Analysis of battle and non-battle traumatic renal injuries: a 6-year experience in a conflict zone in Afghanistan

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Research

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Abstract

Renal trauma occurs in 1-5% of all trauma cases [1]. The kidney is considered the most commonly injured genitourinary organ, with a male to female ratio of 3:1 [2]. Gunshot wounds are the most common causes of penetrating injuries and have the tendency to become more severe and less predictable than blunt trauma. Bullets cause destruction of the parenchyma and are often associated with multiorgan injuries [3]. Penetrating injury contributes to direct disruption of the parenchyma, collecting system, or vascular pedicle tissues.

Background

Renal trauma occurs in 1–5% of all trauma cases [1]. The kidney is considered the most commonly injured genitourinary organ, with a male to female ratio of 3:1 [2]. Gunshot wounds are the most common causes of penetrating injuries and have the tendency to become more severe and less predictable than blunt trauma. Bullets cause destruction of the parenchyma and are often associated with multiorgan injuries [3]. Penetrating injury contributes to direct disruption of the parenchyma, collecting system, or vascular pedicle tissues.

Conservative treatment for minor low-velocity gunshot wounds may produce good results [4]. In the case of tissue damage due to high-velocity gunshot, however, a nephrectomy may be required as tissue injury may be extensive. Non-surgical treatment of penetrating injuries in a select number of stable patients was successful in about 50% of stab wounds and up to 40% of gunshot wounds [5].

An average of 8–10% of blunt and penetrating abdominal injuries involve the kidneys. The incidence of associated injury in penetrating renal trauma ranges from 77–100%. Gunshot wounds result in injury to adjacent organs more often than stab wounds. Most patients with penetrating renal trauma have adjacent organ injuries that may complicate treatment. In case of the lack of an expanding hematoma with hemodynamic instability, multiorgan injuries do not increase the risk of nephrectomy [6].

With a global increase in wars, conflicts, and terrorism acts, blast or bullet abdominal injuries are seen more often and present a surgical challenge.

The amount of tissue damage and the severity of gunshot injuries are due to the force of impact of the bullets or projectiles, depending mainly on their velocity. The injuries therefore classified as either high-energy injury or low-energy injury [7].

Penetrating trauma is further classified according to the velocity of the projectile into high velocity projectiles (e.g. rifle bullets: ~ 800–1000 m/sec), medium-velocity projectiles (e.g. handgun bullets: ~ 200–300 m/sec), and low-velocity items (e.g. knife stab) [8].

Since the kinetic energy of the bullet is equal to half its mass multiplied by the square of its velocity, high-velocity bullets have much higher kinetic energy than low-velocity bullets; KE = 1/2 mv 2 (KE = kinetic energy in joules; m = mass in grams; v = velocity in feet/second.). The high kinetic energy gives rifle bullets a greater wounding potential than handgun bullets [9]. Wounding potential is only a part of the equation. The type of projectile, type of tissue injured, and the distance between the weapon and the victim all have major effects on these injuries [9]. An increase in caliber, load power, and bullet energy corresponds to an increase in the size of injury. The size of a renal injury may be represented as follows: U(t) = K*M*E(t)/Os [U(t) = size of injury; K = caliber; M = load power in bullet; E(t) = bullet energy; Os = distance of gunshot].

The aim of this study was to analyze traumatic renal injuries and determine topography of the most common abdomen injuries.

Hypothesis

The left side of the abdomen is mostly susceptible to trauma, especially on the battlefield, due to the combat posture of the soldier.

Methods

The study was conducted from September 2009 to March 2014. A total of 1266 combat trauma patients were treated in two health centers in the Forward Operating Base, Ghazni, Afghanistan, from the 6 to 14 rotation of the Polish Military Contingent (Medical Support Team Role 2 and Forward Surgical Team). 41 of whom had combat renal injuries. Forty-one (3.23%) patients were enrolled into the study and were reviewed retrospectively. The cohort study involved soldiers, 40 (97%) males and 1 (3%) female. The mean age of patients was 29 years. In most cases, renal injury was concomitant with multiorgan injury.

The following features of renal injury were assessed: etiology or mechanism of trauma, PATI score (Penetrating Abdominal Trauma Index) in penetrating trauma, ISS (Injury Severity Score), treatment method, and multiorgan injury. In addition, it was determined a left-handedness and a right-handedness due to a correlation between side of renal injury and a combat posture of a soldier. PATI and ISS scores were perioperatively calculated to determine the method of treatment and to predict possible postoperative complications respectively.

A radiography of the chest was performed, as well as a focused assessment with sonography for trauma (FAST) exam. In the conditions of battlefield, an access to computed tomography was limited, and the fast diagnostics was necessary. The FAST exam was used to determine the presence or otherwise of blood in the pericardium and/or peritoneum of unstable patient. A negative result, however, did not rule out the possibility of intra-abdominal organ injuries, particularly, hollow-organ injuries.

Statistical analyses were conducted using Stata/IC 14.2. The Kaplan-Meier survival analysis was used to determine the renal salvage rate employing PATI score as an indicator of nephrectomy. Results are expressed on the graph with hazard ratios and 95% confidence intervals.

