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Missed Opportunities to Decrease Radiation Exposure in Children with Renal Trauma

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Abbreviations and Acronyms

CT = computerized tomography

GCS = Glasgow Coma Scale

MVA = motor vehicle accident

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Study received institutional review board approval.

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Purpose: Efforts have been made to reduce use of computerized tomography in children with blunt abdominal injury. Computerized tomography may be overused in pediatric patients with renal trauma.

Materials and Methods: We performed a retrospective chart review of all renal trauma patients younger than 18 years old treated at 2 urban trauma centers from 2002 to 2016. We collected demographic and clinical characteristics, renal trauma grades, urological interventions, and timing and use of computerized tomography and renal ultrasound.

Results: During the study period 145 patients presented with blunt renal trauma. During hospitalization 46 patients (32%) underwent repeat computerized tomography. About 20% of repeat computerized tomograms were performed less than 48 hours after the first scan. After controlling for center, isolated injury (yes/no), stent placement, age and surgical interventions (yes/no) patients who underwent delayed imaging on their first scan had decreased odds of undergoing a second computerized tomogram (adjusted OR 0.2, 95% CI 0.05–0.9, p = 0.04). Number needed to treat to prevent 1 repeat scan in high grade renal trauma patients was 3 (95% CI 2–4). Estimated sensitivity and specificity for ultrasound monitoring to detect an abnormality requiring urological intervention are 50% and 94%, respectively.

Conclusions: Repeat computerized tomography in pediatric patients with renal trauma is common. Obtaining delayed imaging on the initial scan in patients with high grade renal trauma may prevent repeat scans. Renal ultrasound provides diagnostic usefulness in monitoring kidney injuries and should be considered before repeating computerized tomography.

Key Words: kidney; wounds and injuries; tomography, x-ray computed; radiation exposure; ultrasonography

Unintentional injury is the leading cause of death in the pediatric population after the neonatal period.[1] Blunt abdominal trauma causes renal injuries in 10% to 20% of children, making the kidney the most common organ injured in the urinary system.[2] In many respects management of pediatric renal trauma mirrors that in the adult population. However, the pediatric kidney is believed to be more susceptible to trauma because it sits lower in the abdomen.[3] Additionally imaging guidelines have been studied in adults and may not necessarily apply to the pediatric population.[4,5]

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Blunt trauma often requires the use of CT to visualize the extent of internal injuries and grade kidney injuries.[6] Although the initial CT is necessary to accurately stage a renal injury and prevent unnecessary surgery, repeat CT in children with renal trauma may be unnecessary.[7] Delayed imaging, which is defined as waiting 10 to 15 minutes after contrast administration, is often required to visualize the extent of urine extravasation and distinguishes urinomas from hematomas.[8] Cautious use of CT in children is warranted, given its association with malignancies.[9] Specific guidelines surrounding the use of diagnostic radiation in trauma settings are lacking, despite trends of increasing use of ultrasound in these patient populations.[10,11] In fact, although the use of CT is decreasing, there remains extreme variation in CT use among tertiary care hospitals.[12]

We describe the use of CT for renal trauma patients at 2 large trauma centers. We hypothesize that repeat CTs are used largely due to 2 mechanisms. First, lack of delayed imaging on the initial CT makes diagnosing urinary extravasation difficult and leads to repeat imaging. In addition, followup CTs 48 hours after presentation are common given adult imaging guidelines, which state followup CT is necessary in patients with grade 4 to 5 lacerations or patients with signs of complications such as fever and worsening flank pain.[5]

METHODS

Study Population

After institutional review board approval we retrospectively reviewed patient electronic medical records at 2 large trauma centers from 2002 to 2016. One trauma center specializes in pediatric care, whereas the other trauma center does not. All patients were identified using ICD-9 codes for blunt renal trauma (866.0, 866.00, 866.01, 866.02, 866.03) and were younger than 18 years old. All included patients underwent an initial CT confirming renal trauma, and injuries were graded according to the American Association for the Surgery of Trauma Organ Injury Scale.[6] Patients with penetrating trauma were excluded.

Injury Characteristics

We analyzed age at presentation, gender, trauma mechanism (MVA, sports related trauma, nonaccidental trauma, fall or other), whether the patient was transferred from elsewhere (yes/no), side of injury (left/right/bilateral), whether the injury was isolated to the kidneys (yes/no), initial GCS at presentation, whether the patient was immediately taken to the operating room for exploratory laparotomy, any urological specific intervention (stent placement, renorrhaphy, total nephrectomy or embolization) and mortality. We also collected when during the length of stay each of these procedures was performed, if at all. Indication for repeat imaging was not collected due to inconsistencies in the medical records.

