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ORIGINAL

Early prediction of acute kidney injury in neurocritical patients: relevance of renal resistance index and intrarenal venous Doppler as diagnostic tools

Predicción temprana de lesión renal aguda en pacientes neurocríticos: relevancia del índice de resistencia renal y del Doppler Venoso Intrarenal como herramientas de diagnóstico

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ABSTRACT

Introduction: the implementation of renal POCUS in critical care is a valuable tool that complements the physical examination of critically ill patients. It is non-invasive, accessible, harmless, and inexpensive, allowing renal perfusion to be evaluated at the bedside of patients through ultrasound measurements such as the renal resistance index (RRI) and intrarenal venous Doppler (IVD), which are considered early predictors of acute kidney injury (AKI).
Objective: to determine the relationship between the renal resistance index (RRI) and the degree of AKI according to KDIGO in neurocritical patients, and to correlate intrarenal venous Doppler (IVD) flow abnormalities with the degree of AKI according to KDIGO.
Methods: an observational, analytical, prospective, and longitudinal study was conducted in a neurocritical patient ICU with 43 participants. RRI and IVD measurements were performed at admission, 72 hours, and 7 days. The study evaluated which parameter better predicts AKI according to KDIGO.
Results: in the study of 43 critically ill patients, the correlation results between RRI value and AKI according to KDIGO were not significant. On the other hand, the correlation between intrarenal venous Doppler (IVD) at admission, 72 hours, and 7 days with AKI according to KDIGO was significa nt with a value of r: 43=0,95 (P=0,54); 0,49 (P=0,001); 0,58(P=0,000). Analyzing by classification tree, it was determined that the variables that best predict the risk of developing AKI before it occurs are intrarenal venous Doppler (IVD) measurement at 7 days and the cumulative fluid balance value.
Conclusions: there is a positive and significant correlation between intrarenal venous Doppler (IVD) and AKI. Intrarenal venous Doppler (IVD) and cumulative fluid balance predict the risk of developing AKI in critically ill patients. On the other hand, renal resistance index was not related to AKI in the studied population.

Keywords: Renal Resistance Index; Decision Making; POCUS; Point-of-care Ultrasound; Intensive Care; Neurocritical; VexUS.

RESUMEN

Introducción: la implementación del POCUS renal en cuidados críticos es una herramienta valiosa que

complementa el examen físico de los pacientes críticos. Al ser no invasiva, accesible, inocua y económica, permite evaluar al pie de la cama de los pacientes la perfusión renal a través de mediciones ecográficas como el índice de resistencia renal (IRR) y el doppler venoso intrarenal (DVIR), los cuales son considerados predictores tempranos de lesión renal aguda.
Objetivos: determinar la relación entre el índice de resistencia renal (IRR) y el grado de lesión renal aguda según KDIGO en pacientes neurocríticos. Correlacionar las alteraciones del flujo doppler venoso intrarrenal (DVIR) con el grado de lesión renal aguda según KDIGO.
Métodos: se realizó un estudio de tipo observacional, analítico, prospectivo y longitudinal en una UCI con afluencia de pacientes neurocríticos. Participaron 43 pacientes a quienes se les realizaron mediciones del índice de resistencia renal (IRR) y el doppler venoso intrarrenal (DVIR) al ingreso, a las 72 horas y a los 7 días. Se evaluó cuál de estas herramientas predice mejor la lesión renal aguda según KDIGO.
Resultados: en el estudio con 43 pacientes críticos, no se encontró una correlación significativa entre el valor del IRR y la lesión renal aguda según KDIGO. Por el contrario, se encontró una relación significativa entre el doppler venoso intrarrenal (DVIR) al ingreso, a las 72 horas y a los 7 días con la lesión renal aguda según KDIGO, con un valor de r: 43=0,95 (P=0,54); 0,49 (P=0,001); 0,58(P=0,000). Al analizar mediante árbol de clasificación, se determinó que las variables que mejor predicen el riesgo de padecer lesión renal aguda antes de que esto ocurra son la medición del doppler venoso intrarrenal (DVIR) a los 7 días y el valor del balance hídrico acumulado.
Conclusiones: existe una correlación positiva y significativa entre el doppler venoso intrarrenal (DVIR) y la lesión renal aguda. El doppler venoso intrarrenal (DVIR) y el balance acumulado de líquidos predicen mejor el riesgo de sufrir lesión renal aguda en pacientes críticos. En contraste, el índice de resistencia renal (IRR) no se relacionó con la lesión renal aguda en la población estudiada.

