Haemodynamic assessment of the critically ill in the ICU using echo

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Hemodynamic assessment in the ICU

**Invasively**

- Pulmonary artery catheters
- Central venous catheters
- Central arterial catheters

**Non-Invasively**
HISTORICAL ASPECTS

• **Warner Forssman** in 1929, when he threaded a catheter into his own heart, for which he shared the 1956 Nobel Prize along with Drs. Richards and Courmand.

• Bed-side use was facilitated by the addition of a flow directed balloon to the catheter by **Dr. Swan**, and a thermistor tip by **Dr. Ganz** which enabled measurement of cardiac output in 1967.
HISTORICAL ASPECTS

✓ Lack of benefit and potential harm associated with the routine use of RHC.\textsuperscript{1-6}

✓ Superiority of bedside echocardiography over RHC.\textsuperscript{7-9}

✓ Central venous catheters and pulmonary artery catheters (PAC) have not been found to improve survival or decrease the length of stay.\textsuperscript{10}

✓ PAC can be inaccurate in estimating LV filling pressures \textsuperscript{4,10} or diastolic dysfunction which is more predictive of mortality in hospitalized patients.\textsuperscript{11-15}

ADVANTAGES OF ECHO VS OTHER TECHNIQUES FOR HAEMODYNAMIC ASSESSMENT IN ICU

- Non-invasive
- Safety profile
- Portability
- Low cost
- Ease of use
- Speed
- Precise definition of diagnosis and clarification of pathophysiologic mechanisms
- Conduction of a direct anatomic evaluation of the heart in real time
- Adjunct to the physical examination
Focused cardiac ultrasound (FCU)

- Point of care cardiac us
- Bedside cardiac us
- Quick look cardiac us
- Hand held cardiac us

FOCUSED ECHOCARDIOGRAPHY PROTOCOLS

✓ RACE (Rapid Assessment by Cardiac Echo)¹
✓ FATE (Focused Assessed TTE)²
✓ BEAT (Beat - Effusion - Area - Tank)³
✓ FOCUS (Focus Cardiac UltraSound)⁴

(1) what is the LV function?
(2) what is the RV function?
(3) is there any evidence of pericardial effusion & cardiac tamponade?
(4) what is the fluid status?

Echocardiography can be widely used

14 ICU staff specialists with no previous TEE experience received 6 hour of training as mTEE operators. Echocardiographic examinations using mTEE after brief bedside training were feasible and of sufficient quality in a majority of examined ICU patients with good inter-rater reliability between mTEE operators and an expert cardiologist.

Cioccari et al. Critical Care 2013, 17:R121

- In one study, ICU residents were given a short 8 hours course limited to interpretation of LV size and function, RV dilation, pericardial effusion, and pleural effusion. The residents were then able to evaluate 93% of 366 clinical questions with close agreement with the interpretation of expert operators.


- In a similar study, intensivists were given a 10 hour course in echo after which they performed hand-held bedside examinations. Their interpretations correlated well with those of experienced echocardiographers in 84% of the examinations and led to treatment adjustments in 37% of the subjects.


- Several studies have demonstrated that after a brief educational intervention non-cardiologists are able to perform limited transthoracic examinations and correctly interpret studies most of the time.

ROLE OF ECHO IN THE ICU

1. Diagnosis

2. Guidance of interventions and therapy

3. Haemodynamic assessment, monitoring and follow up
Indications of echo in the ICU

- Infective endocarditis
- Aortic dissection
- Unexplained hypoxemia
- Source of embolus
- Complications after cardiothoracic surgery
- Unresponsiveness to therapy
- LVAD
- Trauma
- Tamponade monitoring
- Pulmonary embolism
- Prosthetic valve thrombus
- Kidney/liver/lung transplantation
- Major vascular surgery
- Orthopedic/spinal surgery
- Neurosurgery

Indications of echo in the ICU

1. The spectrum of haemodynamic instability
   - **Shock**
     - SHOCK
     - Septic
     - Hypovolemic
     - Obstructive
     - Cardiogenic
     - K combinations or other kinds of shock
   - **Arrest**  
     Focused Echo Evaluation in Life support (FEEL)
     - Pulseless electrical activity
     - Asystole
     - Pseudo- pulseless electrical activity

2. Acute respiratory failure
   - RESP-F
   - exacerbation of chronic Respiratory disease
   - Pulmonary Embolism
   - ST changes associated with acute cardiac or pericardial disease
   - Pneumonia
   - heart Failure

HAEMODYNAMIC ASSESSMENT WITH ECHO INCLUDES.....

- LV and RV size and function
- Cardiac output
- Filling pressures
- Volume status – fluid responsiveness
- Pulmonary artery pressure
- Valvular function and integrity
- Identification and quantification of pericardial effusion
Haemodynamic assessment means assessment of.....