Imaging Characteristics

We collected the date of every abdominal CT and renal ultrasound performed during hospitalization. Any imaging done elsewhere was included in the data collection. We determined whether delayed imaging was used for each abdominal CT to assess for damage to the renal collecting system. The outcome of interest was undergoing a second CT during hospitalization. Patients with high grade (3 to 5) renal trauma were stratified into 4 groups based on the mode of followup imaging, ie ultrasound only, CT only, ultrasound plus CT or none. Changes in management (eg urological interventions) were explored in each subgroup. High grade injuries were classified as grade 3 to 5 because this subgroup has an increased risk of urinary extravasation. Patients undergoing exploratory laparotomy were excluded from this subgroup analysis since imaging regimens are often different due to multiple severe injuries.

Statistical Analysis

All analyses were performed in Stata®, version 13. We used descriptive statistics to depict the population. We compared patients undergoing a second CT to those who did not. We assessed patient demographic characteristics and injury characteristics using Student t-tests for continuous variables and chi-square or Fisher exact test for categorical variables. We used multivariable logistic regression to determine independent effects of obtaining delayed images on the initial CT regarding undergoing a second CT. Covariates included in the model were selected based on univariable significance ($p < 0.10$) and/or thought to influence exposure (delayed images on initial CT) and outcome (undergoing a second CT). We then performed sensitivity analysis and repeated our models in patients with high grade injury only, those with low grade injury only and those with isolated renal injuries, excluding patients undergoing exploratory laparotomy.

We estimated sensitivity and specificity of ultrasound use in monitoring kidney injuries during hospital stay. The gold standard was whether the patient eventually required urological intervention. We assessed use of ultrasound to monitor injuries throughout the period studied and performed a test for trend by year. All statistical tests were 2-sided. Any p values less than 0.05 were considered statistically significant.

RESULTS

During the study period 145 patients met our inclusion criteria, of whom 96 (66%) were treated at a pediatric trauma center and 49 (34%) were treated at a nonpediatric center. Patient demographics and renal injury grades are outlined in table 1. Urological interventions included ureteral stents, nephrectomy, renorrhaphy during laparotomy and embolization. Of the nephrectomies 90% were performed on admission to the hospital and 10% on hospital day 5. All renorrhaphies were performed at the nonpediatric hospital. Two patients (1%) died during admission with multiple concomitant injuries.

During hospitalization 46 patients (32%) underwent repeat CT. About 20% of patients underwent

Table 1. *Demographic and clinical characteristics of children with renal trauma*

Median yrs age (IQR)	13.8 (9–16)
No. male/total No. (%)	100/145 (69)
No. trauma mechanism/total No. (%):	
MVA/motorcycle	53/145 (37)
Sports related	36/145 (25)
Nonaccidental	27/145 (19)
Fall	23/145 (16)
Other	6/145 (4)
No. transferred from elsewhere/total No. (%)	55/145 (39)
No. injury grade/total No. (%):	
1	44/145 (31)
2	22/145 (15)
3	35/145 (24)
4	39/145 (27)
5	4/145 (3)
No. rt sided injury/total No. (%)	75/145 (52)
No. isolated renal injury/total No. (%)	56/145 (39)
Median initial GCS (range)	15 (3–15)
No. immediate laparotomy/total No. (%)	22/145 (15)
No. urological procedures/total No. (%):	
Stent placement	10/145 (7)
Total nephrectomy	5/145 (3)
Renorrhaphy	5/145 (3)
Renorrhaphy during laparotomy	4/145 (3)
Embolization	1/145 (0.7)
No. mortality/total No. (%)	2/145 (1)

Table 2. *Univariable associations of clinical characteristics and undergoing second CT during hospitalization for pediatric renal trauma*

