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Original Research

Management of grade IV pediatric blunt renal trauma: Conservative, interventional or surgical? Our experience between 2013 and 2020

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Summary

Introduction
The kidney is the most frequently injured organ in pediatric blunt abdominal trauma. The success of conservative treatment is well-demonstrated for American Association for the Surgery of Trauma (AAST) grade I—III renal injuries. However, the optimal management of grade IV trauma remains controversial. This study aims to enhance the understanding of the optimal therapeutic approach for children with such lesions.

Materials and methods
Medical records of all children presenting with blunt abdominal trauma at our center between January 2013 and January 2020 were reviewed. Renal injuries were classified according to the 2018 AAST grading system, and mechanisms of injury were recorded. Detailed analysis was conducted on the patients with grade IV renal trauma, including mechanism of trauma, associated injuries, imaging, management, length of hospital stay, and follow-up.

Results
All 16 children with grade IV renal trauma were initially managed conservatively. Six (38 %) required no further intervention. Minimally invasive measures —ureteral stenting or angioembolization—were necessary for seven (43 %) patients. Urgent surgical exploration was needed in three (19 %) patients due to hemodynamic instability or vascular trauma. Nephrectomy was avoided in all three and no patient developed hypertension during follow-up. Renal function loss was observed in the only patient with renal arterial dissection.

Discussion
Approximately 40 % of our patients with grade IV blunt renal trauma were successfully managed conservatively. When including both conservatively and minimally invasively treated patients, the success rate rose to 80 %. Many injuries resulted from high-velocity winter sports accidents. This may have contributed to the severity of trauma at presentation.

Conclusion
Conservative management was initially attempted in all patients with grade IV blunt renal trauma and succeeded in 40 % of cases. The success rate rose to 80 % when minimally invasive treatments were included. High-velocity winter sports injuries were associated with more severe trauma, but conservative management remained feasible in hemodynamically stable patients. This highlights the importance of mechanism of injury in guiding treatment and the potential need to adapt pediatric grade IV renal trauma classifications to optimize timing of intervention.

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Introduction

The kidney is the most commonly injured organ in pediatric blunt abdominal trauma [1]. Children are more susceptible to renal trauma compared to adults [2]. This is attributed to anatomical differences giving reduced protection to the kidneys: less perirenal fat, smaller abdominal muscles, and lack of thoracic cage ossification [2].

According to the American Association for the Surgery of Trauma (AAST) classification, renal trauma is categorized into five grades from I to V, based on the severity observed in computed tomography findings but the classification can also be made with modern magnetic resonance urography [3]. Grade IV renal injury was originally defined by a parenchymal laceration extending to the collecting system, urinary extravasation, or an injury to the main renal artery or vein with contained hemorrhage [3]. In the 2011 revision, grade IV renal trauma was expanded to include pelvic lacerations, ureteropelvic junction disruptions, and segmental vascular injuries [4]. The latest 2018 revision added active bleeding beyond Gerota's fascia into the retroperitoneum or peritoneum and kidney infarction due to vessel thrombosis to the definition of Grade IV renal injuries [5].

The majority of pediatric blunt renal injuries are low-grade. Grades I, II, III, IV, and V account for 31 %, 30 %, 19 %, 16 %, and 4 % of cases respectively [6]. These figures are based on the 2011 revision of the AAST renal injury classification. Over the last few decades, the management of blunt renal injuries in children has shifted toward a nonoperative approach [7]. While the success of conservative management is well-demonstrated for low-grade traumas up to grade III, the guidelines for suitable management of grade IV pediatric blunt renal trauma are less well defined [8—12]. In particular, the Pediatric Trauma Society released practice guidelines that recommend nonoperative management for hemodynamically stable children with grade IV renal trauma and encourage angioembolization for those with ongoing or delayed bleeding [11].

