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ORIGINAL PAPER

The Role of Urine-1 and Urinalysis in the Diagnosis of Acute Kidney Injury in Liver Transplantation

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ABSTRACT

Introduction: Acute kidney injury (AKI) is a common complication in the intensive care unit. Urine-1 (U-1) is a frequently overlooked tool for assessing AKI; moreover, there is no evidence-based consensus on its use. This study aimed to investigate the role of U-1 and urinary microscopy (UM) in diagnosing severe AKI and the need for renal replacement therapy (RRT) in patients undergoing liver transplantation (LT). **Method:** Our hypothesis was to determine whether the urinary parameters available in U-1 and UM are associated with the diagnosis of severe AKI and the need for RRT. We evaluated U-1 and UM 6 hours after LTx. The criterion for diagnosing AKI was based on Kidney Disease Improving Global Outcomes (KDIGO) guidelines, relying solely on serum creatinine levels within one week. **Results:** Eighty-seven patients developed AKI in the first week after LT. The diagnosis of severe AKI (KDIGO 2 and 3) was found in 59 patients. Six hours after LT, the variables in U-1 were predictors of severe AKI, with the area under the curve (AUC) of 0.65 for proteins, 0.68 for leukocytes, and 0.63 for erythrocytes. In determining RRT, these variables performed better with AUC: 0.72 for proteins, 0.69 for leukocytes, and 0.68 for erythrocytes. The non-AKI and AKI groups showed a similar distribution in UM. **Conclusion:** Simple and commonly used parameters in clinical practice, such as proteinuria, erythrocyturia, and leukocyturia, can be valuable tools for diagnosing severe AKI and the need for RRT.

Descriptors: Acute Kidney Injury; Biomarkers; Liver Transplant; Renal dialysis.

O Papel da Urina-1 e Microscopia Urinária no Diagnóstico da Injúria Renal Aguda no Transplante Hepático

RESUMO

Introdução: A injúria renal aguda (IRA) é uma complicação comum na unidade de terapia intensiva. A urina-1 (U-1) é uma ferramenta frequentemente esquecida para avaliar IRA e, além disso, não existe um consenso baseado em evidências sobre seu uso. O objetivo do estudo foi investigar o papel da U-1 e da microscopia urinária (MU) no diagnóstico da IRA grave e a necessidade de terapia de substituição renal (TSR) em pacientes submetidos ao transplante hepático (TH). **Métodos:** Nossa hipótese foi determinar se os parâmetros urinários disponíveis, U-1 e MU, estão associados ao diagnóstico da IRA grave e à necessidade de TSR. Avaliamos U-1 e MU em 6 horas após o TH. O critério utilizado para o diagnóstico da IRA foi o Kidney Disease Improving Global Outcomes (KDIGO), baseado apenas na creatinina sérica em 1 semana. **Resultados:** Oitenta e sete pacientes desenvolveram IRA na 1ª semana após o TH. O diagnóstico de IRA grave (KDIGO 2 e 3) foi encontrado em 59 pacientes. Seis horas após o TH, as variáveis na U-1 foram preditoras de IRA grave, com área sob a curva [*area under the curve* (AUC)]: 0,65 para proteínas, 0,68 para leucócitos e 0,63 para eritrócitos. Na determinação de TSR, essas variáveis tiveram melhor desempenho com AUC: 0,72 para proteínas, 0,69 para leucócitos e 0,68 para eritrócitos. Os grupos não IRA e IRA apresentaram distribuição semelhante na MU. **Conclusão:** Parâmetros simples e usuais na prática clínica, como proteinúria, eritrocitúria e leucocitúria, podem ser ferramentas valiosas para o diagnóstico da IRA grave e da necessidade de TSR.

Descritores: Injúria Renal Aguda; Biomarcadores; Transplante Hepático; Diálise.

INTRODUCTION

Acute kidney injury (AKI) is a common complication in several settings, especially in intensive care units (ICU), reaching a high incidence of 50%[1]. Survival after diagnosis of AKI is low, and mortality reaches 80% in patients requiring renal replacement therapy (RRT)[2-5].

The etiology of AKI in the ICU environment is multifactorial; therefore, evaluating it in a heterogeneous environment is a challenge[6]. For this reason, many studies use major surgeries for this analysis. The liver transplantation (LT) scenario is validated for the diagnosis of AKI due to the high incidence in the intra- and postoperative (PO) periods[7].

