



Assessment of the Role of Lung Ultrasonography for the Accuracy of Clinically Estimated Dry Weight in Chronic Hemodialysis Patients

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Objective: The aim of this study was to evaluate the utility of lung ultrasonography to determine the accuracy of prescribed dry weight in chronic hemodialysis patients and to ascertain the adequacy of fluid removal.

Methods: In this cross sectional study LUS was performed immediately before and after (within 15 min) the dialysis session on 60 patients on regular hemodialysis, 4-hours per session, three times weekly at Tanta university hospitals, Internal Medicine Department, Nephrology units, Egypt. The ultrasonography B-lines was tabulated and compared to the intradialytic ultrafiltration parameters and dry weight.

Results: Positive significant correlation (P 0.02) was achieved between the intradialytic percentage change in B-lines and the percent change in total body weight reduction and also Positive significant correlation (P 0.05) was achieved between the intradialytic percentage change in B-lines and the ultrafiltration rate.

Conclusion: LUS is a valuable diagnostic tool for recognizing the adequacy of fluid removal and to avoid inaccurate estimation of dry weight by usual clinical parameters or even radiologic studies including chest X-ray.

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1. INTRODUCTION

1.1 Background

Volume overload is a very important prognostic factor, associated with morbidity and mortality being a modifiable and common risk factor for mortality in chronic kidney disease and end-stage renal disease (ESRD) patients. In dialysis patients, volume overload is the most common cause of hypertension and may independently contribute to poor cardiovascular outcomes. Methods of volume assessment have evolved from clinical evaluation to nonclinical assessment but still accurate assessment of dry weight in HD patients is one of the greatest challenges and remains a complex issue. Lung ultrasonography (LUS) is an appealing new modality which has been employed to assess fluid status in hospitalized patients

Volume overload is a very important prognostic factor associated with prolonged hospital stay, morbidity and mortality perhaps being one of the most insidious, modifiable and common risk factor for mortality in chronic kidney disease and end-stage renal disease (ESRD) patients [1]. In dialysis patients, volume overload is the most common cause of hypertension and may independently contribute to poor cardiovascular outcomes [2]. Hydration status and increased mortality are associated independently in ESRD patients [3]. Thus, one of the major goals in the care of chronic hemodialysis patients is to remove excess fluid in order to reach the state of what is termed dry weight [4]. Accurate assessment of dry weight in HD patients is one of the greatest challenges and achieving an optimal dry weight remains a complex issue, in most hemodialysis units, dry weight is determined clinically based on a trial-and-error method, and does not account for changes in nutritional status and lean body mass [5]. Assessment of volume status by clinical evaluation alone is imprecise. Both overestimation and underestimation of dry weight is fraught with complications and associated with significant morbidity and mortality [6]. Moderate to severe lung congestion is a strong predictor of death and cardiovascular events and provides prognostic information independent of New York Heart Association (NYHA) class [7]. Methods of volume assessment have evolved from clinical evaluation to nonclinical assessment as bioimpedance spectroscopy, indexed inferior

vena cava diameter (IVCD) measurement with ultrasonography, blood volume monitoring, and estimation of B-line score (lung comet score) with lung ultrasonography [8]. Bioimpedance spectroscopy and echocardiographic assessment of volume status are limited by their cost, bedside availability and lack of specificity [9]. Lung ultrasonography (LUS) is an appealing new modality which has been employed to assess fluid status in hospitalized patients. In the pulmonary and critical care units, LUS is commonly relied on for the evaluation of hemodynamics and fluid status in critically ill patients [10]. Recently, the nephrology units have been adopted the use of LUS for fluid assessment in the care of chronic hemodialysis patients [11]. Besides its noninvasiveness, freedom from radiation, ease of use, acceptable intra/inter-operator reproducibility, and availability of portable ultrasound devices in dialysis units, sonographic B-lines correlate with the accumulation of fluid representing pulmonary edema [12]. Based on these observations lung ultrasonography can be considered one of the most important methods for near-precise assessment of fluid removal and hence dry weight in patients on maintenance hemodialysis.

2. METHODOLOGY

2.1 Study Design

Cross sectional study.

2.2 Subjects

The study was performed on patients with ESRD undergoing hemodialysis at Tanta university hospitals, Internal Medicine Department, Nephrology units over a period of six months between June 2019 to December 2019.

All patients were screened for eligibility, 130 patients were screened and 70 patients were excluded by virtue of either not meeting the inclusion or meeting the exclusion criteria. The study included 60 patients on regular hemodialysis, 4-hours session, three times weekly.

