# The Promising Role of Chest Ultrasound for Volume Status Assessment in Hemodialysis Children

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## Abstract

**Background:** Volume assessment in hemodialysis (HD) patients remains a challenge. We aimed to assess fluid status in children on regular HD by evaluating the changes in chest B-lines and the inferior vena cava collapsibility index (IVCCI).

**Methods**: In this prospective cohort study a total of sixty children on regular hemodialysis underwent lung and IVC ultrasound before and after dialysis. Pre and post dialysis ultrasound changes were assessed, Correlation analysis between these findings was done.

**Results**: A total of 120 ultrasound assessments were performed. There was a significant reduction in the median number of B-lines (4 to 2) and in IVC collapsibility index (from 36.08 to 53.58) before and after dialysis. There is statistically significant correlation between percent change in weight and percent change in B lines r =0.315 (p=0.049). ROC curve showing the best cutoff of B lines after dialysis for detection of pulmonary congestion was ≥7 with area under curve 0.971(sensitivity 87.5%, specificity 70%, positive predictive value 70%, negative predictive value 98%).

**Conclusion**: Chest ultrasound have a significant diagnostic and prognostic value for volume status assessment in Hemodialysis children, that is safe and easily performed especially during this covid19 pandemic.

**Keywords:** Chest Ultrasound, Hemodialysis, children

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## Introduction:

In patients with chronic kidney disease (CKD), fluid overload increases the risk of mortality and morbidity [1]. Chronic fluid overload can cause edema, hypertension, and cardiac problems [2].

Whereas hypovolemia led to complications like hypotension, nausea, headache, and muscular cramps [3]. There are a variety of methods for completing the clinical evaluation of hydration status: X-ray evaluation of cardiothoracic index, ultrasound measurement of inferior Vena Cava (IVC) diameter, Bioimpedance Spectroscopy (BIS), plasmatic volume variation monitoring, brain natriuretic peptide [4]. All these methods have their limitations.
In recent years, there has been an upsurge in the use of chest ultrasound (CUS) as a noninvasive, simple technique for detecting extravascular lung water (EVLW) [5]. CUS has recently become popular for assessing volume status in adult by counting B-lines in dialysis patients (B-line scores). Lung ultrasonography is a trusted method for detecting tissue fluid overload in these patients, and it can also detect real-time volume changes during dialysis [6]. Although CUS has been used in adult maintenance dialysis for ten years and it is a practical, sensitive method for quantifying fluid overload in pediatric hemodialysis patients, there are few studies on lung ultrasound in children on hemodialysis (HD) [7].
IVC readings, which can be used to calculate the vessel's diameter and collapse index (the percentage of diameter reduction during spontaneous inspiration) are another ultrasonographic technique for assessing intravascular volume status. Central venous pressure (CVP) has a positive relationship with IVC size and a negative relationship with the IVC collapsibility index (IVCCI) [8]. IVCCI may be a stronger predictor than IVC diameter since it is a dynamic metric that accounts for diameter variation during the respiratory cycle [9]. There are few studies in children that look at the relationship between IVC measurements and fluid overload, dialysis tolerance, or cardiovascular events.
The aim of the present study was to evaluate the changes in ultrasound parameters (IVCCI and B-lines) in children with CKD on regular HD.

**Patients and methods:**

In this prospective cohort study, children (< 18 years) on HD attending Nephrology Unit of Pediatric department, between December 2020 and December 2021 that eligible to participate enrolled in this study. the study was performed on total of 60 children receiving maintenance HD. Children with co-existent lung fibrosis, atelectasis, lymphangitis, interstitial lung disease, heart failure or acute respiratory distress syndrome were excluded from the study.

**Ethical Consideration:** The approval for the study was obtained from the Pediatrics Departments of Zagazig University Hospitals after the approval of the Institutional Review Board (ZU-IRB#6135) and informed written consent was obtained from patients and/or their caregivers. This research was carried out in compliance with the Code of Ethics of the World Scientific Association (Declaration of Helsinki) for studies involving humans.

Baseline demographic data were obtained anonymously. Clinical measures such as body weight were measured before and after dialysis, as well as blood pressure and a clinical evaluation of fluid status.

**Chest ultrasonographic assessment:** Both lung and IVC ultrasound imaging was done within 15 minutes before and after the HD session to monitor chest ultrasonography changes in real time following ultrafiltration. All chest ultrasound examinations were performed using (Siemens Vacuson® X300 premium edition sector transducer (1.4-5 MHz) (Siemens Medical Solutions USA Inc. CA, USA). The ultrasound probe was put at four different positions in each hemi thorax to find B-lines, Upper and lower anterior chest in the mid clavicular and mid axillary lines on either side and the total number of B-lines was determined . B lines are well defined, laser like, vertical, hyperechoic, dynamic lines that originate at the pleural line and reach the screen's edge [10] . The lung comet score was classified as mild if it had fewer than 15 B lines, moderate if it had 15–30 B-lines, and severe if it had more than 30 B-lines [11] .

