Point-of-care Ultrasound for Internists– Benefits and Limitations

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After this presentation, participants will be able to:

• Describe Point-of-Care Ultrasound and distinguish how it differs from traditional uses
• Define current evidence and limitations for applications that might be of high interest for internists
• Articulate challenges regarding this disruptive innovation and the need of role of professional societies in and determining training and quality standards
Characteristics of ultrasound paradigms

1. **Traditional**: Images acquired by technologists, described and analyzed by specialists in detail often many hours later.

2. **Procedural**

3. **Point-of-care**: Limited (often dichotomous), goal-directed exams by the clinician at the point-of-care to guide immediate management.
A common case

• 65 year old man with 80 pk-yrs, CHF, moderate COPD is admitted from ED with increasing dyspnea and a non-productive over the last 3 days. Slight PND. No increase in his baseline pedal edema. Mild improvement with albuterol.
• RR:26  HR:85, BP: 125/95.
• -Trop, - D-dimer, BNP 1500 (nl 200-800)
• CXR unremarkable (hyper expanded)?
• EKG basically nl

• As you go to examine your patient, what findings can help you?
An common case

- Exam reveals a man in mild-moderate respiratory distress, 1+ pedal edema, and crackles at his bases.

- Brief parasternal short axis: normal squeeze

- Inferior vena cava with nl size and variability with respiration

- Lung ultrasound reveals A-lines throughout upper and lower lung fields (representative images shown)
Characteristics of point-of-care ultrasound

POSITIVES:
• In many cases exceeds the standards of our physical exam
• Can be performed in several minutes, comparable to traditional physical exam
• Involves personal contact between physician and patient at the bedside.
• Immediate, repeatable
• Without any appreciated harms such as ionizing radiation
• After initial equipment purchase and training time, virtually free.

NEGATIVES:
• Operator –dependent
• High start up costs
• Many limitations of technology compared to CT/ MRI
**Table 1. Selected Applications of Point-of-Care Ultrasonography, According to Medical Specialty.**

<table>
<thead>
<tr>
<th>Specialty</th>
<th>Ultrasound Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anesthesia</td>
<td>Guidance for vascular access, regional anesthesia, intraoperative monitoring of fluid status and cardiac function</td>
</tr>
<tr>
<td>Cardiology</td>
<td>Echocardiography, intracardiac assessment</td>
</tr>
<tr>
<td>Critical care medicine</td>
<td>Procedural guidance, pulmonary assessment, focused echocardiography</td>
</tr>
<tr>
<td>Dermatology</td>
<td>Assessment of skin lesions and tumors</td>
</tr>
<tr>
<td>Emergency medicine</td>
<td>FAST, focused emergency assessment, procedural guidance</td>
</tr>
<tr>
<td>Endocrinology and endocrine surgery</td>
<td>Assessment of thyroid and parathyroid, procedural guidance</td>
</tr>
<tr>
<td>General surgery</td>
<td>Ultrasonography of the breast, procedural guidance, intraoperative assessment</td>
</tr>
<tr>
<td>Gynecology</td>
<td>Assessment of cervix, uterus, and adnexa; procedural guidance</td>
</tr>
<tr>
<td>Obstetrics and maternal–fetal medicine</td>
<td>Assessment of pregnancy, detection of fetal abnormalities, procedural guidance</td>
</tr>
<tr>
<td>Neonatology</td>
<td>Cranial and pulmonary assessments</td>
</tr>
<tr>
<td>Nephrology</td>
<td>Vascular access for dialysis</td>
</tr>
<tr>
<td>Neurology</td>
<td>Transcranial Doppler, peripheral-nerve evaluation</td>
</tr>
<tr>
<td>Ophthalmology</td>
<td>Corneal and retinal assessment</td>
</tr>
<tr>
<td>Orthopedic surgery</td>
<td>Musculoskeletal applications</td>
</tr>
<tr>
<td>Otolaryngology</td>
<td>Assessment of thyroid, parathyroid, and neck masses; procedural guidance</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>Assessment of bladder, procedural guidance</td>
</tr>
<tr>
<td>Pulmonary medicine</td>
<td>Transthoracic pulmonary assessment, endobronchial assessment, procedural guidance</td>
</tr>
<tr>
<td>Radiology and interventional radiology</td>
<td>Ultrasoundography taken to the patient with interpretation at the bedside, procedural guidance</td>
</tr>
<tr>
<td>Rheumatology</td>
<td>Monitoring of synovitis, procedural guidance</td>
</tr>
<tr>
<td>Trauma surgery</td>
<td>FAST, procedural guidance</td>
</tr>
<tr>
<td>Urology</td>
<td>Renal, bladder, and prostate assessment; procedural guidance</td>
</tr>
<tr>
<td>Vascular surgery</td>
<td>Carotid, arterial, and venous assessment; procedural assessment</td>
</tr>
</tbody>
</table>

*FAST denotes focused assessment with sonography for trauma.

