Ultrasound in the ICU

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DISCLOSURES: NONE

Objectives

• Definition
• Scope & Exam Types
• Evidence
• Training & Credentialing
• Clinical Examples

DEFINITION
Critical Care Ultrasound can supplement management of critically ill and injured patients and lead to the rapid diagnosis of the underlying etiology in those suffering cardiopulmonary dysfunction. Providers can also perform many standard bedside procedures under ultrasound guidance, increasing safety and success rates... and also allows critical care providers to obtain diagnostic information in a timely manner.

Pustavoitau, SCCM Ultrasound Taskforce

Critical Care Ultrasound

• Non-invasive
• Intensivist performs & Interprets exam at bedside
• Immediately integrates results into assessment and plan
• Repeated as needed, as often as needed
• Performed within a few minutes
• Focused and Limited

Clinician Performed

SCOPE & EXAM TYPES

Schmidt GA; Chest 2012
Scope of Critical Care Ultrasound

Vascular Ultrasound

Vascular Access

INTERVENTIONAL

VASCULAR
- PERIPHERAL VENOUS
- CENTRAL VENOUS
- ARTERIAL

THORACIC
- THORACENTESIS
- CHEST TUBE PLACEMENT

ABDOMINAL
- PARACENTESIS

DIAGNOSTIC

CARDIAC
- CONTRACTILITY
- GROSS FUNCTION
- EFFUSION
- IVC

THORACIC
- PNEUMOTHORAX
- EFFUSION
- PULMONARY EDEMA

VASCULAR
- THROMBOSIS

ABDOMEN
- FLUID
- GALL BLADDER

Adapted from: Curr Op Anesth 2014; 27:123
Focused & Limited
Bedside cardiac ultrasound ≠ Echocardiogram

Cardiac Ultrasound
• Assessments
  – Contractility
    • Hyperkinetic/normal
    • Depressed
    • Severely depressed
  – Effusions
Cardiac Ultrasound

IVC

Size and dispenserability/collapsibility

http://www.henryfordultrasounduniversity.com/education/online-education

IVC Distensibility

<table>
<thead>
<tr>
<th></th>
<th>T₀</th>
<th>T₁</th>
<th>p⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (bpm)</td>
<td>99±20</td>
<td>96±20</td>
<td>NS</td>
</tr>
<tr>
<td>Systolic arterial pressure (mmHg)</td>
<td>117±34</td>
<td>125±30</td>
<td>0.002</td>
</tr>
<tr>
<td>CI (l/min per m²)</td>
<td>2.7±1.2</td>
<td>3.0±1.2</td>
<td>0.0004</td>
</tr>
<tr>
<td>CVP (mmHg)</td>
<td>10±4</td>
<td>12±4</td>
<td>0.0004</td>
</tr>
<tr>
<td>diVC (%)</td>
<td>23±24</td>
<td>9±1.0</td>
<td>0.0016</td>
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</tbody>
</table>

MAX – MIN

<table>
<thead>
<tr>
<th></th>
<th>Responders</th>
<th>Non-responders</th>
<th>p⁺</th>
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</thead>
<tbody>
<tr>
<td>Heart rate (bpm)</td>
<td>106±25</td>
<td>92±13</td>
<td>NS</td>
</tr>
<tr>
<td>Systolic arterial pressure (mmHg)</td>
<td>112±42</td>
<td>123±26</td>
<td>NS</td>
</tr>
<tr>
<td>CI (l/min per m²)</td>
<td>2.4±1.1</td>
<td>3.0±1.2</td>
<td>NS</td>
</tr>
<tr>
<td>CVP (mmHg)</td>
<td>10±4</td>
<td>9±3</td>
<td>NS</td>
</tr>
<tr>
<td>Dose of vasopressors (µg/kg per min)</td>
<td>0.14±0.19</td>
<td>0.26±0.39</td>
<td>NS</td>
</tr>
<tr>
<td>diVC (%)</td>
<td>9±2.4</td>
<td>8±8</td>
<td>0.0019</td>
</tr>
</tbody>
</table>

