Kidney360

Urinary Sediment Microscopy and Correlations with Kidney Biopsy: Red Flags Not To Be Missed

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Key Points

- Automatic urine analyzers struggle to identify dysmorphic erythrocytes, renal tubular epithelial cells, lipids, crystals, and casts.
- Those particles are identifiable through manual urinary sediment evaluation and are associated with histologic lesions of interest.
- Manual urinary sediment evaluation may help to shape the indications for performing a kidney biopsy.

Abstract

Background Urinary sediment is a noninvasive laboratory test that can be performed by an automated analyzer or manually by trained personnel. Manual examination remains the diagnostic standard because it excels at differentiating isomorphic from dysmorphic red blood cells and identifying other urinary particles such as renal tubular epithelial cells (RTECs), lipids, crystals, and the composition of casts. This study aimed to investigate the prevalence of a complete profile of urinary sediment particles and its associations with histologic lesions on kidney biopsy, regardless of diagnosis.

Methods This was a single-center, observational retrospective study of 131 patients who had contemporary manual urinary sediment evaluation and kidney biopsy. A comprehensive set of urinary particles and histologic lesions were quantified, and their associations were analyzed.

Results In our samples, we found an elevated frequency of findings suggestive of proliferative kidney disease and a low frequency of particles evoking urologic damage. The association of histologic lesions and urinary particles was explored with a multivariate model. We identified urinary sediment characteristics that independently correlated with the presence of some histologic lesions: urinary lipids with mesangial expansion (OR=2.86; 95% confidence interval [95% CI], 1.3 to 6.3), mesangial hypercellularity (OR=2.44; 95% CI, 1.06 to 5.58), and wire loops and/or hyaline deposits (OR=2.89; 95% CI, 1.13 to 7.73); Urinary renal tubular epithelial cells with endocapillary hypercellularity (OR=3.17; 95% CI, 1.36 to 7.39), neutrophils and/or karyorrhexis (OR=4.51; 95% CI, 1.61 to 12.61), fibrinoid necrosis (OR=4.35; 95% CI, 1.48 to 12.74), cellular/fibrocellular crescents (OR=5.27; 95% CI, 1.95 to 14.26), and acute tubular necrosis (OR=2.31; 95% CI, 1.08 to 4.97).

Conclusions In a population of patients submitted to kidney biopsy, we found that the presence of some urinary particles (renal tubular epithelial cells, lipids, and dysmorphic erythrocytes), which are seldom reported by automated analyzers, is associated with active proliferative histologic lesions. In this regard, manual urinary sediment evaluation may help to shape the indications for performing a kidney biopsy.

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Introduction

Diagnosis of kidney disease is complex and requires multiple tools, including careful patient history collection, physical examination, laboratory, and imaging tests. Ideally, a final diagnosis is achieved without invasive procedures. However, many kidney diseases present in similar nonspecific clinical syndromes (*e.g.*, nephrotic syndrome), and nephrologists often require a kidney biopsy to establish a diagnosis. Despite being the current diagnostic gold standard for most kidney diseases, kidney biopsy is a method with some limitations: there can be sampling error (*i.e.*, the sample is not representative) and is only a single frame of a kidney disease that is often a dynamic pathologic process. In addition, kidney biopsies are invasive with a non-negligible rate of complications.[1] Importantly, some clinical settings such as coagulation disorders or solitary kidney advise against performing kidney biopsies. Thus, in some patients, the benefit/risk ratio may be unfavorable. Kidney biopsy also requires technical expertise, which is not universally available. In these scenarios, clinicians must rely

