Ultrasound of the Chest: Applications and Clinical Uses in Adults and Pediatrics

Essay

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Submitted by

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Abstract

bral regions, and the posterior mediastinum as well as in tumour staging and pulmonary embolism CT and MRI are considered superior to ultra-sonography. Ultrasound is a reliable and efficient imaging method to evaluate a wide range of perplexing medical problems in the chest and to guide diagnostic and therapeutic procedures. Although the ribs, spine and air-filled lungs act as barriers to ultrasound visualization of intra-thoracic diseases, the presence of fluid in the pleural space and tumor, consolidation or atelectasis in the lung provide ample sonographic windows for evaluation.

Chest ultra-sonography is considered as a reliable method for the diagnosis of chest wall, pleural, pulmonary and most of the mediastinal diseases as well as guiding interventional procedures for their subsequent management. Its lack of ionizing radiation and need of contrast, low cost, bedside availability and dynamic imaging capacity afford ultrasound certain advantages over other techniques; particularly in the critical care setting where conventional radiography is often suboptimal. On the other hand, in the aortopulmonary window, the subcarinal and paraverte

Key Words :

Brachiocephalic vein - Computed Tomography - Intensive care unit. -

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LIST OF ABBREVIATIONS

A : Aorta.
BV : Brachiocephalic vein.
C : Cartilage.
cm : centi-meter.
C/P : Costophrenic.
COPD : Chronic obstructive pulmonary disease.
CT : Computed Tomography.
EBUS :end-bronchial ultra-sonography.
eg. : Example.
EUS :oesophageal ultra-sonography.
F : French.
FNA :fine needle aspiration.
H : Hour.
H : Heart.
ICU : Intensive care unit.
Kid : Kidney.
L : Lung.
M : Manubrium.
M : Masses.
M : Muscle.
MHZ : Mega hertz.
mm : milli-meter.
MPNST : Malignant peripheral nerve sheath tumour.
MRI : Magnetic resonance imaging.
N : Lymph nodes.
P : Pleura.
PE : Pulmonary embolism.
PAVMS : Pulmonary arterio venous malformations.
R : Ribs.
S : Superior vena cava.
S : Spine.
SP : Spleen.
ST : Sternum.
T : Thymus.
TBNA :trans-bronchial needle aspiration.
US : Ultra-sonography.
V : Vertebra.
VATS : Video assisted thoracoscopy.

INTRODUCTION AND AIM OF WORK

INTRODUCTION

Chest diseases are considered one of the commonest and most widely spread diseases among pediatric and adult age groups. Because of its wide spread it has to be properly diagnosed in order to be properly managed. Many imaging techniques are used for proper diagnosis of chest diseases including plain films,CT scan,MRI,angiography and the intra-thoracic ultra-sound ***[Antoine et al., 2005].***

Examination of the chest is a rapidly developing application of ultrasound (US) and may be used to evaluate a wide range of peripheral parenchymal, pleural and chest wall diseases. Most chest diseases are adequately evaluated with chest radiography. However, when chest radiography does not allow identification of the location and nature of an area of increased opacity, ultrasonography (US) can help establish the diagnosis ***[Stephens et al., 2007].***

Ultrasonography (US) has been underused or often ignored as a diagnostic tool in the chest, especially in the lung, because air and the bony thorax were traditionally considered an obstacle to transmission of the ultrasound beam. However, since US has been gaining recognition as a highly useful tool in the evaluation of pleural lesions, its role in imaging of the lung and extracardiac mediastinum has expanded and its usefulness has been recognized ***[Mathis,1997].***

Computed tomography and magnetic resonance imaging are superior to US in evaluation of the mediastinum, but US is a reasonable alternative in certain situations (eg, to avoid unnecessary investigation of a normal thymus simulating a mediastinal mass). In cases of chest wall lesions, US may enable localization of the site of origin to soft tissues or an extrapleural intrathoracic location. Osseous involvement, particularly rib involvement, is easily evaluated with US ***[Kim et al., 2000].***

