LUNG ULTRASOUND IN THE ASSESSMENT OF HYPERVOLEMIA IN HEMODIALYSIS PATIENTS – TWO CASE REPORTS

ULTRAZVUK PLUĆA U PROCENI HIPERVOLEMIJE KOD PACIJENATA NA HEMODIJALIZI – PRIKAZ DVA SLUČAJA

Vladimir VESELINOV1, Igor IVANOV2-3, Jadranka DEJANOVIĆ2,3 and Dejan ĆELIĆ3,4

Introduction

Chronic volume overload is frequent among hemodialysis patients. It leads to hypertension, left ventricular hypertrophy and heart failure [1]. Adequate volume control in these patients decreases morbidity and mortality [2].

Case Reports

The first patient was a 57-year-old male. The hemodialysis vintage was 4 years. His interdialytic weight gain was 2.8 kg. The lung ultrasound was performed before and after dialysis and B line score was calculated. The pre-dialysis score was 15 and post-dialysis score was 2. The second patient was a 72-year-old male. The hemodialysis starts 5 years before. This patient was noncompliant with the medical advice of his physician regarding diet and medications. His interdialytic weight gain was 5.6 kg. His pre-dialysis score was 26 and post-dialysis score was 15. Both patients were without signs and symptoms of hypervolemia after dialysis. Nevertheless, the second patient was 1.6 kg over his dry weight after dialysis. An additional dialysis session was scheduled, after which his post-dialysis B line score fell to 5. Conclusion. Lung ultrasound can be used to assess volume status in dialysis patients. It can identify hypervolemia in asymptomatic patients and allow necessary corrections.

Key words: Lung; Ultrasonography; Renal Dialysis; Kidney Failure, Chronic; Plasma Volume; Water-Electrolyte Imbalance; Pulmonary Edema; Edema; Signs and Symptoms
Dry weight is defined as the lowest tolerated post-dialysis weight and is reached with gradual lowering of weight to the value at which there are minimal signs and symptoms of hypo- or hypervolemia [3]. This clinical assessment of volume status is often inadequate [1]. New techniques for assessing dry weight have been developed, including bioimpedance, biospectroscopy [4], natriuretic peptide serum levels [5], and ultrasonography methods, the most common being inferior vena cava diameter [6]. A novel ultrasonography method described here is lung ultrasound (LUS) [7].

Lung ultrasound can detect extravascular lung water (EVLW), fluid present in lung interstitium, which is strongly dependent on the left ventricle filling pressure [2]. LUS detects EVLW by B lines on the screen of the device, B lines are well defined, dynamic, hyperechoic lines that stretch from the pleural line all the way to the bottom of the screen without any loss of intensity [8]. The sum of all B lines detected over the front and lateral sides of the chest represents the B line score (BLS), a numerical marker of pulmonary congestion [8].

This topic was chosen to demonstrate a simple method for detection of hypervolemia in hemodialysis patients, because of its high prevalence and associated complications. The aim of this paper is to show the use of LUS in two patients on chronic hemodialysis in Kikinda General Hospital.

Case Reports

The first patient was a 57-year-old male with end stage chronic renal disease due to nephroangiosclerosis. His hemodialysis vintage (time on dialysis) was 4 years, with three dialysis sessions per week, each lasting 4.5 hours. On patient’s first weekly dialysis he was eupneic, normotensive (TA: 120/60 mmHg), with normal heart rate (75 bpm), normal lung and heart auscultation sounds and without peripheral edema. His kT/V was 0.94. His comorbidities included hypertension and renal osteodystrophy. On the day of dialysis his interdialytic weight gain was 5.6 kg. Ultrafiltration was set to 4000 ml and the duration of dialysis to 4 hours. LUS examination was performed using the same method as in patient number one. The B line score in this case was 26. The dialysis was uneventful. After dialysis the patient was symptom free, normotensive (TA: 120/60 mmHg), with normal heart rate (90 bpm). LUS was performed after dialysis and single B lines were detected over two lung fields. The BLS was 2.