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on other tools, such as urinary sediment (U-Sed) examination. This is a noninvasive procedure that may be performed by an automated analyzer or manually by a trained clinician. The former allows for the analysis of hundreds of samples a day, with reproducible results throughout, which in turn partially explains why the expertise on manual U-Sed reading has been fading. Still, manual U-Sed provides a wealth of information[2] that automatic analyzers struggle to offer, namely distinguishing isomorphic from dysmorphic red blood cells, identifying renal tubular epithelial cells (RTECs), lipids, crystals, and the composition of casts.[3] Those shortcomings can be partly explained by the automated analyzer's inability to integrate U-Sed findings with the clinical context. In centers with proficient manual U-Sed reading such as ours, physicians regularly perform urinalysis to determine if a kidney biopsy is of additional benefit. Albeit U-Sed rarely provides a final diagnosis in the same fashion as a kidney biopsy can, its noninvasive nature means it can be repeated at will. This is particularly appealing because it can elucidate clinical changes without requiring repeated kidney biopsy; for example, a patient with clinical remission of lupus nephritis will be deemed to have disease relapse in case of reemergence of dysmorphic hematuria. Findings in U-Sed reflect damage that is occurring within the kidney, which can be documented by kidney biopsy. This correlation has been explored to some degree in selected kidney diseases. Martinez evaluated only a few urine particles (erythrocytes, leukocytes, and casts) exclusively in lupus nephritis patients. Bobart investigated hematuria and the MEST-C histologic classification in IgA nephropathy. Yuan evaluated a more complete urinary particle profile but only analyzed endocapillary proliferative lupus nephritis and IgA.[4–6] Fogazzi took a wider approach by evaluating a complete urinary profile in patients with proliferative and nonproliferative glomerular diseases.[7] However, proliferative glomerular diseases frequently share histologic features with nonproliferative ones. Using such a dichotomizing methodology means that the histologic information on the lesions (which cause urinary sediment particles to exist) may be blurred. Our study aims to take this a step further in the cross-analysis of U-Sed particles and kidney biopsy histologic lesions.

We investigated the prevalence of a complete profile of urinary sediment particles and determined its associations with histologic lesions seen on contemporary kidney biopsy, regardless of diagnosis. To the best of our knowledge, this is the first time this broader systematic approach has been explored.

Materials and Methods

Study Design and Population

We performed an observational retrospective study, including all patients who performed a complete urinary sediment evaluation and a contemporary kidney biopsy at our institution, from 2018 to 2021. We considered urinary sediment and kidney biopsy to be contemporary when the former was performed up to 7 days before kidney biopsy. Kidney biopsies with fewer than seven glomeruli were deemed inadequate due to insufficient tissue for histologic diagnosis.[8] Kidney transplant patients were excluded. We subsequently cross-evaluated the urinary sediment, kidney biopsy, and laboratory data of patients who met the inclusion criteria. Informed consent was obtained from each patient for kidney biopsy, urine and blood sampling, and data collection.

Procedures

Urinary Sediment Preparation and Examination

U-Sed evaluation and examination in our laboratory is performed by collection of a urine sample (*i.e.*, midstream urine) in a proper container, macroscopic examination of sample and sediment, and testing of the sample with a reagent strip (which measures specific gravity, pH, albumin, hemoglobin, leukocyte esterase, and nitrites). Ten milliliters of urine is centrifuged at 400 *g* for 10 minutes, and then 9.5 ml of supernatant urine is discarded. Next, we re-suspend the sediment in the remaining 0.5 ml of urine and transfer 50 μL to a glass slide and cover with a 22 × 22 coverslip.[9]

Samples were examined under phase contrast microscopy at low (×10) and high (×40) magnification and under polarized light to identify lipids and crystals. Particles evaluated included casts, erythrocytes (Figure 1), leukocytes, RTECs (Figure 2), urothelial transitional cells (superficial and deep), lipids (Figure 3, A and B), crystals, squamous cells, and bacteria. Lipiduria was defined as the presence of isolated lipid drops, oval fat bodies, and/or lipid casts. One or two of the authors (D.N. and/or N.M.F.) performed the reading and used a semi-quantitative method to count particles from 0 (absent) to 3+. For casts, at least 50 low power fields (×10) were observed, and casts were classified as hyaline, granular, waxy, fat, erythrocytic, leukocytic, epithelial, or mixed. For the remaining particles, we examined at least 20 high power fields (×40). Erythrocyte morphology was evaluated and classified as

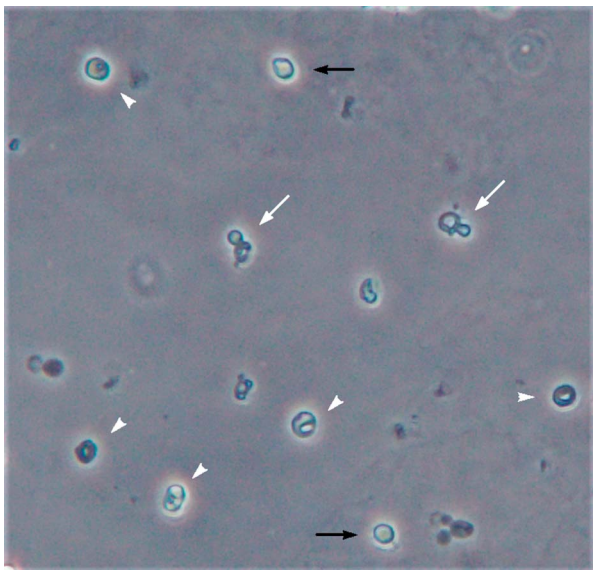

Figure 1. Different types of erythrocytes under phase contrast. White arrows, acanthocytes; white arrowheads, dysmorphic; black arrows, isomorphic. Original magnification ×40.