2.3 Inclusion Criteria

All subjects must be on chronic HD at least three times a week and have a dialysis vintage of at least 3 months.

2.4 Exclusion Criteria

- 1-Interstitial lung disease
- 2-Pulmonary consolidation on chest X-ray (CXR)
- 3-NYHA class III-IV heart failure
- 4- Inability to obtain standing weights
- 5- Patients refusing to perform the study. .
- 6- Recent acute coronary syndrome (within 4 weeks).
- 7- Bleeding complications during the admission.

2.5 Methods

Clinical and laboratory data were collected from the records of the patients. All patients had chest X-ray performed. This was portable anteroposterior film obtained prior to the initial LUS study.

All patients included in this study were subjected to:

1. Full history taken.
2. Complete clinical examination:

2.5.1 Dry weight is determined by

- Patient history may provide some useful information on the volume status.
- Weight measurements before and after each haemodialysis session.
- Blood pressure should be within the patient normal range after dialysis or before next session.
- Peripheral edema but it is required at least 3–5 kg of excess Extra Cellular Fluid Volume to be manifest.

2.6 Radiological Assay

Lung ultrasound was performed immediately before and after (within 15 min) the dialysis session.

Measurements were taken with a handheld ultrasound scanner with a 2–5 MHz phased array probe.

Ultrasound examination of the anterolateral chest was performed with longitudinal scans of the intercostal spaces of the right and left hemithoraces, from the second to fourth intercostal spaces (to the fifth intercostal space on the right hemithorax) at the parasternal, mid-clavicular, anterior axillary and mid-axillary lines (28 total sectors per examination).

The sectors were examined on three zones along three stages of each hemithorax as seen in Fig 2 as follow:

- Stage 1 represents the investigation of the anterior chest wall (zone 1) in a supine patient (1' in this semirecumbent patient).
- Stage 2 adds the lateral wall (zone 2) [left panel].
- Stage 3 adds the posterolateral chest wall using a short probe, moving the patient only minimally (zone 3) [right panel]. Each wall is divided into upper and lower halves, resulting in six areas of investigation.

B-lines were defined as an echogenic artifact with a narrow origin on the pleural line. The sum of the number of B-lines from all sectors was used. An independent physician trained in lung sonography assessed the images after being captured to ensure operator concordance. Data were recorded in a digital format and stored in a secure server.

2.7 Statistical Analysis of the Data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0.(2019) (Armonk, NY: IBM Corp) Q. Qualitative data were described using number and percent. Quantitative data were described using range (minimum and maximum), mean standard deviation and median. Significance of the obtained results was judged at the $p < 0.05$ level. Pearson coefficient test was used to correlate between two normally distributed quantitative variables. All study protocols and procedures were in accordance with the Declaration of Helsinki.

3. RESULTS

Demographic and basal clinical data.

As seen in Table 1 that the mean age of the patients was 50.67 ± 13.29 years and males were represented by 51.7% and females by 48.3%.

Table 2. shows that the duration of dialysis of studied participants was ranged from 0.4 to 20 years with a mean (5.49 ± 4.58) years.

As seen in Table 3. 21.7% of the patients had signs of lower limb edema while there was no lower limb edema in 78.3% of patients.

As seen in Table (4) chest x -ray before admission showed clear lungs in 65% of cases and interstitial edema in 35% of cases.

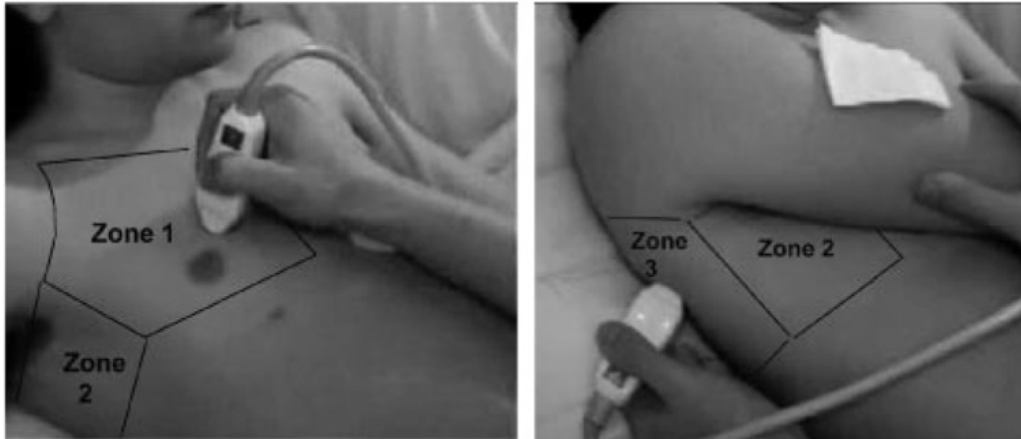


Fig. 1. Ultrasound areas of examination [13]

