Focused Chest Ultrasound

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Addenbrooke’s Hospital, Cambridge
Ultrasound Training Recommendations for Medical and Surgical Specialties

Faculty of Clinical Radiology
The Royal College of Radiologists

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Level 1: Competencies to be Acquired

• Recognition of normal anatomy of pleura and diaphragm.
• Identification of the heart, liver and spleen.
• Pleural effusion recognition, including the different echogenic patterns.
• Pleural thickening and its differentiation from fluid using colour flow Doppler if appropriate.
• Consolidated lung and its differentiation from effusion.
• Estimation of depth of effusion and its measurement.
• Guided thoracocentesis and drain placement.
Focused Emergency Ultrasound (RCR 2005)

Level 1: Competency to be Acquired
- pleural disease
  - identify and assess pleural effusions

Level 2: Competency to be Acquired
- ultrasound-guided invasive procedures (chest drain insertion)
- pleural disease
  - exclude pneumothorax
Objectives

- Fluid Collections
- Lung tissue
- Pneumothorax
Anatomy
Thoracic windows
Thoracic windows

- spinal process
- clavicle
- scapula
- aortic knob
- left bronchus
- hilum
- descending aorta
- breast soft tissue
- gastric air bubble

- trachea
- bronchial bifurcation
- vascular hilum
- posterior rib
- right atrium
- diaphragm
- liver

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Thoracic windows
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Thoracic windows

- Spinal process
- Clavicle
- Scapula
- Anterior rib
- Bronchial bifurcation
- Vascular hilum
- Posterior rib
- Right atrium
- Diaphragm
- Liver
- Gastric air bubble
- Aortic knob
- Left bronchus
- Hilum
- Descending aorta
- Breast soft tissue

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Chest Ultrasound Examination

Equipment suitable for chest US imaging

- 3.5 - 5 MHz convex/phased array transducer
  - suitable for general scanning and for visualization of deeper structures

- 7.5 -10 MHz (higher frequency) linear transducers
  - provides better resolutions of near structures, such as the chest wall and pleura
Techniques for Chest Ultrasound Examination

Technique for chest US examination,

- patients can be scanned in a sitting or supine position.
- bedridden patients can be examined by turning them to oblique or lateral decubitus positions.
Techniques for Chest Ultrasound Examination

- First, locate the diaphragm and the lungs.
- Lung consolidation or pleural effusion are found predominantly in dependant and dorsal lung regions and can be easily distinguished from liver or spleen once the diaphragm has been located.
Adaptation of FAST

- Increased sensitivity with increased number of views
- Will identify pleural effusions
- Reliably detects as little as 50-100ml in the thorax
- Sensitivity >96%, specificity 99-100%

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Adapted RUQ window

- Move probe
  - cephalad
  - longitudinal

- Image
Adapted RUQ window

- Move probe
  - cephalad
  - longitudinal
- Image

Liver
Adapted RUQ window

- Move probe
  - cephalad
  - longitudinal

- Image

Liver

Diaphragm
Adapted RUQ window

- Move probe
  - cephalad
  - longitudinal

- Image
  - Liver
  - Diaphragm
  - Pleural space
Adapted RUQ window

- **Move probe**
  - cephalad
  - longitudinal

- **Image**
  - Liver
  - Diaphragm
  - Pleural space
Techniques for Chest Ultrasound Examination

- The chest wall can be divided into six lung regions
  - upper and lower
  - anterior, lateral and posterior chest wall
    - anterior and posterior-axillary lines

- Intercostal spaces offer acoustic windows

- Only the upper posterior lung segments behind the scapula cannot be explored by lung ultrasound
Techniques for Chest Ultrasound Examination
Ultrasound appearances

- Normally, ultrasound is not transmitted through structures filled with gas.
- Lung parenchyma is not visible beyond the pleura.
Ultrasound appearances

- Normal
- Interstitial syndrome (B lines 7 mm apart)
- Alveolar-interstitial syndrome (B lines less than 3 mm apart)
- Alveolar consolidation
- Pleural fluid
Normal

- A normal ultrasound pattern is defined by
  - ‘lung sliding’ with
  - Artifactual horizontal A-lines

- In one third of patients with normal lungs isolated vertical B-lines (comet tails) can be detected in dependant lung regions

