The Egyptian Journal of Hospital Medicine (July 2022) Vol. 88, Page 2661-2667

Role of Renal Doppler Ultrasound in Early Detection of Acute Kidney Injury in Critically Ill Patients

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ABSTRACT

Background: Acute kidney injury is a potentially fatal condition with high mortality rate, treatment cost and poor outcome. The most crucial end-point in forecasting AKI is monitoring microcirculation parameters. Renal resistive index has been proposed as a new tool in intensive care unit (ICU) patient's microcirculation monitoring.

Objective: The research study aimed to determine if there is a relation between change in renal resistive index (RRI) and acute kidney injury (AKI) in the first week of ICU admission.

Patients and Methods: This was an observational prospective study of ICU patients. All participants underwent history taking, clinical examination with calculation of sequential organ failure assessment (SOFA) and acute physiology and chronic health evaluation (APACHE II) score. RRI was calculated using Doppler ultrasound with the following formula: (peak systolic velocity – end diastolic velocity)/ peak systolic velocity.

Results: Patients with AKI had significantly higher peak-systolic velocity, end-diastolic velocity and renal resistive index (P< 0.001). Patients with stage III AKI had significant higher RRI in comparison with stage I and stage II (p value < 0.001). RRI had 75% sensitivity, 87% specificity for prediction of stage II and III AKI with over all accuracy was 83%.

Conclusions: Assessment of RRI in the first 24 hours of ICU admissions was valuable in predicting the development of AKI especially in the stage II, III and persistent AKI. It is recommended to evaluate it early to prevent AKI development in ICU patients.

Keywords: Renal resistive index, Acute kidney injury, Intensive care unit, APACHE, SOFA.

INTRODUCTION

Acute kidney injury is a complex of functional renal disorders, presents with an abrupt loss of kidney function, which is detected by an elevated serum creatinine level and decreased urinary output that is limited to 7 days [(1)]. Incidence of AKI in the ICU ranges from 5.7% to 67%. The length of hospital stays, as well as the expense of treatment, has increased in recent years as a result of the large increase in complications and mortality[(2)]. Old age, acute infections, sepsis, severe trauma, hypovolemia, major surgeries, preexisting CKD, urinary tract obstruction, acute organ failure, nephrotoxic drugs administration, chemotherapy, graft rejection, and autoimmune disorders with rapid progressive kidney injury are all important risk factors for AKI [(3)]. Both functional impairments (elevated serum creatinine and/or decreased urine output) and the presence of biomarkers suggesting renal structural damage are linked to a three- to seven-fold increase in hospital mortality [(3)]. AKI is potentially fatal. As a result, meticulous treatment, including, if necessary, kidney replacement therapy, is required [(1)].

Evidence is growing that the impact of AKI goes beyond the acute phase, with progression to CKD, increased cardiovascular consequences, repeated AKI events, and death [(4)].

Hemodynamic and fluid status stabilization, as well as avoidance of nephrotoxic drugs, are used to prevent AKI development [(5)]. A spike in serum creatinine and/or a decrease in urine output are used to diagnose AKI. Serum creatinine, on the other hand, has been shown in studies to be a poor predictor of acute changes in renal function, and it fluctuates greatly depending on sex, age, muscle mass, diet, medicines, and hydration state. Furthermore, serum creatinine is a reflection of the glomerular filtration rate (GFR) rather than a direct indicator of renal tubular damage [(6)]. Furthermore, serum creatinine rise occurs many hours after renal damage and only when the GFR is significantly lowered. As a result, AKI stage III is frequently diagnosed within 12 to 24 hours, and patients with this stage of AKI have consistently bad prognosis. As a result, an indication that may predict AKI stage III within 6 hours after admission can assist patients in receiving proper medical care and achieving better results [(7)].