Several authors have established the success of nonoperative therapy even for high-grade injuries [13—19]. Minimally invasive or surgical treatments are recommended for children with hemodynamic instability, suspicion of ureteropelvic junction (UPJ) disruption, collecting system hematoma, dissociated kidney fragments, presence of interpolar contrast, or large urinoma (>4 cm) [20]. Predictive factors for conservative treatment failure in high-grade renal trauma commonly include large perirenal hematomas (>3.5 cm), contrast extravasation, medial renal lacerations, and suspected preexisting UPJ obstruction [20—23]. Notably, the definition of conservative management lacks uniformity across the literature.

This retrospective study aims to enhance the understanding of the optimal therapeutic approach for children presenting with grade IV blunt renal trauma by assessing their outcomes.

Materials and methods

Medical records of all children who presented with blunt abdominal trauma at our hospital between January 2013 and January 2020 were reviewed. For all patients with renal injuries, the 2018 AAST classification was applied, and trauma mechanisms were recorded. A more detailed analysis was conducted on the patients with grade IV renal trauma, focusing on imaging, management, intervention indications, length of hospital stay, and short-term follow-up outcomes.

Associated injuries were characterized as solid organ injuries and fractures. Grade IV renal trauma was categorized based on imaging findings to describe the extent of laceration: '*incomplete*' refers to partial-thickness lacerations of the renal pelvis or UPJ, '*complete*' indicates full-thickness transection of these structures, and '*multifragmentary*' describes lacerations with multiple fragments while preserving the overall renal architecture.

The initial evaluation included laboratory testing (hemoglobin and urine analysis) and Focused Assessment with Sonography for Trauma (FAST) followed by an abdominal ultrasound. CT and/or MRI were performed when perirenal or intra-abdominal fluid was present. In cases of suspected renal trauma after high-velocity collisions, Doppler ultrasound was additionally carried out to assess renal blood flow. Radiological follow-up during hospitalization was individualized, with additional imaging performed as indicated by clinical findings and hemodynamic status. Hemodynamic stability was defined by stable vital signs (age-appropriate blood pressure and heart rate) and a hemoglobin concentration greater than 7 g/dL, which also served as the threshold for blood transfusion.

For hemodynamically stable children, conservative management involved complete bed rest and administration of intravenous fluids. Antibiotics were given prophylactically to prevent urinary tract infection in patients with large urinomas requiring surgery. Operative management consisted of minimally invasive procedures such as ureteral stenting and angioembolization, as well as surgical exploration.

Ureteral stenting was performed for symptomatic urinomas, defined as perirenal fluid collections on ultrasound accompanied by clinical signs such as fever and/or unilateral flank pain, without a strict size cutoff. Surgical exploration was reserved for patients with persistent hemodynamic instability.

Patients were followed up monthly for 3—6 months, depending on injury severity upon presentation, with blood pressure monitoring and ultrasound. Afterwards, they were examined once a year. DMSA scans were performed in selected cases to assess renal cortical function.

The Swiss Ethics Committee has confirmed that our study does not require ethical approval, as it falls outside the scope of the Human Research Act.

Results

Patient characteristics

A total of 231 patients (79 females and 152 males) with blunt abdominal trauma were identified. Among them, 58 patients (25 %; 19 females and 39 males) presented with renal injury at a mean age of 10.2 years (range 0.1—16). An AAST grade I, II, III and IV renal trauma was observed in 30

(52 %), 5 (9 %), 7 (12 %) and 16 (28 %) patients, respectively. No patients were diagnosed with AAST grade V injuries (Fig. 1). The mean follow-up period was 16 months (range 7—50).

Our study focuses on the patients with grade IV blunt renal traum. This group included 16 patients (5 females and 11 males) with a mean age of 10.7 years (range 5.7—14.1). All patients underwent a preliminary ultrasound, with the diagnosis of grade IV injury established by computed tomography imaging in 13 cases and magnetic resonance imaging (MRI) in 3 cases. Eleven patients (68 %) presented with associated nonrenal injuries, the two most common being splenic trauma (n = 6) and pulmonary contusion (n = 6). Two patients required surgical treatment for nonrenal injury. One of them was treated with an external fixator for a lower leg fracture, while the other underwent osteosynthesis for a femur fracture. The principal mechanism of injury were winter sports accidents in 7 patients (44 %) and falls in 4 patients (25 %). The other mechanisms of injury were bicycle, skateboard or scooter accidents as well as one horse-riding accident.

