Published in final edited form as:
J Urol. 2012 July ; 188(1): 163–168. doi:10.1016/j.juro.2012.03.003.

Renal Trauma from Recreational Accidents Manifests Different Injury Patterns than Urban Renal Trauma

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Abstract

Purpose—The majority of blunt renal trauma is a consequence of motor vehicle collisions and falls. Prior publications based on urban series have shown that significant renal injuries are almost always accompanied by gross hematuria alone or microscopic hematuria with concomitant hypotension. We present a series of blunt renal trauma sustained during recreational pursuits, and describe the mechanisms, injury patterns and management.

Materials and Methods—Database review from 1996 to 2009 identified 145 renal injuries. Children younger than age 16 years, and trauma involving licensable motor vehicles, penetrating injuries and work related injuries were excluded from analysis. Grade, hematuria, hypotension, age, gender, laterality, mechanism, management, injury severity score and associated injuries were recorded.

Results—We identified 106 patients meeting the criteria and 85% of the injuries were snow sport related. Age range was 16 to 76 years and 92.5% of patients were male. There were 39 grade 1 injuries, 30 grade 2, 22 grade 3, 12 grade 4 and 3 grade 5 injuries. Gross hematuria was present in 56.7%, 77.2% and 83.3% of grade 2, grade 3 and grade 4 injuries, respectively. None of the patients with grade 2 or greater injuries and microscopic hematuria had hypotension except 1 grade 5 pedicle injury. The nephrectomy and renorrhaphy rate for grade 1 to grade 4 injuries was 0%.

Conclusions—Compared to urban series of blunt renal trauma, recreationally acquired injuries appear to follow different patterns, including a paucity of associated injuries or hypotension. If imaging were limited to the presence of gross hematuria, or microscopic hematuria with hypotension, 23% of grade 2 to grade 4 injuries would be missed. Men are at higher risk than women. However, operative intervention is rarely helpful.

Keywords

kidney; multiple trauma; retrospective studies; wounds; nonpenetrating; injury severity score

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[†]Trainee in the Medical Scientist Training Program at the University of Rochester funded by NIH T32 GM07356. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute of General Medical Sciences or the National Institutes of Health.

RENAL injuries are detected in 1.2% to 3.25% of trauma cases presenting to hospitals in the United States.[1,2] Between 71% and 95.4% of kidney injuries occur in the setting of blunt trauma. While less common, kidney injuries due to penetrating trauma (firearms or stab wounds) tend to be more severe and are more likely to require surgical management.[1,3,4] The predominant mechanisms of injury that cause blunt renal trauma mirror those reported in population based trauma databases, which are motor vehicle collisions followed by falls.[2,5] In a query of the NTDB (National Trauma Data Bank) more than 80% of reported blunt renal injuries were caused by MVC related trauma and falls.[5] By default, these series represent injury patterns primarily of urban populations, and large databases have been assembled that describe the diagnostic and imaging characteristics of these injuries.[3,5–7] Among patients with significant renal injuries, there is a high rate of coexisting abdominal lesions, which has been attributed to the major forces required to produce renal injury.[1] Severity of overall injury as measured by ISS scores as well as renal injury grade are predictive of nephrectomy in population-wide data sets.[5]

A landmark renal trauma series from the University of California, San Francisco demonstrated that 99.5% of patients with significant renal injuries from blunt trauma (G2 or greater) had 1 of the 2 identifying criteria of gross hematuria or shock with MH.[3] These criteria have been validated in other series[8–11] and in combination with clinical assessment provide a useful guideline for the evaluation of blunt trauma. However, few institutions have assessed the application of these imaging criteria to injuries incurred via nonMVC mechanisms. A series of falls suggested that these presumably MVC based criteria may not extrapolate to other mechanisms. Of the 24 G2 to G5 renal injuries identified 7 (29.2%) would have been missed using these criteria alone.[12] In a separate series 8 renal injuries sustained via falls from tree stands while hunting were studied. However, 6 of these injuries were G1 and commentary on imaging indications was difficult.[13] With so few series focused on kidney injuries incurred via nonurban mechanisms, we hypothesized that these injury patterns and characteristics differ compared to those secondary to high energy, total body decelerations of urban injuries. We report a series of renal injuries sustained during recreational and athletic pursuits in the alpine community surrounding Vail, Colorado, compare injury patterns and report our experience with management.

