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Role of point of care ultrasound and parathormone hormone in management of acute kidney injury in emergency department

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ABSTRACT

Background: Role of point of care ultrasound in management of acute kidney injury (AKI) is still unclear. The discrimination between AKI and chronic kidney disease (CKD) in ED, especially in the absence of clear CKD history, represents a dilemma.

Aim: To test the accuracy of POCUS and intact parathormone hormone (iPTH) as differentiators between AKI and CKD, and to investigate the role of POCUS in management of AKI in the ED.

Methods: This prospective study involved 95 adult patients presented to ED of Alexandria Main University Hospital, with signs and/or symptoms suggesting renal impairment in the absence of prior renal functions tests from April 2022 to December 2022. POCUS was done and iPTH was measured for all enrolled patients. Validity of renal length and iPTH to discriminate AKI and CKD were tested. POCUS were used to identify different underlying causes of AKI.

Results: Renal length ≤ 9.62 cm could diagnose CKD (Area under curve-AUC 0.926) with 82.46% sensitivity, 92.11% specificity, 94.0% PPV and 77.8% NPV. Intact PTH level > 161 pg/ml could diagnose CKD (AUC 0.844) with 73.17% sensitivity, 92.11% specificity, 90.9% PPV and 76.1% NPV.

Conclusion: Both renal length and iPTH are accurate tests to differentiate AKI from CKD in ED. POCUS help identifying the different causes of AKI and reaching appropriate management decisions.

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Acute kidney injury; point of care ultrasound; intact parathormone hormone

1. Introduction

Point of care ultrasound (POCUS) performed by the emergency physician (EP) is considered one of the main pillars of patient management in emergency medicine (EM) [1–4]. Studies have tested the competency of EP to perform POCUS, with recommendations from various societies of EM supporting EP training on POCUS and approving many protocols for different emergency conditions in the emergency department (ED) [5–7]. One of unclear issues is the role of POCUS in acute kidney injury (AKI), which is considered one of the most common diagnoses in the ED and carries high mortality and morbidity [8–10]. The incidence of AKI in developing countries reaches up to 60% among critically ill patients [11,12]. At the same time, the development or progression of chronic kidney disease (CKD) after having one or more attacks of AKI has great socioeconomic and public health effects with increased healthcare costs in both high- and low-income countries [13]. AKI is differentiated from CKD by its rapid and reversible deterioration of renal functions [14]. Kidney Disease Global Improvement Outcome (KDIGO) guidelines define AKI as an abrupt decrease in kidney function diagnosed by an increase in serum creatinine (SCr) by ≥0.3 mg/dl within 48 h, an increase in SCr to ≥ 1.5 times baseline within 7 days or a urine volume <0.5 ml/kg/h for 6 h [15].

Intact parathormone hormone (iPTH) as a laboratory biomarker could solve the problem of differentiating AKI and CKD, as it increases in CKD as a result of secondary hyperparathyroidism and is recommended to be used in the monitoring of CKD patients [16,17]. In addition, iPTH was also found to be increased in AKI which enhances its potential role as a discriminator [18,19]. POCUS can also play an important role in differentiating AKI from CKD especially if baseline renal function tests are not available. Additionally, POCUS may help in the rapid identification and management of different etiologies of AKI, especially that rapid identification and management of reversible causes of AKI are highly recommended [15].

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2. Patients and methods

95 adult patients presented to the ED of Alexandria Main University Hospital in Egypt were prospectively enrolled to the study from April 2022 to December 2022. Informed consent was obtained from all patients or next of kin. Eligible patients were adults with signs and/or symptoms suggesting renal impairment; oliguria (<0.5 ml/Kg/hr), anuria, abnormal renal function test, electrolyte disturbance, metabolic abnormalities and/or volume overload, with absent baseline renal functions. We excluded pregnant patients, patients with history of parathyroid disease or surgery or patients on calcium or phosphate binder treatment. All eligible patients underwent both POCUS and departmental ultrasound (by radiologist). POCUS was done by specialist of EM, experienced in POCUS and he was not blinded to the results of patients' examinations and investigations. Both radiologist and POCUS physician were blinded to results of each other. The results of ultrasound scans were documented and reviewed with the final diagnosis by an observer who was blind to both ultrasound scans results. Data collection included demographic characteristics, clinical and laboratory data. A serum sample for iPTH was taken for all enrolled patients and was analyzed using Elecsys PTH stat 2010 and Cobas-e 411 (Roche) with a normal reference range of 1565 pg/ml.

2.1. POCUS examination

POCUS was carried out using different ultrasound machines according to availability: Mindray DP-5 and DP-20 and Toshiba Xario 200 TUS-X200. Curvilinear or phased array probes with low frequencies (2–5 MHz) were used for renal and abdominal examinations. For cardiac examination, a phased array probe was used, while a high-frequency linear probe (5–12 MHz) was used for lung ultrasound. Patients were routinely examined in the supine position, although the lateral position was sometimes used for better imaging. Renal ultrasound (RUS) was performed in two planes, longitudinal and transverse, and includes measuring renal length and assessment of cortical echogenicity and corticomedullary differentiation (CMD). Renal length was measured from pole to pole, assuming the normal renal length from 10 to 12 cm, and shorter length was assumed as CKD [20]. Cortical echogenicity assessed qualitatively in relation to liver and spleen [21]. Qualitative assessment for left and right ventricular functions was done by the eyeballing method, also pericardial effusion or tamponade were also assessed [22,23]. The inferior vena cava (IVC) was assessed with B and M mode in the subcostal window at 2 to 3 cm distal to its entrance to the right atrium to estimate the intravascular volume, both IVC diameter and collapsibility index were calculated [24,25].

