

Original Article
Clinical Investigation**Ureteral contrast findings as a potential predictor for invasive intervention in high-grade pediatric renal trauma: A retrospective analysis**Hansen Lui,¹ Phillip J. Kim,¹ Lisa H. Kang,² Blythe P. Durbin-Johnson³ and Eric A. Kurzrock¹ ¹Department of Urology, University of California Davis, Sacramento, California, USA, ²Department of Radiology, The University of Chicago, Chicago, Illinois, USA, and ³Division of Biostatistics, University of California Davis, Davis, California, USA**Abbreviations & Acronyms**

AAST = American Association for the Surgery of Trauma
AIS = abbreviated injury score
CI = confidence interval
IQR = interquartile ranges
NOM = non-operative management
UC = ureter contrast

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Objectives: To determine if patient variables were associated with intervention in pediatric patients presenting with high-grade renal injuries.

Methods: A retrospective review of pediatric patients presenting with grade IV/V renal injury between 2003 and 2021 at a Level 1 trauma center was performed. Renal injury grade was verified and updated based upon the 2018 American Association for the Surgery of Trauma injury scale. Multivariable logistic regression analyses were performed.

Results: Seventy-five patients (median age 13 years old, IQR 9–16) with Grade IV ($n = 53$) or Grade V ($n = 22$) injury were identified. 33% (25/75) had immediate renal intervention within 24 h of admission. Of the remaining 50 children who were observed, 47 had blunt trauma, and outcomes were analyzed. The median age of observed patients was 12 years (IQR 8–14) and 30% (14/47) had intervention. Delayed images on CT showed ureteral contrast was present in 87% (41/47) of observed patients. Multivariable analysis demonstrated that the presence of contrast in the ureter is associated with significantly lower odds of intervention, OR 0.06 [0–0.73, 95% CI], $p = 0.03$.

Conclusion: After grades IV and V blunt renal injury, for those children who are considered safe to observe, AAST grade of injury did not associate with procedural intervention. The presence of contrast in the ureter on delayed CT imaging was associated with a significantly lower odds of procedural intervention.

Key words: high-grade, pediatrics, renal trauma, urogram.

INTRODUCTION

Unintentional traumatic injury is the most common cause of death in pediatric patients. Due to anatomic differences, children are at higher risk of renal injury after blunt trauma.^{1,2} Of those who sustain blunt trauma to the abdomen, 5%–20% present with a renal injury.³

Once the diagnosis of kidney injury is made upon admission, subsequent workup and management of children is controversial. In contrast to adult patients, there are no universally accepted guidelines for the management of children after high-grade renal injury. WSES-AAST guidelines state that “no specific recommendations exist for non-operative management (NOM) in blunt and penetrating kidney and urogenital tract injuries in children that are different than those used for adults. Therefore, pediatric patients should be treated as adult patients keeping into account the rule that being less invasive is better.”⁴

For adult patients presenting with high-grade renal trauma, the current guidelines promote NOM with a period of observation and repeat imaging in 48–72 h or sooner if there are signs of clinical complications.^{4–7} Perirenal hematoma and renal fragmentation are not absolute indications for acute operative management.⁴ Judicious use of urinary diversion (stents or nephrostomy tubes) and/or perinephric drainage in children has been shown to obviate the need for open surgery and preserve the kidney. Failure of NOM has been associated with large perinephric hematomas in adults and children.^{8,9}

The lack of pediatric guidelines is likely due to the relatively smaller number of patients available for investigation. The relevant patient factors and timing for minimally invasive urinary diversion have not been determined for adults or children. Although early intervention may prevent further leakage and/or open surgery, this practice may lead to overapplication. We hypothesized that after pediatric high-grade renal injury, the presence of contrast in the ipsilateral ureter on initial CT imaging is a sign of a “less risky” urine leak and that urinary diversion may not be necessary. A better understanding of the mechanics and outcomes after high-grade injuries via a retrospective analysis may provide evidence to support prospective investigations.

