CASE REPORTS
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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

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Summary
Introduction. Hemodialysis patients often have chronic volume overload, hypervolemia, which may cause severe complications. In some patients hypervolemia is masked, without any signs and symptoms, such as hypertension, edema and bibasilar crackles on lung auscultation. Lung ultrasound can be used to detect these patients. Pre- and post-dialysis lung ultrasound can be used to quantify lung congestion using the B line score. High post-dialysis B line score can identify patients with residual hypervolemia and adequate measures can be taken (increasing ultrafiltration, extended duration of hemodialysis, additional dialysis sessions). **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 started 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

Sažetak
Uvod. Hronično opterećenje volumenom se često registruje kod pacijenata na hemodijalizi, često i sa komplikacijama. Hipervolemija kod pacijenata na dijalizi može biti skrivena. Pacijenti bez hipertenzije, bez perifernih edema i bez patološkog auskultatornog nalaza na plućima i dalje mogu imati ozbiljnu hipervolemiju. Ultrazvukom pluća pre i nakon hemodijalize možemo identifikovati pacijente sa rezidualnom hipervolemijom pomoću patološki visokog postdijaliznog B-linijskog skora, uprkos odsustva drugih simptoma i znakova hipervolemije. Potom možemo preduzeti potrebne mere kao što su povećanje ultrafiltracije, produženje trajanja hemodijalize ili čak zakazivanje vanredne hemodijalize. **Prikaz slučaja.** Prvi pacijent je muškarac star 57 godina, sa dijaliznim stažom od 4 godine i interdijaliznim prinosom od 3 kg. Pre i posle dijalize urađen mu je ultrazvuk pluća i izračunat B-linijski skor. Predijalizni skor je bio 15, a postdijalizni 2. Drugi pacijent je muškarac star 72 godine, sa dijaliznim stažom od 5 godina. Nedisciplinovan je, sa velikim interdijaliznim prinosom od 5,6 kg. Njegov B-linijski skor pre dijalize bio je 26, a posle dijalize 15. Oba pacijenta su bila bez simptoma i znakova hipervolemije nakon dijalize. Ipak, drugom pacijentu je ostalo 1,6 kg „viška" te mu je zakazana vanredna dijaliza, nakon koje je skor bio 5. **Zaključak.** Ultrazvuk pluća se može koristiti za procenu opterećenja volumenom kod pacijenata na hemodijalizi. On može da identifikuje pacijente sa skrivenom hipervolemijom, one bez jasnih simptoma i znakova hipervolemije, što je bitno zbog sprečavanja komplikacija koje su česte među ovom populacijom pacijenata.
Ključne reči: pluća; ultrasonografija; hemodijaliza; hronična bubrežna insuficijencija; volumen plazme; elektrolitski disbalans; plućni edem; edem; znaci i simptomi

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].

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Abbreviations

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

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: 130/80 mmHg), with normal heart rate (80 bpm), normal lung and heart auscultation sounds and without peripheral edema. His average interdialytic gain was around 3 kg, and his marker of dialysis adequacy (kT/V) was 1.18. His comorbidities included hypertension and secondary anemia. On the day of the dialysis his interdialytic weight gain was 2.8 kg. His dialysis session lasted for 4.5 hours. Ultrafiltration was set to 3100 ml.

Lung ultrasound was performed before dialysis using a Samsung Medison MySono U6 ultrasound device, with a 3.5 MHz convex probe. The patient was placed in a semi recumbent position, with torso at 45 degree angle knee. The probe was placed longitudinally in the 2[nd] intercostal space on the left parasternal line and the classically described "bat sign" was seen **(Figure 1A)**. The "bat sign" is made up of the upper and lower ribs representing the "wings" and the pleural line between them, resembling the "back" of the bat. The movement of the pleural line is also seen as a sliding motion back and forth, as well as acoustic shadows behind each rib. Hyperechoic horizontal lines appearing at equal distances below the pleural line are also seen. These reverberation artifacts represent the pleura and are called A lines. Thus far, it is a normal lung ultrasound finding. Placing the probe was continued along the 2[nd] intercostal space in the midclavicular, anterior axillary and midaxillary line and then in the same fashion along the 3[rd] and 4[th] intercostal spaces on the left and the 2[nd], 3[rd], 4[th] and 5[th] intercostal spaces on the right. B lines were detected over the lower parts of the chest. They are seen as hyperechoic dynamic vertical lines that start at the pleural line and spread to the bottom of the screen without loss of intensity. breaking the continuity of A lines **(Figure 1B)**. The total number of B lines in each of the 28 spaces was noted **(Table 1)**. The sum of these numbers represents the BLS which equaled 15 in our first patient. The dilaysis 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

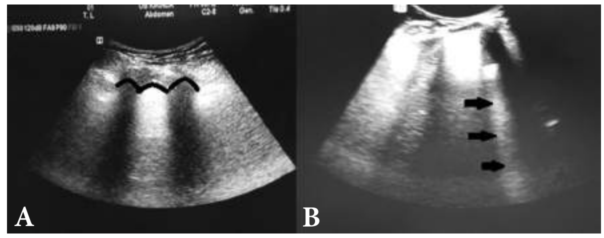

Figure 1 A. Normal lung ultrasound – bat sign visible; **B**. B line visible on the right, marked with arrows
Slika 1 A. *Uredan ultrazvuk pluća, vidljiv znak slepog miša;* ***B.*** *B linija desno, obeležena strelicama*

Table 1. Probe placement scheme
Tabela 1. *Shema plasiranja sonde*

Right hemithorax/*Desni hemitoraks*								Left hemithorax/*Levi hemitoraks*
Mid-axillary line *Srednja pazušna linija*	Anterior axillary line *Prednja pauzušna linija*	Midclavicular line *Srednja ključnjačna linija*	Para-sternal line/*Parasternalna linija*	Inter-costal space *Međurebarni prostor*	Para-sternal line/*Parasternalna linija*	Midclavicular line/*Srednja ključnjačna linija*	Anterior axillary line *Prednja pazušna linija*	Mid-axillary line *Srednja pazušna linija*
				II				
				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].

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.

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.

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