Management

Ten (63 %) patients had gross hematuria upon presentation. Imaging revealed an incomplete renal rupturein 11 patients (68 %), a complete renal rupture in three patients (18 %) and a multifragmentary renal rupture in two patients (13 %). Additionally, a perirenal hematoma was observed in every patient (size 21.5 mm, range 7—50 mm), measured from the kidney to the outer extent of the hematoma. Notably, one patient had been diagnosed with hydronephrosis in infancy without routine follow-up or functional study. This patient presented with an incomplete renal rupture and urinoma with flank pain. After initial treatment of the trauma, an MRI revealed lower pole vessels and a retrograde pyelogram later confirmed a UPJ obstruction.

Every patient was hemodynamically stable at presentation, leading to an initial conservative approach in all cases without any immediate need for intervention. This strategy was successful in six patients (38 %) who required no further intervention. Subsequently, seven patients (44 %) required minimally invasive management, and three (19 %) underwent surgical exploration (Table 1).

The indication for minimally invasive treatment was the presence of a symptomatic urinoma, detected by ultrasound in 7 patients (44 %) on serial imaging between days 1 and 12 after injury (size 26.9 mm, range 5—70 mm). Three patients required ureteral stenting within 72 h of the injury, while the mean time to intervention for all seven patients was 4.7 days (range 1—13).

One patient needed coil embolization 8 days after ureteral stenting due to a pseudoaneurysm causing secondary bleeding, with a 38 mm perirenal hematoma, hematuria, and a significant drop in hemoglobin 11 days after injury. Nevertheless, the minimally invasive approach without further surgery was successful in all seven patients.

Surgical exploration was required in three patients (18 %) at a mean time of 7.3 days (range 2—13) after injury. Indications included hemodynamic instability due to secondary bleeding into the Gerota fascia and collecting system with severe hematuria, or renal vascular injury (Fig. 2). Two patients required heminephrectomy with reconstruction of the renal pelvis and collecting system due to secondary bleeding on post-injury days 7 and 13, respectively. They had perirenal hematomas measuring 41 mm and 50 mm, accompanied by urinomas. In one of them, the urinoma was not present at admission or on earlier follow-up ultrasounds. This patient later developed an obstructive ileus due to postoperative adhesions nine days after the transperitoneal heminephrectomy, which required surgical revision.

In the third patient, renal artery reconstruction was performed on post-injury day 2 due to a renal artery dissection detected after admission. The FAST without Doppler renal sonography at presentation showed minimal perirenal fluid and a grade II laceration of the spleen. The next day, free retroperitoneal fluid was observed on ultrasound due to persisting pain. An MRI revealed an

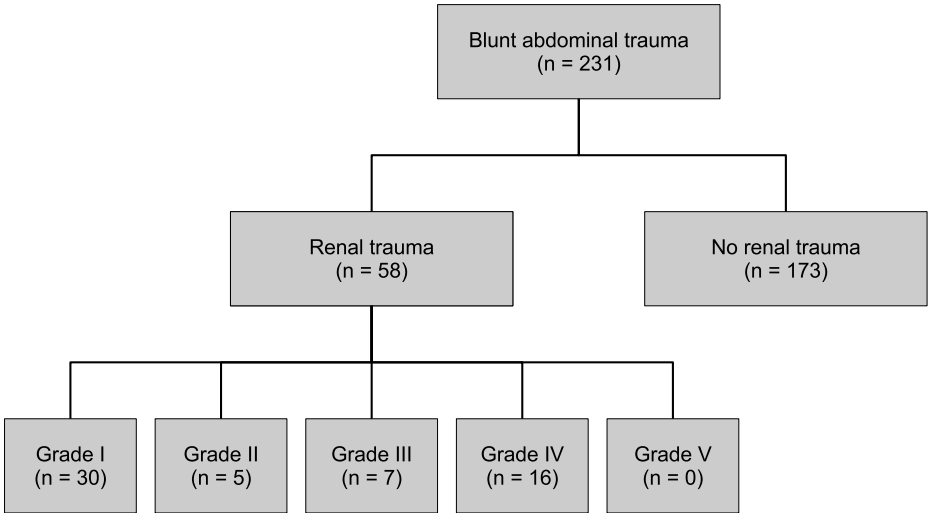

Fig. 1 Flowchart showing the distribution of renal trauma among 231 patients with blunt abdominal trauma. Renal injuries were further classified by AAST grade.