Palabras Clave: Índice de Resistencia Renal; Toma de Decisiones; POCUS; Ecografía en el Punto de Atención; Cuidados Intensivos; Neurocríticos; VexUS.

INTRODUCTION

For the last 40 years, acute renal lesion (ARL) management has changed considerably from a single-organ disease managed only by nephrologists to a disease managed by intensive care specialists and nephrologists.[1] Early detection and prevention are crucial as ARL increases morbidity and mortality.[2,3]

Its incidence ranges from 4 % to 20 % in hospitalized patients. It reaches 60 % of patients admitted to intensive care, and it is related to a prolonged stay at the ICU and the hospital.[4] New studies validated the diagnostic scales using the alteration of serum creatinine and urinary output to define the presence and severity of the acute renal lesion, such as RIFLE (2004), AKIN (2007), and KDIGO (2012).[5] In our piece of research, we used the Renal Point of Care Ultrasound (POCUS), which is an accessible, innocuous tool easy to use by emergency doctors, intensive care specialists, and nephrologists, available at the bedside of the patient, very useful to monitor renal functioning with the use of the Pulsed Color Doppler measuring the Renal Resistance Index (RRI) and Intrarenal Venous Doppler (IRVD) Flow in critical patients.[6,7,8] Measuring the Renal Resistance Index (RRI) and Intrarenal Venous Doppler seems to be a fast, noninvasive tool that assesses renal perfusion, so it could identify the subclinical diagnosis of ARL and/or predict the course of renal recovery (9, 10) but is relation and/association with ARL in neurocritical patients is unknown.

RRI and Doppler's ultrasound are gaining ground quickly as detection tools in critical patients. Renal vasoconstriction is an early manifestation of AKI.[11,12] Doppler ultrasound of the systemic veins adds other data when assessing the hemodynamic condition bedside and constitutes a fundamental piece, together with the clinical, ultrasound, and laboratory parameters.[13,14]

Many studies suggest the implementation of renal POCUS to monitor, assess and follow up on critical patients. Early prediction is fundamental to identifying patients with a high risk of ARF and offering preventive and early treatment measures. For this reason, recent research has focused on developing predictive models that stratify patients according to several clinical factors.[15] In our context, there are just a few studies relating renal resistance index and intrarenal venous Doppler to acute renal lesions in patients with a critical pathology. Therefore, the main goal of our research is to predict acute renal lesions by measuring RRI and intrarenal venous Doppler in the seriously ill person.

METHODS

Type of Study: Prospective, longitudinal, descriptive observational.

Analysis approach of the study: It corresponds to an observational, analytical, prospective, longitudinal study. The analytical approach is quantitative. The research approach is positivistic. The degree of association

was measured via the Pearson correlation coefficient.

Classification trees: Methods: CHAID, QUEST, **CART** (computer-aided regression trees)

Universe: Critical patients admitted into a multipurpose intensive care unit from August 1 to December 31, 2022.

Inclusion criteria: Older than 18 to 59 years. Patients without acute or chronic renal pathology are hospitalized in the Intensive Therapy Service of Viedma Clinical Hospital.

Exclusion criteria: Bad ultrasound window (artifacts). Hypophysis tumor and/or Diabetes insipidus, patient with hepatic cirrhosis, heart failure with reduced LVEF, chronic malnutrition, and a patient who abandoned the institution before 7 days.

Descriptive analysis: The variable age will be described in terms of mean and standard deviation (or mean and range, according to the normality test). For the categorical variables, frequency charts were prepared or combined with bar charts, as long as necessary for the explanation. Pearson correlation tests (r) were performed. Inferential statistics related to the research work were used.

Classification trees: Method: CART (computer-aided regression trees).

Procedure: The study was conducted at the Intensive Care Unit for adults at Viedma Clinical Hospital. Data on health history, intensive care flowchart sheets, ventilation sheets, laboratory sheets, geometries, and Doppler ultrasound measurements were gathered. The results were compiled in the data collection sheet.

Renal resistance index (RRI) measurement: The patients were examined in their IUC bed in a supine position. Measures in both kidneys or on the most accessible side were made since it has been demonstrated that the difference in RRI values between the right and the left kidneys is insignificant both in healthy and critical patients.[22] Color Doppler was applied to visualize the global organization of the intrarenal blood vessels and pulsed wave Doppler in the smallest possible width between 2 and 5 mm to measure the flow speeds in an interlobular or arcuate artery in the upper, middle, and lower pole of the kidney. Doppler gain was configured to obtain a clear contour of the flow waves with minimal background noise. The pulse wave Doppler spectrum was optimal when at least three consecutive waveforms of similar aspects were visualized for each pole. RRI was calculated for each kidney [(maximum systolic speed-telediastolic speed)/maximum systolic speed]. Based on the RRI values of both kidneys, the mean RRI was calculated.