1. Myocardial function

2. Volume status – fluid responsiveness
Assessment of LV systolic function

1. Fractional shortening (M-mode)

2. Ejection fraction (2D: Teichholz formula, FAC from SA views, volume estimations: area-length formula or Simpson’s method, 3D, visual assessment)

A low ejection fraction can reflect either an intrinsic LV systolic dysfunction or an excessive LV afterload, but in both conditions it reflects the fact that ventriculoarterial coupling is inadequate.
Assessment of LV diastolic function

A: PW for Mitral Inflow E Velocity
B: TDI for e' Velocity Lateral Wall
C. TDI for e’ Velocity Medial Wall

Table 1 Specific echocardiographic monitoring parameters and monitoring values

<table>
<thead>
<tr>
<th>Monitoring parameter Role Reference</th>
<th>System requirements</th>
<th>Important technical features</th>
<th>Specific values to use while guiding interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmirtal E/e' for LAP Nagueh et al.</td>
<td>Pulsed Doppler Tissue Doppler</td>
<td>Doppler alignment End-expiratory acquisition</td>
<td>$E/e' &lt; 8$; normal LVEF = normal LAP $E/e' &gt; 13$; normal LVEF = increased LAP $E/A &gt; 2; DT &lt; 150$ msec; depressed LVEF = increased LAP $E/A &lt; 1$ and $E &lt; 50$ cm/sec; depressed LVEF = normal LAP</td>
</tr>
</tbody>
</table>

Assessment of RV systolic function

1. **Qualitative**: - RV free wall and IVS endomyocardial thickening and contraction.

2. **Quantitative**: ejection fraction (RVEF), fractional area change (FAC), systolic tissue annular motion by two-dimensional, M-mode (TAPSE) or tissue Doppler (TV S wave), myocardial performance index (MPI) and measurement of dP/dt.
Continuous echo monitoring

The ClariTEE probe uniquely may remain indwelling for up to 72 hours providing direct visualization of the heart over time, thereby enabling gold standard hemodynamic management.
Transgastric short axis view
LV filling and function

Four Chamber view
Biventricular function

Superior vena cava view
Fluid responsiveness
Assessment of Cardiac Output

**Stroke volume** is calculated using Doppler to measure the velocity time integral (VTI) of the flow signal at a given site, and 2D echo to measure the cross sectional area of the same site.
Assessment of Cardiac Output

Transcutaneous ultrasound

TRANSCUTANEOUS ULTRASOUND

- Provides “continuous” assessment of
  - SV
  - CO
  - SVV
  - Corrected flow time (FTc)
  - Peak flow velocity
  - SVR
- Feasible for short-term, intermittent monitoring
Echo – Hemodynamic Monitoring of Cardiac Output

Oesophageal Doppler Monitoring (CardioQ-ODM)

measures blood flow velocity in the descending aorta by using a Doppler transducer at the tip of a probe, which is inserted into the oesophagus via the mouth or nose.
Using oesophageal Doppler-guided fluid management can result in 57% less chance of complications. Complications fall 57% with ODM use (Hamilton et al., 2011).

Potential benefits of ODM use:

- Reduce length of stay by at least 2 ½ days
- Reduce CVC insertion by at least 23%
- With reduction (not statistically significant) in re-admissions and re-operations
Volume status - fluid responsiveness

A. Static parameters

1. IVC size at end-expiration
   - <10mm - positive response to fluid infusion
   - >20mm - exclude any fluid responsiveness
Volume status - fluid responsiveness

2. Restrictive pattern of MV inflow -> fluid unresponsiveness

3. LV and RV diastolic diameters, areas and volumes
Volume status- fluid responsiveness

B. Dynamic parameters
**Volume status- fluid responsiveness**

I. **In patients on mechanical ventilation**

1. Respiratory changes of the stroke volume
   Cut-off value ≥12% of AV Vmax and 20% of aortic VTI

2. IVC-SVC diameter changes


Limitations

- On mechanical ventilation and without spontaneous breathing effort during the measurement.\(^1\)
- In sinus heart rhythm (except for IVC and SVC variations).\(^1\)
- Low tidal volume ventilation <7ml/kg (eg in ARDS) -> false negative results.\(^2\)
- RV dysfunction -> false positive results.\(^3\)
- Pitfalls with IVC and SVC measurements.\(^1\)

Volume status - fluid responsiveness

II. In spontaneously breathing patients

- Profound hypovolemia
- Leg bandages
HEMODYNAMIC MONITORING IN SPECIAL SCENARIOS

The Critically Ill Under Special Circumstances
Echo in hemodynamic monitoring of patients with mechanical circulatory support

- Echocardiography is an important tool in the management of patients undergoing VAD implantation, since it can easily provide critical information about pre-operative anatomic abnormalities, guide the device implantation procedure, and evaluate post-insertion cardiac and device function.


- Echocardiography has emerged as an important tool to assess and optimize hemodynamic performance in patients assisted with a ventricular assist device.