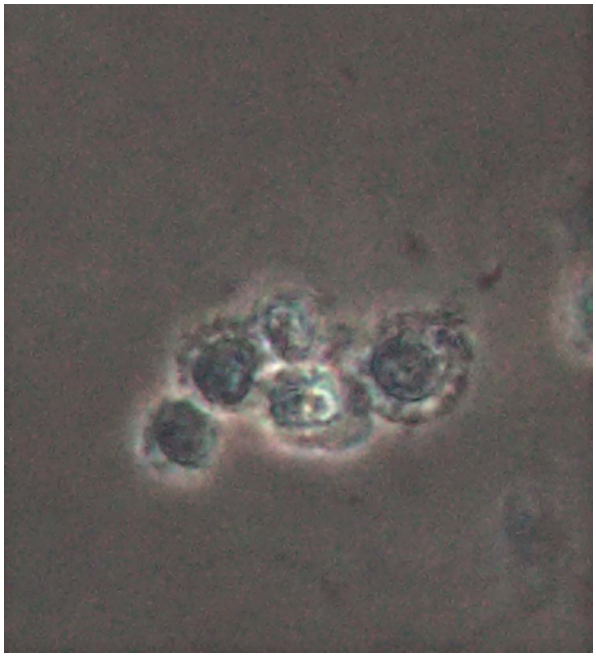

Figure 2. A group of renal tubular epithelial cells under phase contrast. Original magnification ×40.

isomorphic or dysmorphic. Hematuria was considered present if there were three or more erythrocytes per high power field (×40). Hematuria was regarded as glomerular if any of the following three criteria were present: (*1*) ≥40% of erythrocytes were dysmorphic; (*2*) ≥5% of erythrocytes were acanthocytes; or (*3*) there was at least one erythrocytic cast.[10] Lipids, crystals, squamous cells, and bacteria were evaluated in a subjective fashion (absent to 3+) without further quantification. Crystal type identification was performed, including but not limited to crystals composed of whewellite (Figure 4A), weddellite (Figure 4B), uric acid (Figure 4C), and struvite (Figure 4D). The quantification methodology can be found in Supplemental Table 1.

Kidney Biopsy Preparation and Examination

Kidney biopsies were performed under ultrasound guidance with a 16G needle, obtaining two cores. Preparation of the sample was performed with hematoxylin and eosin, periodic acid–Schiff, methenamine silver, and Masson's trichrome stains.

Samples were retrospectively reviewed by three trained nephropathologists (H.S., M.G., and R.B.), who were blinded to other clinical information. They performed an evaluation of a comprehensive set of frequent kidney histologic lesions (Supplemental Table 2). When present, lesions were semi-quantified from 0 (absent) to 3+. Proliferative renal disease was defined as the presence of any of the following histologic lesions: mesangial hypercellularity (Figure 5A), endocapillary hypercellularity (Figure 5B), neutrophils and/or karyorrhexis, fibrinoid necrosis, or cellular/fibrocellular crescents (Figure 5C). Hyaline deposits were defined as homogeneous, dense eosinophilic deposits, often with clear fine lipid droplets (Figure 5D). Wire loops were defined as eosinophilic thickening of the glomerular capillary wall due to subendothelial deposits.

Data Collection

Demographic and clinical data were collected from the electronic medical record and included age, sex, serum creatinine, eGFR (obtained with the eGFR CKD-EPI equation), and urine protein excretion (grams per 24 hours when available; otherwise random urinary protein to creatinine ratio [g/g]) at the time of kidney biopsy.

Statistical Analyses

Data are presented as frequencies for categorical variables and as mean±SD for continuous variables, when normally distributed, or as median (interquartile range) otherwise.

Urinary sediment and histologic variables were analyzed as binary (absent or present). By quantifying their presence (1+ to 3+), we obtained ordinal categories.