	Scanned Twice	Scanned Once	p Value
Median age (IQR)	15 (10–17)	13 (9–16)	0.06
No. male/total No. (%)	34/46 (74)	66/99 (67)	0.38
No. trauma mechanism/total No. (%):			0.23
MVA/motorcycle	16/46 (35)	37/99 (37)	
Sports related	8/46 (17)	28/99 (28)	
Nonaccidental	8/46 (17)	15/99 (15)	
Fall	13/46 (28)	14/99 (14)	
Other	1/46 (2)	5/99 (5)	
No. pediatric trauma center/total No. (%)	20/46 (43)	76/99 (77)	<0.001
No. delayed imaging on first scan/total No. (%)	9/46 (20)	11/99 (13)	0.30
No. transferred from elsewhere/ total No. (%)	18/46 (39)	37/99 (39)	0.95
No. injury grade/total No. (%):			<0.001
1	4/46 (9)	40/99 (41)	
2	5/46 (11)	17/99 (17)	
3	14/46 (30)	21/99 (21)	
4	20/46 (43)	19/99 (19)	
5	3/46 (7)	1/99 (1)	
No. rt sided injury/total No. (%)	21/46 (46)	54/99 (56)	0.24
No. isolated renal injury/total No. (%)	15/46 (33)	41/99 (43)	0.21
Median initial GCS (range)	15 (3–15)	15 (3–15)	0.66
No. immediate laparotomy/total No. (%)	10/46 (22)	12/99 (12)	0.13
No. urological procedures/total No. (%):			
Stent placement	8/46 (17)	2/99 (2)	0.002
Total nephrectomy	2/46 (4)	3/99 (3)	0.51
Renorrhaphy	2/46 (4)	3/99 (3)	0.65
Renorrhaphy during laparotomy	1/46 (2)	3/99 (3)	1.00
Embolization	1/46 (2)	0/99 (0)	0.32
No. mortality/total No. (%)	1/46 (2)	1/99 (1)	0.54

repeat CT less than 48 hours after the first scan. An additional 5% to 7% of patients underwent repeat CT on day 2 or 3. Of the 46 repeat CTs 25 (54%) were repeated with delayed imaging.

Table 2 shows the univariable analysis comparing patients who underwent a second CT and those who underwent only 1 during hospitalization. Patients undergoing 2 scans were more likely to have presented to the nonpediatric trauma center compared to the pediatric trauma center (57% vs 43%, $p < 0.001$). In the univariable analysis there was no statistical difference in the proportion of patients who underwent delayed images on the first CT (20% vs 13%). Patients with repeat CTs were more likely to have high grade renal trauma (80% vs 41%) compared to those undergoing 1 CT. No differences were found in any of the urological interventions between the 2 populations except for ureteral stenting. Patients undergoing a second scan were more likely to have a stent placed (17% vs 2%, $p = 0.002$) compared to those undergoing 1 scan. No statistical differences by age, gender, mechanism, transfer status, side of injury, isolated injury, GCS, laparotomy or mortality were found between the 2 groups.

After controlling for trauma center, renal injury grade, isolated injury (yes/no), stent placement, age, kidney intervention (yes/no) and whether a patient underwent exploratory laparotomy those who underwent delayed images on the first scan had decreased odds of undergoing a second CT (adjusted OR 0.2, 95% CI 0.05–0.9, $p = 0.04$). Of patients with high grade renal trauma those who underwent delayed images on the first scan had decreased odds of undergoing a second CT (adjusted OR 0.1, 95% CI 0.01–0.9, $p = 0.04$). The association was not statistically significant for low grade or isolated injuries. Excluding those with exploratory laparotomies, the estimate is similar (adjusted OR 0.1, 95% CI 0.02–0.9, $p = 0.04$). In patients with high grade renal injuries the risk difference for a second CT between those undergoing vs not undergoing delayed imaging on the first CT was 30% (95% CI 24.4–37.0). Therefore, obtaining delayed images on the first scan for 3 patients (95% CI 2–4) prevents 1 repeat CT during admission. Additionally patients presenting to the nonpediatric trauma center had increased odds of undergoing a second CT (adjusted OR 15.1, CI 3.9–58.4, $p < 0.001$) after adjusting for covariates. This association was not statistically significant for isolated injuries.

A total of 75 patients (52%) presented with high grade renal trauma, of whom 20 (27%) underwent surgery on the day of injury and 55 (73%) were initially observed. Of the patients who were initially observed 13 (24%) underwent reimaging with ultrasound only and 2 of these patients underwent ureteral stent placement. Of the observed patients 20 (36%) underwent repeat CT and 4 received a ureteral stent. Of these same patients 6 (11%) underwent ultrasound plus CT for repeat imaging. In 2 cases the ultrasound did not yield sufficient information, and thus CT was performed. Both