MATERIALS AND METHODS

Vail Valley Medical Center is a 50-bed community hospital located in Vail, Colorado. It carries a Level III trauma designation and its catchment area is such that in the 2004 to 2005 ski season it included 6 large ski resorts, which saw 6.1 million combined skier days,[14] as well as millions of acres of highly traveled backcountry terrain. The institution had a trauma surgery service in place throughout the majority of this study period (since 1999) and on-site urological consultation available beginning in late 2003. Colorado state patient transfer rules require severely injured patients in the area to be evaluated at the nearest designated trauma center. Thus, no injured patients were formally evacuated without passing through our system.[15] After institutional review board approval was obtained, review of the trauma database from 1996 to 2009 allowed identification of 145 renal injuries. Patients with incomplete data, age less than 16 years or injuries from nonrecreational mechanisms were excluded from study. Accidents involving a licensable motorized vehicle (car, truck, motorcycle), injuries sustained while working, penetrating injuries, and any interactions with a truck or automobile while walking, skiing or bicycling were excluded.

Once identified, renal injuries were graded using the AAST Organ Injury Scaling Committee scale by staff radiologists at the time of injury (see Appendix). Studies not initially graded were reviewed and graded by radiology staff during data acquisition.[16] ISS scores were recorded from the database using the Abbreviated Injury Scale 98 by a

dedicated trauma registrar.[17] Hypotension was defined as systolic blood pressure less than 90 mm Hg at any time in the pre-hospital or emergency department phase. GH was defined as visible blood in the urine. Documentation included nursing notes, patient report or visual description from urinalysis. MH was defined as documented denial of visible blood in the urine and/or the presence of a red cell count on spun urine microscopy fewer than 200 and a recorded color not consistent with blood. Age, laterality, mechanism of injury, management and associated injuries were also recorded.

RESULTS

A total of 106 patients had complete data and met the study inclusion criteria (table 1). Patient age ranged from 16 to 76 years and 85% had renal injuries related to snow sports. Gender was reported as male in 98 (92.5%) subjects and female in 8 (7.5%). The average age of women injured in this series was 38.9 years vs a male average of 30.4. The left kidney was injured in 51 patients (48.1%), the right kidney in 34 (32.1%) and nonlateralizing G1 injuries were found in the remaining 21 (19.8%). Mechanisms of injury are described in table 1.

There were 87 injuries (82.1%) that occurred while skiing or snowboarding and the balance occurred during activities such as bicycling. There were 39 G1 injuries (36.8%), 30 G2 (28.3%), 22 G3 (20.1%), 12 G4 (11.3%) and 3 G5 (2.8%) injuries (table 2). Among the patients with higher grade injuries GH was present in 17 of 30 G2 cases, 17 of 22 G3, 10 of 12 G4 and 2 of 3 G5 cases. None of the patients with G2 or greater injuries and MH had hypotension except 1 with a G5 pedicle injury. The UCSF criteria predicting significant renal injury were lacking in 13 of 30 (43%) grade 2 injuries, 5 of 22 (23%) grade 3 and 2 of 12 (17%) grade 4 cases. The average injury grade was 2.1 for skiers and snowboarders. Injury grade was correlated with ISS category (table 3). An illustrative case is presented in the figure.

The renal exploration rate for G1 to G4 injuries was 0%. Of the G4 injuries 2 required endoscopic intervention (stent placement for persistent urine leak with growing urinoma, retrograde urogram to rule out ureteropelvic junction disruption). G5 injuries resulted in nephrectomy (2) or vascular reconstruction (1) in all cases. A high percentage of injury was isolated to the kidney alone, with 9 of 30 (30%) G2 injuries, 10 of 22 (45%) G3, 9 of 12 (75%) G4 and 0 of 3 (0%) G5 cases without any associated injury documented. There were 3 patients with preexisting renal abnormalities including hydronephrosis (2) and simple cyst (1).