Figure 1. Ultrasound image showing (a) an IRR: 0,70 and a continuous normal intrarenal venous flow that rules out renal congestion (b) an IRR: 0,8 which is elevated with respect to the normal value.

Renal vein Doppler measurement: When measuring the RRI, the image of the venous flow below the baseline was observed and interpreted as follows.

Degree 0 = Continuous and monophasic.

Degree 1 = Discontinuous and biphasic flow.

Degree 2 = Discontinuous and monophasic (only diastole).

To determine if patients developed ARL, the first seven days after admission at the ICU were selected, the ARL criteria based on the urinary and creatinine volume (KDIGO). Creatinine before admission was defined as the last known measured value of creatinine or the final known value of the information system at the hospital was obtained, such as the previous health history. When the value of serum creatinine before admission was unavailable, the serum creatinine upon admission was cataloged as a basis.

Statistical Methods: They were expressed via frequencies and percentages to describe continuous and categorical variables. In the association of two variables, we used the Pearson correlation coefficient. We considered $p<0.05$ to be significant and, to predict the risk of the acute renal lesion, a data-running program

was devised using the R statistical method and **Generating Classification Trees** according to the Method: CART (computer-aided regression trees).

RESULTS

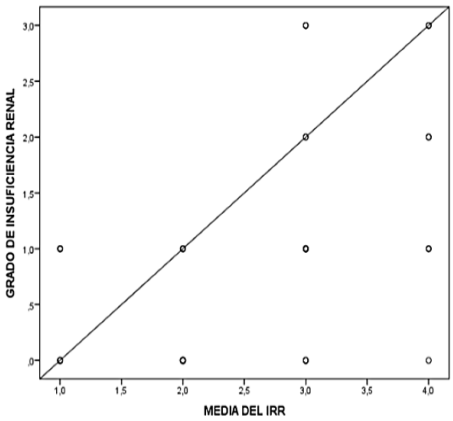
This piece of research included 58 critical patients, 15 out of them being excluded (6 patients older than 60 years, 2 patients younger than 18 years, 3 patients died within 48 hours after admission into the ICU, 1 patient with hypophysis macroadenoma, 1 patient who had a home-requested discharge, and 2 patients due to bad ultrasound window and/or difficulty in the ultrasound assessment). Taking as samples 43 patients who met the criteria for admission into the study.

Relational analysis

The results of the correlation between the RRI value upon admission, 72 hours later, and 7 days after admission with acute renal lesion ranged from moderate to low, with a value of r: 43 =0,32 (p=0,03); 0.42 (p=0,004); 0,26 (p=0,87) respectively, which indicates that there is no relation between the RRI value and acute renal lesion.

Table 1. Pearson Correlation between the value of the renal resistance index (RRI) and acute renal lesion (ARL)

		VALOR DE INDICE DE RESISTENCIA RENAL AL INGRESO	VALOR DE INDICE DE RESISTENCIA RENAL A LAS 72 HORAS	VALOR DE INDICE DE RESISTENCIA RENAL A LOS 7 DIAS
LESION RENAL AGUDA	Correlación de Pearson	,326*	,426**	,264
	Sig. (bilateral)	,033	,004	,087
	N	43	43	43



Source: Self-made

The results of the correlation between IRVD upon admission, 72 hours later, and 7 days after admission with acute renal lesion were significant with a value of r: 43=0,95 (p=0,54), 0,49 (p=0,001), 0,58 (p=0,000) respectively. This means there is a relation between these two study variables, mostly with Intrarenal Venous Doppler measured 7 days after admission r: 43 = 0,58 (p=0,000).

Table 2. Pearson Correlation between the degree of intrarenal venous Doppler (IRVD) and acute renal lesion according to KDIGO

		DOPPLER VENOSOS INTRARENAL GRADO VEXUS AL INGRESO	DOPPLER VENOSOS INTRARENAL GRADO VEXUS A LAS 72 HORAS	DOPPLER VENOSOS INTRARENAL GRADO VEXUS A LOS 7 DIAS
LESION RENAL AGUDA	Correlación de Pearson	,095	,490**	,588**
	Sig. (bilateral)	,544	,001	,000
	N	43	43	43

Source: Self-made.

