

# Risk Stratification for Hydronephrosis in the Evaluation of Acute Kidney Injury

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## Research article

**Keywords:** Acute Kidney Injury, Renal Ultrasound, Risk Stratification, Clinician Decision Tools

**Posted Date:** June 5th, 2020

**DOI:** <https://doi.org/10.21203/rs.2.10735/v2>

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# Abstract

**Background:** Renal ultrasounds (RUS) are commonly ordered in hospitalized patients with acute kidney injury (AKI). Clinical decision support tools could be used to inform which patients may benefit from RUS to rule out hydronephrosis, however current risk stratification frameworks are underutilized.

**Methods:** We performed a cross-sectional study of hospitalized adults with AKI at a large, tertiary, academic medical center who had a RUS ordered. We validated an existing risk stratification framework to predict hydronephrosis based on 7 criteria. Outcomes were presence of unilateral or bilateral hydronephrosis and incidental findings on RUS.

**Results:** Two hundred and eighty-one patients were included in the study cohort; 111 (40%), 76 (27%), and 94 (33%) patients were in the high-, medium-, and low-risk groups for hydronephrosis, respectively, based on the risk stratification framework. Thirty-five patients (12%) were found to have hydronephrosis, of whom 86% were captured in the high-risk group. A nephrology consult was involved in 168 (60%) patients and RUS was recommended by the nephrology service in 95 (57%) cases. Of the 95 patients recommended for a RUS, 9 patients (9%) had hydronephrosis. Among the patients with a nephrology consultation, 9 (56%) of the 16 total patients with hydronephrosis were recommended to obtain a RUS.

**Conclusions:** We further validated a risk stratification framework for hydronephrosis and found that nephrology recommendations predicted hydronephrosis less well than the risk stratification framework. Decision support tools for hydronephrosis may be useful to supplement clinical judgement in the evaluation of AKI.

## Background

Renal ultrasounds (RUS) are commonly ordered in hospitalized patients with acute kidney injury (AKI) to evaluate kidney size, parenchyma, and rule out obstructive pathology.<sup>1,2</sup> Hydronephrosis causing obstructive uropathy is an uncommon cause of AKI, and clinical decision support tools could be used to inform which patients may benefit from RUS to rule out hydronephrosis.<sup>1,3-10</sup>

A risk stratification framework to identify patients who are high-risk for having hydronephrosis has been previously described and validated, but is currently underutilized.<sup>11,12</sup> Several factors may account for this: lack of knowledge of the framework, lack of workflow integration, and lack of assessment of costs of unnecessary imaging. Recommendations from nephrologists also inform RUS ordering for hospitalized patients with AKI, however the relationship between the risk stratification framework and nephrologist recommendations is unclear.

In this study, we validated the risk stratification framework for hydronephrosis at our institution and compared it to nephrology consultation recommendations for RUS ordering. We also examined the reason for exam, incidental findings, and additional workup from RUS. Understanding the potential role of clinical

decision support tools to risk stratify patients for hydronephrosis may improve the appropriateness of RUS ordering in the clinical evaluation of AKI.<sup>13</sup>

## Methods

### Study Design and Population

We performed a cross-sectional study of hospitalized adults at the Mount Sinai Hospital, an urban, 1134-bed academic medical center in New York, NY. We included all patients who (1) were admitted to the hospitalist service between June 9, 2013 and October 24, 2014, (2) experienced AKI (defined as creatinine rise  $> 0.3$ ), and (3) had a formal RUS ordered. Imaging was performed by trained, experienced ultrasonographers.

### Risk Stratification

Our primary predictor was high-risk, medium-risk, or low-risk category for hydronephrosis based on the risk stratification framework developed by Licurse et al. (Supplemental Table 1).<sup>12</sup> The 7 criteria included in the framework are: a past history of hydronephrosis (4 points), and nonblack race, history of recurrent urinary tract infections (UTIs), diagnosis consistent with possible obstruction (abdominal or pelvic mass, benign prostatic hypertrophy, pelvic surgery, or neurogenic bladder) absence of exposure to inpatient nephrotoxic agents (aspirin  $> 81$  mg, diuretics, angiotensin converting enzyme inhibitors, or vancomycin), absence of congestive heart failure, and/or absence of prerenal AKI (pressor use or sepsis) (1 point each). A total score of 4 or more points was classified as high-risk, 3 points as medium-risk, and 2 or fewer points as low-risk.<sup>12</sup> We performed an additional sensitivity analysis defining prerenal AKI as pressor use, sepsis, or history of hypotension defined as at least 2 consecutive blood pressure measurements below 80 mm Hg systolic or below 60 mm Hg diastolic. Additional predictors were presence of nephrology consultation and RUS recommended by nephrology.

