Surgery Open Science 5 (2021) 19–24

Contents lists available at ScienceDirect

Surgery Open Science

journal homepage: https://www.journals.elsevier.com/surgery-open-science

Implementation of a clinical guideline for nonoperative management of isolated blunt renal injury in children

Allie E. Steinberger, MD, MPH [a], Nicole A. Wilson, PhD, MD [a,b,*,1], Connor Fairfax, BSN, RN [b], Stephanie J. Treon, RN, CPNP, TNS [a], Michele Herndon, MSN, RN, CPEN, TCRN, TNS [b], Tamar L. Levene, MD, MS [c], Martin S. Keller, MS, MD [a]

[a] Washington University in St. Louis School of Medicine, 1 Barnes Jewish Hospital Plaza, St. Louis, MO 63110
[b] St. Louis Children's Hospital, 1 Children's Place, St. Louis, MO 63110
[c] Joe DiMaggio Children's Hospital, 1005 Joe DiMaggio Dr, Hollywood, FL 33021

ARTICLE INFO

Article history:
Received 15 March 2021
Received in revised form 12 April 2021
Accepted 26 April 2021
Available online 3 May 2021

ABSTRACT

Background: The aim was to evaluate the impact of a standardized nonoperative management protocol by comparing patients with isolated blunt renal injury before and after implementation.
Methods: We retrospectively reviewed the trauma registry at our Level 1 pediatric trauma center. We compared consecutive patients (≤18 years) managed nonoperatively for blunt renal injury Pre (1/2010–9/2014) and Post (10/2014–3/2020) implementation of a clinical guideline. Outcomes included length of stay, intensive care unit admission, urinary catheter use, and imaging studies.
Results: We included 48 patients with isolated blunt renal injuries (29 Pre, 19 Post). There were no differences in age, sex, injury grade, or mechanism ($P > .05$). Postprotocol had decreased length of stay ($P = .040$), intensive care unit admissions ($P = .015$), urinary catheter use ($P = .031$), and ionizing radiation imaging ($P < .001$).
Conclusion: These data suggest improved outcomes and resource utilization following implementation of a nonoperative management protocol of pediatric isolated blunt renal injuries.

INTRODUCTION

Blunt force trauma is responsible for 90% of renal injuries in children, and the kidney is injured in approximately 10% of all pediatric blunt abdominal trauma [1]. Compared to adults, children are at higher risk of renal injury from blunt mechanisms due to several anatomic factors that contribute to less protection for the kidney (eg, relatively increased renal size and mobility; decreased perirenal fat; weaker abdominal musculature; and a more compliant, less ossified thoracic cage) [2,3]. Isolated renal injuries in children are uncommon, as renal injuries concomitant with multiorgan injuries represent the majority of patient presentations [4].

Nonoperative expectant management is the standard of care in hemodynamically stable adults with blunt renal injury [5]. Based primarily on data from the adult trauma literature [5] and retrospective series in pediatric patients [6,7], the management of pediatric renal injuries has also largely shifted toward nonoperative management in hemodynamically stable patients [3]. In 2017, Cunningham et al published an expedited recovery protocol for management of pediatric blunt solid organ injury using a series of 106 patients with solid organ injuries, including spleen, liver, and kidney [8]. In 2019, the Pediatric Trauma Society and EAST guidelines committees published guidelines strongly recommending nonoperative over operative management in hemodynamically stable patients with blunt renal trauma [9]. Despite these recommendations, there are few published algorithms that provide specific guidance on the details of nonoperative management of isolated renal trauma in pediatric patients.

Our American College of Surgeons (ACS)–verified Level 1 pediatric trauma center implemented a standardized consensus pathway for the nonoperative management of hemodynamically stable patients with isolated blunt renal injury in September 2014. The development of this clinical guideline was based on previously published experience

Abbreviations: ACS, American College of Surgeons; LOS, length of stay; ICU, intensive care unit; AAST, American Association for the Surgery of Trauma; CAUTI, catheter-associated urinary tract infections; CDC, Centers for Disease Control and Prevention (CDC); CBC, complete blood count; CT, computed tomography; VCUG, voiding cystourethrogram; SPECT, single-photon emission computerized tomography; DMSA, dimercaptosuccinic acid; MAG3, mercaptuacetyltriglycine scan; ROUT, robust regression with outlier detection.

