Annals of Medical Research
DOI: 10.5455/annalsmedres.2019.01.077 2020;27(2):499-503

Original Article

Is Thorax ultrasound efficient in diagnosis and follow-up of childhood pneumonia?

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Abstract

Aim: Chest X-ray (CXR) is the first step imaging method for childhood pneumonia. However, radiation exposure is the main concern especially during follow-up due to increased risk for malignancies. Therefore, thorax ultrasound (TUS) has been used recently as a complementary method to assess lung diseases. We aim to show if TUS is a useful diagnostic tool in childhood pneumonia by comparing CXR findings.

Material and Methods: One hundred and twenty-four patients who presented with pneumonia (67 girls, 57 boys; mean age: 6.29±3.66 years) were prospectively included in our study. After the chest X-ray was performed for each patient, they underwent a TUS on the same day. Radiologists were blinded to any clinical data. Imaging findings were compared statistically.

Results: Of 124 patients (67 girls, 57 boys; mean age: 6.29±3.66 years), 79 patients (63.7%) had bacterial and 39 patients (31.45%) had viral pneumonia. The overall sensitivity of TUS was 86.06% for detecting pneumonia. There was not any statistical difference between TUS and CXR for identifying pneumonia on the bacterial subgroup (p=0.157). TUS was more efficient in recognizing bacterial pneumonia rather than viral pneumonia (Z sensitivity = 5.33>1.96).

Conclusion: The use of TUS for initial diagnosis and follow-up of childhood pneumonia should be considered as a complementary imaging method to CXR rather than a substitutive role. TUS is more useful in bacterial pneumonia rather than viral pneumonia by showing findings such as subpleural pneumonitis, consolidation, pleural and pericardial effusion, empyema and the response to the medical therapy.

Keywords: Viral pneumonia; bacterial pneumonia; childhood; Ultrasound; Chest X-ray

INTRODUCTION

Community-acquired pneumonia (CAP) is a common and potentially serious infection that afflicts children throughout the world (1). Viruses and bacteria are the main cause of infectious pneumonia in children: viral pneumonia is more common in the first years of life, while bacterial ones are more frequent in preschool and school-age. The most frequently involved viruses are the respiratory syncytial virus (RSV), influenza, parainfluenza, rhinovirus and the adenoviruses, while the most common bacteria are: Group B streptococcus, Escherichia coli and Enterobacteriaceae spp. in newborns; Streptococcus pneumonia, Staphylococcus aureus, and Haemophilus influenza in preschool age and Mycoplasma pneumonia and Chlamydia pneumonia in school-age (2,3). A Chest X-ray (CXR) is the primary diagnostic tool for both adults and children with positive physical examination or risk factors for CAP. (1). It is an easy, fast, and cheap imaging method. CXR is widely performed even in mild or non-complicated cases recently (2-4). Nevertheless, radiation exposure is a problem for children especially during follow-up due to increased risk for malignancies. Therefore, thorax ultrasound (TUS) has been used lately as a valid complementary method to assess lung diseases (5-14).

Received: 29.01.2020 **Accepted:** 27.02.2020 **Available online:** 09.03.2020
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In this study, we aim to show if TUS is a useful diagnostic tool in childhood pneumonia by comparing CXR findings.

MATERIAL and METHODS

One hundred and twenty-four patients who presented with pneumonia were prospectively included in our study. After CXR (PA and lateral) was performed, a TUS (GE Logiq S7 Expert, GE Healthcare USA; 1-6mHz Broad-spectrum convex transducer, 2-8mHZ Broad-spectrum linear matrix array transducer) by an experienced pediatric radiologist (S.B.G, 8-year experience in the field) without using any sedation on the same day for each patient. CXRs were interpreted by two radiologists (S.B.G and E.U (4-year experience). Radiologists were blinded to each other and any clinical data during CXR and TUS evaluation. Patients were grouped by clinicians into viral, bacterial and complicated pneumonia due to their physical and radiological examination, radiological and routine blood tests (2,3).

CXR

We grouped our findings as consolidation and infiltration for opacification of the lung parenchyma, air bronchogram for air-filled bronchi, pleural and pericardial effusion for opacification of pleural and pericardial space including sinuses ; atelectasis for opacified loss of lung volume; peribronchial cuffing as haziness or increased density around the walls of a bronchus or large bronchiole; diaphragm elevation for abnormal contour of the diaphragmatic; cavitation for thick-walled the abnormal air-filled spaces; abscess for air-fluid level; ground-glass opacity for haziness within the lung parenchyma; empyema for infected loculated pleural effusion on CXR (4), (see Table 1).