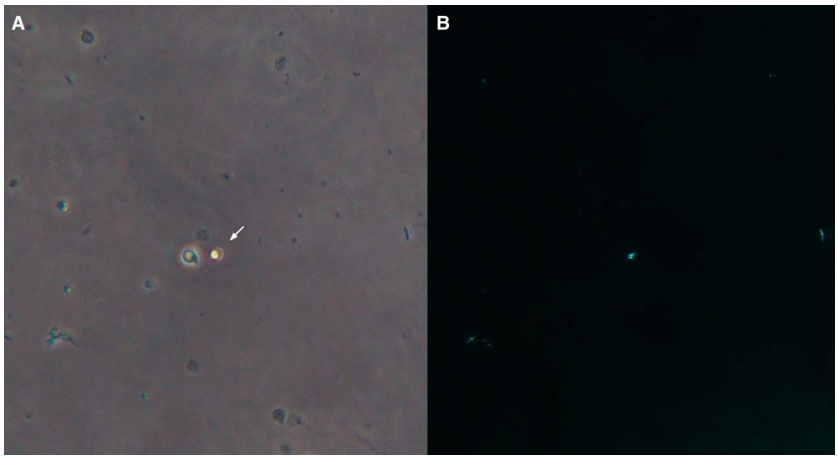

Figure 3. Lipiduria. (A) A lipid drop under phase contrast. Original magnification ×40. (B) The same lipid drop under polarized light. Original magnification ×40.

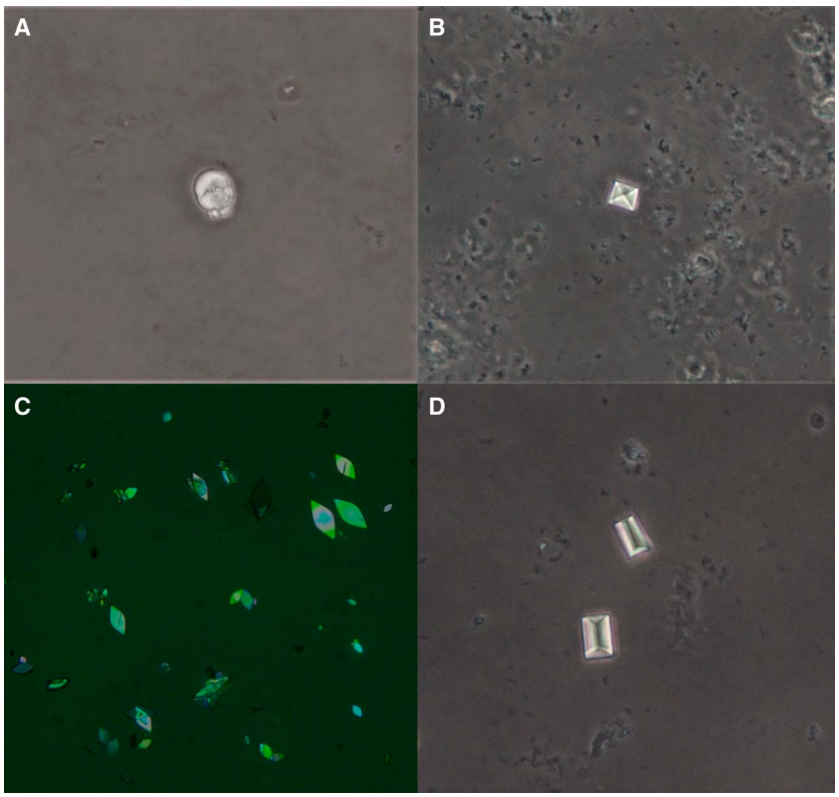

Figure 4. Urinary crystals. (A) Whewellite crystal under phase contrast. Original magnification ×40. (B) Weddellite crystal under phase contrast. Original magnification ×40. (C) Uric acid crystals under polarized light. Original magnification ×10. (D) Struvite crystals under phase contrast. Original magnification ×40.

The outcome variables were the histologic lesions. We performed a logistic regression, using a forward stepwise approach ($P \leq 0.1$) to identify potential associated urinary sediment predictors. After this first analysis, we elaborated a multivariate logistic regression model to account for potential confounders in the association of a urinary sediment predictor and histologic lesions outcomes. We also performed an ordered logistic regression using histologic variables as ordinal outcomes.

All tests were performed using STATA v16.1 (StataCorp, College Station, TX), and $P<0.05$ was considered statistically significant.

Results

From January 2018 to December 2021, 1152 manual U-Seds were performed in our institution. U-Sed was performed for 172 patients who also had a kidney biopsy. Of those, 41 were excluded from analysis: 20 were from kidney transplant patients, eight were not contemporary, five had insufficient tissue for interpretation, five histologic sets of slides were not available, and three had inadequate urine samples. We included 131 patients. Our population's demographic and clinical data comprised mainly White patients, equally distributed among sexes, who presented with varying degrees of kidney dysfunction and/or proteinuria. Table 1 summarizes the demographic and clinical data of patients at time of kidney biopsy.