DISCUSSION

Identification of the Significant Renal Injury

Significant renal injuries sustained via what might be called nonMVC mechanisms appear to follow patterns that differ from their more common counterparts. The UCSF criteria of MH and hypotension, or GH alone, were present in 30 of 32 (93.8%) major lacerations (G3 and G4) in their original urban series, missing only 6.2%. Applying those same criteria to our recreational injuries, 22% of G3 and 17% of G4 injuries are missed. However, the UCSF criteria continue to perform well by ensuring the identification of patients who would benefit from intervention, which may well be a better definition of significant renal injury than the historical imaging based definition. The majority of G2 to G3 renal injuries may not need any particular care, underscoring the challenge of defining what constitutes significant renal injury. What benefit diagnosis does confer may lie in appropriate counseling to prevent secondary bleeding and to facilitate early diagnosis of secondary hypertension, although the true long-term risk of these complications remains unknown.[1] We are aware of no

significant sequelae in our series. However, followup is limited as patients often depart the area when well enough to do so.

Contemporary medical practice is making the diagnosis of incidental renal injury far more likely. Since 1996 the use of computerized tomography in United States emergency departments for flank and abdominal pain has increased approximately tenfold.[18] In our series imaging studies were performed for clinical indications such as localized pain after a direct blow or significant injury mechanism. The importance of using appropriate clinical judgment cannot be overemphasized in the diagnosis and management of these injuries.

The mechanics underlying these different injury patterns are unknown. We postulate that force applied focally to the flank is more likely to create an isolated, high grade renal injury, or at least an injury that lacks GH, than is the total body deceleration of MVC. Many of the patients in this study were able to identify a direct blow to the flank as a part of the injury. Direct flank impact from a tree, a fall on a camera, ski pole handle, the patients' own elbow or the bony protuberances of a fellow skier were among those cited. There is no mechanistic reason why a G2 or G3 renal injury involving only the cortex should unfailingly produce collecting system bleeding to the extent that it becomes visible as GH. Gross hematuria in G2 and G3 injuries may be more of a marker for high energy renal deceleration than the inevitable result of a cortical laceration producing collecting system hemorrhage.

The percentage of renal injury that was isolated to the kidney was seen to increase with grade, which seems paradoxical. In many cases the complaint that brought the lower grade injuries to medical attention was not the renal injury itself, but rather a different and more severe injury such as rib fractures or splenic rupture, with the renal injury identified incidentally. Some intermediate grade injuries, especially if not accompanied by gross hematuria, may go unidentified. This could lead to a bias toward isolated renal injuries presenting with greater severity and at higher grades, as seen in this series. A number of patients with G2 to 4 injuries continued skiing or boarding and only later presented with the complaint of persistent flank pain or gross hematuria.

We identified 3 renal injuries in patients who were found to have predisposing conditions such as ureteropelvic junction obstruction or renal cyst. While these conditions are believed to predispose the kidney to injury, they only represented 2.8% of this series. Schmidlin et al reported a background incidence of 4.4% to 19% for preexisting renal lesions.[19] Our lower incidence may reflect the general state of fitness and health required to perform recreational alpine activity. All patients recovered un-eventfully and were scheduled for urological followup.

To Explore or Not to Explore?

In this series open operative intervention was used for all G5 injuries, although 2 G4 injuries required endoscopic intervention. To our knowledge no patient required any delayed procedures of any sort (endoscopic, angiographic, percutaneous or open) for G1 to G4 injuries, and we are unaware of any nonG5 injury that required transfusion as a result of the renal injury, although this variable was not specifically queried. This strongly supports nonoperative management in this population. Importantly this rate of renal exploration appears appropriate. We could identify no patient who would have benefitted from exploration and failed to receive it.

Other institutions have reported much higher rates of renal surgery. When we restrict our attention to G4 injuries 67.3% of UCSF cases required surgery, the Parkland group explored 41.6% and the NTDB survey reported 37.9% underwent exploration.[20–22] However, these 3 series all included penetrating trauma, which requires a higher rate of renal exploration and

nephrectomy.[1,4] As summarized by Santucci and Fisher, expectant management is becoming an accepted approach,[23] and rates of exploration in certain systems can be decreased by the use of observation based surgical decision protocols in the absence of significant active hemorrhage.

