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High grade renal trauma: Does the mechanism of penetrating injury influence renal salvage rate?

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ABSTRACT

Background: Most of the data on high grade Traumatic renal injuries (TRI) has come from centres which predominantly encounter blunt trauma. Blunt and penetrating mechanisms are not analogous, and it is imprudent to blindly extrapolate management strategies between the two groups. In addition, within the broad group of penetrating mechanisms of injury there are also major differences between gunshot wounds (GSW) and stab wounds (SW). The aim of this comparative study of GSW and SW to the kidney is to quantify the impact of the mechanism of injury on nephrectomy rate in high grade TRI.

Methods: A prospective trauma registry was interrogated retrospectively. All patients sustaining a high grade (Grade III to V) penetrating TRI were included. The diagnosis was made either with cross-sectional imaging or intra-operative findings. The nephrectomy rate of the different mechanisms of penetrating (GSW vs SW) TRI was compared in each grade.

Results: A total of 28 GSW and 27 SW causing high grade TRIs (Grade III-V) were included over the 85 months of the study. GSW lead to a higher nephrectomy rate than SWs 50.0 vs 19%, ($p = 0.023$). When comparing grade for grade, Grade III: 20.0 (GSW) vs 21% (SW), ($p = 1$). Grade IV: 71 (GSW) vs 17%, (SW) ($p = 0.058$) and Grade V: 100 (GSW) vs 0%, (SW) ($p = 0.28$). When comparing Grade IV – V together, the difference is 85 (GSW) vs 15%, (SW) ($p = 0.001$).

Conclusion: On a grade to grade comparison GSWs have a much higher risk for nephrectomy than SW's in grade IV and V TRI. TRI secondary to GSWs appears to be an independent risk factor for nephrectomy in high grade injuries. The mechanism of penetrating TRI should be considered in future management algorithms and clinical approaches.

Introduction

Over the last half century there has been a move towards conservatism in trauma care in general and in the management of renal trauma in particular [1,2]. This trend has been underpinned by a philosophy of selective nonoperative management (SNOM) and the rapid development, and increasing availability of imaging, especially Computed Tomography [1,3] and minimally invasive endourological approaches [1,4]. Traumatic renal injuries (TRI) are present in up to 5% of all trauma cases [5,6] and between 80–95% of TRI's have other associated organ injuries [7,8]. However, most TRI's occur secondary to a blunt mechanism. Globally, penetrating mechanisms of injury account for only 7-10% of all TRI's [9,10]. Most of the data on high grade TRI's (defined as AAST grade III and higher) has come from centres which predominantly encounter blunt trauma. The pathophysiology of blunt and penetrating trauma is different and this impacts on approaches to these renal injuries [7]. Penetrating trauma is more commonly associated with other injuries in the abdomen [8] and these may in themselves determine the imperatives of care. Blunt trauma is more likely to be confined to a single organ injury and there is a higher chance of treating the patient non-operatively [7]. It is imprudent to blindly extrapolate management strategies between the blunt

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Renal trauma classification by the American association for the Surgery of Trauma (AAST 2018)	
Grade*	**Description of injury**
I	Subcapsular haematoma Parenchymal contusion
II	Perirenal haematoma, confined to Gerota's fascia Parenchymal laceration <1cm depth without urinary extravasation
III	Parenchymal laceration >1cm depth without collecting system rupture or urinary extravasation Vascular injury or active bleeding contained within Gerota's fascia
IV	Parenchymal laceration extending into collecting system Renal pelvis laceration or complete ureteropelvic disruption Segmental renal artery or vein injury Segmental or complete kidney infarction caused by vessel thrombosis Active bleeding beyond Gerota's fascia
V	Shattered kidney with loss of identifiable renal parenchymal anatomy Devascularized kidney with active bleeding Main renal artery or vein injury Avulsion of renal hilum
*Advance one grade for bilateral injuries up to Grade III	

Fig. 1. Renal trauma classification by the American association for the Surgery of Trauma (AAST 2018).