The most frequent diagnoses were ANCA vasculitis ($n=20$; 15%), proliferative lupus nephritis ($n=18$; 14%), IgA nephropathy ($n=18$; 14%), FSGS ($n=13$; 10%), and membranoproliferative glomerulonephritis ($n=10$; 8%). The full list of histologic diagnosis can be found in Figure 6.

In our samples, we found an elevated frequency of findings suggestive of intrinsic kidney disease, such as dysmorphic hematuria ($n=71$; 54%), leukocyturia ($n=62$; 47%), RTECs ($n=53$; 41%), and lipiduria ($n=45$; 34%), and a low frequency of particles evoking urologic damage, such as isomorphic hematuria ($n=29$; 22%), and urothelial transitional cells ($n=26$; 10%). Isolated U-Sed and histologic review findings are summarized in Tables 2 and 3. Ordinal data can be found in Supplemental Tables 3 and 4.

Performing a univariate analysis, we identified potential predictors ($P<0.1$) in urinary sediment of specific histologic lesions (Supplemental Table 5). Lipids were associated with mesangial expansion and hypercellularity, wire loops and/or hyaline deposits, and internal elastic lamina duplication; RTEC were associated with neutrophils and/or karyorrhexis, fibrinoid necrosis, wire loops and/or hyaline deposits, cellular and fibrocellular crescents, and acute tubular necrosis.

We further explored a multivariate model, which included a urinary profile model as a predictor for the histologic lesion outcomes: presence and type of casts, erythrocytes, leukocytes, RTECs, and lipids. We identified U-Sed characteristics independently associated with

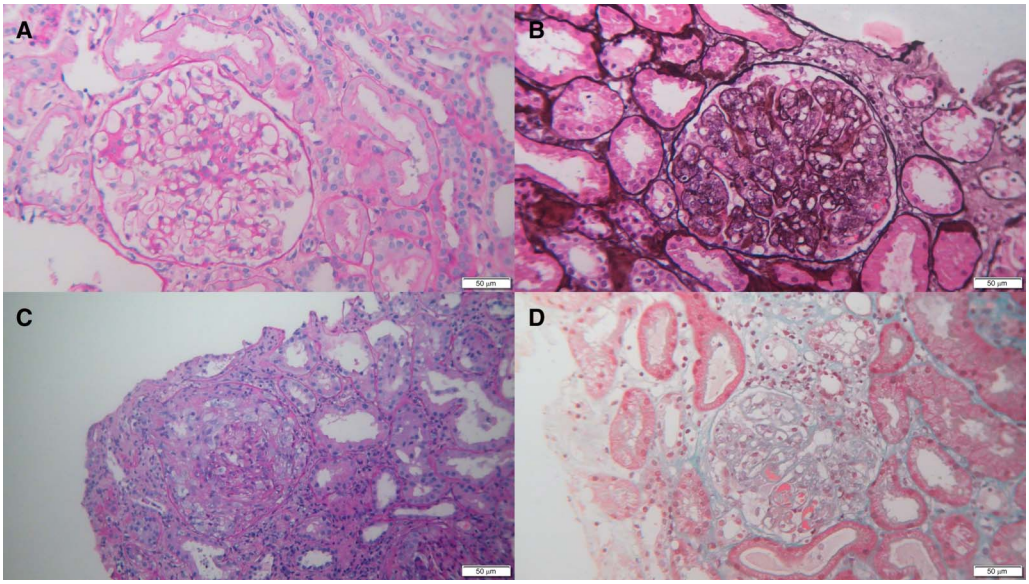

Figure 5. Kidney histological lesions. (A) Mesangial hypercellularity, periodic acid–Schiff. Original magnification ×25. (B) Endocapillary hypercellularity, methenamine silver. Original magnification ×25. (C) Cellular crescent, periodic acid–Schiff. Original magnification ×25. (D) Hyaline deposits, Masson's trichrome. Original magnification ×25.

specific histologic findings, which are summarized in Table 4. Mesangial abnormalities (expansion and hypercellularity) were associated with the presence of lipids. Additionally, lipids were also associated with wire loops and/or hyaline deposits, as was the presence of RTECs. RTECs were also associated with endocapillary hypercellularity, fibrinoid necrosis, and the presence of cellular/fibrocellular crescents, and, as expected, acute tubular necrosis. Surprisingly, dysmorphic hematuria was not associated with glomerular inflammation when adjusting for the presence of RTECs, with only a trend toward association with the presence of cellular/fibrocellular crescents (odds ratio=3.19, P=0.06).

