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Dry Weight Assessment in Children on Regular Hemodialysis with Special Relation Between Acute and Chronic Renal Failure

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ABSTRACT

Background: Adequate assessment of fluid status is an imperative objective in the management of HD patients. An inaccurate assessment of dry weight leads to many complications.

Objective: The aim was to assess applicability of clinical using inferior vena cava (IVC) and lung ultrasonography to assess dry weight and the adequacy of fluid removal in hemodialysis children with special relation between acute and chronic renal failure.

Patients and methods: 75 children were classified into two groups: Group (1): Chronic renal failure and group (2): Acute renal failure.

Results: A statistically positive significant correlation between percent of weight loss after dialysis among the studied patients and all of serum ferritin, creatinine, phosphorus and iron. There was statistically negative significant correlation between percent of weight loss after dialysis among the studied patients and serum creatinine. There was statistically significant negative correlation between percent of weight loss after dialysis among the studied patients and SPAP. There was statistically non-significant correlation between percent of weight loss after dialysis among the studied patients and percent change in IVC inspiratory diameter, expiratory diameter, collapse index and B lines. There was statistically significant difference between the studied groups and expiratory IVCD, collapse index before and after dialysis, difference in B lines.

Conclusion: Lung ultrasound is an accurate and sensitive method of quantifying subclinical fluid overload in children on dialysis before its clinical manifestation. IVC measurement is reliable to assess intravascular fluid overload in children on HD and was not correlated with extracellular fluid volume as need more time (2-3h) after dialysis and maneuver difficult with young age.

Keywords: Dry weight, Hemodialysis, Renal failure, Evaluation.

INTRODUCTION

Adequate assessment of fluid status is an imperative objective in the management of HD patients. Fluid overload is one of the most common modifiable risk factors directly associated with hypertension, heart failure, left ventricular hypertrophy, and eventually, higher morbidity and mortality risk in these categories of patients [(1)]. An inaccurate assessment of dry weight leads to hypertension /hypotension, cardiac and vascular dysfunction, omission of small changes in nutritional status and intradialytic morbidity and mortality [(2)].

Different methods are commonly used to determine fluid status (eg, clinical assessment, natriuretic peptide concentrations, cardiothoracic index based on chest X-ray, echocardiography, inferior vena cava measurements, or bioimpedance analysis. In recent years, lung ultrasonography, through the assessment of extravascular lung water, has received growing attention in clinical research in infant and children of HD [(1)].

So, our cross-sectional study was conducted to assess applicability of clinical using IVC and lung ultrasonography to assess dry weight and the adequacy of fluid removal in hemodialysis children.

PATIENTS AND METHODS

This study was performed at Pediatric Nephrology Unit and Echo Cardiology Unit of Children Hospital, Zagazig University. It was carried out over a period of one and half years from June 2019 to December 2020.

Ethical approval:

This study was approved by Ethics Review Committee of Faculty of Medicine, Zagazig University. Written informed consents from all parents of children were obtained. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Seventy five children were classified into two groups.

Group 1: (Chronic renal failure): They comprised 60 children on regular HD [33 male (55%) and 27 female (45%)]. Their ages ranged from 3 to 18 years.

Group 2 (Acute renal failure): They comprised 15 children of newly diagnosed acute kidney injury on HD during period of admission in PICU to maximum period one month later at hemodialysis unit. Nearly fifty percent of this group became on regular HD later on.

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They were 12 males (80%) and 3 females (20%) and their age ranged from 2.5 to 9 years.

Inclusion criteria: Age from 2-18 years, both sexes are included. Patients ongoing hemodialysis during the study in Pediatric Nephrology unit or PICU at Children Hospital.

Exclusion criteria: Pulmonary or cardiac pathology that may confuse the assessment of generalized fluid overload with lung ultrasound and echo for example interstitial lung disease, atelectasis, co-existent lung fibrosis, acute respiratory distress syndrome (ARDS), heart failure, congenital cardiac anomalies, pulmonary edema and lymphangitis.

All hemodialysed patients were subjected to the following:

A) Personal history:
B) Special history on the renal disease:
C) History of cardiac symptoms:
D) History of dialysis settings:
E) Clinical parameters including weight, height and body mass index, Patient's clinical fluid status was assessed using physical signs including skin turgor, mucous membrane appearance, jugular venous pressure and edema. Blood pressure was measured consistent with international guidance.

