable volume of pleural effusion and cadaver's height, weight and BSA was demonstrated.

It is logical to presume that in more corpulent patients with greater BSA more liquid will be needed to diagnosticate pleural effusion by ultrasonography. It is important to point out the great variability in the amount of minimal detectable fluid in the thorax between cadavers varying from 160 ml on the left side to over 190 ml on the right side. Such large range together with a significant correlation between a minimal detectable volume of fluid in the thorax and cadaver's height, weight and BSA, shows that in clinical preconditions negative ultrasound findings do not exclude the presence of a small pleural effusion. Such findings should be interpreted in the context of all available information about the patient's habitus.

However, this study has an important deficiency. First, data of a cadaver study cannot be quite transferable to the clinical examination of patients (respiratory effects, lung compliance, etc.). Furthermore, in clinical conditions it is usually possible to position a patient to a half-sitting position. It is presumable that such movement, difficult to perform on cadavers, could influence on the delectability of fluids.

On the basis of the results from the experimental, cadaveric model it can be concluded that ultrasonography enables the visualisation of relatively small amount of pleural fluid in patients in the supine position, but negative finding does not exclude minimal effusion.

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