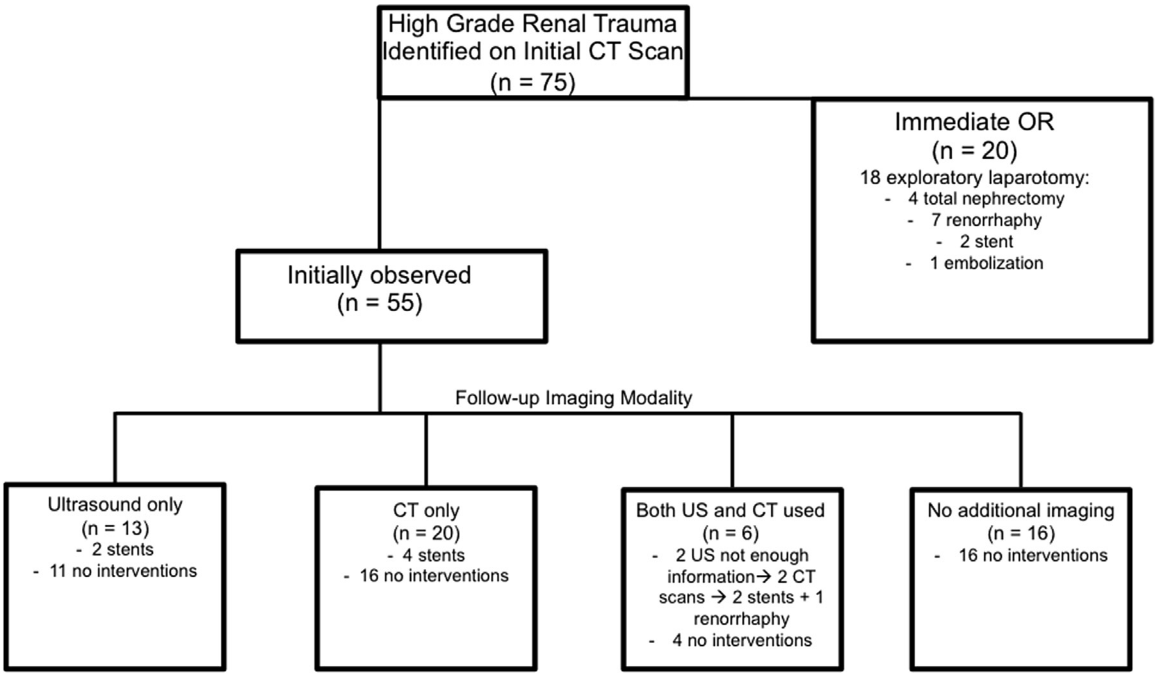

Figure 1. Use of diagnostic radiological scans and changes in management of children with renal trauma. *OR*, operating room. *US*, ultrasound.

patients received a ureteral stent and 1 also underwent renorrhaphy after undergoing the repeat CT. Of the observed patients 16 (29%) underwent no reimaging after initial CT.

Figure 1 contains a flow diagram of repeat imaging in patients with high grade renal trauma. With any urological intervention as our outcome true-positive ultrasounds were observed in 2 patients, while false-negatives were noted in 2 (ie repeat CT was necessary). True-negative ultrasounds were observed in 15 patients, while there were no false-positives. Assuming a value of 1 for mathematical purposes, estimates of sensitivity and specificity for ultrasound to detect an abnormality sufficient for urological intervention are 50% and 94%, respectively. Figure 2 illustrates ultrasound usage (yes/no) during hospital admission by year ($p < 0.001$ for trend). Ultrasound usage increased at the pediatric and nonpediatric centers. By 2016 half of patients underwent at least 1 ultrasound during admission.

DISCUSSION

Repeat CTs in children with renal trauma is common. Approximately 1 of 5 children underwent repeat CT less than 48 hours after the initial CT. Delayed imaging on the initial CT is independently protective of undergoing a second CT, especially in patients with high grade renal trauma. We approximate the number needed to treat with delayed images on the initial CT among patients with high grade renal trauma (grade 3 to 5) to be 3 to prevent 1 repeat CT. Followup imaging with ultrasound during admission may be sufficient to inform management decisions. We estimate the sensitivity and specificity of ultrasound for urological intervention to be 50% and 94%, respectively. Additional research is necessary to confirm these estimates. Overall, initial delayed imaging in patients with high grade renal trauma may prevent additional CTs.

