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Ultrasonographic Forms of Pleural Space in Healthy Children

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A B S T R A C T

This prospective study was conducted to detect physiological pleural fluid using chest ultrasonography in healthy children, to assess frequency of this finding, to check the general status of pleural space and to describe possible individual variations of the amount of pleural fluid present in healthy children. Chest ultrasonography of both pleural spaces was performed in a group of 100 randomly selected healthy children, searching for pleural fluid. Children were examined in the elbow position after leaning five minutes in lateral decubitus position. Ultrasonographic images were acquired with a 3–12 MHz linear transducer. The presence of the fluid was assessed and measured as an anechoic layer exceeding at least 2 mm in thickness. The study was repeated on each subject after a time interval of one to two months. Fluid was quantified and compared intraindividually using student t-test. Presence of pleural fluid was found in 35/100 healthy children (35%) in both the baseline study and the follow-up study. Only two children had different results at follow up. In case of a positive finding, the fluid was found in both, left and right pleural space in fourteen out of 35 children (40%). In the remaining 21 out of 35 (60%) children fluid was detected only in one pleural space. Thickness of the pleural fluid ranged from 2 mm to 3.4 mm (mean 2.4±0.3 mm) in the baseline group and from 2 mm to 3.7 mm (mean 2.5±0.4 mm) in the follow-up group. Overall pleural fluid was observed in 36 subjects with high reproducibility of 94% after delay of 1–2 month as 34 of them presented pleural fluid twice. Chest ultrasonography allows detecting small collections of pleural fluid in healthy children. The results of our study prove that the amount of physiologic pleural fluid is a stable individual characteristic of a healthy child. Such a positive result (less than 4 mm in the elbow position), if isolated, should be taken as normal finding, and requires no additional investigation.

Key words: *pleura, fluid, physiology, ultrasound, children*

Introduction

There are different data on the smallest amounts of physiologic fluid within a pleural space that can be detected with computed tomography, sonography or conventional X-ray examination in case of pathologic conditions (i.e. pleural effusions) of pleural space. However they are within the same broad range whether one or the other imaging modality is used[1–4]. As reported previously a small amount of liquid (5–20 mL) is present in the pleural space of healthy individuals[5]. Two recent studies[6,7] confirm that few millimeters of free pleural fluid can be visible at the level of phrenicocostal sinuses by chest ultrasonography in healthy adult individuals.

To our knowledge no data have been reported on imaging of physiological pleural fluid with chest ultrasonography in healthy children. Thus, the purpose of our study was conducted to determine prospectively the performance of ultrasonography for detecting physiological pleural fluid in healthy children and to assess the frequency and importance of this finding.

Materials and Methods

Prior to inclusion of the first child the Medical Ethics Committee of the Republic of Slovenia had approved this research study which was carried out according to good-clinical-practice guidelines. Written informed consent was obtained from accompanying parent prior to inclusion of the child in the study.

Between September 2006 and February 2007 one hundred children (40 males and 60 females, 3 to 15 years old, mean age 9.2 years, standard deviation 3.2 years)

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were included into this clinical study. All examined subjects were healthy according to medical history and short preceding physical examination.

Ultrasonography of both pleural spaces was performed in all individuals following a standard protocol. Initially, each individual was placed in lateral decubitus position for 5 minutes. Than the ultrasonographic (US) examination of the lower pleural space with the subject leaning on one elbow[6] (Figure 1) still in the lateral decubitus position, was performed. During the imaging performed by two experienced physicians (the author was one of them) it was searched for possible fluid accumulation with the probe along the mid-axillary line.

Fig. 1. Drawing shows the »elbow examination position« with the placement of the transducer during examination of the right pleural space.

Images were either acquired with an Envisor HD ultrasound scanner (Phillips, Best, The Netherlands) and a 3–12 MHz single element linear transducer or with a SSA-390 ultrasound scanner (Toshiba, Tokyo, Japan) and a 9–12 MHz linear transducer. The sonographic criterion for the presence of pleural fluid was defined as follows: detection of an anechoic zone present between the parietal and visceral pleura, with a cross-section thickness of at least 2 mm thick, with changing appearance in inspiration and expiration status and/or with varying appearances when moving during examination[2,6,8]. Maximum cross-section fluid thickness was measured during the examination with the position of the probe perpendicular to the thoracic wall. Examinations were performed by the two observers at random. Each subject underwent the follow-up study one to two months after the initial one. These subjects served as their own controls with quantitative measurements of the fluid.

Descriptive statistics were calculated for all the studied variables. Significant differences between mean pleural fluid thicknesses were tested using student t-test (for independent or paired samples, as appropriate). Group dependent presence of pleural fluid was compared using exact Mann-Whitney test. Correlation was assessed using Pearson's r. Difference in proportion was tested using Fisher's exact test, and classification agreement was assessed using Cohen Kappa statistic. Agreement was considered fair and good if κ values were between 0.40 and 0.75 and high if κ values were greater than 0.75.

