IT’S TIME TO MONITOR EVLW

Dr RJ Tshitangano
Wits University
<table>
<thead>
<tr>
<th>Technique</th>
<th>Accuracy</th>
<th>Clinical value</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravimetry</td>
<td>Postmortem gravimetry is used as the reference technique for determination of EVLW in the experimental setting.</td>
<td>Since gravimetry is possible only in non-survivors, the clinical value of this method is low.</td>
<td>Low</td>
</tr>
<tr>
<td>Chest radiography (CR)</td>
<td>An approx. 35% increase in EVLW is required for the diagnosis of pulmonary edema. Absence of CR signs virtually rules out significant pulmonary edema.</td>
<td>As a non-quantitative method, CR has been shown to be a relatively poor indicator of pulmonary edema of various etiologies. The results depend on a variety of uncontrollable factors.</td>
<td>Relatively low</td>
</tr>
<tr>
<td>Computer tomography (CT)</td>
<td>CT may provide more detailed information about regional lung density changes that correlates with localized pulmonary edema.</td>
<td>Cannot be used at the bedside. Changes are non-specific. High radiation dose makes the CT inappropriate for frequently repeated measurements.</td>
<td>High</td>
</tr>
<tr>
<td>Magnetic resonance imaging (MRI)</td>
<td>MRI has significant advantages over CT and plain CR. EVLW cannot be subtracted from the intravascular volume.</td>
<td>Cannot be used at the bedside. No radiation but long image acquisition time and difficulties of frequently repeated measurements in ICU patients.</td>
<td>High</td>
</tr>
<tr>
<td>Positron emission tomography (PET)</td>
<td>EVLW can be separated from total water by $^{15}$O labeled carbon monoxide.</td>
<td>PET requires radioactive tracers and is not intended for repeated measurements. Available in outstanding scientific centers only.</td>
<td>Very high</td>
</tr>
<tr>
<td>Bioimpedance plethysmography</td>
<td>The technique does not differentiate the intrathoracic fluid. Absolute values cannot be obtained.</td>
<td>Method has not attained wide clinical use but is a non-invasive alternative to indicator dilution techniques.</td>
<td>Low</td>
</tr>
<tr>
<td>Multiple gas technique</td>
<td>The method measures only EVLW that is accessible to the airways.</td>
<td>Method has not attained wide clinical use.</td>
<td>Relatively low</td>
</tr>
<tr>
<td>Double thermo-dye indicator dilution</td>
<td>Details are expounded in this review. One of the modifications uses heavy water (D$_2$O) as a thermo-indicator that increases the accuracy of the method.</td>
<td>Invasive method. Details are expounded in this review. Method is relatively cumbersome and sophisticated. Hepatic failure may affect clearance of dye-indicator (Indocyanine green).</td>
<td>Relatively high</td>
</tr>
<tr>
<td>Single (thermal) indicator dilution</td>
<td>Acceptable. Use of thermal indicator alone has been shown to have approximately the same sensitivity as double dilution.</td>
<td>This invasive method is intended for repeated measurements at the bedside. Details are expounded in this review.</td>
<td>Relatively low</td>
</tr>
</tbody>
</table>
Comparison of thermodilution measured extravascular lung water with chest radiographic assessment of pulmonary oedema in patients with acute lung injury

Lisa M Brown¹,², Carolyn S Calfee³,⁴, James P Howard²,⁵, Thelma R Craig⁶,⁷, Michael A Matthay²,³,⁸*, and Daniel F McAuley⁶,⁷

Conclusion: EVLW measured by CXR was modestly correlated with thermodilution measured EVLW. Unlike CXR findings, transpulmonary thermodilution EVLWI measurements over time predicted mortality in patients with ALI/ARDS.

Fig. 1. Methodology of transpulmonary thermodilution. a Thermodilution curves and Stewart-Hamilton equation. b Intrathoracic volumes. T: temperature; CO: cardiac output (arterial thermodilution); MTt: mean transit time of indicator; DST: downslope time of indicator; At: indicator appearance time; c(t): concentration of indicator; ITTV: intrathoracic thermal volume; PTV: pulmonary thermal volume; RAEDV: right atrium end-diastolic volume; RVEDV: right ventricle end-diastolic volume; LAEDV: left atrium end-diastolic volume; LVEDV: left ventricle end-diastolic volume; GEDV: global end-diastolic volume; ITBV: intrathoracic blood volume; PBV: pulmonary blood volume; EVLW: extravascular lung water
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Calculation</th>
<th>Normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac Index (CI)</td>
<td>Area under transpulmonary thermodilution curve</td>
<td>3.0–5.0 l/min/m²</td>
</tr>
<tr>
<td>Extravascular Lung Water Index (EVLWI)</td>
<td>EWLV = (ITTV–ITBV)/BW</td>
<td>3.0–7.0 ml/kg</td>
</tr>
<tr>
<td>Intrathoracic Blood Volume Index (ITBVI)</td>
<td>ITBVI = 1.25×GEDV/BW</td>
<td>850–1000 ml/m²</td>
</tr>
<tr>
<td>Pulmonary Vascular Permeability Index (PVPI)</td>
<td>PVPI = EVLV/PBV</td>
<td>1–3</td>
</tr>
<tr>
<td>Cardiac Function Index (CFI)</td>
<td>CFI = CI/GEDV</td>
<td>4.5–6.5 min⁻¹</td>
</tr>
<tr>
<td>Global Ejection Fraction (GEF)</td>
<td>GEF = 4×SV/GEDV</td>
<td>25–35%</td>
</tr>
</tbody>
</table>