The diagnosis of AKI is based on the Kidney Disease Improving Global Outcomes (KDIGO) criteria, according to changes in serum creatinine (sCr) and urinary output (UOP) parameters[8]. However, both current diagnostic parameters, sCr and UOP, have limitations in cirrhotic patients due to factors such as malnutrition, loss of muscle mass, and fluid accumulation. These limitations may result in underestimation of sCr values, delaying the proper diagnosis of the condition. Furthermore, UOP can be preserved even in the presence of oliguria, and diuretics are common in these patients, making UOP a less reliable parameter for assessment. It is important to note that the diagnosis does not provide detailed information about kidney injury type, intensity, and location. Although several biomarkers can aid in diagnosing AKI, most are restricted to research, unavailable in clinical practice, and often expensive. Therefore, better exploring the resources available in clinical practice, such as the type I urine test (U-1) and urinary microscopy (UM) – laboratory tests used in medicine for thousands of years – seems promising.

U-1 and UM are tests that can provide valuable information and are considered a "window to the urinary tract". In addition to being easy to obtain, these tests are relatively simple, low-cost, and non-invasive. U-1 generally includes physical characteristics (volume, appearance, odor, color, density, and pH), chemical characteristics (testing for proteins, sugars, ketone bodies, bilirubin, urobilinogen, urea, creatinine, and uric acid), and microscopic examination of the urinary sediment[9].

Several studies have highlighted changes in renal function with coronavirus disease 2019 (COVID-19) in urinary sediment, proteinuria, and hematuria, suggesting the presence of a renal reservoir for the virus. Proteinuria has been commonly observed during severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection and is reported in 7 to 63% of cases[10-13]. Cheng et al.[11] reported hematuria in 26.7% of patients.

The study hypothesis is to evaluate whether urinary parameters available in U-1 and UM could be valuable tools in the diagnosis of severe AKI and the need for RRT in patients undergoing LT.

METHODS

The University of São Paulo Ethics Committee approved the study under protocol number CAAE: 06636513.4.0000.0068. All reported clinical and research activities are consistent with the Principles of the Istanbul Declaration and the Declaration of Helsinki. The protocol is registered in Clinical Trials and is available at https://clinicaltrials.gov under identifier NCT 02095431. Patients were included in the study after obtaining the Free and Informed Consent Form (FICF), following the institution's Ethics Committee guidelines.

Patients

During 24 months from June 2013 to June 2015, 189 LTs were performed; 139 recipients were eligible for the study, and 100 were included. Fig. 1 shows the reasons for non-inclusion. All patients undergoing LT who were over 18 were screened during this period. Patients were included in the study after obtaining the informed consent form following the guidelines of the institutional ethics committee. Exclusion criteria included the following: need for preoperative dialysis, second liver transplant, combined transplant, chronic kidney disease stage 5, or previous kidney transplant.

Patients were divided into six categories according to the etiology of end-stage liver disease (ESLD): hepatitis B or C, cirrhosis, alcoholic cirrhosis, cryptogenic cirrhosis, acute hepatitis, and miscellaneous causes. The miscellaneous group included patients with nonalcoholic steatohepatitis, autoimmune hepatitis, hemochromatosis, Budd-Chiari syndrome, biliary atresia, Wilson's disease, primary sclerosing cholangitis, polycystic disease, biliary cirrhosis, and hepatocellular carcinoma.

Baseline renal function and history of comorbidities were recorded from electronic medical records. The following perioperative variables were included: main patient characteristics, clinical follow-up in the 1st week after LT, data on the need for RRT, and outcomes.

The functional model for end-stage liver disease (MELD) was calculated according to serum bilirubin, international normalized ratio (INR), and sCr, using the formula MELD score = 0.957 × Log(creatinine mg/dL) + 0.378 × Log(bilirubin mg/dL) + 1.120 × Log(INR) + 0.643 × 10. The liver transplantation MELD is the sum of the functional MELD value and the special transplant priority situation score[14].

Urine samples were collected 6 hours after surgery. We recorded vital signs, care process, and laboratory results daily for 7 days after LT.