Because renal artery vasoconstriction is an early indicator of AKI, monitoring microcirculatory measures may be the most essential end-point for predicting AKI and optimising therapy, because microcirculatory dysfunction may continue despite improvements in macrocirculatory parameters [(8)]. Renal resistive index is a noninvasive ultrasonographic Doppler measure of blood flow velocity in intra-parenchymal renal arteries that can be used to predict renal failure [(9)]. It represents the relationship between the apex of systole and the end of diastole in renal vessels and the drop in flow velocity. Its value is computed using this formula = peak systolic velocity – end-diastolic velocity)/ peak-systolic velocity. Normal values are reported between 0.60 and 0.70 with the difference between both kidneys being mostly less than 5% [(10)].

We aimed to evaluate the reliability of RRI in predicting AKI development in the ICU patients in the

Received: 06/01/2022
Accepted: 06/03/2022

first week of admission and its correlation with AKI stages' severity and AKI persistency.

PATIENTS AND METHODS

This observational prospective study included ICU patients admitted during the period from February 2019 to August 2020 in Critical Care Units of Assiut University Hospital and Internal Medicine Department. 350 patients were recruited and screened where 240 patients were excluded due to: e GFR < 30 ml/min/m^2 (n=124), on dialysis (n=50), poor abdominal echogenicity (n=43), renal tumors (n=1), pregnancy (n=10), nephrectomy (n=5), patients' refusal (n=5) and renal artery stenosis (n=2).

All of the selected 110 patients underwent history taking, general examination (Glasgow Coma Scale, arterial blood pressure, pulse, mean arterial pressure (indicator of tissue perfusion) = 1/3SBP + 2/3 DBP) [(11)], respiratory rate, temperature, urine output, central venous pressure and oxygen saturation) and detailed systematic examination. SOFA and APACHE II scores were assessed to evaluate the severity of disease of each patient at inclusion in the study and the need for vasopressor drugs were documented.

The Kidney Disease Improving Global Outcome (KDIGO) classification system was used to categorize AKI into stages I, II, and III. The reversibility of AKI was classified as either temporary or permanent. Transient AKI was classified as AKI that cleared up within 3 days of being admitted utilizing standard ICU therapy. In the absence of diuretics, recovery from AKI was defined as a 50% drop in S Cr or normalization of urine output, or both. For at least 3 days, chronic AKI was defined as persistent high S Cr or oliguria (less than 0.5 mL/kg per hour) [(12)]. Each patient included in the study was evaluated using Doppler abdominal ultrasound for both renal arteries within the first 24 hours of ICU admission just after hemodynamic stabilization. Renal resistive index was measured using a trans-parietal 5MHz pulsed-wave Doppler probe. The same operator performed RRI measurements daily until the third day of admission, death, or renal replacement therapy requirement which ever occurred first.

Inclusion criteria:

1. Patients > 18 years, admitted in ICU within 24 hours.
2. Acute ischemic insults (cerebrovascular stroke, myocardial angina and infarction)
3. Shock (persistent hypotension required vasopressor therapy after adequate fluid resuscitation in the presence of perfusion abnormalities, manifested by poor peripheral perfusion, organ dysfunction or lactate > 2 mmol/L) [(13)].
4. Sepsis (proven or suspected infection with persistent hypotension, requiring vasopressor therapy despite adequate fluid resuscitation) [(14)].
5. Respiratory failure, coagulation or hemorrhagic disorders, liver diseases and chronic kidney diseases (eGFR < 60 mL/min per 1.73 m^2& > 30 mL/min per 1.73 m^2).

Exclusion criteria:

1. Patients with end stage renal disease or renal replacement therapy as they had high RRI.
2. Patients with body mass index (BMI) > 40 kg/m^2
3. Pregnancy.
4. Tense ascites due to poor abdominal echogenicity.
5. Known renal artery stenosis.
6. Patients continued on vasopressor therapy.

Ethics approval:

There was no risk during the application of the research. Privacy and confidentiality were maintained during all stages of assessment. Every patient subjected to this study was informed about the results of the research. The work was approved by Ethical Committee of Faculty of Medicine of Assiut University on number (17100733) and clinical trial approval (NCT03902483). Informed and written consent were obtained from all participants according to the declaration of Helsinki. Refusal would not affect medical services which are usually offered.