Results

Forty-one patients with combat renal injuries were recruited for this retrospective study. The cohort comprised 40 (97%) males and 1 (3%) female. The mean age of patients was 29 years, the youngest being 19 years old, and the oldest, 50 years old. Of the 44 renal injuries, 21 injuries were of the right whilst 23 injuries were of the left kidney (Table 1). In most cases, renal injuries were concomitant with multiorgan injury. Other organs affected by the injury included the spleen (n = 10), large bowel (n = 7), small bowel (n = 9), bladder (n = 4), liver (n = 6), thorax (n = 22), lower extremities (n = 14), upper extremities (n = 7) and head (n = 8) (Fig. 1). With respect to trauma, 37 cases (84.09%) were a result of battle injury while 7 (15.90%) resulted from non-battle injury. Thirty-two cases of renal trauma were caused by penetrating trauma while 12 cases were as result of blunt trauma. The mechanism of renal trauma resulted from GSW (Gunshot Wound) in 7 (15.90%) patients, IED (Improvised Explosive Device) in 15 (34.09%) patients, MVA (Motor Vehicle Accident) in 6 (13.63%) patients, Apache shelling in 2 (4.54%) patients, mine blast in 6 (13.63%) patients, IDF (Indirect Fire) in 1 (2.27%) patient, RPG (Rocket Propelled Grenade) in 4 (9.09%) patients, fall from bastion HESCO in 1 (2.27%) patient and shooting in 3 (6.81%) patients (Fig. 2–3). In addition, injuries were classified as being of high-velocity (9 patients), low-velocity (8 patients), low energy (6 patients) and high-energy (21 patients).

Table 1
Patient’s characteristics.

Age	Sex	BT/NBT	Mechanism	Kidney (L/R)	ISS	B/P	PATI score	Type of trauma	Treatment	Blood transfusions
42	M	BT	GSW	L	26	P	54	HV	LN	4U pRBC, 4U FFP, 6U FWB, 10U Cryo
19	M	NBT	MVA	R	6	B	N/A	HE	conservative	NO
26	M	NBT	HESCO	R	34	B	N/A	LE	conservative	NO
20	M	BT	IDF	R	27	P	15	LV	NSS	3U pRBC, 3U FFP, 6U FWB, 10U Cryo
22	M	BT	GSW	R	29	P	22	HV	NSS	4U pRBC, 4U FFP, 6U FWB, 10U Cryo
21	M	BT	GSW	L	21	P	34	HV	LN	4U pRBC, 4U FFP, 8U FWB, 10U Cryo
21	M	BT	GSW	R	21	P	9	HV	RL-drainage	3U pRBC, 3U FFP, 10U Cryo
23	M	BT	mine blast	R	26	P	19	LV	RL-drainage	3U pRBC, 3U FFP, 5U FWB, 10U Cryo
27	M	BT	IED	L	57	P	54	LV	LN	5U pRBC, 5U FFP, 10U FWB, 10U Cryo
40	M	BT	Apache shelling	R	41	P	36	LV	NSS	3U pRBC, 3U FFP, 4U FWB, 10U Cryo
24	M	BT	mine blast	L	75	P	44	LV + HE	LN	4U pRBC, 4U FFP, 8U FWB, 10U Cryo
50	M	BT	shooting	L	34	P	20	HV	LN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
22	M	BT	Apache shelling	L	57	P	54	HV	LN	5U pRBC, 5U FFP, 10U FWB, 10U Cryo
23	M	BT	RPG	R	48	P	11	LV	RN	NO

Age	Sex	BT/NBT	Mechanism	Kidney (L/R)	ISS	B/P	PATI score	Type of trauma	Treatment	Blood transfusions
23	M	BT	IED	R	41	P	25	LV	suturation of right renal vein with venous patch	3U pRBC, 3U FFP, 8U FWB, 10U Cryo
43	M	BT	IED	R	27	P	19	LV	RL-shrapnel remove from kidney	3U pRBC, 3U FFP, 5U FWB, 10U Cryo
21	M	NBT	MVA	R	17	B	N/A	LE	conservative	NO
27	M	BT	GSW	L/R	34	P	63	HV	LN; suturation of right kidney, drainage	4U pRBC, 1U WBC, 3U FFP, 4U Cryo
42	M	BT	shooting	L	22	P	24	HV	LN	3U pRBC, 3U FFP, 5U Cryo
27	M	BT	IED	R	22	P	19	LE	conservative	4U pRBC, 4U FFP, 8U FWB, 10U Cryo
34	M	NBT	MVA	L	75	B	N/A	LE	conservative	NO
32	M	BT	IED	R	75	P	28	HE	RN	5U pRBC, 5U FFP, 10U Cryo
27	M	BT	IED	L/R	75	B	55	HE	conservative (right kidney); suturation of left renal parenchyma	6U pRBC, 5U FFP, 4U FWB, 10U Cryo
24	M	BT	GSW/mine blast	L	26	P	37	HE	LN	3U pRBC, 3U FFP, 4U FWB, 10U Cryo
23	M	BT	IED	L	35	P	58	HE	LN, packing	5U pRBC, 5U FFP, 4U FWB
34	M	BT	IED	L	35	P	61	HE	suturation and drainage	4U pRBC, 4U FFP, 5U FWB, 10U Cryo
25	M	BT	IED	R	19	P	49	HE	RN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
29	M	BT	IED	L	9	P	51	HE	LN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo

Age	Sex	BT/NBT	Mechanism	Kidney (L/R)	ISS	B/P	PATI score	Type of trauma	Treatment	Blood transfusions
26	M	BT	IED/mine blast	L	29	B	15	HE	suturation of renal left parenchyma	3U pRBC,3U FFP
23	M	BT	IED/mine blast	L/R	9	B	N/A	LE	conservative	NO
32	M	BT	IED	L	6	P	33	HE	conservative	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
29	F	NBT	MVA	L	29	B	N/A	HE	conservative	NO
28	M	BT	RPG/mine blast	L	29	P	N/A	HE	conservative	NO
28	M	BT	RPG	R	43	P	14	HE	RL-shrapnel remove and suturation	3U pRBC, 3U FFP
31	M	BT	IED	L	22	P	36	HE	LN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
24	M	NBT	MVA	L	22	B	N/A	HE	conservative	NO
25	M	BT	rocket shelling	L	27	P	13	LE	suturation, drainage	3U pRBC, 3U FFP
27	M	NBT	MVA	R	27	B	N/A	HE	conservative	NO
38	M	BT	RPG	R	48	P	25	HE	suturation, packing	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
29	M	BT	IED	L	42	P	55	HE	LN	5U pRBC, 5U FFP, 4U FWB, 10 U Cryo
42	M	BT	GSW	R	41	P	25	HE	RN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo

BT = battle trauma; NBT = non-battle trauma; L = left; R = right; B = blunt; P = penetrating; LN = left nephrectomy; RN = right nephrectomy; ISS-Injury Severity Score;

RL = right lumbotomy; HV = high-velocity; LV = low-velocity; HE = high-energy; LE = low-energy; N/A = non applicable

A PATI score ranged 9–63 and ISS score ranged 6–75 (Fig. 4). Twelve patients were managed with conservative treatment, three patients underwent NSS (Nephron Sparing Surgery). In 3 patients surgical revision of the right retroperitoneal space, perirenal hematoma, without any visible renal injuries, drainage; one patient underwent suture of the right renal vein with a venous patch. In 5 patients saturation of the renal parenchyma was performed. In addition, shrapnel from the renal parenchyma was excised. In 17 patients, nephrectomy was performed, nephrectomy of the left kidney (n = 13) including 11 right-handed patients and 2 left-handed patients, and 4 nephrectomy of the right kidney including 3 right-handed patients and 1 left-handed patient. The remaining 24 patients were 21 right-handed and 3 left-handed.

In 31 out of 41 patients, blood transfusions were performed as follows: 3–6 units of pRBC (packed Red Blood Cells), 3–5 units of FFP (Fresh Frozen Plasma), 4–10 units of FWB (Fresh Whole Blood), and 10 units of Cryo (Cryoprecipitate).

The renal salvage rate was 61.36% and overall survival rate was 90.24%. Battle injury died of wounds (DOW) casualty occurred in 4 (9.75%) patients. Statistical analysis including a Kaplan-Meier survival curve showed a significant correlation between PATI score and the need for a nephrectomy procedure as well as a relatively high rate of kidney salvage using conservative treatment ($p = 0.0269$) (Fig. 5).

Discussion

The damage of tissues caused by penetrating bullets depends on the intensity of impact. The complex interactions of the projectile with the various tissues result in a wide range of ballistic injury patterns and a characteristic bullet trajectories. Knowledge of the specific mechanisms that lead to increased tissue destruction will assist in the recognition of the less common injuries involving high-intensity impact, which are also associated with a higher risk of infectious complications [10]. According to Taş et al., injuries to the left kidney significantly occurred more often than injuries to the right kidney. However, the mean PATI score and the number of injured organs and blood transfusions did not differ by which side the injury occurred. In scientific publications, different opinions exist with respect to the side of renal injury. In the case of blast effects, the authors observed intraoperatively that the liver has a protective effect on the right kidney such that it may sustain the impact of the blast injury. In renal and liver injuries not directly attributable to projectile, although the blast effect caused higher-grade liver injuries, it was observed that a lower-grade right kidney injury occurred at the same time [11]. Voelzke et al. presented 201 patients (206 renal units) with renal gunshot wound: 96.5% (194 of 201) of them had multiorgan injury with more 74.6% having more than one organ involved. The liver was considered the most commonly injured organ. Ninety-five renal units (excluding nephrectomy) with associated small or large bowel injuries were repaired. The renal salvage rate was 85.4% and the total number of nephrectomies was 30 out of the 206 renal units. The overall survival rate was 90.6%, with 2 intraoperative and 17 postoperative deaths [12].

Complex genitourinary injuries are associated with injuries to the lower extremities, or even amputation, as well as pelvic and abdominal wounding in military combat operations. The nature of combat injuries of the genitourinary tract depends on the strategies used in their management. For example, 5% of all combat injuries include wounds of the urinary system or genitalia. For injuries that are predominantly penetrating, immediate care requires is required to ensure the preservation of viable tissue [13].

Paquette presented results of a research in which, out of the 2712 trauma cases, 76 (2.8%) out of 98 cases had one or more genitourinary injuries. Out of the 29 kidney injuries, 2 were explored without any treatment, 7 were observed, 1was repaired and 19 casualties required nephrectomy [14].

In our study, 17 nephrectomies procedures were performed, 13 of which involved the left kidney alone. In addition, the most commonly injured abdominal organs were the spleen (in 10 patients) and the large bowel (in 7 patients). These results confirmed our hypothesis that the left side of abdomen is most often susceptible to trauma especially on the battlefield. This is because the bandolier that holds the ammunition is strapped on the right side, thereby providing adequate protection to that side of abdomen. The renal salvage rate was 61.36% and overall survival rate was 90.24%.