Series on the incidence of exploration are reporting institutional decision making patterns more than the physiological status of their patients. Thus, it is difficult to draw conclusions about the underlying patient substrate from surgical rates. Our patients proved themselves capable of surviving all nonG5 blunt injures without renal exploration or significant sequelae.

There likely exists a bias toward excellent baseline health among skiers and snowboarders compared to the typical urban trauma case. The strength and cardiovascular conditioning required to engage in vigorous activity at high altitude might convey increased resistance to hypotension, hemorrhage or clinical shock. Alternatively, it may be that the interval from injury occurrence to first measured blood pressure is such that the opportunity to record transient hypotension is reduced during patient extraction from the hillside in an inclement setting where measurement of blood pressure is unlikely to occur. Cold weather, dehydration from athletic activity or the bicarbonate diuresis of altitude acclimatization could convey protection against hemorrhage via vasoconstriction, hypercoagulability or other mechanisms.

Men are at Higher Risk

We observed a much higher number of injuries in men than women as only 8 of 106 patients were female. The National Sporting Goods Association annual databases from 2005 to 2010 show female ski participation stable at just under 40% (38.1% in 2010), and the proportion of female snowboarders increasing from 25.8% in 2005 to 32.8% of the total in 2010.[24] Clearly there are plenty of women on the ski hill. We speculate that male participants in resort skiing/snowboarding engage in behavioral patterns that predispose them to injury more so than their female counterparts. Intriguingly 3 of the 6 women whose injury happened while skiing or snow-boarding were injured as a result of a collision with another person. Unfortunately the gender of the other person involved in these collisions was not recorded. This exceeds even the male-to-female ratio in gunshot wounds to the kidney.[25]

Prior studies have shown an increased risk of renal injury with snowboarding accidents compared to skiing accidents.[26] While our study was not designed to address this question, the grade and gender distributions of skiing and snowboarding renal injuries were similar. Furthermore, without data on the ski-to-snowboard ratio at participating resorts it is not possible to draw conclusions about the sport specific risks confronting an individual. With an average of less than 10 significant renal injuries per year cast against a denominator of approximately 6 million skier/boarder days per year, and only 2 nephrectomies during that 10-year experience, the likelihood of an individual experiencing renal loss via that mechanism is quite small. Increasing the exploration rate would likely increase the renal loss rate. While it is possible that our local experience may underestimate the total injury rate as a result of delayed out of area presentation, this seems unlikely, at least for high grade, acute injuries that would be considered for exploration.

Conclusions about risks associated with sledding, mountain biking or other mechanisms reported here are difficult to draw without information about the background population participating in those activities in our catchment area. National Forest Service reported use by bicyclists is a tenth that of the use by skiers (2.1% vs 23%).[27] While these figures do not include road cycling, they suggest that mountain biking, similar to snow sports, represents a

low risk for significant renal morbidity. This has favorable implications for the counseling of patients with a solitary kidney regarding these recreational activities.

CONCLUSIONS

Significant adult renal injury suffered in nontypical mechanisms may present without gross hematuria or hypotension, and is frequently an isolated injury. Men appear to be at higher risk than women, and surgery is rarely necessary for grade 1 to 4 injuries.

APPENDIX

APPENDIX

The AAST Organ Injury Severity Scale for Kidney[16]

Grade	Type	Description
1	Contusion	Microscopic or gross hematuria, urological studies normal
	Hematoma	Subcapsular, not expanding with no parenchymal laceration
2	Hematoma	Nonexpanding perirenal hematoma confined to renal retroperitoneum
	Laceration	Less than 1.0 cm parenchymal depth of renal cortex with no urinary extravasation
3	Laceration	Greater than 1.0 cm parenchymal depth of renal cortex with no collecting system rupture or urinary extravasation
4	Laceration	Parenchymal laceration extending through renal cortex, medulla and collecting system
	Vascular	Main renal artery or vein injury with contained hemorrhage
5	Laceration	Completely shattered kidney
	Vascular	Avulsion of renal hilum which devascularizes kidney

