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Value of B lines score on lung ultrasound as a direct measure of respiratory dysfunction and volume overload in critical care patients with acute kidney injury

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Abstract

Background: Fluid overload is commonly detected in critically ill cases with AKI and is accompanied by serious outcome. Lung US (LUS) is an efficiently used tool to assess volume noninvasively. We assessed the importance of these measurements in combination, for estimation of the PaO_2/FiO_2 ratio in critical patients with AKI.

The aim of the study: To evaluate the value of B-lines on chest ultrasound in predicting respiratory dysfunction in AKI and to assess the relation between the B lines on chest ultrasound and po2/fio2 ratio in acute kidney injury patients.

Patients and methods: This was a prospective observational study in which 40 cases who were presented on admission or developed at any time during ICU stay acute kidney injury determined based on the KDIGO criteria and according to RIFLE classification. Cases were studied at baseline as well as following 48 hrs using lung US, in addition to measuring the arterial blood gases.

Results: The PaO_2/FiO_2 ratio showed negative correlation with the B-lines score, and this correlation was kept even following adjustment. A cut of value of 15 for the B-lines score has a sensetivity of 94% and a specificity of 77.3% in detecting cases with PaO_2/ FiO_2 of less than 300.

Conclusion: It can be concluded that B-lines on chest US can predict volume overload and respiratory dysfunction in cases with AKI.

Keywords: Acute kidney injury, respiratory dysfunction, lung ultrasound, B lines, volume overload, respiratory dysfunction

Introduction

Acute kidney injury (AKI) refers to a clinical syndrome that may complicate the course and worsen the outcomes in a great number of hospitalized individuals. It manifests in about 1-5 percent of all hospitalized cases. The incidence is markedly increasing with progressive severity of the underlying causes; ~ 50 percent of the cases managed at the ICU develop AKI, in a lot of cases due to the generalized infections as well as sepsis [1].

Thus, AKI or acute kidney failure, as it was termed before means a sudden or rapid decrease in the kidney filtration functions that's often manifested by an elevated serum creatinine level or azotemia (increased blood urea nitrogen [BUN] level). Nevertheless, rapidly following a renal injury, BUN or Cr level might become normal, and the only manifestation of the renal insult might be reduced urine output [2].

In cases suffering pre-renal AKI and hemodynamic instability proper fluid replacement may restore COP, systemic BP and kidney perfusion. In contrast, exaggerating fluid administration is usually accompanied by high mortality or poor recovery of kidney functions [3-5]. Excessive resuscitation and fluid overload might lead to compromised pulmonary gas exchange, delay healing of wounds, promote the nosocomial infection risks and is accompanied by organ's dysfunction. This is more commonly determined in ICU cases with AKI, in whom the impact of frequent fluid challenge is aggravated by reduced Na+ and H2O excretion. In fact, one great observational multicentric RCT [6] has revealed that in adult cases with ARDS conservative fluid therapy is accompanied by increased oxygenation index, a short duration of ventilation and ICU stay in addition to decreases requirements in kidney replacement therapy.

Fluid overload has major adverse influences on the lungs, yet objective assessment of lung water in ICU cases isn't an easy task and it isn't precise as well. Conventionally, determination of interstitial pulmonary oedema depends upon chest radiography finding, usually hardly interpreted. Interstitial lung oedema could be evaluated via noninvasive method by lung US (LUS) exhibiting "comet-tail" artifacts (B-lines) that originate due to the presence of water-thickened interlobular septa [7]. various observational studies revealed a good correlation between US B-lines and interstitial oedema reported by CT scanning [7, 8] or with quantitative measurement of extravascular lung water (EVLW) using PiCCO [9].

In addition, LUS is currently highly used in ICU to diagnose various lung problems such as pleural effusion, pneumothorax, alveolar interstitial syndrome, lung consolidation, as well as lung abscess [10].

The aim of the study was to assess the value of B-lines on chest ultrasound in predicting respiratory dysfunction in AKI and to evaluate the relationship between the B lines on chest ultrasound and po2/fio2 ratio in acute kidney injury patients.

