European Journal of Radiology 83 (2014) 1507–1518

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Potential of ultrasound in the pediatric chest

Panruethai Trinavarat[a,*], Michael Riccabona[b]

[a] Department of Radiology, Faculty of Medicine, Chulalongkorn University, Rama IV Road, Pathumwan, Bangkok 10330, Thailand
[b] Department of Radiology, Division of Pediatric Radiology, University Hospital Graz, Austria

ARTICLE INFO

Article history:
Received 2 April 2014
Accepted 16 April 2014

Keywords:
Thorax
Chest
Children/pediatrics
Ultrasound

ABSTRACT

Ultrasound (US) of chest, even with inherent limitations of the US beam and air, has been useful in many pediatric chest conditions. It has extended its role and is now widely used by many subspecialists in medicine. This review article will cover techniques, indications, and applications of chest US in neonates, infants and children, including also different common as well as some rare and modern aspects and applications, such as pleural effusion, pneumothorax, pulmonary lesions, mediastinum, diaphragm, and chest wall. Other related imaging modalities are also briefly discussed.

1. Introduction

In the past US seemed to be an inappropriate modality for the chest where the bony cage and the aerated lung limit US transmission. However, US has had its established role for a long time in the chest wall, the breast, the diaphragm, in echocardiography, and for pleural effusions – which all can be accessed without intervening aerated lung. In infants and young children with the presence of a large thymus gland, the mediastinum can be evaluated by US using this window. During the past decade, the extended use of chest US for evaluation of the pleura including pneumothorax and the lung has been established. The practice of chest US today is not only static evaluation of thoracic structures but also assessment of dynamic processes, not only using conventional echo based images for interpretation but also artifacts. US guidance for central venous access and for biopsy or aspiration of mediastinal, pleural, and pulmonary lesion is also increasing, in both adults and children. And US of the chest is now being performed by many subspecialties, including (pediatric) radiologists, sonographers, pediatricians and neonatologists, physicians in (pediatric) emergency department and (pediatric or neonatal) intensive care unit, (pediatric) pulmonologists, and (pediatric) anesthesiologists.

2. Technique of chest ultrasound

Type and frequency of the US transducer is selected considering patient's size and age, the site of the US approach, and the depth of a lesion. For the chest wall, the pleura and the subpleural space high-frequency (5–15 MHz) linear (or small convex) transducers are preferred. For the diaphragm or peridiaphragmatic lesions, convex transducers with lower frequencies (3–6 MHz) are used – often with a transabdominal approach. For accessing a lesion through a small US window, a sector transducer may be more suitable.

The approach depends on location of the studied lesion or condition. For mediastinal lesions one may choose a para- or suprasternal or even a dorsal paraspinal approach; a transternal access is feasible in neonates because most of the sternum is still cartilaginous. For the pleura or peripheral pulmonary lesions, an intercostal approach at the level of interest is used. For subclavian vein evaluation or access, supra- or infraclavicular approaches are suitable. Subxiphoid and subcostal transabdominal approaches are used for evaluation of the diaphragm and peridiaphragmatic lesions.

The conventional B-mode US is routinely used, complemented by color Doppler sonography (CDS) providing information on vascular flow, and M-mode for documentation of (diaphragmatic or pleural) motion.

Clinical information are essential before performing the chest US; furthermore it is usually very helpful to have the most recent chest radiograph of the patient, as it will allow to guide the study to the area of interest.

3. Indications of chest ultrasound

Indications of chest US widely vary depending on the patient's disease and condition as well as regional imaging concepts and needs. Common reasons to consider a chest US – besides echocardiographic queries – are:

- to evaluate a chest wall lesion

* Corresponding author. Tel.: +66 2256 4417; fax: +66 2256 4417.
E-mail addresses: pantrinavarat@hotmail.com (P. Trinavarat), michael.riccabona@klinikum-graz.at (M. Riccabona).

http://dx.doi.org/10.1016/j.ejrad.2014.04.011
0720-048X/

- to confirm and characterize pleural effusions
- to detect pleural thickening and/or a pleural tumor
- to assess an abnormal high or lobulated diaphragm as well as diaphragmatic motion
- to assess an radiologically opaque lung
- to confirm pulmonary consolidations and to detect complications
- to evaluate a widened mediastinum
- and to assess patency of systemic veins at thoracic inlet.

Furthermore, US can be used to detect pneumothorax; this is often performed at emergency departments or a (pediatric or neonatal) intensive care unit as well as in the operating theater. And chest US is also used for interventional purposes, e.g., for guiding aspirations or a biopsy of pleural, mediastinal or lung lesions, and for guiding central venous placement.

4. Clinical applications of chest ultrasound

4.1. Ultrasound for pleural effusions

US is a very good modality for detection of pleural effusions even if of very small amount. It is the best option to classify effusion into simple or complex, i.e., free of echoes, or loculated and full of floating debris echoes, respectively. US is even more sensitive than a lateral-decubitus chest radiograph in detection of small pleural effusions, if performed properly, best in an upright sitting position evaluating the base of the lung with a high resolution linear transducer [1]. The "fluid-colour" sign can be used to identify minimal pleural effusions [2] (Fig. 1). US is also better than CT (or MRI) in showing septae and fibrin in pleural effusions [3] (Fig. 2). Thus the optimal imaging approach in children for assessment of a suspected empyema is first having a chest radiograph followed by a chest US; a routine use of CT is not necessary or adequate – not only for radiation protection issues, but also due to the inherent restrictions of CT compared to modern chest US [4]. CT should be reserved for preoperative planning or for complex pulmonary conditions, such as a suspected having a lung abscess not accessible by US, a broncho-pleural fistula, or an underlying pulmonary structural abnormality and interstitial lung disease [4].