Table 1. Classification of the patients according to demographic data

Age (years)	Minimum	20		
	Maximum	70		
	Mean	50.67		
	S. D	13.29		
Sex	Male	N	31	
		%	51.7	
	Female	N	29	
		%	48.3	

Table 2. Distribution of the studied cases according to duration of dialysis in years

	Minimum	Maximum	Mean	S. D
Duration of dialysis	0.4	20	5.49	4.58

Table 3. Classification of the studied cases according to lower limb edema

Lower limb edema	Edema	N	%
	No edema	13	21.7
		47	78.3

Table 4. Classification of cases according to chest x-ray

Chest x-ray before admission	Clear lungs	N	%
	Interstitial edema	39	65
		21	35

Table 5. Classification of cases according to the cause of CKD

Cause of chronic kidney disease(CKD)	Hypertension	N	%
	Diabetes mellitus	20	33.33
	Hypertension & Diabetes mellitus	15	25.00
	Obstructive uropathy	8	13.33
	Pyelonephritis	4	6.66
	Glomurlonephritis	2	3.33
	Adult Polycystic Kidneys	6	10.00
		5	8.33

As seen in Table (4) hypertension represented 33.3%, diabetes mellitus represented 25% of the cases while both diabetes mellitus and hypertension represented 13.3%. Obstructive uropathy represented 6.6% of cases. Adult Polycystic Kidneys represented 8.3% of the cases.

Eight of the sixty patients exhibited no B-lines pre-HD during initial evaluation.

Twenty-three patients finished the dialysis session without B-lines.

Twenty-nine patients finished dialysis with residual B-lines.

Table (6) shows that:

Eight of the sixty patients exhibited no B-lines pre-HD during initial evaluation & they were able to achieve their DW target.

Fifty-two (52) of the 60 patients exhibited B-lines at the beginning of the first dialysis session.

Twenty-three patients finished the dialysis session without B-lines.

Twenty-nine patients finished dialysis with residual B-lines.

The twenty of 23 patients who could eliminate B-lines (mean B-lines 0- 6.25), they could reach the estimated DW.

Their mean variance was 1.69 kg below DW. Their mean % TBW removed was 6.03, mean net UF was 4472.22 ml, mean UFR 15.08 ml/kg/hour, mean systolic blood pressure before HD was 131.11 mmHg and after HD was 106.39 mmHg, mean diastolic blood pressure before HD was 96.94 mmHg and after HD was 72.22 mmHg.

Three of the 23 patients could eliminate B-lines (mean B-lines 0-5.33) but they could not reach the estimated dry weight (DW) as their mean variance was 1 kg away from the prescribed DW.

Their mean % TBW removed was 3.03, mean net UF was 2333.33 ml, mean UFR 7.59 ml/kg/hour, mean systolic blood pressure before HD was 116.67 mmHg and after HD was 90.00 mmHg, mean diastolic blood pressure before HD was 76.67 mmHg and after HD was 60.00 mmHg.

The twenty-two of 29 patients did not eliminate the B-lines (mean B-lines 18.04–6.50) but they could reach the estimated DW and their mean variance was 1.41 kg below DW.

Their mean % TBW removed was 6.30, mean net UF was 5022.73 ml, mean UFR 15.76 ml/kg/hour, mean systolic blood pressure before HD was 137.05 mmHg and after HD was 108.18 mmHg, mean diastolic blood pressure before HD was 95.68 mmHg and after HD was 74.55 mmHg.

Seven of 29 patients did not eliminate the B-lines (mean B-lines 22.71–11.28) and they could not reach the estimated DW and their mean variance was 1.29 kg away from DW.

Their mean % TBW removed was 4.14, mean net UF was 3428.57 ml, mean UFR 10.36 ml/kg/hour, mean systolic blood pressure before HD was 115.71 mmHg and after HD was 85.00 mmHg, mean diastolic blood pressure before HD was 79.29 mmHg and after HD was 57.86 mmHg.

As seen in Table (7) 22 patients who exhibited residual B-lines and achieved EDW at the end of the first HD session had their DW re-estimated and had a second consecutive HD session in which their DW was further challenged. Six of 22 patients were able to eliminate the B-lines (mean 7.83–0) and reached 1.86 kg below EDW, they reached 0.92 kg below new EDW. Their mean % TBW removed was 6.89, mean net UF was 5428.57 ml, mean UFR 17.23 ml/kg/hour, mean systolic blood pressure before HD2 160.00 mmHg and after HD2 was 127.14 mmHg, mean diastolic blood pressure before HD2 was 105.71 mmHg and after HD2 was 85.71 mmHg.