Materials and Methods

We carried out the current study on forty adult cases who diagnosed or developed acute kidney injury during ICU stay, all patients had the following criteria: Patients admitted to ICU aged ≥ 18 y, Patient had a working diagnosis of AKI on admission to ICU based on the following criteria:

KDIGO criteria: An increment of serum Cr of 0.3mg/dl or more within 48 hrs or UOP less than 0.5mL/kg/h for > 6hs despite fluid resuscitation when applicable

RIFLE criteria: A twofold elevation in baseline serum Cr or 50%reduction in the GFR.

We excluded patients with the following criteria: Patients with known history of CKD, Chronic heart failure with NYHA class III/IV, also, Patients with history of chronic parenchymatous lung disease, pneumonectomy, or pulmonary fibrosis.

Analysis of the arterial blood gases

Synchronously, collection of LUS arterial blood was performed to measure the PaO2 using GEM® Premier 3000 PAK. For all cases, the PaO2/FiO2 ratio was estimated at the beginning of the study then at 48 hrs. Respiratory dysfunction was determined as PaO2 divided to fraction of inspired O2 (PaO2/FiO2) less than 300.

Lung ultrasonography

All patients had lung ultrasonography performed once a definite diagnosis of AKI was made and 48 hours and DAY 4 after initiation of medical management.

Lung Ultrasound was performed using the US probe of Siemens Acuson X300 PE US machine (2-4 MH frequency).

Lung ultrasound score was calculated by 4 US aeration patterns were determine.

1. Normal aeration (N): existence of lung sliding with A lines or < 2 separate B lines.
2. Moderate loss of lung aeration: several, well-determined B lines (B1 lines).
3. Marked loss of lung aeration: several coalescent B lines (B2 lines).
4. Lung consolidation (C), existence of a tissue form with characteristic dynamic air bronchogram.

N=0, B1 lines=1, B2 lines=2, C= 3.

The last score, ranged between zero and thirty-six, is the sum of the values, from zero to three, assigned to the LUS patterns seen in each of the twelve areas evaluated. The twelve anterior, lateral, and posterior areas are delineated by anatomical landmarks as recommended in the unanimity conference for point of-care LUS (195). Each intercostal space of superior and inferior portions of the anterior, lateral, and posterior areas of the left and right chest walls was cautiously evaluated.

Data collection

Clinical data obtained from patients include CBC, coagulation profile, renal function, liver profile, arterial blood gases, lung ultrasound, abdominal ultrasound.

ECG, bed side CXR, and ECHO on day of diagnosis of acute kidney injury and same clinical data assessed after 48 hours of diagnosis in addition of assessment of volume status and fluid balance.

Statistical analysis

Coding and entering of data were carried out by the statistical package for the SPSS version 25 (IBM Corp., Armonk, NY, USA). Data was summarized via the use of mean, SD, median, minimum, and maximum in quantitative data and via the use of frequency and relative frequency (%) for categorical data. Comparing the quantitative variables were carried out via the use of the non-parametric Kruskal-Wallis and Mann-Whitney test For categorical data, Chi square ($\chi 2$) test was carried out. If the expected frequency was < 5 Exact test was utilized as an alternate. Correlations between quantitative variables were done using Spearman correlation coefficient. ROC curve was done with area under curve analysis carried out to determine best cutoff value of B LINES ON LUS in discrimination of respiratory dysfunction in acute kidney injury. P-value <0.05 was defined to be statistically significant.

Results

A total of 40 cases were enrolled in our study and included twenty-nine men (72.5%) and eleven women (27.5%), with mean age 61±11years with median 61years. And on evaluation of comorbidities, we found that Hypertension had a frequency of 52 patients (62.5%), diabetes had a frequency of 20 patients (50%) and sepsis in 11 patients (27.5%) there were no hepatic or chest problems. Most patients were admitted with sepsis (27.5%) and dehydration (27.5%). (Table 1)

Table 1: General characteristics, comorbidities, and cause of admission of the studied cases (n=40)

General characteristics		
Age (years)		**61±11**
Sex	Male	29 (72.5%)
	Female	11 (27.5%)

Comorbidities	
DM	20 (50%)
HTN	25 (62.5%)
Liver	0 (0%)
Chest	0 (0%)
Sepsis	11 (27.5%)
Cause of admission	
Dehydration	11 (27.5%)
UTI	11 (27.5%)
GIT bleeding	6 (15%)
AKI	10 (25%)
Stroke	2 (5%)

Data are presented as number (%).

