Urine leaks in children sustaining blunt renal trauma

Muhammad Owais Abdul Ghani, MBBS, Elizabeth Snyder, MD, Mark C. Xu, MD, Katlyn G. McKay, BS, Jarrett Foster, MD, Carmen Tong, DO, Douglas B. Clayton, MD, Amber Greeno, BSN, Bassil Azam, MBBS, Shilin Zhao, MD, Marta Hernanz-Schulman, MD, *and* **Harold N. Lovvorn, III, MD***, Nashville, Tennessee*

BACKGROUND: Few consensus statements exist to guide the timely diagnosis and management of urine leaks in children sustaining blunt renal trauma (BRT). The aims of this study were to characterize kidney injuries among children who sustain BRT, evaluate risk factors for urine leaks, and describe the negative impact of urinoma on patient outcomes and resource consumption.

METHODS: A retrospective review was performed of 347 patients, younger than 19 years, who presented with BRT to a single American College of Surgeons–verified Level I Pediatric Trauma Center between 2005 and 2020. Frequency of and risk factors for urine leak after BRT were evaluated, and impact on patient outcomes and resource utilization were analyzed.

RESULTS: In total, 44 (12.7%) patients developed urine leaks, which exclusively presented among injury Grade 3 (n = 5; 11.4%), Grade 4 (n = 27; 61.4%), and Grade 5 (n = 12; 27.3%). A minority of urine leaks (n = 20; 45.5%) were discovered on presenting CT scan but all within 3 days. Kidney-specific operative procedures (nephrectomy, cystoscopy with J/ureteral stent, percutaneous nephrostomy) were more common among urine leak patients (n = 17; 38.6%) compared with patients without urine leaks (n = 3; 1.0%; $p = 0.001$). Patients with urine leak had more frequent febrile episodes during hospital stay (n = 24; 54.5%; $p = 0.001$) and showed increased overall 90-day readmission rates (n = 14; 33.3%; $p < 0.001$). Independent risk factors that associated with urine leak were higher grade (odds ratio [OR], 7.9; 95% confidence interval [CI], 2.6–24.3; $p < 0.001$), upper-lateral quadrant injuries (OR, 2.9; 95% CI, 1.2–7.1; $p = 0.02$), and isolated BRT (OR, 2.6; 95% CI, 1.0–6.5; $p = 0.04$).

CONCLUSION: In a large cohort of children sustaining BRT, urine leaks result in considerable morbidity, including more febrile episodes, greater 90-day readmission rates, and increased operative or image-guided procedures. This study is the first to examine the relationship between kidney quadrant injury and urine leaks. Higher grade (Grade 4–5) injury, upper lateral quadrant location, and isolated BRT were independently predictive of urine leaks. (*J Trauma Acute Care Surg.* 2022;93: 376–384. Copyright © 2022 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic/Care Management; Level III.

KEY WORDS: Pediatric trauma; blunt abdominal trauma; blunt renal trauma; urine leak; urinoma.

Renal injury occurs in 1% to 5% of all trauma patients, of whom 90% sustain blunt mechanisms.[1,2] Children show an increased frequency of renal trauma compared with adults, owing to developmental differences in anatomy, including larger kidney to body ratio, less perirenal fat, thinner fascia and muscle, and a more pliable thoracic cage.[3,4] Among adults, urinary leak is a frequent complication after renal trauma, having an incidence of 30% to 50% following high-grade injuries, but is less well characterized in the pediatric population.[5] Although most renal injures are managed nonoperatively in children, urinary extravasation can cause delayed complications that result in additional interventions, making timely diagnosis and management important to reduce morbidity.[6–8] Consensus exists that most kidney injuries can be treated initially with conservative management, which is well established for hemodynamically stable children having American Association for the Surgery of Trauma (AAST) Grades 1 to 3 injuries. Moreover, initial observation of blunt, Grade 4 renal lacerations has become standard of care as well.[6,7]

Subsequent management of stable patients sustaining higher-grade injuries and urinary leak is less well established, however, as many existing guidelines are based on low levels of evidence.[5] The European Association of Urology recommends that follow-up imaging is performed in AAST Grades 4 and 5 injuries to assess for leak, which, if persistent, should be treated with ureteral stent placement or percutaneous drainage.[9] These recommendations generally align with the American Urological Association guidelines, although the American Urological Association advises more aggressive intervention for injuries involving the renal pelvis.[1] However, no set of guidelines establishes the optimal timing of follow-up imaging or the severity (in terms of persistence or symptoms) of urinary leak that requires drainage or other intervention, and certainly not for children. Moreover, no standardized clinical algorithms or radiological features exist to warn trauma providers of impending urine leaks.

To explore the optimal management strategies for trauma-induced urine leak in children, our attention was directed at uncovering clinical characteristics that predict urine leaks (at the level of the kidney) on admission or after failure of conservative management. This study aimed to identify risk factors for urine

Submitted: March 5, 2021, Revised: November 5, 2021, Accepted: November 12, 2021, Published online: January 5, 2022.
From the Department of Pediatric Surgery (M.O.A.G., M.C.X., K.G.M., J.F., A.G., H.N.L.), Department of Radiology and Radiological Sciences (M.H.-S.), Department of Pediatric Urology (E.S., C.T., D.B.C.), Monroe Carell Jr. Children's Hospital at Vanderbilt; Department of Biostatics (S.Z.), Vanderbilt University Medical Center, Nashville, Tennessee; and Newham University Hospital (B.A.), Barts Health, London, United Kingdom.
This study was presented at the Pediatric Trauma Society 7th Annual meeting in New Orleans LA, November 4–7, 2020
Address for reprints: Muhammad Owais Abdul Ghani, MBBS, Department of Pediatric Surgery, Monroe Carell Jr. Children's Hospital at Vanderbilt, Suite 7102, 2200 Children's Way, Doctor's Office Tower, Nashville, TN 37232; email: muhammad.o.ghani@vumc.org.