Table 1 Patient characteristics of the study population with grade IV blunt renal trauma.

	Total (n = 16)	Successful conservative management (n = 6)	Minimally invasive surgery (n = 7)	Surgical exploration (n = 3)
Sex — F: M	5 : 11	1 : 5	3 : 4	1 : 2
Age (years)	10.7 (5.7—14.1)	11.9 (9.4—14.1)	9.8 (5.7—13.9)	10.2 (7.4—11.8)
No. mechanism of injury				
Fall	4	0	4	0
Winter sports	7	3	1	3
Bicycle	2	1	1	0
Skateboard or scooter	2	2	0	0
Horse riding	1	0	1	0
Gross hematuria at presentation	10	4	4	2
Perirenal hematoma (mean size, range)	21.5 mm, 7—50 mm	16.2 mm, 10—31 mm	21.3 mm, 16—30 mm	32.7 mm, 7—50 mm
No. type of renal rupture				
Incomplete	10	6	4	0
Complete	3	0	1	2
Multifragmentary	2	0	2	0
Vascular injury	1	0	0	1
No. urinoma (mean size, range)	8 (25.3 mm, 5—70 mm)	0	7 (26.9 mm, 5—70 mm)	1 (14 mm, 14-14 mm)
Preexisting urologic malformation	1	0	1	0

unexpected renal artery dissection without evidence of renal perfusion. Since the Duplex sonography of the kidney showed some perfusion, an interdisciplinary decision was made to proceed with surgical exploration and revascularization using an aortorenal bypass with a reversed great saphenous vein. The management of symptomatic or progressive urinoma is summarized in Fig. 3. No patient required nephrectomy.

The median length of bed rest was 9.6 days (range 4—19). Six (38 %) patients required blood transfusions due to anemia or hemodynamic instability. Urethral catheterization was performed in 13 (81 %) patients with a median length of 21 days (range 1—64). In total, 10 (63 %) patients were closely observed on the intensive care unit (ICU) for a median length of 2 days (range 1—5). The overall median length of hospital stay was 18.9 days (range 8—60) and was higher among the patients who were treated with a minimally invasive or surgical approach. No readmission was necessary.

Outcome

No patient developed hypertension, and no nephrectomy was required. Renal DMSA scans were performed in the three surgically managed patients and in one patient with preexisting urologic malformation. The two patients who underwent heminephrectomy had partial loss of renal function, with split function of 21 % and 22 % in the damaged kidneys, respectively. The patient with a vascular injury showed loss of renal function in the affected kidney, with split function of 4 % despite successful restoration of renal vascularization after surgical repair. The patient with the preexisting urologic malformation was initially treated with ureteral stenting due to a symptomatic urinoma. After removal of the stent, progressive hydronephrosis developed due to a crossing vessel, thus requiring repeat stenting at 86 days after injury. Because the split renal function remained reduced at 40 % on DMSA scan, pyeloplasty was finally performed 149 days after trauma.

Discussion

All patients with grade IV renal trauma in our study were primarily managed conservatively without any intervention, and this approach was successful in 38 % (6/16) of cases. Recent systematic reviews reported higher success rates, up to 80 %, for conservatively treated grade IV blunt renal trauma patients [20,24]. However, the definition of conservative management lacks uniformity across the literature and in some studies, minimally invasive interventions like ureteral stenting were considered conservative. When both conservatively and minimally invasively treated patients are considered, the success rate in our study increases to 81 % (13/16) and could therefore be considered similar to previously reported results.