- The clinical impression of each patient's fluid status was scored before and after dialysis by the attending physician with representing dehydration, euvolaemia, and fluid overload: 1, 2 and 3 representing mild, moderate and severe fluid overload, respectively.
- Clinical criteria for underhydration including systemic hypotension (blood pressure < 5th percentile), symptoms of muscle cramps or dizziness, signs of cool peripheries, tachycardia, sunken eyes and reduced skin turgor or dry mucous membranes.
- Clinical criteria for fluid overload included interdialytic weight gain, edema, increased jugular venous pressure, crackles on chest auscultation, low oxygen saturations, presence of a third or fourth heart sound and hypertension (blood pressure > 95th percentile).

Laboratory investigations including:

1. Complete blood count (CBC).
2. Liver function (Albumin).
3. Kidney functions (blood urea and creatinine).
4. Serum calcium, phosphorus, iron, ferritin and PTH.

Measurement of IVC diameter:

Echocardiography was performed by one expert pediatric cardiologist at the bedside using Vivid E9 equipment (General Electric Medical Systems, Milwaukee, WI). Studies were performed in guided B- and M-mode with concurrent electrocardiography, with transducer frequencies appropriate for body size as per the recommendations of the American and European Society of Echocardiography for pediatric patients [3, 4]. The echocardiographic measurements were performed 15 min before the connection and beginning dialysis sessions with the patients and one hour after the end of the session to allow vascular refilling after dialysis. Echocardiograms were not performed 2-3 h after HD sessions due to need for vascular refilling; waiting after dialysis sessions was not acceptable to children and their parents as recommendation from Pediatric Council of the American Society of Echocardiography 2006 [3]. The IVC diameter was measured at end-expiration (maximal diameter) and at end-inspiration (minimal diameter) at the entry of the hepatic veins as recommended by the American Society of Echocardiography guidelines and performed in the study by **Kutty *et al.*** [5]. We chose to make the measurements with the two-dimensional technique, B-mode that had the spatial orientation advantages we lose in M-mode [5, 6]. For more explanation, the probe was placed on the longitudinal plane over the vena cava, and the heart was displayed in cranial angulation. The middle hepatic vein draining into the inferior vena cava could be found in the same section. The maximum IVC diameter during expiration and the minimum diameter during deep inspiration were measured in long axis/ subxyphoid view from the subxiphoidal position, 1.5 cm from the right atrial junction. Measurements were taken before the electrocardiographic P wave. The mean IVC diameter was calculated from the maximum IVC diameter during expiration and the minimum diameter during deep inspiration.

Inferior vena cava collapse Index (IVCCI) was calculated as IVCCI= (maximal diameter – minimal diameter)/maximal diameter. Maximal or minimal IVC diameter superior to +2SD and IVCCI inferior to -2SD were considered as a dilatation of IVC [5].

Lung ultrasound:

Lung ultrasound was used to quantify B-lines in infants and children. They underwent lung ultrasound in supine or near-supine or sitting upright as per patient preference. Infants were scanned supine with distraction from a parent, carer or play specialist [7].

Position before and after they had completed their regularly scheduled HD session and had achieved their target weight. All ultrasound examinations were performed at the bedside with a commercially available portable device (SonoSite S-ICU C60; SonoSite; Bothell, WA) equipped with a 6- to 13-MHz linear probe (L25x; SonoSite) in B mode. B-lines are reverberation artifacts that originate at the pleural line, extend to the lower edge of the screen, move synchronously with pleural sliding and obliterate A lines. Lung scans proceeded from the second to the fourth intercostal space on the left chest, from the second to the fifth intercostal space on the right and from parasternal to mid-axillary lines on both sides [8]. In each intercostal space, the lung comet-tail signs (Kerley-B lines) on several sections (parasternal, midclavicular, anterior and middle axillary lines) were counted and registered, totaling 28 scanning areas. The sum of B-lines was provided as an echo comet score for lung extravascular fluid.

Statistical Analysis

The collected data were computerized and statistically analyzed using SPSS program 24.0. For the statistical calculations data coding was done. Qualitative data were represented as frequencies and percentages and Chi- Square test and fisher exact test were used. Quantitative data were represented as mean and standard deviation (SD) and student's t-test and Mann-Whitney test were used. As regards correlation we used Pearson correlation coefficient that is appropriate for quantitative data. Also, we use Spearman correlation coefficient for non-normally distributed data.