We performed a retrospective chart review of data in the electronic health record (EHR) to determine the presence or absence of each predictor, using only data available before the RUS was ordered. One author (JZ) performed the initial chart review, which was recorded in the REDCap web-based application (Vanderbilt University). Another author (CG) independently reviewed a random selection of 10% of medical records with 96% agreement (Cohen's  $\kappa = 0.913$ ,  $p < 0.001$ ).

### Outcomes

Our primary outcome was presence of unilateral or bilateral hydronephrosis. Secondary outcomes were incidental findings in the RUS radiology report, urologic procedure after RUS, and further imaging as a result of RUS during the hospitalization. Incidental findings were classified into the following categories: increased echogenicity, simple cysts, complex cysts, renal atrophy or cortical thinning, non-obstructive nephrolithiasis, renal enlargement, renal mass, absence of kidney, obstructive nephrolithiasis, or other.<sup>14</sup>

We also determined the reason for RUS ordering based on comments written in “Reason for exam” field in the RUS order.

## Analysis

We described patient characteristics according to risk group for hydronephrosis, presence of nephrology consultation, and RUS recommended by the consult service. We determined the prevalence of patients with hydronephrosis by risk group, nephrology consultation, and RUS recommendation. Chi-squared and analysis of variance tests were performed to determine if the proportion of patients in each group had different characteristics and risks of hydronephrosis. We calculated Pearson correlation coefficients to assess the correlation of factors in the risk score with hydronephrosis in our population. Analyses were performed in Stata statistical software.<sup>15</sup> Our study was reviewed and approved by the Mount Sinai Institutional Review Board.

## Results

### Patient Demographics

Three hundred and twenty-two patients admitted to the hospitalist service received a RUS during the study period. Forty-one of these patients were not included because they did not have AKI. The final cohort included 281 patients. The mean age was 64 years, 57% of patients were male, and 63% were non-black (Table 1).

### Risk Stratification Framework

There were 111 (40%), 76 (27%), and 94 (33%) patients in the high-, medium-, and low-risk groups for hydronephrosis, respectively. Patients in the high-risk group were less likely to be black (14% vs. 63%,  $p < 0.001$ ) and had higher creatinine levels at admission (4.2 vs 3.0 mg/dL,  $p = 0.048$ ), compared with those in the low-risk group (Table 1). Thirty-five patients (12%) were found to have hydronephrosis, of whom 86% were captured in the high-risk group. Thirty of the high-risk patients (27%), one medium-risk patient (1%), and four of the low-risk patients (4%) were found to have hydronephrosis on RUS (Table 3). In terms of hydronephrosis severity, 53% of hydronephrosis was bilateral, 17% was severe, 39% moderate, and 56% mild. The prevalence of patients with hydronephrosis in the high-risk group was significantly higher compared to the combined medium- and low-risk group ( $p < 0.001$ ), which did not change after sensitivity analysis changing the definition of prerenal AKI (Supplemental Table 2). Five of these seven criteria were found to be statistically significantly correlated with increased risk of hydronephrosis in our population (Supplemental Table 3).

### Nephrology Consultation

A nephrology consult was involved in 168 patients (60%). Patients with nephrology consultation had fewer recurrent UTIs (2 vs. 17%,  $p < 0.001$ ), higher creatinine levels at admission (4.7 vs 2.2 mg/dL,

p<0.001), and higher baseline creatinine (2.1 vs 1.3mg/dL, p<0.001) compared to those who did not have nephrology consultation (Table 2). RUS was recommended by the nephrology service in 95 of 168 cases (57%). Similarly, in the low-risk patient group, of the 61 low-risk patients (65%) who had a nephrology consult, 35 (57%) were recommended to obtain a RUS. Of the 95 patients recommended for a RUS, 9 patients (9%) had hydronephrosis. Among the patients with a nephrology consultation, 9 (56%) of the 16 total patients with hydronephrosis were recommended to obtain a RUS (Table 3).