Conclusions

The left side of the abdomen is more often susceptible to trauma and as a result, there are numerous multiorgan injuries involving the abdomen, spleen, large bowel, and left kidney. The combat posture of a soldier on the battlefield determines the abdominal injuries of the left side. This is because the bandolier that holds the ammunition is strapped on the right side, thereby protecting that side from injury.

Abbreviations

KE = kinetic energy in joules;

m = mass in grams;

v = velocity in feet/second;

U(t)=size of injury;

K=caliber;

M=load power in bullet;

E(t)=bullet energy;

Os=distance of gunshot;

PATI=Penetrating Abdominal Trauma Index;

ISS=Injury Severity Score;

FAST=focused assessment with sonography for trauma;

GSW=Gunshot Wound;

IED (Improvised Explosive Device;

MVA=Motor Vehicle Accident;

IDF=Indirect Fire;

RPG=Rocket Propelled Grenade;

NSS=Nephron Sparing Surgery;

pRBC=packed Red Blood Cells;

FFP=Fresh Frozen Plasma;

FWB=Fresh Whole Blood;

Cryo=Cryoprecipitate;

DOW=died of wounds.

Declarations

Ethics approval and consent to participate

The study was qualified as noninterventional observation study. Moreover, the researchers did not transfer the personal data of observed patients to the organizer. Thus, this study did not require approval by Ethics Commitee and registration in Central Register of Clinical Studies.

Consent for publication

Not applicable.

Availability of Data and Materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declares that they have no financial and non-financial competing interests.

Funding

There is no funding.

Authors' Contribution

TZ conceived the idea for the study. TZ and RB contributed to the design of the research. RB was involved in data collection. TZ analyzed the data. All authors edited and approved the final version of the manuscript.

Acknowledgement

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Tables

Table 1. Patient's characteristics.

Age	Sex	BT/NBT	Mechanism	Kidney (L/R)	ISS	B/P	PATI score	Type of trauma	Treatment	Blood transfusions
42	M	BT	GSW	L	26	P	54	HV	LN	4U pRBC, 4U FFP, 6U FWB, 10U Cryo
19	M	NBT	MVA	R	6	B	N/A	HE	conservative	NO
26	M	NBT	HESCO	R	34	B	N/A	LE	conservative	NO
20	M	BT	IDF	R	27	P	15	LV	NSS	3U pRBC, 3U FFP, 6U FWB, 10U Cryo
22	M	BT	GSW	R	29	P	22	HV	NSS	4U pRBC, 4U FFP, 6U FWB, 10U Cryo
21	M	BT	GSW	L	21	P	34	HV	LN	4U pRBC, 4U FFP, 8U FWB, 10U Cryo
21	M	BT	GSW	R	21	P	9	HV	RL-drainage	3U pRBC, 3U FFP, 10U Cryo
23	M	BT	mine blast	R	26	P	19	LV	RL-drainage	3U pRBC, 3U FFP, 5U FWB, 10U Cryo
27	M	BT	IED	L	57	P	54	LV	LN	5U pRBC, 5U FFP, 10U FWB, 10U Cryo
40	M	BT	Apache shelling	R	41	P	36	LV	NSS	3U pRBC, 3U FFP, 4U FWB, 10U Cryo
24	M	BT	mine blast	L	75	P	44	LV+HE	LN	4U pRBC, 4U FFP, 8U FWB, 10U Cryo
50	M	BT	shooting	L	34	P	20	HV	LN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
22	M	BT	Apache shelling	L	57	P	54	HV	LN	5U pRBC, 5U FFP, 10U FWB, 10U Cryo
23	M	BT	RPG	R	48	P	11	LV	RN	NO
23	M	BT	IED	R	41	P	25	LV	suturation of right renal vein with venous patch	3U pRBC, 3U FFP, 8U FWB, 10U Cryo

43	M	BT	IED	R	27	P	19	LV	RL-shrapnel remove from kidney	3U pRBC, 3U FFP, 5U FWB, 10U Cryo
21	M	NBT	MVA	R	17	B	N/A	LE	conservative	NO
27	M	BT	GSW	L/R	34	P	63	HV	LN; suturation of right kidney, drainage	4U pRBC, 1U WBC, 3U FFP, 4U Cryo
42	M	BT	shooting	L	22	P	24	HV	LN	3U pRBC, 3U FFP, 5U Cryo
27	M	BT	IED	R	22	P	19	LE	conservative	4U pRBC, 4U FFP, 8U FWB, 10U Cryo
34	M	NBT	MVA	L	75	B	N/A	LE	conservative	NO
32	M	BT	IED	R	75	P	28	HE	RN	5U pRBC, 5U FFP, 10U Cryo
27	M	BT	IED	L/R	75	B	55	HE	conservative (right kidney); suturation of left renal parenchyma	6U pRBC, 5U FFP, 4U FWB, 10U Cryo
24	M	BT	GSW/mine blast	L	26	P	37	HE	LN	3U pRBC, 3U FFP, 4U FWB, 10U Cryo
23	M	BT	IED	L	35	P	58	HE	LN, packing	5U pRBC, 5U FFP, 4U FWB
34	M	BT	IED	L	35	P	61	HE	suturation and drainage	4U pRBC, 4U FFP, 5U FWB, 10U Cryo
25	M	BT	IED	R	19	P	49	HE	RN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
29	M	BT	IED	L	9	P	51	HE	LN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
26	M	BT	IED/mine blast	L	29	B	15	HE	suturation of renal left parenchyma	3U pRBC,3U FFP
23	M	BT	IED/mine blast	L/R	9	B	N/A	LE	conservative	NO
32	M	BT	IED	L	6	P	33	HE	conservative	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
29	F	NBT	MVA	L	29	B	N/A	HE	conservative	NO