and penetrating mechanisms of trauma. In addition, within the broad group of penetrating mechanisms of injury there are also major differences between stab wounds (SW) and gunshot wounds (GSW). With SW the destructive force is confined to the local region around the tract, whilst with GSW the tract may be complex, and the projectile forces of the missile may cause tissue destruction and disruption. It is difficult to develop large enough cohorts of TRI which correspond to each individual mechanism and most authors, out of necessity have tended to place all TRI's into a single group for analysis. This approach results in inhomogeneous data sets and prohibits meaningful conclusions. When considering the management of high-grade TRI's, good quality data sets are sparse. This is a major limitation, as it is precisely the management of these high-grade injuries which remains controversial [11,12]. The American Association for the Surgery of Trauma (AAST) system, first published in 1989 [13] and updated in December 2018 [14] is the gold standard in grading the severity of a TRI. See Fig. 1. Increasing grade of TRI's is associated with increasing rates of operative management and ultimately nephrectomy [15,16]. Expanding the role of non-operative treatment and renal salvage in this group requires better definition of the predictors of operative intervention and nephrectomy. This can only be achieved by ongoing analysis of clinical data sets. As imaging, endovascular and endourological capacities increase, more and more severe renal injuries may be suitable for SNOM [17,18] and ongoing audit is essential. The aim of this comparative study of GSW and SW to the kidney is to quantify the impact of the mechanism of injury on nephrectomy rate in high grade, penetrating TRI and to assist in refining treatment algorithms and future grading systems.

Clinical setting

Grey's Hospital based in Pietermaritzburg is a tertiary hospital offering surgical services to the Western half of KwaZulu-Natal Province, South Africa. It serves a total population of three million people. The department of surgery prospectively collects admission, discharge, operative and morbidity data for all surgical admissions using the Hybrid Electronic Medical Registry (HEMR). The HEMR has been well described in the literature [19]. All patients admitted with a TRI secondary to either a SW or a GSW between April 2013 and May 2020 were identified as the primary cohort. All patients with an AAST grade III TRI or higher were included in the final study subset.

Management of penetrating renal trauma by the Pietermaritzburg Metropolitan Trauma Service (PMTS)

All patients with penetrating abdominal trauma are managed according to a selective non operative approach [15]. Patients with peritonitis, or who are unstable are expedited to the operating room. Patients who do not meet these indications for laparotomy are selectively imaged, based on the trajectory of the weapon or missile and the presence of haematuria. Following imaging, the vast majority of these patients are admitted for observation. The imaging modality of choice is a contrast enhanced CT scan, including a delayed phase. At laparotomy all injuries are dealt with on their merit. Peri-renal haematomas are not routinely explored [20] unless there is compelling evidence that the haematoma is expanding or of active haemorrhage. If a peri–renal haematoma is explored acutely, attempts may be made to repair the renal injury if the patient is stable. However, if the injury is high grade and if the patient's physiology is compromised then nephrectomy is the default procedure. Renal trauma is managed by the trauma surgeons in charge of PMTS. Complex injuries which require more advanced urological skills are managed in conjunction with the urology department.

Methods

The Hybrid Electronic Medical Registry (HEMR) [19] was interrogated retrospectively for the period April 2013 to May 2020. All

Table 1
Cases managed non-operatively, laparotomy without renal exploration and cases explored expressed in number and percentage of total cases presenting.

	Gunshot wounds			Stab wounds		
	Total gunshot wounds ($n = 28$)			Total stab wounds ($n = 27$)		
	Non-operative management	Laparotomy, without renal exploration	Laparotomy with renal exploration	Non-operative management	Laparotomy, without renal exploration	Laparotomy with renal exploration
Grade 3	3 (20%)	5 (33%)	7 (47%)	6 (43%)	1 (7%)	7 (50%)
Grade 4	0 (0%)	0 (0%)	7 (100%)	8 (67%)	0 (0%)	4 (33%)
Grade 5	0 (0%)	0 (0%)	6 (100%)	0 (0%)	0 (0%)	1 (100%)
	3 (11%)	5 (18%)	20 (71%)	14 (52%)	1 (4%)	12 (44%)

Table 2
Cases and outcome per grade.