The associations between the histologic lesions and the presence of RTECs kept their statistical strength when controlling for the presence of acute tubular necrosis.

Discussion

This study evaluated the associations between a complete profile of urinary particles by manual microscopy, and histologic findings in patients who performed contemporary urinalysis and kidney biopsy. By focusing on histologic lesions instead of histologic diagnosis, our approach is less limiting and allows for direct analysis of each lesion with a complete urinary sediment profile. We found that the presence of some urinary particles, which are seldom reported by automated analyzers, is associated with active proliferative histologic lesions. These findings should be interpreted in context: this was a population of patients where proliferative kidney diseases represented 51% of the diagnoses (n=67). As such, the presence of RTECs probably reflects the ongoing inflammation and shedding of tubular cells. If the population were composed of patients with AKI after surgical cardiac intervention, the presence of RTECs would not have the same interpretation.

Demographic and clinical characteristics of our population reflected the frequent indications for kidney biopsy. The list and distribution of histologic diagnoses followed an expected distribution for a nephrology department in a tertiary center such as ours, with the most frequent diagnosis being proliferative glomerular diseases and podocytopathies. The distribution of histologic lesions reflected these diagnoses.

In the uni- and multivariate analysis of histologic lesions and urinary sediment particles, we found some interesting associations. As expected, the presence of RTECs was strongly associated with the presence of acute tubular necrosis. This is in line with the work by Perazella *et al.*[11] and Chawla *et al.*[12], with both studies demonstrating that the quantification of epithelial cells (isolated or

Table 1. Demographic and clinical data

Feature	Value
Sex (men/women)	55 (72)/45 (59)
Age (yr)	59.7 (46–72.8)
Race	
White	86 (113)
Black	10 (13)
Other	4 (5)
Serum creatinine (mg/dl)	2.24 (1.33–3.74)
eGFR (ml/min per 1.73 m^2)	37.3±31.3
Proteinuria (g per 24 h or uPRC g/g)	2.8 (0.92–5)
Diabetes	12 (16)
Patients with AKI	31 (41)
Patients with CKD	27 (35)
Patients with AKI on CKD	42 (55)

Data shown as % (n), median (IQR), or mean (SD). uPRC, urinary protein to creatinine ratio; IQR, interquartile range.

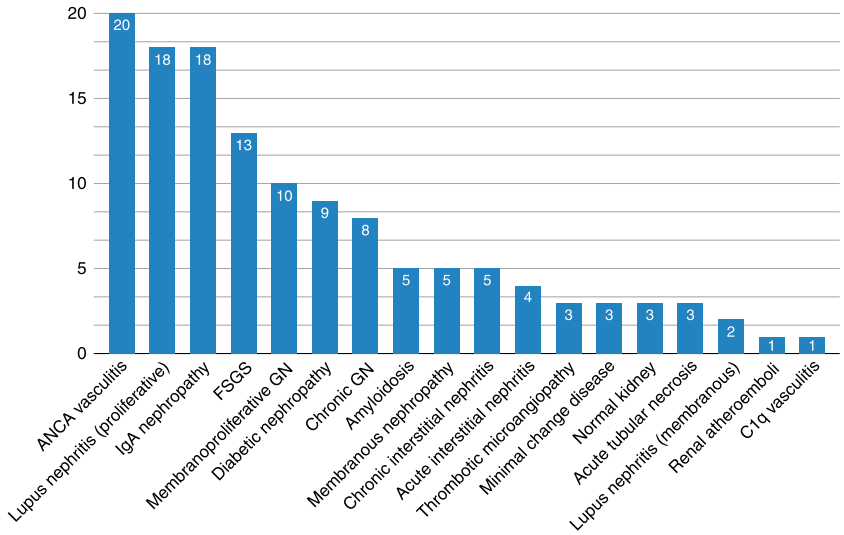

Figure 6. Histologic diagnoses. The most frequent diagnoses were proliferative glomerular diseases and podocytopathies.

included in casts) and granular casts (including muddy brown casts) are associated with the severity of AKI. The role of U-Sed in AKI is further emphasized in a recent study where muddy brown casts had a 100% specificity and 100% positive predictive value for acute tubular injury.[13]

Remarkably, the presence of RTECs associated with the presence of many histologic lesions typically related to acute proliferative diseases, such as endocapillary hypercellularity, neutrophils and/or karyorrhexis, wire loops and/or hyaline deposits, fibrinoid necrosis, and cellular/fibrocellular crescents, even when controlling for the presence of acute tubular necrosis. Many of those histologic lesions are related to proliferative glomerulonephritis. We speculate that the ongoing glomerular inflammation ensuing in glomerular washout of cellular debris, which causes a noxious intratubular milieu, results in RTEC shedding.