POCUS was used to differentiate between AKI and CKD and to identify AKI causes (pre-renal, renal and post-renal). IVC assessment used to differentiate between fluid depletion and overload. POCUS findings and clinical parameters were used together to identify different types of shock, where shock was defined as SBP <90 mm Hg, or shock index ≥ 1 [26]. Cardiorenal cause was considered if signs of acute decompensated heart failure present: decreased contractility, plethoric IVC, pulmonary B lines [27]. Lung ultrasound was performed to identify signs of overload, congestion (B lines, pleural effusion) or pneumothorax (absence lung sliding and stratosphere sign) [28]. The Possibility of renal causes was considered if clear history of using nephrotoxic drugs, evidence of renal infection and acute renal ischemia were present. Hydronephrosis and its possible causes were identified by US as obstructive causes of AKI [29]. (Figure 1)

3. Statistical analysis

Data were entered into IBM SPSS software package version 20.0 for statistical analysis. Qualitative data were described using numbers and percent. Quantitative data were described using mean, standard deviation (SD), median and interquartile range (IQR). The Shapiro–Wilk test was used to verify the normality of distribution, and the significance of the obtained results was judged at the 5% level. Chi-square test was used to compare categorical variables. F-test (ANOVA) and Post-Hoc test (Tukey) for pairwise comparisons and Kruskal–Wallis test and Post-Hoc (Dunn's multiple comparisons test) for pairwise comparisons were used to compare between quantitative variables in more than two studied groups. Receiver operating characteristic curve (ROC) was used to investigate the diagnostic performance of iPTH and renal length as discriminators, with area under curve (AUC) greater than 50% indicating acceptable performance and an area about 100% indicating the best performance for the test. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated. The minimum sample needed was 80 patients to achieve significance level of 5% and a power of 80% with an assumption of 80–95% sensitivity of the test [30].

4. Results

95 adult patients were enrolled in the study, 50 were females (52.6%) and 45 were males (47.7%). The median of age was 69 (IQR 62–75) years and mean of Body Mass Index (BMI) 28.61 ± 6.52 Kg/m^2. Patients were classified according to final diagnosis into three groups: AKI (group 1, $n = 38$), AKI on top of CKD

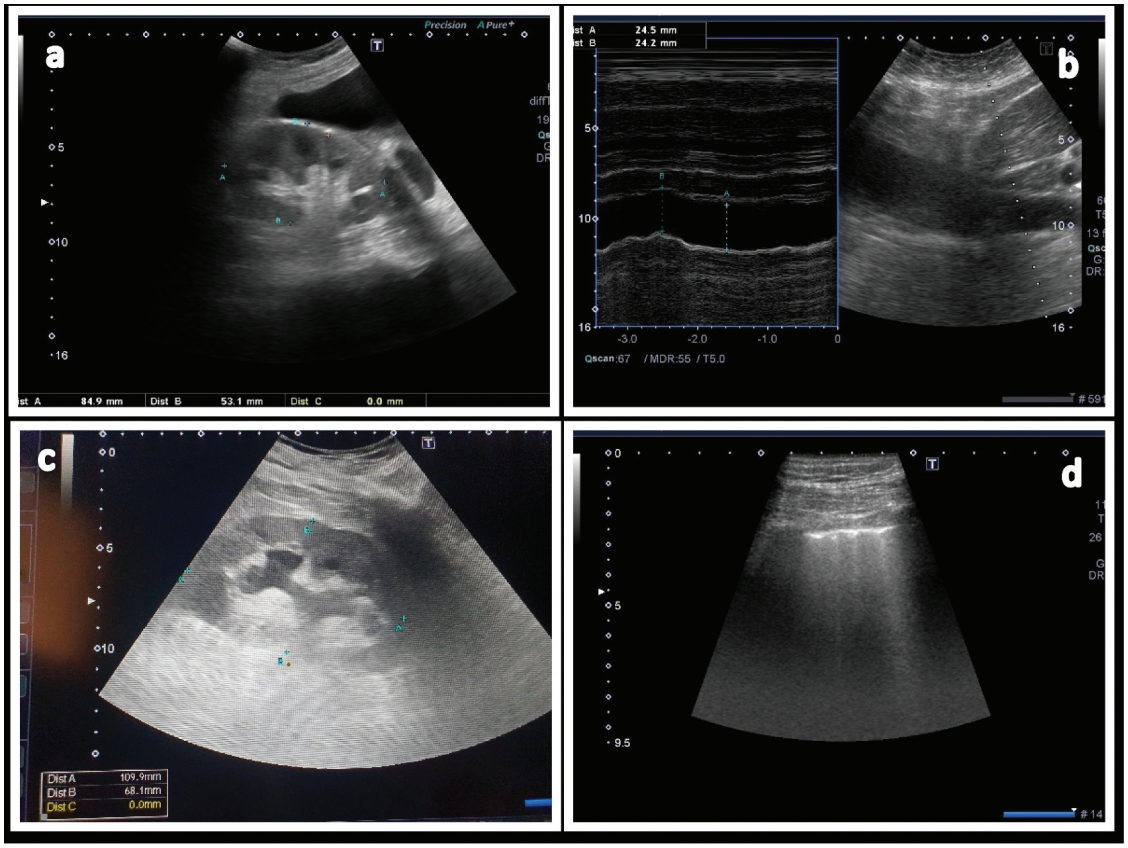

Figure 1. Different POCUS findings: (a) short hyperechogenic right kidney reflecting CKD; (b) B and M modes of IVC assessment show plethoric IVC; (c) hyperechogenic kidney with moderate degree of hydronephrosis; (d) lung ultrasound shows lung congestion (B lines).