In our cohort, high-velocity sports accidents predominated, likely reflecting our regional trauma center's proximity to numerous winter resorts. This contrasts with existing literature, where falls, recreational motor vehicle and bicycle accidents are more commonly reported mechanisms of injury [9]. Ureteral stenting was performed in

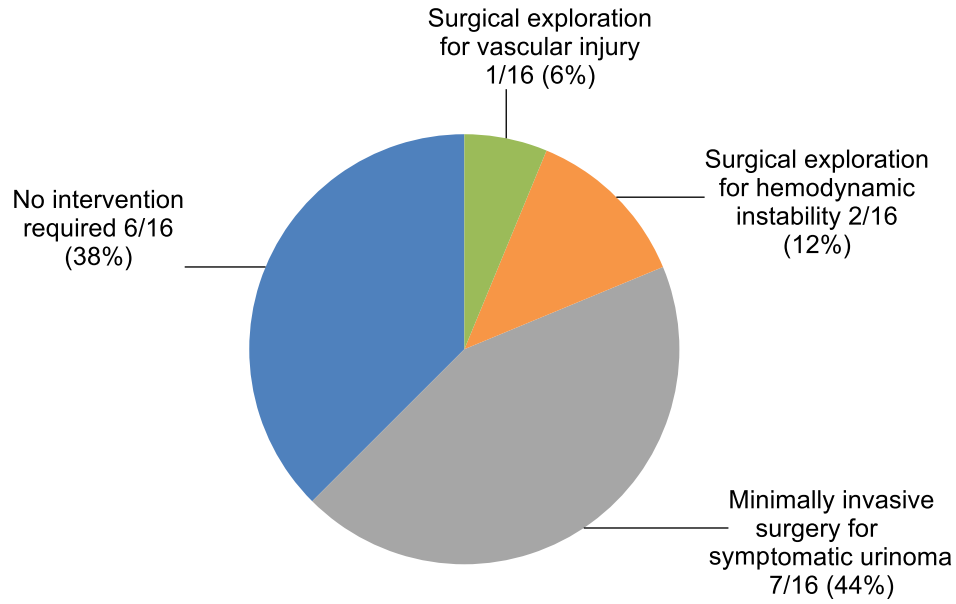

Fig. 2 Illustration of the proportion of patients with grade IV blunt renal trauma who received no intervention, minimally invasive surgery or surgical exploration, along with the indications motivating each approach.

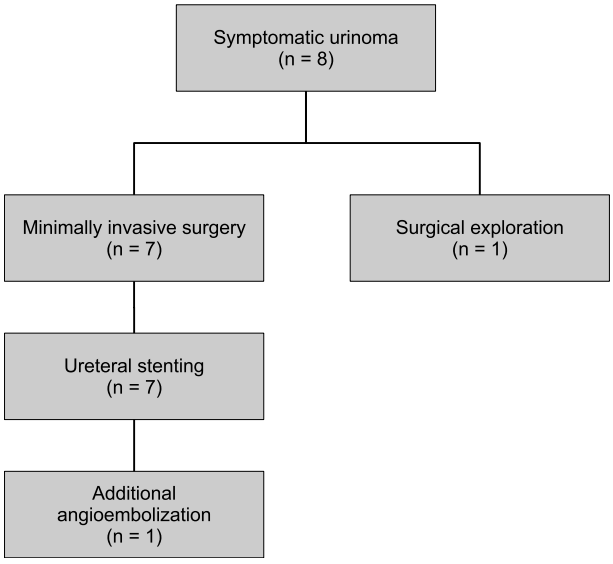

Fig. 3 Flowchart of management strategies in eight patients with symptomatic urinoma. Patients underwent either minimally invasive surgery or surgical exploration.

43 % of patients for symptomatic urinomas, and surgical exploration was required in 18 % due to hemodynamic instability or vascular injury. These indications are consistent with established criteria for operative management [19,20,24]. Two children (12.5 %, 2/16) with complete renal ruptures and secondary bleeding underwent hemi-nephrectomy, whereas Umbreit et al. reported delayed bleeding and hemodynamic instability in approximately 7 % of cases [19]. They also noted that only 17 % required intervention for symptomatic urinomas and 11 % for hemodynamic instability [19]. Similarly, a recent multicenter study by Lee et al. observed ureteral stenting in only 7.6 % of pediatric patients with grade IV renal trauma [25].