TUS

The chest was divided into six zones including anterior, lateral and posterior; upper, middle and lower zones. All patients were individually examined in a seated or half-seated or lateral decubitus position. The transducers were moved along the intercostal spaces back to front for axial scanning and longitudinally top to bottom for vertical scanning.

US findings were grouped as consolidation and infiltration for hypoechoic infiltration of the air spaces; air bronchogram for punctiform-to-linear echogenic foci within the consolidation; pleural and pericardial effusion for fluid within pleural and pericardial space; atelectasis for echogenic linear loss of lung volume; pleural irregularity / B lines for irregularity of the echogenic pleural line or thickened subpleural interlobular septae; diaphragm elevation for the abnormal contour of the diaphragmatic dome; cavitation for thick-walled abnormal air-filled spaces, abscess for air-fluid level; empyema for heterogeneous loculated pleural effusion on TUS (5), (see Table 1).

Patient Management and Follow-Up

40 patients were administered at hospital whereas 84 patients were ambulatory treated. Patients with CAP were received wide spectrum antibiotics based on the clinical guidelines (2, 3). The first follow-up TUS examination was performed after 5-10 days (n=85) and the second one was done after one month later (n=5) by S.B.G.

Statistical Analysis

Kolmogorov-Smirnov test was used for assessment for continuous variables, and results show that normal distribution in patients. Sensitivity was calculated for subgroups with Wilson Method in 95% confidential interval. McNemar's χ 2 test was used for correlation between CXR and TUS in paired groups. Two-sided values of $p< 0.05$ was statistically significant. Z statistics was used for comparison between independent subgroups sensitivity. Z value (0.05/2)>1.96 was statistically significant in 95% confidential interval. Kappa coefficient was used for interpretation of the agreement between radiologists (Turcosa Analytics Software.)

RESULTS

The evaluation of CXR was concordant in between two radiologists (S.B.G and E.U) (κ=0.95). Of 124 patients (67 girls, 57 boys; mean age: 6.29±3.66 years), 79 patients (63.7%) had bacterial and 39 patients (31.45%) had viral pneumonia. Five patients were diagnosed as complicated pneumonia and one patient had cyst hydatid. Four patients were negative on both CXR and TUS. The overall sensitivity of TUS was 86.06% for detecting pneumonia (Table 2). There was not any statistical difference between TUS and CXR for identifying pneumonia on the bacterial subgroup (p=0.157). TUS was more efficient in recognizing bacterial pneumonia rather than viral pneumonia (Z sensitivity = 5.33>1.96). On the first follow-up, the sensitivity of TUS was 37.64% for detecting findings. Besides, no statistical difference was found between TUS and CXR on overall, bacterial and viral subgroups for first follow-up p=0.366, 0.705 and 1 respectively. However, TUS was superior identifying bacterial pneumonia than viral pneumonia on the first follow up (Z sensitivity = 2.57>1.96). TUS failed to demonstrate any findings in 2 patients with complicated pneumonia on the first follow-up. Five patients were examined on the second follow-up (Table 2).

Correlation of CXR and TUS findings

See Table 1. Pleural irregularity/B lines, pericardial effusion, and empyema were only demonstrated on TUS whereas peribronchial cuffing, ground-glass opacity, central infiltration were only detected on CXR. TUS was superior to CXR in depicting air bronchogram, peripheral infiltration, and pleural effusion. However, CXR was more efficient than TUS to demonstrate the atelectasis.

Table 1. Correlation of Findings on CXR & TUS

Findings		CXR (%) (n=120/124)	TUS (%) (n=103/124)
Air Bronchograms	+	**72.5% (n=90/124)**	**83% (n=103/124)**
	-	27.5% (n=30/124)	17% (n=21/124)
Pleural irregularity / B lines	+	-	81.4% (n=101/124)
	-		18.6% (n=23/124)
Consolidation	+	68.5% (n=85/124)	75.8% (n=94/124)
	-	31.5% (n=49/124)	24.2% (n=30/124)
Peribronchial cuffing	+	12.9% (n=16/124)	-
	-	87.1% (n=108/124)	
Atelectasis	+	8% (n=10/124)	0.8% (n=1/124)
	-	92% (n=114/124)	99.2% (n=123/124)
Peripheral infiltration	+	8% (n=10/124)	83% (n=103/124)
	-	92% (n=114/124)	17% (n=21/124)
Pleural effusion	+	5.6% (n=7/124)	16.1% (n=20/124)
	-	94.4% (n=117/124)	83.9% (n=104/124)
Parahilar - Paracardiac Infiltration	+	4.83% (n=6/124)	-
	-	95.17% (n=118/124)	
Diaphragm Elevation	+	3.2% (n=4/124)	2.4% (n=3/124)
	-	96.8% (n=120/124)	97.6% (n=121/124)
Cavitation	+	2.4% (n=3/124)	2.4% (n=3/124)
	-	97.6% (n=121/124)	97.6% (n=121/124)
Abscess	+	0.8% (n=1/124)	4% (n=5/124)
	-	99.2% (n=123/124)	96% (n=119/124)
Ground Glass Opacity	+	0.8% (n=1/124)	-
	-	99.2% (n=123/124)	
Pericardial Effusion	+	-	0.8% (n=1/124)
	-		99.2% (n=123/124)
Empyema	+	-	0.8% (n=1/124)
	-		99.2% (n=123/124)