Clinical outcomes

The primary outcome was the development of AKI during the 1st week of LT. Baseline renal function was the lowest value in the last 3 months and was used to assess renal recovery. The diagnosis of AKI was based on KDIGO[8]. We considered the baseline sCr as the lowest value in the week before liver transplantation, and this value was used to determine the diagnosis of AKI. The stage of AKI was defined according to KDIGO: stage 1 (1.5-1.9 times baseline sCr or increase ≥ 0.3 mg/dL within 48 hours), stage 2 (2.0-2.9 times baseline sCr), stage 3 (3.0 times baseline sCr or increase > 4.0 mg/dL). The severe AKI group was categorized as KDIGO 2 or 3.

sCr was measured using the automatic kinetic method. Urine output was collected in a urine bottle with a minimum optimal volume of 10 mL. Urine and sufficient diuresis volume were collected in patients with an indwelling urinary catheter to perform the analysis. All urine collection was conducted from fresh urine. The sample was transported in a Gelóx to the Central Laboratory immediately after collection. For the analysis of the UM, the standard optical microscopy technique (bright field/phase contrast) was used on the Olympus CX41 bright field microscopy analyzer. The materials used were a conical tube from the urine collection kit, slides, glass coverslips, disposable tips and 50 µL automatic micropipettes. The UM readings were blinded to the diagnosis of AKI. The urinary scoring system by Perazella et al.[15] was used for subsequent analysis. The score classification adapted for this study was 0 (absence or presence of hyaline casts), 1 (rare granular casts) and 2 (some and numerous granular casts, presence of red blood cells, leukocyte or epithelial casts).

All investigators responsible for microscopy and analysis of U-1 were blinded to the clinical history and results of the patients. To ensure impartiality, we used anonymous identifiers for each patient, which prevented any bias resulting from the direct identification of cases. In addition, data analysis was performed independently, without the participation of the researchers who collected the data, thus ensuring the maintenance of blinding throughout the study.

Statistical analysis

The sample size was calculated according to the study's primary objective, considering that the incidence of AKI diagnosis after LT is approximately 70%. With a statistical power of 80% and an alpha error of 0.05, it was determined that 101 patients would be necessary for the study. Categorical variables were expressed as numbers (%), continuous variables were expressed as means and standard deviations, and nonparametric variables were expressed as medians and 25-75 percentiles. Gaussian distribution was determined by the Shapiro-Wilk test. For the correlation (analysis) of continuous variables with normal distribution, the t-test or Pearson's test was used. We used the Mann-Whitney (Wilcoxon rank) or Spearman's test for continuous variables with non-normal distribution. Categorical data were compared using the chi-square or Fisher's exact test. Values of $p < 0.05$ were considered statistically significant. To calculate sensitivity and specificity for biomarker measurements at varying cutoff values, a conventional receiver operating characteristic (ROC) curve was generated; the area under the curve (AUC) was calculated to quantify the accuracy of biomarkers for predicting AKI, severity, and need for RRT. The 95% confidence interval (CI) was shown for the results. Analyses were performed using SPSS (Statistical Package for Social Sciences) version 20 (Chicago, IL, USA).

RESULTS

Patient characteristics and evolution of AKI

The demographic and clinical characteristics of the patients are presented in Table 1. The most common comorbidities were hypertension and diabetes. The main reasons for liver dysfunction were hepatitis C (46), alcoholic cirrhosis (13) and cryptogenic cirrhosis (11). Eighty-seven patients developed AKI in the 1st week after LT. The KDIGO classification was 0 (13), 1 (28), 2 (23) and 3 (36). The diagnosis of severe AKI (KDIGO 2 and 3) was found in 59 patients. Patients with severe AKI were younger and had higher functional MELD; there were no differences between the groups in the univariate analysis regarding baseline characteristics, liver disease, donor and comorbidities. The need for RRT occurred in 34 patients the 1st week after LT. The 60-day mortality was 21% (21).