* Corresponding author at: Division of Pediatric General Surgery, Golisano Children's Hospital, University of Rochester School of Medicine & Dentistry, 601 Elmwood Avenue, Box SURG, Rochester, NY 14642. Tel.: +1 585 275 4435 (Office).
E-mail addresses: Nicole.Wilson@RothAffinity.com, Nicole_Wilson@urmc.rochester.edu (N.A. Wilson).
[1] Present address: University of Rochester School of Medicine & Dentistry, 601 Elmwood Ave, Box SURG, Rochester, NY 14642.

https://doi.org/10.1016/j.sopen.2021.04.003
2589-8450/

demonstrating preserved renal function in children after nonoperative management [10,11], a contemporary literature review, and an internal retrospective review of consecutive patients in the 5 years prior to implementation that identified variances in care and the need to adopt current best practices (unpublished data). The purpose of this study was to evaluate the effect of this standardized nonoperative management protocol by comparing data from consecutive patients presenting with isolated blunt renal injury after protocol implementation to historical controls. We hypothesized that a standardized approach to the nonoperative management of isolated blunt renal injuries would be associated with improvements in patient care and decreased resource utilization.

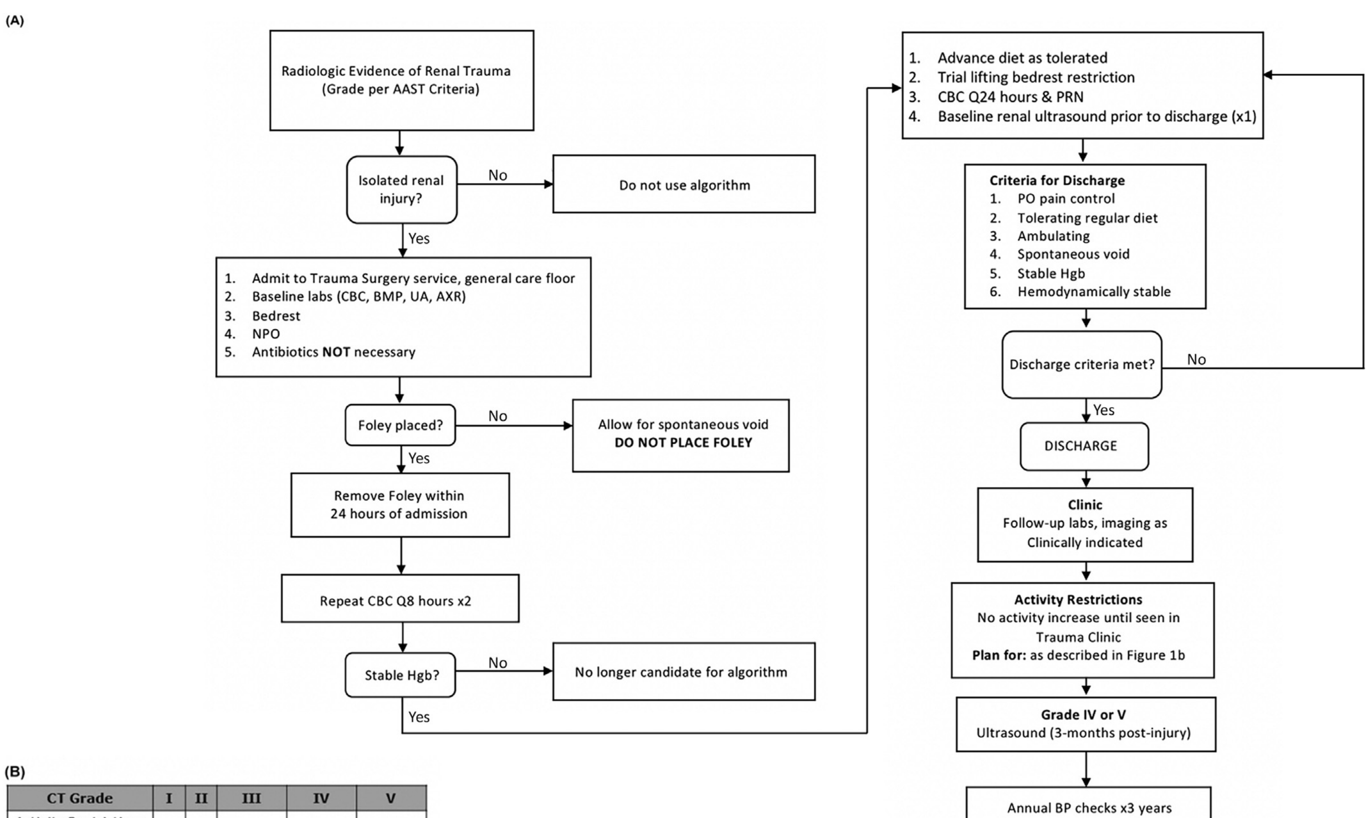
METHODS

After obtaining institutional review board approval, we evaluated the trauma registry (a prospective patient registry) at our Level 1 pediatric trauma center. Patients with renal trauma were treated according to a consensus nonoperative blunt renal trauma protocol instituted in September 2014 (Fig 1). Consecutive patients 18 years of age and younger who presented with a diagnosis of kidney injury from January 2010 to March 2020 were identified from the trauma registry, and a retrospective review of all patients' medical records and radiologic imaging was conducted.