### **Reason for Exam, Incidental Findings, and Additional Workup**

The majority of RUS were ordered for AKI or renal failure (57%) or to rule out hydronephrosis or obstruction (24%). Additional reasons for exam were oliguria or anuria, rule out pyelonephritis or abscess, evaluate for nephrolithiasis, and others (Table 4).

Only 37 patients (13%) had no abnormal findings on RUS. Even within the low-risk group, only 16% of RUS were without abnormalities. The most common finding was increased echogenicity, which occurred in 195 patients (69%). One hundred and two (36%) had simple cysts and 34 (12%) had complex cysts (Table 5).

Four patients (1.4%) in the entire cohort underwent a urologic procedure, all of whom were in the high-risk group. Thirty-five patients (12%) received further imaging as a result of the RUS findings. Of the patients who underwent further imaging, 21 (60%), 11 (31%), and 3 (9%) were in the high-, medium-, and low-risk groups, respectively.

## **Discussion**

We found that a risk stratification framework predicted 86% of episodes of hydronephrosis in hospitalized patients with AKI who had obtained a RUS.<sup>11,12</sup> The majority (60%) of RUS were ordered on medium- or low-risk patients, while only 3% of these patients were found to have hydronephrosis. Previous analyses have found that appropriateness of certain diagnostic testing in AKI may increase when recommended by nephrology consultation, and our analysis extends previous validations by evaluating the role of nephrology consultation in RUS ordering.<sup>4,11</sup> We found that the risk stratification tool predicted 86% of hydronephrosis cases, whereas RUS was recommended by nephrology consultation in 56% of hydronephrosis cases.

The risk stratification framework studied was aimed specifically at identifying obstructive pathology on RUS in patients with AKI. To assess if consulting or primary teams requesting RUS were evaluating factors other than hydronephrosis, such as size or echogenicity of kidneys, we assessed reasons for RUS ordering listed in the "Reason for exam" field. The majority of RUS were ordered for AKI or renal failure (57%), without further explanation. We were thus unable to reliably assess the clinical rationale for RUS ordering. Twenty-four percent of RUS listed rule out hydronephrosis or obstruction as the reason for exam. Only 3 RUS specifically listed the reason for exam as evaluating kidney size, echogenicity, or chronicity of kidney disease.

We found that the majority (87%) of RUS had incidental findings, which was similar to prior estimates.<sup>16</sup> Incidental findings pose challenges to physicians and patients, and can cause patient anxiety and additional interventions.<sup>17</sup> While the majority of RUS had abnormalities, there was a low prevalence of urologic procedures and further imaging during the hospitalization. Importantly, over 10% of patients had important incidental findings such as complex cysts, which may require further imaging and evaluation. The high prevalence of incidental findings with RUS imaging raises questions about when disclosure of these findings is warranted.<sup>18</sup>

Our findings highlight the potential utility of clinical decision support tools to supplement comprehensive clinical evaluation in AKI. The major strength in our approach is the detailed chart review used in our analysis. There are also limitations to our results. We conducted a single-site study and did not assess all patients with AKI, only those who had a RUS ordered. Our analysis was limited to information present in the EHR, so we did not capture recommendations that may have been given verbally. In some cases where RUS was obtained prior to nephrology consultation, it was unclear based on the available documentation whether the consultant would have also recommended the study. Lastly, the definition used for prerenal AKI was use of pressors or history of sepsis, which may lack sensitivity for other clinically significant hypovolemic states.<sup>12</sup>

## Conclusions

In conclusion, we further validated a risk stratification framework for hydronephrosis at our institution. We found nephrology consultation predicted hydronephrosis less well than the risk stratification framework. There was a very high prevalence of incidental findings, but additional imaging and procedures were low during the inpatient hospitalization. Our findings highlight the potential additive role of decision support tools for hydronephrosis in supplementing clinical judgement in the evaluation of AKI.

## Declarations

**Ethics approval and consent to participate:** This study was reviewed and approved by the Mount Sinai Institutional Review Board and Program for the Protection of Human Subjects (study number available upon request).

**Consent for publication:** Not applicable.

**Availability of data and material:** The datasets generated and analyzed during the current study are not publicly available as they contain protected health information, but summary statistics and statistical code are available from the corresponding author on reasonable request.