Transudates sonographically appear usually as an echo-free simple effusion [5], while an exudate may exhibit US finding of a simple or a complex effusion. Complex pleural effusions are – based on their US appearance – further subdivided into effusions with mild echogenic floating particles ("low-grade effusion"), those with more complex echogenic content ("complex effusion"), and those which additionally exhibit septae ("complex septated effusion") [5]. Effusion with fibrinous strands, fronds, septations, loculations, and a thickened pleura are suggestive "high-grade pleural effusion" – these may need more aggressive treatment [6]. A "malignant effusion" is to be considered if there is nodular pleural thickening in addition to a pleural effusion, in pediatric age group mostly due to pleural metastasis [5]. Another differential diagnosis for nodular pleural thickening is tuberculous pleuritis (Fig. 3). However, US cannot replace pleural tapping in differentiating between transudate and exudate; and US also cannot predict whether the effusion contains protein, blood, or chyle.

Pleural tapping is proven to be easier and safer using US guidance, with a lower incidence of pneumothorax, as common reasons for failed blind pleural tapping (such as wrong location, very thick fluid with multiple fibrinous strands and septation, or a very thick pleura) can be avoided or overcome [7] (Fig. 4).

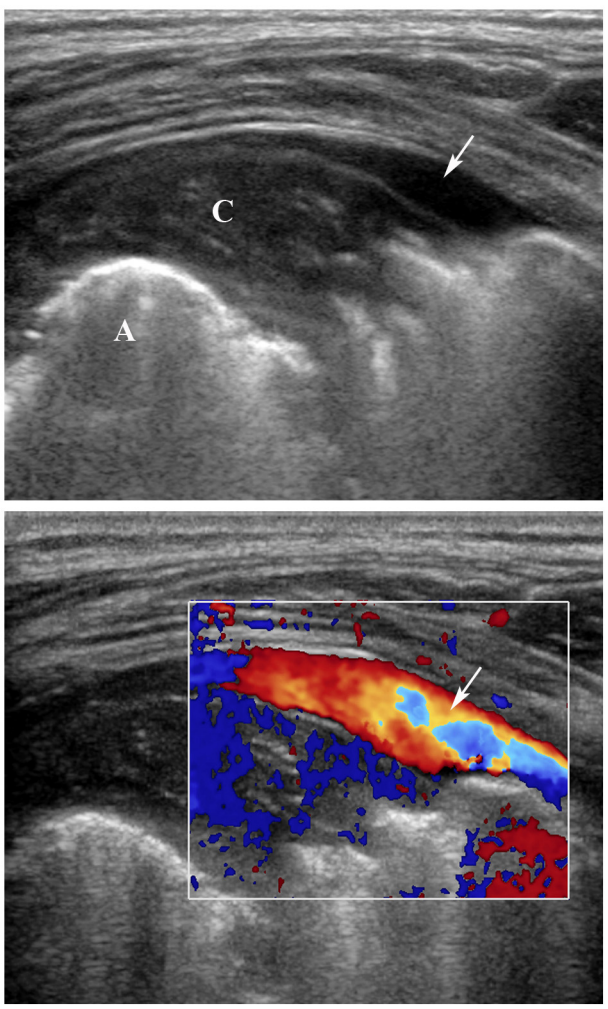

Fig. 1. Small amount of pleural effusion in a 7 years old girl with subacute fever. (a) B-mode US reveals subpleural consolidation (C) and small amount of echo-free pleural effusion (arrow). (b) Applying color mode, free-flow effusion during respiration shows bright color or "fluid color" sign (arrow). A = aerated lung.

4.2. Ultrasound for pneumothorax

The US ability to detect a pneumothorax is well documented [8]. This approach is particularly beneficial for patients arriving at the emergency department and for patients on ventilation support at the intensive care unit.

The typical dynamic image finding of normal pleural line on US is a to-and-fro motion of the visceral pleura on the parietal pleura which can be seen during respiration in real time with B-mode called "gliding" or "sliding" sign [9]. When pneumothorax is directly beneath the US transducer, there is no visible pleural sliding [8,9]. To document this dynamic finding in static image, M-mode is used. The gliding movement of the pleura results in some unsharpness of the pleural line giving the appearance of the sea reaching the sand, called "seashore" sign [9] (Fig. 5a). When the visceral pleural line is hidden under the pneumothorax, M-mode will show a sharp reflection from the interface between parietal pleura and pneumothorax, and it does not move with respiration. This sharp parietal pleural line and the deeper reverberation artifact lines give the appearance of a "barcode" or "stratosphere" sign [9] (Fig. 5b). Note that there could be a false positive finding from pulmonary conditions with hyper-extended over-ventilated lung or air-trapping, such as in COPD [10], air-filled over-extended bronchial cyst, and may be