The second patient was a 72-year-old male with end stage chronic renal disease due to nephroangiosclerosis. His hemodialysis vintage was 5 years with three dialysis sessions per week, each lasting 4 hours.

On his first weekly dialysis the patient complained of mild fatigue. He denied dyspnea in exertion, at rest or orthopnea. He was eupneic, hypertensive (TA: 150/90 mmHg), with normal heart rate (75 bpm), normal heart and lung auscultation, and with discrete crural pitting edema. He was noncompliant with medical advice on medications and dietary restrictions. His average interdialytic gain was around 6 kg, and his kT/V was 0.94. His comorbidities included hypertension and renal osteodystrophy. On the day of dialysis his interdialytic weight gain was 5.6 kg. Ultrafiltration was set to 4000 ml and the duration of dialysis to 4 hours. LUS examination was performed using the same method as in patient number one. The B line score in this case was 26. The dialysis was uneventful. After dialysis the patient was symptom free, normotensive.

**Abbreviations**

LUS – lung ultrasound
EVLW – extravascular lung water
BLS – B line score
kT/V – marker of dialysis adequacy

Figure 1 A. Normal lung ultrasound – bat sign visible; B. B line visible on the right, marked with arrows

*Slika 1 A. Uredan ultrazvuk pluća, vidljiv znak slepog miša; B. B linija desno, obeležena strelicama*
Daniel Lichtenstein was one of the first to interpret that lung parenchyma cannot be visualized, due to the fact that ultrasound energy quickly dissipates in the air [7]. The only structure that can be visualized was the pleura [7]. Visualization of structures below the pleura is only possible if there is consolidation of lung parenchyma below it. Still the presence of air is responsible for several ultrasound artifacts that can be interpreted in different clinical context. Daniel Lichtenstein was one of the first to interpret these artifacts in intensive care patients, identified the key ones, and introduced LUS nomenclature [10]. The B lines are crucial for identifying lung congestion, but can also be seen in acute respiratory distress syndrome and lung fibrosis [11]. In our patients, increased number of B lines represents lung congestion due to hypervolemia. The B lines in this case occur when ultrasound waves meet thickened, edematous interlobular septa. This produces artifacts on screen which we see as B lines [8]. A greater number of B lines represent a greater degree of lung congestion [8]. For easier interpretation BLS was established, being the sum of all B lines detected over the 28 defined fields on the chest [12]. The BLS less than 8 is considered normal. Lung congestion is estimated as light if BLS is between 8 and 13, medium between 14 and 30, and severe if BLS equals or is above 30 [12].

Our first patient had a pre-dialysis BLS of 15 (medium lung congestion). This correlated with his lower interdialytic gain of 2.8 kg. Nevertheless, this patient had normal physical findings, no edema or pathologic lung sounds on auscultation. After adequate dialysis and ultrafiltration of 3100 ml his post-dialysis BLS equaled 2 (within reference range) meaning no lung congestion was present. We concluded that this patient reached his dry weight. The second, noncompliant patient’s pre-dialysis BLS was 26 (medium lung congestion). This was consistent with his physical findings including discrete pitting pretibial edema. Because his interdialytic weight gain was 5.6 kg, his dialysis duration was 4 hours, and maximal ultrafiltration was 4000 ml. After dialysis the patient was 1.6 kg above his dry weight. His post-dialysis BLS was 15 (medium lung congestion). No signs and symptoms of hypervolemia were present. An additional dialysis session was scheduled and at the end of it, the BLS was 5, meaning a significant BLS reduction.

These results are supported by the research of Basso et al. who demonstrated significant BLS reduction after dialysis in a 30-patient sample [1]. Mallamaci et al. showed a significant BLS reduction after dialysis as well as correlation of post-dialytic BLS with the ejection fraction and left atrial volume in a sample of 75 dialysis patients. They showed that cardiac function plays a significant role in EVLW control [12]. Trezzi et al. have performed a study that confirms these results [9].

Noble et al. followed the B line number dynamics during the course of a hemodialysis session on a sample of 45 patients. They measured BLS before, halfway through the dialysis and after dialysis. They showed significant BLS reduction during and after dialysis, which is in agreement with our observations [13].