MATERIALS AND METHODS

After IRB approval (#1417488-1), a retrospective review of pediatric patients (less than 18 years of age) presenting with renal injuries between 2003 and 2021 at a Level 1 trauma center was performed using the existing institutional trauma registry. Patients with grades IV or V injury based on the American Association for the Surgery of Trauma (AAST) scale were included in the study. Patients who did not have a CT delayed phase (excretory phase, 12–15 min after IV contrast injection) imaging to allow identification of urinary extravasation on initial presentation or who had a congenital anomaly of the injured kidney were excluded.

All CT images were reviewed by a board-certified pediatric radiologist. The renal injury grade was verified and updated, if necessary, based upon 2018 AAST guidelines. The presence of contrast in the ureter (UC) was also assessed. Patient variables, including demographics (age, gender, race/ethnicity), mechanism of injury (blunt vs. penetrating), presence of any non-genitourinary injuries (non-renal abbreviated injury score), and any procedural interventions that were performed during the initial admission and within 90 days of discharge, were documented. Indications for intervention were also recorded.

The medical records of patients who were taken to the OR within 24 h of admission due to hemodynamic instability were evaluated but not analyzed statistically. Patients who were hemodynamically stable and did not require urgent surgery during the first 24 h of admission were categorized as “Intent to Observe,” also termed “Non-Operative Management” by some. This group of patients was further grouped into those with and without contrast in any portion of the ureter below the ureteropelvic junction on delayed CT imaging. To determine if the presence of contrast in the ipsilateral ureter was more predictive of a “less risky” collecting system injury, we sought to distinguish those with vascular and collecting system injuries. In addition to grade, the presence of vascular and/or collecting system injury was recorded. Descriptive statistics were calculated, and interquartile ranges (IQR) were reported.

Multivariable models included variables: contrast in the ureter (yes/no), injury (vascular/collecting system/both), age (continuous), and non-renal abbreviated injury (AIS) score (continuous). Continuous variables were compared between UC+ and UC– groups using the Wilcoxon rank-sum test,

and categorical variables were compared between groups using Fisher’s Exact test. The odds of intervention were modeled by patient and imaging characteristics using univariable and multivariable logistic regression, with estimates and their standard errors obtained using Firth’s bias-reduced penalized likelihood method due to the small number of UC– patients who did not have intervention. *p*-values reported were adjusted for all other variables in the model. Analyses were conducted using R version 4.0.5 (2021-03-31), and Firth’s bias-reduced logistic regression was implemented using the R package *logistf*, version 1.24.1.

RESULTS

Seventy-five pediatric patients with high-grade (IV and V) renal injury using our institutional trauma database met inclusion criteria.

Acute operative management

Twenty-five patients (33%, 25/75) had immediate renal intervention within 24 h of admission due to hemodynamic instability. The median age was 17 years (range 5–18), and 84% (21/25) were male. Fifty-two percent (13/25) of the injuries were blunt type. Thirteen patients (52%, 13/25) had grade IV and twelve patients (48%, 12/25) had grade V injuries. Trauma surgeons brought 16 (64%) of the twenty-five patients to the operative suite for hemodynamic instability and/or non-renal injuries. All twelve patients with grade V injuries had nephrectomy. The remaining 4 patients with grade IV injuries had subsequent renorrhaphy (*n* = 3) and partial nephrectomy (*n* = 1). All retained their kidneys. The remaining 9 patients with grade IV underwent embolization (*n* = 2), urinary diversion in the form of stent (*n* = 5), or perinephric drain (*n* = 1). Of these 9 children, 3 subsequently required nephrectomy.

Intent to observe

Fifty patients (50/75) were closely monitored after abdominal trauma presentation with an intent to observe the injured kidney without intervention. We excluded 3 children with penetrating injuries and thus limited our analysis to the 47 patients with blunt trauma (Figure 1). The median age was 12 years (IQR 8–14), and two-thirds were male (Table 1). Of these patients, 79% (37/47) had grade IV and 21% (10/47) had grade V injury. All patients had follow-up imaging within 48 h of presentation. Of the 47 patients observed, 30% (14/47) received a procedure during hospitalization or within 90 days of discharge. There was no statistically significant association of procedural intervention with variables: gender, age, insurance, or non-renal AIS score (Table 1).