(Moore and Copel, NEJM, 2011)
• Today we’ll focus on applications which are relatively well-developed and may be of immediate interest

• We will limit ourselves to the literature from internal medicine, emergency medicine, and critical care
Inferior vena cava can help estimate intravascular volume

- Our physical exam is often limited
- Inferior vena cava influenced by volume status
  - Often large and invariable with respiration when overloaded
  - Often smaller collapsible with respiration when hypovolemic
Inferior vena cava can help estimate intravascular volume

**TECHNICAL/ PHYSIOLOGY:**

- Changes with fluids given/ removed/ lost:
  - Closely tracks blood volume during ultrafiltration
    (Tetsuka 1995; Katzarski 1997, Agarwal 2011)
  - Blood donors, 1 of 2 studies
  - Improves with treatment of shock (Yanagawa, 2005, Ferrada, 2012)

**DIAGNOSTIC ACCURACY:**

- Correlates moderately with Invasively Measured CVP (Brennan 2007; Stawicki 2009; Goonewardena 2010; Yildirimturk, 2011; De Lorenzo 2012; Uthoff 2012; Wiwatworapan 2012)
- Correlates with other markers:
  - Dialysis complications
  - Expert status of volume (Carr, 2007)

**AFFECTS MANAGEMENT:**

- Predicts changes in Cardiac Index with fluid bolus (Barbiert, 2004, Feiseel 2004, Machare-Delgado, 2011)
Cardiac: Contractility, Effusion

**CONTRACTILITY:**

**DIAGNOSTIC ACCUARCY:**

- Better estimates contractility than traditional physical exam (Kobal 2005; Martin 2007)
- Correlates moderately well with traditional Echo but falls short of that expected of cardiologists (DeCara 2003; Alexander 2004; Martin 2007; Kirpatrick 2008; Lucas 2009; Andersen 2011; Kimura 2011)

**MANAGEMENT CHANGES:**

- Medicine residents with limited training can detect EF< 40% with sensitivity, specificity 94%, NPV: 88%, PPV: 97% In this setting this occurred 22 hours before echo results available (Razi, 2011)

**PERICARDIAL EFFUSIONS:**

**DIAGNOSTIC ACCUARCY:**

- Hospitalists’ sensitivity much better than their physical exam (0.07 to 0.79 (Martin, 2007)
- Moderate sensitivity (lowest 0.54) and specificity (0.68-0.99) compared with traditional Echo (Lucas 2009; DeCara 2003; Martin 2007; Alexander, 2004; Vignon 2007; Andersen 2011)
MANAGEMENT CHANGES:


- Others noted changes of management in 16-37% (Hauser 1989, Jensen 2004, Manasia 2005)
Pulmonary: Comet tails and Interstitial Syndrome

COMET TAILS: Vertical, hyperechoic lines that obliterate A-lines, go to end of screen

These become dominant when interstitial spaces become thickened (interstitial syndrome), which occurs in:

1. pulmonary edema
2. ARDS
3. Interstitial fibrosis
4. Pneumonias
Pulmonary: Interstitial Syndrome

**DIAGNOSTIC ACCURACY:**

- Lung ultrasound appears superior to CXR for ruling in and out significant interstitial syndrome (Kobal 2005; Martin 2007)

- Presence or absence of interstitial syndrome effectively differentiates cardiogenic vs. pulmonary etiologies of dyspnea