Table 2. Comparison of Groups on CXR&TUS

All patients at initial diagnosis

	CXR+	CXR-	Total
TUS+	103	0	103
TUS-	17	4	21
Total	120	4	124

κ,p=0.281, 0.013 Sensitivity = 86.06% p<0,001

All patients at I. Follow-up

	CXR+	CXR-	Total
TUS+	28	4	32
TUS-	7	46	53
Total	35	50	85

κ,p=0.729, p<0.001 Sensitivity =37.64% p=0.366

Bacterial Pneumonia at initial diagnosis

	CXR+	CXR-	Total
TUS+	77	0	77
TUS-	2	0	2
Total	79	0	79

κ,p= 0 Sensitivity = 97.46% p=0.157

Bacterial Pneumonia at I. Follow-up

	CXR+	CXR-	Total
TUS+	25	3	28
TUS-	4	28	32
Total	29	31	60

κ,p=0.766, p<0.001 Sensitivity = 46.66% p=0.705

Viral Pneumonia at initial diagnosis

	CXR+	CXR-	Total
TUS+	21	0	21
TUS-	14	4	18
Total	35	4	39

κ,p=0.235, 0.026 Sensitivity = 53.84% p<0.001

Viral Pneumonia at I. Follow-up

	CXR+	CXR-	Total
TUS+	3	1	4
TUS-	1	16	17
Total	4	17	21

κ,p=0.691, p<0.001 Sensitivity = 19.04% p=1.000

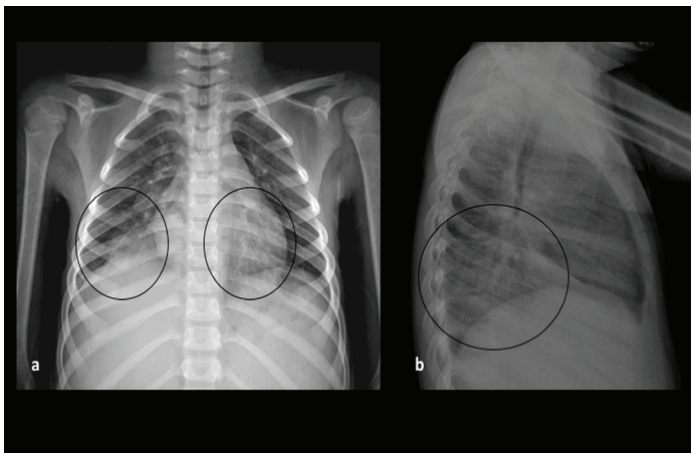

Figure 1 (a, b). 7-year-old girl; On PA (a) and lateral views (b) of thorax demonstrate pneumonic opacifications and infiltrations of the right lower zone, paracardiac region, and left retrocardiac region (circles)

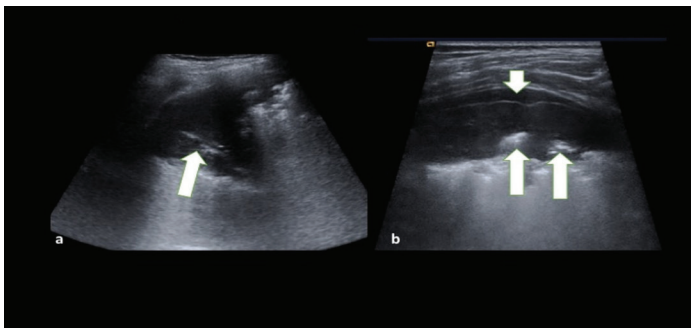

Figure 2 (a, b). 7-year-old girl; Ultrasound of the right middle zone through intercostal region shows the hypoechoic consolidation area with echogenic air bronchograms (arrows) by convex probe (a). The pleural effusion, echogenic irregular pleural line (short arrow) and hypoechoic consolidation area with air bronchograms (arrows) are demonstrated by linear probe (b).

