Pulmonary ultrasound and dialysis

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Conflicts of interest

Dr. A. Seidowsky and Prof. Z.A. Massy are investigators of the LUST trial
Never go to a doctor whose office plants have died.

― Erma Bombeck
• Formation of images in pulmonary ultrasound

• Pulmonary ultrasound in emergencies and intensive care unit

• Pulmonary ultrasound for the detection of heart failure

• Detection of subclinical pulmonary congestion in chronic kidney disease

• Pathophysiology of pulmonary congestion in chronic kidney disease

• Impact of the use of pulmonary ultrasonography on morbidity and mortality in hemodialysis patients

• Comparison and Combination of Pulmonary Ultrasound with Other Methods

• Conclusions
Formation of images in pulmonary ultrasound

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Comparison and Combination of Pulmonary Ultrasound with Other Methods

Conclusions
Ultrasound Lung Comets: A Clinically Useful Sign of Extravascular Lung Water

Eugenio Picano, MD, PhD, Francesca Frassi, MD, Eustachio Agricola, MD, Suzana Gligorova, MD, Luna Gargani, and Gaetano Mottola, MD, Pisa, Milan, and Mercogliano, Italy
The Comet Tail Artifact

Marvin C. Ziskin, MD, David I. Thickman, MD, Nancy Jacobs Goldenberg, MD,
Marc S. Lapayowker, MD, Joseph M. Becker, MD

J Ultrasound Med 1.1-7, Jan-Feb 1982

Figure 1. Patient with shotgun wound of abdomen. Left, abdominal roentgenogram showing multiple lead pellets scattered throughout abdomen. Above, B-scan of right upper quadrant showing prominent comet tail patterns beyond three pellets.
Ultrasound of extravascular lung water: a new standard for pulmonary congestion

Eugenio Picano and Patricia A. Pellikka
• Formation of images in pulmonary ultrasound

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• Conclusions
Lung ultrasound in the critically ill

Daniel A Lichenstein Lichenstein annals of Intensive Care 2014, 4;1
B-lines score on lung ultrasound as a direct measure of respiratory dysfunction in ICU patients with acute kidney injury

Adi Ciumanghel¹ · Iainis Siriopol¹ · Mihaela Blaj¹ · Dimitrie Siriopol² · Cristina Gavriloici³ · Adrian Covic²


Fig. 1 Correlation between log B-line score and log \( \text{PaO}_2/\text{FiO}_2 \) levels

Fig. 2 B-line score’s area under the receiver operating characteristics for predicting \( \text{PaO}_2/\text{FiO}_2 < 300 \)
• Formation of images in pulmonary ultrasound

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• **Pulmonary ultrasound for the detection of heart failure**

• Detection of subclinical pulmonary congestion in chronic kidney disease

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• Comparison and Combination of Pulmonary Ultrasound with Other Methods

• Conclusions
# The Comet-tail Artifact

An Ultrasound Sign of Alveolar-Interstitial Syndrome

DANIEL LICHTENSTEIN, GILBERT MÉZIÈRE, PHILIPPE BIDERMAN, AGNÈS GEPNER, and OLIVIER BARRÉ

Service de Réanimation Médicale and Service de Radiologie, Hôpital Ambroise-Paré, Boulogne (Paris), and Service de Réanimation Polyvalente, Centre Hospitalier Général, Saint-Cloud (Paris), France

*AM J RESPIR CRIT CARE MED 1997;156:1640-1646.*

## Correlation Between Radiologic and Sonographic Patterns

<table>
<thead>
<tr>
<th></th>
<th>Artifact Extending Beyond the Last Intercostal Space</th>
<th>Artifact Confined to the Last Intercostal Space</th>
<th>Absence of Artifact</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse alveolar-interstitial syndrome</td>
<td>86</td>
<td>3</td>
<td>3</td>
<td>92</td>
</tr>
<tr>
<td>Localized alveolar-interstitial syndrome</td>
<td>19</td>
<td>4</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>Absence of alveolar-interstitial syndrome</td>
<td>9</td>
<td>36</td>
<td>84</td>
<td>129</td>
</tr>
<tr>
<td>Total</td>
<td>114</td>
<td>43</td>
<td>93</td>
<td>250</td>
</tr>
</tbody>
</table>
Usefulness of ultrasound lung comets as a nonradiologic sign of extravascular lung water