<table>
<thead>
<tr>
<th>Study</th>
<th>yr:</th>
<th>n:</th>
<th>sensitivity</th>
<th>specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lichtenstein</td>
<td>1998</td>
<td>66</td>
<td>100</td>
<td>92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cibinel</td>
<td>2012</td>
<td>80</td>
<td>94</td>
<td>84</td>
<td>88</td>
<td>92</td>
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<tr>
<td>Siva</td>
<td>2012</td>
<td>218</td>
<td>100</td>
<td>95</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>Sperandeo</td>
<td>2012</td>
<td>193</td>
<td>Unable to differentiate COPD and cardiogenic</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Pulmonary: Pneumothorax**

**DIAGNOSTIC ACCURACY:**
- Point-of-care Ultrasound is very accurate in the diagnosis of pneumothorax

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>Gold Standard</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
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</thead>
<tbody>
<tr>
<td>Licthenstein</td>
<td>111</td>
<td>CXR, CT</td>
<td>95</td>
<td>91</td>
<td>87</td>
<td>100</td>
</tr>
<tr>
<td>Licthenstein</td>
<td>115</td>
<td>CXR, CT</td>
<td>100</td>
<td>96</td>
<td>89</td>
<td>100</td>
</tr>
<tr>
<td>Dulchavsky</td>
<td>382</td>
<td>CXR, CT</td>
<td>94</td>
<td>100</td>
<td>95</td>
<td>99</td>
</tr>
<tr>
<td>Blaivas</td>
<td>176</td>
<td>CT/ chest tube</td>
<td>98</td>
<td>99</td>
<td>98</td>
<td>99</td>
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<tr>
<td>Rowarn</td>
<td>27</td>
<td>CT</td>
<td>100</td>
<td>94</td>
<td>92</td>
<td>100</td>
</tr>
<tr>
<td>Soldati</td>
<td>109</td>
<td>CT</td>
<td>92</td>
<td>99</td>
<td>96</td>
<td>99</td>
</tr>
</tbody>
</table>

Adapted from Volpicelli et al, 2012
 DIAGNOSTIC ACCURACY:  

- Point-of care Ultrasound superior to physical diagnosis  (Lichtensetein 2004, Patterson 2004)  

- Detected with sonography at higher rate than CXR  (Lichtenstein 1999, Kocijancic 2003, Lichtenstein 2004, Medford 2010)
Superficial abscesses

**DIAGNOSTIC ACCURACY:**

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exam alone</td>
<td>US</td>
</tr>
<tr>
<td>Berger et. al</td>
<td>400.76 (0.5-0.89)</td>
<td>0.83 (0.36-0.99)</td>
</tr>
<tr>
<td>Iverson et. al</td>
<td>650.79 (0.71-0.84)</td>
<td>0.98 (0.90-0.99)</td>
</tr>
<tr>
<td>Squire et al.</td>
<td>640.86 (0.76-0.93)</td>
<td>0.98 (0.93-1.00)</td>
</tr>
</tbody>
</table>

**MANAGEMENT CHANGES:**

Iverson et al: (n: 65) changed management in 9/65

Jaovishidha: (n: 38): no correlation in mgmt chance. Referral population where most common indication for referral was to eval for necrotizing fasciitis.

Squire: (n: 64), 17/18 patient where physician exam and US divergent success/failure of I&D agreed with US.
Abdominal Aortic Aneursym

**DIAGNOSTIC ACCURACY:**

Numerous, small studies show that various types of providers can detect AAA with good sensitivity and specificity

<table>
<thead>
<tr>
<th>Study</th>
<th>n:</th>
<th>Setting:</th>
<th>Sens</th>
<th>Spec</th>
<th>Avg diff (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailey (2001)</td>
<td>80</td>
<td>Primary Care</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Blois (2012)</td>
<td>45</td>
<td>Primary Care</td>
<td>100</td>
<td>100</td>
<td>2</td>
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<tr>
<td>Tayal (2003)</td>
<td>125</td>
<td>ED</td>
<td>100</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>Knaut (2005)</td>
<td>104</td>
<td>ED</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Costantino (2005)</td>
<td>238</td>
<td>ED</td>
<td>94</td>
<td>100</td>
<td>4.4</td>
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<tr>
<td>Dent (2007)</td>
<td>120</td>
<td>ED</td>
<td>96</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Moore (2008)</td>
<td>179</td>
<td>ED</td>
<td></td>
<td></td>
<td>3.9</td>
</tr>
</tbody>
</table>
Deep Venous Thrombosis

DIAGNOSTIC ACCURACY:

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>S (%)</th>
<th>SP (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blaivas</td>
<td>112</td>
<td>ED</td>
<td>100</td>
<td>97 (94-100)</td>
<td>94 (87-100)</td>
</tr>
<tr>
<td>Frazee</td>
<td>76</td>
<td>ED</td>
<td>88 (65-98)</td>
<td>75 (62-86)</td>
<td>53 (34-71)</td>
</tr>
<tr>
<td>Magazzini</td>
<td>399</td>
<td>ED</td>
<td>100 (96-100)</td>
<td>98 (97-98)</td>
<td>94 (89-93)</td>
</tr>
<tr>
<td>Jacob</td>
<td>121</td>
<td>ED</td>
<td>89 (51-99)</td>
<td>97 (92-99)</td>
<td></td>
</tr>
<tr>
<td>Kline</td>
<td>183</td>
<td>ED</td>
<td>70 (50-86)</td>
<td>89 (83-94)</td>
<td>53 (36-69)</td>
</tr>
<tr>
<td>Crisp</td>
<td>199</td>
<td>ED</td>
<td>100 (92-100)</td>
<td>99 (96-100)</td>
<td>98 (94-100)</td>
</tr>
<tr>
<td>Kory</td>
<td>128</td>
<td>CC</td>
<td>86</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Torres-Macho</td>
<td>76</td>
<td>ED</td>
<td>92 (82-100)</td>
<td>98 (94-100)</td>
<td>96 (88-100)</td>
</tr>
</tbody>
</table>

Adapted from Torres-Macho et al.

- Physician-performed compression ultrasonography can be very sensitive and accurate for DVT.
- It appears to vary significantly from study to study
Back to our case

Brief parasternal short axis: normal squeeze

Inferior vena cava with nl size and variability with respiration

Lung ultrasound reveals A-lines throughout upper and lower lung fields (representative image shown)
Some themes

• Literature is heterogenous by application. For some, just in technical and diagnostic accuracy. In other applications has moved on to decision making and patient outcomes research. (Hwang, 2011)

• There do appear to be numerous areas in which ultrasound offer us an opportunity to improve our physical exam

• There is great need to evaluate outcomes such as length of stay, missed diagnoses, etc.
“Disruptive innovation”

• A radical, non-incremental, innovation that goes on to disrupt an existing market/ framework and displace it in a way that is not expected in the field.

• Not surprisingly, many traditional imagers (e.g. radiologists and cardiologist), have voiced significant concern, noting that in many cases it did not meet the high standard that their fields have established.
“Disruptive innovation”

• “That it will ever come into general use, notwithstanding its value, is extremely doubtful; because its beneficial application requires much time and gives a good bit of trouble both to the patient and the practitioner; because its hue and character are foreign and opposed to all our habits and associations.”
“Disruptive innovation”

• “That it will ever come into general use, notwithstanding its value, is extremely doubtful; because its beneficial application requires much time and gives a good bit of trouble both to the patient and the practitioner; because its hue and character are foreign and opposed to all our habits and associations.”

London Times, 1834
1999: AMA resolution 802

• Acknowledged, “broad and diverse use of ultrasound,” and that it is, “within the scope of practice of appropriately trained physicians.”

• Hospitals should grant privileges based upon, “recommended training and education standards developed by each physician's respective specialty society”
  - specified training (didactic, bedside practice, apprenticing)
  - saving images, clear documentation, and performing QI/QA
  - staying within limitations of literature
  - oversight by specialty society
Response by Professional Societies:

• Emergency Physicians published thorough reviews of literature applicable to their uses, standards for training, and QI/QA, in 2001.
• Critical Care published 2008.
• The American College of Physicians has not yet developed these standards and policies.
Risks of failing to adopt training and QI/QA standards:

• “In fact, within a decade of the publication of *On Mediate Auscultation*, popular sentiment in favor of the technique had become so strong that a physician who did not employ the stethoscope jeopardized his professional reputation. Some physicians who did not know how to auscultate patients took to carrying stethoscopes with them for display purposes”

  (Reiser, 1979)
Take home points

• Point-of-care Ultrasound is an emerging tool that can augment many areas of our physical exam
• The evidence surrounding this is heterogenous in quality, and there is little patient-outcome data
• There is significant need for standards in training and quality to ensure that this done in a way that benefits our patients.
Bibliography


Bibliography