The other sixteen patients did not eliminate the B-lines (mean 10.65–4.06) but were able to reach 1.20 kg below EDW following the challenge, they reached 1.36 kg below new EDW.

Their mean % TBW removed was 6.03, mean net UF was 4833.33 ml, mean UFR 15.08 ml/kg/hour, mean systolic blood pressure before HD2 130.00 mmHg and after HD2 was 100.33 mmHg, mean diastolic blood pressure before HD2 was 87.33 mmHg and after HD2 was 68.00 mmHg.

As seen in Table (8) and Fig. (2): Positive significant correlation (P 0.02) was achieved

Table 6. results of hemodialysis session 1

N of patients	B lines before dialysis	B lines after 1st session	Post HD weight (kg) relative to EDW	% TBW removed	Net UF(ml)	UFR (mL/kg/hr)	Systolic Bpr before HD (mmHg)	Diastolic Bpr before HD (mmHg)	Systolic Bpr after HD (mmHg)	Diastolic Bpr after HD (mmHg)
8	0.00	0.00	-0.30	4.34	2450.00	10.84	129.00	86.00	107.00	72.00
23	3	5.33	0.0	1.00	2333.33	7.59	116.67	76.67	90.00	60.00
	20	6.25	0.0	-1.69	4472.22	15.08	131.11	96.94	106.39	72.22
29	22	18.04	6.50	-1.41	5022.73	15.76	137.05	95.68	108.18	74.55
	7	22.71	11.28	1.29	3428.57	10.36	115.71	79.29	85.00	57.86

Table 7. Results of hemodialysis session 2

	B lines before 2nd session	B lines after 2nd session	Post HD weight (kg) relative to new EDW	Post HD weight (kg) relative to initial EDW	Net UF (ml)	UFR (mL/kg/hr)	% TBW removed	Pre HD sys Bpr (mmHg) session 2	Pre HD dia Bpr (mmHg) session 2	Post HD sys Bpr (mmHg) session 2	Post HD dia Bpr (mmHg) session 2
Removed (6)	7.83	0.0	-0.923	-1.86	5428.57	17.23	6.89	160.00	105.71	127.14	85.71
Not removed(16)	10.56	4.06	-1.36	-1.20	4833.33	15.08	6.03	130.00	87.33	100.33	68.00

Table 8. B-lines in relation to TBW% removed and UFR%

	% change in B-lines	
	r	p
% TBW removed	0.435	00.02*
UFR (mL/kg/hr)	0.392	00.05*

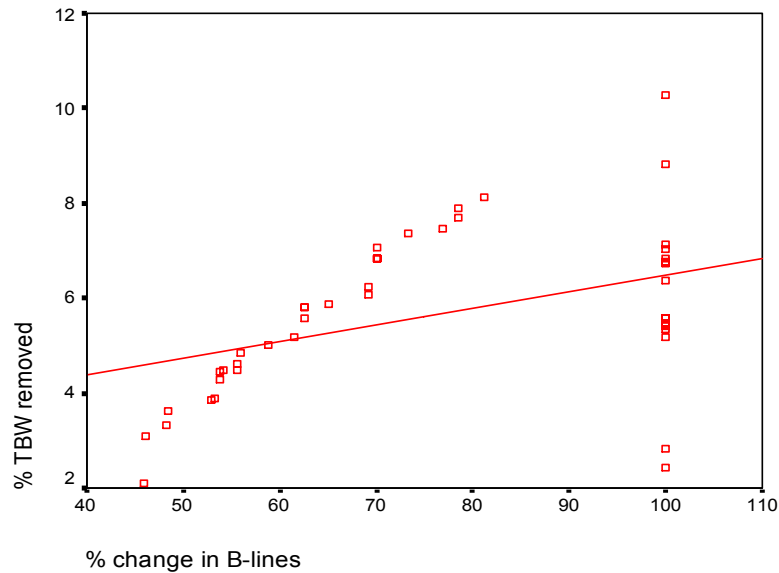


Fig. 2. Correlation between the intradialytic percentage change in B-lines and the percent change in total body weight reduction and the ultrafiltration rate

between the intradialytic percentage change in B-lines and the percent change in total body weight reduction ($r = 0.43$) and also positive significant correlation ($P < 0.05$) was achieved between the intradialytic percentage change in B-lines and the ultrafiltration rate ($r = 0.39$). However, there is no significant correlation between the absolute change in B-lines and the absolute change in systolic blood pressure or diastolic blood pressure.