Ultrasound may be helpful in evaluation of persistent or unusual areas of increased opacity in the peripheral lung, pleural abnormalities, and mediastinal widening. US is particularly useful in patients with complete opacification of a hemithorax at radiography. In cases of pulmonary parenchymal lesions, identification of air or fluid bronchograms at US and of pulmonary vessels at color flow imaging is useful for differentiating

pulmonary consolidation or atelectasis from lung masses and pleural lesions. US allows characterization of pleural fluid collections as simple, complicated, or fibroadhesive ***[Kim et al., 2000].***

Ultrasound is an excellent imaging modality for assessing the motion and integrity of the diaphragm. The demonstration of normal diaphragmatic excursions, diaphragmatic paralysis and paradoxical motion. The movement of each hemidiaphragm can be observed on individual longitudinal scans.Normal and compromised movement is best appreciated ***[Sutton et al.,2003].***

The optimal frequency of the transducer for chest US varies with the age of the patient, the location of the lesion, and the planned approach.Transthoracic chest US can be performed with any modern US unit. A 2–5-MHz curvilinear probe allows visualization of the deeper structures, and the sector scan field allows a wider field of view through a small acoustic window. The chest wall, pleura, and lungs may be quickly surveyed with the curvilinear probe. Once an abnormality has been identified, a high-resolution 7.5–10-MHz linear probe can be used to provide detailed depiction of any chest wall, pleural, or peripheral lung abnormality. Both gray-scale and color Doppler imaging are useful for the assessment of pleural and parenchymal abnormalities ***[Koh et al., 2002].***

However, neonates and infants are best imaged with a high-resolution 5–10-MHz linear-array transducer; children and adolescents may require a 2–4- or 4–7-MHz sector or linear-array transducer. Trans-sternal, para-sternal, and inter-costal approaches are good for imaging of the lung, pleura, and anterior mediastinum. Sector transducers are used in subxiphoid and transdiaphragmatic approaches with the liver used as the acoustic window for evaluating juxtaphrenic paravertebral lesions. Suprasternal and supraclavicular approaches facilitate evaluation of the upper mediastinum and lung apexes ***[Herman et al., 1995].***

US is increasingly used to guide interventional procedures of the chest. Percutaneous pleural and lung biopsy can be performed under US guidance, with either the freehand technique or a needle guide. Effusions and other pleural collections may also be safely drained or aspirated under US guidance. A range of self-retaining pigtail catheters (8–14-F) is suitable for this purpose ***[Tatersall et al., 2000].***

Sonography has been found to be reliable and accurate for assessing and following chest problems that cannot be elucidated with conventional plain film radiography alone. The conventional plain film radiography imaging technique appears to be complementary with sonography serving to localize an abnormality, characterize a mass and provide information about the pleural space, underlying lung, and diaphragm. It can be safely used for guidance during biopsy, thoracentesis and tube placement. It is particularly recommended for children since it is a readily available, non-invasive technique that does not employ ionizing radiation and that requires no anesthesia and only rarely requires sedation. With the rising costs in medicine, the fact that sonography is relatively inexpensive is an additional advantage. The portable capability of this modality facilitates the examination and guidance of interventional techniques in critically ill or isolated patients ***[Sutton et al., 2003].***

AIM OF WORK

The aim of this study is to evaluate the diagnostic role of ultrasonography in detecting and differentiating chest abnormalities and guiding interventional procedures of the chest in the pediatric and adult age groups. A representative number of cases will be done.

SONOGRAPHIC ANATOMY

Ultrasound is a reliable and efficient imaging method to evaluate a wide range of perplexing medical problems in the chest and to guide diagnostic and therapeutic procedures. Although the ribs, spine and air-filled lungs act as barriers to ultrasound visualization of intra-thoracic diseases, the presence of fluid in the pleural space and tumor, consolidation or atelectasis in the lung provide ample sonographic windows for evaluation ***[McLoud and Flower, 1991].***

The chest wall muscles:

The normal chest wall appears as a series of echogenic soft-tissue layers, representing the layers of muscles and the fascial planes. The ribs below the soft tissue of the chest wall the ribs appear as curvilinear structures on transverse scans, associated with posterior acoustic shadowing. When the ribs are scanned along the long axis, the anterior cortex should appear as a continuous smooth echogenic line ***[Koh et al, 2002].***

Diaphragm:

On ultrasound scan of the abdomen, the diaphragm is recognized as a bright, curving echogenic line defining the cephalad extent of the abdomen. The bright line is produced by strong sound wave reflection from the interface between the diaphragm and the air-filled lung above it ***[Verschakelen et al, 2005].***

High-resolution ultrasound demonstrates a more complex appearance. The muscle of the diaphragm is seen as a thin echogenic line representing the diaphragm-liver capsule interface on the abdominal side and a brighter, thicker echogenic line representing the surface of the air-filled lung on the thoracic side. A third echogenic line is sometimes seen on the thoracic side is a mirror image artifact of the diaphragm-lung surface. When disease is present in the thorax, such as pleural effusion or tumor, the diaphragm is seen as a thin echogenic line ***[Lewandowski and Winsberg, 1983].***

Abdominal approach: When imaged from the abdomen, the normal diaphragm is approximately 5mm thick and is covered by parietal pleura on its thoracic side and by peritoneum on its abdominal side ***[Beckh et al, 2002].***

Pleural space:

The pleural space is superficial and readily examined by ultrasound using either a direct intercostals or an abdominal approach. A high-frequency (5-7.5 MHz) linear transducer applied directly to the chest (direct intercostals approach) provides a broad, near field of view that allows excellent visualization of the pleural space. The lower reaches of the pleural space may be effectively examined by use of sector or convex-array (3.5 MHz) transducers directly superiorly from the abdomen (abdominal approach).The liver and spleen provide sonographic windows to the thorax. Sector transducers are frequently unsatisfactory for examination of the pleural space when applied directly to the chest .The sector scanner has a narrow view in the near field and the pleural space is frequently obscured by near-field artifacts ***[Beckh et al, 2002].***

Direct inter-costal approach: The normal pleural space is readily recognized when the ribs are used as sonographic landmarks. With a linear-array transducer oriented perpendicular to the intercostals spaces, the ribs are displayed as rounded echogenic interfaces with prominent acoustic shadowing. Intercostal muscle is visualized between the rib shadows. The location and depth of the ribs are noted and the thickness of the subcutaneous tissues and the overlying muscles of the chest wall are determined. The air-filled lung, covered by visceral pleura, is a potent reflector of the ultrasound beam, blocking sound penetration deeper into the chest and producing a bright linear interface that moves with respiration. The normal back-and-forth movement of the lung surface has been called [gliding sign] ***[Targhetta et al, 1992].***

The bright linear interface of the lung surface is the sonographic marker of the visceral pleura. A thin dark line of pleural fluid is normally present, separating the parietal from the visceral pleura. The parietal pleura appears as a less distinct, weakly echogenic line, often obscured by reverberation artifact. Its location is inferred by its relationship to the ribs and the visceral pleura ***[Beckh et al, 2002].***

Lung parenchyma:

Air-filled lung covered by visceral pleura, causes a highly reflective interface that blocks transmission of the sound beam into the chest. However, the ultrasound image will display a pattern of bright echoes caused by acoustic reverberation artifact ***[Kremkau and Taylor, 1986].***

These echoes are usually intense but formless and diminish in intensity with distance from the transducer. However, whenever the ultrasound beam is directly perpendicular to the visceral pleura-lung interface, the bright linear surface of the air-filled lung will be repeatedly duplicated on the images as a series of bright lines at fixed intervals. The strength of these pattern reverberation artifacts also diminishes with increasing distance from the transducer. The normal lung surface is identified by its motion, gliding back and forth with inspiration and expiration, the ‘gliding sign’ ***[Beckh et al, 2002].***

In addition, vertically oriented "comet-tail" artifacts can also be normally seen, originating at the pleura-lung interface. The visualization of these artifacts in a healthy adult is usually confined to the last intercostal space above the diaphragm. With a curvilinear probe, these artifacts are seen to fan out to the edge of the screen. The comet-tail artifact results from the fluid-rich subpleural interlobular septae, which are surrounded by air. Hence, these artifacts appear closely spaced, separated from each other by an average distance of 7 mm ***[Koh et al., 2002].***

Mediastinum:

Because the mediastinum is surrounded by shadowing bone and reflective lung, it offers a challenge to sonographic evaluation. However, with careful attention to technique and patient positioning, most areas of the mediastinum can be efficiently examined ***[Betsch 1994].***

Ultrasound is best for examination of the superior and anterior mediastinum and is less useful for the posterior mediastinum and para-vertebral region. When abnormalities are detected, sonographic guidance can be used for biopsy. The ability to visualize the needle continually as it courses to the lesion is a significant advantage because this area is so rich with major vascular structures. Detailed knowledge of the three-dimensional anatomy of the mediastinum is critical because the planes of sonographic examination are usually oblique and not readily related to the standard orthogonal planed of computed tomography (CT) and magnetic resonance imaging (MRI) ***[Beckh et al, 2002].***

The upper mediastinum is accessible to sonographic investigation by use of supra-sternal approach .The innominate veins, common carotid, brachiocephalic and subclavian arteries are examined. Each vessel is identified by its location and Doppler characteristics. Tortuous vessels, which cause abnormal widening of the mediastinum on chest x-ray films, are easily recognized. Mediastinal masses are precisely localized and characterized as solid, cystic, vascular or calcified. The relationship of masses to cardiac and vascular structures can be accurately defined ***[Beckh et al, 2002].***

The ascending aorta, anterior mediastinum and sub-carinal region are best imaged from a right para-sternal approach with the patient lying with the right side down. The pulmonary trunk and left side of the anterior mediastinum are best imaged with a left para-sternal approach with the patient in a left lateral decubitus position ***[Wernecke et al, 1990].***

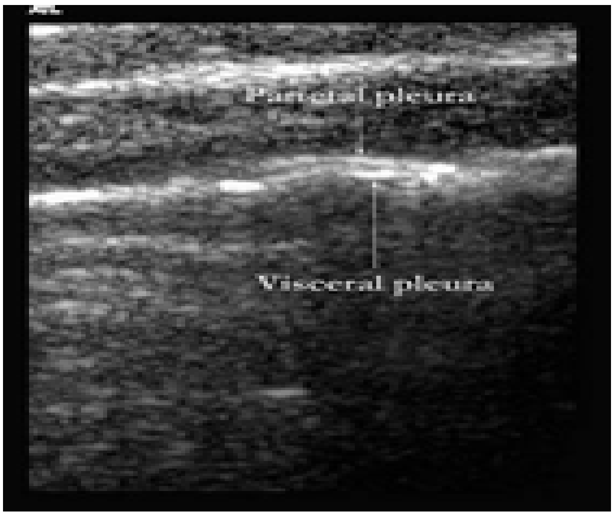
Large posterior masses may be imaged from a posterior para-vertebral approach. Lesions near the diaphragm are evaluated from the abdomen through the liver or spleen. Large masses displace lung and may be imaged directly through the intercostal spaces ***[Junpei et al, 2005].***

The thymus is a prominent normal anterior mediastinal structure in children up to 8 years of age. The thymus has two well-defined, triangle-shaped lobes with homogenous echogenicity slightly less than thyroid gland. The normal gland is closely applied to mediastinal vessels and may completely encircle the left innominate vein. In infants less than 2 years old, the normal thymus extends from the thoracic inlet to the base of the heart. From the age of 2 to 8 years, the thymus remains a prominent sonographic landmark when scanning the mediastinum, even though it is less obvious on chest radiographs. Progressive fatty replacement makes the thymus blend with mediastinal fat and become sonographically invisible in older children and adults. Sonographic visualization of the thymus in an adult suggests neoplastic disease ***[Wernecke and Diederich, 1994].***

<u>Figure 1:</u> Normal US appearance of the chest ***[Koh et al, 2002].***

<u>Figure 1A:</u>

- **Below the relatively echogenic subcutaneous tissue, the intercostal muscles appear hypoechoic but contain multiple echogenic fascial planes.**
- **The pleural interface appears as an echogenic line.**
- **The sharp change in the acoustic impedance at this interface results in reverberation artifacts (*), appearing as a series of horizontal lines parallel to the pleural interface.**
- **Vertical comet tail artifacts (+) can also be seen.**



<u>Figure 1B:</u>

- **On the high-resolution scan, the visceral and parietal portions of the pleura can be resolved.**