The results of the correlation between IRVD measured 7 days after admission with the degree of the acute renal lesion were significant with a value of r: 43=0,58 (p=0,000).

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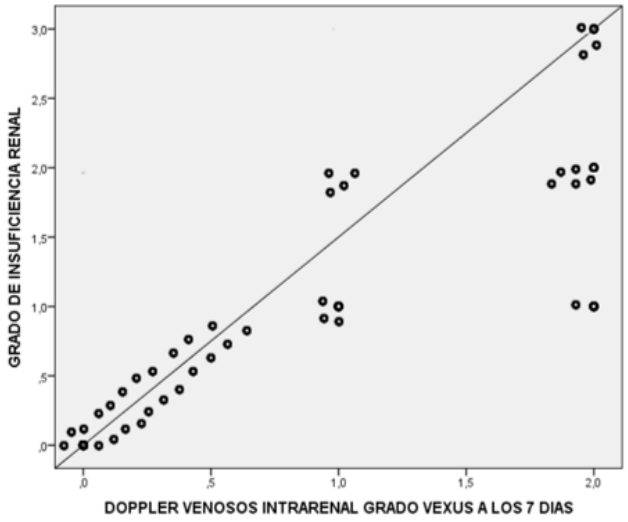
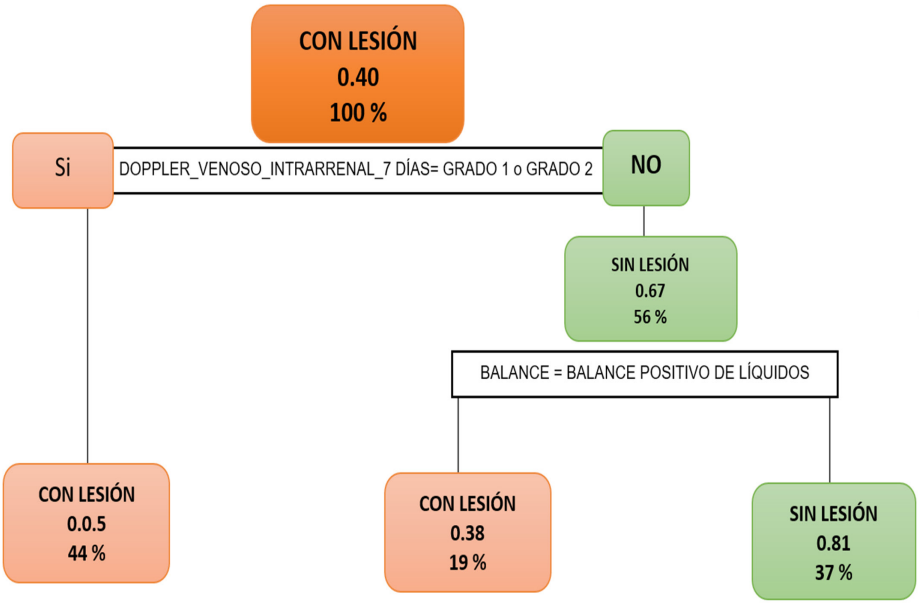
Figure. 1 Pearson Correlation between the degree of intrarenal venous Doppler (IRVD) measured 7 days after admission and the degree of acute renal lesion according to KDIGO.



Source: Self-made

Prediction of acute renal lesion

Figure 2. Classification tree to predict renal lesion based on venous Doppler diagnosis 7 days after admission and water balance.



Source: Self-made.

The classification tree shows that the variables that can better explain renal lesion before its occurrence are Doppler diagnosis 7 days after admission and the accumulated water balance. The other RRI variables, diuresis, nephrotoxic, diuretic contrast, and gender, do not predict renal lesions better than the variables above. The classification tree has a decision rule based on Doppler diagnosis 7 days after admission and the accumulated water balance. If Doppler analysis 7 days after admission is Degree 1, 2, and 3, then the patient will likely have a renal lesion of 0,95. 44 % of patients in the study had these characteristics. If the Doppler analysis 7 days after admission is degree 0, but the patient has a positive balance, then the patient will likely have an acute renal lesion of 0,38. 19 % of patients in the study had these characteristics. If Doppler analysis 7 days after admission is Degree 0 and the water balance is negative or neutral, then the patient WILL NOT develop an acute renal lesion with a probability of 0,81. 37 % of patients in the study had these characteristics. As we can see, the variables better predicting the risk of suffering from a renal lesion before it occurs are intrarenal venous Doppler (IRVD) measurement 7 days after admission and the accumulated water balance.