Our hospital is an ACS-verified Level 1 pediatric trauma center and tertiary referral center. Our immediate service area includes the states of Missouri and Illinois, specifically the 12 counties surrounding the St. Louis area which represent a population of 609,425 people <18 years of age. During the study period, a mean of 1,621 new patients were entered into the trauma registry annually.

Inclusion/Exclusion Criteria. Patients were considered for inclusion if they had evidence of renal trauma. Inclusion criterion was the presence of isolated blunt renal injury, which was defined as patients with documented renal injuries from a known blunt mechanism and with no other injuries that required hospital admission or were likely to lengthen hospital stay for management. Exclusion criteria were as follows: multisystem injuries, including nonrenal trauma that would otherwise require extended hospital admission; hemodynamic instability; hemoglobin decrease of >1 g/dL on 2 consecutive lab draws at least 6 hours apart; penetrating mechanism; and suspected nonaccidental trauma or unknown mechanism of injury.

Data Collection. Patients were identified using the trauma registry, and additional data were collected from the electronic medical record. Data collected included sex, age, height, weight, length of hospital stay (LOS), mechanism of injury, computed tomography (CT), grade of renal injury, other injuries, urinary catheter placement and duration, incidence of catheter-associated urinary tract infections (CAUTI) [defined according to the Centers for Disease Control (CDC) guidelines] [14], Urology service consultation, number of complete blood count (CBC) laboratory tests performed, intensive care unit (ICU) admissions, length of ICU stay, failure of nonoperative management, readmissions within 30 days for related complaints, and the type and number of imaging studies obtained at follow-up (if any). Failure of nonoperative management was defined in patients initially treated according to the nonoperative protocol that were subsequently censored due to decreasing hemoglobin and patients that ultimately required nephrectomy, renorrhaphy, or invasive procedure for management specific to the kidney (ie, embolization). Follow-up imaging types were subdivided into those that expose the patient to ionizing radiation (ie, CT, voiding cystourethrogram



CT Grade	I	II	III	IV	V
Activity Restrictions (weeks)	1	2	4-6	4-6	6-8

Fig 1. Protocol for nonoperative management of patients with isolated blunt renal injuries. (A) Nonoperative management protocol. (B) Activity restriction guidelines based on AAST CT grade of injury. *AAST*, American Association for the Surgery of Trauma; *CBC*, complete blood count; CT, computed tomography; *BMP*, basic metabolic panel; *UA*, urinalysis; *AXR*, abdominal x-ray; *NPO*, nil per os (ie, nothing to eat or drink allowed); *PO*, per os (diet allowed); *PRN*, as needed; *DMSA*, nuclear medicine scan using dimercaptosuccinic acid; *BP*, blood pressure.

(VCUG)), nuclear imaging studies (ie, single-photon emission computerized tomography (SPECT), dimercaptosuccinic acid (DMSA), and mercaptuacetyltriglycine (MAG3) scans), and imaging that does not involve exposure to ionizing radiation (ie, ultrasound).

The American Association for the Surgery of Trauma (AAST) kidney trauma grading system was used to grade all renal injuries based on imaging obtained at the time of presentation [12]. The AAST kidney trauma grading system was originally introduced in 1989 [13], but for consistency, all imaging was re-reviewed at the time of data collection and grading was based on the published 2018 revision [12]. There were no changes in grade of renal injury with this update.

Statistical Analysis. Patients were subsequently divided into two groups: Pre and Post. The Pre group consisted of patients who presented prior to protocol implementation (1/2010 to 9/2014), whereas the Post group consisted of patients that presented after protocol implementation (10/2014 to 3/2020). Patient characteristics and management variables were compared between the Pre and Post patient groups. For each variable, Pre and Post groups were compared using unpaired comparisons (Fisher exact test for categorical variables, Mann–Whitney *U* test for continuous variables). The Kruskal–Wallis test was used to compare multiple groups (distribution of renal injury by grade and LOS by injury grade). Data are reported using median and interquartile range, unless otherwise noted. Deviation from the protocol (nonadherence) was identified using outlier detection. Outliers were identified using the robust regression with outlier detection (ROUT) method [15]. Outliers were identified but not removed from further analysis. For our analysis, the threshold for outlier detection (Q) was preset to a stringent value = 0.1% (making it more difficult to identify outliers and thus more likely that the identified points represent true deviations in care). Alpha and beta were preset to .05 and .20, respectively. Statistical tests were performed using Prism 8 (GraphPad, San Diego, CA).