(group 2, $n = 41$) and CKD (group 3, $n = 16$). No statistical significance differences regarding demographic characteristics between groups were present. However, the hemoglobin and serum calcium levels were significantly lower in groups 2 and 3, in comparison with group 1 (p 0.004 for both), while serum creatinine and phosphorus levels were lower in group 1 in comparison with group 2 and 3 (p 0.002 and < 0.001, respectively). These parameters were not significantly different between groups 2 and 3. Additionally, the level of iPTH was elevated among the three groups, but was lower for group 1 in comparison with other two groups: Median of iPTH in group 1 was 94.9 pg/ml (1QR 80.1–122), while in group 2 median was 230 pg/ml (IQR 152–345) and 204 pg/ml (IQR160.7–297) in group 3 ($p_{1\&2}$ <0.001). (Table 1)

Regarding RUS, the median of renal length was statistically significant different between groups, where shorter renal length was found in both group 2 (8.6 cm and IQR 7.9–9.5) and group 3 (9.13 cm, IQR 8.6–9.4), while the difference between these two groups was not significant (p3 = 0.647). On the other hand, the renal length for group 1 was 11.2 cm IQR 10.5–12.3, significantly different from other groups ($p_{1\&2}$ <0.001). Cortical echogenicity and CMD were not statistically significantly different between group 2 and 3, but the difference was significant with group 1. Most of patients in group 1 had normal cortical echogenic (>70%), while ≥ 25% had grade I echogenicity, one case grade II, and no cases were grade III. On the contrary, most of cases in CKD groups (2&3) had increased echogenicity, especially grades II and III ($p < 0.001$). CMD was preserved for most of patients in group 1 in comparison with group 2 and 3 ($p < 0.001$) but not significantly different between group 2 and 3. (Table 2)

By Comparing AUC for renal length and iPTH, both showed excellent performance, but the renal length found to have outstanding performance as differentiator between AKI and CKD with AUC = 0.934 (95% CI 0.885–0.983), AUC for iPTH was 0.844 (95% CI 0.764–0.925). A cut-off value ≤9.62 cm of renal length could diagnose CKD with 82.46% sensitivity, 92.11% specificity, 94.0% PPV and 77.8% NPV (Figure 2). Additionally, cut-off value of iPTH >161 pg/ml could diagnose CKD and discriminate it from AKI with 73.17%, sensitivity, 92.11%, specificity, 90.9% PPV and 76.1% NPV. (Figure 3)

No significant differences between AKI and AKI on top of CKD in results of POCUS regarding the underlying causes of AKI were found. 50% of AKI patients (group 1 and 2) were found to have decreased IVC diameter with increased CI (>50%), while about quarter of them have plethoric IVC. Decreased cardiac

Table 1. Baseline patients' characteristic and laboratory results total sample and in each group.

	Group 1 ($n = 38$)	Group 2 ($n = 41$)	Group 3 ($n = 16$)	Test of sig.	p
Sex					
Male	18 (47.4%)	19 (46.3%)	8 (50%)	$x^2 = 0.062$	0.970
Female	20 (52.6%)	22 (53.7%)	8 (50%)		
Age (years)				H = 2.879	0.237
Median (IQR)	65 (62–72)	70 (62–75)	70 (63–74.5)		
BMI (kg/m^2)				F = 1.717	0.185
Mean ± SD.	30.12 ± 7.22	27.60 ± 6.07	27.62 ± 5.49		
Hgb (g/dl)				H = 11.085*	0.004*
Median (IQR)	10.95(10–12.3)	9.20 (7.5–11)	9.2 (6.7–12.1)		
Sig. bet. grps		$p_1 = 0.002$*,$p_2 = 0.021$*,$p_3 = 0.958$			
Creatinine (mg/dl)				H = 12.900*	0.002*
Median (IQR)	2.75 (2–5.3)	5.6 (3.9–6.9)	6.1 (5.1–6.8)		
Sig. bet. grps		$p_1 = 0.002$*,$p_2 = 0.003$*,$p_3 = 0.510$			
Phosphorus (mg/dl)				F = 9.871*	<0.001*
Mean ± SD.	4.78 ± 1.18	5.94 ± 1.47	6.15 ± 1.26		
Sig. bet. grps		$p_1 = 0.001$*,$p_2 = 0.002$*,$p_3 = 0.858$			
Calcium (mg/dl)				F = 6.008*	0.004*
Mean ± SD.	8.02 ± 0.93	7.45 ± 0.89	7.18 ± 1.05		
Sig. bet. grps		$p_1 = 0.021$*,$p_2 = 0.008$*,$p_3 = 0.578$			
IPTH (pg/ml)				H = 32.333*	<0.001*
Median (IQR)	94.9 (80.1–122.)	230 (152–345)	204.5(160.7–297)		
Sig. bet. grps		$p_1 <0.001$*, $p_2 <0.001$*, $p_3 = 0.617$			

Group 1: AKI Group 2: AKI on top of CKD Group 3: CKD BMI: Body mass index.
Data are expressed mean ± Standard deviation (SD), median and interquartile rang (IQR).
χ^2: Chi-square test.
F: One-way ANOVA test, Pairwise comparison between each two groups was done using Post-Hoc Test (Tukey).
H:Kruskal Wallis test, Pairwise comparison between each two groups was done using Post-Hoc Test (Dunn's for multiple comparisons test).
p:Comparing the three studied groups. p1: comparison between group1and group 2. p2: comparison between group 1 and group3. p3: comparison between group 2 and group 3
*:Statistically significant at $p \leq 0.05$.

contractility was diagnosed in one third of cases, while only in 11% assumed to be the cause of AKI. B lines were present in about 40% of patients, while around 32% were having pleural effusion (Table 3).