DOI: 10.1097/TA.0000000000003532

leaks in pediatric blunt renal trauma (BRT) patients that improve surgical decision-making and to optimize resource-utilization and patient outcomes. We hypothesized that urine leaks can be predicted based upon certain features of patients at initial admission such as kidney injury location, presence of hematuria, and higher grade.

METHODS

Our independent and free-standing Pediatric Level I Trauma Center was verified through the American College of Surgeons (ACS) in 2016.[10] We queried our comprehensive

TABLE 1. Demographics and Presenting Factors

Variable	N	No Urine Leak (n = 303)	Urine Leak (n = 44)	Combined (N = 347)	*p*
Sex	347				0.8
Male		38% (116)	36% (16)	38% (132)	
Female		62% (187)	64% (28)	62% (215)	
Race	347				0.6
White		84% (254)	77% (34)	83% (288)	
Black		10% (29)	14% (6)	10% (35)	
Asian		1% (4)	2% (1)	1% (5)	
Other		4% (11)	7% (3)	4% (14)	
Unknown		2% (5)	0% (0)	1% (5)	
ISS	282	24 (14–34)	17 (16–29)	22 (14–34)	0.3
Injury context	319				<0.001
Isolated BRT		13% (37)	40% (17)	17% (54)	
Multisystem trauma		87% (239)	60% (26)	83% (265)	
Vital status	347				0.1
Alive		95% (289)	100% (44)	96% (333)	
Deceased		5% (14)	0% (0)	4% (14)	
Age (y)	347	16 (13–18)	13 (9–16)	16 (12–18)	0.004
ED systolic BP EDA	343	122 (110–132)	116 (110–130)	122 (110–132)	0.4^2
Hypotension EDA	346				0.8
No		96% (292)	95% (42)	96% (334)	
Yes		3% (10)	4% (2)	4% (12)	
Tachycardia EDA	343				1.0
No		77% (230)	77% (34)	77% (264)	
Yes		23% (69)	23% (10)	23% (79)	
Fever EDA	333				0.006
No		62.6% (181)	40.9% (18)	59.8% (199)	
Yes		37.4% (108)	59.1% (26)	40.2% (134)	
Transfusions	347				0.488
No		66.7% (202)	61.4% (27)	66.0% (229)	
Yes		33.3% (101)	38.6% (17)	34.0% (118)	
Hematuria EDA	337				0.017
No		48.8% (143)	29.5% (13)	46.3% (156)	
Yes		51.2% (150)	70.5% (44)	53.7% (181)	
Delayed CT images on arrival	239				0.1
No		69.2% (135)	56.8% (25)	66.9% (160)	
Yes		30.8% (60)	43.2% (19)	33.1% (79)	
Delayed CT images on arrival by grade	233				
Grade 3					
No		77.4% (84)	100% (6)	77.6% (90)	0.2
Yes		23.6% (26)	0% (0)	22.4% (26)	
Grade 4					
No		64.7% (44)	48.1% (13)	60% (57)	0.1
Yes		35.3% (24)	51.9% (27)	40% (38)	
Grade 5					
No		54.5% (6)	72.7% (8)	63.6% (14)	0.4
Yes		45.5% (11)	27.3% (3)	36.4% (8)	

All ranges are IQR.
ED, emergency department; EDA, emergency department arrival; fever, temperature >37.9°C.

TABLE 2. Outcomes and Injury Characteristics

	N	No Urine Leak (n = 303)	Urine Leak (n = 44)	Combined (N = 347)	*p*
Grade	347				0.001
1		17.5% (53)	0% (0)	15.2% (53)	
2		18.5% (56)	0% (0)	16.1% (56)	
3		36.7% (111)	11.4% (5)	33.4% (116)	
4		22.4% (68)	61.4% (27)	27.4% (95)	
5		3.3% (10)	27.3% (12)	6.3% (22)	
Ungraded		1.7% (5)	0% (0)	1.4% (5)	
Injury quadrant	347				
UM		63.4% (192)	45.5% (20)	61.1% (212)	0.02
UL		26.7% (81)	72.7% (32)	67.4% (234)	0.001
LM		30.0% (91)	75.0% (33)	35.7% (124)	0.001
LL		24.4% (74)	65.9% (29)	29.7% (103)	0.001
Injury combination of quadrants	347				0.001
None		37.6% (114)	0.0% (0)	32.9% (114)	
LL		4.0% (12)	0.0% (0)	3.5% (12)	
LM		7.3% (22)	2.3% (1)	6.6% (23)	
LL, LM		4.6% (14)	9.1% (4)	5.2% (18)	
UL		5.0% (15)	4.5% (2)	4.9% (17)	
UL, LL		1.7% (5)	4.5% (2)	2.0% (7)	
UL, LM		1.0% (3)	2.3% (1)	1.2% (4)	
UL, LM, LL		2.3% (7)	22.7% (10)	4.9% (17)	
UM		12.9% (39)	6.8% (3)	12.1% (42)	
LL, UM		0.7% (2)	0.0% (0)	0.6% (2)	
LM, UM		4.3% (13)	6.8% (3)	4.6% (16)	
LL, LM, UM		2.0% (6)	2.3% (1)	2.0% (7)	
UM, UL		6.6% (20)	9.1% (4)	6.9% (24)	
UM, UL, LL		1.7% (5)	0.0% (0)	1.4% (5)	
UM, UL, LM		1.0% (3)	2.3% (1)	1.2% (4)	
UM, UL, LL, LM		7.6% (23)	27.3% (12)	10.1% (35)	
Febrile episode during hospital stay*	333				0.001
No		88.2% (255)	45.5% (20)	82.6% (275)	
Yes		11.8% (34)	54.5% (24)	17.4% (58)	
LOS (hospital), d	324	4 (2–8)	5 (4–8)	4 (2–8)	0.01
ICU days	322	0 (0–0)	0.5 (0–3)	0.0 (0–3)	0.9
Antibiotic use (Grades 3–5)	213				0.122
No		92 (53.8%)	17 (40.5%)	109 (51.2%)	
Yes		79 (46.2%)	25 (59.5%)	104 (48.8%)	
Antibiotic duration (Grades 3–5)	104	4 (2–8)	4 (2–7.5)	4 (2–8)	0.403
Discharged home on antibiotics (Grades 3–5)	211				0.003
No		156 (92.3%)	32 (76.2%)	188 (89.1%)	
Yes		13 (7.7%)	10 (23.8%)	23 (10.9%)	
Antibiotic use (Grades 3–5 and isolated BRT)	43				0.003
No		24 (92.3%)	8 (47.1%)	32 (74.4%)	
Yes		2 (7.7%)	9 (52.9%)	11 (25.6%)	
Antibiotic duration (Grade 3–5 and isolated BRT)	11	4.5 (1–8)	3 (3–4)	3 (2–6)	1.000
Discharged home on antibiotics (Grades 3–5 and isolated BRT)	43				0.019
No		26 (100%)	13 (76.5%)	39 (90.7%)	
Yes		0	4 (23.5%)	4 (9.3%)	
Foley catheter	285				0.001
No		88.0% (221)	64.7% (22)	85.3% (243)	
Yes		12.0% (30)	35.3% (12)	14.7% (42)	
Procedure	347				0.001
None		99.0% (300)	61.4% (27)	94.2% (327)	