Abbreviations and Acronyms

AAST	American Association for the Surgery of Trauma
G	grade
GH	gross hematuria
ISS	Injury Severity Score
MH	microhematuria
MVC	motor vehicle collision
UCSF	University of California, San Francisco

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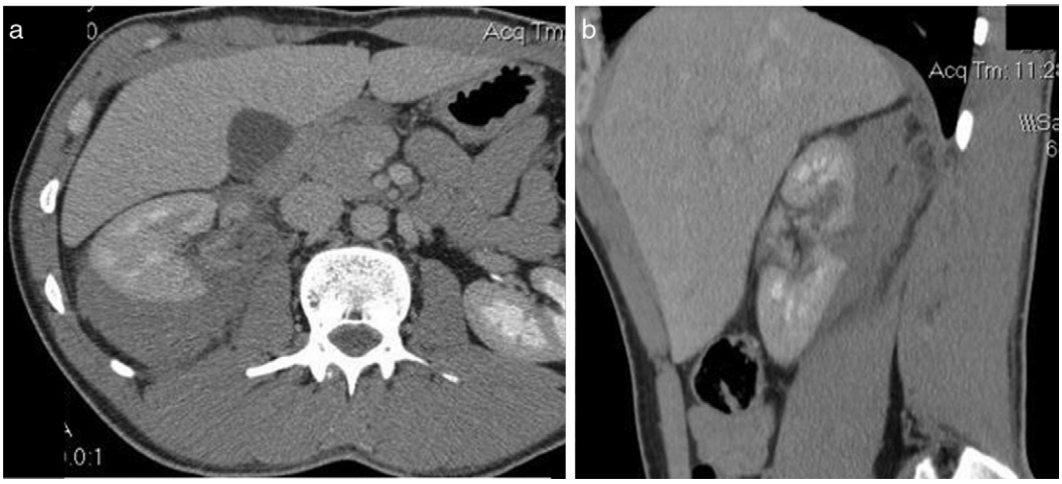

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Coronal (*a*) and sagittal views (*b*) of male patient in his 20s with flank pain, clear urine and normal vital signs after ski accident and isolated G3 renal injury. No treatment was necessary other than observation.

Table 1

Demographics of recreational renal injury

	Total No. (%)	Av AAST Grade (SD)	Av Age (SD)	No. M/F (% male)
Skiing	47 (44.3)	2.1 (1.0)	36 (17)	43/47 (91)
Snowboarding	41 (38.7)	2.1 (1.1)	23 (6.1)	39/41 (95)
Bicycling (mountain or road)	6 (5.7)	2.1 (1.2)	37 (10)	5/6 (83)
Sledding	3 (2.8)	2.3 (2.3)	33 (9.8)	3/3 (100)
All-terrain vehicle	2 (1.8)	3.0 (1.4)	32 (7.8)	2/2 (100)
Other (pedestrian, climbing + equestrian falls)	7 (6.6)	2.0 (1.4)	43 (15)	6/7 (86)

Table 2

Grade of renal injury by clinical features

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
No. GH (%)	9 (23)	17 (57)	17 (77)	10 (83)	0 (0)
No. MH + hypotension (%)	0 (0)	0 (0)	0 (0)	0 (0)	2 (67)
No. MH only (%)	28 (71)	13 (43)	5 (22)	2 (17)	1 (33)
No. isolated injury to kidney (%)	7 (18)	9 (30)	10 (45)	9 (75)	0 (0)
Mean ISS (SD)	9.3 (6.7)	11 (6.6)	12 (5.9)	14 (7.3)	36 (33.8)
No. renal exploration (%)	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)
No. pts (%)	39 (36.8)	30 (28.3)	22 (20.1)	12(11.3)	3 (2.8)

Table 3

Grade of injury by ISS category

ISS Categories	No. Grade 1	No. Grade 2	No. Grade 3	No. Grade 4	No. Grade 5	Total No. (%)
Less than 9	22	15	2	2	0	41 (38.7)
9–15	12	4	14	2	0	32 (30.2)
16–24	3	10	5	7	2	27 (25.5)
Greater than 25	2	1	1	1	1	6 (5.7)