Of the patients in the Intent to Observe group, 87% (41/47) were noted to have contrast in the ureter on delayed imaging (Figure 2). Notably, the intervention group included significantly fewer subjects with contrast in the ureter (*p* = 0.01). Of the patients who did not require any intervention, 58% (19/33) had collecting system injury only, 24% (8/

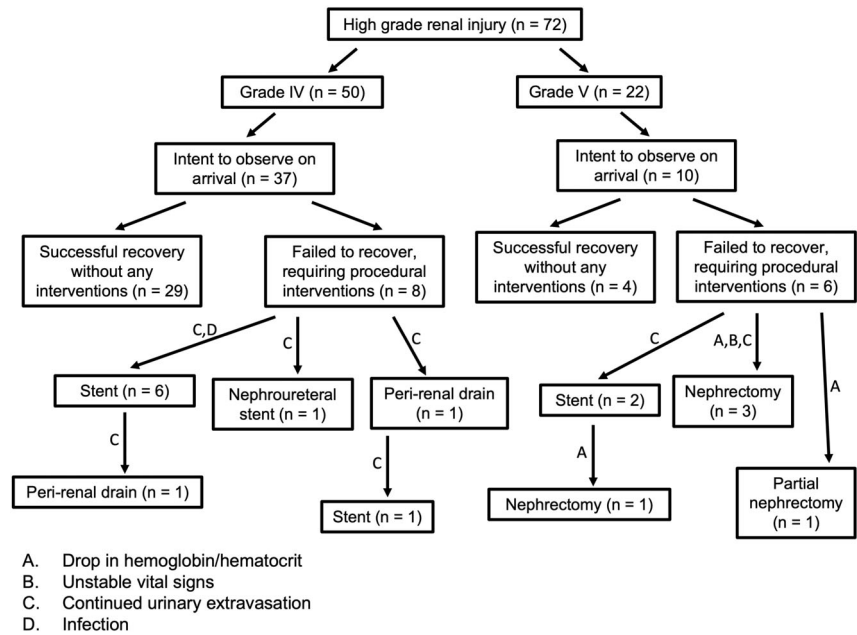


FIGURE 1 Flowsheet diagram of blunt renal trauma Grade IV and V patients upon admission.

TABLE 1 Patient and imaging characteristics by intervention.

	No intervention (n = 33)	Any intervention (n = 14)	p-Value ^a
Age			1.00
Mean (SD)	10.8 (4.3)	11.2 (3.4)	
Median (range)	12 (2–18)	11.5 (6–17)	
Gender			0.09
F	14 (42.4%)	2 (14.3%)	
M	19 (57.6%)	12 (85.7%)	
Insurance			0.38
Private	15 (45.5%)	7 (50.0%)	
Public	13 (39.4%)	3 (21.4%)	
Self-pay/other/non-specified	5 (15.2%)	4 (28.6%)	
Grade			0.05
4	29 (87.9%)	8 (57.1%)	
5	4 (12.1%)	6 (42.9%)	
Non-renal AIS			0.17
Mean (SD)	1.9 (1.8)	1.1 (1.7)	
Median (range)	2 (0–5)	0 (0–5)	
Contrast in ureter			0.01
No	1 (3.0%)	5 (35.7%)	
Yes	32 (97.0%)	9 (64.3%)	
Injury			1.00
Vascular	8 (24.2%)	3 (21.4%)	
Collecting system	19 (57.6%)	8 (57.1%)	
Both	6 (18.2%)	3 (21.4%)	

Abbreviation: AIS, abbreviated injury score.

^ap-Values for continuous variables are from the Wilcoxon rank-sum test, and p-values for categorical variables are from Fischer's Exact Test. Significance of p-Value defined as < 0.05

33) had vascular injury only, and 18% (6/33) had both vascular and collecting system injuries.

In the Intent to Observe Group, 78% (29/37) with a grade IV injury recovered without intervention. Of the 8 children

who had treatment, intervention included ureteral stent ($n = 6$), nephroureteral stent ($n = 1$), and perinephric drain placement ($n = 1$).