Statistical analysis

Data were collected and analyzed using SPSS (Statistical Package for the Social Science, version 20, IBM, and Armonk, New York). Continuous data were expressed in form of mean ± SD while nominal data were expressed in form of frequency (percentage). Chi^2-test was used to compare the nominal data of different groups in the study while student t-test was used to compare mean of different two groups and ANOVA test for more than two groups. Multivariate regression analysis was used to determine the independent risk factors for prediction of AKI in critical ill patients. ROC curve was used to determine the diagnostic accuracy of different predictors for prediction of AKI in critical ill patients in ICU. Level of confidence was kept at 95%, and p value was significant if ≤ 0.05.

RESULTS

Baseline data of enrolled patients (Table 1):

110 patients were enrolled in the analysis out of them 53 (48.2%) patients developed AKI and 57 (51.8%) didn't. Out of those with AKI 17/53 (32%), 26/53 (49%) and 10/53 (19%) patients had stage I, II, and III AKI respectively. 30 (56.6%) patients from those with AKI group had persistent AKI while 23 (43.4%) patients had transient AKI.

AKI group had significantly higher baseline bilirubin, creatinine, urea, leucocytic count, AST, ALT and micro-albuminuria but urine output and estimated glomerular filtration rate were significantly higher in patients with non-AKI. Those with AKI had significantly higher APACHE II and SOFA scores in comparison with those with non-AKI. Other clinical and baseline laboratory data showed non-significant differences between both groups ($P > 0.05$).

Significantly higher peak-systolic velocity (115.41 ± 24.30 vs. 92.96 ± 22.06 m/sec; $P < 0.001$), end-diastolic velocity (25.47 ± 4.65 vs. 23.38 ± 5.72 m/sec; $P < 0.001$) and resistive index (0.74 ± 0.10 vs. 0.62 ± 0.08; $P < 0.001$) were detected in AKI patients in comparison to those with non-AKI.

Table (1): Baseline clinical, laboratory and radiological data of enrolled patients

Parameter	Non-AKI(n=57)	AKI (n= 53)	P value
Age (years) Age group < 60 years ≥ 60 years	 44.96 ± 15.1 40(70.2%) 17(29.8%)	 54 ±12.21 22(41.5%) 31(58.5%)	 **<0.001** **0.04**
Sex Male Female	 34(59.6%) 23(40.4%)	 30(56.6%) 23(43.4%)	 0.44
BMI (kg/m^2)	23.92 ± 3.9	23.11 ± 3.21	0.22
Heart rate(beat/minute)	106.63 ±18.90	108.26 ± 19.59	0.16
Respiratory rate (c/m)	29.70 ± 6.08	27.75 ± 8.33	0.65
Mean arterial pressure(mmHg)	90.76 ± 6.36	89.62 ± 6.46	0.35
Hemoglobin (g/dl)	10.57 ± 2.10	10.81 ± 1.81	0.51
Leucocytes (x10^3/ ml)	6.37 ± 1.27	9.63 ± 2.71	**<0.001**
Platelets (x10^3/ml)	305.28±9.15	276.72 ±7.54	0.08
Bilirubin (mg/dl)	0.81 ± 0.20	1.09 ± 0.26	**0.01**
Aspartate transaminase(U/L)	30.90 ± 1.41	61.48 ± 2.41	**<0.001**
Alanine transaminase(U/L)	39.36 ± 7.55	66.31 ± 9.91	**<0.001**
Albumin (mg/dl)	3.76 ± 0.49	3.75 ± 0.39	0.86
C-reactive protein(mg/dl)	17.71 ± 4.73	23.24 ± 3.50	0.29
Random blood sugar (mg/dl)	106.37±7.74	97.94 ± 7.88	0.14
Urea (mg/dl)	4.96 ± 1.38	7.43 ± 1.44	**0.03**
Creatinine (mg/dl)	1.04 ± 0.12	1.71 ± 0.13	**<0.001**
Microalbuminuria(mg/l)	14.33 ± 1.79	17.09 ± 4.77	**<0.001**
Urinary output(ml/day)	1095.33±5202	543.56±134.56	**0.04**
eGFR (ml/min/m^2)	91.52 ± 28.41	48.56 ± 9.54	**<0.001**
APACHE-II score	14.30 ± 4.78	23.22 ± 5.21	**<0.001**
SOFA score	2.89 ± 0.99	5.01 ± 1.82	**<0.001**
Peak-systolic velocity (m/sec)	92.96 ± 22.06	115.41 ±24.30	**<0.001**
End-diastolic velocity (m/sec)	23.38 ± 5.72	25.47 ± 4.65	**<0.001**
Resistive index	0.62 ± 0.08	0.74 ± 0.10	**<0.001**
Need to mechanical ventilation	7 (12.3%)	5 (9.4%)	0.31
Hospital stays (day)	3.88 ± 0.75	6.55 ± 3.74	**<0.001**
Outcome Alive Died	 54 (94.7%) 3 (5.3%)	 39 (73.6%) 14 (26.4%)	 **<0.001**