- B-lines move with the pleural line
Alveolar-interstitial syndrome

- ‘B-lines’ or ‘comet tails’ appear as shining vertical lines arising from the pleural line and reach the edge of the screen.
- The number of these vertical B-lines depends on the degree of lung aeration loss.
Alveolar consolidation

- loss of lung aeration enables ultrasound to be transmitted
- lung consolidation appears as a hypoechoic tissue structure that is poorly defined and wedge-shaped
  - massive lung oedema
  - lobar bronchopneumonia
  - pulmonary contusion
  - lobar atelectasis
Abscess

- Peripheral lung abscesses with pleural contact or included inside a lung consolidation are also detectable by ultrasound
- Rounded hypoechoic lesions with outer margins
Pleural fluid
Haemothorax
Haemothorax
Thoracic “FAST”

- Acute diagnosis of haemothorax
- **US vs CXR**\(^1\)
  - Faster
  - Equivalent accuracy
  - Sensitivity (97.4%, specificity 99.7%)
- Cardiac tamponade
  - Accuracy 97.3% \(^2\)
- Pericardial effusion

1. Sisley J Trauma 1998
2. Rozycki J Trauma 1999
Pleural effusion

- Pleural effusion is presented as an echo-free space between the visceral and parietal pleura.
- Compressive atelectasis of the lung may be seen in a huge effusion.
Case
Pleural effusion

- Transudates are always anechoic.

- An anechoic effusion can be either a transudate or an exudate.

- Pleural effusions with complex nonseptated, complex septated, and homogenously echogenic patterns are always exudates.

- Homogenously echogenic effusions are typically seen in hemorrhagic effusion and empyema.
Pleural effusion

- anechoic
Pleural effusion

- complex nonseptated
Pleural effusion

- complex septated
Pleural effusion

- homogenously echogenic
Pleural effusion

- paraneoplastic
Pleural effusion - pitfalls
Pleural effusion - pitfalls

- Peritoneal fluid
Pleural effusion - pitfalls
Pleural effusion - pitfalls

- Pleural fluid
Pleural effusion - pitfalls
Pleural effusion - pitfalls

- Pericardial fluid
Ultrasound appearances

- Normal
- Interstitial syndrome (B lines 7 mm apart)
- Alveolar-interstitial syndrome (B lines less than 3 mm apart)
- Alveolar consolidation
- Pleural fluid
Pneumothorax

- Pneumothorax is defined by the interposition of gas between visceral and parietal pleural layers.
- As a consequence, lung sliding is abolished, ultrasound cannot be transmitted through the lung parenchyma and comet tails (vertical B-lines) are no longer visible.
- Only longitudinal reverberations of motionless pleural line (horizontal A-lines) can be seen
# US for Pneumothorax

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients Details</th>
<th>Study Type</th>
<th>Diagnosis Type</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dulchavsky et al.</td>
<td>382 stable surgical patients (95% post-traumatic)</td>
<td>Prospective diagnostic study</td>
<td>USS v CXR diagnosis</td>
<td>95% (89-95)</td>
<td>100% (99-100)</td>
</tr>
<tr>
<td>Rowan et al.,</td>
<td>27 patients sustaining blunt chest trauma who had CT scans</td>
<td>Prospective blinded diagnostic study</td>
<td>USS v CT diagnosis</td>
<td>100% (82.6-100)</td>
<td>94% (82-94)</td>
</tr>
<tr>
<td>Knudtson et al.,</td>
<td>328 consecutive trauma patients</td>
<td>Prospective diagnostic study</td>
<td>USS v CXR diagnosis</td>
<td>92.3% (74.4-97.9)</td>
<td>99.7% (98.9-99.9)</td>
</tr>
<tr>
<td>Kirkpatrick et al.</td>
<td>225 trauma patients</td>
<td>Prospective diagnostic study</td>
<td>USS v CT diagnosis or escape of air on thoracostomy</td>
<td>58.9% (45.0-71.9)</td>
<td>99.1% (97.6-99.8)</td>
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</table>
Hand-Held Thoracic Sonography for Detecting Post-Traumatic Pneumothoraces: The Extended Focused Assessment With Sonography For Trauma (EFAST).