The pre-renal causes of AKI were the most common causes identified (92.4%), mostly due to decreased oral intake (69.6%) or hypo-perfusion (24.1%). Sepsis was a pre-renal factor in 67.1% patients and was mixed with hypovolemia and decreased oral intake in 59.5% of cases. 13.9% patients were having obstructive causes, where stones were the most common cause. 5.1% of cases were considered having renal causes: nephrotoxic dugs, pyelonephritis or renal ischemia. (Table 4)

5. Discussion

In this study, we offered solutions for a common dilemma of distinguishing acute and chronic renal impairment in ED, especially when the baseline renal function tests are unavailable. The renal length was not surprisingly to be short in CKD, but its outstanding performance as discriminator makes it an excellent choice. Although both tests could be used but the higher performance of renal length (AUC 0.934 versus 0.844) makes it the first choice. Intact PTH might help in certain conditions; CKD is associated with normal or increased renal length. In the present study, a cut-off value of renal length ≤9.62 cm diagnoses CKD with high sensitivity. Ozman et al., [20] set a cut-off 7.1 cm (AUC 0.865) with 100% sensitivity and specificity, which is shorter than our results. We agreed with this study in that short length kidney is diagnostic for CKD, but we does not agree with setting shorter cut-off value for diagnosing CKD. As for patients not previously diagnosed as CKD (not complained), the probability of having very short kidney may be uncommon and can limit the use of renal length as a discriminator.

In our study, we found that although the increased cortical echogenicity commonly was found in CKD ($p < 0.001$), but there is still grey zone in this aspect, makes the depending on the increased cortical echogenecity alone to diagnose CKD (except for higher grades of CKD) can't accurately differentiate AKI and CKD, as grade I echogenicity and to lesser extent grade II were present in quarter of AKI cases; hence increase echogenicity can't accurately alone exclude AKI. O'Neill et al. [31] explained different situations of AKI, where kidney shows increased echogenicity as in ischemic acute tubular necrosis and glomerulonephritis. Also, Ozmen et al. [20] concluded that echogenicity has poor performance as discriminator between AKI and CKD. In general, short kidney with increased echogenicity usually diagnose CKD, while normal length and echogenic or slight increased echogenic kidney indicating less severe renal condition coinciding with diagnosis of AKI condition.

Parathormone hormone was found to be increased in both AKI and CKD secondary to hyperparathyroidism accompanying renal impairment [32,33]. Unlike the traditionally measured whole

Table 2. Renal ultrasound results among the studied groups.

	Renal Ultrasound	Group 1 ($n = 38$)	Group 2 ($n = 41$)	Group 3 ($n = 16$)	Test of sig	p
Renal length cm (max.)	**RT**				H = 51.797*	<0.001*
	Median (IQR)	11.5(10.7–12.5)	8.4 (7.6–9.7)	9.3 (8.8–9.5)		
	Sig. bet. grps	p_1 <0.001*, p_2 <0.001*, p_3 = 0.651				
	LT				H = 42.726*	<0.001*
	Median (IQR)	11 (10.2–12.3)	8.73(7.8–9.7)	9.10 (8.3–9.3)		
	Sig. bet. grps	p_1 <0.001*, p_2 <0.001*, p_3 = 0.906				
	Mean renal length				H = 51.223*	<0.001*
	Median (IQR)	11.2 (10.5–12.3)	8.6 (7.9–9.5)	9.13 (8.6–9.4)		
	Sig. bet. grps	p_1 <0.001*, p_2 <0.001*, p_3 = 0.647				
CMD	**RT**					
	Poor	3 (7.9%)	18 (43.9%)	7 (43.8%)	χ^2 = 69.407*	^{MC}p
	Fair	0 (0%)	18 (43.9%)	8 (50%)		<0.001*
	Preserved	35 (92.1%)	5 (12.2%)	1 (6.3%)		
	Sig. bet. grps	$^{MC}p_1$ <0.001*, $^{MC}p_2$ <0.001*, $^{MC}p_3$ = 0.916				
	LT					
	Poor	3 (7.9%)	18 (43.9%)	6 (37.5%)	χ^2 = 66.902*	^{MC}p
	Fair	1 (2.6%)	19 (46.3%)	9 (56.3%)		<0.001*
	Preserved	34 (89.5%)	4 (9.8%)	1 (6.3%)		
	Sig. bet. grps	p_1 <0.001*, $^{MC}p_2$ <0.001*, $^{MC}p_3$ = 0.908				
Echogenicity	**RT**					
	Normal	27 (71.1%)	1 (2.4%)	0 (0%)	χ^2 = 67.646*	^{MC}p
	Grade I	10 (26.3%)	14 (34.1%)	4 (25%)		<0.001*
	Grade II	1 (2.6%)	22 (53.7%)	9 (56.3%)		
	Grade III	0 (0%)	4 (9.8%)	3 (18.8%)		
	Sig. bet. grps	$^{MC}p_1$ <0.001*, $^{MC}p_2$ <0.001*, $^{MC}p_3$ = 0.705				
	LT					
	Normal	28 (73.7%)	0 (0%)	1 (6.3%)	χ^2 = 74.647*	^{MC}p
	Grade I	10 (26.3%)	15 (36.6%)	5 (31.3%)		<0.001*
	Grade II	0 (0%)	24 (58.5%)	9 (56.3%)		
	Grade III	0 (0%)	2 (4.9%)	1 (6.3%)		
	Sig. bet. grps	$^{MC}p_1$ <0.001*, $^{MC}p_2$ <0.001*, $^{MC}p_3$ = 0.587				
Others	**RT**					
	Hydronephrosis	5 (13.2%)	3 (7.3%)	1 (6.3%)	χ^2 = 0.905	^{MC}p = 0.647
	Cyst	7 (18.4%)	5 (12.2%)	3 (18.8%)	χ^2 = 0.702	0.704
	Stone	3 (7.9%)	5 (12.2%)	0 (0%)	χ^2 = 1.792	^{MC}p = 0.381
	LT					
	Hydronephrosis	2 (5.3%)	4 (9.8%)	1 (6.3%)	χ^2 = 0.668	^{MC}p = 0.863
	Cyst	9 (23.7%)	7 (17.1%)	3 (18.8%)	χ^2 = 0.558	0.757
	Stone	0 (0%)	2 (4.9%)	0 (0%)	χ^2 = 1.908	^{MC}p = 0.649