The association of the presence of lipiduria with mesangial expansion and hypercellularity is also intriguing, as is the apparent lack of association with podocyte hypertrophy. Even though lipiduria is classically associated with the latter and with nephrotic syndrome,[14] it can also be present even in nonglomerular kidney disease.[15,16] A possible explanation is that the crosstalk between mesangial and endothelial cells is disrupted by the cytokines generated from mesangial injury, allowing for plasma lipids to escape into Bowman's space.[17] Additionally, lipiduria may represent an early marker of podocytopathy, only detectable at this stage by electron microscopy, thereby explaining why we could not find an association with podocyte hypertrophy.

We expected dysmorphic erythrocytes to associate strongly with a wide array of proliferative histologic lesions. We have two possible explanations for our results. First, although specific for glomerular disease, the sensibility of dysmorphic hematuria can be variable.[18] Second, our population presents a high prevalence of dysmorphic hematuria (found in 54% of patients) and glomerular histologic lesions (present in 92% of patients). In such a population, dysmorphic hematuria may be a poor discriminator of which glomerular lesions one can expect to find. This held true, even when considering only Köhler's 5% acanthocyte criteria for classifying dysmorphic hematuria.[19]

Some limitations of this study should be stated. The sample size limited the statistical analysis of ordinal data, and the retrospective nature of the study did not allow for

Table 2. Urinary sediment particles prevalence

Finding	Absent	Present	Finding	Absent	Present
Casts	30 (23)	101 (77)	Lipids	86 (66)	45 (34)
Type of casts (exclusively hyaline and/or granular versus others)	48 (48)	53 (53)	Superficial UTC	111 (85)	20 (15)
Erythrocytes	31 (24)	100 (76)	Deep UTC	125 (95)	6 (5)
Erythrocyte morphology (isomorphic/dysmorphic)	29 (29)	71 (71)	Crystals	119 (91)	12 (9)
Leukocytes	69 (53)	62 (47)	Squamous cells	95 (73)	36 (28)
RTECs	78 (60)	53 (41)	Bacteria	114 (87)	17 (13)

Data shown as *n* (%). UTC, urothelial transitional cell; RTEC, renal tubular epithelial cell.

Table 3. Histologic lesions prevalence

Glomerular Findings			Interstitial Findings			Vascular Findings		
Finding	Absent	Present	Finding	Absent	Present	Finding	Absent	Present
Total glomerulosclerosis score	52 (41)	75 (59)	Interstitial fibrosis	38 (29)	93 (71)	Intima hypertrophy	78 (62)	47 (38)
Glomerular hypertrophy	104 (83)	21 (17)	Tubular atrophy	39 (30)	92 (70)	Internal elastic lamina duplication	87 (70)	37 (30)
Basal glomerular membrane thickening/ subepithelial deposits	105 (83)	22 (17)	Interstitial inflammation	25 (19)	106 (81)	Arteriolar hyalinosis	103 (81)	25 (20)
Hyalinosis/segmental sclerosis	96 (76)	31 (24)	Acute tubular necrosis	69 (53)	62 (47)	Fibrinoid necrosis	127 (98)	2 (2)
Podocyte hypertrophy	93 (73)	34 (27)	Protein tubular reabsorption	107 (83)	22 (17)	Vascular inflammation	125 (98)	3 (2)
Mesangial expansion	74 (58)	53 (42)	Foamy cells	127 (97)	4 (3)	Amyloid deposits	123 (95)	6 (5)
Mesangial hypercellularity	88 (70)	38 (30)	Crystal deposition	128 (99)	1 (0.8)			
Endocapillary hypercellularity	88 (70)	38 (30)	Intratubular casts	45 (34)	86 (66)			
Neutrophils and/or karyorrhexis	104 (81)	24 (19)	Intratubular neutrophils	127 (97)	4 (3)			
Wire loops and/or hyaline deposits	101 (80)	26 (21)	Interstitial hemorrhage	125 (95)	6 (5)			
Fibrinoid necrosis	105 (83)	22 (17)	Amyloid deposits	130 (99)	1 (0.8)			
Cellular/fibrocellular crescents	98 (77)	30 (23)	Granulomas	131 (100)	0 (0)			
Fibrous crescents	111 (87)	16 (13)						
Amyloid deposits	123 (96)	5 (4)						