**Inferior vena cava assessment:** While the patient is supine, the ultrasound probe is positioned 2 cm caudal to the diaphragm in the subxiphoid region to observe and measure the maximum and minimum IVC diameters by measuring the distance between the anterior and posterior IVC walls in M mode during a spontaneous breathing cycle. IVCCI = (maximal diameter – minimal diameter)/maximal diameter [12].

**Statistical analysis:**

The statistical analysis was performed using Social Sciences Statistical Package (SPSS version 20.0). The following tests were used to test for significance of differences based on the type of data: qualitative data (number and percentage), quantitative data (mean and SD). Differences between parametric quantitative independent groups by t test, non-parametric by Man Whitney, and paired by Paired t and Spearman's correlation for correlation. Receiver-operating characteristic (ROC) curves were used to determine the diagnostic utility of B lines in detecting congestion. Selecting the point on the ROC curve that maximised both sensitivity and specificity yielded the best threshold. P value was set at <0.05 for significant results & <0.001 for high significant result.

**Results**

**Patients' characteristics:** Sixty patients were included (26 boys and 34 girls) end-stage renal disease (ESRD) on regular HD. Age ranged from 4 to 16 years with Mean ± SD (11.63 ± 3.25) years. Weight ranged from 15 to 58 kg with Mean ± SD (33.78 ± 12.43) kg. About 47% of patients did not receive antihypertensives and 53% received antihypertensive drugs. (Table1)

**Hydration status assessment before and after dialysis:** There is a statistically significant decrease in weight after dialysis from median (35.5kg to 34kg) with (p=0.003) and the median of percent change in weight was -3.57 among the studied patients. There is statistically significant increase in IVC collapsibility index after dialysis Mean ± SD from (36.08 ± 9.48 to 53.58 ± 11.24) with (p<0.001). There is statistically significant decrease in chest ultrasonography B lines after dialysis from (4 to 2) with (p<0.001). There is statistically significant improvement in chest US congestion after dialysis, while 65% of the studied patients had no congestion which increased to 83.3% after dialysis (p=0.001). (**Table 2**)

**Correlation studies:** There is statistically significant correlation between percent change in weight and percent change in B lines r =0.315 (p=0.049) while there is statistically non-significant correlation between percent change in weight and IVCCI, r = -0.024 (p=0.853). (**Table3**)

**Scatter dot blot** showing significant negative correlation (r=-0.559) between chest B lines and IVCCI after dialysis with (p<0.001). (**Fig1**)

**ROC curve** showing the best cutoff of B lines after dialysis in detection of congestion is ≥7 with area under curve 0.971(sensitivity 87.5%, specificity 70%, positive predictive value 70%, negative predictive value 98% and accuracy 93.3%) with p<0.001. (**Fig2)**

**Table (1)** Distribution of the studied patients according to demographic and anthropometric data:

| Parameter | N=60 | % |
|---|---|---|
| Gender: | | |
| Girls | 34 | 56.7 |
| Boys | 26 | 43.3 |
| Age (year): | | |
| Mean ± SD | 11.63 ± 3.25 | |
| Min - Max | 4 – 16 | |
| Weight (kg): | | |
| Mean ± SD | 33.78 ± 12.43 | |
| Min - Max | 15 – 58 | |
| Antihypertensives: | | |
| No treatment | 28 | 46.7 |
| 1 drug | 18 | 30 |
| 2 drugs | 13 | 21.7 |
| 3 drugs | 1 | 1.7 |

AKI: acute kidney injury ESRD: end-stage renal disease

**Table (2)** Changes in ultrasonographic& weight parameters before and after dialysis among the studied patients:

| Parameters | Dialysis | | Test | |
|---|---|---|---|---|
| | Before N=60 (%) | After N=60 (%) | t/Wx | p |
| **Weight kg:** | | | | |
| **Median** | 35.5 | 34 | -2.952 | 0.003* |
| **Min – Max** | 15 – 58 | 14 – 58 | | |
| **% Change in weight Median (range)** | -3.57 (-6.98, 11%) | | | |
| **IVC collapsibility index** | | | | |
| **Mean ± SD** | 36.08 ± 9.48 | 53.58 ± 11.24 | -17.176 | <0.001** |
| **Min - Max** | 20 – 50 | 30 – 80 | | |
| **Chest B lines:** | | | | |
| **Median** | 4 | 2 | -6.594 | <0.001** |
| **Min - Max** | 2 – 31 | 1 – 25 | | |
| **lung comet score:** | | | | |
| **No congestion** | 39 (65) | 50 (83.3) | | |
| **Mild congestion** | 16 (26.7) | 9 (15) | -4 | 0.001** |
| **Moderate congestion** | 4 (6.7) | 1 (1.7) | | |
| **Severe congestion** | 1 (1.7) | 0 (0) | | |