Original Articles

Kirkpatrick, A W; MD; FACS; Simia, M MD; Laupland, K B; MD; Liu, D MD; Rowan, K MD; Ball, C G; MD, MSc; Hameed, S M; MD; Brown, R MD; FACS; Simons, R MD, FACS; Dulchavsky, S A; MD, FACS; Hamilton, D R; MD, PhD; Nicolaou, S MD

Abstract:
Background: Thoracic ultrasound (EFAST) has shown promise in inferring the presence of post-traumatic pneumothoraces (PTXs) and may have a particular value in identifying occult pneumothoraces (OPTXs) missed by the AP supine chest radiograph (CXR). However, the diagnostic utility of hand-held US has not been previously evaluated in this role.

Methods: Thoracic US examinations were performed during the initial resuscitation of injured patients at a provincial trauma referral center. A high frequency linear transducer and a 2.4 kg US attached to a video-recorder were used. Real-time EFAST examinations for PTXs were blindly compared with the subsequent results of CXRs, a composite standard (CXR, chest and abdominal CT scans, clinical course, and invasive interventions), and a CT gold standard (CT only). Charts were reviewed for in-hospital outcomes and follow-up.

Results: There were 225 eligible patients (207 blunt, 18 penetrating); 17 were excluded from the US examination because of battery failure or a lost probe. Sixty-five (65) PTXs were detected in 52 patients (22% of patients), 41 (63%) being occult to CXR in 33 patients (14.2% whole population, 24.6% of those with a CT). The US and CXR agreed in 186 (89.4%) of patients, EFAST was better in 16 (7.7%), and CXR better in 6 (2.9%). Compared with the composite standard, the sensitivity of EFAST was 58.9% with a likelihood ratio of a positive test (LR+) of 69.7 and a specificity of 99.1%. Comparing EFAST directly to CXR, by looking at each of 266 lung fields with the benefit of the CT gold standard, the EFAST showed higher sensitivity over CXR (48.8% versus 20.9%). Both exams had a very high specificity (99.6% and 98.7%), and very predictive LR+ (46.7 and 36.3).

Conclusion: EFAST has comparable specificity to CXR but is more sensitive for the detection of OPTXs after trauma. Positive EFAST findings should be addressed either clinically or with CT depending on hemodynamic stability. CT should be used if detection of all PTXs is desired.
COPD Can Mimic the Appearance of Pneumothorax on Thoracic Ultrasound*

Andrew Slater, MB, ChB; Mark Goodwin, BM, BCH;
Kirsty E. Anderson, MA, MB, ChB; and Fergus V. Gleeson, MB, ChB

Purpose: To determine the diagnostic accuracy of ultrasound in the diagnosis of pneumothorax in patients with COPD with particular regard to false-positive diagnoses.

Materials and Methods: This was a single-center, prospective, blinded study. Nine patients with pneumothorax, 9 patients with cystic fibrosis, 17 patients with COPD, and 9 control subjects were studied. Ultrasound clips were recorded at three positions in both hemithoraces of each patient and then reviewed by two observers blinded to patient status. Each clip was scored for the presence or absence of pneumothorax and the degree of observer confidence.

Results: The sensitivity and specificity for a pneumothorax were 100% and 84% for the experienced observer and 78% and 81% for the inexperienced observer, respectively. In the COPD patient group, specificity was 71% for the experienced observer and 63% for the inexperienced observer. There were no false-positive diagnoses in the cystic fibrosis or the control group.

Conclusion: Patients with COPD commonly show signs on ultrasound mimicking a pneumothorax, but this was not seen in patients with cystic fibrosis. In patients with COPD, ultrasound may be used to exclude the presence of a pneumothorax, but it cannot be used to confidently diagnose pneumothorax without using other imaging modalities.

(CHEST 2006; 129:545–550)

Key words: diagnosis; pneumothorax; ultrasound

Abbreviation: CXR = chest radiograph/radiography
Linear High Frequency Probe

high frequency 7.5 -10 MHz linear transducers.