Clinical and Doppler ultrasound data in patients with AKI based on its reversibility (Table 2):

Patients with persistent AKI had significantly higher age, random blood sugar, and micro-albuminuria and significantly lower eGFR in comparison with those with transient AKI. Also, patients with persistent AKI had significantly higher peak-systolic velocity (123.61 ± 24.43 vs. 109.13 ± 22.63 (mL/sec); P= 0.03), end-diastolic volume (27.43 ± 5.09 vs. 23.97 ±3.69 (mL/sec); P< 0.001), and RRI (0.81 ± 0.06 vs. 0.66 ± 0.08; P< 0.001).

Table (2): Clinical and Doppler ultrasound data in patients with AKI based on its reversibility

	Transient AKI (n= 23)	**persistent AKI (n= 30)**	**P value**
Age	45.60 ±18.36	60.43 ±15.49	**<0.001**
Random blood sugar(mg/ dl)	91.54 ±13.49	102.85 ±19.43	0.02
Microalbuminuria (mg/l)	14.01 ±3.44	19.45 ± 4.31	<0.001
eGFR (ml/min/m^2)	52.71 ±10.27	50.14 ±9.21	0.03
APACHE-II score	21.83 ±5.17	24.28 ±5.07	0.08
SOFA score	5 ± 2.13	5.03 ± 1.58	0.94
Peak systolic velocity (m/sec)	109.13 ±22.63	123.61 ±24.43	**0.03**
End diastolic velocity(m/sec)	23.97 ± 3.69	27.43 ± 5.09	**<0.001**
Resistive index	0.66 ± 0.08	0.81 ± 0.06	**<0.001**

Predictors of acute kidney injury in the study (Table 3): Based on the current study, the predictors of AKI patients were sepsis, APACHE-II score, SOFA score and resistive index. While Age (> 60 years), chronic kidney disease, nephrotoxic drug, liver cell failure and heart failure were not significant as predictors of AKI development.

Table (3): Predictors of acute kidney injury in the current study

Predictors	**Odd's ratio**	**95% confidence interval**	**P value**
Age (> 60 years)	1.59	0.15-2.95	0.69
Chronic kidney disease	1.33	0.06-2.63	0.49
Nephrotoxic drug	1.02	0.03-1.67	0.33
Liver cell failure	1.83	1.23-2.84	0.61
Heart failure	1.32	0.99-2.34	0.76
Sepsis	**1.08**	**1.01-2.10**	**0.04**
APACHE-II score	**1.22**	**1.19-2.46**	**<0.001**
SOFA score	**1.50**	**1.34-2.01**	**<0.001**
Resistive index	**1.70**	**1.45-2.86**	**<0.001**

Accuracy of different predictors for detection of acute kidney injury (Table 4):

At cut-off point > 0.72, RRI had 86% sensitivity, 72% specificity for predicition of AKI with over all accuracy of 79% and area under curve of 0.91. At cut-off point > 3, SOFA score had 77.4% sensitivity, 77.2% specificity for predicition of AKI with over all accuracy of 73.6% and area under curve of 0.83. At cut-off point >17, APACHE-II score had 74% sensitivity, 39% specificity for predicition of AKI with over all accuracy of 57% and area under curve of 0.57.