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DISCUSSION

Our discussion is divided into 2 main sections, first, we identified which ultrasound measurement in Doppler mode (RRI or IRVD) had a higher correlation with the presence of acute renal lesion according to KDIGO and, finally, we determined which of the two measurements predicted acute renal lesion better. Over 50 % of patients under study were diagnosed upon admission as having severe cranial-cerebral trauma followed by a hemorrhagic cerebrovascular accident. This could be explained because Viedma clinical hospital is a 3rd level reference center belonging to the public system, and it is experienced in providing care to neurocritical patients.

It was determined that RRI had a low correlation with the degree of acute renal lesion according to KDIGO, which coincides with the multicentric prospective cohort study carried out by Miguel Darmon, Aurelie Bourmaud, María Reynaud, et al.[16] that included unselected critical patients and performed renal Doppler upon admission into intensive care and assessed the diagnostic performance of RRI to predict persistent AKI on day 3. However, the general performance in predicting persistent ARL was deficient, with an area below the ROC curve of 0,58 (95%CI: 0,52 – 0,64) for RRI, so they concluded that, though there was a statistical association between RRI and occurrence of AKI, RRI has bad performance in predicting persistent AKI on day 3. In our study, this could be explained because most patients were neurocritical and had no acute renal lesion, according to KDIGO, upon admission. Still, there was a slight increase in creatinine classifying for KDIGO 1 or 2 without losing renal function. We conjecture this increase in nitrogen-containing matter occurred because of secondary hypotension to hypovolemia and exposure of the neurocritical patients to major surgery; as it is a prerenal acute renal lesion, the Renal Resistance Index (RRI) does not generally increase.[9] Besides being a fast, noninvasive tool proposed to assess renal perfusion, identify the early risk of ARL, or predict the course of renal recovery, the Doppler-based renal resistance index (RRI) was believed to show mainly renal vascular resistance. Still, RRI is really influenced by many factors of confusion, such as renal interstitial pressure, intraabdominal pressure, oxygen or CO_2, pulse pressure, and vascular distensibility. Though the initial reports in studies with little potency suggested good discrimination in predicting renal prognosis, some studies indicate that this technique's prognostic performance is limited.[16,17]

The results of the correlation between Intrarenal Venous Doppler (IRVD) measurement upon admission, 72 hours later, and 7 days after admission according to KDIGO was significant with a value of r: 43=0,95 (p=0,54), 0,49 (p=0,001), 0,58 (p=0,000) respectively. This means there is a positive correlation between these two study variables, mostly with Intrarenal Venous Doppler measured 7 days after admission r: 43 = 0,58 (p=0,000). Our result is similar to the historical study performed by Lida and colleagues, where the alterations in the IRVD strongly correlated with adverse effects, including hospitalization and death by cardiovascular disease in patients with heart failure with biphasic (HR: 8,23; CI: 3,45-19,7; p<0,001) and monophasic patterns (HR: 23,1; CI: 10,0-53,5; p<0,001).[35] Finally, the statistical analysis of the classification tree evidenced that the variables better predicting the risk of suffering from renal lesion before it occurs are intrarenal venous Doppler measured 7 days after admission and the accumulated water balance. Several studies firmly back up this result of predicting the acute renal lesion.[18,19,20,21,22,23,24], where the alterations to intrarenal venous Doppler flow (biphasic or monophasic waves) were better to predict the primary result than any other variable.

Some weaknesses of the study were: a small sample, the difficulty of performing an abdominal ultrasound on obese patients due to bad ultrasound window, and on those patients who did not collaborate with the procedure and caused delays in time. However, the strengths were more significant: a studied population of young and adults with renal function and preserved renal functional reserve, which reduces the bias, the type of analysis used to predict the risk of suffering from acute renal lesion before it occurs. The classification tree demonstrated that the variables that can better predict renal lesion before it happens are Doppler diagnosis 7 days after admission and the accumulated water balance.

CONCLUSIONS

The correlation between the RRI value upon admission, 72 hours later, and 7 days after admission with an acute renal lesion, according to KDIGO, ranged from moderate to low. So we can interpret that there is no relation between the value of the renal resistance index and acute renal lesion. There is a positive and significant correlation between intrarenal venous Doppler and acute renal lesions, so we can infer that IRVD measurements better predict the risk of suffering from acute renal lesions. The variables better predicting the risk of suffering from acute renal lesion before it occurs are Intrarenal Venous Doppler (IRVD) measurement 7 days after admission and the accumulated water balance.

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CONFLICT OF INTEREST

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