Continued next page

TABLE 2. *(Continued)*

	N	No Urine Leak (n = 303)	Urine Leak (n = 44)	Combined (N = 347)	*p*
Cystoscopy		0.3% (1)	9.1% (4)	1.4% (5)	
Cystoscopy with stent		0.0% (0)	15.9% (7)	2.0% (7)	
IR nephrostomy tube		0.3% (1)	2.3% (1)	0.6% (2)	
Nephrectomy		0.3% (1)	11.4% (5)	1.7% (6)	
90-d readmission	318				0.000
No		96.7% (267)	66.7% (28)	92.8% (295)	
Yes		3.3% (9)	33.3% (14)	7.2% (23)	
Follow-up with pediatric surgery	318				0.187
No		81.2% (224)	71.4% (30)	79.2% (252)	
Yes		18.8% (52)	28.6% (12)	20.8% (66)	
Follow-up with trauma	318				0.078
No		67.0% (185)	81.0% (34)	68.9% (219)	
Yes		33.0% (91)	19.0% (8)	31.1% (99)	
Follow-up with urology	318				0.000
No		95.7% (264)	64.3% (27)		
Yes		4.3% (12)	35.7% (15)		
Follow-up with nephrology	318				0.234
No		98.3% (271)	95.2% (40)	97.8% (311)	
Yes		1.7% (5)	2.3% (2)	2.2% (8)	

*Fever defined as >37.9°C; all ranges are IQR.
IR, interventional radiology.

institutional trauma registry for all patients 18 years and younger who presented with BRT from January 1, 2005, to October 1, 2020. We excluded patients who had any penetrating injury, as these children often needed operative management, whereas the principal focus of the current study was on the conservative management of BRT. The Vanderbilt Institutional Review Board approved this retrospective study (VUIRB 162129).

To develop an algorithm that is predictive of renal injury with urine leak, multiple variables were considered. Specifically, demographic (e.g., sex, age, race) and presenting factors (e.g., Injury Severity Score [ISS], multisystem injuries versus isolated BRT [I-BRT], systolic blood pressure, hypotension, tachycardia, pulse, temperature, transfusions, hematuria, and CT scan with delayed kidney images) were recorded. Grade, renal quadrant of injury, febrile episodes during hospital stay, hospital length of stay (LOS), intensive care unit days, foley catheter use, operative procedures, 90-day readmissions, and follow-up with different departments were also recorded. Antibiotic use was characterized for the entire cohort of children having renal injury grades of 3 and higher. Also, a subgroup analysis of antibiotic use among those patients having isolated BRT only was performed.

One pediatric radiologist (M.H.S.), blinded to other clinical data, reviewed all CT scans for each patient to grade renal injuries, to record whether on-table delayed images were obtained with the same scan, and to document a urine leak, including time from admission. To preserve blinding integrity, a second pediatric radiologist (E.S.) evaluated independently all CT scans detecting a urine leak to describe injury location in each quadrant of the kidney, namely upper medial (UM) and upper lateral (UL), lower medial (LM) and lower lateral (LL).

Categorical variables were analyzed using the Pearson χ^2, one-way analysis of variance or Fisher's exact test where appropriate. Data were evaluated for normality using the Kolmogorov Smirnov test, and depending on results, continuous variables were analyzed using the *t* test or the Mann-Whitney *U* test. Multivariate analysis was also performed to determine independent risk factors for urine leaks. The variables were selected based on clinical relevance, validated by the current literature or based on clinical suspicion. The logistic regression was evaluated by a receiver operating characteristic curve. Statistical significance was set a priori, $p < 0.05$, and data were analyzed using IBM SPSS version 26 (IBM SPSS Statistics, Version 26.0) and R studio.

RESULTS

Demographics and Presenting Factors

The total cohort consisted of 347 children who experienced BRT, and 44 (12.4%) developed a urine leak group (Table 1). For the entire cohort, the predominant sex was male, comprising 64% (n = 28) and 62% (n = 187) of the urine leak and nonurine leak group, respectively. Predominant race for the entire cohort was White (n = 288; 83%), with no significant differences detected between groups. The median age of the total cohort was 16 years (interquartile range [IQR], 13–18 years), but the urine leak group was younger, having a median age of 13 years (IQR, 9–16 years; $p = 0.004$).