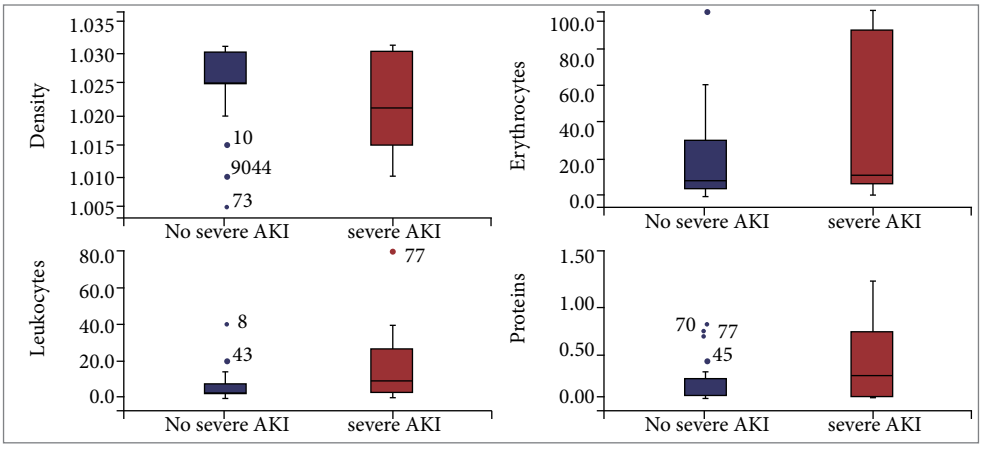
Table 1. Clinical and demographic characteristics of the group.

Patient characteristics and outcomes	Total	No severe AKI	Severe AKI	*p*-value
n (%)	100 (100.0)	41 (41.0)	59 (59.0)	< 0.0001
Cohort characteristics				
Age	58.00 (SD 12.00)	57.00 (SD 12.00)	53.00 (SD 12.00)	0.01
Sex (male)	64 (64.0%)	27 (42.0%)	37 (58.0%)	0.75
Body Mass Index	26.00 (SD 4.00)	26.00 (SD 4.00)	26.50 (SD 5.00)	0.65
Non-Caucasian	14 (14.0%)	5 (36.0%)	9 (64.0%)	0.11
MELD-Na	28.55 (SD 5.97)	27.62 (SD 4.51)	29.25 (SD 6.83)	0.21
MELD LT	29.19 (SD 5.25)	28.22 (SD 3.29)	29.90 (SD 6.23)	0.15
A plasma	140.53 (SD 5.18)	140.56 (SD 4.32)	140.50 (SD 5.76)	0.39
Liver disease				
Hepatitis C	46 (46.0%)	17 (37.0%)	29 (63.0%)	0.44
Alcoholic cirrhosis	13 (13.0%)	6 (46.0%)	7 (54.0%)	0.68
Cryptogenic cirrhosis	12 (12.0%)	5 (42.0%)	7 (58.0%)	0.96
Acute hepatitis	6 (6.0%)	3 (50.0%)	3 (50.0%)	0.64
Hepatitis B	4 (4.0%)	2 (50.0%)	02 (50.0%)	0.70
Others	19 (19.0%)	8 (42.0%)	11 (57.0%)	0.91
Comorbidities				
Hypertension	33 (33.0%)	12 (36.0%)	21 (64.0%)	0.43
Diabetes mellitus	28 (28.0%)	14 (50.0%)	14 (50.0%)	0.26
Kidney function				
sCr base	0.77 (IQR 0.63-0.99)	0.77 (IQR 0.62-0.98)	0.77 (IQR 0.65-1.00)	0.87
sCr reference	0.78 (IQR 0.62-1.02)	0.77 (IQR 0.64-1.02)	0.80 (IQR 0.61-1.00)	0.96
Estimated GFR (CKD-EPI) based on sCr	99.65 (IQR 74.00-110.00)	99.25 (IQR 75.00 -108.00)	108.52 (69.00-117.00)	0.67
UOP 1st PO (mL)	475.00 (SD 45.00)	608.00 (SD 79.00)	383.00 (SD 49.00)	0.01
Water balance 1st PO (mL)	+0.535 (IQR +500 ± 2.315)	+1.010 (IQR +367 ± 1.782)	+1.655 (IQR +890 ± 2.447)	0.008
Outcomes				
Time using VAD (days)	2.00 (SD 1.78)	1.00 (SD 1.18)	2.00 (SD 2.00)	0.01
Mechanical ventilation time (days)	2.00 (SD 1.82)	1.00 (SD 0.57)	3.00 (SD 2.00)	< 0.0001
Length of ICU stay (days)	9.81 (SD 13.00)	5.59 (SD 6.30)	12.75 (SD 2.00)	0.003
Length of hospital stay (days)	29.00 (SD 28.00)	19.17 (SD 14.60)	36.00 (SD 4.20)	< 0.0001
Retransplantation	11 (11.0%)	1 (9.0%)	10 (91.0%)	0.02
Need for RRT	36 (36.0%)	4 (10.5%)	34 (89.5%)	< 0.0001
60-day mortality	21 (21.0%)	3 (14.3%)	18 (85.7%)	0.004

Source: Elaborated by the authors.Data expressed in n (%), SD = mean standard deviation (±), median and percentile (25-75) according to their distribution. CKD-EPI = Chronic Kidney Disease Epidemiology Collaboration; IQR = interquartile range; GFR= glomerular filtration rate; VAD= vasoactive drug.