On Assessment of volume status and respiratory dysfunction of enrolled patients on first day of diagnosis (day0) and after 48 hours of diagnosis (day2) we measured the following parameters: a) CVP and was found to be 4.7 ± 2cmh2o b) sCr was 3.9±2mg/dl c) serum urea 166±73mg/dl. d) fluid balance 3±1 liters e) B lines via chest ultrasound (10±3) and PO_2/fio_2 ratio 331±57. Day 2measurement: after local fluid resuscitation protocol the same parameters were remeasured and found to be CVP was 11 ±4 cmH2o, serum creatinine was 3±2 mg/dl, serum urea 120±61mg/dl, fluid balance 6.8±2 liters, B lines via chest ultrasound 17±35, and $PO_2/$ FiO_2 ratio 266±65. After initial assessment in ICU via fluid resuscitation as per local protocol was found that: Creatinine, urea and PO2/Fio2 were statistically significant decreasing after 48 hours than time of admission (P-value <0.05), while B lines, CVP and fluid balance were statistically significant increasing after 48 hours than time of admission (P-value <0.05), which denotes that enrolled study population with acute kidney injury were at risk of fluid overload after initial ICU resuscitation protocol were implemented. (Table 2)

Table 2: Comparison between day 0 and day 2 of studied parameters among the studied patients

Parameters	Day 0	Day 2	P-value
B lines	10±3	17±5	0.001
Creatinine	3.9±2	3±2	0.001
Urea	166±73	120±61	0.001
CVP	4.7±2	11±4	0.001
Fluid balance	3±1	6.8±2	0.001
PO2/Fio2	331±57	266±65	0.001

Data are presented as mean ± SD.

On assessment of B-lines score in addition to calculating po2/fio2 to all our study population on admission, day 2 after fluid resuscitation, and day 4 after adjust fluid resuscitation strategy we found that: Calculated p/f ratio on admission (331±57) worsened on day 2 follow up (277±65) after fluid resuscitation, trend was towards increase on day 4 (337±14) after adjusting fluid resuscitation protocol and as 14 patient receive diuretics, 7 patient receive dialysis and others develop polyuric phase of acute tubular necrosis. The same concept applied to B-lines were b lines measured on admission was 10±3, then increased to 17±5 on day 2 follow up after fluid resuscitation then trend improved by day 4 to be (11±3) after adjusting management plan. Statistically significant differences were demonstrated between b lines score and p/f ratio on follow up day 0, 2, 4 p value of 0.001 or less). (Table 3)

Table 3: Comparison between day 0, day 2 and after treatment of studied parameters among the studied patients

Parameters	Day 0	Day 2	Day 4	P-value
B lines	10±3	17±5	11±3	0.001
PO2/Fio2	331±57	266±65	337±14	0.001

Data are presented as mean ± SD.

We studied Correlation of b lines to different measured parameters in our study population to determine incidence of respiratory dysfunction in addition to CVP and fluid balance founded that The best cut-off values of B lines was≥15.5 with sensitivity 94.4% and specificity 77.3%, and the best cut off values of CVP ≥ 9.5 with sensitivity 94.4%and specificity 54.5%, and the best cut off values of fluid balance≥ 4.5 with sensitivity 94.4% and specificity 18.2% using ROC curve, The AUC were statistically significant for B lines and CVP (P-value ≤ 0.05) but not fluid balance (P-value higher than 0.05), which means that only B lines and CVP can be used to anticipate the incidence of respiratory dysfunction in cases AKI, however, The area under curve was the highest for B lines, 0.948 which makes it an excellent test with the highest both sensitivity and specificity too. (Figure 1)