**Transpulmonary cardiac output and pulse contour analysis derived parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Calculation</th>
<th>Normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac Index (Cl)</td>
<td>Integral calculation of the area under curve</td>
<td>3.0–5.0 l/min/m²</td>
</tr>
<tr>
<td>Stroke Volume Index (SVI)</td>
<td>SVI = CI/HR</td>
<td>40–60 ml/m²</td>
</tr>
<tr>
<td>Stroke Volume Variations (SVV)</td>
<td>SVV = (SVmax–SVmin)/SVmean</td>
<td>≤10%</td>
</tr>
<tr>
<td>Pulse Pressure Variations (PPV)</td>
<td>PPV = (PPmax–PPmin)/PPmean</td>
<td>≤10%</td>
</tr>
<tr>
<td>Left ventricle contractility index (dPmax)</td>
<td>Analysis of arterial pulse contour (max. velocity of systolic part increase); dPmax = d(P)/d(t)</td>
<td>1200–2000 mmHg</td>
</tr>
<tr>
<td>Systemic Vascular Resistance Index (SVRI)</td>
<td>SVRI = 80×(MAP–CVP)/CI</td>
<td>1200–2000 dyne×s×cm⁻⁵/m²</td>
</tr>
</tbody>
</table>

ITTV: intrathoracic thermal volume; BW: body weight; GEDV: Global end diastolic volume; EVLW: extravascular lung water; PBV: pulmonary blood volume; SV: stroke volume; HR: heart rate; PP: pulse pressure; P: pressure; t: time; MAP: mean arterial pressure; CVP: central venous pressure.
Pulmonary vascular permeability index

Increased hydrostatic pressure

Increased fluid filtration

Increased permeability

Normal hydrostatic pressure
**Lung**

**ELWI**

- Day 4: 11 ml/kg
- Day 6: 10 ml/kg
- Day 8: 9 ml/kg
- Day 10: 8 ml/kg
- Day 12: 7 ml/kg

**PVPI**

- Day 4: 3.2
- Day 6: 3.1
- Day 8: 3.0
- Day 10: 2.9
- Day 12: 2.8

---

**Hydrostatic Pulmonary edema**

- EVLW↑ → Hydrostatic pulmonary edema

**Permeability Pulmonary edema**

- EVLW↑ → PVPI↑ → Permeability pulmonary edema

**PVPI**

- Normal
- PBV

**EVLW**

- Normal
- PBV↑
Ratio of extravascular lung water to preload; Supposedly a measure of pulmonary capillary leakyness

\[ PVPI = \frac{EVLW}{PBV} \]
Assessing pulmonary permeability by transpulmonary thermodilution allows differentiation of hydrostatic pulmonary edema from ALI/ARDS

In conclusion, this study demonstrates that pulmonary permeability indexes obtained by transpulmonary thermodilution can be helpful for distinguishing between hydrostatic pulmonary edema and ALI/ARDS.
Conclusions: Extravascular lung water index and pulmonary vascular permeability index measured by transpulmonary thermodilution are independent risk factors of day-28 mortality in patients with acute respiratory distress syndrome. (Crit Care Med 2013;41:0–0)
Background: Extravascular lung water (EVLW) is a sensitive prognostic indicator of pulmonary edema. Thus, EV LW may be an advantageous method of fluid management. This study aims to evaluate the outcomes of using EVLW and pulmonary artery wedge pressure (PAWP) as strategies for fluid management in patients with acute respiratory distress syndrome (ARDS).

Conclusions: EVLW for fluid management improved clinical results in patients with ARDS better than PAWP.
The clinical usefulness of extravascular lung water and pulmonary vascular permeability index to diagnose and characterize pulmonary edema: a prospective multicenter study on the quantitative differential diagnostic definition for acute lung injury/acute respiratory distress syndrome

Shigeki Kushimoto¹, Yasuhiro Taira², Yasuhide Kitazawa³, Kazuo Okuchi⁴, Teruo Sakamoto⁵, Hiroyasu Ishikura⁶, Tomoyuki Endo⁷, Satoshi Yamanouchi⁸, Takashi Tagami⁹, Junko Yamaguchi¹⁰, Kazuhide Yoshikawa¹¹, Manabu Sugita¹², Yoichi Kase¹³, Takashi Kanemura¹⁴, Hiroyuki Takahashi¹⁵, Yuichi Kuroki¹⁶, Hiroyo Izumino¹⁷, Hiroshi Rinka¹⁸, Ryutarou Seo¹⁹, Makoto Takatori²⁰, Tadashi Kaneko²¹, Toshiaki Nakamura²², Takayuki Irahara²³, Nobuyuki Saito²⁴ and Akihiro Watanabe⁸, for The PiCCO Pulmonary Edema Study Group
Key messages