Zoccali et al. followed a sample of 392 patients and showed that around 70% of dialysis patients with medium or severe lung congestion have no or very discrete symptoms. This is in accordance with what we saw in our two patients. In his prospective study, Zoccali et al. showed that BLS is a strong and independent mortality and adverse cardiac event predictor [14, 15]. Siriopol et al. went even further in the follow-up of dialysis patients and showed that a BLS is a significant predictor of survival time in dialysis patients, independent from heart function.

**Table 1. Probe placement scheme**

| Right hemithorax/Desni hemitoraks | Left hemithorax/Levi hemitoraks |
|----------------------------------|--------------------------------|
| Mid-axillary line                | Midclavicular line / Srednja paužušna linija |
| Anterior axillary line / Prednja paužušna linija | Anterior axillary line / Prednja paužušna linija |
| Midclavicular line / Srednja ključnjačna linija | Midclavicular line / Srednja ključnjačna linija |
| Para-sternal line / Paraster nalna linija | Para-sternal line / Parasternalna prostor |
| Inter-costal space / Medurebaharni prostor |  |
| II                               | V |
| III                              | / |
| IV                               | / |
| V                                | / |

(TA: 120/70 mmHg), with normal heart rate (90 bpm). There was no edema. Lung ultrasound was performed after dialysis and a decrease in the number of B lines was registered. The BLS was 15.

**Discussion**

Dry weight assessment was never simple. Its definition changed frequently, and the current one is in use since 2009 [3].Still, all definitions were based on arterial tension as an easily measured but imprecise volume indicator [9]. This led to a search for more objective methods of evaluating volume status and dry weight, respectively.

Standard ultrasound dogma, until recently, was that lung parenchyma cannot be visualized, due to the fact that ultrasound energy quickly dissipates in the air [7]. The only structure that can be visualized was the pleura [7]. Visualization of structures below the pleura is only possible if there is consolidation of lung parenchyma below it. Still the presence of air is responsible for several ultrasound artifacts that can be interpreted in different clinical context. Daniel Lichtenstein was one of the first to interpret these artifacts in intensive care patients, identified the key ones, and introduced LUS nomenclature [10]. The B lines are crucial for identifying lung congestion, but can also be seen in acute respiratory distress syndrome and lung fibrosis [11]. In our patients, increased number of B lines represents lung congestion due to hypervolemia. The B lines in this case occur when ultrasound waves meet thickened, edematous interlobular septa. This produces artifacts on screen which we see as B lines [8]. A greater number of B lines represent a greater degree of lung congestion [8]. For easier interpretation BLS was established, being the sum of all B lines detected over the 28 defined fields on the chest [12]. The BLS less than 8 is considered normal. Lung congestion is estimated as light if BLS is between 8 and 13, medium between 14 and 30, and severe if BLS equals or is above 30 [12].
In this prospective study the author followed 96 patients during 400 days and showed that patients with high pre-dialysis BLS presented with significantly higher mortality [2].

Patients with end stage renal disease have a high mortality rate regardless of the chosen dialysis method [14, 15]. Chronic volume overload is frequent in patients on standard chronic hemodialysis (3 times a week, duration 4 – 4.5 h), so one of the main goals of dialysis is maintaining normal extracellular volume levels [16]. Prevention of volume overload is the central recommendation of all dialysis guidelines [2]. Additional information about the patients’ volume status contributes to a better understanding of their general condition, and is even more important if we know that some of them can be hypervolemic and asymptomatic [1, 7]. Yet, there are no clear recommendations about monitoring the volume status of dialysis patients, or information if this monitoring and subsequent actions lead to a mortality reduction. The Lung Water by Ultra-Sound Guided Treatment to prevent death and cardiovascular complications in high-risk end-stage renal disease patients with cardiomyopathy study should provide answers to this question and clarify if there is a place for lung ultrasound and BLS in standard dialysis practice [17].