Group 1: AKI Group2: AKI on top of CKD Group 3: CKD CMD: corticomedullary differentiation.
Data are expressed as number (n), percentage (%), median and interquartile rang (IQR).
χ^2: Chi-square test ^{MC}: Monte Carlo.
H: Kruskal–Wallis test, Pairwise comparison between each two groups was done using Post Hoc Test (Dunn's for multiple comparisons test).
p: Comparing the three studied groups. p1: comparison between group1and group 2. p2: comparison between group 1 and group3. p3: comparison between group 2 and group 3
*:Statistically significant at $p \leq 0.05$.

PTH assay, intact PTH is not metabolized by kidney, so its results will not be affected by the renal impairments. As renal length, the iPTH level could differentiate AKI from CKD but could not discriminate between AKI on top of CKD or CKD. The cut-off level >161 pg/ml could diagnose CKD with good sensitivity (73.17%) and high specificity (92.11%). In the study by Ozmen S et al. [18], similar results were concluded and found that a cutoff >170 pg/ml of iPTH could discriminate CKD (AUC 0.66, 88% sensitivity and 89% specificity).

Similar previous studies (as previously mentioned) focused on either POCUS role in discriminating AKI and CKD or identifying the obstructive causes of AKI [34]. In this study, we extended the role of POCUS using POCUS assessment (IVC, heart, lung, abdomen and kidney assessment) with the clinical parameters to identify the causes of AKI and help reaching appropriate medical decision.

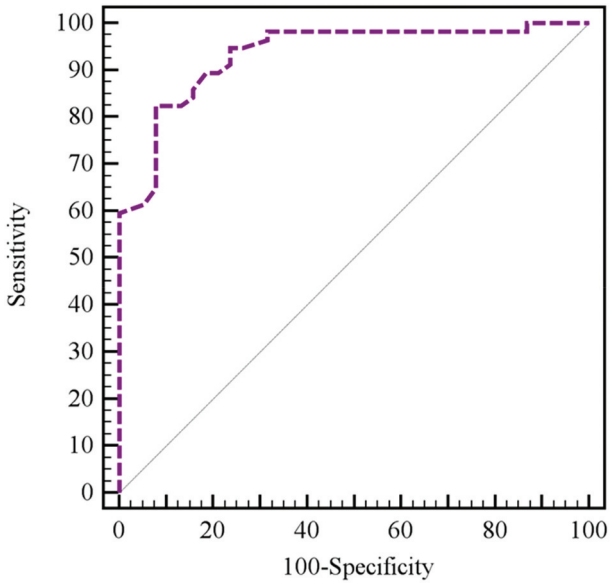

Figure 2. ROC curve for renal length to differentiate CKD from AKI, AUC 0.934 (95% CI 0.885–0.983).

Table 3. Point of care ultrasound findings in AKI patients.

POCS finding in AKI patient	Total AKI ($n = 79$)	Group 1 ($n = 38$)	Group 2 ($n = 41$)	x^2	p
-IVC					
Max. diameter (cm)					
<1.5 cm	37 (46.8%)	19 (50%)	18 (43.9%)	0.641	0.726
1.5–2 cm	20 (25.3%)	10 (26.3%)	10 (24.4%)		
>2 cm	22 (27.8%)	9 (23.7%)	13 (31.7%)		
Collapsibility index (%)					
>50%	40 (50.6%)	18 (47.4%)	22 (53.7%)	0.539	0.764
20–50%	20 (25.3%)	11 (28.9%)	9 (22%)		
<20%	19 (24.1%)	9 (23.7%)	10 (24.4%)		
Eye bullying assessment of cardiac contractility					
Left ventricle					
Normal	56 (70.9%)	26 (68.4%)	30 (73.2%)	0.216	0.642
Reduced	23 (29.1%)	12 (31.6%)	11 (26.8%)		
Hyper dynamic	10 (12.7%)	8 (21.1%)	2 (4.9%)	4.667*	$^{FE}p = 0.043$*
Cardiac tamponade	1 (1.3%)	1 (2.6%)	0 (0%)	1.093	$^{FE}p = 0.481$
Lung US					
B. lines	32 (40.5%)	17 (44.7%)	15 (36.6%)	0.544	0.461
Effusion	26 (32.9%)	12 (31.6%)	14 (34.1%)	0.059	0.808
Ascites	4 (5.1%)	1 (2.6%)	3 (7.3%)	0.901	$^{FE}p = 0.616$
Hydronephrosis	11 (13.9%)	5 (13.2%)	6 (14.6%)	0.036	0.850
Extra renal	2 (2.5%)	1 (2.6%)	1 (2.4%)	0.020	$^{FE}p = 1.000$
Intra renal	9 (11.4%)	4 (10.5%)	5 (12.2%)		

Group 1: AKI Group2: AKI on top of CKD.
Data are expressed as number (n), percentage (%).
χ^2: Chi-square test ^{FE}: Fisher Exact.
p: p value for comparing between the two studied groups
*: Statistically significant at $p \leq 0.05$.