Injury Severity Score was similar between the two groups, with a median of 17 (IQR, 16–30.5) and 24 (IQR, 14–34) for the urine leak and nonurine leak groups respectively. No significant difference in heart rate was detected on arrival, with a median of 106 (IQR, 90–122) and 105 beats per minute (IQR, 90–122 beats per minute) in the urine leak and nonleak groups, respectively. Interestingly, urine leaks were more common in patients with isolated BRT (n = 17; 31.5%) compared with patients with multisystem injuries (n = 27; 10.2%; $p = 0.000$). Fever (defined as temperature over 37.9°C) at presentation was more common in the urine leak group (n = 26; 59.1%) compared with the nonurine leak group (n = 108; 37.4%; $p = 0.006$). A greater frequency in hematuria on arrival to the ED was found in the urine leak (n = 31; 70.5%) compared with the nonurine leak group (n = 150; 51.2%; $p = 0.02$). For the whole cohort, 96% (333) of patients were alive at time of review, with no significant difference in vital status detected between groups.

Imaging Features

After trauma resuscitation and assessment in the ED, on-table delayed CT images to detect urine leak were completed in 80 (33.5%) patients having BRT, with 20 (45.5%) and 60 (30.8%; $p = 0.062$) obtained in the urine leak and nonleak groups, respectively (Tables 1 & 2). Grade 4 injuries were most likely to receive a delayed CT scan (n = 38; 40%), followed by Grade 5 (n = 8; 36.4%), and then Grade 3 (n = 26; 22.4%; $p = 0.001$), respectively. In a subset analysis of only urine leak patients, a significant difference in the day of diagnosis was observed for patients having an on-table delayed CT image at presentation. All (n = 20) patients who had on-table delayed images on arrival with presenting CT scan were diagnosed on injury Day 1 compared with 50% (n = 12; $p = 0.003$) of patients who did not have delayed images on arrival. Those patients who did not have on-table delayed images with the presenting scans were subsequently diagnosed on hospital days 2 (n = 2; 8.3%), 3 (n = 8; 33.3%), and 4 (n = 2; 8.3%; $p = 0.003$).

To determine the anatomic location within a kidney that predicts greatest susceptibility to urine leak, each injured kidney was divided radiographically (i.e., craniocaudal through mid-kidney and medial-lateral through mid-hilum) into four roughly equal quadrants: UM, UL, LM, and LL quadrants (Figs. 1 and 2). Both mutually exclusive and nonexclusive distributions of injuries in each quadrant were described. In the urine leak group, the most commonly injured quadrant was LM with 33 (75%) of patients suffering at least injury in this location ($p < 0.001$). Respectively, in descending order of frequency, injuries located in UL were observed in 32 (73%) patients ($p < 0.001$), LL in 29 (66%) patients, and finally UM in 24 (54%) patients (Fig. 2). As might be expected, injury location based on the combinations (mutually exclusive) of quadrants showed that the most commonly injured areas were all four quadrants with 12 (27.3%) patients. Following suit was UL, LM, LL combination of quadrants with 10 (22.7%) of patients (Table 2).

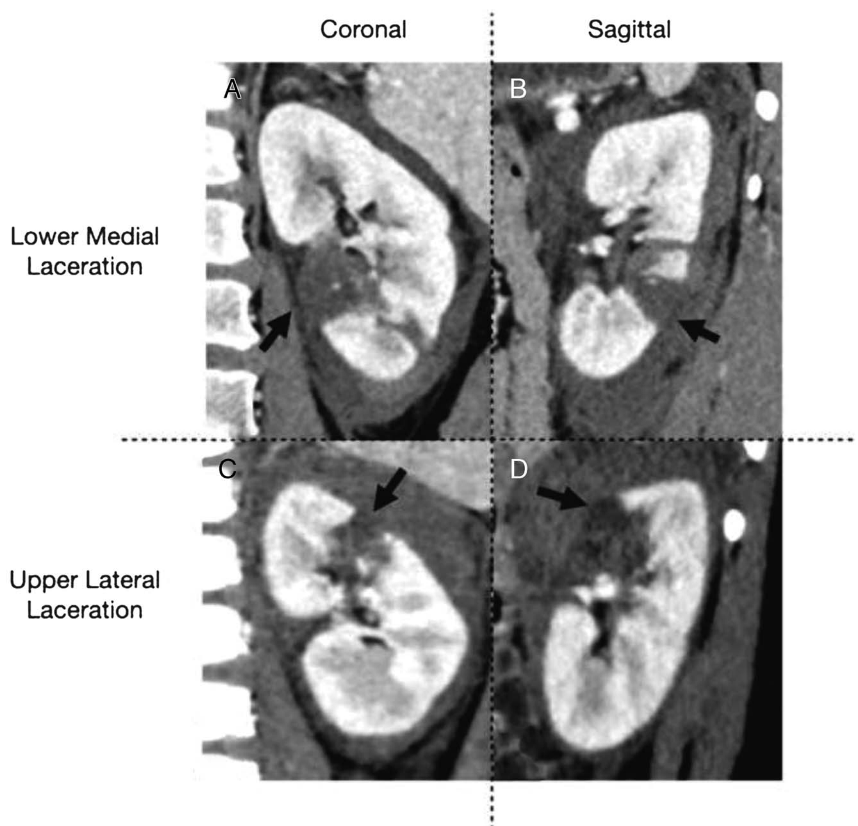

Figure 1. Coronal (*A*) and sagittal (*B*) images of the left kidney in a 12-year-old child after an accident. Laceration in the lower medial pole (arrows) is shown. The inferior laceration extends slightly into the lateral pole. Coronal (*C*) and sagittal (*D*) images of the left kidney in a 5-year-old child after a fall shows a laceration involving the upper, outer quadrant (arrows) extending to the collecting system. Both children developed a urine leak.

Renal Trauma Injury Grade

In descending order of injury grade frequency, a majority sustained Grade 3 injuries (n = 116; 33%), followed by Grade 4 (n = 95; 27%), Grade 2 (n = 56; 16%), Grade 1 (n = 53, 15%), and Grade 5 (n = 22; 6%), respectively (Table 2). Urine leaks occurred exclusively in patients with an injury grade of 3 and above. Frequency of urine leaks differed significantly according to grade, with increasing proportions observed with increasing grade: Grade 3, 4.3% (5 of 116 cases), Grade 4, 28.4% (27 of 95 cases), and Grade 5, 54.5% (12 of 22 cases; $p < 0.001$).