**Conclusion**

Lung ultrasound can be used to assess volume status in hemodialysis patients. It can identify hypervolemic patients without clear signs and symptoms of hypervolemia. Lung ultrasound could be an important step to decrease the high rate of complications in these patients.

**References**

1. Basso F, Milan Manani S, Cruz DN, Teixeira C, Brendolan A, Nalesso F, et al. Comparison and reproducibility of techniques for fluid status assessment in chronic hemodialysis patients. Cardiorenal Med. 2013;3(2):104-12.
2. Siriopol D, Hogas S, Voroneanu L, Onofriescu M, Apetrii M, Oleniuc M, et al. Predicting mortality in haemodialysis patients: a comparison between lung ultrasonography, bioimpedance data and echocardiography parameters. Nephrol Dial Transplant. 2013;28(11):2851-9.
3. Agarwal R, Weir M, Dry-weight: a concept revisited in an effort to avoid medication-directed approaches for blood pressure control in hemodialysis patients. Clin J Am Soc Nephrol. 2010;5(7):1255-60.
4. Oei EL, Fan SL, Practical aspects of volume control in chronic kidney disease using whole body bioimpedance. Blood Purif. 2015;39(1-3):32-6.
5. Ishigami J, Imori S, Kuwahara M, Sasaki S, Tsukamoto Y, Diagnostic value of B-type natriuretic peptide for estimating left atrial size and its usefulness for predicting all-cause mortality and cardiovascular events among chronic haemodialysis patients. Nephrology (Carlton). 2014;19(12):777-83.
6. Vitturi N, Dugo M, Soattin M, Simoni F, Maresca L, Zagatti R, et al. Lung ultrasound during hemodialysis: the role in the assessment of volume status. Int Urol Nephrol. 2014;46(1):69-74.
7. Gargani L, Volpicelli G. How I do it: lung ultrasound. Cardiovasc Ultrasound. 2014;12:25.
8. Picano E, Pellikka PA. Ultrasound of extravascular lung water: a new standard for pulmonary congestion, Eur Heart J. 2016;37(27):2097–104.
9. Trezzi M, Torzillo D, Ceriani E, Costantino G, Caruso S, Damavandi PT, et al. Lung ultrasonography for the assessment of rapid extravascular water variation: evidence from hemodialysis patients. Intern Emerg Med. 2013;8(5):409–15.
10. Lichtenstein D, Axler O. Intensive use of general ultrasound in the intensive care unit. Intensive Care Med. 1993;19(6):353-5.
11. Xiouchaki N, Georgopoulos D. The use of lung ultrasound: a brief review for critical care physicians and pneumologists. Pnumon. 2007;20(2):134-41.
12. Mallamaci F, Benedetto FA, Tripepi R, Rastelli S, Castellino P, Tripepi G, et al. Detection of pulmonary congestion by chest ultrasound in dialysis patients. JACC Cardiovasc Imaging. 2010;3(6):586–94.
13. Noble VE, Murray AF, Capp R, Sylvia-Reardon MH, Steele DJR, Liteplo A. Ultrasound assessment for extravascular lung water in patients undergoing hemodialysis: time course for resolution. Chest. 2009;135(6):1433–9.
14. Zoccali C, Torino C, Tripepi R, Tripepi G, D’Arrigo G, Postorino M, et al. Pulmonary congestion predicts cardiac events and mortality in ESRD. J Am Soc Nephrol. 2013;24(4):639-46.
15. Zoccali C, Tripepi R, Torino C, Bellantoni M, Tripepi G, Mallamaci F. Lung congestion as a risk factor in end-stage renal disease. Blood Purif. 2013;36(3):489–94.
16. Đurić PS, Đurić Ž, Janković A, Tošić J, Popović J, Dimković N. Influence of hemodialysis duration per week on parameters of dialysis adequacy and cardiovascular morbidity, Med Pregl. 2014;67(11-12):385-91.
17. Torino C, Gargani L, Sicari R, Letachowicz K, Ekart R, Fliser D, et al. The agreement between auscultation and lung ultrasound in hemodialysis patients: The LUST Study, Clin J Am Soc Nephrol, 2016;11(11):2005–11.