**Competing interests:** The authors have no conflicts of interest to disclose.

**Funding:** This work was not supported by funding.

**Authors' contributions:** Research idea and study design: SLT, HC, CG; data acquisition: JZ, CG; data analysis/interpretation: SLT, JZ; statistical analysis: SLT, JZ; supervision or mentorship: HC, CG. Each author contributed important intellectual content during manuscript drafting or revision and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

**Acknowledgements:** The authors thank Dr. Andrew S. Dunn for editorial assistance.

## Abbreviations

Renal ultrasound (RUS), acute kidney injury (AKI), urinary tract infections (UTIs), electronic health record (EHR)

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## Tables

**Table 1. Baseline characteristics of patients by risk group for hydronephrosis.**

	High-risk (%, n =111)	Medium- risk (%, n =76)	Low-risk (%, n =94)	p-value
<b>Sociodemographics</b>				
Age				
18-39	9%	7%	12%	0.30
40-59	19%	22%	31%	
60-74	37%	42%	33%	
≥75	35%	29%	24%	
Sex				
Male	64%	51%	53%	0.15
Female	36%	49%	47%	
Race/Ethnicity				
Non-Hispanic White	34%	24%	11%	<0.001*
Non-Hispanic Black	14%	39%	63%	
Hispanic	32%	29%	22%	
Other	20%	8%	4%	
<b>RiskCriteria</b>				
History of hydronephrosis	27%	0%	0%	<0.001*
Nonblack race	86%	61%	37%	<0.001*
History of recurrent UTIs	18%	3%	1%	<0.001*
Diagnosis c/w possible obstruction	70%	45%	16%	<0.001*
Absence of nephrotoxins	68%	39%	10%	<0.001*
Absence of CHF	92%	86%	44%	<0.001*
Absence of prerenal AKI	78%	67%	53%	0.005*
<b>LaboratoryResults</b>				
Creatinine at admission, mean(SD)	4.2 (4.1)	3.7 (3.9)	3.0 (2.3)	0.048*
Baseline Creatinine, mean(SD)	2 (1.5)	1.8 (1.3)	1.6 (0.9)	0.078

\* Statistically significant at p<0.05.

UTIs - urinary tract infections; CHF - congestive heart failure; AKI - acute kidney injury; SD - standard deviation.

**Table 2. Baseline characteristics of patients by nephrology consultation.**

	Nephrology Consult, RUS Recommended (% , n = 95)	Nephrology Consult, RUS Not Recommended (% , n = 73)	No Nephrology Consult (% , n = 113)	p-value
<b>Sociodemographics</b>				
<b>Age</b>				
18-39	12%	7%	9%	0.70
40-59	23%	26%	23%	
60-74	41%	37%	34%	
≥75	24%	30%	35%	
<b>Sex</b>				
Male	56%	56%	58%	0.92
Female	44%	44%	42%	
<b>Race/Ethnicity</b>				
Non-Hispanic White	28%	22%	20%	0.30
Non-Hispanic Black	31%	36%	44%	
Hispanic	28%	34%	23%	
Other	13%	8%	12%	
<b>Risk Criteria</b>				
History of hydronephrosis	9%	10%	12%	0.75
Nonblack race	69%	64%	56%	0.12
History of recurrent UTIs	1%	4%	17%	<0.001*
Diagnosis c/w possible obstruction	40%	45%	50%	0.39
Absence of nephrotoxins	39%	37%	44%	0.57
Absence of CHF	67%	77%	78%	0.19
Absence of prerenal AKI	68%	60%	66%	0.53
<b>Laboratory Results</b>				
Creatinine at admission, mean(SD)	5.2 (4.4)	4.0 (3.6)	2.2 (1.6)	<0.001*
Baseline Creatinine, mean(SD)	2.3 (1.4)	2.0 (1.4)	1.3 (0.7)	<0.001*

\* Statistically significant at p<0.05.

RUS - renal ultrasound; UTIs - urinary tract infections; CHF - congestive heart failure; AKI - acute kidney injury; SD - standard deviation.