Outcomes

Length of stay was statistically longer in the urine leak group, revealing a median of 5 days (IQR 4–8 days) compared with a median of 4 days (IQR 2–8 days) in the nonurine leak group ($p = 0.01$) (Table 2). The urine leak group also had more febrile episodes (n = 25; 54.5%) compared with the nonurine leak group (n = 34; 11.8%; $p = 0.001$) during their hospital stay. Similarly, foley use (n = 12; 35% vs. n = 30; 12%; $p < 0.001$), operative procedures (n = 17; 38.6% vs. n = 3; 0.1%; $p < 0.001$), and readmission within 90 days from discharge (n = 14; 33.3% vs. n = 9; 3.3%; $p < 0.001$) were more common in the urine leak group than nonurine leak group, respectively. In the urine leak group, the most common operative procedure was cystoscopy with ureteral stenting (n = 7; 15.9%), followed by nephrectomy (n = 5; 11.4%), cystoscopy without stent (n = 4; 9.1%), and interventional radiology placement of nephrostomy tube (n = 1; 2.8%). The urine leak group had increased follow up with urology (n = 15; 35.7%) compared with the nonurine leak group (n = 12; 4.3%), whereas no group differences in

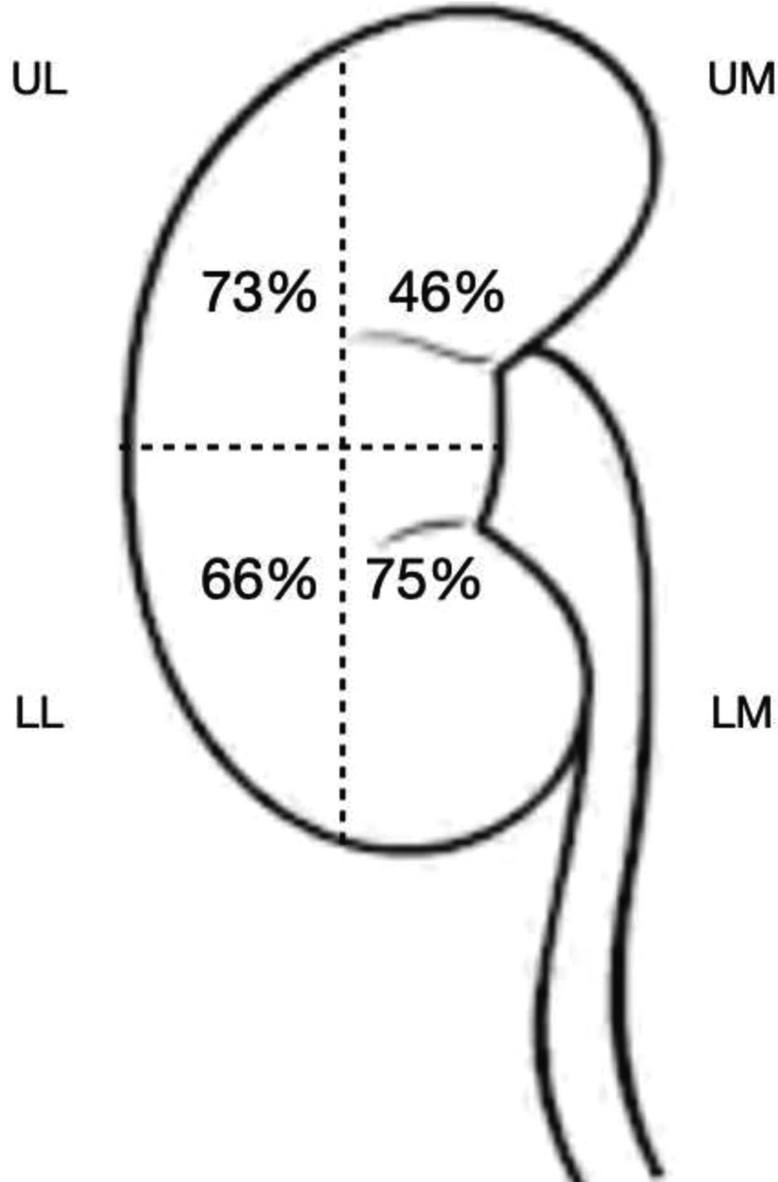

Figure 2. Injury location percentage by kidney quadrants—most commonly injured quadrant was UL, followed by UM, LM, LL.

TABLE 3. Multivariate Analysis

	OR	Lower*	Upper*	Sig.
High grade (4-5)	**7.91**	2.59	24.25	0.000
Isolated BRT	**2.56**	1.03	6.46	0.042
Hematuria	2.21	0.98	5.03	0.057
Fever on arrival	1.87	0.81	4.3	0.144
UL	**2.88**	1.17	7.10	0.022
UM	0.66	0.28	1.55	0.340
LL	0.56	020	1.57	0.267
LM	2.41	0.88	6.59	0.086

Bold items significantly associated with urine leaks ($p < 0.05$).
*95% CIs for OR.
OR, odds ratio.

follow up with pediatric surgery (i.e., trauma) or nephrology were observed.

When considering all patients with Grade s 3 to 5 BRT, no significant difference was detected in any antibiotic use during the index hospital stay (n = 25; 59.5% vs. n = 79; 46.2%) nor in the duration of antibiotic use (4 [IQR, 2–8] vs. 4 [IQR, 3–7.5]) between urine leak and nonurine leak groups, respectively. However, patients with urine leaks were more likely to be discharged home on antibiotics (n = 10; 23.8%) compared with patients without urine leaks (n = 13; 7.7%; $p = 0.003$). When considering children having only isolated BRT of Grade 3 or higher, the urine leak group was prescribed an antibiotic significantly more often than those without leak (n = 9, 52.9% vs. n = 2, 7.7%; $p = 0.003$). No child having isolated BRT without a urine leak was discharged home on oral antibiotic, whereas 4 (23.5%) having a leak were ($p = 0.009$).