Results

Results of descriptive statistics are listed in Table 1. We sonographically detected anechoic fluid layer in the pleural space in 35/100 children (35%) in both the baseline study as well as in the follow-up (control) study. Among those children with pleural fluid, the mean values of all fluid layer cross-section thickness measurements attained 2.4 mm (standard deviation SD 0.3 mm) in the baseline study. In the follow-up study the mean fluid layer thickness reached 2.5 mm (SD 0.4 mm). Overall fluid was observed in 36 different subjects, twice in 34 of them (94%) and once each in 2 different subjects (6%). In the baseline study, the fluid was observed bilaterally in 14/35 children (40%) and unilaterally in 21/35 children (60%), and the same proportion of bilaterally vs. unilaterally present fluid was observed at follow-up.

TABLE 1
DESCRPTIVE STATISTICS FOR PLEURAL FLUID LAYER THICKNESS

	Baseline study			Follow up study		
	NP	M	SD	NP	M	SD
Positive findings	35	2.4	0.3	35	2.5	0.4
of right pleural space	26	2.4	0.4	27	2.7	0.4
of left pleural space	23	2.3	0.2	22	2.3	0.3
unilaterally	21	2.4	0.4	21	2.4	0.5
bilaterally	14	2.3	0.2	14	2.6	0.3

NP – number of positive results, M – mean, SD – standard deviation

Maximum observed thickness was 3.4 in the baseline and 3.7 mm in the follow up study, respectively. When pooling positive data from both studies, we found the average fluid layer was statistically significantly thicker in the right pleural space then in the left pleural space ($p<0.001$). The difference in average fluid layer thickness between the two pleural spaces in children with unilaterally visible fluid was not statistically significant at baseline (*t*-test: $p=0.782$), but significantly thicker on the right side in this group in the follow up study (*t*-test: $p=0.004$). Moreover, the difference in mean fluid layer thickness (defined as within-subject average of all positive measurements from both studies) between the children with unilaterally and those with bilaterally visible fluid (at least in one of the studies) was not statistically significant (*t*-test: $p=0.890$).

We can conclude that the number of positive results is related to mean fluid layer thickness. The two children with fluid detected only in one study had values near the lower threshold limit with a mean of 2.1 mm (SD 0.1 mm). This differs significantly in comparison to the 34 children with fluid detected in both studies (mean 2.4 mm, SD 0.3 mm; exact Mann-Whitney test: p=0.038).

Since in the large majority of children fluid if present could be observed in both studies (94%), a high concordance of both studies follows with a Kappa coefficient of 0.956. Therefore, our measurement method is reliable and allows measuring pleural fluid in children. As expected, the difference between the averages (2.4 mm vs. 2.5 mm) were not statistically significant (paired student *t*-test: p=0.235). Mean difference within subjects for the two studies amounted –0.1 (SD 0.5, SE 0.1).

Fig. 2. Sonographic appearance of normal »dry pleural space«, examination of the right pleural space in elbow position. Narrow anechoic zone between the parietal (arrowheads) and visceral (arrows) pleura is normal, with no visible free fluid. L – liver.

Discussion

Physiological pleural fluid accumulation is sonographically habitually represented as a wedge-shaped echo free layer with the base orientated towards costophrenic angle[6] although both pleurae cross-sections and the space in between measure only 0.3 to 0.4 mm[4] (Figure 2). Ultrasonographic examination of the pleural space in elbow position which is proven to be useful when searching for small effusions[3] is also proven to demonstrate physiologic accumulation of pleural fluid in adults[6,7].

Recent investigations of Noppen and colleagues[9] undoubtedly confirmed that no more than about 18 ml of pleural fluid are usually persent in the pleural space cavity of healthy adult individual. In case of reduced amount the fluid is not free within the pleural space[10] and for that reason difficult to depict with ultrasonography. This was the case in around two thirds of our population consisting of healthy children with sonographically »dry pleural space«. In cases with somewhat more physiological pleural fluid it accumulates within the pleural cavity[10] at the sites such as the costodiaphragmatic sinuses, around the hila or lobar margins[10] improving sonographic visibility – actually defined as individuals with sonographically »wet pleural space«[10] (Figure 3a). Such condition we detected ultrasonographically in about one third of examined children In the examined child with so called »wet pleural space«, some pleural fluid first accumulates between lateral costal pleurae during the initial 5 minutes of leaning in a decubitus position. Such fluid tends to shift towards to lateral phrenicocostal sinus immediately after changing subject's decubitus position to elbow position and thus improving detectability since as such could be easily detected by the observer.

Some fine echoes seen within the pleural space are artifacts due to adjacent hyperechoic parietal and visceral pleura, but this limitation does not hamper diagnostic performance.