RESULTS

Patient Selection. Overall, between January 2010 and March 2020, 127 patients with renal trauma were identified from the trauma registry (Fig 2). Seventy-nine patients were excluded from the study, and 48 (38%) patients were ultimately included for further analysis. There were 29 patients in the Pre group and 19 patients in the Post group.

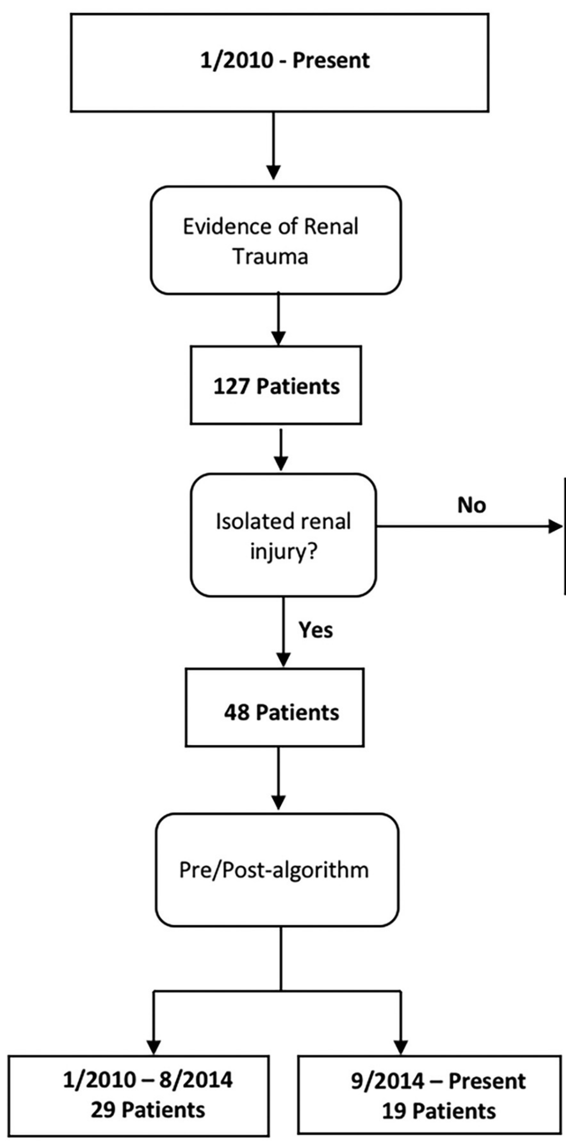


Fig 2. Flowchart illustrating the inclusion/exclusion of patients for this study.

Table 1
Patient demographic characteristics

	All included	*Pre*	*Post*	P *value*
Number of patients	48	29	18	–
Male patients (%)	62.5%	69.0%	52.6%	.362
Age (y)*	12.80 (6.4)	12.45 (7.7)	13.75 (6.2)	.161
Height (cm)*	159.75 (34.4)	157.00 (45.1)	162.00 (17.2)	.168
Weight (kg)*	50.55 (31.5)	49.00 (33.5)	53.98 (31.1)	.494

* Data are reported in median (interquartile range).

Table 2
Injuries other than renal injury by organ system

	All included	*Pre*	*Post*
Abrasion/laceration	12	6	6
Fracture	4	2	2
Liver injury (Grades 1–2)	4	1	3
Spleen injury (Grades 1–2)	6	3	3
Adrenal hemorrhage	1	0	1

Demographics and Injury Characteristics. There were no significant differences between the demographic characteristics of the 2 groups [sex, age at the time of injury, height, and weight (Table 1)]. A summary of other (nonrenal) injuries in the 2 groups is shown in Table 2. Overall, associated injuries included multiple superficial skin abrasions and lacerations, humerus fractures ($n = 2$), isolated rib fractures ($n = 2$), Grade 1–2 splenic lacerations, Grade 1–2 liver lacerations, and a right adrenal hemorrhage (Table 2). No injury was deemed significant enough, based on standard management practices, to warrant deviation from protocol by lengthening hospital stay or changing the frequency of laboratory tests.

The common mechanisms of injury in the 2 groups are shown in Fig 3, *A*. Falls were more common in the Pre group, whereas motor vehicle collision (MVC) was a more common mechanism for renal injury in the Post group (Fig 3, *A*). Four patients had mechanisms of injury that were not easily classified [ie, struck by a pole ($n = 2$), pulled countertop onto self, and sledding]. The majority of injuries were Grade 3 and 4 renal injuries in both groups (Fig 3, *B*). There was no difference in the distribution of renal injury by grade between the Pre and Post protocol groups ($P = .313$).