Independent Variables

Multivariate analysis was performed to ascertain the independent effects of BRT types (i.e., multisystem or isolated), injury in different kidney quadrants, hematuria, and fever on arrival, and grade (intermediate Grade 3 vs. high 4–5) on the odds of urine leak (Table 3). The logistic regression model was statistically significant (χ^2 [4] 50.466; $p < 0.001$; Hosmer–Lemeshow test, $\chi^2 = 8.167$, $p = 0.318$). The model explained 33.3% (Nagelkerke's R2) of the variance in urine leaks and correctly classified 81.4% of cases. The area under the receiver operating characteristic curve (c-index) was 0.82 (95% confidence interval [CI], 0.76–0.90; Fig. 3). Of the seven predictive variables, high-grade injury (Grades 4 and 5), isolated BRT, and injury in UL location were

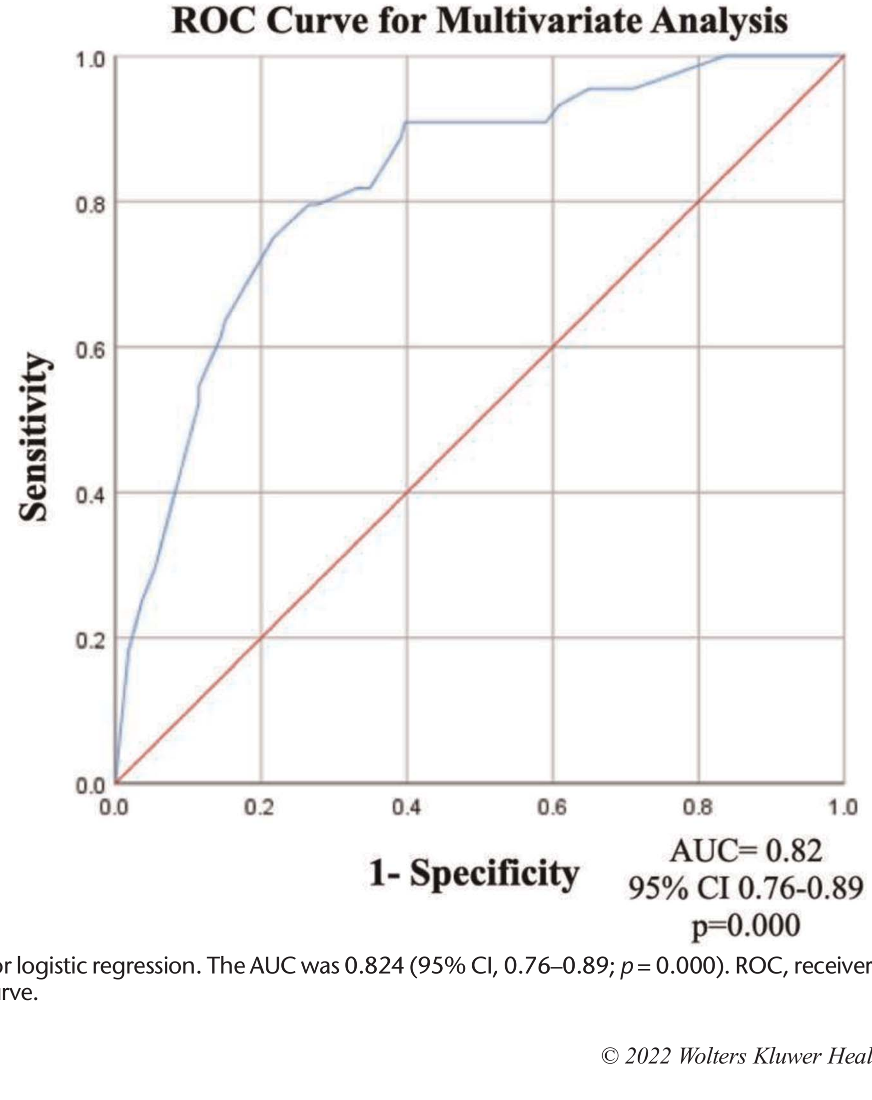

Figure 3. ROC Curve for logistic regression. The AUC was 0.824 (95% CI, 0.76–0.89; $p = 0.000$). ROC, receiver operating characteristic; AUC, area under the curve.

associated independently with urine leaks. High-grade injury was associated with a 7.92-fold higher odds (95% CI, 2.59–24.25; $p < 0.001$), upper lateral quadrant injury was associated with a 2.88-fold higher odds (95% CI, 1.17–7.10; $p = 0.022$), and isolated BRT was associated with a 2.56-fold higher odds (95% CI, 1.0.3–6.36; $p = 0.042$) for development of urine leak (Table 3).

DISCUSSION

From this large experience with BRT in children, urine leaks emerged as an infrequent consequence but prompted significantly greater resource consumption. To streamline detection and management, this study identified several risk factors that predict urine leaks among children sustaining BRT and established an expected association between urine leaks and greater resource utilization. Inconsistent data exist on the incidence of urine leak after BRT in children, which from this study appeared less common than reported among adults and its impact on outcomes.[5] On univariate analysis in this study, younger age, hematuria, injury grade, fever at initial ED presentation, and injury location associated with increased frequency of urine leak. Multivariate analysis, however, revealed that high-grade injuries, UL location, and isolated BRT were independently associated with urine leaks, with, not surprisingly, high-grade injuries (4 and 5) being the most prominent risk factor.

Children are known to be uniquely susceptible to renal injuries, as they have relatively larger kidneys and decreased torso protection.[3,4] This vulnerability may serve to increase the risk of higher AAST grade injuries, which were found to be associated with urine leak in this present and prior studies.[5] High injury grade has also been associated with a failure of conservative management in children for multiple reasons.[11,12] Urine leaks account for the majority of the subsequent procedural interventions, and Grade 4 injuries are particularly at-risk.[13] From our study we too observed that greater hospital resources were consumed in the context of a urine leak complicating BRT.