Table 4. Causes of AKI among AKI groups; AKI and AKI on top of CKD.

	Total AKI ($n = 79$)	Group 1 ($n = 38$)	Group 2 ($n = 41$)	x^2	p
Pre-renal	**73 (92.4%)**	**35 (92.1%)**	**38 (92.7%)**	0.009	$^{FE}p = 1.000$
Hypovolemia (dehydration or others)	**72 (91.1%)**	**34 (89.5%)**	**38 (92.7%)**	0.253	0.705
Volume loss	15 (19%)	7 (18.4%)	8 (19.5%)	0.015	0.902
Decrease intake	55 (69.6%)	27 (71.1%)	28 (68.3%)	0.071	0.790
Hypoperfusion (shock)	19 (24.1%)	13 (34.2%)	6 (14.6%)	4.138*	0.042*
Vasodilatation (sepsis)	53 (67.1%)	25 (65.8%)	28 (68.3%)	0.056	0.813
Decrease cardiac function	11 (13.9%)	8 (21.1%)	3 (7.3%)	3.104	0.078
Renal	**4 (5.1%)**	**2 (5.3%)**	**2 (4.9%)**	0.006	$^{FE}p = 1.000$
Nephrotoxic drugs	2 (2.5%)	2 (5.3%)	0 (0%)	3.374	$^{MC}p = 0.0334$
Renal artery thrombosis	1 (1.3%)	0 (0%)	1 (2.4%)		
Intra renal sepsis (pyelonephritis)	1 (1.3%)	0 (0%)	1 (2.4%)		
Post-renal	**11 (13.9%)**	**5 (13.2%)**	**6 (14.6%)**	0.036	0.850
Extra renal	2 (2.5%)	1 (2.6%)	1 (2.4%)	0.020	$^{FE}p = 1.000$
Intra renal	9 (11.4%)	4 (10.5%)	5 (12.2%)		
Mixed causes	**69 (87.3%)**	**34 (89.5%)**	**35 (85.4%)**	0.301	$^{FE}p = 0.739$
Mixed pre-renal	**57 (72.2%)**	**29 (76.3%)**	**28 (68.3%)**	0.632	0.427
Hypovolemia & vasodilation (sepsis)	47 (59.5%)	22 (57.9%)	25 (61%)	0.078	0.780
Hypovolemia, vasodilation& decreased cardiac functions	6 (7.6%)	3 (7.9%)	3 (7.3%)	0.009	$^{FE}p = 1.000$
Hypovolemia & decreased cardiac function	4 (5.1%)	4 (10.5%)	0 (0%)	4.546	$^{FE}p = 0.050$
Pre- & Post-renal	**10 (13.9%)**	**5 (13.2%)**	**5 (12.1%)**	0.036	0.850
Pre-renal, renal & post-renal	**1 (1.3%)**	**0 (0%)**	**1 (2.4%)**	0.939	$^{FE}p = 1.000$

Group 1: AKI Group2: AKI on top of CKD.
Data are expressed as number (n), percentage (%).
χ^2: Chi-square test ^{FE}: Fisher Exact MC: Monte Carlo.
p: p value for comparing between the two studied groups
*: Statistically significant at $p \leq 0.05$.

In the current study, POCUS protocol was used to identify variable underlying causes of AKI in addition to the presence of multiple factors simultaneously. Pre-renal causes were the most common (92%) factors identified, and wherein 72.2% of cases, we identified the presence of more than one factor together; hypo-volemia and volume depletion were common factors present together and in more than 50% of cases accompanied by sepsis. These results agreed with Goswami et al., [35] as in that study they found that most common cause for community acquired AKI (CA AKI) in developing countries is the pre-renal causes, where volume depletion and hypo-perfusion are most underlying factors. Although the previous study stated lower percentage than us, but this may be because they had used different categorizations for the

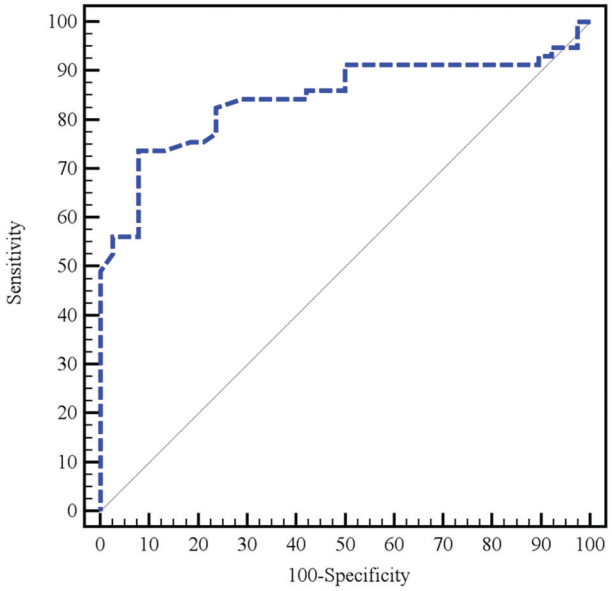

Figure 3. ROC curve for intact parathormone hormone to differentiate CKD from AKI, AUC was 0.844 (95% CI 0.764–0.925)..

etiological factors, also they did not use POCUS in the assessment and did not state clearly the existence of multifactor for AKI simultaneously. As example of the presence of pre-renal, renal and post-renal factors simultaneously in same case, where POCUS diagnosed bilateral pyelonephritis (renal cause), hydronephrosis (obstructive cause) and volume depletion (pre-renal), through IVC assessment.