Zoltan Jambrik et al. *The American Journal of Cardiology, 2004*
“Ultrasound Comet-Tail Images”: A Marker Of Pulmonary Edema*

A Comparative Study With Wedge Pressure And Extravascular Lung Water

Eustachio Agricola, MD; Tiziana Bove, MD; Michele Oppizzi, MD; Giovanni Marino, MD; Alberto Zangrillo, MD; Alberto Margonato, MD; and Eugenio Picono, MD

CHEST / 127 / 5 / MAY, 2005
Persistent pulmonary congestion before discharge predicts rehospitalization in heart


Kaplan Meier survival curves in HF patients stratified according to the number of β lines before discharge, at 6 months follow-up
Acute respiratory distress syndrome and Acute lung injury have B-lines

\[ n = 10 \]
\[ * p = 0.001 \text{ vs baseline} \]
• Formation of images in pulmonary ultrasound
• Pulmonary ultrasound in emergencies and intensive care unit
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• Pathophysiology of pulmonary congestion in chronic kidney disease
• Impact of the use of pulmonary ultrasonography on morbidity and mortality in hemodialysis patients
• Comparison and Combination of Pulmonary Ultrasound with Other Methods
• Conclusions
Fig. 2. Patients’ distribution according to the Lung Comets Score and NYHA class.
Pre-Dialysis US-B lines (logarithm) vs. KDQOL physical functioning score

$r = 0.40$
$p = 0.002$
• Formation of images in pulmonary ultrasound
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Chest ultrasound and hidden lung congestion in peritoneal dialysis patients

Vincenzo Panuccio, Giuseppe Enia, Rocco Tripepi, Claudia Torino, Maurizio Garozzo, Giovanni Giorgio Battaglia, Carmelia Marcantoni, Lorena Infantone, Guido Giordano, Maria Loreta De Giorgi, Mario Lupia, Vincenzo Bruzzese and Carmine Zoccali

Relationship of lung comets score with ejection fraction

Relationship of lung comets score with left atrial volume
Uremic lung: new insights into a forgotten condition

Paul J. Scheel¹, Manchang Liu¹ and Hamid Rabb¹

Brain:
- ↑ KC & G-CSF
- ↑ GFAP & microglia
- ↑ Vascular permeability

Heart:
- ↑ TNF-α, IL-1
- ↑ Neutrophil trafficking
- ↑ Apoptosis
- ↑ Fractional shortening

Lung:
- ↑ Vascular permeability
- Dysregulated channels
- Cytokines/chemokines
- Transcriptomic changes
- Leukocyte trafficking
- Altered response to ventilator-associated injury

Liver:
- ↑ Leukocyte influx
- ↑ Oxidation products
- ↑ Antioxidants (GSH)
- ↑ Altered liver enzymes

Bone marrow:
- Anemia
- Coagulation disorders
- Immune dysfunction

Gastrointestinal tract:
- ↑ Channel-inducing factor
- ↑ Potassium excretion

AKI:
• Formation of images in pulmonary ultrasound
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• Conclusions
Pulmonary Congestion Predicts Cardiac Events and Mortality in ESRD

Carmine Zoccali,* Claudia Torino,* Rocco Tripepi,* Giovanni Tripepi,* Graziella D'Arrigo,* Maurizio Postorino,* Luna Gargani,† Rosa Sicari,† Eugenio Picano,† and Francesca Mallamaci,* on behalf of the Lung US in CKD Working Group