Table (4): Accuracy of different predictors for detection of acute kidney injury

	Resistive index	**SOFA**	**APACHE-II**
Sensitivity	86%	77.4%	74%
Specificity	72%	77.2%	39%
Positive predictive value	83%	76%	53%
Negative predictive value	77%	79%	61%
Cut-off point	> 0.72	> 3	> 17
Accuracy	79%	73.6%	57%
Area under curve(AUC)	0.91	0.83	0.57
P value	< 0.001	< 0.001	< 0.001

Renal resistive index among studied patients based on the stage of AKI (Table 5):

RRI had no significant difference between patients with stage I AKI and those with non-AKI (0.62 ± 0.09 vs. 0.62 ± 0.08; P= 0.82). Patients with stage III AKI had significant higher RRI (0.86 ± 0.05) in comparison with other groups of patients.

Table (5): Renal resistive index among studied patients based on stage of AKI

Stage of AKI	Resistive index
No-AKI (n= 57)	0.62 ± 0.08
Stage I (n= 17)	0.62 ± 0.09
Stage II (n= 26)	0.77 ± 0.05
Stage III (n= 10)	0.86 ± 0.05
Significance	
P1	0.82
P2	< 0.001
P3	< 0.001
P4	< 0.001
P5	< 0.0001
P6	< 0.001

P1 compares between no-AKI and stage I-AKI; P2 compares between no-AKI and stage II-AKI; P3 compares between no-AKI and stage III-AKI; P4 compares between stage I and II-AKI; P5 compares between stage I and III-AKI; P6 compares between stage II and III-AKI**.**

Correlation of resistive index with other parameters in the study (Table 6): Age, mean arterial blood pressure and blood urea had no significant correlation with the RRI. While, serum creatinine had significant positive correlation with RRI, and glomerular filtration rate had significant negative correlation with RRI.

Table (6): Correlation of resistive index with other parameters in the study

	r value	P value
Age	0.17	0.12
Mean arterial blood pressure	-0.08	0.37
Blood urea	0.19	0.37
Serum creatinine	0.32	**0.01**
Glomerular filtertaion rate	-0.41	**< 0.001**

Accuracy of resistive index for persistence of AKI (Table 7): At cut-off point > 0.69, RRI had 100% sensitivity, 74% specificity for predicition of persistence of AKI with over all accuracy of 88.7% and area under curve of 0.89.

Table (7): Accuracy of resistive index for persistance of AKI

	Resistive index
Sensitivity	100%
Specificity	74%
Positive predictive value	83%
Negativ predictive value	100%
Cut-off point	> 0.69
Accuracy	88.7%
Area under curve	0.89
P value	< 0.001

DISCUSSION

After application of inclusion and exclusion criteria, 110 patients were enrolled in the analysis; out of them 53 patients (48.2%) developed AKI in the first week based on KIDGO criteria and 57 (51.8%) didn't develop. Out of patients with AKI, 17/53 (32%) were classified as stage I, 26/53 (49%) were stage II and 10/53 (19%) were stage III. These values are in concordance with **Mulier *et al.*** [10] study, who found that 49% of patients developed AKI, 32.6% of whom were stage I AKI, 53%were in stage II and 14% were in stage III AKI.

The base line data of routine investigations as bilirubin level, AST and ALT were significantly higher in patients with AKI compared to non-AKI group. This could be referred to hepatic injury associated with sepsis or the already presented hepatic affection more in the AKI group as liver cell failure present in 15.1% of AKI group compared to 1.8% of non-AKI group (P = 0.01).

Patients with persistent AKI had significantly higher micro-albuminuria (mg/l) and lower eGFR than transient AKI group (P < 0.001 and P= 0.03 respectively). This finding could be explained by **Zhang *et al.*** [15] who stated that under pathologic conditions, inflammatory insults lead to an increase in glomerular permeability to albumin and a reduction in tubular reabsorption, which consequently contributes to micro-albuminuria development. They hypothesized that micro-albuminuria occurred early after inflammatory renal insult so the detection of it would predict the development of AKI in septic patients.