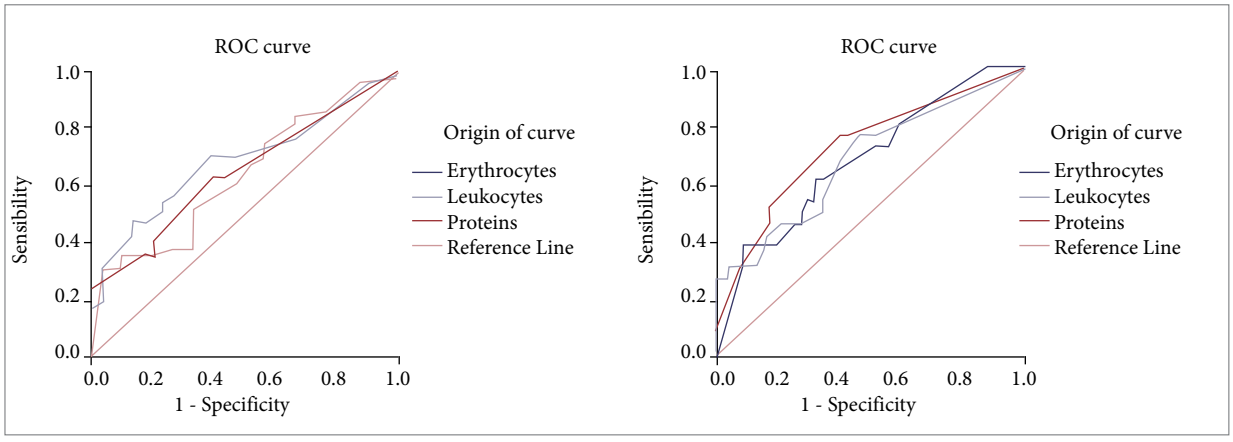
U-1 Assessment

Six hours after LT, urine variables (protein, leukocytes, and erythrocytes) were expressed in more significant numbers in the severe AKI and RRT groups, as observed in Fig. 1 and Table 2. Proteinuria had an AUC of 0.65 (CI 0.52-0.77; $p = 0.04$) in severe AKI and 0.72 (CI 0.60-0.85; $p = 0.002$) for RRT. Leukocyturia had an AUC of 0.68 (CI 0.56-0.80; $p = 0.009$) in severe AKI and 0.69 (CI 0.56-0.82; $p = 0.009$) for RRT. The presence of erythrocytes in urine demonstrated, respectively, in severe AKI and need for RRT, AUC of 0.63 (CI 0.50-0.76; $p = 0.05$) and AUC of 0.68 (CI 0.56-0.81; $p = 0.01$) (Fig. 2).



Source: Elaborated by the authors.

Figure 1. Box plot of some urine variables: specific gravity, erythrocytes, leukocytes, and protein among severe AKI groups 6 hours after surgery.



Source: Elaborated by the authors.

Figure 2. ROC AUC curve for severe AKI on the right and for the need for RRT on the left.

Table 2. U-1 variables with parametric distribution, expressed as mean and SD 6 hours after TH.

Variable	No severe AKI (n = 30)	Severe AKI (n = 42)	*p*-value	No RRT (n = 47)	Need for RRT (n = 25)	*p*-value
pH	5.40 (0.64)	5.28 (0.62)	0.48	5.37 (0.64)	5.26 (0.61)	0.56
Density	1.024 (0.006)	1.022 (0.006)	0.07	1.024 (0.006)	1.022 (0.006)	0.18
Glucose	20.59 (75.96)	7.44 (46.25)	0.09	13.26 (61.11)	12.29 (58.95)	0.28
Proteins	0.23 (0.27)	0.44 (0.40)	0.03	0.24 (0.30)	0.57 (0.49)	< 0.0001
Leukocytes	6.40 (7.85)	24.88 (34.20)	0.008	8.64 (10.12)	33.24 (41.41)	0.009
Erythrocytes	17.40 (22.68)	37.81 (41.38)	0.05	20.75 (28.98)	45.40 (42.76)	0.01

Source: Elaborated by the authors. pH = potential of hydrogen.