28	M	BT	RPG/mine blast	L	29	P	N/A	HE	conservative	NO
28	M	BT	RPG	R	43	P	14	HE	RL-shrapnel remove and suturation	3U pRBC, 3U FFP
31	M	BT	IED	L	22	P	36	HE	LN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
24	M	NBT	MVA	L	22	B	N/A	HE	conservative	NO
25	M	BT	rocket shelling	L	27	P	13	LE	suturation, drainage	3U pRBC, 3U FFP
27	M	NBT	MVA	R	27	B	N/A	HE	conservative	NO
38	M	BT	RPG	R	48	P	25	HE	suturation, packing	4U pRBC, 4U FFP, 4U FWB, 10U Cryo
29	M	BT	IED	L	42	P	55	HE	LN	5U pRBC, 5U FFP, 4U FWB, 10 U Cryo
42	M	BT	GSW	R	41	P	25	HE	RN	4U pRBC, 4U FFP, 4U FWB, 10U Cryo

BT=battle trauma; NBT=non-battle trauma; L=left; R=right; B=blunt; P=penetrating; LN=left nephrectomy; RN=right nephrectomy; ISS-Injury Severity Score;

RL=right lumbotomy; HV=high-velocity; LV=low-velocity; HE=high-energy; LE=low-energy; N/A=non applicable

Figures

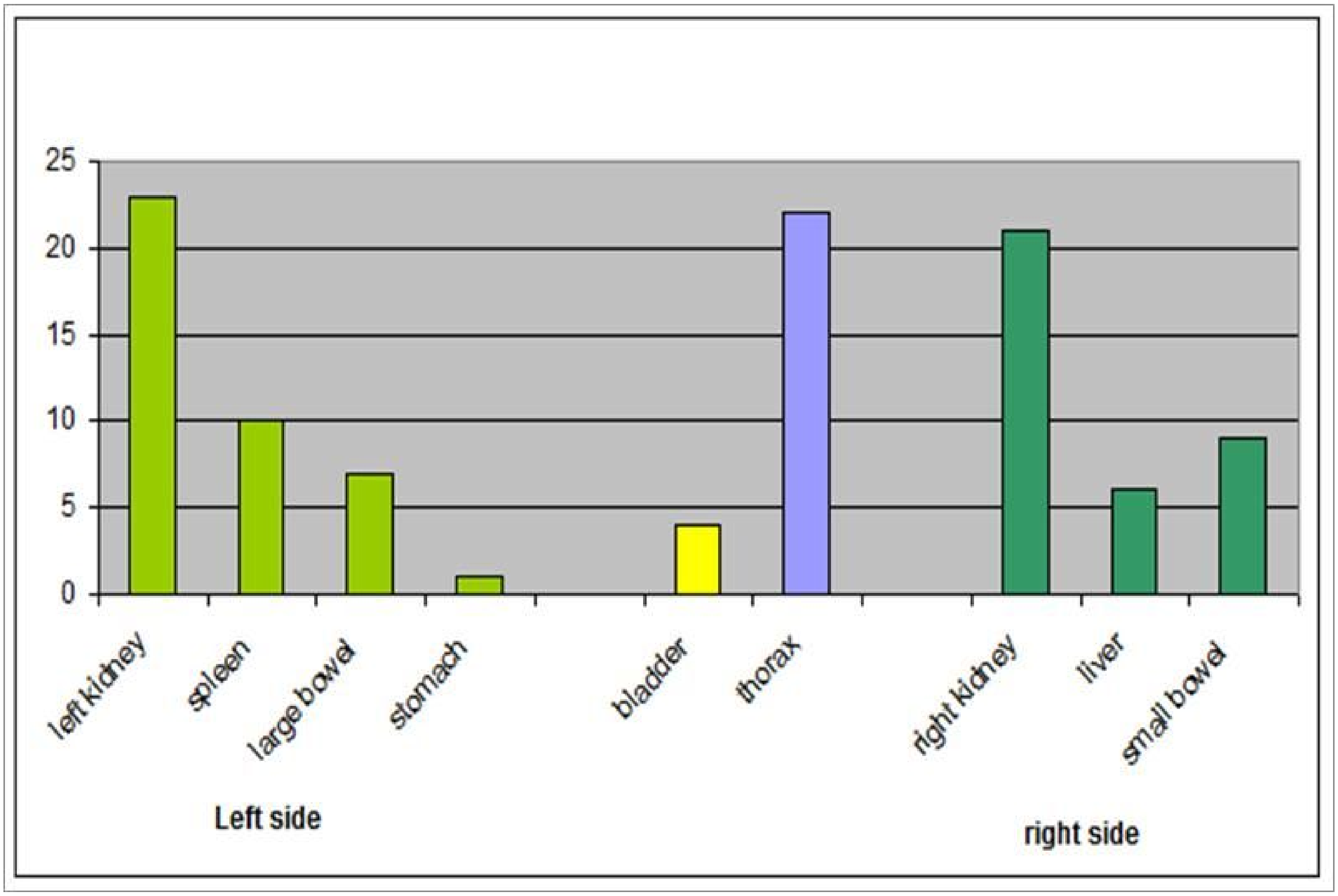

Figure 1

Multiorgan injuries with regard to left and right side of abdomen.