DISCUSSION

This is the first study in the literature that shows the use of TUS in bacterial and viral pneumonia findings in children. TUS is a feasible and complementary imaging method with a sensitivity of 86.06% in detecting and follow-up of childhood pneumonia. It is a comparable imaging method to CXR with bedside option and no radiation exposure. It is also cheap and can be applied repeatedly. Recent pediatric literature suggests TUS as a reliable method for avoiding the excess use of CXR (5). Yadav et al. showed that transthoracic ultrasound can be considered first before CXR in children with suspected CAP in order to decrease radiation exposure (6). Our study also supports the literature findings. Regarding the comparison of bacterial and viral pneumonia, TUS is able to show more findings in bacterial rather than viral. In addition, viral pneumonia has subtle or fewer infectious findings within the lung compared to bacterial pneumonia on both TUS and CXR. Thus, radiologists should discuss the possible etiology of pneumonia with the clinician about using the accurate diagnostic tool.

Authors state that TUS is more superior for the subpleural major consolidations and space occupying lesions, and pleural effusion (7-11). There are undetermined findings on TUS such as peribronchial cuffing, ground-glass opacity and central (para hilar and para cardiac) consolidation detected on CXR in our study. A standard CXR can identify pneumonia in almost all areas of the lung and helps to define its severity (multilobar or not), also providing information about other intra-thoracic organs (12-14). TUS may not succeed to assess the whole lung parenchyma due to the anatomical restriction of the thoracic rib cage and the lung itself which is an air-filled organ (10,11). Therefore, centrally located pathologies could fail to be depicted on TUS which is also the main limitation for this study. Considering this limitation, we may suggest TUS as a complementary method to CXR in childhood pneumonia. It is more efficient to show the peripheral regions including subpleural infiltrates, effusions, and empyema.

Pleural irregularity/B lines were only depicted on TUS in our study. Toma et al. showed that these are findings associated with pneumonia, which are causative production of signals due to the modification of the plane immediately below the pleura (10,11). We also agree with the literature that those findings may be observed in any infectious and inflammatory process infiltrating the pleural-subpleural spaces. Air bronchograms are punctiform-to-linear echogenic foci within the consolidation where fluid-filled alveoli act as a perfect background for them in which the comet-tail artifacts are more visible on ultrasound compared to CXR (15). TUS is also able to detect the diaphragm elevation, cavitation and abscess formation according to our results.

Sperandeo et al. showed that significant dimensional changes of consolidation areas which were detected on TUS follow-up (8). Considering the late resolution of the findings on CXR, TUS could be an alternative imaging method for immediate response to medical treatment and resolution of the findings. Our results are concordant with the literature.

Ultrasound is an operator-dependent imaging method. Even clinicians with ultrasound training may not succeed to demonstrate all pathologies. The latest meta-analyses showed that TUS was highly dependent on the “type of medical ward”, “experience of the operator” and “type of ultrasound system” (16-18). Our study is one of the first in the literature in which an experienced pediatric radiologist scanned the patients. In order to decrease the discrepancy between the operators and readers, we should consider the pediatric sonographic experience of the operator. We also acknowledge the limitation of inter- and intra-observer variability in the interpretation of CXR and TUS. Despite the fact that TUS is a promising non-radiation imaging technique for childhood pneumonia, the heterogeneity of the studies in the recent literature should not be ignored (16). Moreover, future studies including more patients would be useful to confirm our results.

CONCLUSION

The use of TUS for initial diagnosis and follow-up of childhood pneumonia should be considered as a complementary imaging method to CXR rather than a substitutive role. TUS is more useful in bacterial pneumonia rather than viral pneumonia by showing findings such as subpleural pneumonitis, consolidation, pleural and pericardial effusion, empyema and the response to the medical therapy.

Acknowledgement: This study was presented at 55th Annual Meeting and 41st Post Graduate Course of the European Society of Paediatric Radiology. We would like to thank Dr. Neslihan Günay, Dr. Fulya Gedikli, Dr. Ahmet Oğuzhan Gürek, and Dr. Abdulhakim Coşkun for their contributions.

Competing interests: The authors declare that they have no competing interest.

Financial Disclosure: There are no financial supports.

Ethical approval: Written informed consent was taken before the TUS examination. The Ethics Committee (2015/296) approved the study protocol.

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