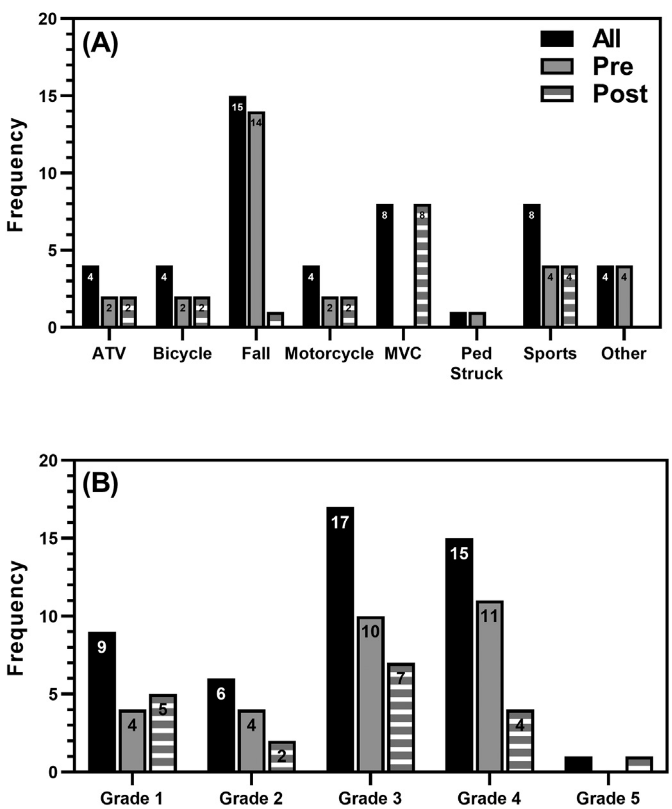


Fig 3. (A) Frequency distribution of mechanisms of injury. (B) Frequency distribution of grade of renal injury for each group. Numerals at the top of bars indicate the individual frequencies for each bar. *ATV*, all-terrain vehicle; *MVC*, motor vehicle crash, *ped struck*, pedestrian struck.

Length of Stay and ICU Admissions. Implementation of a standardized nonoperative management protocol was associated with a decrease in the mean length of hospital admission and fewer ICU admissions (Table 3). Length of stay decreased by a mean of 0.76 days after protocol implementation. Median LOS for all patients was 2.27 days; 2.45 (2.0) days in the Pre group, and 2.07 (1.9) days in the Post group ($P = .040$). There was no difference in LOS by injury grade between the Pre and Post groups ($P = .113$). Using the ROUT method for LOS, no outliers were identified. Therefore, we were unable to detect any large variations in care with respect to length of stay. Overall, 16.7% of patients were admitted to the pediatric ICU during the entire 10-year study period. In the Pre group, 27.6% of patients were admitted to the ICU, whereas no patients (0.0%) were admitted to the ICU postimplementation ($P = .015$). Patients admitted to the pediatric ICU stayed a mean of 0.82 days prior to protocol implementation, which decreased to zero days postimplementation ($P = .015$).

Laboratory Testing. Significantly fewer CBCs were performed during admission after implementation of the standardized protocol. For all included patients, the median number of CBCs performed during admission was 3.0 (3.0). In the Pre group, there were 4.0 (2.0) CBCs drawn per patient, which decreased to 2.0 (3.0) in the Post group ($P = .041$). For the number of CBCs performed, a single outlier was detected in each of the Pre and Post groups. In the Pre group, a single patient with a Grade 4 renal injury had 13 CBCs drawn during their index hospitalization. In the Post group, a single patient with a Grade 2 renal injury had 7 CBCs drawn during their index hospitalization. These outliers represent variations in care and likely imply deviations from or nonadherence with the standardized protocol.

Urinary Catheters and Urology Specialty Consultation. The frequency of urinary catheter placement also decreased after implementation of the standardized protocol. Overall, 35.4% of patients had a urinary catheter placed on presentation due to their renal injury. In the Pre group, 48.3% of patients had a urinary catheter placed, whereas 15.8% of patients underwent catheter placement postimplementation ($P = .031$). Interestingly, although fewer patients in the Post group had a catheter placed, the median duration that urinary catheters remained in place was similar between the 2 groups [Pre: 32.7 (28.4), Post: 40.0 (21.8) hours; $P = .843$]. The incidence of CAUTI was 0% in both groups. Urology specialty consultation was obtained at time of presentation with similar frequency for both study groups (Pre: 48.3%, Post: 42.1%; $P = .771$).