	Gunshot wounds: n (%)	Stab wounds: n (%)	
Grade 3			
Nephrectomy	3 (20%)	3 (21%)	$P = 1$
Renal salvage	12 (80%)	11 (79%)	
	15	14	29
Grade 4			
Nephrectomy	5 (71%)	2 (17%)	$P = 0.058$
Renal salvage	2 (29%)	10 (83%)	
	7	12	19
Grade 5			
Nephrectomy	6 (100%)	0 (0%)	$PP = 0.28$
Renal salvage	0 (0%)	1 (100%)	
	6	1	7
Grade 4–5			
Nephrectomy	11 (85%)	2 (15%)	$P = 0.001$
Renal salvage	2 (15%)	11 (85%)	
	13	13	26
Total (Grade 3–5)			
Nephrectomy	14 (50%)	5 (19%)	$P = 0.028$
Renal salvage	14 (50%)	22 (82%)	
	28	27	55

patients sustaining a high grade (Grade III to V) penetrating traumatic renal injury (TRI) were included. The diagnosis was made either with cross-sectional imaging or intra-operative findings. The nephrectomy rate of the different mechanisms of penetrating (GSW vs SW) TRI was compared for each grade using Fisher's exact tests, reporting the p-value as double the exact one-tailed probability. The analysis was performed with Stata V15.1. A p-value of <0.05 was considered statistically significant. Concomitant organ injuries were either diagnosed intraoperatively, or with CT-scan for those managed non-operatively.

Results

A total of 55 patients sustained a high-grade TRI (Grade III-V) secondary to a penetrating mechanism over the seven-year period. There were 28 GSW and 27 SW in this cohort. A total of 38 patients underwent emergency laparotomy as shown in Table 1. A total of 19 (35%) patients required nephrectomy. All 19 patients who underwent nephrectomy were in the cohort of patients who underwent emergency laparotomy. GSW had a significantly higher overall nephrectomy rate than SW (50.0 vs 19%, $p = 0.028$). The nephrectomy rate was similar between SW and GSW for grade III injuries (20 vs 21%, $p = 1$). However, grade by grade comparison showed a significantly higher rate of nephrectomy for grade IV and V TRI's secondary to a GSW compared to a SW. Grade IV (71 vs 17%, $p = 0.058$) and Grade V (100 vs 0%, $p = 0.28$). When comparing Grade IV and V together the difference is (85 vs 15%, $p = 0.001$). This is shown in Table 2. We encountered a single shotgun injury; this injury was a grade IV TRI, and the patient underwent nephrectomy. The mean and median length of admission for patients discharge alive, was 18 and 12 days respectively for GSW (SD 14 days; range 2–50 days), compared to that for SW of 8 and 5 days (SD 7 days; range 1–33 days) respectively. See Table 3. Five patients died secondary to GSW, and two patients secondary to SW. The causes of death included haemorrhagic shock (1), haemorrhagic shock combined with septic shock (1), ventilator associated pneumonia (1), respiratory failure (1) and systemic sepsis (3). The renal injury contributed to death, in the two patients in which haemorrhagic shock was a major cause of death.

Operative management

Almost all patients (25/28) 89% with a GSW required an emergency laparotomy. Of the SW victims only (13/27) 48% required an emergency laparotomy. Of the 20 Grade III TRI's identified at laparotomy, 14 were explored and 6 underwent nephrectomy. Of the 18 Grade IV and V injuries identified at laparotomy, all were explored. The nephrectomy rate in patients undergoing laparotomy, differs according to mechanism: GSW vs SW (14/25) 56% vs (5/13) 39%. If only Grade IV and V TRI's are compared, the difference is more marked (11/13) 85% vs (2/5) 40%. See Tables 1 and 2.