4. DISCUSSION

Volume overload is a very important prognostic factor and one of the most insidious and common risk factor for mortality in chronic kidney disease and end-stage renal disease patients, so the need for a concept of dry weight derives from an awareness of the dangers of being fluid overloaded.

Only 21.7% of studied participants had signs of lower limb edema while there was no lower limb edema in 78.3% of studied population before hemodialysis session so there was a poor agreement between US-B lines (found in 86.6% of cases) and cases who exhibited peripheral edema across the observation. This finding was in agreement with Torino C et al (2016) who found in their study on 79 patients that peripheral edema was absent in as many as 87% of the cases while lung US indicated moderate and

severe lung congestion in 80% of the cases [14]. Also this was in agreement with Mohammad WH et al who found in their study on 38 patients that lower limb edema has no significance in evaluation of volume status in hemodialysis patients with (p significance 0.324) [15]

Also Sinha et al and Zucchelli et al proved that clinical judgment of dry weight is often imprecise in clinical practice since the one to three liters fluid overload characteristic of many dialysis patients cannot be detected by current routine physical examination [16, 17].

JL Martindale et al reported in their prospective observational study that the overall agreement with gold standard interpretation of pulmonary edema on lung ultrasound was superior to chest radiographs with p significant ($P < 0.0001$) [18]. This agreed with the present study as chest x-ray before admission showed clear lungs in 65% of cases and interstitial edema in 35% of cases while B lines found in 86.6% of cases (52 cases). Also this was in agreement with Ely E. W et al (2001) who found in their study on 100 patients that chest x-ray was only 56% accurate without clinical data and only 65% accurate with clinical data in evaluation of volume status [19].

In this study there was a positive significant correlation ($P < 0.02$) between the intradialytic percentage change in US B-lines and the

percentage change in total body weight reduction ($r = 0.43$). Also there was a positive significant correlation ($P < 0.05$) between the intradialytic percentage change in B-lines and the ultrafiltration rate ($r = 0.39$).

The results of the study support the hypothesis that recognition of the presence of pulmonary congestion, as determined by B-lines on lung sonography, can be a useful tool in guiding the determination of DW for patients receiving haemodialysis. This is in agreement with Vitturi N et al who documented in their study on 71 patients that the reduction in B-lines correlated with residual weight measured with bioimpedance spectroscopy (BIS) during dialysis with positive significant correlation was ($p 0.007$) [20]. Also this is in agreement with Trezzi M et al who found in their study carried on 41 hemodialysis patients using LUS that the number of B-lines was associated with accumulated fluid before the dialysis session and decreases during intradialytic weight loss with significance ($p < 0.05$) [21].

In this study there was no significant correlation between the B-lines and the systolic blood pressure or diastolic blood pressure and when hypotension, muscle cramps and nausea occurred to the patients during the dialysis session, there were still B-lines by lung ultrasound indicating they did not reach their dry weight yet. This is in disagreement with Daugirdas et al who defined DW as "the post-dialysis weight at which all excess body fluids have been removed below which the patient more often than not will develop symptoms of hypotension [22].

Also this in disagreement with Agarwal et al and Leyboldt et al who defined DW as the weight at which hypotension and symptoms such as muscle cramps, nausea and vomiting occurs [23, 24].

A commonly recognized problem with the blood pressure dependent definitions of DW is that the blood pressure is not only determined by the filling status of the arterial part of the vascular system, but also by cardiac output (which depends on heart rate and stroke volume) and peripheral resistance (which depends on local auto-regulation and autonomic nervous system inputs) [25].

Also changes in lean body mass or the use of blood pressure medications may obscure increases in hydration [26, 27].

5. CONCLUSION

Lung ultrasound has been proposed for the non-invasive, inexpensive, radiation free, bedside estimation of extravascular lung water through B-lines assessment.

The present study aimed for the assessment of the role of lung ultrasonography to determine the accuracy of clinically estimated dry weight in chronic hemodialysis patients.

We concluded that the intradialytic percentage change in B-lines is associated significantly with the percent change in total body weight reduction and the ultrafiltration rate.

With its noninvasiveness, freedom from radiation, ease of use, acceptable intra/inter-operator reproducibility, and availability of portable ultrasound devices in dialysis units, so lung ultrasonography can be considered one of the most interesting methods for near-precise assessment of volume status in patients on maintenance hemodialysis. Consequently, as demonstrated in this study lung ultrasound is valuable guide for the evaluation of dry weight.

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CONSENT AND ETHICAL APPROVAL

As per international standard or university standard guideline patients consent and ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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