Table 3
Comparative outcome measures in Pre and Post groups

	All included	*Pre*	*Post*	P *value*
Length of stay (d)†	2.27 (1.5)	2.45 (2.0)	2.07 (1.9)	0.040*
ICU admissions (%)	16.7%	27.6%	0.0%	0.015*
ICU LOS (d)†	–	0.71 (0.5)	0.0 (0)	0.015*
CBCs (n)†	3.00 (3.0)	4.00 (2.0)	2.00 (3.0)	0.041*
Urinary catheter (%)	35.4%	48.3%	15.8%	0.031*
CAUTI incidence (%)	0%	0%	0%	–
Urology consultation (%)	–	48.3%	42.1%	0.771
Failure of nonop management (n)	1	1	0	–
30-d readmissions (n)	3	3	0	0.267
Follow-up imaging (%)	–	72.4%	57.9%	0.027*
Ionizing radiation	–	37.9%	10.5%	< 0.001*

* Indicates statistical significance.
† Data reported in median (interquartile range).

Patient Outcomes. There was a single (2%) documented failure of nonoperative management for a delayed complication in the entire cohort. This patient (in the Pre group) required embolization of a traumatic pseudoaneurysm, which presented with persistent hematuria complicating a Grade 4 injury. Overall, there were 3 (6.25%) readmissions within 30 days for complaints related to the renal injury. All readmissions occurred in the Pre group. Although readmissions decreased in the Post group, the difference did not reach statistical significance because of the rare occurrence of the outcome [Pre: 10.3% ($n = 3$), Post: 0% ($n = 0$); $P = .267$]. No patient in the study developed hypertension.

Follow-Up Imaging. The use of any follow-up imaging, and particularly the use of ionizing radiation, decreased after implementation of the standardized protocol. The number of patients that underwent any follow-up imaging decreased after protocol implementation (Pre: 72.4%, Post: 57.9%; $P = .027$). In addition, the use of ionizing radiation for follow-up imaging decreased after protocol implementation (Pre: 37.9%, Post: 10.5%; $P < .001$).

DISCUSSION

Numerous published reports support nonoperative management of hemodynamically stable pediatric patients with renal injuries. In 2004, Buckley and McAninch demonstrated a >99% renal salvage rate in their series of 374 patients [16]. They suggested that nonoperative management of injury Grades 1–3 required a period of observation until resolution of hematuria, at least 24 hours of bedrest for Grade 2 and 3 injuries, and a postinjury CT/functional scan at 3 months. For more severe injuries (≥ Grade 4), successful nonoperative management required close observation, serial hematocrits, at least 48 hours of bedrest, and repeat imaging at 48 hours or earlier if clinically prompted to reassess the injury status [16].

To standardize care, similar to the well-documented approaches utilized for isolated liver and spleen injuries in children [18], our Level 1 pediatric trauma center implemented a standardized clinical pathway for nonoperative management of hemodynamically stable patients with isolated blunt renal injury in September 2014 (Fig 1). The development of this protocol was based on previously published experience demonstrating preserved renal function in children after nonoperative management [10,11], literature review (as of 2014), and an internal retrospective review of consecutive patients in the 5 years prior to implementation that identified variances in care and current best practices (unpublished data). This algorithm represented the consensus of the primary stakeholders in renal trauma management at our institution (pediatric general surgeons, emergency physicians, urologists, and a dedicated trauma nurse practitioner). It was reviewed and approved by our institutional trauma committee. It was generated to guide management of pediatric patients with isolated renal trauma from the time of admission through discharge from the hospital and initial follow-up. As a major academic medical center, there are a range of practitioners (eg, attending surgeons, nurse practitioners, fellows, and residents) that regularly participate in the care of trauma patients. Our protocol provides guidelines for the standardized management of included patients, leading to decreased length of stay, fewer ICU admissions, and fewer invasive laboratory tests/procedures. Similarly, in their series of 106 patients with solid organ injuries (liver, spleen, and kidney), Cunningham et al demonstrated decreases in hospital stay, ICU stay, and total phlebotomy after implementation of a standardized protocol [8].

There were no failures of nonoperative management and no readmissions after protocol implementation in this series. As noted, our institution treated patients with isolated renal injury with expectant nonoperative management prior to implementation of the standardized protocol. One patient in the Pre group eventually required embolization of a traumatic pseudoaneurysm, constituting a single failure of nonoperative treatment at our institution over the full study period. After protocol implementation, no patients were censored or "fell off the pathway" due to decreasing hemoglobin levels or due to the need for conversion to operative/invasive intervention, underscoring the safety and efficacy of our standardized protocol in this series. After discharge, no patients failed due to development of ischemic renal tissue or developed resultant hypertension. Annual blood pressure checks for 3 years are requested in a follow-up letter sent to pediatricians. This is consistent with previous studies of blunt solid organ injury in which the incidence of posttraumatic renal failure and hypertension (Page kidney) was exceedingly low [7,11].