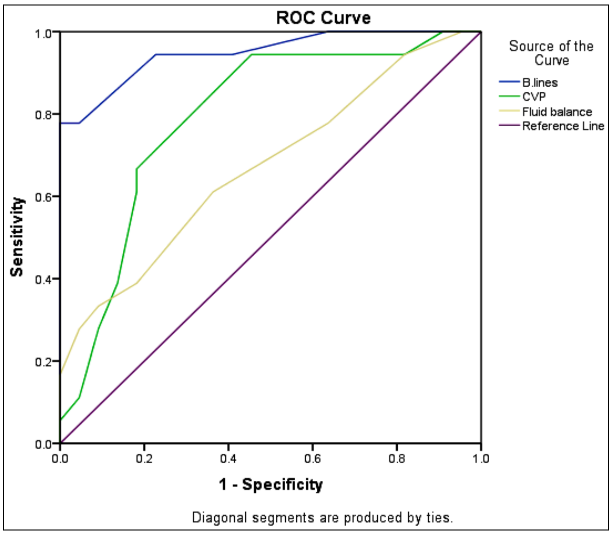

Fig 1: ROC curve for B lines, CVP and fluid balance to diagnose Respiratory dysfunction among the studied patients

We studied Correlations of $PO_2 \backslash FiO_2$ ratio and measured B lines and CVP to determine fluid overload and respiratory dysfunction by assessment po_2/fio_2 at day 0, day2 and day 4 as an indicator of respiratory dysfunction in cases admitted with AKI or developed AKI during the ICU stay founded that there was negative correlation between B lines and

PO2\FiO2 ratio, at day 0,R value -0.785 and P value 0.001, at day 2, R value -0.807 and P value 0.001 and at day 4, R value -0.668 and P value 0.001. Additionally, a negative correlation between $PO_2\backslash FiO_2$ ration and CVP was demonstrated. On day 0, R value -0.505 and P value 0.001, at day 2, R value -0.474 and P value 0.002 and at day 4, R value-.183 and P value 0.333. On day 4, no significant correlation between CVP and PO2\FiO_2 ratio. Also**,** Correlations between B lines, fluid balance and CVP among the studied patients to determine fluid overload by assessment B lines at zero-day, 2nd day and 4th day as an indicator of fluid overload, there was positive correlation between B lines and CVP. On day 0, R value 0.448 and P value 0.004, at day 2, R value 0.527 and P value 0.001 and at day 4, R value -0.023 and P value 0.903, no statistically significant correlation was demonstrated at day 4 between B lines and CVP. Additionally, we found that there is no statistically significant correlation between b lines and fluid balance at day 0, 2, 4. As R value at day 0 -0.084, p value 0.606. R value at day 2 0.092, p value 0.572. R value at day 4 -0.28 with p value 0.133 (Table 4)

Table 4: Correlations between PO2/FIO2, B lines, CVP and correlations between B lines, fluid balance and CVP among the studied patients

		po2/fio2	B lines	CVP
Correlations between PO2/FIO2, B lines and CVP				
Day 0	R	-0.785	-0.505	
	P-value	0.001*	0.001*	
Day 2	R	-0.807	-0.474	
	P-value	0.001*	0.002*	
Day 4	R	-0.668	-0.183	
	P-value	0.001*	0.333	
Correlations between B lines, fluid balance and CVP				
	B lines	CVP	Fluid balance	
Day 0	R	0.448	-0.084	
	P-value	0.004*	0.606	
Day 2	R	0.527	0.092	
	P-value	0.001*	0.572	
Day 4	R	-0.023	-0.28	
	P-value	0.903	0.133	

*: significant P-value

On evaluation of outcome in our study population 11 patients (27.5%) needed mechanical ventilation with mean 9±8 days with median 9 days. The mean duration of staying in the ICU was 11±6 days with median 10 days. (Table 5)

Table 5: Need for ventilation and ICU stay

Ventilation	**11 (27.5)**
Ventilation days	9 (0-25)
ICU stay	10 (4-30)

Data are presented as median.