With regard to other identified risk factors, isolated BRT is rarer and often presumed a more minor injury,[14,15] leading potentially to less timely evaluation. Nonetheless, case reports of severe isolated kidney injuries have been reported,[16] as well as retrospective studies suggesting isolated renal injuries are more common in younger children.[17] In this context, the finding that isolated BRT is independently associated with urine leaks in children indicates that this population may benefit from greater clinical suspicion, earlier diagnostic evaluation, and closer monitoring. Specifically, although it did not meet statistical significance, our study showed that children developing urine leaks had a lower ISS (n = 17) relative to those who did not (n = 24), which likely reflects isolated BRT having more frequent urine leaks yet lower ISS. We suspect that isolated kidney injuries result from greater focal energy transfer (e.g., sports injury) than multisystem scenarios in which the energy transfer is more diffuse (e.g., motor vehicle crash), thereby explaining this detected difference in susceptibility to urine leak. Speculating further to explain the association of higher fever on ED arrival in patients who develop urine leak, it is possible that isolated renal injury had a more delayed presentation after injury, prompting the febrile response.

The location of renal injury has been previously shown to affect failure of conservative management for pediatric BRT, with anteromedial injuries and medial contrast extravasation predicting increased interventions.[8,18] This location susceptibility was hypothesized to be due to nearer proximity with the peritoneum in this area, allowing greater expansion of any urinomas. Our unexpected finding that the upper lateral region was independently associated with urine leak is novel and may be unique to children, requiring further exploration. It is possible that the upper lateral region affords reduced protection given that the thoracic cage is more pliable and weaker in childhood.

The optimal usage and timing of delayed excretory phase CT scans in pediatric renal trauma remains an area of debate, given the desire to limit radiation exposure to children. Many clinicians use hematuria to determine the necessity of imaging, as previously discussed, but standardization is lacking regarding the amount of hematuria that meets the cutoff for imaging.[19] Some have questioned the necessity of obtaining CT imaging in pediatric renal trauma, with one study demonstrating that outcomes were not different between patients who had on-table delayed excretory CT and those who did not.[20] However, other studies have shown that obtaining the delayed phase CT scans at initial imaging for any detected renal laceration may in fact reduce the number of follow up CT scans required.[21] This present study definitively argues for obtaining an on-table delayed excretory CT scan in the context of any renal laceration scored Grade 3 or higher, which captured all urine leaks in our larger series. Furthermore, we found that having CT imaging on arrival was closely associated with day one detection of urine leaks and more streamlined management. Our data demonstrated that children with BRT and urine leaks have more febrile episodes, more frequent urologic procedures, greater consumption of antibiotics, significantly longer LOS, and significantly higher rates of 90-day readmissions. Poor compliance with obtaining initial excretory images in high-grade renal injury has been linked to delayed diagnosis and persistent leakage in a population already at risk for readmission and subsequent urologic intervention.[5,13] Though relatively rare, a symptomatic urinary leak benefits from earlier diagnosis and more timely management.

In the present analysis, urine leaks occurred exclusively in Grade 3 and above injuries, and our findings show the effectiveness of on-arrival delayed CT scan to diagnose such patients. Therefore, we recommend that management algorithms consider adding on-arrival delayed CT scan in patients who have BRT with an injury grade of 3 and above. This practice change is being implemented at our institution as a result.

Seventeen patients had urine leaks and did not receive antibiotics, neither during hospital stay nor upon hospital discharge. Importantly, none of these patients was readmitted for fever or abdominal pain. Moreover, the patient from the urine leak group that was readmitted for fever had received antibiotics both during hospital stay and discharge. Although a more thorough analysis is required to understand the role of antibiotics, in this era of antibiotic stewardship providers must remain cautious not to prescribe antibiotics routinely. Therefore, the authors recommend against routine prescription of antibiotics in the absence of a documented positive urine culture or retroperitoneal abscess.

Hematuria has historically been used to decide whether to obtain imaging in blunt abdominal trauma, with either gross or microscopic hematuria generally being indications for imaging.[7,19] This variable aligns with the findings in the current study, which showed that the presence of any hematuria is associated with urine leak. However, hematuria on admission did not hold up as an independent risk factor for urine leak.

The authors acknowledge several limitations to the study that temper rigorous conclusions, including those inherent to retrospective reviews, such as missing data, small sample of urine leaks despite a large cohort, and incomplete accounting for potential confounders. Further, our findings are limited to a single institution and are only applicable to BRT and therefore cannot be applied to penetrating injuries. Our initial hypothesis was that LM injuries would be a major risk factor for urine leak due to its proximity to the urine calyces and ureteropelvic junction; however, our multivariate analysis did not show an independent association. Unexpectedly, the UL quadrant emerged as the location after injury most susceptible to urine leak. Although we speculate that this susceptibility could be due to reduced protection of this region in children, further exploration of this association is required. The LM and UL were the most frequently injured quadrants in the urine leak group, and therefore one explanation for the association between UL injuries and urine leaks could be that kidney lacerations in a diagonal pattern from UL to LM encompass the greatest volume of parenchyma and therefore highest risk for urine leaks. Our cohort includes older adolescents whose physiology maybe closer to adults, and whose injury mechanism maybe unique. Therefore, any conclusion on effects of BMI and age on risk of urine leak must be confirmed with additional studies that have a more thorough analysis. Although this study showed that antibiotics were overprescribed in patients developing urine leaks, further data are needed to confirm this finding. Similarly, routine delayed CT scans for Grade 3 and above were appropriate in our cohort, however, further studies are warranted to determine the utility of routine delayed CT scan for BRT regarding detection of urine leaks. Moreover, the administration of the delay excretion phase was completed at different times throughout our cohort. This inconsistency has fueled quality improvement initiatives in collaboration with our radiology colleagues to create a standardized approach to evaluate urine leaks in children sustaining BRT within our system.