Barbier, Intensive Care Med 2004

Perera; Emerg Med Clin N Am 2010; http://echocardiographer.org/TTE.html

http://www.henryfordultrasounduniversity.com/education/online-education
• $\Delta D_{IVC}$ predicts volume responsiveness  
  – $r=0.82$, $p<0.001$

• 12% $\Delta D_{IVC}$  
  – PPV 93%  
  – NPV 92%  

Lung Exam

• Lung parenchyma  
  – Edema  
  – Consolidations  
• Pleural fluid  
• Pneumothorax
Cardiogenic Pulmonary Edema

Pleural Fluid

- US can detect as little as 5-50 ml fluid
- AP film can detect >100 ml of fluid

Absence of Lung Sliding and PTX

<table>
<thead>
<tr>
<th>Population</th>
<th>Specificity</th>
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<tbody>
<tr>
<td>General</td>
<td>91%</td>
</tr>
<tr>
<td>Critically Ill</td>
<td>78%*</td>
</tr>
</tbody>
</table>

*Absence of lung sliding is also associated with:
- ARDS
- Atelectasis
- Pleural adhesions
- Mainstem intubation
- Pulmonary contusion
- Severe COPD w/ Blebs
- Phrenic nerve palsy

CCM 2007; 35: S250-S261
## DIAGNOSTIC

<table>
<thead>
<tr>
<th>CARDIAC</th>
<th>THORACIC</th>
<th>VASCULAR</th>
<th>ABDOMEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>• CONTRACTILITY</td>
<td>• PNEUMOTHORAX</td>
<td>• THROMBOSIS</td>
<td>• FLUID</td>
</tr>
<tr>
<td>&amp; GROSS FUNCTION</td>
<td>• EFFUSION</td>
<td></td>
<td>• GALL BLADDER</td>
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<td>EFFUSION</td>
<td>• PULMONARY EDEMA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IVC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adapted from: Curr Op Anesth 2014; 27: 122

## Abdominal: FAST

![Abdominal FAST Image](http://www.acssurgery.com/acssurgery/institutional/fig7bPopup.action?linkid=pant07_ch01_fig7&type=fig; http://www.henryfordultrasounduniversity.com/2education/online-education)

## Positive FAST

![Positive FAST Image](http://www.acssurgery.com/acssurgery/institutional/fig7bPopup.action?linkid=pant07_ch01_fig7&type=fig; http://www.henryfordultrasounduniversity.com/2education/online-education)

## EVIDENCE
Evidence

• Data supports use of cardiac US by Intensivists:
  – 10 hour training allowed successful cardiac US by intensivists with 84% correct interpretation
  – Emergency physicians learn cardiac US during 6 hour program
  – ICU trainees can learn cardiac ultrasound in a short course and use it to answer relevant clinical questions

Credentialing

- US imaging is within scope of practice of appropriately trained physicians
- Acknowledges broad & diverse use and application
- Privileging should be a function of hospital medical staffs
- Each hospital should review & approve criteria for credentialing based upon standards by respective specialty
- Follow specialty-specific guidelines
- Give separate privileges for CCUS & Advanced cardiac echo
- Provide continuous quality assessment & improvement
- Decide which core ultrasound applications are applicable to that institution

EXAMPLES

<table>
<thead>
<tr>
<th>Type of Ultrasound</th>
<th>Application</th>
<th>Minimum Number Interpreted</th>
<th>Minimum Number Personally Performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic</td>
<td>Basic CCE</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Pleural/pulmonary ultrasound</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Focused abdominal ultrasound</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Vascular ultrasound</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Procedural</td>
<td>Vascular access</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Thoracentesis/thoracostomy</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Paracentesis</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Paracentesis</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Other needle guidance procedures</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

AMA H-230.960; Pustavoitau, SCCM
Volume up or down?

- 75 year old
- PMHx:
  - Bilateral Lung Transplant (> 5 years ago)
  - ESRD on HD
- Admitted to ICU:
  - Hypercarbic respiratory failure (intubated)
  - Pneumonia
  - C. Diff colitis
  - CRRT
- Now worsening hypotension
- Lactate 3
- LOS: + 7 L

Volume up or down?