Even with the limited number of patients in this cohort, striking improvements in care and resource utilization were achieved and likely could be replicated with implementation of a standardized care protocol for trauma patients. Several studies have included cost analyses with respect to length of stay in children's hospitals [8,19]. Although no direct cost analysis was performed in the current study, based on previously published data, the mean decrease in length of stay of 0.76 days represents an estimated cost savings of $1,900–$2,500 per patient [8,19]. Further substantial cost savings are implied by the decreased/eliminated ICU stays, decreased number of laboratory tests performed, decreased urinary catheter placement, decreased exposure to ionizing radiation for follow-up imaging, and decreased readmission rates in patients managed according to our protocol.

As nonoperative management of blunt renal trauma has become more common, published series have shifted toward shorter periods of observation and bedrest and away from mandatory follow-up imaging during index hospitalization, particularly for those studies requiring ionizing radiation. Malcolm et al showed that routine follow-up imaging is unnecessary in adult patients with blunt renal injuries of Grades 1–3 and that Grade 4 renovascular injuries can be followed clinically without routine early follow-up imaging [17]. Previous large patient series have demonstrated predictable and durable posthealing renal function based on injury grade at presentation [10,11]. These series used DMSA imaging, which can be supplanted with imaging that does not involve exposure to ionizing radiation to screen for asymptomatic healing complications as we have done in this study. In follow-up, DMSA scans have been largely replaced by ultrasound for high-grade injuries (4 and 5) to assess for urinoma or perfusion deficits. This is compared to a baseline ultrasound obtained for each patient during the index admission. As a caveat, follow-up imaging via MAG3 renal scan or MRI is recommended for patients in whom there is any indication of compromised renal function or hypertension.

The results of this study must be interpreted with respect to its limitations. Isolated renal injuries are uncommon in blunt pediatric trauma. Therefore, only 48 patients were identified over a 10-year period despite this study being set at a busy Level 1 pediatric trauma center. Although small sample sizes may limit our ability to detect differences between groups, the decreases in length of stay, ICU admissions, and invasive procedures are likely robust outcomes that reflect changes in practice and improvements in care with a standardized protocol. There were no differences in urologic consultation despite this being a primarily surgeon-dependent variable. In general, consults were requested for patients with injuries to the urinary collecting system. Although there was a decrease in Foley catheter placement postimplementation, there were no firm indications for catheter placement at baseline. Most patients who received Foley catheters had them placed at an outside hospital prior to transfer/arrival at our institution. As such, the more important end point here is time to catheter removal which was similar between groups. In addition, although the implemented protocol provides guidelines for the practitioner caring for each trauma patient, variances from the guideline or adherence to the protocol was not strict because of allowances made for individual clinical judgement. Adherence postimplementation was monitored by the authors of this study. Although adherence to the protocol was not addressed directly, the outliers identified in the CBC counts (1 in each of the groups) indicate reasonable adherence to the every-8-hour CBC recommendation. Of note, there was no transition period after approval and implementation of the protocol. However, all of the stakeholders involved in the creation of the clinical guideline were the providers responsible for management of these trauma patients.

In conclusion, the goals of managing renal injuries in children are the same as in adults, namely, rapid detection of injury and renal preservation. Although the management of pediatric renal injuries has largely shifted toward nonoperative management of hemodynamically stable patients, there are few published protocols that provide specific guidance on the details of nonoperative management of isolated renal trauma in this population. This study addresses that gap by providing a specific set of guidelines for the care of hemodynamically stable pediatric patients with isolated renal injuries managed at our institution. This series demonstrates that implementation of a standardized nonoperative management protocol was associated with significant improvements in care and decreased resource utilization in patients with isolated blunt renal injuries.

Conflict of Interest

None.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Credit Statement

AES: Formal analysis, Writing – review & editing, Visualization; NAW: Conceptualization, Methodology, Formal analysis, Writing, Visualization, Project administration; CF: Resources, Data curation, Writing – review & editing; SJT: Resources, Data curation, Writing – review & editing; MH: Resources, Data curation, Writing – review & editing; TLL: Conceptualization, Formal analysis, Writing – review & editing; MKS: Conceptualization, Formal analysis, Resources, Writing, Supervision.

References

[1] McAninch JW, Carroll PR, Klosterman PW, Dixon CM, Greenblatt MN. Renal reconstruction after injury. J Urol. 1991;145(5):932–7. https://doi.org/10.1016/s0022-5347(17)38494-x.

[2] Brown SL, Elder JS, Spirnak JP. Are pediatric patients more susceptible to major renal injury from blunt trauma? A comparative study. J Urol. 1998;160(1):138–40 PMID: 9628634.