Diagnosing hydronephrosis by ultrasound and the accuracy of its identification by non-radiologist has been tested [36,37]. In this study, hydronephrosis was identified in 13.9%, these results agreed with the international prevalence of post-renal AKI (10%) [38]. Nepal S [37] stated that the post-renal AKI is around 8.5%, while Goswami S [35] said that it reached 9% in the developing countries.

Diagnosing renal structural damage as a cause of AKI (renal causes) usually needs advanced investigations as renal biobsy for histopathological examination to confirm the diagnosis of acute tubular necrosis or in some situations more advanced laboratory investigation as antiglomular basment membrane or immunological assays to diagnose renal causes of AKI which not routinely performed in ED, but with ultrasound we could diagnose some causes as ischemic or infective renal causes, in all diagnosed renal cases (four cases) clear history of nephrotoxic drugs or evidence of intrarenal infection were present.

Ultrasound assessment of IVC (diameter and collapsibility) was used as surrogate for intravascular volume assessment to differentiate if patient was hypovolemic, euvolemic or overloaded [39,40]. The identification of overload helps in avoiding the fatal consequences of giving fluids (if was overloaded) for suspected AKI patient with oliguria or anuria in ED, also IVC could help as noninvasive monitoring of the fluid status to avoid over-hydration in refractory AKI. IVC assessment in addition to data obtained from the focused cardiac ultrasound assessment and lung and abdominal ultrasound examinations provided great clues for identifying the underlying factors and optimizes the medical decision.

We offered a simple POCUS approach for emergency physicians for management of AKI in ED, which is not a replacement of the comprehensive ultrasound scan or other radiological and laboratory investigations.

The present study is limited by a relatively small convenience sample size of patients where POCUS performed by single operator; therefore, inter-rater reliability of the protocol could not be tested.

6. Conclusion

According to this study, incorporating POCUS in the management of AKI in ED could add great value for patients in rapidly identifying most of AKI etiologies and reaching appropriate medical decision that could improve patients' outcomes. Both POCUS and iPTH could accurately differentiate AKI and CKD.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Availability of data and material

Data generated and/or analyzed in this study are available from the corresponding author upon reasonable request.

References

[1] Lewis D, Rang L, Kim D, et al. Recommendations for the use of point-of-care ultrasound (POCUS) by emergency physicians in Canada. Canad J Emerg Med. 2019;21(6):721–726. doi: 10.1017/cem.2019.392

[2] Lee L, DeCara JM. Point-of-care ultrasound. Curr Cardiol Rep. 2020;22(11):1–10. doi: 10.1007/s11886-020-01394-y

[3] Mateer J, Plummer D, Heller M, et al. Model curriculum for physician training in emergency ultrasonography. Anna Emerg Med. 1994;23(1):95–102. doi: 10.1016/S0196-0644(94)70014-1

[4] Physicians ACoE. Emergency ultrasound guidelines. Anna Rmerg Med. 2009;53(4):550–570. doi: 10.1016/j.annemergmed.2008.12.013

[5] Samuel AE, Chakrapani A, Moideen F. Accuracy of extended focused assessment with sonography in trauma (e-FAST) performed by emergency medicine residents in a level one tertiary center of India. Adv J Emerg Med. 2018;2(2):e15.