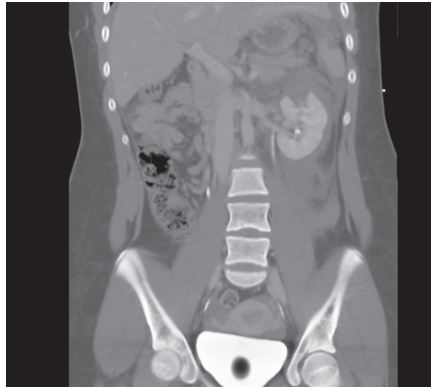
For grade IV, the median and range of time from the onset of injury to intervention were 72 h and 48–72 h, respectively, versus grade V, whose median and range times were 78 h and 54–111 h, respectively.

Among the grade V Intent to Observe group ($n = 10$), six patients had intervention including nephrectomy ($n = 3$), partial nephrectomy ($n = 1$), and ureteral stent ($n = 2$) placement. Four of 10 patients with grade V injury (40%), who were observed, had no intervention and maintained their injured kidney. Figure 1 describes a flowchart with annotations on the indications for interventions for all patients who were initially observed, but eventually needed an intervention. Nephrectomy and partial nephrectomy were performed in patients who had persistently declining hematocrit during observation. Genitourinary decompression with a stent or nephrostomy tube was pursued when patients demonstrated continued or worsening urinary extravasation on repeat imaging. Other clinical signs during the observation period, such as tachycardia, fever, and decreased hematocrit were reviewed for these cases (Table S1). Of the patients who required any intervention, 43% (6/14) demonstrated tachycardia, 43% (6/14) were febrile, and 50% (7/14) demonstrated a decline in hematocrit. Case 14 describes a patient who got a nephrectomy for a shattered kidney with an enlarging hematoma. Patients with imaging that showed no contrast down the ureter and had any intervention ($n = 5$) also demonstrated other clinical signs such as fever and/or tachycardia. Among patients who did not receive an intervention, 9% (3/33) demonstrated tachycardia, 30% (10/33) were febrile, and 3.0% (1/33) demonstrated a decline in hematocrit. There was one patient with a grade 4 renal injury and no contrast going down the ureter who did not require any urologic intervention.

Right grade IV injury without ureter contrast



Left grade IV injury with ureter contrast

**FIGURE 2** CT of blunt renal trauma with examples of delayed imaging.**TABLE 2** Logistic regression analyses of any intervention by patient and imaging characteristics, all subjects.

Variable	Univariate analysis		Multivariate analysis	
	Odds ratio (95% CI)	p-Value	Odds ratio (95% CI)	p-Value
Contrast in ureter: yes vs. no	0.08 (0.01–0.47)	0.004	0.06 (0–0.73)	0.03
Injury: collecting system vs. vascular	1.06 (0.25–5.17)	0.94	11.71 (0.78–2216.5)	0.08
Injury: both vs. vascular	1.31 (0.21–8.31)	0.77	6.96 (0.37–1276.9)	0.21
Age (years) ^a	1.02 (0.88–1.20)	0.80	1.01 (0.84–1.23)	0.95
Non-renal AIS score ^a	0.80 (0.53–1.13)	0.23	0.79 (0.44–1.22)	0.30
Grade V vs. IV	5.01 (1.24–22.36)	0.02	5.73 (0.62–91.61)	0.12

Abbreviations: AIS, abbreviated injury score; CI, confidence interval.

^aOdds ratios for age and non-renal AIS score are the change in odds for a one-unit increase in age or AIS. Significance of p-Value defined as < 0.05

Patients with grade V injury had higher odds of intervention on univariable analysis, but this did not persist after multivariable analysis (Table 2). Both univariable and multivariable analyses showed that the presence of contrast in the ureter was associated with a 13-fold lower odds ratio of an intervention (univariate: OR 0.08 [0.01–0.47, 95% CI], $p = 0.004$; multivariate: OR 0.06 [0–0.73, 95% CI], $p = 0.03$) (Table 2). Among those who sustained only renal collecting system injury, both univariable and multivariable analyses did not show a statistically significant association between the presence of contrast in the ureter and the likelihood of intervention (most likely due to population size) (Table 3).