–provides better resolutions of near structures, such as the chest wall and pleura
Pneumothorax
Pneumothorax
Pneumothorax
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Pneumothorax
Pneumothorax

- Normal side of the chest; US shows
  - Gliding of the visceral and parietal pleura
  - Comet tail sign
  - Seashore sign – M mode

- with pneumothorax, these signs are absent in real-time US
Normal US Pattern: Static signs

- B line – “comet-tail” artifact
Normal US Pattern: Dynamic signs

- The seashore sign – M-mode sign

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US Diagnosis of Pneumothorax

- No seashore sign – no lung pulse
US Diagnosis of Pneumothorax

- The lung point – specific sign
Ultrasound-Guided Invasive Interventions

US can guide many invasive or interventional procedures, including:

– diagnostic thoracocentesis

– Insertion of chest drain for pleural effusion
Diagnostic thoracocentesis

- US is superior to chest radiographs in identifying the fluid and choosing the optimal site for diagnostic thoracocentesis.
- The largest and most accessible area of fluid accumulation can be identified, and the depth for the needle to penetrate can be measured by chest US.
Diagnostic thoracocentesis

- With real-time US, direct visualization of the effusion during thoracocentesis is applicable.
- US-guided measures help to improve the success rate of thoracocentesis and avoid complications, such as pneumothorax.
- It is especially helpful when the effusion is minimal or loculated.
- The success rate of US-guided thoracocentesis can be as high as 97%.
Insertion of chest drain

- Complications include
  - laceration of the lung, diaphragm, liver, and spleen.
  - malposition of the tube can result in failure of the drainage, particularly in loculated effusion.

- As with diagnostic thoracocentesis, US can decrease the risk of malposition and various complications by identifying the suitable site for the procedure.
Chest Ultrasound

Evidence for further use
Heart Failure – differentiating Failure from COPD

Prospective study in a Paris ITU. Scans on 66 patients (40 with LVF and 26 with COPD) as well as 80 normals.

1 Minute exam looking for comet-tail artifact arising from the lung wall interface, multiple and bilaterally disseminated to the anterolateral chest wall.

Sensitivity of 100% and a specificity of 92%.

Lichtenstein D Meziere G Intensive Care Med 1998 Dec 24(12) 1331-4
### ARDS in Critical Care

Study from Paris ITU on 32 ARDS and 10 normal to see accuracy of auscultation, CXR and US

<table>
<thead>
<tr>
<th></th>
<th>Pleural Effusion</th>
<th>Consolidation</th>
<th>Alveolar interstitial</th>
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<tbody>
<tr>
<td>Auscultation</td>
<td>61%</td>
<td>36%</td>
<td>55%</td>
</tr>
<tr>
<td>Port CXR</td>
<td>47%</td>
<td>75%</td>
<td>72%</td>
</tr>
<tr>
<td>US</td>
<td>93%</td>
<td>97%</td>
<td>95%</td>
</tr>
</tbody>
</table>

Comparative diagnostic performances of auscultation, chest radiography and lung ultrasonography in ARDS Lichtenstein D Goldstein I Mourgon Anaesthesiology 2004 Jan;100(1):1-2
Mathis et al showed in 70 patients that chest ultrasound alone looking for triangular or rounded hypoechoic was 91% accurate.

Chest US in diagnosis of PE in comparison to Helical CT

<table>
<thead>
<tr>
<th></th>
<th>US</th>
<th>CT</th>
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<tbody>
<tr>
<td>Sens</td>
<td>94%</td>
<td>85%</td>
</tr>
<tr>
<td>Spec</td>
<td>87%</td>
<td>100%</td>
</tr>
<tr>
<td>NPV</td>
<td>91%</td>
<td>83%</td>
</tr>
<tr>
<td>PPV</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>91%</td>
<td>92%</td>
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Mathis G Bitschnau R
Ultraschall Med 1999 20 54-9
Thoracic Ultrasound for diagnosing Pulmonary Embolism
Mathis Blank Chest 2005;128 1531-8

Multicentre 352 patients with suspected PE compared with CTPA

1 PE Confirmed  2 or more typical triangular or rounded pleural based lesions
2 PE probable  1 typical lesion with pleural effusion
3 PE possible small ( < 5 mm) subpleural lesions or effusion
4 Normal TUS
194 patients had a PE

144 showed multiple lesions

49% had a narrow pleural effusion

Sensitivity 74%  Specificity 95%

PPV 95%  NPV 75%

Accuracy 84% at a prevalence of 55%
Technical Problems

- Narrow intercostal spaces
- Obesity
- Muscular chest
- COPD
- Calcified rib cartilages
- Abdominal distention
ANY QUESTIONS?
Summary

- Fluid Collections
- Lung tissue
- Pneumothorax
- Emboli?