- 75 year old
- PMHx:
  - CAD
  - HTN
  - Known PE on heparin
- Admitted to ICU:
  - POD 2 knee tumor resection & free flap
- Now atrial fibrillation (RVR)
- Persistent 4-6 L NC
- LOS: + 3 L
Shock

• 35 year old
• PMHx:
  – None
• Admitted to ICU:
  – Acute liver failure
  – Intubated for hypoxemic respiratory failure
  – HLH/autoimmune
• Now increasing vasopressor requirement
• UOP 20-30 cc/hr
• Lactate ~ 3
• MCVO2 = 47% (PICC)
Shock

- 35 year old
- PMHx:
  - Thyroid goiter
- Admitted to ICU:
  - Thyroidectomy with upper median sternotomy
  - Serial neck circumference checks
- Now:
  - Tachycardic
  - Tachypneic
  - Dyspnea
  - O2 Saturation 80%’s
- CXR ordered (10 minutes)

What do you need?

- Ultrasound
  - 2 D
  - M- Mode
- Probes
  - Linear (high frequency)
  - Phased Array (lower frequency)
- Image Capture
- Quality Assessment and Review
Conclusions

- Critical Care Ultrasound is a portable, practitioner performed and interpreted exam that establishes diagnoses and guides procedures
- Scope includes: Diagnostic & Interventional
- Exams include: Cardiac, Pulmonary, Vascular & Abdominal
- Training is an important and evolving area for critical care trained practitioners & trainees
- This technology will make a difference in your critical care practice

Know Your Limits!!

- Do not comment on findings that are not within your expertise
- If you see something you do not understand or that concerns you, obtain appropriate imaging performed by a specialist PROMPTLY

Cardiac Ultrasound for ICU

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hand-carried ultrasound</th>
<th>Limited</th>
<th>Comprehensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Brief, extension of physical examination</td>
<td>Limited, if any</td>
<td>Goal-directed, follow-up</td>
</tr>
<tr>
<td>Report</td>
<td></td>
<td></td>
<td>Permanent and complete</td>
</tr>
<tr>
<td>Minimal training (ASE recommended)</td>
<td>Level 1</td>
<td>Level 2</td>
<td>Level 2-3 Recommended</td>
</tr>
<tr>
<td>ICATEC accreditation</td>
<td>To be determined</td>
<td>Level 3</td>
<td>Recommended</td>
</tr>
<tr>
<td>Duration of examination</td>
<td>Brief, ≤ 15 min</td>
<td>15-30 min</td>
<td>Long, &gt; 30 min</td>
</tr>
<tr>
<td>Archival image</td>
<td>Limited, if any</td>
<td>Yes</td>
<td>Yes</td>
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[ASE, American Society of Echocardiography; ICATEC, Intersociety Commission for Accreditation of Echocardiography Laboratories]
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<th>Design</th>
<th>Result</th>
<th>Comment</th>
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<td>JCVA 2005; 19: 155-159</td>
<td>ICU fellows performed and interpret a limited cardiac echo study - Results compared to a cardiologist • 90 pts studied</td>
<td>Fellows successfully performed (94%) and interpreted (84%) a limited cardiac echo</td>
<td>Post-echo management chart in 37% of pts • Ave time for image acquisition and interpretation 10.5 min +/-4</td>
</tr>
<tr>
<td>8 h</td>
<td>ICU fellows performed and interpret a limited cardiac echo study • Results compared to level II echocardiographer • 61 pts studied</td>
<td>Fellows adequately appraised: LV fx, LV dilatation, RV dilatation, parietal effusion and pleural effusion (Kappa 0.66-0.76)</td>
<td>-84% of patients were on MV • Residents previously trained in the FAST exam</td>
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<td>J Trauma 2008; 65: 509-516</td>
<td>Surgical residents echo-based estimation of CVP and CI • Results compared to PAOP • 85 trauma and general surgery patients studied</td>
<td>-97% of CI exams and 87% of IVC exams were adequate • Overall correlation was 0.76 (p=0.0001)</td>
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<td>Chest 2009; 135: 1416-1420</td>
<td>Intensivists evaluated LV fx • Results compared to experienced echocardiographers • 44 medical ICU patients</td>
<td>Intensivists correctly identified normal (92%) and abnl (60%)</td>
<td>Acquisition and interpretation &lt; 10 min</td>
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