Almost all nephrectomies (18/19) 95% were performed at index laparotomy, and only a single nephrectomy was performed at a repeat laparotomy (1/19) 5%. This patient had a Grade V renal injury secondary to a GSW as well as a liver, gastric, pancreas, pancreaticoduodenal artery and inferior vena-caval injury. The clinical situation was confusing, and the patient underwent a sequential laparotomy, thoracotomy and repeat laparotomy at the same sitting. Only four patients underwent renorrhaphy (4/55, 7%). Of these two had a Grade III SW, one a Grade III GSW and one a Grade 5 SW with an injury to renal vein. All the repairs were successful.

Two patients were stented with a JJ stent, one Grade III SW, and one Grade IV SW. Repeat laparotomy was required for (19/28) 68% of GSW and (4/27) 15% of SW. The indications included initial damage control laparotomy, gross bowel oedema and sepsis.

Table 3
Length of admission (days) for patients discharged alive.

Days admitted	Gunshot wounds			Stab wounds		
	Mean	median	standard deviation	mean	median	standard deviation
Grade 3						
Nephrectomy	25	22 (9–43)	17	19	19 ($n = 1$)	0
Renal salvage	10	11 (2–23)	6	6	9 (2–9)	3
	13	12	11	8	7	5
Grade 4						
Nephrectomy	22	19 (5–45)	17	23	23 (12–33)	15
Renal salvage	8	8 (8–8)	0	4	4 (1–8)	2
	19	14	15	7	4	9
Grade 5						
Nephrectomy	37	22 (22–50)	14	–	–	–
Renal salvage	–	–	–	17	17 ($n = 1$)	0
	37	22	14	17	17	0
Total (Grade 3–5)						
Nephrectomy	26	21 (5–50)	16	21	12 (12–33)	11
Renal salvage	10	11 (2–23)	6	6	5 (1–33)	4
	18	12 (2–50)	14	8	5 (1–33)	7

Table 4
Associated organ injuries.

	Gunshot wounds			Stab wounds			
	Associated injuries (n)	Total	%	Associated injuries (n)	Total	%	p-value
Laparotomy only	23	25	92	11	13	85	0.85
Non-operative (CT only)	3	3	100	4	14	29	0.10
Total	26	28	93	15	27	56	0.003

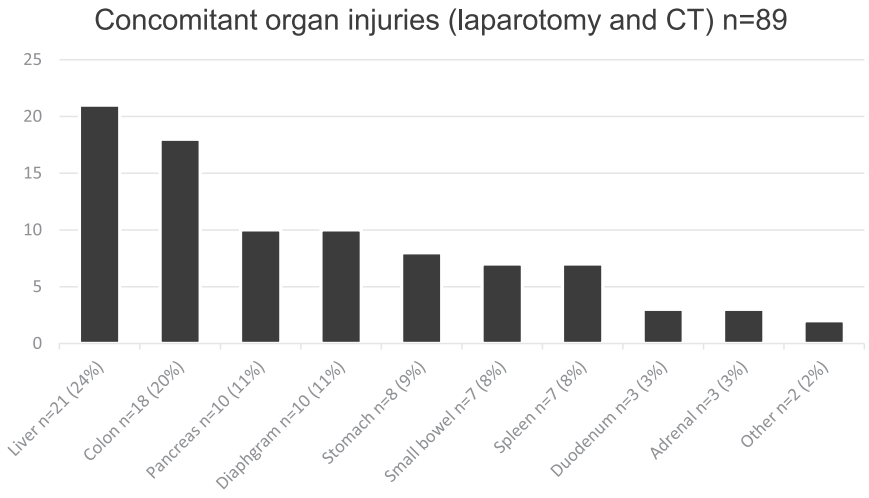

Fig. 2. Number of concomitant organ injuries.