Level of significance: For all above mentioned statistical tests done, the threshold of significance is fixed at 5% level (P-value). **The formula for calculating a z-score is $z = (x-\mu)/\sigma$**, where x is the raw score, μ is the population mean, and σ is the population standard deviation [9]**.** P value ≤ 0.05 was considered significant.

RESULTS

There was statistically significant difference between the studied groups regarding age. On the other hand, there was non-significant difference between them regarding gender (Table 1).

Table (1): Comparison between the studied groups (type of CKD) regarding demographic data

Parameter	Type of kidney disease		Test	
	Chronic(Group1)	Acute (Group2)	Z/χ^2	p
	Median (range)	Median (range)		
Age (years)	14.5 (3 – 18)	5 (2.5 –9)	-3.778	<0.001**
Gender				
Male Female	33 (55) 27 (45)	12 (80) 3 (20)	3.125	0.077

Z (Mann Whitney test) - χ^2 Chi square test **p ≤ 0.001 is statistically highly significant

There was a significant decrease in IVC inspiratory after dialysis. There was a highly significant decrease in IVC expiratory and B lines after dialysis. There was a significant increase in IVC collapse index after dialysis (Table 2).

Table (2): Change in ultrasonographic parameters before and after dialysis among the studied patients

Ultrasonographic parameters	Dialysis		Test	
	Before	After	paired t	p
IVC inspiratory • Mean ± SD • Range	9.849 ± 3.646 3.2 – 18.8	7.979 ± 2.746 3 – 13	6.273	0.029*
IVC expiratory • Mean ± SD • Range	13.877 ± 3.899 6.4 – 21	11.831 ± 3.428 4.2 – 18.2	5.862	<0.001**
Collapse index (%) • Median • Range	30 1 – 58	34 3 – 57	Z -2.229	0.026*
B lines • Median • Range	24 4 – 93	16 5 – 55	Z -5.851	<0.001**

t Paired t test Z Wilcoxon signed rank test *p<0.05 is statistically significant **p≤0.001 is statistically highly significant.

There was statistically non-significant correlation between percent of weight loss after dialysis among the studied patients and all of weight before or after dialysis, height or BMI (Table 3).

Table (3): Correlation between percent of weight loss after dialysis and anthropometric measures of the studied patients

Parameter	Percent of weight loss	
	r	p
Age (year)	0.177	0.129
Dry weight	0.133	0.254
Height (cm)	0.004	0.974
BMI (kg/m^2)	-0.08	0.493

r: Spearman rank correlation coefficient p > 0.05 is statistically non-significant

There was statistically positive significant correlation between percent of weight loss after dialysis among the studied patients and all of serum ferritin and iron. There was statistically negative significant correlation between percent of weight loss after dialysis among the studied patients and serum creatinine and phosphorus. There was statistically non-significant correlation between percent of weight loss after dialysis among the studied patients and all of hemoglobin, white blood cell count, platelet count, serum albumin, BUN, or parathyroid hormone (Table 4).

Table (4): Correlation between dry weight and laboratory data among the studied patients

Parameter	Percent of weight loss	
	r	p
Hemoglobin (g/dL)	-0.175	0.132
TLC	-0.114	0.328
Platelet (mcL)	-0.104	0.374
Albumin (g/L)	0.008	0.948
BUN (mmol/L)	-0.095	0.613
Creatinine (mg/dL)	-0.298	0.009*
Calcium (mg/dL)	0.190	0.102
Phosphorus (mg/dL	-0.306	0.008*
Ferritin (ng/dL)	0.545	<0.001**
Iron (mg/dL)	0.329	0.004*
PTH (pg/mL)	0.074	0.526

R: Spearman rank correlation coefficient p>0.05 is statistically non-significant **p≤0.001 is statistically highly significant

There was statistically significant negative correlation between percent of weight loss after dialysis among the studied patients and SPAP. There was statistically non-significant correlation between percent of weight loss after dialysis among the studied patients and other Echocardiographic parameters (Table 5).

Table (5): Correlation between dry weight and Echo data before dialysis among the studied patients

Parameter	Percent of weight loss	
	r	p
Mitral A	-0.023	0.843
Mitral E`	0.111	0.343
A/E`	-0.141	0.226
EF	0.13	0.266
FS	0.156	0.183
SPAP	-0.319	0.005*

r: Spearman rank correlation coefficient p>0.05 is statistically non-significant **p≤0.001 is statistically highly significant

There was statistically non-significant correlation between percent of weight loss after dialysis among the studied patients and percent change in systolic or diastolic blood pressures after dialysis (Table 6).