Data shown as *n* (%).

immunofluorescence. There is also the bias of convenience sampling: this was a single-center population of patients who had clinical indication for kidney biopsy. This was also a descriptive retrospective study, which analyzes exclusively patients who had kidney biopsy and urinary sediment evaluation, with a significant proportion having AKI or AKI on CKD (96/131; 73%). Nephrologists frequently attend to patients who have AKI where kidney biopsy is not

Table 4. Multivariate logistic regression model: outcome variable as the histologic lesions; urinary sediment particles as predictors

Histologic Finding (Outcome)	U-Sed Finding (Predictor)	OR (95% Confidence Interval)	*P* Value
Mesangial expansion	Lipids	2.86 (1.3 to 6.3)	0.009
Mesangial hypercellularity	Lipids	2.44 (1.06 to 5.58)	0.04
Podocyte hypertrophy	Lipids	0.97 (0.41 to 2.29)	0.95
Endocapillary hypercellularity	RTECs	3.17 (1.36 to 7.39)	0.007
Neutrophils and/or karyorrhexis	RTECs	4.51 (1.61 to 12.61)	0.004
Wire loops and/or hyaline deposits	RTECs	2.59 (0.99 to 6.8)	0.05
	Lipids	2.89 (1.13 to 7.37)	0.03
Fibrinoid necrosis	Leukocytes	2.72 (0.96 to 7.73)	0.06
	RTECs	4.35 (1.48 to 12.74)	0.007
Cellular/fibrocellular crescents	RTECs	5.27 (1.95 to 14.26)	0.001
	Dysmorphic hematuria	3.19 (0.96 to 6.87)	0.06
Acute tubular necrosis	RTECs	2.31 (1.08 to 4.97)	0.03

U-Sed, urinary sediment; OR, odds ratio; RTECs, renal tubular epithelial cells.

performed. That can happen for many reasons, such as the presence of contraindication or because there is an obvious culprit such as acute tubular necrosis. We cannot sustain that the associations that we have found in our population would similarly be present in such cases. We also did not use Sternheimer–Malbin stain when evaluating U-Sed, and we only performed electron microscopy when histologic diagnosis was uncertain. A main strength of this study was that the histologic review was blinded to other clinical information. Additionally, we evaluated a comprehensive set of histologic lesions and urinary particles—an approach not employed to this extent in the published literature.

In conclusion, RTECs, dysmorphic erythrocytes, and lipids are urinary particles that are frequently missed by automated urine analyzers, whereas they are identifiable with a proficient manual urinary sediment evaluation. It is important not to misidentify them because their presence appears to be a red flag for relevant proliferative histologic lesions. As such, manual U-Sed is an important tool for physicians who manage patients with kidney disease, and it may help to shape the indication for performing a kidney biopsy.

Disclosures

A.C. Ferreira reports consultancy for Viphor; honoraria from Amgen and Viphor; and an advisory or leadership role for the Portuguese Society of Nephrology (unpaid). N. Moreira Fonseca reports research funding from Bayer and GSK, and honoraria from Fresenius Medical Care. F. Nolasco reports an advisory or leadership role for Diaverum and the Portuguese Society of Nephrology. All remaining authors have nothing to disclose.

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Author Contributions

R. Barata, A.C. Ferreira, M. Góis, N. Moreira Fonseca, F. Nolasco, and H. Sousa reviewed and edited the manuscript; R. Barata, M. Góis, N. Moreira Fonseca, D. Navarro, and H. Sousa were responsible for data curation; A.C. Ferreira and N. Moreira Fonseca were responsible for validation; A.C. Ferreira, N. Moreira Fonseca, and D. Navarro were responsible for conceptualization; A.C. Ferreira and D. Navarro were responsible for formal analysis, the investigation, and the methodology; A.C. Ferreira and F. Nolasco were responsible for supervision; N. Moreira Fonseca and D. Navarro wrote the original draft of the manuscript; and D. Navarro was responsible for project administration and resources.

Supplemental Material

This article contains the following supplemental material online at http://links.lww.com/KN9/A314.

Supplemental Table 1. Semi-quantitative evaluation of urinary sediment findings.

Supplemental Table 2. Semi-quantitative evaluation of histological lesions.

Supplemental Table 3. Urinary sediment particles prevalence—ordinal data.

Supplemental Table 4. Histological lesions—ordinal data.

Supplemental Table 5. Univariate logistic regression stepwise approach: outcome variable as the histological lesions; urinary sediment particles as predictors.

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