**t** paired sample t test **Wx** Wilcoxon signed rank test **p≤0.001 is statistically highly significant

**Table (3)** Correlation between percent change in weight and percent change in B lines& IVC collapsibility:

| Percent change in US parameters | Percent change in weight | |
|---|---|---|
| | r | p |
| B lines | 0.315 | **0.049*** |
| IVC collapsibility index | -0.024 | 0.853 |

r spearman rank correlation coefficient

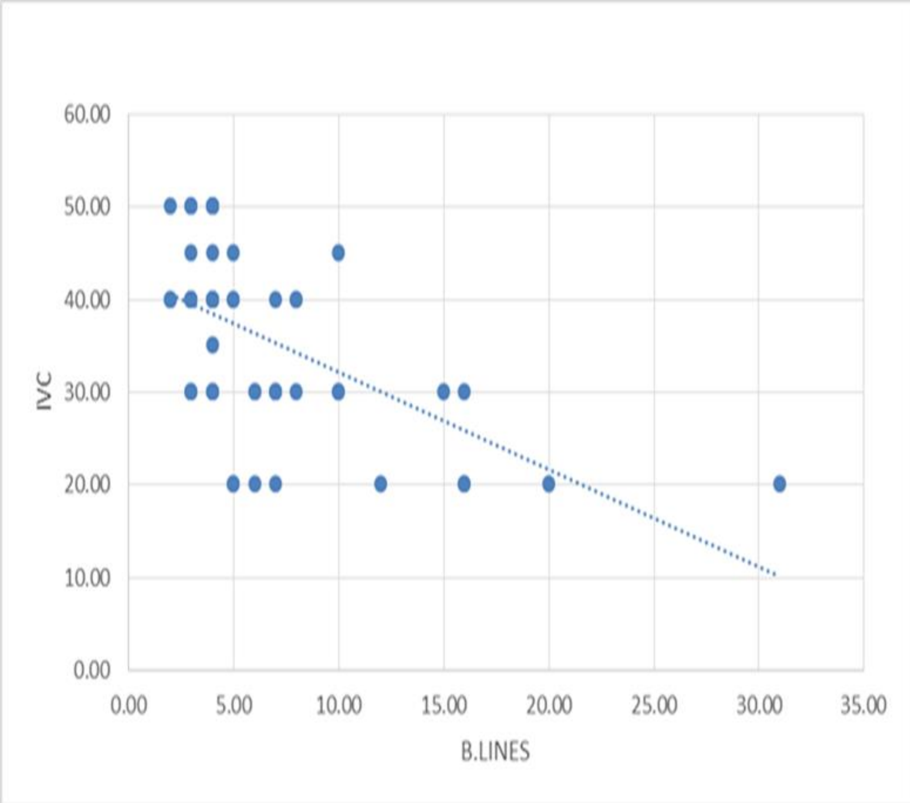


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Fig.1 Scatter dot blot showing significant negative correlation (r=-0.559) between chest B lines and IVC collapsibility index after dialysis with (p<0.001)

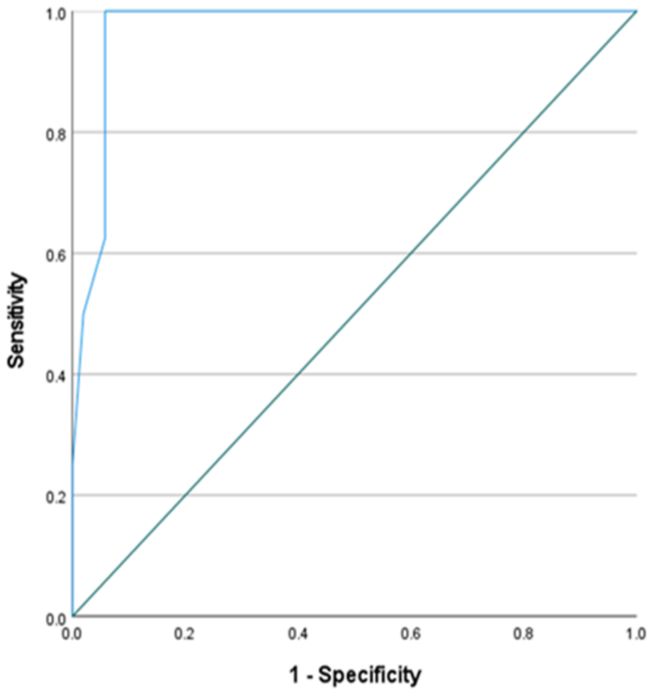


Fig.2 A receiver operating characteristic (ROC) curve showing the best cutoff of B lines after dialysis in detection of congestion is ≥7 with area under curve 0.971, sensitivity 87.5%, specificity 70%, positive predictive value 70%, negative predictive value 98% and accuracy 93.3% with p<0.001

**Discussion**

Patients with CKD are more likely to have hidden lung congestion in the absence of clinical symptoms and signs of volume overload and this can increase cardiovascular events and death [13].
Different imaging modalities have been used for the detection of pulmonary complications in dialysis children. However, the main challenge was the radiation exposure and the availability [14].
CUS, on the other hand, may be a more feasible and practical option since it can be rapidly done at the bedside, is repeatable and lower the possibility of cross infections making its critical especially during this COVID-19 outbreak [15].