**Table 3: Riskstratification versus nephrology consult recommendation for RUS in-hospitalized patients with AKI and prevalence of hydronephrosis.**

	Total cases (N =281)	Hydronephrosis (N =35)	Hydronephrosis(%)
<b>Risk Stratification</b>			
High-risk	111	30	27%
Medium-risk	76	1	1%
Low-risk	94	4	4%
<b>Nephrology Consult Recommendation</b>			
RUS Recommended	95	9	9%
Not Recommended	73	7	10%
No Nephrology Consult	113	19	17%

RUS - renal ultrasound; AKI -acute kidney injury.

**Table 4: Reason for RUS exam.**

Reason for Exam	Total (N = 236)* Number(%)
AKI or renal failure	134 (57)
Rule out hydronephrosis or obstruction	56 (24)
Oliguria or anuria	9 (4)
Rule out pyelonephritis or abscess	6 (3)
Other	6 (3)
Evaluate for nephrolithiasis	4 (2)
ESRD or new ESRD	4 (2)
CKD	4 (2)
Recurrent UTIs	3 (1)
Costovertebral tenderness or flank pain	3 (1)
Evaluate ureteral stent or nephrostomy tube	2 (1)
Hematuria	2 (1)
Concern for hepatorenal syndrome	2 (1)
Renal cyst or mass seen on CT scan	1 (0.4)
Obstructive nephrolithiasis	1 (0.4)

\*Excludes exams with "Reason for exam" listed as blank or N/A.

RUS - Renal ultrasound; AKI -acute kidney injury; ESRD - end-stage renal disease; CKD - chronic kidney disease; UTIs - urinary tract infections; CT - computed tomography.

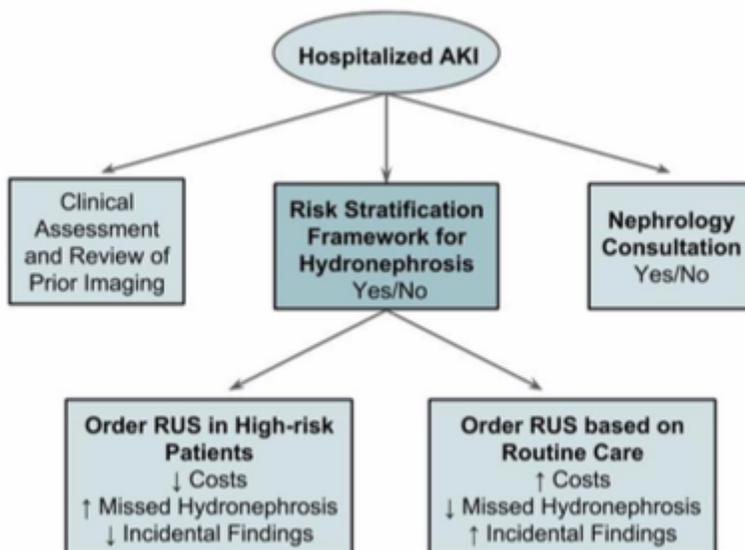
**Table 5: Ultrasoundfindings by risk group.**

Finding	High-risk (%, n =111)	Medium-risk (%, n =76)	Low-risk (%, n =94)	p-value
Increased renal parenchymalechogenicity	65%	72%	72%	0.41
Simple cyst	39%	33%	35%	0.70
Other	25%	20%	27%	0.55
Complex cyst	14%	12%	11%	0.82
Bilateralhydronephrosis	14%	1%	1%	<0.001*
Unilateralhydronephrosis	13%	0%	3%	0.001*
Renal atrophy or corticalthinning	11%	13%	7%	0.47
No abnormalities	10%	15%	16%	0.41
Non-obstructivenephrolithiasis	8%	5%	9%	0.69
Renal mass	4%	3%	2%	0.81
Renal enlargement	4%	3%	2%	0.81
Absence of kidney (whole orpartial, congenital or acquired)	4%	1%	3%	0.63
Obstructivenephrolithiasis	2%	1%	0%	0.44

\* Statistically significant at p<0.05.

There were no patients withstaghorn calculi, anatomic urinary tract abnormalities, mass ofgenitourinary tract, other abdominal mass, pelvic kidney, orhorseshoe kidney.

## Figures



AKI – acute kidney injury; RUS – renal ultrasound.

## Figure 1

Framework for ordering RUS in hospitalized patients with AKI.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [STROBEchecklistRUSAKI.doc](#)