  LVIDD, LVIDS, AV opening, AR and MR severity and RVSP

- Detect complications (thrombosis – mechanical obstruction)

  LVIDD to revolution per minute slope ≥0.16

- Weaning from the LVAD

  LVIDD <60mm and ↓MR severity
  LVAD off: LVEF>50%, without worsening of RV dilatation

Echo in hemodynamic monitoring of patients with ECMO (extra-corporeal membrane oxygenation)

- Assess appropriateness of ECMO
- Guidance and confirmation of the insertion site
- Monitoring
  - **VV-ECMO**: RV size and systolic function, SPAP.
  - **VA-ECMO**: LV and RV size and function.
- Complications
  - Pericardial effusion
  - Malposition or migration of ECMO
  - Intravascular or intracardiac thrombosis
- **Weaning from VA-ECMO**
  - LVEF ≥20-25%, AV VTI ≥ 12cm, TDI lat S’ ≥ 6cm/s, absence of LV dilatation and pericardial effusion, recovery of RV function

Victor K et al. Echo research and practice. 2015;14-0111.
CHALLENGES OF ECHO IN THE ICU

• Image acquisition (sternotomies, chest drains, dressings)
• Lung interference
• Positioning limitations
• Confounding effects of: positive pressure ventilation, sedation, inotropic and pressor agents and pacing
• Variations in loading conditions
• Failure of 10-30%
• Normal values for indices commonly measured in the non-critical care setting are not necessarily applicable to the ICU patients

<table>
<thead>
<tr>
<th>Echocardiographic monitoring parameter</th>
<th>IOV/CV</th>
<th>Monitoring setting</th>
<th>Meaningful changes from baseline in a monitoring setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVC collapsibility index</td>
<td>Not demonstrated</td>
<td>CHF, trauma, perioperative</td>
<td>&gt;10%&lt;sup&gt;[32]&lt;/sup&gt; Change from &lt;50% to &gt;50%&lt;sup&gt;[31]&lt;/sup&gt;</td>
</tr>
<tr>
<td>E/A ratio</td>
<td>6% CV&lt;sup&gt;[88]&lt;/sup&gt;</td>
<td>CHF, perioperative</td>
<td>Change from &lt;1 to 1-2 to 2</td>
</tr>
<tr>
<td>Depressed LV systolic function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E/e'&lt;sup&gt;[9]&lt;/sup&gt;</td>
<td>8% CV</td>
<td>CHF, perioperative</td>
<td>&gt;8%&lt;sup&gt;[93]&lt;/sup&gt; Change from &lt;8 to 9-14 to ≥15&lt;sup&gt;[15]&lt;/sup&gt;</td>
</tr>
<tr>
<td>Normal LV systolic function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LVOT VTI</td>
<td>6% IOV</td>
<td>CHF, perioperative setting</td>
<td>&gt;6% change in VTI or SV&lt;sup&gt;[90]&lt;/sup&gt;</td>
</tr>
<tr>
<td>LVOT area</td>
<td>4% IOV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PASP</td>
<td>3% IOV</td>
<td>Pulmonary embolus, perioperative, CHF</td>
<td>&gt;3%&lt;sup&gt;[91]&lt;/sup&gt; Change from &lt;40 to 40-60 to &gt;60 mm Hg&lt;sup&gt;[31]&lt;/sup&gt;</td>
</tr>
<tr>
<td>LVIDD, LVIDS</td>
<td>8% IOV</td>
<td>Perioperative, CHF ramp/weaning</td>
<td>&gt;8%&lt;sup&gt;[92]&lt;/sup&gt;</td>
</tr>
<tr>
<td>RV FAC, S', and TAPSE</td>
<td>RV FAC:10% (IOV)</td>
<td>Pulmonary embolus</td>
<td>RV FAC &gt; 10%&lt;sup&gt;[93]&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>RV s': 1.6 mm/sec (IOV)</td>
<td>Perioperative</td>
<td>RV s' &gt; 1.6 mm/sec&lt;sup&gt;[93]&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>TAPSE: 1.9 mm (IOV)</td>
<td>Pulmonary hypertension, CHF LVAD</td>
<td>TAPSE &gt; 1.9 mm&lt;sup&gt;[93]&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

CV, Coefficient of variation; IOV, interobserver variability; PASP, PA systolic pressure.

Therapeutic Impact of Critical Care Echocardiography

- Effect varies depending on the type of ICU population.

- Critical care echocardiography has documented a direct impact on therapy in up to 50% of ICU patients.

- TEE has a therapeutic impact that is consistently superior to that of TTE when ventilated ICU patients are evaluated with both procedures.

- TEE has been shown to prompt cardiac surgery in up to 20% of examined patients.

- Need for prospective randomized trials to study the effect of bedside echo on mortality and morbidity in the ICU.

Σας ευχαριστώ πολύ