Experiences of Conflict Zone-Related Ballistic Renal Injury

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Abstract To analyze our approaches and experiences in patients with renal injuries accompanying penetrating abdominal injuries admitted to the hospital due to high kinetic energy weapons. Patients including renal injuries associated with penetrating abdominal injuries due to gunshot wounds and fragments of shell treated at our institution between February 2002 and May 2013 were retrospectively analyzed. Total 21 patients were included in this study, 20 of whom (86.2 %) were male and 1 (13.8 %) female. Renal injury was scaled in 2 patients as grade 1, 4 patients as grade 2, 4 patients as grade 3, 8 patients as grade 4, and 3 patients as grade 5. While conservative treatment was applied to patients with grade 1 and 2 injuries, 2 patients with grade 3 injury underwent renal repair and the other 13 patients underwent nephrectomy. The amount of blood transfused in all cases was determined to be mean 8.28 (6–16) units for red blood cells (ES) and 9 (6–17) units for fresh frozen plasma. When patients were assessed according to the Penetrating Abdominal Trauma Index (PATI) scores, the median score and average PATI score were 35 and 37.6 (10–70), respectively. A physical examination along with a quick assessment of vital signs should be made, and unnecessary and time-consuming investigations such as abdominal tomography and angiographic intervention should be avoided. Conservative and organ preservation should be considered absolutely for appropriately selected patients, namely in stable patients in whom kinetic

energy transfer is less and who have bullet path away from midline. However, the majority of these patients are considered to be hemodynamically unstable condition, possible complications of the procedure to be applied, and selection of patients should be carefully evaluated.

Keywords High kinetic energy · Penetrating injury · Kidney · Trauma

Introduction

High kinetic energy (HKE) gunshot wounds (GSWs) and those associated with renal injuries have still considerably high mortality and morbidity despite both innovations in diagnosis and treatment modalities. The most important reason of this is that fragments of bullets and explosives with HKE can cause damage to adjacent tissues depending on blast effect (temporary cavity) while traveling within the abdomen [1]. In this way, both direct and indirect blast effect of bullets increase the likelihood of kidney injury. Besides the temporary and permanent cavity effects of HKE weapons, the damage caused by both fragments of the bullet that change directions and also disrupted bone tissues has increased when they progress within the abdomen. For this reason, predictions about the dimension of renal injury and complications developing in patients are difficult [2, 3].

The kidneys are the most affected organ of the genitourinary system in abdominal injury due to gunshot wounds [4]. Renal injuries with gunshot wounds, according to their direct and blast effects, have different treatment options with regard to blunt or penetrating stab injuries. While injuries due to HKE are more serious with higher damages, low-grade injuries occur with other low kinetic energy or penetrating stab wounds [5].

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Renal trauma requiring immediate intervention is usually encountered in emergency conditions [6]. In most of injuries with HKE, laparotomy is required for accompanying intraabdominal multiorgan injuries. Major trauma centers have reported that renal injuries due to GSWs are 4.04 % of all renal injuries [7]; nevertheless, distinction showing percentage of renal injuries with HKE is not found in literature.

Some publications have reported that early control of main renal vasculature lowers the percentage of nephrectomy in renal injuries [8, 9]. As with other solid organ injuries due to firearms, to protect the kidney and to prevent its loss is of great importance for renal injuries. The primary aim of this study is to evaluate our management of renal GSWs in the acute setting and present experiences about renal injuries associated with HKE weapons.

Materials and Methods

A total of 125 patients injured by HKE weapons such as gunshots and fragments of shell at conflict zones were treated at an urban level 1 trauma center between February 2002 and May 2013. The retrospective review of medical records for all patients who sustained HKE injury was approved by an institutional review board. A total of 21 patients (20 of whom were males and 1 female) including renal injuries associated with penetrating abdominal injuries due to HKE weapons were identified for the study. All patients had associated multiorgan injuries.