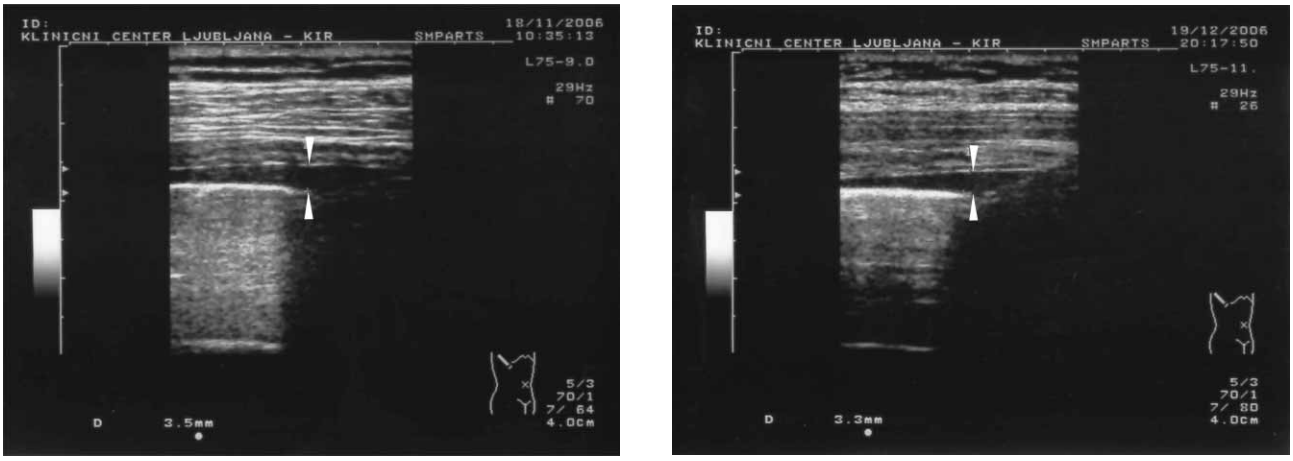

Fig. 3. Sonographic appearance of normal »wet pleural space«, examination of the right pleural space in elbow position. a) Baseline study showed typically wedge-shaped 3 mm thick fluid layer (between arrowheads.) b) In the follow-up study one month later a fluid layer (between arrowheads) of almost the same thickness was found.

In conclusion, the results of our clinical study demonstrate that free pleural fluid is often present in healthy children and is as a reproducible individual characteristic over longer time periods (1–2 months) in this population (Figure 3b). Moreover, in disagreement to adults, significantly more free pleural was observed on right side[11]. Compared to previous reported study results with adults[11–13] the mean cross-section thickness were about 1 mm smaller, what we expected.

It is obvious that ultrasonographic appearance of healthy children's pleural space is not uniform. As in adults[6] also in children it must be born in mind that there are at least two appearances and both normal. The relative high incidence of 35% pediatric subjects with present free pleural fluid should not be misinterpreted as a sign of the disease and there is no need to claim any additional diagnostic examinations to rule out the possible pathologic condition.

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ULTRAZVUČNI OBLICI PLEURALNOG PROSTORA KOD ZDRAVE DJECE

SAŽETAK

Ova prospektivna studija provedena je s ciljem da se pomoću ultrazvuka prikaže fiziološki prisutna pleuralna tekućina kod zdrave djece, da se procijeni učestalost prisutnosti tekućine u pleuralnom prostoru, prosječni obujam pleuralnog prostora te moguća individualna odstupanja u količini pleuralne tekućine kod zdrave djece. Ultrazvučni pregled oba pleuralna prostora, sa svrhom prikaza pleuralne tekućine, učinjen je u skupini od 100 nasumce izabrane zdrave djece. Djeca su pregledavana u položaju naslonjena na lakat, nakon što su pet minuta odležala u bočnom položaju. Korištena je linearna sonda frekvencije 3–12 MHz. Prisutnost tekućine ocjenjivala se i mjerila kao anehogeni sloj debljine od najmanje 2 mm. Svako dijete ponovo je pregledano nakon jedan do dva mjeseca. Količna tekućine ocjenjivala se i uspoređivala intraindividualno uporabom student t-testa. Pleuralna tekućina bila je prisutna kod 35/100 zdrave djece (35%) kod prvog, kao i kod ponovnog pregleda. Samo je dvoje djece imalo različit rezultat kod ponovnog pregleda. Kod 14 od 35 djece (40%) s pleuralnom tekućinom, ona je pronađena i u lijevom i u desnom pleuralnom prostoru, dok je kod ostalih 21/35 (60%) tekućina nađena samo u jednom pleuralnom prostoru. Debljina sloja pleuralne tekućine iznosila je od 2 mm do 3,4 mm (srednja vrijednost 2,4±0,3 mm) kod prvog pregleda te 2 mm do 3,7 mm (srednja vrijednost 2,5±0,4 mm) kod ponovnog pregleda. Ukupno je pleuralna tekućina uočena kod 36 djece, s visokom reproducibilnošću od 94%, jer je nakon 1–2 mjeseca pleuralna tekućina uočena i na ponovnom pregledu kod 34/ 36 djece. Ultrazvučni pregled prsnog koša omogućuje pronalaženje pleuralne tekućine kod zdrave djece. Rezultati ovog istraživanja pokazuju da je količina pleuralne tekućine stabilna individualna osobina zdravog djeteta. Stoga se ultrazvučni nalaz prisutnosti pleuralne tekućine debljine ispod 4 mm kod djeteta naslonjenog na lakat, ako se radi o izoliranom nalazu, može smatrati normalnim i ne zahtijeva dopunske pretrage.