[6] Pelkmans L, López Matta J, Tuinman P, et al. POCUS series: assessment of shock using the rapid ultrasound in shock (RUSH) protocol. Neth J Crit Care. 2020;28 (6):231–235.
[7] Bekgoz B, Kilicaslan I, Bildik F, et al. BLUE protocol ultrasonography in Emergency Department patients presenting with acute dyspnea. Am J Emerg Med. 2019;37(11):2020–7. doi: 10.1016/j.ajem.2019.02.028
[8] Levy EM, Viscoli CM, Horwitz RI. The effect of acute renal failure on mortality: a cohort analysis. JAMA. 1996;275(19):1489–1494. doi: 10.1001/jama.1996.03530430033035
[9] Hoste EA, Clermont G, Kersten A, et al. RIFLE criteria for acute kidney injury are associated with hospital mortality in critically ill patients: a cohort analysis. Crit Care. 2006;10(3):1–10. doi: 10.1186/cc4915
[10] Bucaloiu ID, Kirchner HL, Norfolk ER, et al. Increased risk of death and de novo chronic kidney disease following reversible acute kidney injury. Kidney Int. 2012;81(5):477–485. doi: 10.1038/ki.2011.405
[11] Prakash J, Singh TB, Ghosh B, et al. Changing epidemiology of community-acquired acute kidney injury in developing countries: analysis of 2405 cases in 26 years from eastern India. Clin Kidney J. 2013;6 (2):150–5. doi: 10.1093/ckj/sfs178
[12] Case J, Khan S, Khalid R, et al. Epidemiology of acute kidney injury in the intensive care unit. Crit Care Res Pract. 2013;2013:1–9. doi: 10.1155/2013/479730
[13] Uchino S. Acute renal failure in critically ill patientsa multinational, multicenter study. JAMA. 2005;294 (7):813–818. doi: 10.1001/jama.294.7.813
[14] ERBP: a-hwgo, Fliser D, Laville M. A European renal best practice (ERBP) position statement on the kidney disease improving global outcomes (KDIGO) clinical practice guidelines on acute kidney injury: part 1: definitions, conservative management and contrast-induced nephropathy. Nephrol Dial Transplant. 2012;27(12):4263–4272.
[15] Kellum JA, Lameire N, Aspelin P, et al. Kidney disease: improving global outcomes (KDIGO) acute kidney injury work group. KDIGO clinical practice guideline for acute kidney injury. Kidney Int Suppl. 2012;2 (1):1–138.
[16] Massry SG, Coburn JW, Chertow GM, et al. K/DOQI clinical practice guidelines for bone metabolism and disease in chronic kidney disease. Am J Kidney Dis. 2003;42(4):i–S201.
[17] Arenas MD, Alvarez-Ude F, Gil MT, et al. Implementation of 'K/DOQI clinical practice guidelines for bone metabolism and disease in chronic kidney disease'after the introduction of cinacalcet in a population of patients on chronic haemodialysis. Nephrol Dial Transplant. 2007;22(6):1639–1644. doi: 10.1093/ndt/gfl840
[18] Ozmen S, Danis R, Akin D, et al. Parathyroid hormone as a marker for the differential diagnosis of acute and chronic renal failure. Ren Fail. 2007;29(4):509–12. doi: 10.1080/08860220701275006
[19] Cavayero C, Kar S, Kar P. Blast from the past-using PTH to differentiate acute versus chronic kidney disease. J Nephrol Ther. 2014;5:1–4.
[20] Ozmen C, Akin D, Bilek S, et al. Ultrasound as a diagnostic tool to differentiate acute from chronic renal failure. Clin Nephrol. 2010;74(1):46–52.
[21] Manley JA, O'Neill WC. How echogenic is echogenic? Quantitative acoustics of the renal cortex. Am J Kidney Dis. 2001;37(4):706–11. doi: 10.1016/S0272-6386(01)80118-9
[22] Gudmundsson P, Rydberg E, Winter R, et al. Visually estimated left ventricular ejection fraction by echocardiography is closely correlated with formal quantitative methods. Int J Cardiol. 2005;101(2):209–12. doi: 10.1016/j.ijcard.2004.03.027
[23] Members ATF, Torbicki A, Perrier A, et al. Guidelines on the diagnosis and management of acute pulmonary embolism: the task force for the diagnosis and management of acute pulmonary embolism of the european society of cardiology (ESC). Eur Heart J. 2008;29(18):2276–2315. doi: 10.1093/eurheartj/ehn310
[24] Stawicki SP, Braslow BM, Panebianco NL, et al. Intensivist use of hand-carried ultrasonography to measure IVC collapsibility in estimating intravascular volume status: correlations with CVP. J Am Coll Surg. 2009;209(1):55–61. doi: 10.1016/j.jamcollsurg.2009.02.062
[25] Furtado S, Reis L. Inferior vena cava evaluation in fluid therapy decision making in intensive care: practical implications. Rev Bras Ter Intensiva. 2019;31 (2):240–247. doi: 10.5935/0103-507X.20190039
[26] Allgöwer M, Burri C. Schockindex. Dtsch Med Wochenschr. 1967;92(43):1947–1950. doi: 10.1055/s-0028-1106070
[27] Gargani L, Palazzuoli A. POCUS in Diagnosis: Acute Heart Failure. In: Cardiopulmonary point of care. Ultrasound: Springer; 2023. pp. 79–92.
[28] Lichtenstein DA, Meziere GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure*: the BLUE protocol. Chest. 2008;134(1):117–25. doi: 10.1378/chest.07-2800
[29] Alshoabi SA. Association between grades of Hydronephrosis and detection of urinary stones by ultrasound imaging. Pak J Med Sci. 2018;34 (4):955–958. doi: 10.12669/pjms.344.14602
[30] Lwanga SK, Lemeshow S. World Health Organization (WHO). In: Sample size determination in health studies: a practical manual. Geneva: WHO; 1991.
[31] O'Neill WC. Sonographic evaluation of renal failure. Am J Kidney Dis. 2000;35(6):1021–38. doi: 10.1016/S0272-6386(00)70036-9
[32] Cunningham J, Locatelli F, Rodriguez M. Secondary hyperparathyroidism: pathogenesis, disease progression, and therapeutic options. Clin J Am Soc Nephrol. 2011;6(4):913–21. doi: 10.2215/CJN.06040710
[33] Zhang M, Hsu R, C-Y H, et al. FGF-23 and PTH levels in patients with acute kidney injury: a cross-sectional case series study. Ann Intensive Care. 2011;1(1):21. doi: 10.1186/2110-5820-1-21
[34] Raviv B, Israelit SH. Renal ultrasonography in the Evaluation of Acute Kidney Injury in the emergency department. Am J Clin Med Res. 2014;2(5):103–105. doi: 10.12691/ajcmr-2-5-3
[35] Goswami S, Raju BM, Purohit A, et al. Clinical spectrum of community-acquired acute kidney injury:

a prospective study from central India. Saudi J Kidney Dis Transpl. 2020;31(1):224–34. doi: 10.4103/1319-2442.279945

[36] Javaudin F, Mounier F, Pes P, et al. Evaluation of a short formation on the performance of point-of-care renal ultrasound performed by physicians without previous ultrasound skills: prospective observational study. Crit Ultrasound J. 2017;9(1):1–4. doi: 10.1186/s13089-017-0078-8

[37] Nepal S, Dachsel M, Smallwood N. Point-of-care ultrasound rapidly and reliably diagnoses renal tract obstruction in patients admitted with acute kidney injury. Clin Med. 2020;20(6):541. doi: 10.7861/clinmed.2019-0417

[38] Team NGU. Acute kidney injury: prevention, detection and management. UK: National Institute for Health and Care Excellence (UK); 2019.

[39] Allgöwer M, Burri C. Schockindex. DMW-Dtsch Med Wochenschr. 1967;92(43):1947–1950.

[40] Jassim HM, Naushad VA, Khatib MY, et al. IJV collapsibility index vs IVC collapsibility index by point of care ultrasound for estimation of CVP: a comparative study with direct estimation of cVP. Open Access Emerg Med. 2019;Volume 11:65–75. doi: 10.2147/OAEM.S176175