TABLE 3 Logistic regression analyses of any intervention by patient and imaging characteristics, subjects with collecting system injuries.

Variable	Univariate analysis		Multivariate analysis	
	Odds ratio (95% CI)	p-Value	Odds ratio (95% CI)	p-Value
Contrast in ureter: yes vs. no	0.13 (0.001–2.68)	0.184	0.09 (0.001–2.13)	0.135
Age (years) ^a	1.07 (0.88–1.34)	0.498	1.09 (0.88–1.42)	0.439
Non-renal AIS score ^a	0.94 (0.58–1.44)	0.775	0.83 (0.43–1.34)	0.467
Grade V vs. IV	7.80 (0.37–1192)	0.184	10.12 (0.45–1590)	0.140

Abbreviations: AIS, abbreviated injury score; CI, confidence interval.

^aOdds ratios for age and non-renal AIS score are the change in odds for a one-unit increase in age or AIS.

DISCUSSION

The management of high-grade renal injuries in pediatric patients is inconsistent between centers due to a lack of large studies and strong evidence. Therefore, pediatric providers often reference management plans developed for adult patients, which may not be safe to extrapolate. Even in adult patients, AAST grading alone has not been a comprehensive tool for predicting prognosis, and, thus, attempts have been made to develop an algorithm for adult patients.^{4,10} Currently, there is none available for pediatric patients.

For adults, indications for operative intervention include hemodynamic instability despite aggressive resuscitation due to renal hemorrhage, an expanding, pulsatile perirenal hematoma found intraoperatively (during exploration for non-renal associated injuries), and radiographic findings of an enlarging urinoma.¹¹ In the absence of these conditions, non-operative management has been shown to be safe.^{12–15} Lanchon et al. demonstrated patients were successfully managed with non-operative management in 89% of those with grade IV injury and 52% of those with grade V injury. In one meta-analysis, non-operative management showed a higher rate of renal preservation (84%–100%) compared to immediate open surgical operation (10%–76%) for those presenting with

high-grade renal injuries.¹³ Similar to adults, a select group of pediatric patients presenting after high-grade renal injury can be managed non-operatively based upon several studies.^{16–18} Aligning with these studies, our results show a high nephrectomy rate (15/25) when emergent surgery is required due to hemodynamic instability. On the other hand, renal salvage was achieved in 94% (47/50) of children deemed safe to observe. Clinical signs such as tachycardia, fever, and hemodynamic instability are often used, in addition to imaging, to decide on procedural intervention. We found that 30% (10/33) of patients who developed a fever during the observation period clinically improved without any urologic intervention. As expected, patients who demonstrated a persistent drop in hematocrit had a higher rate of procedural intervention.

Further, recent investigations suggest repeat imaging may not be necessary if the patient is clinically stable.^{19,20} The utility of repeat imaging in adult patients has been questioned in two recent studies that showed routine repeat imaging led to unnecessary radiation exposure and over-treatment.^{21,22} In order to reduce radiation exposure for children, there is a need to determine radiographic findings during the initial workup, which could predict the need or not for subsequent intervention. Cannon et al. analyzed the outcomes of 17 patients and found that lack of ureteral contrast (1 patient) and large separation of the upper and lower poles (1 patient) were associated with needing intervention.²³ A study of 27 patients found 78% with ureteral contrast avoided intervention but multivariable analysis did not show ureteral opacification to be a significant variable²⁴ possibly due to small sample size.

In the past, other authors discussed the importance of radiologic findings in identifying adult patients who will require intervention for bleeding after renal trauma.^{25–28} However, most of these studies assessed the likelihood of interventions needed to control bleeding, not urine leaks. We further stratified high-grade AAST injury into collecting system, vascular, or combined collecting system/vascular injuries. AAST grading does not discriminate against the collecting system or vascular injury when assigning a grade. Our thought was that the presence of ureteral contrast might be more meaningful when the injury was limited to the parenchyma and collecting system (no major vascular injury). Unfortunately, despite the larger size of this series, there was not enough power after stratifying into 3 different cohorts.