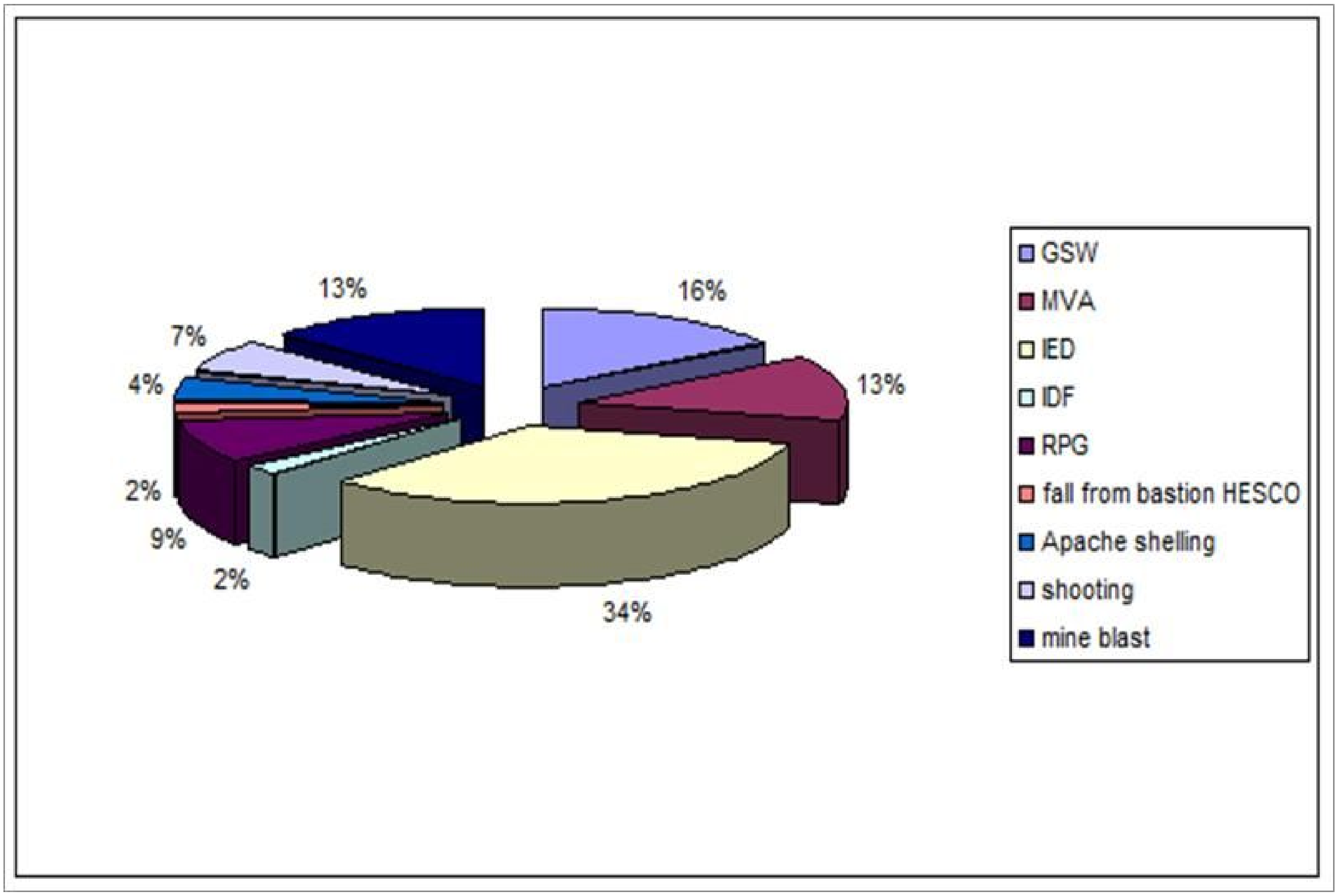

Figure 2

Mechanism of injury

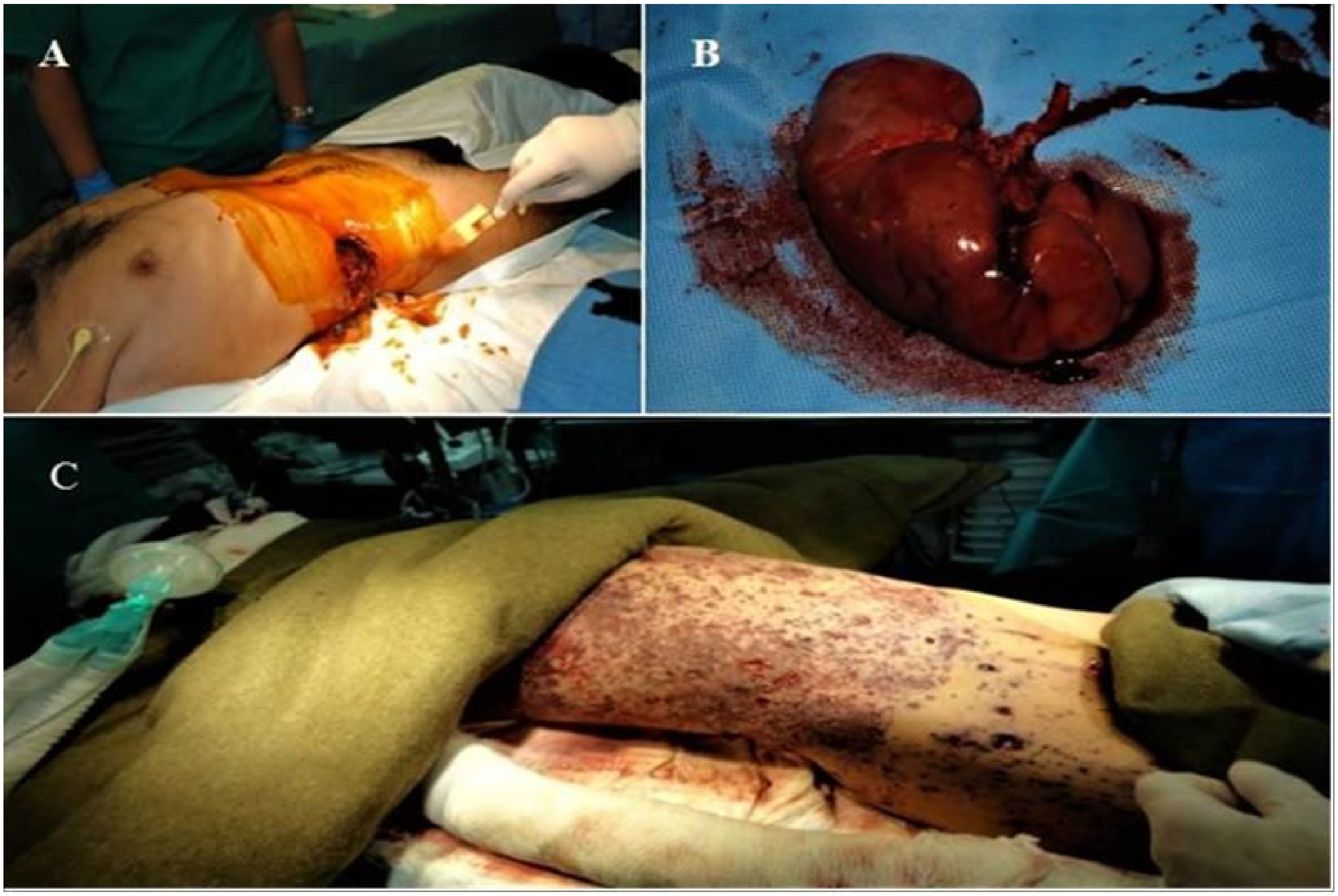

Figure 3

A - Shrapnel wound of abdomen with kidney rupture of the right side. B – Gunshot wound with the left renal vascular pedicle injury. C – Loculated shrapnel injuries after IED.