All patients accepted to our center were initially evaluated in the emergency department with a multidisciplinary approach. Inspection of the entire body, obtaining vascular access, the assessment of vital signs and laboratory tests (complete blood count, cross matching, emergency biochemistry tests including kidney function tests) were performed quickly. All patients were assessed by digital rectal examination for prostatic deformation, rectal perforation, and hemorrhage, and Foley catheterization was performed. Thereafter, presence of macroscopic hematuria was evaluated. Hemodynamically stable patients (defined as systolic blood pressure greater than 90 mmHg and heart rate less than 110 bpm, and no signs of peritoneal irritation) were evaluated in a detailed fashion by radiography, ultrasonography, and computed tomography scan of the abdomen in the emergency room and then underwent laparotomy. However, patients who were hemodynamically unstable, in a state of preshock or shock ($n=13$) underwent emergency laparotomy.

Laparotomy with supraumbilical and infraumbilical median incision was performed in all patients to thoroughly explore the abdomen. Throughout the course of exploration, hematoma and actively bleeding areas were first tackled. After controlling the active bleeding, the entrance wound of foreign objects and their possible axes were assessed. Patients whose bone tissues (rib, vertebrae, pelvic bones, etc.) were seen

around the entrance point were investigated for lesions which they could intraabdominally create because of the possibility of changing directions of fragments of bullet and bone. Primarily, solid organs on the side of the bullet entrance and then the other organs on opposite sides were assessed. During renal examination, Gerota's fascia was uncovered except for 2 patients treated conservatively, and assessment was made with inspection and palpation. Pedicle control and complete mobilization was first performed, and ureter was controlled later. Exploration started with the esophagus and included the entire gastrointestinal tract and pelvic peritoneum. The amount of blood transfusion and IV fluids given were also recorded.

Patients with penetrating abdominal gunshot wounds were scored according to the Penetrating Abdominal Trauma Index (PATI) [10]. Patients with renal injuries were classified according to the staging of the American Association for the Surgery of Trauma (AAST) [11]. PATI and AAST scores were perioperatively calculated to determine our treatment method and to predict complications that may occur in the postoperative period. Finally, the treatment protocols applied to all patients were recorded. Patients were followed with renal function tests in terms of possible complications and crush syndrome which might occur.

Results

A total of 21 patients with military injuries due to HKE were included in this study. Of these, 20 (86.2 %) were male and 1 (13.8 %) female. The mean age of patients was 23.5 years (20–38).

Injuries to the other organs accompanied by renal injuries in this study were shown as solid organs, non-solid organs, and extra-abdominal organs in Table 1. While solid organs accompanying the left kidney injuries were mostly the spleen and pancreas, those accompanying the right kidney injury were only liver injury. It was observed that the colon and small bowel injury were seen in both kidney injuries, but the stomach and diaphragmatic injury were seen in only the left kidney injury. Right kidney injury was predominantly observed to be accompanied by extra-abdominal organ injuries.

According to renal injury scale of AAST, it was observed that 2 patients were classified as grade 1, 4 patients as grade 2, 4 patients as grade 3, 8 patients as grade 4, and 3 patients as grade 5 injury (Table 2). While renal conservative treatment was applied to patients with grade 1 and 2 injuries, 2 patients with grade 3 injury underwent renal repair. In the rest of other renal injuries, nephrectomy was performed after the opposite kidney was observed to be normal. We have no opportunity to confirm this with using IVP. While only 2 of the patients who underwent nephrectomy had grade 4 injury due to the right kidney injury, the other 11 patients (2 of them as grade 3, 6 of them as grade 4, 3 of them as grade 5) had lesions due to the left kidney injury.