In this investigation, we evaluated whether there is an association between the presence of contrast in the ipsilateral ureter during initial workup and interventions that occurred for those who were hemodynamically and clinically stable and deemed safe to observe. We hypothesized that the presence of ureteral contrast could be a surrogate marker for the severity of collecting system injury and potentially complement current AAST grading. Both univariable and multivariable analyses showed the presence of contrast in the ureter is associated with significantly lower odds of intervention (13-fold lower odds, $p < 0.01$ univariable analysis and 17-fold lower odds, $p = 0.03$ multivariable analysis) (Table 2). Contrast in the ureter may indicate that the more proximal collecting system injury is less severe

and/or the peristaltic function of the kidney is intact such that urinary diversion is not necessary. Of the 41 observed patients with contrast in the ureter, only 9 required intervention. As this is a retrospective study, we are not suggesting refraining from necessary imaging and/or intervention with the presence of ureteral contrast. If other institutions find these results reliable, this additional radiographic variable could complement AAST grading and support observation. At the same time, it could lead to risk-directed imaging and earlier intervention for those who would benefit and lower length of stay and morbidity.

Prior studies have proposed risk factors such as laceration and hematoma size as predictors for intervention after high-grade renal trauma. In their retrospective single-institution study of 26 children, Lee et al. identified that patients with hematomas that were larger than 2.2 cm required intervention. They further describe the laceration site of antero-medial, antero-lateral, postero-medial, and postero-lateral.⁸ Although their study examined hematoma size and location, the study design was limited by its descriptive analysis given the sample size and permutations due to multiple hematoma locations. Reese et al. performed a retrospective review that also found collecting system clot and mean largest diameter of the urinoma (greater than 4.3 cm) as predictors of failure of conservative management.²⁹ The validity of hematoma or urinoma length as a proxy for volume has not been evaluated, nor is there an accepted critical size in adults or children.

This study is limited by its retrospective nature. As a single-institution investigation, there is a risk of bias, and the cohort of children may not be representative of the general population. As described, indications for intervention were objectively noted, but the intensity and longevity are subjective and were not recorded. Despite the large size, further investigation using a multi-institutional or prospective study to assess long-term outcomes after intent to observe can help better inform future renal trauma guidelines in the pediatric population.

In summary, after grades IV and V blunt renal injury in children who are considered safe to observe, the AAST grade of injury did not associate with procedural intervention. On the other hand, the presence of contrast in the ureter on delayed CT imaging was associated with a significantly lower odds of procedural intervention. The presence of contrast in the ureter on index delayed CT imaging may indicate a more physiologically intact genitourinary tract that does not necessarily warrant procedural intervention. Taken together with the patient's clinical examination and lab findings, the absence of contrast in the ureter may provide additional information on how to stratify pediatric patients who may fail NOM. As greater efforts are being made to reduce radiation exposure in pediatric trauma patients, the finding of contrast flowing down the ureter on index imaging may also indicate a population who could avoid repeat cross-sectional imaging, yet this has to be considered as one variable among many, especially the clinical stability of the patient. Additional prospective and longitudinal studies are needed to assess the outcomes of NOM in the pediatric renal trauma population.

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None.

AUTHOR CONTRIBUTIONS

Hansen Lui: Writing – original draft; data curation; methodology; investigation. **Phillip J. Kim:** Methodology; data curation. **Lisa H. Kang:** Methodology; formal analysis; investigation. **Blythe P. Durbin-Johnson:** Methodology; formal analysis; investigation; writing – original draft. **Eric A. Kurzrock:** Conceptualization; investigation; writing – original draft; methodology; validation; writing – review and editing; formal analysis; project administration; supervision.

CONFLICT OF INTEREST STATEMENT

The named authors have no conflict of interest, financial or otherwise.

APPROVAL OF THE RESEARCH PROTOCOL BY AN INSTITUTIONAL REVIEWER BOARD

University of California School of Medicine IRB approval #1417488-1.

INFORMED CONSENT

N/A.

REGISTRY AND THE REGISTRATION NO. OF THE STUDY/TRIAL

N/A.

ANIMAL STUDIES

N/A.

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HUMAN STUDIES

This retrospective study was conducted with Institutional Review Board approval (#1417488-1).

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1.