Table (6): Correlation between weight loss and blood pressure among the studied patients before and after dialysis

Parameter	Percent of weight loss	
	r	p
% change in SBP	0.095	0.419
% change in DBP	-0.198	0.088

r Spearman rank correlation coefficient p>0.05 is statistically non-significant

There was statistically significant difference between the studied groups and expiratory IVCD, collapse index before and after dialysis and difference in B lines. There was statistically non-significant difference between the studied groups and inspiratory IVCD, and B lines before and after dialysis.

Within the group of chronic kidney disease, there was a highly significant change in inspiratory, expiratory and B line after dialysis and significant change for collapse index after dialysis. With the group of acute kidney injury, there was a highly significant change in all inspiratory, expiratory IVCD, and B lines after dialysis. On the other hand, there was non-significant change in collapse index**.**

There was a highly statistically significant difference between the studied groups regarding percent of weight loss (being higher in patients with chronic kidney diseases) **(Table 7)**.

Table (7): Comparison between the studied groups (type of CKD) and ultrasonographic data and percent of weight loss:

Parameter	Type of kidney disease		Test	
	Chronic	Acute	t	p
	Mean ± SD	Mean ± SD		
IVCDi before	10.097 ± 3.849	8.86 ± 2.557	1.178	0.243
IVCDi after	7.98 ± 2.696	7.973 ± 3.04	0.008	0.993
P	<0.001**	<0.001**		
IVCDE before	14.52 ± 3.806	11.307 ± 3.236	3.006	0.004*
IVCDE after	12.365 ± 3.414	9.693 ± 2.621	2.824	0.006*
P	<0.001**	<0.001**		
Collapse index before	0.0032 ± 0.0015	0.0021 ± 0.0012	-2.557	0.011*
Collapse index after	0.0035 ± 0.0015	0.002 ± 0.0016	-2.889	0.004*
P	0.03*	>0.999		
B lines before	30.683 ± 19.099	23.2 ± 14.693	-1.061	0.289
B lines after	18.75 ± 10.782	16.067 ± 8.713	-0.902	0.367
P	<0.001**	0.001**		
Difference in B lines	11 (1 – 61)	5 (1 – 22)	Z=-2.038	0.042*
Percent of weight loss: • Mean • Range	5.559 0.265 – 24.05	2.027 0.292 – 5.66	Z=-3.803	< 0.001**

t Independent sample t test Z Mann Whitney test *p<0.05 is statistically significant **p≤0.001 is statistically highly significant

Among patients with chronic kidney diseases:

There was a negative non-significant correlation between percent of weight loss after dialysis among the studied patients and IVC inspiratory diameter and collapse index. There was a positive non-significant correlation between percent of weight loss after dialysis among the studied patients and IVC expiratory diameter and B lines.

Among patients with acute kidney diseases:

There was a highly significant negative correlation between percent of weight loss after dialysis among the studied patients and IVC expiratory diameter. There was a non-significant correlation between percent of weight loss after dialysis among the studied patients and IVC inspiratory diameter, collapse index and B lines **(Table 8)**.

Table (8): Correlation between percent of weight loss and ultrasonographic data of patients before and after dialysis

% change	Percent of weight loss			
	Chronic KD		Acute KD	
	r	p	r	p
IVC inspiratory diameter	-0.006	0.96	-0.27	0.331
IVC expiratory diameter	0.033	0.822	-0.84	<0.001**
Collapse index	-0.022	0.865	-0.363	0.184
B lines	0.17	0.184	-0.313	0.256

DISCUSSION

Our study showed a significant decrease in body weight from 32.276 kg before dialysis to 30.576 kg after dialysis. Also, percent of weight loss after dialysis ranged from 0.26% to 24.05% with median 5%. Decrease in body weight associated with significant decrease in percent of patients presented with dyspnea, edema after dialysis and decrease in both systolic and diastolic blood pressure after dialysis. Current results match with **Rodriguez *et al.*** [(10)] and **Agarwal *et al.*** [(11)]**.** They reported that two most frequently used methods to assess fluid status; measurement of blood pressure and body weight. In the absence of overt clinical signs of dehydration or over hydration, normal blood pressure is often considered as an index of correct hydration. However, these current clinical assessments are not sufficient to optimize the target weight in children receiving dialysis.