Our intervention rates exceed those reported in these larger series. This likely reflects our relatively small, single-center cohort, in which the predominance of high-velocity sports accidents suggests a degree of selection bias. Failure of conservative treatment in our study group also appears to be influenced by the overall severity of injury: 31 % (5/16) had complete or multifragmentary renal ruptures, and one patient presented with a vascular lesion. A direct comparison with Lee et al. is difficult, as their study only reports the injury severity score without specifying the exact renal lesion patterns [25]. The severity of trauma in our cohort is further highlighted by the rate of associated nonrenal injuries, affecting 68 % (11/16) of patients compared to 40—53 % in similar series [23,26]. High-velocity collisions with rapid deceleration in sports accidents may have contributed to the overall severity of trauma. Notably, all three patients who required surgical exploration sustained renal lesions from this mechanism of injury. Limited data on renal lesions associated with winter sports suggest that approximately 20 % of affected patients need surgical management [27,28]. These observations suggest that high-velocity sports accidents in grade IV renal lesions may be associated with a more severe injury pattern and, consequently, a higher risk of requiring surgery.

Previously identified risk factors for conservative treatment failure include large perirenal hematomas (>3.5 cm), intravascular contrast extravasation, medial renal lacerations, and suspected preexisting UPJ obstruction [20—23]. Chiron et al. have proposed to revise the grading scale for grade IV renal injuries by adding the risk factors mentioned above to better determine the optimal timing for intervention [29]. Our findings support that opinion, as all patients who required intervention or surgery met these criteria. Future pediatric classifications for grade IV blunt

renal trauma may include the mechanism of injury alongside these risk factors to better define the need for intervention in high-risk subgroups.

The renal salvage rate in our study was 93 % (15/16), and no nephrectomy was required. Our findings correspond to those reported in the systematic review by LeeVan et al., which found salvage rates exceeding 90 % in children with grade IV blunt renal trauma [24]. The only loss of renal function in the affected kidney occurred in the patient with a vascular injury, despite surgical revascularization. This is consistent with the results of Santucci et al. which showed that the renal salvage rate is lower in cases of grade IV vascular injuries compared to grade IV laceration injuries [30]. Even with successful surgical repair, the salvage rate for kidneys with pedicle injuries under ideal circumstances is reported to be less than 30 % [30].

In the patient with a vascular injury, Doppler renal sonography was performed the day after presentation, once intraperitoneal fluid was detected on ultrasound. Earlier Doppler imaging might have been considered based on the high-velocity mechanism of injury and flank pain. However, it is unclear whether this would have changed the outcome, as loss of renal function is often unavoidable in cases of intimal vascular injury without perfusion. Performing Doppler imaging as a standard procedure in all cases of blunt abdominal trauma can be challenging because of limited resources. The number needed to treat to prevent one missed vascular injury has yet to be determined and requires further research.

The retrospective design and small sample size limit the generalizability of our analysis. Being a single-center study may also introduce selection bias. There is extensive overlap in the presenting characteristics between children successfully managed conservatively and those requiring surgery, which restricts statistical comparisons. Nevertheless, our results indicate that conservative management is feasible in hemodynamically stable children with grade IV renal trauma, including those injured in high-velocity sports accidents.

Conclusion

Conservative management was initially attempted in all patients with grade IV blunt renal trauma, but was successful in only 40 %. When including both conservatively and minimally invasively treated patients, the overall success rate rose to 80 %. High-velocity winter sports injuries predominated in our cohort and were associated with more severe trauma patterns. While hemodynamically stable children could still be treated conservatively, those who required surgical exploration had all sustained trauma from high-velocity sports accidents. This may suggest that the mechanism of injury should be considered when deciding on the optimal therapeutic approach. Further research could help adapt pediatric grade VI renal trauma classifications to better guide the timing of operative management.

Ethical approval

Approval from our ethics committee was not required.

Declaration of Generative AI and AI-assisted technologies in the writing process

Generative AI and AI-assisted technologies were NOT used in the preparation of this work.

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Conflicts of interest

None of the authors have any conflicts of interest to declare.

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