In evaluating categorical variables such as bile pigments, ketone bodies, epithelial cells, granular casts, and crystals, a higher proportion was observed in few and mainly numerous in the group with severe AKI. However, there was no statistically significant difference between the severe AKI groups, as shown in Table 3, as well as for the need for RRT. Urinary crystals showed a trend with $p = 0.06$, but in the evaluation of AUC, they presented 0.60 (CI 0.48-0.74; $p = 0.12$).

Table 3. U-1 categorical variables expressed as absolute numbers and percentages 6 hours after LT.

Variable	Outcome	0 (Absent)	1 (Few)	2 (Numerous)	*p*-value
Bile pigments	No severe AKI	26 (35.6)	3 (10.0)	1 (3.3)	0.42
	Severe AKI	35 (47.9)	3 (7.0)	5 (11.6)	
Ketone bodies	No severe AKI	24 (80.0)	5 (16.7)	1 (33.3)	0.50
	Severe AKI	34 (79.1)	7 (16.3)	2 (66.7)	
Epithelial cells	No severe AKI	7 (23.3)	16 (53.3)	7 (23.3)	0.40
	Severe AKI	9 (20.9)	19 (44.2)	15 (34.9)	
Granular cylinders	No severe AKI	26 (66.7)	8 (20.5)	5 (12.8)	0.89
	Severe AKI	39 (63.4)	16 (26.2)	6 (9.8)	
Crystals	No severe AKI	17 (53.7)	-	13 (43.3)	0.06
	Severe AKI	15 (34.9)	-	28 (65.1)	

Source: Elaborated by the authors. Data expressed in n (%). The non-AKI and AKI groups have a similar distribution of UM, although stage 2 cylinders are more frequent in the AKI group.

DISCUSSION

U-1 is an often overlooked tool in the assessment of AKI. Furthermore, there is no evidence-based consensus on its use, and the few published studies focus on urinary sediment analysis and urinary tract infection[15-16]. This article reveals a prediction of the diagnosis of severe AKI using U-1, with emphasis on proteinuria, leukocyturia, and erythrocyturia.

The diagnosis of AKI in cirrhotic patients is particularly challenging due to factors such as changes in volume status, malnutrition, and the use of diuretics, which can influence sCr levels. Although several biomarkers have been investigated to aid in this diagnosis, their application in clinical practice is still limited. Therefore, the findings related to U-1 parameters deserve further exploration.

Recent studies[17-19] conducted in renal dysfunction associated with SARS-CoV-2 revealed findings such as proteinuria and hematuria. In addition to glomerulopathy, both were associated with increased hospital mortality[11].In the pathophysiology of SARS-CoV-2, we know that there is an increase in the activation of angiotensin II, leading to nephrin endocytosis, increasing glomerular permeability, and, consequently, increasing protein loss[20].

Our study revealed the presence of higher proteinuria in patients with severe AKI, 0.44 (SD 0.40) versus 0.23 (SD 0.27) without severe AKI ($p = 0.03$), with AUC of 0.65 (CI 0.52-0.77). There was also higher expression of proteinuria in patients requiring RRT: 0.57 (SD 0.49) versus 0.24 (SD 0.30) without need for RRT ($p < 0.001$), with AUC of 0.72 (CI 0.60-0.85). We recognize that the AUC obtained in our study indicates moderate predictive accuracy. This measure must be considered in the clinical context of AKI. This integrative approach will allow a more robust interpretation of the results and their application in clinical practice. In a prospective cohort including 701 patients with COVID-19, the second most frequent finding after proteinuria (present in 43.9%) was hematuria, observed in 26.7% of patients[11]. The same study reported that both parameters were independent predictors of mortality: odds ratio (OR) for severe AKI of 1.80 (0.81-4.00) for proteinuria 1; 4.84 (2.00-11.70) for proteinuria 2 +~ 3; hematuria 1 + with OR of 2.99 (1.39-6.42); 5.56 (2.58-12.01) for hematuria 2 +~ 3[11]. As reported, hematuria was associated with severe AKI and the need for RRT in this article.