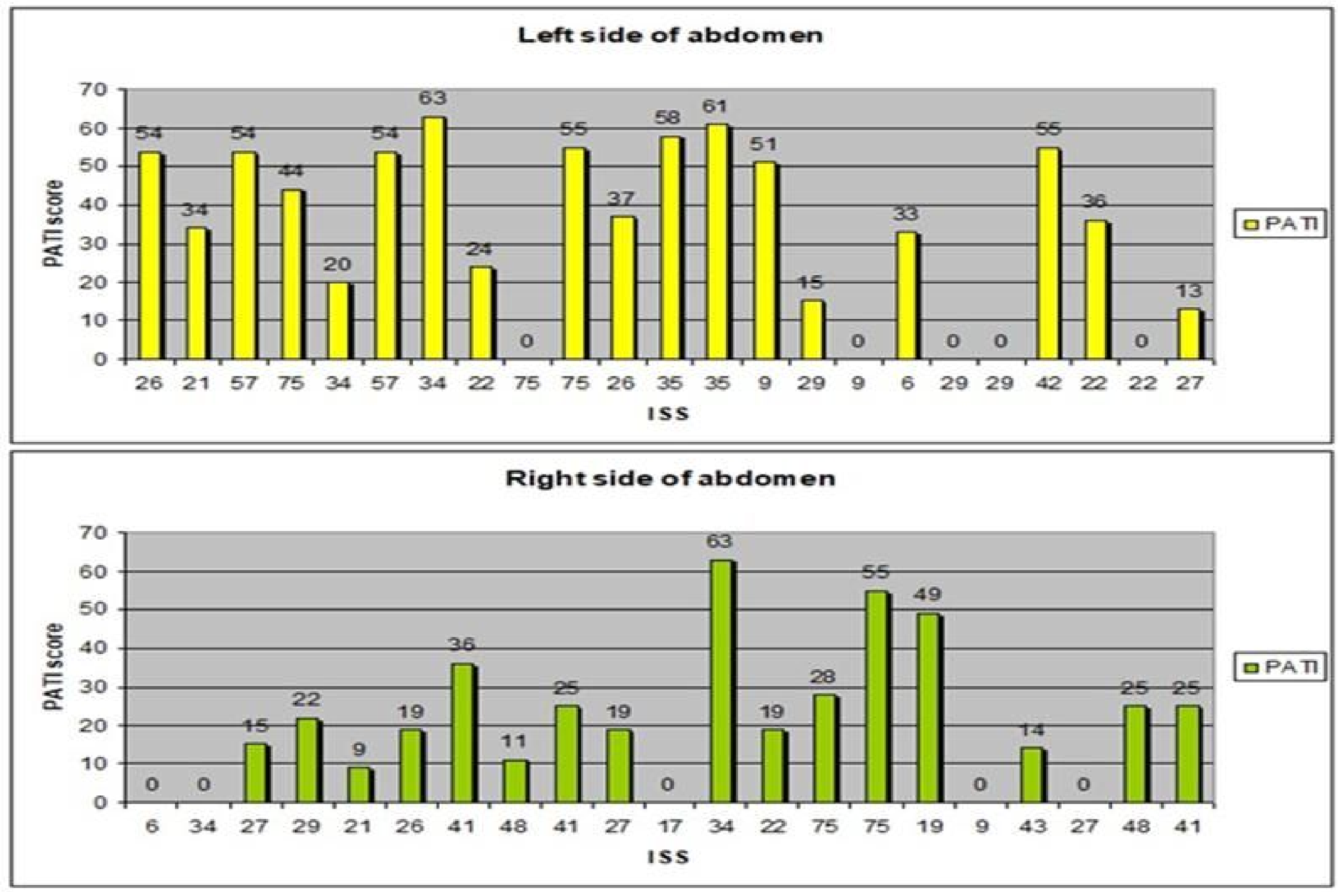

Figure 4

Correlation between PATI score and ISS scale.

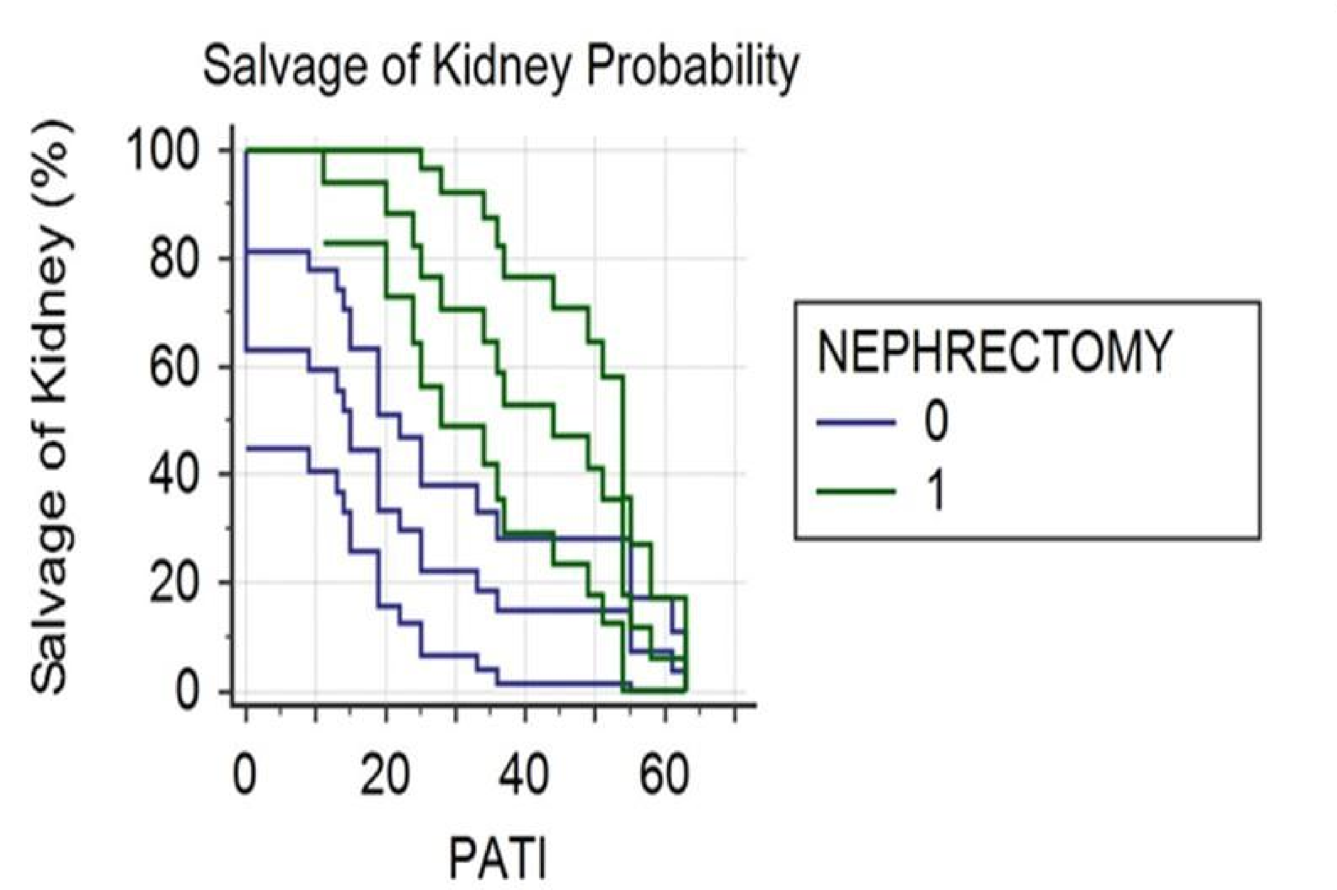

Figure 5

Salvage of kidney probability.