In conclusion, urine leaks after BRT lead to considerable morbidity in the pediatric population, including increased fevers, 90-day readmission rates, and need for operative or interventional management. This study is the first to examine the relationship between kidney quadrants and urine leaks, and we found that high grade,[4,5] isolated BRT, and upper lateral quadrant injuries were independent predictors of urine leaks. BRT protocols should consider decision trees based on the presence of urine leaks. Prompt discovery of these conditions and adequate care will streamline resource utilization and optimize patient outcomes.

AUTHORSHIP

M.O.A.G.: Literature search, study design, data collection, data analysis, data interpretation, writing. E.S.: study design, data collection, critical revision. M.C.X.: literature search, data collection, writing. K.M.: literature search, data collection, writing. J.F.: data collection, writing. C.T.: critical revision. D.B.C.: critical revision. A.G.: study design, critical revision. M.H.-S.: study design, critical revision. H.N.L., III: study design, writing, critical revision.

DISCLOSURE

The authors declare no funding or conflicts of interest.

REFERENCES

1. Morey AF, Brandes S, Dugi DD 3rd, Armstrong JH, Breyer BN, Broghammer JA, Erickson BA, Holzbeierlein J, Hudak SJ, Pruitt JH. Urotrauma: AUA guideline. *J Urol*. 2014;192(2):327–335.
2. Grimsby GM, Voelzke B, Hotaling J, Sorensen MD, Koyle M, Jacobs MA. Demographics of pediatric renal trauma. *J Urol*. 2014;192(5):1498–1502.
3. Miller RC, Sterioff S Jr., Drucker WR, Persky L, Wright HK, Davis JH. The incidental discovery of occult abdominal tumors in children following blunt abdominal trauma. *J Trauma*. 1966;6(1):99–106.
4. Murphy GP, Gaither TW, Awad MA, Osterberg EC, Baradaran N, Copp HL, Breyer BN. Management of pediatric grade IV renal trauma. *Curr Urol Rep*. 2017;18(3):23.
5. Keihani S, Anderson RE, Hotaling JM, Myers JB. Diagnosis and management of urinary extravasation after high-grade renal trauma. *Nat Rev Urol*. 2019;16(1):54–64.
6. Henderson CG, Sedberry-Ross S, Pickard R, Bulas DI, Duffy BJ, Tsung D, Eichelberger MR, Belman AB, Rushton HG. Management of high grade renal trauma: 20-year experience at a pediatric level I trauma center. *J Urol*. 2007;178(1):246–250.
7. Santucci RA, Wessells H, Bartsch G, Descotes J, Heyns CF, McAninch JW, Nash P, Schmidlin F. Evaluation and management of renal injuries: consensus statement of the renal trauma subcommittee. *BJU Int*. 2004;93(7):937–954.
8. Lee JN, Lim JK, Woo MJ, Kwon SY, Kim BS, Kim HT, Kim TH, Yoo ES, Chung SK. Predictive factors for conservative treatment failure in grade IV pediatric blunt renal trauma. *J Pediatr Urol*. 2016;12(2):93.e1–93.e7.
9. Erlich T, Kitrey ND. Renal trauma: the current best practice. *Ther Adv Urol*. 2018;10(10):295–303.
10. Phelps HM, Lovvorn HN 3rd. Minimally invasive surgery to treat embryonal tumors of childhood. *Cancer Metastasis Rev*. 2019;38(4):695–708.
11. Au JK, Tan X, Sidani M, Stanasel I, Roth DR, Koh CJ, Seth A, Gargollo PC, Tu D, Gonzales ET. Imaging characteristics associated with failure of nonoperative management in high-grade pediatric blunt renal trauma. *J Pediatr Urol*. 2016;12(5):294.e1–294.e6.
12. Rogers CG, Knight V, MacUra KJ, Ziegfeld S, Paidas CN, Mathews RI. High-grade renal injuries in children—is conservative management possible? *Urology*. 2004;64(3):574–579.
13. Winters B, Wessells H, Voelzke BB. Readmission after treatment of grade 3 and 4 renal injuries at a level I trauma center: statewide assessment using the comprehensive hospital abstract reporting system. *J Trauma Acute Care Surg*. 2016;80(3):466–471.
14. Cass AS, Luxenberg M, Gleich P, Smith CS. Clinical indications for radiographic evaluation of blunt renal trauma. *J Urol*. 1986;136(2):370–371.
15. Govindarajan KK, Utagi M, Naredi BK, Jindal B, Sambandan K, Subramaniam D. High grade renal trauma due to blunt injury in children: do all require intervention? *J Bras Nefrol*. 2019;41(2):172–175.
16. Fanning DM, Forde JC, Mohan P. A simple football injury leading to a grade 4 renal trauma. *BMJ Case Rep*. 2012;2012:bcr1020114959.
17. Nakao S, Katayama Y, Hirayama A, Hirose T, Ishida K, Umemura Y, Tachino J, Kiguchi T, Matsuyama T, Kiyohara K. Trends and outcomes of blunt renal trauma management: a nationwide cohort study in Japan. *World J Emerg Surg*. 2020;15(1):50.
18. Dalton BGA, Dehmer JJ, Shah SR. Blunt Renal Trauma. *J Pediatr Intensive Care*. 2015;4(1):16–20.
19. Bartley JM, Santucci RA. Computed tomography findings in patients with pediatric blunt renal trauma in whom expectant (nonoperative) management failed. *Urology*. 2012;80(6):1338–1344.
20. Fuchs ME, Beecroft N, Dajusta DG, McLeod DJ. Is delayed phase computed tomography imaging necessary after blunt renal trauma in children? *Urology*. 2018;113:187–191.
21. Gaither TW, Awad MA, Leva NV, Murphy GP, Breyer BN, Copp HL. Missed opportunities to decrease radiation exposure in children with renal trauma. *J Urol*. 2018;199(2):552–557.