The incidence of mortality in our studied patients, 7 patients (17.5%) died, and 33 patients (82.5%) survived. (Table 6)

Table 6: Outcome of the studied patients

Outcome	**Frequency**	**Percent**
Survivors	33	(82.5%)
Non-survivors	7	(17.5%)

Data are presented as number (%)

Discussion

We assessed incidence of acute kidney injury using RIFLE classification and revealed there were 12 cases in risk group (30%), 13 patients in injury group (32.5%) and 15 patients (37.5%) in failure group.

Also, we assessed using KDIGO stages for incidence of acute kidney injury, 12 patients were in stage I (30%), 13 patients were at stage II (32.5%) and 15 patients in stage III (37.5%). Similarly, Hoste *et al.*, [11] studied RIFLE criteria for AKI and hospital mortality on 5,383 patients were 12% in risk group, 27% in injury group and 28% in failure group, Additionally, Tele s *et al.*, [12] studied acute kidney injury in leptospirosis, in 182 patients, 33(16%) patients in stage I, 36 (17.6%) in Stage 2 and 113 (55.1%) in stage III.

We studied correlation of b lines and po2/fio2 ratio for discrimination of respiratory dysfunction in AKI and we found that cut-off values of B lines was≥15.5 and was statistically significance with po2/fio2 p value (0.001) with sensitivity 94.4% and specificity 77.3%. There was statistically significance negative correlation between b lines and po_2/fio_2. similarly, Ciumanghel *et al.*, [13] evaluated b lines score on LUS to determine respiratory distress in acute kidney injury founded A B-line score of more than 17 had a sensitivity of seventy-six percent and a specificity of sixty-five percent for prediction of volume overload.**(15)** Additionally, Panuccio *et al.*, [14], conducted Apilot study in nephrology ward,including 40 patients.The average age was 68±16 y and patient admitted according to KDIGO classification to diagnose acute kidney injury, lung ultrasound b lines score correlate with lung crackles severity detected by auscultation to detect pulmonary congestion and found that b lines ≥15 are accompanied by moderate to severe lung congestion.**(16)** in contrast to our study, Enghard *et al.*, [15] studied LUS protocol and showed excellent prediction of EVLW in ventilated ICU cases.**(17)** In this study mechanically ventilated patients admitted with different causes of admission, subjected to LUS and trans-pulmonary thermodilution measurement using the PiCCO equipment for determination of volume over load. B lines score ≥18.5 had a sensitivity of 92.3% and specificity of 94.6% to detect extra vascular lung water, The correlations between the B lines and the PaO2/FiO2 were weak, yet it was significant (Spearman's r = -0.37, P 0.01). The difference between studies may be due to the type of patient and presence of mechanical ventilation as main category of study, also use of Transpulmonary thermodilution to detect EVLW. Additionally, B lines were measured for one day only, in our study we followed up patients for four days.

We studied also CVP significance in detection of respiratory dysfunction in AKI cases and revealed that the best cut off values of CVP was≥ 9.5 cmh2o with sensitivity 94.4%and specificity 54.5% and was statistically significant p value (0.001).

We also studied correlation between CVP and po2 /fio2 on day 0 of diagnosis of acute kidney injury and after 48 hours and day4 there was negative correlation between CVP and po2/fio2 on day zero, 2nd day and no correlation on the 4th day and it was statistically significant.