[3] Fernández-Ibieta M. Renal trauma in pediatrics: a current review. Urology. 2018; 113:171–8. https://doi.org/10.1016/j.urology.2017.09.030.

[4] Casale AJ. Urinary tract trauma. In: Gearhart J, Rink R, Mouriquand P, editors. Pediatric urology. Philadelphia, PA: Saunders/Elsevier; 2010. p. 720–36.

[5] Santucci RA, Fisher MB. The literature increasingly supports expectant (conservative) management of renal trauma—a systematic review. J Trauma. 2005;59(2): 493–503. https://doi.org/10.1097/01.ta.0000179956.55078.c0.

[6] Fitzgerald CL, Tran P, Burnell J, Broghammer JA. Instituting a conservative management protocol for pediatric blunt renal trauma: evaluation of a prospectively maintained patient registry. J Urol. 2001;185:1058–64. https://doi.org/10.1016/j.juro.2010.10.045.

[7] Margenthaler JA, Weber TR, Keller MS. Blunt renal trauma in children: experience with conservative management at a pediatric trauma center. J Trauma. 2002;52 (5):928–32. https://doi.org/10.1097/00005373-200205000-00018.

[8] Cunningham AJ, Lofberg KM, Krishnaswami S, Butler MW, Azarow KS, Hamilton NA, et al. Minimizing variance in care of pediatric blunt solid organ injury through utilization of a hemodynamic-driven protocol: a multi-institution study. J Pediatr Surg. 2017;52(12):2026–30. https://doi.org/10.1016/j.jpedsurg.2017.08.035.

[9] Hagedorn JC, Fox N, Ellison JS, Russell R, Witt CE, Zeller K, et al. Pediatric blunt renal trauma practice management guidelines: collaboration between the Eastern Association for the Surgery of Trauma and the Pediatric Trauma Society. J Trauma Acute Care Surg. 2019;86(5):916–25. https://doi.org/10.1097/TA.0000000000002209.

[10] Keller MS, Eric Coln C, Garza JJ, Sartorelli KH, Christine Green M, Weber TR. Functional outcome of nonoperatively managed renal injuries in children. J Trauma. 2004;57(1):108–10 discussion 110 https://doi.org/10.1097/01.ta.0000133627.75366.ca.

[11] Keller MS, Green MC. Comparison of short- and long-term functional outcome of nonoperatively managed renal injuries in children. J Pediatr Surg. 2009;44(1): 144–7 discussion 147 https://doi.org/10.1016/j.jpedsurg.2008.10.022.

[12] Kozar RA, Crandall M, Shanmuganathan K, et al. Organ injury scaling 2018 update: spleen, liver, and kidney. J Trauma Acute Care Surg. 2018;85:1119. https://doi.org/10.1097/TA.0000000000002058.

[13] Moore EE, Shackford SR, Pachter HL, McAninch JW, Browner BD, Champion HR, et al. Organ injury scaling: spleen, liver, and kidney. . J Trauma. 1989;29(12): 1664–6. 2593197.

[14] Centers for Disease Control and Prevention. Urinary tract infection (catheter-associated urinary tract infection [CAUTI] and non-catheter-associated urinary tract infection [UTI]). https://www.cdc.gov/nhsn/PDFs/pscManual/7pscCAUTIcurrent.pdf; 2020.

[15] Motulsky HJ, Brown RE. Detecting outliers when fitting data with nonlinear regression – a new method based on robust nonlinear regression and the false discovery rate. BMC Bioinformatics. 2006;7:123. https://doi.org/10.1186/1471-2105-7-123.

[16] Buckley JC, McAninch JW. Pediatric renal injuries: management guidelines from a 25-year experience. J Urol. 2004 Aug;172(2):687–90 discussion 690 https://doi.org/10.1097/01.ju.0000129316.42953.76.

[17] Malcolm JB, Derweesh IH, Mehrazin R, DiBlasio CJ, Vance DD, Joshi S, et al. Nonoperative management of blunt renal trauma: is routine early follow-up imaging necessary? BMC Urol. 2008;8:11. https://doi.org/10.1186/1471-2490-8-11.

[18] Notrica DM, Eubanks 3rd JW, Tuggle DW, Maxson RT, Letton RW, Garcia NM, et al. Nonoperative management of blunt liver and spleen injury in children: evaluation of the ATOMAC guideline using GRADE. J Trauma Acute Care Surg. 2015;79(4): 683–93. https://doi.org/10.1097/TA.0000000000000808.

[19] Merenstein D, Egleston B, Diener-West M. Length of stay and costs associated with children's hospitals. Pediatrics. 2005;115:839–44. https://doi.org/10.1542/peds.2004-1622.