Patients with AKI had significantly higher APACHE II and SOFA scores compared to non-AKI (P < 0.001). This is in concordance with **Mulier *et al.*** [10] stud**y** in which APACHE II score was significantly higher in AKI compared to non-AKI (P value= 0.003). **Uhel *et al.*** [16] found that SOFA score was variable between non-AKI, transient and persistent groups with significant higher level was associated with the persistent AKI (p < 0.001). Also, **dos Santos *et al.*** [17] found that AKI patients had significant higher APACHE II and SOFA scores compared to non-AKI (p < 0.001).

Other clinical and baseline laboratory data as heart rate, respiratory rate, diastolic blood pressure, systolic blood pressure, mean arterial pressure, hemoglobin, random blood sugar, albumin, C-reactive protein and electrolytes level showed non-significant differences between both groups. This is in agreement with **Darmon *et al.*** [18] who found no significance of heart rate, systolic arterial pressure, mean arterial pressure and SaO2 (p = 0.22, 0.84, 0.18 and 0.89 respectively) between both AKI and non -AKI groups. However, **dos Santos *et al.*** [17] found significant difference as regards these clinical parameters between AKI and non-AKI group with heart rate (p = 0.006), respiratory rate (p = 0.011), body temperature (p = 0.029), systolic arterial pressure (p = 0.002), diastolic

arterial pressure (p = 0.060) and mean arterial pressure (p = 0.008).

The development of acute kidney injury in critically ill patients was associated with increased incidence of mortality where 26.4% of patients with AKI died versus 5.3% of patients with non-AKI (P < 0.001). In **Oliveira *et al.*** [19] study, total studied patients' number were 83, the ICU mortality was 4/21 (19%) in non-AKI group, 5/25 (20%) in transient AKI and 14/37 (38%) in the persistent AKI group. **Hoste *et al.*** [20] mentioned that AKI mortality was strictly associated with AKI severity independently of the classification used.

It was noticed that patients with AKI had significantly higher peak-systolic velocity (115.41 ± 24.30 vs. 92.96 ± 22.06 m/sec in non-AKI; P< 0.001), end-diastolic velocity (25.47 ± 4.65 vs. 23.38 ± 5.72 m/sec in non-AKI; P< 0.001) and renal resistive index (0.74 ± 0.10 vs. 0.62 ± 0.08 in non-AKI; P< 0.001). Also, patients with persistent AKI had significantly higher peak-systolic velocity (123.61 ± 24.43 vs. 109.13 ± 22.63 m/sec; P= 0.03), end-diastolic velocity (27.43 ± 5.09 vs. 23.97 ± 3.69 (m/sec); P< 0.001), and RRI (0.81 ± 0.06 vs. 0.66 ± 0.08; P< 0.001) in comparison with transient AKI group). These results are in concordance with **Dewitte *et al.*** [12], where RRI was 0.76 in patients with AKI and 0.72 in non-AKI patients (P = 0.001), **Oliveira *et al.*** [19] who found that RRI values were 0.64 ± 0.06 in non-AKI, 0.64 ± 0.07 in transient AKI and 0.70 ± 0.08 in persistent AKI groups (p < 0.01) with mild difference between value of non-AKI and transient group and significantly higher RRI in patients with persistent AKI than in the other groups. This association between acute kidney injury and RRI suggested a pathophysiological reasoning, reflecting renal structural alterations in the tubule-interstitial and vascular compartments and consequent increases in renal impedance values [21]. It was believed that the transient AKI was due to reversible and non-structural functional abnormality. So, mild difference observed between RRI values in patients with non-AKI and transient AKI patients was explained with this pathophysiological finding [19].