**Figure 1.** Kaplan–Meier survival analyses of all-cause mortality and fatal and nonfatal cardiac events according to the BL-US.
Lung Water by Ultra-sound Guided treatment to Prevent Death and Cardiovascular Complications in High risk End Stage Renal Disease (ESRD) Patients With Cardiomyopathy (LUST)
• Formation of images in pulmonary ultrasound
• Pulmonary ultrasound in emergencies and intensive care unit
• Pulmonary ultrasound for the detection of heart failure
• Detection of subclinical pulmonary congestion in chronic kidney disease
• Pathophysiology of pulmonary congestion in chronic kidney disease
• Impact of the use of pulmonary ultrasonography on morbidity and mortality in hemodialysis patients

• Comparison and Combination of Pulmonary Ultrasound with Other Methods
• Conclusions
The Agreement between Auscultation and Lung Ultrasound in Hemodialysis Patients: The LUST Study


### Table 2. Ultrasound B lines number across lung crackles strata of increasing severity

<table>
<thead>
<tr>
<th>Crackles Category</th>
<th>Ultrasound B Lines No.</th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;5</td>
<td>≥5 to &lt;15</td>
<td>≥15 to ≤30</td>
<td>&gt;30</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>370</td>
<td>388</td>
<td>88</td>
<td>60</td>
<td>906</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>35</td>
<td>7</td>
<td>6</td>
<td>61</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>26</td>
<td>24</td>
<td>37</td>
<td>93</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>14</td>
<td>9</td>
<td>11</td>
<td>35</td>
</tr>
<tr>
<td>Total</td>
<td>391</td>
<td>466</td>
<td>131</td>
<td>118</td>
<td>1106</td>
</tr>
</tbody>
</table>

22.5 %
The Agreement between Auscultation and Lung Ultrasound in Hemodialysis Patients: The LUST Study


Figure 1. Poor correlation between ultrasound (US) B lines and clinical signs of lung congestion. Correlation between the severity of lung congestion as detected by US-B lines with (A) pulmonary crackles and (B) peripheral edema.
Table 4. Diagnostic value of pulmonary crackles and peripheral edema for the diagnosis of moderate and severe lung congestion in the 1106 paired measurements (in 79 patients) of these clinical signs and simultaneous ultrasound B lines

<table>
<thead>
<tr>
<th>Diagnostic Value</th>
<th>Pulmonary Crackles</th>
<th>Peripheral Edema</th>
<th>Crackles and Edema</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mild Lung</td>
<td>Moderate Lung</td>
<td>Severe Lung</td>
</tr>
<tr>
<td></td>
<td>Congestion</td>
<td>Congestion</td>
<td>Congestion</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>172/644 (27%)</td>
<td>27/249 (11%)</td>
<td>11/118 (9%)</td>
</tr>
<tr>
<td>False positive rate</td>
<td>28/462 (6%)</td>
<td>19/857 (2%)</td>
<td>24/988 (2%)</td>
</tr>
<tr>
<td>Specificity</td>
<td>434/462 (94%)</td>
<td>838/857 (98%)</td>
<td>964/988 (98%)</td>
</tr>
<tr>
<td>False negative rate</td>
<td>472/644 (73%)</td>
<td>222/249 (89%)</td>
<td>107/118 (91%)</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>172/200 (86%)</td>
<td>27/46 (59%)</td>
<td>11/35 (31%)</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>434/906 (48%)</td>
<td>838/1060 (79%)</td>
<td>964/1071 (90%)</td>
</tr>
<tr>
<td>Positive likelihood ratio</td>
<td>4.41</td>
<td>4.89</td>
<td>3.84</td>
</tr>
<tr>
<td>Negative likelihood ratio</td>
<td>0.78</td>
<td>0.91</td>
<td>0.93</td>
</tr>
</tbody>
</table>

The positive likelihood ratio (i.e., sensitivity-to-false positive rate ratio) of peripheral edema could not be calculated, because the corresponding false positive rates were zero. —, value cannot be calculated.
Biodependance Technology and Optimal Fluid Management

Intradialytic hypotension stunning
- Heart (regional wall motion)
- Brain (depression)
- Gastrointestinal (endotoxin)
- Kidney (residual function)
  Access Clotting

ECF Deficit / Excess (L)

Relative Risk

± 2.0L

Left ventricular hypertrophy Hypertension
- Stroke
- Congestive heart failure myocarde infarction ?
  Sudden death ?