Sonographic measurement of IVCD for HD children in our study found a significant decrease in IVCD inspiratory, highly significant decrease in IVCD expiratory and a significant increase in IVC collapse index after dialysis. This is consistent with another study by **Torterüe *et al.*** [(12)] who found significant modifications of IVC diameter between pre and post dialysis measurements. Although IVC measurements reflect the intravascular filling grade and are thus potentially less influenced by volume variations during dialysis [(13).]

Also, our study found a significant increase in IVC collapse index after dialysis. This is in agreement with **Haciomeroglu *et al.*** [(14)] who found IVCCI to be significantly lower in nine dialysis patients before hemodialysis sessions than in healthy patient. This difference did not remain significant after dialysis sessions. **Torterüe *et al.*** [12] explained this by the repartition of extravascular volume between the interstitial and the intravascular compartments. Despite being a good marker of CVP, IVC measurements are poor markers of extracellular hydration. The modification of IVC diameter and IVCCI during dialysis session may thus only be a marker of intravascular volume depletion.

Dry weight estimates are very important because there is no clinical gold standard. There have been several studies on B-line images [15, 16]. Our data are substantially consistent with these studies with respect to the significant reduction in B-line score before and after dialysis. Unfortunately, our patients' B-line scores were substantially the highest result (median 24 (4-93) pre-dialysis and median 16 (5-55) post-dialysis) in comparision with previous studies **Trezzi *et al.*** [15] (24 ± 25 pre-dialysis and 9 ±10 post-dialysis). **Liang *et al.*** [16] reported median 10 pre-dialysis and median 4 post-dialysis) that was higher than those of **Vitturi *et al.*** [17] (3.5 ± 4 pre-dialysis; 1.7±3.1 post-dialysis). To achieve dry weight in our study, active measure was done in subsequent sessions by increase ultrafiltration gradually without symptoms or signs of hypotension until decrease of B-line (1-8) and reach ideal dry weight for every child. This might be due to the basic status and cardiovascular comorbidity of the patients in those studies. We excluded patients with a history of heart failure or active lung infections, which may bias the measurements. **Liang *et al.*** [16] suggested that the lung compartment might be the most prognostically relevant in terms of total extracellular body water and therefore, would be amenable for intervention. lung water reflects the grade of extravascular imbibition in the lung interstitium, therefore lung water is most affected after dialysis [13].

In current study, B lines in the studied patients ranged from 1 to 61 with median 10. Ultrafiltration volume was most associated with lung water, reflected by variation in B-line score. It was not associated with cardiac function, IVC diameter, IVC collapse rate or TT. Lung ultrasound is a useful imaging tool for dialysis patients [16]. We evaluated the effects of ultrafiltration volume in hemodialysis patients in terms of intravascular and extravascular water (including lung water and other extravascular water as edema). We found thatthere was no significant correlation between percent of weight loss after dialysis among the studied patients and percent change in IVC inspiratory diameter, expiratory diameter, collapse index and B lines. This disagrees with several studies that reported correlations of IVC measurements with volume changes during dialysis sessions and indicated the feasibility of the examination in dialysis patients [18]. The diameter of the inferior vena cava has often been used with the intent to assess hydration status [19]. IVCe is significantly reduced after dialysis [20].

Our study found a significant negative correlation between percent of weight loss and SPAP only without correlation with other Echo parameter after dialysis among the studied patients. **Liang *et al.*** [16] found that the B-line score after dialysis was associated with LVEF after dialysis and TT. This suggests that extravascular lung water after dialysis is highly dependent on left ventricular systolic function. The close inverse association between lung water and LVEF after dialysis clearly points to left ventricular dysfunction as a main driver of pulmonary congestion. TT after dialysis was also affected by extravascular lung water. However, no association was found between B-line score post-dialysis and E/e' postdialysis or IVCe post-dialysis. This suggests that cardiac diastolic function and intravascular water were not affected by lung water in these patients.

CONCLUSION

Lung ultrasound is a practical, accurate and sensitive method of quantifying subclinical fluid overload in infants and children on dialysis before its clinical manifestation. IVC measurement is reliable to assess intravascular fluid overload in children on HD and was not correlated with extracellular fluid volume as need more time (2-3h) after dialysis and maneuver is difficult with young age. Achieving and maintaining dry-weight appears to be an effective and active strategy that must be taken in our consideration for maintaining normotension among HD infants and children to avoid both hypotension and hypertension either during or after dialysis and its complication.

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