Optimizing the hydration status of dialysis especially on children group remains a significant clinical challenge as previous study groups were mostly adults with HD, so we aimed to evaluate the changes in ultrasound parameters (IVCCI and B-lines) in children on HD therapy to prevent pulmonary complications and improve dialysis follow-up and outcome.

Our study included sixty children on dialysis with mean age 11.3years old. was done in pediatrics nephrology unit of a tertiary center. we have done about 120 chest ultrasounds to detect lung congestion score and IVCCI in children before and after dialysis.

In our study there is statistically significant decrease in median B lines after dialysis from 4 to 2 lines this matches Vitturi et al. study [6] who found a strong significant difference in the number of B lines before and after dialysis, also in Allinovi et al. study [7] showed that the median B line score decreased from 5 at presentation to 1.5 at recovery (P = 0.04) with concurrent improvement in fluid overload in 23 children with AKI concluded that Lung ultrasound is a practical and sensitive method of measuring subclinical fluid overload in infants and children on dialysis.

In our study there is statistically significant improvement in chest ultrasound congestion after dialysis as 65% of the studied patients at presentation had no congestion which increased to 83.3% after dialysis this matches Fahmy, et al [16] study included 30 patients on dialysis stated that in children with CKD after dialysis shows that the number of patients with moderate and severe lung congestion significantly decreased after dialysis.

In our study there is statistically significant increase in IVCCI after dialysis that is in agreement with Kaptein et al,[17] study that found that IVC US might be a valuable technique for determining whether critically ill patients will achieve volume reduction with HD.

In our study there is statistically non-significant correlation between percent change in weight and IVC collapsibility index .This in agreement with Mohammad et al ,study [18] that showed there was no significant correlation between IVCCI with volume loss by ultrafiltration that signify the limitations of IVC parameters in the assessment of volume status in HD patients, while there is statistically significant correlation between percent change in weight and percent change in B lines in agreement with Fu et al, study [19]that showed rapid weight loss during the dialytic period is directly and positively correlated with B line score variation . Previous research has shown that lung ultrasound measurements are preferable to IVC measurements for assessing the volume status of patients on HD [20].

In our study there is significant negative correlation between chest B lines and IVCCI after dialysis this is in agreement with Arun Thomas et al,[21] study that hypothesized that combining lung and IVC USG can result in a more accurate estimation of volume overload since its measure separate compartments of body water.

Moreover, during our study we detected two covid patients before onset of clinical symptoms suspected by presence of B lines at CUS with a collapsing or close to collapsing IVC before the dialysis session that is not compatible with a condition of hypervolemia. This is agreement with the finding of Allinovi et al.,[22] where CUS suggested the possibility of COVID 19 in two patients who were clinically euvolemic with mild, nonspecific clinical symptoms, which was verified by a positive nasopharyngeal RT-PCR. By extending the ultrasound examination to the heart and IVC, a more thorough examination can be performed If the patient has an unusual pattern of B lines and hydrostatic edema remains [23].

The role of CUS to evaluate several respiratory conditions is nowadays widely documented [24]. US can be used as alternative to CT in detection of lung pathologies [25]. Considering that dialysis patients showed a poor prognosis during COVID 19 pandemic, and that COVID19 symptoms in patients on dialysis are often mild or absent, CUS may play a significant role in the screening of hemodialysis patients during the COVID 19 pandemic [22].

In our study, the cutoff point of total B-lines to detect congestion was ≥7 with area under curve 0.971 (sensitivity 87.5%, specificity 70%, positive predictive value 70%, negative predictive value 98% and accuracy 93.3%) with $p<0.001$ in the diagnosis of post dialysis lung water excess. Previous studies reported similar results that lung US is sensitive in detecting fluid overload in the absence of fluid-related symptoms [16] .

## Conclusions

CUS have a significant diagnostic and prognostic value for volume status assessment in HD children, that is easily performed and safety without complications or delays, especially during this covid19 pandemic.

## Disclosure statement

The author (s) did not disclose any potential conflicts of interest.

## Data availability

The data arrangements used and evaluated in this present study were available from the corresponding author upon reasonable request.

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