- EVLW was greater in patients with ALI/ARDS and cardiogenic edema than patients with pleural effusion with atelectasis.
- Pulmonary vascular permeability was increased in patients with ALI/ARDS compared with cardiogenic edema and pleural effusion with atelectasis patients.
- The cutoff value of the PVPI for the quantitative diagnosis of ALI/ARDS was between 2.6 and 2.85, with a specificity of 0.9 to 0.95, and PVPI < 1.7 ruled out an ALI/ARDS diagnosis (specificity, 0.95).
Conclusions: Perioperative extravascular lung water indexed to predicted body weight is an early marker that predicts risk of clinically significant postoperative pulmonary edema in at-risk surgical patients. Pulmonary vascular permeability index effectively discriminated postoperative acute respiratory distress syndrome from cardiogenic pulmonary edema. These measures will aid in the early detection of subclinical lung injury in at-risk surgical populations. (*Crit Care Med 2015; 43:665–673*)
Conclusions: This study may provide the first validated quantitative bedside diagnostic tool for diffuse alveolar damage. Extravascular lung water may allow the detection of diffuse alveolar damage and may support the clinical diagnosis of acute respiratory distress syndrome. The best extravascular lung water cut-off value to discriminate between normal lungs and lungs with diffuse alveolar damage is around 10 mL/kg. (Crit Care Med 2013; 41:2144–2150)
Extravascular lung water in acute respiratory distress syndrome and the Berlin definition: time for real change

Michelle S Chew
Conclusions: The EVLW/blood volume ratios are determined, at least in part, by moderately increased pulmonary permeability in nonseptic critically ill patients with or at risk for ALI/ARDS, independent of fluid status and pressure forces. Normal ratios may help to exclude high permeability.
Extravascular Lung Water, B-Type Natriuretic Peptide, and Blood Volume Contraction Enable Diagnosis of Weaning-Induced Pulmonary Edema*

Martin Dres, MD\textsuperscript{1,2}; Jean-Louis Teboul, MD, PhD\textsuperscript{1,2}; Nadia Anguel, MD\textsuperscript{1}; Laurent Guerin, MD\textsuperscript{1,2}; Christian Richard, MD\textsuperscript{1,2}; Xavier Monnet, MD, PhD\textsuperscript{1,2}

Conclusions: Spontaneous breathing trial–induced increases in extravascular lung water indexed for ideal body weight, plasma protein concentrations, hemoglobin concentration, and B-type natriuretic peptide are reliable alternatives to the pulmonary artery catheter for diagnosing weaning-induced pulmonary edema. (Crit Care Med 2014; 42:1882–1889)
Extravascular lung water index as a sign of developing sepsis in burns

Z. Bognar *, V. Foldi, B. Rezman, L. Bogar, C. Csontos

Our data suggest that EVLWI is an early warning sign of developing infection and its continuous elevation can predict poor prognosis in burns.

Shock. EVLWI $>14 \text{ ml kg}^{-1}$ has been associated with a significantly higher in-hospital mortality [14].
Impact of extravascular lung water index on outcomes of severe sepsis patients in a medical intensive care unit

Fu-Tsai Chung\textsuperscript{a, 1}, Shu-Min Lin\textsuperscript{a, 1}, Shinn-Yn Lin\textsuperscript{b, c, d}, Horng-Chyuan Lin\textsuperscript{a,*}

A cut-off value for EVLI of 10 ml/kg had good sensitivity (88.2%) and specificity (68.7%) by ROC curve analysis. Medical ICU patients with extremely severe sepsis and a high EVLI (≥10 ml/kg) had lower in-hospital survival rate than those with a low EVLI (<10 ml/kg) (15% vs. 67.7%, respectively, \( p < 0.001 \)).
Fluid management in critically ill patients: the role of extravascular lung water, abdominal hypertension, capillary leak, and fluid balance

Colin Cordemans¹, Inneke De laet¹, Niels Van Regenmortel¹, Karen Schoonheydt¹, Hilde Dits¹, Wolfgang Huber², Manu LNG Malbrain¹

Conclusion: There seems to be an important correlation between CLI, EVLWI kinetics, IAP, and fluid balance in mechanically ventilated patients, associated with organ dysfunction and poor prognosis. In this context, we introduce the global increased permeability syndrome.

CONCLUSION

EVLW is an important element in the fluid management of the critically ill.

EVLW may contribute to a better understanding, diagnosis and treatment of ARDS.

Bedside measurement of EVLW is easy.
This is not the end.
Thank You