Lung water measurement
Valid parameters for clinical use

Quantify pulmonary oedema and identify the cause

This document is intended to provide information to an international audience outside of the US.
**Physiology of lung water**
characteristics of ELWI and PVPI

### Extra Vascular Lung Water Index (ELWI)

<table>
<thead>
<tr>
<th>Definition</th>
<th>Physiology</th>
<th>Characteristics</th>
</tr>
</thead>
</table>
| • Extra vascular lung water (EVLW) is the interstitial, intracellular, alveolar and lymphatic fluid in the lungs, outside the pulmonary vasculature  
• By indexing EVLW to the predicted body weight it becomes comparable between individuals (ELWI) | • EVLW is controlled by the lymphatic drainage system of the lung to protect alveoli from fluids  
• EVLW can change as result of pressure changes in the lung or increased permeability of the alveo-capillary barrier | • Reported normal value of ELWI ≤10ml/kg  
• Predictor of mortality in severe sepsis, ARDS, burned patients and critically ill patients [5,6,11,12]  
• Marker for pulmonary oedema (indicates the severity of the pulmonary leak) |

### Pulmonary Vascular Permeability Index (PVPI)

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| • PVPI is the ratio between ELWI and pulmonary blood volume  
• PVPI enables differential diagnosis of the source of pulmonary oedema (cardiogenic or permeability) [9,11,12] | • Intravascular fluid overload leads to an increase of hydrostatic pressure which results in fluid transfer into the extravascular space (cardiogenic pulmonary oedema)  
• Increased vascular permeability (e.g. caused by inflammation) leads to an increased transfer of fluids to the extravascular space (permeability pulmonary oedema) | • PVPI in range 1-3 points to cardiogenic pulmonary oedema  
• PVPI greater than 3 points to permeability pulmonary oedema  
• The only parameter that characterises degree of impairment of alveolo-capillary barrier and quantifies pulmonary leak at the bedside |
Evaluation of extravascular lung water
a unique evaluation method

\[ \text{ITTV} - \text{ITBV} = \text{EVLW} \]

\[ \frac{\text{EVLW}}{\text{PBV}} = \text{PVPI} \]

PVPI
1.0 - 3.0
cardiogenic pulmonary oedema
> 3.0
permeability pulmonary oedema
Benefits of ELWI and PVPI parameter use in clinical practice

Clinical issue:
Chest x-rays do not reflect the level of pulmonary oedema

Quality of x-ray is influenced by many factors
- accurate patient position
- x-ray intensity
- radiologist

Correlation of ELWI and PVPI regarding outcome:

<table>
<thead>
<tr>
<th></th>
<th>ELWI (p-value)</th>
<th>PVPI (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of mechanical ventilation</td>
<td>&lt; 0.001</td>
<td>0.11</td>
</tr>
<tr>
<td>Duration of ICU stay</td>
<td>&lt; 0.001</td>
<td>0.09</td>
</tr>
<tr>
<td>Duration of hospital stay</td>
<td>0.01</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Ref [6]
Accuracy of ELWI and PVPI
clinical use of the parameters

Clinical situations to use ELWI and PVPI:

- ARDS - ELWI helps to identify ARDS. [5,6]
- Fluid management – indicate risk of fluid overload [9]
- Weaning from mechanical ventilation – diagnosis of weaning induced pulmonary oedema [2]
- Lung transplantation – prediction of suitability of the pulmonary graft [8]
- Clinical outcome – prediction of mortality in critically ill patients [1, 3, 4]

In the lung the lymphatic drainage system controls the fluid filtration between microvessels and interstitium. A balance exists between alveolar pressure ($P_{alv}$), hydrostatic pressure ($P_h$), oncotic pressure ($P_{onc}$) and interstitium. In critically ill patients, the balance between $P_{alv}$, $P_h$ and $P_{onc}$ does often not exist anymore - the risk for pulmonary oedema increases significantly. PVPI can help to identify the cause of a pulmonary oedema:

Cardiogenic lung oedema

- $P_h$↑
- $H_2O$↑ (Alveoli)
- PVPI 1.0 - 3.0

Permeability lung oedema

- Permeability Alveoli↑
- $H_2O$↑ (Alveoli)
- PVPI > 3.0
Correlation of ELWI and PVPI sensitivity and specificity

Relationship between EVLW and pulmonary capillary hydrostatic pressure for different levels of pulmonary vascular permeability.

PVPI effectively discriminates ARDS from cardiopulmonary oedema (CPE): Prediction of postoperative pulmonary oedema in patients with ARDS (with or without CPE) versus no ARDS (CPE alone or no oedema). AUC = area under the curve.
## Validity of EVLW and PVPI clinical studies and literature

<table>
<thead>
<tr>
<th>Study</th>
<th>Clinical practice</th>
<th>Prognostic value</th>
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<tbody>
<tr>
<td><strong>Extravascular Lung Water Index (ELWI)</strong></td>
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**Pulmonary Vascular Permeability Index (PVPI)**

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<tr>
<td>10</td>
<td>Berbara H, Mair S, et al. Pulmonary vascular permeability index and global end-diastolic volume: are the data consistent in patients with femoral venous access for transpulmonary thermodilution. BMC Anesthesiol 2014;14:81</td>
<td>General critically ill patients</td>
</tr>
</tbody>
</table>
Literature


Philips CR. The Berlin definition: real change or the emperor’s new clothes? Crit Care 2013;17:174

Perel A. Extravascular lung water and the pulmonary vascular permeability index may improve the definition of ARDS. Crit Care 2013;17:108


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