We found that RRI had no significant difference between patients with stage I AKI (0.62 ± 0.09) and those with non-AKI (0.62 ± 0.08) with P value = 0.82. Patients with stage III AKI had significant higher RRI (0.86 ± 0.05) in comparison with stage I (P < 0.0001), and stage II (0.77 ± 0.05) with p < 0.001. These results are in concordance with **Mulier *et al.*** [10] who found that RRI was significantly higher in patients developed AKI stage II (RRI = 0.72) and stage III (RRI = 0.74) than in patients with non-AKI where RRI was 0.65 (p value = 0.001 and 0.006 respectively).

The AUC of RRI to predict AKI stage II or III was 0.72 and for AKI stage III was 0.74 and the optimal cutoff point of RRI for discrimination of AKI stage II and III was 0.74, with a sensitivity and specificity of 53% and 87% respectively. **Renberg *et al.*** [9] recruited their study in ICU patient and found that RRI was higher in patients with AKI stage III (0.83; p = 0.006), but not in patients with AKI stage I (0.76; p = 0.347) or AKI stage II (0.79; p = 0.134).

Regarding the correlation between RRI and the clinical data as age, mean arterial pressure and blood urea, we found no significant correlation between them (P = 0.12, 0.37 and 0.37 respectively). But, it had negative high significant correlation with glomerular filtration rate (r=-0.41, P< 0.001) and positive correlation with creatinine level p = 0.01). This is in concordance with **Garnier *et al.*** [22] who found that RRI was not correlated with either age or mean arterial pressure (P = 0.23 and 0.16 respectively). This disagrees with **Oliveria *et al.*** [19] who found that age, mean arterial pressure and presence of persistent AKI were associated with higher RRI. He explained this association with vascular changes due to loss of large vessel compliance, so that in some studies, aging was associated with vascular changes, and decreased renal vascular compliance that affected RRI value [23].

The predictors of AKI in such patients were RRI (P < 0.001), SOFA score (P < 0.001), APACHE-II scores (P< 0.001) and at the last sepsis (P= 0.04). This agrees with **Mulier *et al.*** [10] who found that the predictors for the AKI were RRI (P = 0.043) and APACHE score (P = 0.013). **dos Santos *et al.*** [17] found that the predictors of AKI at ICU admission included hypertension (P=0.017), high serum creatinine concentration (p<0.001), low serum albumin concentration (p=0.015) and high APACHE II score (p< 0.001).

As regards the predictors of persistent AKI, age > 60 years (P< 0.001) and resistive index (P< 0.001). This is in concordance with **Zhang *et al.*** [15] who reported that age and albumin creatinine ratio were the predictors of AKI development with positive significant correlation between the age and AKI development (p =0.04) and albumin creatinine ratio and AKI (p < 0.01) but no detected correlation between AKI and APACHE II (p= 0.36).

At cut-off point > 0.75, RRI had 75% sensitivity, 87% specificity for prediction of stage II and III AKI with over all accuracy of 83% and area under curve of 0.88. At cut-off point > 4, SOFA score had 83% sensitivity and 68% specificity for prediction of stage II and III AKI with over all accuracy of 73% and area under curve was 0.83. As regards persistent AKI, our study showed that at cut-off point > 0.69, RRI had 100% sensitivity, 74% specificity for prediction of AKI persistence with over all accuracy of 88.7% and area under curve of 0.89. In **Matthieu *et al.*** [24] the performance of RRI was better for diagnosing persistent AKI and the RRI predicted AKI with high sensitivity of 85% and specificity of 94%. In **Garnier *et al.*** [22], area under the curve of RRI to predict persistent AKI was 0.93 and RRI > 0.685 had sensitivity of 78% and specificity of 90%.

CONCLUSIONS AND RECOMMENDATION

The RRI has been used as a bedside tool in critically ill patients. It is a non-invasive, rapid and repeatable technique, allows renal hemodynamics assessment and evaluation through flow velocity analysis of the renal arterioles obtained by pulsed Doppler ultrasonography. Assessment of RRI early in the first 24 hours of ICU admissions is valuable in predicting the development of AKI especially in the stage II, III and persistent AKI with high sensitivity.

Conflict of interest: The authors declared no conflict of interest.

Sources of funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contribution: Authors contributed equally in the study.

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