Concomitant organ injuries

In the patients requiring a laparotomy, there was a similar spectrum of concomitant abdominal organ injuries if GSW are compared to SW (92 vs 85%, $p = 0.85$). This is markedly different for those managed non-operatively (received cross sectional imaging), where (100 vs 29%, $p = 0.10$) had concomitant organ injuries. See Table 4. The most commonly associated injured organs were the liver, large bowel, pancreas and diaphragm. This is slightly different to other author's findings [21]. See Fig. 2 .

Discussion

There is now consensus that low grade renal injuries (AAST I and II) can be successfully managed conservatively [22]. This applies to both injuries identified on pre-operative imaging and those encountered intra-operatively. Even if such an injury is encountered intra-operatively there is no need to explore it. Exploring such an injury and opening the peri–renal fascia is potentially hazardous as any haematoma is released and the subsequent bleeding may end up necessitating a nephrectomy [11,22]. The principles of selective conservatism and surgical minimalism can be safely applied to low grade injuries. From our data it appears that even Grade III penetrating TRI's have a relatively high rate of renal salvage (80%) and low rate of nephrectomy (20%). This is consistent for both GSW and SW. For grade I-III penetrating renal injuries mechanism does not appear to be a confounding factor in surgical decision making.

However, at higher grades (IV and V) this data shows that GSW and SW have very different outcomes, and this suggests that

the two mechanisms require different management algorithms and clinical approaches. GSW are more destructive than SW and especially in grade IV and grade V injuries renal salvage and successful NOM is very unlikely. In addition, most patients with a high-grade TRI secondary to a GSW, require laparotomy (GSW vs SW: 89 vs 48%) and emergency laparotomy usually lead to nephrectomy.

SW are less destructive than GSW and the tissue loss and disruption is confined to the tract [23]. This implies that there is greater potential for successful NOM and renal salvage with high grade SW than GSW. However, if a patient with a grade IV or V TRI secondary to a SW, requires a laparotomy, renal exploration is usually indicated, and this generally necessitates nephrectomy. Renal salvage for Grade IV and V TRI's is generally only possible for SW and in patients who do not undergo a laparotomy. It is only in this group of patients where renal salvage of high-grade TRI's appears possible. The two major risk factors for nephrectomy with a Grade IV and V TRI are the mechanism with GSW being more likely to require nephrectomy, and the need for laparotomy.

The majority of nephrectomies (95%) were performed at index laparotomy, and only a single nephrectomy (5%) at repeat laparotomy. This implies that the concomitant organ injuries' contribution to the need for nephrectomy is generally haemorrhage, necessitating damage control surgery, rather than ongoing sepsis or urinary extravasation.

The similar spectrum of concomitant injuries between GSW and SW suggests that it is the presence of concomitant injuries which necessitates laparotomy. Despite this, the nephrectomy rate in patients undergoing laparotomy differs according to mechanism (GSW vs SW 56 vs 39%). When only Grade IV and V injuries are compared, the difference is even more stark (85 vs 40%). This supports the contention that a GSW is an independent risk factor for nephrectomy.

The low rate of rhenorraphy (7%) in this cohort is different to the rate of (69%) reported in the literature [21]. This may reflect the fact that in our setting the sub specialist urology service is seldom involved in the index laparotomy [21]. Ongoing attempts to involve the urology service in the acute management are a potential area for quality improvement in the management of renal trauma. There are a number of limitations to this study, which include the retrospective interrogation of a prospectively collected data set, and the fact that this is a single centre trauma registry. In addition, the relative lack of access to interventional radiology and angio-embolization at our centre, may affect our results. It is important to keep in mind that mortality confounds the length of hospital admission. The lack of long-term follow-up remains a problem in trauma research.

Conclusion

Grade IV and V TRI's secondary to GSW are more likely to undergo nephrectomy than the equivalent grade TRI's secondary to a SW. It would appear that a GSW is an independent risk factor for nephrectomy in grade IV and V TRI's.

Ethics approval

Ethics approval for the study was granted by the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (BE435/19).

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Declaration of Competing Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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