Similarly**,** Ismail *et al.*, [16] studied role of LUS in determination end point of fluid resuscitation in septic shock cases.it was carried out on 80 cases classified in 2 groups one of them received early directed goal treatment with a target CVP of 8–12mmHg, while the 2nd received fluids guided by simplified LUS protocol till achieving a scoreof16.exhibited a negative correlation between CVP and hypoxia index (Spearman's r=-0.39, P=0.012). Additionally, Semler *et al.*, [17], conducted a study to detect effect of Initial CVP on the Outcome of Conservative Vs. Liberal Fluid therapy in ARDS,it was done on 609 patient admitted without shock and subdivided in two groups based on initial measurement of CVP first group when CVP <8cmh2o and second group when CVP >8 cmh_2o and also compare between conservative and liberal fluid management between the two groups,it was found that patient with low CVP on initial measurement and treated with liberal fluid management had increased incidence of respiratory dysfunction and decrease in po2/fio2 ratio. in contrast to our study, Enghard *et al.*, [15] studied mechanical ventilation to predict extra vascular lung water. There was no significant correlation between CVP and decreased po2/fio2 (Spearman's r = -0.011, P = 0.4924), as CVP is more used for intravascular volume and in this study they used transpulmonary thermodilution which has high sensitivity for extra alveolar lung water.**(17)** In our study, we studied effect of fluid balance as predictor of occurrence of respiratory dysfunction.we found best cut off values of fluid balance≥ 4.5littres with sensitivity 94.4% and specificity 18.2%.Similarly, Wiedemann *et al.*, [18],in comparison with 2 Fluid-therapeutic Strategies in Acute Lung Injury. This study included two groups one of them followed conservative fluid management and second group had liberal fluid management and followed up to seven days in mechanically ventilated patients. Results showed the mean (±SE) cumulative fluid balance during the 1st 7 days was – 136±491 ml in the conservative-strategy group and 6992±502 ml in the liberal-strategy group (P≥ 0.001). In comparison with the liberal strategy, the conservative strategy ameliorated the O2 index and increase numbers of ventilator free days (14.6±0.5 vs. 12.1±0.5, P<0.001) in conservative vs liberal fluid management respectively. Also we studied correlation between b lines and positive fluid balance and revealed no statistically significant correlation between b lines and fluid balance at day 1 of diagnosis of acute kidney injury, 48 hours after diagnosis, and after four days of diagnosis, in contrast to this Wang *et al.*, [19] studied US B-Lines, Fluid replacement, and Hypoxia in Malawian cases with Suspected Sepsis It was done on seventy patient admitted to Queen Elizabeth Central Hospital with suspected sepsis during weekdays with sepsis or septic shock that required fluid resuscitation and lung ultrasound done to detect presence of b lines, lung ultrasound done on admission and again 3, 6, 24, 48, and 72 hours after starting of fluid resuscitation, result of study show significant correlation between fluid balance and number of b lines. Difference may be due to different fluid administration protocol, type and number of patients, in this study some patients had base b- lines on lung ultrasound may be due to increased permeability in sepsis and septic shock versus patient in our study, who were mostly dehydrated and absence of b lines on diagnosis of acute kidney injury and after fluid resuscitation they developed improvement in urine output and also some receive diuretics and dialysis. Also, in our study we found that on assessment of B lines at zero day, 2nd day and 4th day as indicator of fluid overload there was positive correlation between B lines and CVP and it was statistically significant at day 0 and day 2, but There was no statistically significant correlation at day 4 between B lines and CVP. Likewise, Ismail *et al.*, [16] studied detection of end point of fluid resuscitation via the use of simplified LUS protocol in cases suffering septic shock, in the current study 80 cases enrolled with septic shock and was found that moderately significant positive correlation with each of the CVP reading (Spearman's r=0.50, P=0.001) and the congestion by CXR (Spearman's r=0.47, P=0.002).

Study limitation

1. Few numbers of cases enrolled; our results needed to be emphasized by greater multicentric studies.
2. Since it was an observational study, no cause-effect relationship was made.
3. It was single center experience thus factors may limit generalizability.
4. Single physician do chest ultrasound.

Conclusion

LUS assessment offers a simple as well, non-invasive, low-cost alternate tool to available approaches of detection and quantification of EVLW, and,might be utilized as a routine method for management of fluid administration in cases suffering AKI in ICU, via detection of cases with compromised gas exchange at a high risk for evident pulmonary congestion as there was negative correlation between B lines and po_2/fio_2 ratio in these patients, notably The best cut-off values of B lines was ≥15.5 with sensitivity 94.4% and specificity 77.3%.

Conflict of Interest

Not available

Financial Support

Not available

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