Hematuria is a common finding in several glomerulopathies (glomerular disease), most frequent in IgA nephropathy, Alport syndrome, and thin basement membrane disease. Approximately 25% of patients with AKI associated with macroscopic hematuria do not recover to baseline renal function[21].

In this pathological context, hemoglobin, heme, or iron released from red blood cells into the urinary space can cause direct tubular cell injury, oxidative stress, production of proinflammatory cytokines, and subsequent recruitment of monocytes/macrophages[22]. This cycle leaves us to doubt whether hematuria is a cause or a consequence of renal inflammation; in any case, the results are unfavorable. In the presence of erythrocytes in the urine, our study demonstrated, respectively, an AUC of 0.63 (CI 0.50-0.76; $p = 0.05$) and AUC of 0.68 (CI 0.56-0.81; $p = 0.01$) in severe AKI and the need for RRT.

Our study in patients undergoing LT revealed the presence of leukocyturia. In the Gala et al.[23] study, leukocyturia was present in 15 (CI 9-23) patients.

Acute interstitial nephritis accounts for 10 to 30% of all cases of biopsy-proven acute kidney injury[24]. We know that biopsy is an invasive procedure that is not always available and involves risks to the patient. Therefore, a surrogate marker that could inform this state of inflammation in a non-invasive way would be ideal. Leukocyturia can be found in the inflammatory state in tubular epithelial tissue when it is infiltrated by leukocytes and monocytes, initiating a repair process that can progress to fibrosis[25,26].

Previous studies have shown that the presence of renal epithelial casts may be helpful in the differential diagnosis of AKI, from transient to persistent[27-31]. In 2009, Perazella et al.[15] proposed a urinary sediment scale to assess the differential diagnosis of AKI. Our study used this classification. Although stage 2 casts were more frequent in patients with severe AKI, they did not achieve significant differences.

In the setting of sepsis[32], A study using U-1 and UM parameters demonstrated that UM was more valuable, as it is less affected by hydration status and medications. However, promising results with U-1 were found 6 hours after LT in this study, at a time when fluid overload is high. The use of immunosuppressive drugs with nephrotoxicity, such as calcineurin inhibitors, has also been reported during this period.

This study has strengths. Although not multicenter, it includes the largest cohort of LT patients published in the literature. The prospective analysis allowed for consistent data collection, and the diagnosis of AKI was made within 7 days, whereas most studies limit this assessment to 48 hours. This 1-week approach provides a more realistic view of the diagnosis of AKI and reduces the likelihood of a subclinical diagnosis.

However, this study also has limitations. Similar to other investigations[33,34], our group included severe cases of AKI, which limits the assessment of the capacity of biomarkers in the early stages of the disease. The lack of a multicenter design highlights the need for validation in different clinical settings. For future studies, we suggest the inclusion of other biomarkers that can complement urinary predictors, as well as the performance of more extended collection periods. It is vital to explore steps for implementing the findings, such as the engagement of nephrologists for early evaluation and the consideration of interventions, such as the initiation of RRT or adjustments in the immunosuppression regimen. These approaches may provide a more comprehensive and accurate assessment of AKI.

CONCLUSION

Using urinary parameters obtained by U-1 examination revealed a significant association between severe AKI and the need for RRT with the parameters of proteinuria, erythrocyturia and leukocyturia collected after LT. In contrast, the UM data did not demonstrate utility for the identification of severe AKI and RRT. Therefore, we recommend the inclusion of U-1 collection in the standard monitoring protocols for patients undergoing LT who are at risk of developing AKI.

CONFLICT OF INTEREST

Nothing to declare.

AUTHOR'S CONTRIBUTION

Substantive scientific and intellectual contributions to the study: Lima C, Brandão LS, Correa MF, Macedo E; **Conception and design:** Lima C, Brandão LS, Correa MF, Macedo E; **Data analysis and interpretation:** Lima C, Brandão LS, Correa MF, Macedo E; **Article writing:** Lima C, Brandão LS, Correa MF, Macedo E; **Critical revision:** Lima C, Brandão LS, Correa MF, Macedo E; **Final approval:** Lima C.

DATA AVAILABILITY STATEMENT

Data will be available upon request.

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