Exposure to ionizing radiation is common in children presenting with blunt abdominal trauma.[13] Efforts have been made to decrease use of CT in

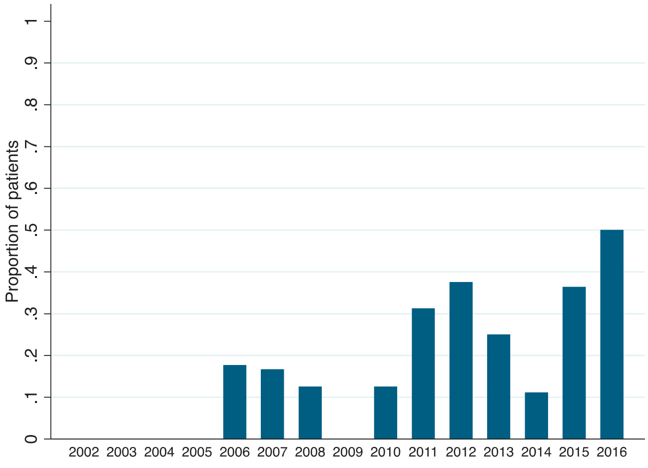

Figure 2. Prevalence of children undergoing at least 1 renal ultrasound during hospitalization for renal trauma.

children with the use of clinical prediction tools.[10,14] In our analysis we uncovered 2 potential avenues to reduce CT in children. First, obtaining delayed imaging with initial scan in children with blunt abdominal trauma suspected of high grade renal injury on initial images may decrease the need for subsequent scans. In addition, obtaining ultrasound imaging to follow high grade renal trauma may be sufficient to enable treatment decisions.

In children with suspected kidney injury excretory phase contrast material (ie delayed imaging) is necessary to visualize the collecting system.[15] Approximately 5 to 8-minute delayed imaging increases the probability of visualizing extravasation of contrast material from the renal collecting system.[16] Although such a protocol may not be feasible for all blunt abdominal trauma cases due to hemodynamic instability, we provide evidence that waiting for delayed imaging in suspected cases of high grade renal trauma from initial images may prevent future CT.

Clinicians should have a high suspicion for renal injury in children with blunt abdominal trauma as the kidney is the third most common organ injured and kidney injury may be seen during the contrast phase.[15] Moreover, children are particularly susceptible to ureteropelvic junction disruption, and delayed imaging helps to prevent misdiagnosis of this complication.[16,17] Although adding delays increases the radiation dose, we believe that by applying this recommendation to patients with high grade renal injury on initial imaging, this increased radiation dose initially will prevent further scans and thus decrease overall radiation exposure.[18] Additionally, avoiding a second CT will decrease contrast exposure and may prevent acute kidney injury.[19] Delayed imaging in patients with low grade renal trauma is unnecessary.

Current AUA guidelines suggest repeat CT 48 hours after presentation in patients with documented grade 4 to 5 renal trauma or symptoms concerning for complications.[5] However, application of these guidelines in children is controversial. As children have longer life expectancies and increased radiation sensitivity, the ALARA (as low as reasonably achievable) principle advocates decreasing radiation whenever possible.[20]

Eeg et al reported that ultrasound monitoring did not delay significant diagnosis of complications in children with renal trauma.[7] Conservative initial and followup imaging with ultrasound was prospectively applied in 47 patients with renal trauma.[21] The ultrasound correctly diagnosed renal injury in 87% of patients but false-negative results were common. Although the sensitivity of ultrasound to inform intervention is poor, the combined sensitivity (0.5) and specificity (0.94) is beyond 1, suggesting diagnostic utility.[22] Based on previous findings and those presented herein, we recommend that patients with high grade renal injury be monitored with ultrasound. However, due to false-negative findings, repeat CT may be unavoidable, especially if ureteropelvic junction disruption is suspected.

The findings of our study derive from trauma centers in 1 geographic region and thus may not be generalizable to other institutions. Although we controlled for whether the injury was an isolated renal injury or consisted of multiple injuries, other clinical findings that may lead to repeat CT, such as patient subjective report, vital signs and physical examination findings, were not measured in our study. The sensitivity and specificity of renal ultrasound to determine changes in management were reported but we were unable to directly compare ultrasound to CT findings because few patients underwent both. Future research should incorporate a more concrete gold standard. Data were collected from hospital admissions, and long-term followup or hospital readmission of these patients was not obtained.

CONCLUSIONS

A large proportion of pediatric patients (32%) with renal trauma undergo at least 2 CTs during admission. We estimate that obtaining delayed imaging on the initial CT in 3 patients with high grade renal trauma will prevent 1 repeat CT during admission. Renal ultrasound provides diagnostic utility in monitoring kidney injuries and should be considered before repeating CT. We recommend obtaining delayed imaging on the initial CT in all stable pediatric patients with high grade (3 to 5) renal trauma and monitoring renal injuries with ultrasound during hospitalization.

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