Table 1 Other organ injuries accompanying renal injuries

Renal injury	Solid abdominal organs accompanying renal injuries				Non- solid abdominal organs accompanying renal injuries				Extra-abdominal organ injuries <i>n</i> (%)	Total organs accompanying renal injuries <i>n</i> (%)
	Kidney <i>n</i> (%)	Liver <i>n</i> (%)	Spleen <i>n</i> (%)	Pancreas <i>n</i> (%)	Colon <i>n</i> (%)	Small bowel <i>n</i> (%)	Stomach <i>n</i> (%)	Diaphragm <i>n</i> (%)		
Left side	15 (24.2)	2 (3.2)	6 (9.7)	5 (8.1)	9 (14.5)	9 (14.5)	7 (11.3)	3 (4.8)	6 (9.7)	62 (100)
Right side	6 (26.1)	5 (21.7)	–	–	2 (8.7)	3 (13)	–	–	7 (30.4)	23 (100)
Total	21 (24.7)	7 (8.2)	6 (7.1)	5 (5.9)	11 (12.9)	12 (14.1)	7 (8.2)	3 (3.5)	13 (15.3)	85 (100)

Extra-abdominal organs include injuries of respiratorial, musculoskeletal, and central nervous system

As all of nephrectomy procedures were performed in the acute setting, there were no delayed nephrectomy procedures. Additionally, it was observed that all of the patients who underwent nephrectomy (*n*:13) were injured directly by the projectile itself and that the remaining of patients who underwent renal repair and renal conservative treatment were indirectly injured with the blast effect which the projectile with HKE exerts.

Of 21 patients with kidney injury evaluated retrospectively, 11 (57 %) were observed to have macroscopic hematuria. When patients with macroscopic hematuria were classified according to renal injury grade, 2 patients had grade 3 injury, 8 patients had grade 4, and 1 patient had grade 5 injury. High PATI score and multiorgan injury was observed in 2 of 10 patients without macroscopic hematuria (grade 5), and therefore, these patients underwent nephrectomy.

When patients were assessed according to PATI scores, the median value was 35, and the average PATI score was 37.6 (10–70), respectively. When the numbers of injured organ increase, PATI scores naturally do (Fig. 1).

The amount of transfused blood was determined to be mean 8.28 (6–16) units for red blood cells (ES) and 9 (6–17) units for fresh frozen plasma in our study. None of the patients in the acute phase were given any cryoprecipitate or platelets transfusion. There was significant correlation of PATI scores with the amount of transfusion and multiorgan organ injury.

There were no complications directly related to the kidney in these 21 young patients and no mortality. In addition to this, there were no pathological changes at renal function test in follow-up.

Discussion

The severity of the damage increases for injuries caused by HKE weapons due to both the projectile itself and its blast effect [2]. As a result, the high mortality and morbidity rates in this type of injury seem inevitable. Cessation of renal bleeding often requires invasive and major interventions because renal blood flow is approximately 12 % of cardiac output or 500 ml/dk [12].

Blunt trauma gets the first place in renal trauma followed by penetrating trauma [13]. Kidney injuries due to firearms account for only 4 % of all renal trauma [7]. Previously, nephrectomy was performed more frequently in the past provided the opposite kidney was normal. However, nowadays, organ sparing approach is preferred both for blunt and penetrating injuries. [14–16]. In a large series of penetrating renal trauma, Wessels and his colleagues reported that the number of patients treated conservatively might increase [16]. Velmahos and his colleagues were able to follow up only 38 % of 1856 firearm injuries to kidney treated conservatively [17]. However, whether firearms had high or low kinetic energy were not specified in these studies.

We adopt the principle of early vascular control in patients with severe renal injury [7]. However, unlike the above-mentioned study, we believe in being selective in exploration between high and low kinetic energy weapons. Even in some centers, which prefer conservative or salvage treatment, it was observed that they have explored all patients with penetrating abdominal gunshot wounds [18]. In our study, we explored all

Table 2 Classification and treatment options according to the staging of the American Association for the Surgery of Trauma (AAST)

Grade	The number of patient <i>n</i> (%)	Treatment options		
		Conservative <i>n</i> (%)	Renorrhaphy <i>n</i> (%)	Nephrectomy <i>n</i> (%)
1	2 (9.5)	2	0	0
2	4 (19)	4	0	0
3	4 (19)	0	2	2
4	8 (38)	0	0	8
5	3 (14.5)	0	0	3
Total	21 (100)	6 (28.6)	2 (9.5)	13 (61.9)