Relative Risk

American Journal of Kidney Diseases 2013 61, 861-864DOI: (10.1053/j.ajkd.2013.03.004)
Overhydration, Cardiac Function and Survival in Hemodialysis Patients

Mihai Onofriescu¹, Dimitrie Siriopol¹, Luminita Voroneanu¹, Simona Hogas¹, Ionut Nistor¹, Mugurel Apetrii¹, Laura Florea¹, Gabriel Veisa¹, Irina Mititiuc¹, Mehmet Kanbay³, Radu Sascau², Adrian Covic¹ *

Table 2. Survival analysis using the predefined cut-off of RFO (15%).

<table>
<thead>
<tr>
<th></th>
<th>All-cause mortality</th>
<th>Cardiovascular events</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HRᵃ</td>
<td>95% CI</td>
</tr>
<tr>
<td>Unadjusted</td>
<td>2.12</td>
<td>1.30–3.47</td>
</tr>
<tr>
<td>Adjustedᵇ</td>
<td>1.87</td>
<td>1.12–3.13</td>
</tr>
</tbody>
</table>

a. The group of patients with a RFO ≤15% was used as reference.
Effect of Fluid Management Guided by Bioimpedance Spectroscopy on Cardiovascular Parameters in Hemodialysis Patients: A Randomized Controlled Trial

Ender Hur, MD,1 Mehmet Usta, MD,2 Huseyin Toz, MD,1 Gulay Asci, MD,1 Peter Wabel, PhD,3 Serdar Kahvecioglu, MD,4 Meral Kayikcioglu, MD,5 Meltem Sezis Demirci, MD,1 Mehmet Ozkahya, MD,1 Soner Duman, MD,1 and Ercan Ok, MD1

Figure 2. Changes in time-averaged fluid overload (TAFO) in the intervention and control groups over the 12-month study period (P < 0.001 to baseline; P < 0.001 to 3 month; P = 0.04 between 12-month measurements).
Figure 3. Intervention and control groups: changes between baseline and 12-month follow-up measurements of pulse wave velocity (PWV) and left ventricular mass index (LVMI).
Value of bioimpedance analysis estimated “dry weight” in maintenance dialysis patients: a systematic review and meta-analysis

Adrian Covic¹ · Adi-Ionut Ciumanghel¹ · Dimitrie Siriopol¹ · Mehmet Kanbay² · Raluca Dumea¹ · Cristina Gavrilevici³ · Ionut Nistor¹,⁴

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Bioimpedance</th>
<th>Control</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
</tr>
<tr>
<td>Huan-Sheng 2016</td>
<td>1.49</td>
<td>1.04</td>
<td>148</td>
</tr>
<tr>
<td>Hur 2013</td>
<td>0.87</td>
<td>0.88</td>
<td>64</td>
</tr>
<tr>
<td>Luo 2011</td>
<td>1.72</td>
<td>1.51</td>
<td>78</td>
</tr>
<tr>
<td>Ponce 2014</td>
<td>2.92</td>
<td>1.47</td>
<td>101</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>391</td>
<td></td>
<td>382</td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.04; Chi² = 5.72, df = 3 (P = 0.13); I² = 48%
Test for overall effect: Z = 2.99 (P = 0.003)

Fig. 4 Forest plot for change in overhydration (L)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Bioimpedance</th>
<th>Control</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
</tr>
<tr>
<td>Hur 2013</td>
<td>8.1</td>
<td>2.3</td>
<td>64</td>
</tr>
<tr>
<td>Onofriescu 2014</td>
<td>6.68</td>
<td>1.89</td>
<td>62</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>126</td>
<td></td>
<td>131</td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 1.83; Chi² = 11.98, df = 1 (P = 0.0005); I² = 92%
Test for overall effect: Z = 1.18 (P = 0.24)