Fig. 1 Comparison of all patients' PATI scores with the number of injured organ

the patients who sustained HKE abdominal injuries. Renal conservative approaches were performed in 6 patients (28.6 %), and renal repair was performed in 2 (9.5 %) patients, and these patients were explored due to penetrating abdominal injuries and also were injured indirectly by blast effect of the projectile. On the other hand, nephrectomy was performed in the remainder of 13 (61.9 %) patients who were injured directly by the projectile itself. Blast effect needs to be considered in high-velocity injuries including roughly 25 % of patients in whom renorrhaphy was practiced. The most important factors affecting kinetic energy are the velocity and weight of the bullet in the formula where blastic effect is evaluated as $E=1/2 mv^2$ (E: energy (joules), m: mass (kg), v: velocity (m/s)) [19]. The use of low-velocity bullets and the small bullet mass in civilian life reveal the differences from the injuries in conflict zones.

As we noted in one of our previous studies, we would like to emphasize the following three points that need attention during treatment procedures to be applied in injuries caused by HKE weapons [6]. Firstly; penetrating abdominal gunshot injuries should be considered as an absolutely multiorgan injury because of their blast effect. Secondly; again considering that patients brought to the first intervention centers in a state of shock or preshock, effective and rapid intervention is required. Finally, late complications of blast effect should be considered in patients injured in conflict zones and transferred to civilian centers because such patients could have injured by large caliber bullets and effective explosives.

In urinary tract injuries, hematuria has been reported to be a good diagnostic criterion; however, there was no relationship between the degree of hematuria and renal trauma. Moreover, 36 % of patients were not observed to have hematuria even in renal vascular injury [20]. Macroscopic hematuria has been reported to be 35 % in renal injuries due to firearms [5]. In our study, 11 patients (57 %) were observed to have macroscopic hematuria especially in grade 3 and 4 renal injuries. This could be explained that high blast effect constituted cortical and

medullar hemorrhage without disturbing the integrity of kidney in grade 3 renal injury. In the event of ureter is intact, macroscopic hematuria can be observed in grade 4 renal injuries. Macroscopic hematuria can be seen to a lesser extent because of completely destroyed feeding and collecting systems of kidney in grade 5 renal injuries.

Moore and colleagues have defined PATI scores to predict mortality and morbidity rates in patients with penetrating abdominal trauma. The complication rate has been reported to be 46 % in patients who have the score of 47 and above, while complication rate has been 7 % in those who have the score of under 25 [10]. It has been reported by the publications that PATI score is associated with morbidity and mortality, and complication rates may be higher in patients with higher scores [21, 22]. No complications attributable to kidney were observed in our study, although the mean value of PATI was over 25. Considering in terms of the amount of blood transfusion, there was close parallelism between the volume of blood transfusion performed in all patients and high PATI scores and multiorgan injury.

In our study, the left kidney injuries were significantly higher than the right ones, but the average value of PATI scores, the number of injured organs and blood transfusions related to injuries on both sides did not show any difference. Literature reviews give different opinions regarding the side of renal injury. Considering the blast effects, according to our observation obtained intraoperatively, we believe that protective effect which the liver creates on the right kidney through absorbing the energy could be preventive in blast injury. In renal and liver injuries not directly attributable to projectile, although blast effect caused a higher grade liver injuries, it was observed that a lower-grade right kidney injury occurred at the same time.

As a result, we do believe that patients sustaining abdominal trauma by HKE weapons should be explored. The careful evaluation of entire systemic findings in patients with these types of injuries will provide the detection of lesions less

likely to be skipped. In hemodynamically unstable patients injured by HKE weapons with an open wound and bullet entry hole, a quick physical examination and vital sign assessment should be made, request for the radiological examinations that could help the surgeon to change his decision of exploration should be provided, and unnecessary and time-consuming investigations such as abdominal tomography and angiographic intervention should be avoided. Renal conservative and organ preservation should be considered absolutely in appropriately selected patients, namely in stable patients in whom kinetic energy transfer is less and who have bullet path away from midline. However, the majority of these cases are considered to be hemodynamically unstable condition, complications of the procedures to be applied and selection of patients should be carefully evaluated.

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