Fig. 7 Forest plot the effect on arterial stiffness (pulse wave velocity in m/s)
**Fig. 6** Forest plot for systolic blood pressure control

**Fig. 3** Forest plot for all-cause mortality
Bioimpedance analysis versus lung ultrasonography for optimal risk prediction in hemodialysis patients

Dimitrie Siriopol\textsuperscript{1,2} · Luminita Voroneanu\textsuperscript{1,2} · Simona Hogas\textsuperscript{1,2} · Mugurel Apetrii\textsuperscript{1,2} · Angelica Gramaticu\textsuperscript{1,2} · Raluca Dumea\textsuperscript{1,2} · Alexandru Burlacu\textsuperscript{1,3} · Radu Sascau\textsuperscript{1,3} · Mehmet Kanbay\textsuperscript{4} · Adrian Covic\textsuperscript{1,2}

![Graph A](image1)

![Graph B](image2)

\textbf{Fig. 1} Kaplan–Meier analysis for all-cause mortality according to B-lines score (a) and relative fluid overload (b) cut-offs
Table 5  Lung congestion and relative fluid overload association with all-cause mortality

<table>
<thead>
<tr>
<th></th>
<th>ULC</th>
<th>RFO</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>HR(^a)</td>
<td>95 % CI</td>
</tr>
<tr>
<td>Unadjusted</td>
<td>3.08</td>
<td>1.45–6.54</td>
</tr>
<tr>
<td>Adjusted</td>
<td>2.72</td>
<td>1.19–6.16</td>
</tr>
</tbody>
</table>

Adjusted for: severity of NYHA class (0—NYHA class 1, 2; 1—NYHA class 3, 4), diabetes, hs-CRP, and left ventricular mass index

\(^a\) The group with ≤22 ULC was used as reference

\(^b\) The group with ≤6.88 RFO was used as reference
Table 6 Performance of the models

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Discrimination</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔC statistics, 95% CI</td>
<td>Reference</td>
<td>0.017 (-0.060–0.094)</td>
<td>0.058 (0.003–0.114)</td>
</tr>
<tr>
<td><strong>Calibration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>299.69</td>
<td>299.53</td>
<td>293.88</td>
</tr>
<tr>
<td>BIC</td>
<td>305.42</td>
<td>306.71</td>
<td>301.05</td>
</tr>
<tr>
<td>H-L</td>
<td>$\chi^2 = 8.25$</td>
<td>$\chi^2 = 13.91$</td>
<td>$\chi^2 = 13.61$</td>
</tr>
<tr>
<td></td>
<td>$p = 0.41$</td>
<td>$p = 0.08$</td>
<td>$p = 0.09$</td>
</tr>
<tr>
<td><strong>Reclassification</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IDI, 95% CI</td>
<td>Reference</td>
<td>0.036 (-0.005–0.141)</td>
<td>0.036 (0.000–0.096)</td>
</tr>
<tr>
<td>NRI, 95% CI</td>
<td>Reference</td>
<td>0.125 (-0.188–0.350)</td>
<td>0.248 (0.021–0.112)</td>
</tr>
</tbody>
</table>

C statistic with only conventional predictors was 0.728

Model 1—severity of NYHA class, diabetes, hs-CRP, and left ventricular mass index

Model 2—Model 1 + LogULC score

Model 3—Model 1 + RFO

* Comparison with model 1
• Formation of images in pulmonary ultrasound
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• Conclusions
Dry weight assessment by combined ultrasound and bioimpedance monitoring in low cardiovascular risk hemodialysis patients: a randomized controlled trial

Dimitrie Siriopol

Fig. 3 Kaplan–Meier curves comparing the two groups for the time to the first primary composite outcome (Panel a), all-cause mortality (Panel b), and cardiovascular events (Panel c)
Table 4  Secondary outcome data for the entire cohort

<table>
<thead>
<tr>
<th>Event</th>
<th>Control group (N = 127) (236.3 Patient-years at risk)</th>
<th>Active group (N = 123) (232.3 Patient-years at risk)</th>
<th>Rate ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of events</td>
<td>No. of events/100 patient-years</td>
<td>No. of events</td>
</tr>
<tr>
<td>Intradialytic hypotension</td>
<td>1035</td>
<td>438.1</td>
<td>1104</td>
</tr>
<tr>
<td>Intradialytic cramps</td>
<td>1056</td>
<td>446.9</td>
<td>1313</td>
</tr>
<tr>
<td>Pre-dialytic dyspnea</td>
<td>302</td>
<td>127.8</td>
<td>240</td>
</tr>
<tr>
<td>Hospitalizations</td>
<td>89</td>
<td>37.7</td>
<td>103</td>
</tr>
<tr>
<td>Vascular access thrombosis</td>
<td>13</td>
<td>5.5</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 5  Biomarker levels and arterial stiffness outcomes

<table>
<thead>
<tr>
<th>Biomarker</th>
<th>Baseline</th>
<th>12 months</th>
<th>24 months</th>
<th>p*</th>
<th>p†</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT-proBNP (pg/ml)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>8722.2 (6478.5–10,965.8)</td>
<td>9123.6 (6387.6–11,859.6)</td>
<td>12,186.4 (9256.6–15,115.6)</td>
<td>0.09</td>
<td>0.72</td>
</tr>
<tr>
<td>Active</td>
<td>8896.3 (6944.8–10,847.8)</td>
<td>9428.4 (6642.8–12,213.9)</td>
<td>10,728.6 (7775.4–13,680.7)</td>
<td>0.88</td>
<td>0.49</td>
</tr>
<tr>
<td>Hs-cTnT (ng/l)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>42.9 (37.9–47.8)</td>
<td>45.4 (40.1–50.7)</td>
<td>44.6 (38.9–50.2)</td>
<td>0.14</td>
<td>0.65</td>
</tr>
<tr>
<td>Active</td>
<td>44.0 (38.7–49.3)</td>
<td>49.4 (43.9–54.7)</td>
<td>45.0 (39.4–50.7)</td>
<td>0.30</td>
<td>0.91</td>
</tr>
<tr>
<td>PWV (m/s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>10.3 (9.8–10.9)</td>
<td>11.0 (10.0–12.1)</td>
<td>12.3 (11.1–13.6)</td>
<td>&lt;0.001</td>
<td>0.32</td>
</tr>
<tr>
<td>Active</td>
<td>9.7 (9.1–10.4)</td>
<td>11.5 (10.8–12.3)</td>
<td>12.6 (11.7–13.5)</td>
<td>0.45</td>
<td>0.77</td>
</tr>
</tbody>
</table>
• Formation of images in pulmonary ultrasound

• Pulmonary ultrasound in emergencies and intensive care unit

• Pulmonary ultrasound for the detection of heart failure

• Detection of subclinical pulmonary congestion in chronic kidney disease

• Pathophysiology of pulmonary congestion in chronic kidney disease

• Impact of the use of pulmonary ultrasonography on morbidity and mortality in hemodialysis patients

• Comparison and Combination of Pulmonary Ultrasound with Other Methods

• Conclusions
Lung Ultrasound in Hemodialysis: A Card to be Played

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Preclinical phase

Clinical

**Lung**
- Increased lung permeability

**Systemic Circulation**
- Fluid overload

**Heart**
- Augmented LV filling pressure
- Reduced ejection fraction
- Augmented left atrial volume

EVLW

Reduced physical function

Dyspnea

Increasing B-lines number
Detection of Pulmonary Congestion by Chest Ultrasound in Dialysis Patients

Figure 2. Individuals Pre- and Post-Dialysis Lung Comets Score

Among patients, comparison was made by using the Wilcoxon signed ranks test (see the Statistical Analysis section for details).