ORIGINAL ARTICLE

Operative and non-operative management of children with abdominal gunshot injuries

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ABSTRACT

BACKGROUND: Non-operative management (NOM) is a standard treatment method for solid organ injuries worldwide. There is no consensus on the management of gunshot wounds (GSW) because of the higher frequency of hollow viscus injuries (HVI) and the unpredictable depth of tissue damage produced by kinetic energy transfer during retardation of the bullet. Here we aimed to re-evaluate indications for surgery and NOM based on our pediatric patients with abdominal GSW.

METHODS: We performed a retrospective analysis of patients evaluated and treated for abdominal GSW at University of Dicle between January 2010 and October 2016. Patients with hemodynamic instability, signs of peritonitis on serial abdominal examination, and free air in the abdomen underwent laparotomy; these were included in group I (n=17). Patients managed non-operatively were included in group II (n=13).

RESULTS: Our statistical analysis showed significantly lower Hb levels and systolic blood pressure levels ($p<0.001$) and higher pulse rate, higher mean injury severity score, and longer length of stay at intensive care unit in patients in group I than in those in group II ($p<0.001$). We further detected colon perforation (n=10) and small bowel perforation (n=7) in patients in group I; liver laceration (n=4), splenic injury (n=1), and renal injury (n=3) but no solid organ injury or HVI (n=5) were detected in patients in group II.

CONCLUSION: The major drawback of NOM is the difficulty in diagnosing HVI in abdominal GSW, which may delay treatment. We suggest that patients with solid organ damage who are hemodynamically stable and exhibit no signs of peritonitis upon serial abdominal exam may be treated with NOM.

Keywords: Children; gunshot injuries; hollow viscus injuries; non-operative management.

INTRODUCTION

The incidence of penetrating trauma due to firearms has significantly increased worldwide.[1,2] Injuries due to firearms are the second leading cause of pediatric trauma deaths in the United States.[3] Although non-operative management (NOM) is a standard treatment method for solid organ injuries after blunt trauma, there is no consensus on its utility in managing penetrating gunshot wounds (GSW). Laparotomy is generally preferred among surgeons in cases of GSW because of the possibility of organ damage resulting from unpredictable kinetic energy transfer during passage and retardation of the bullet, which results in a higher frequency of hollow viscus injuries (HVI) and more difficulty in accurately diagnosing HVI, and thus there is a greater potential for treatment delays more than blunt trauma.[4,5] In the present study, we aimed to re-evaluate indications for surgery in pediatric patients with GSW and to determine the effectiveness of non-operative treatment of solid organ damage after exclusion of HVI, using NOM criteria.

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MATERIALS AND METHODS

We performed a retrospective analysis of patients evaluated and treated for GSW at Dicle University Emergency Department between January 2010 and October 2016. The study was approved by the Dicle University Ethics Committee. Patients included in the study were aged <17 years with abdominal GSW, where the bullet track was directly intra-abdominal and/or where the bullet track was observed to be adjacent to the intra-abdominal area, but high-density fluid was noted in the pelvis. Patients with head and extremity injuries were excluded from the study. After initial evaluation at the emergency department, all patients underwent computed tomography (CT). CT images were interpreted by a radiology specialist according to the following criteria for abdominal evaluation: 1) free air in the abdomen and/or retroperitoneum, 2) free fluid in the pelvis without solid organ injury, 3) bullet track injuries, 4) intraperitoneal contamination, and 5) bowel wall thickening. Immediate laparotomy was planned for all patients who fit at least two of the above criteria with ongoing hemodynamic instability and peritonitis (Fig. 1, 2). The patients were divided into two groups. Patients with hemodynamic instability, signs of peritonitis on serial abdominal examination, and free air in the abdomen were included in group I and underwent emergent laparotomy. Stable patients without the above-mentioned signs were included in group II and managed non-operatively (Fig. 3). Patients were analyzed by age, sex, hemoglobin (Hb) levels at admission, blood pressure, pulse rate, cause of injury, mean injury severity score (ISS), length of stay in the intensive care unit (ICU), and mortality and morbidity criteria. Data were statistically analyzed using Statistical Package for the Social Sciences (SPSS) (Windows 10.0, SPSS Inc., Chicago, IL) to determine significant factors affecting NOM. For comparisons of incidences for univariate analyses, Chi-square or Fisher's exact test were used, whereas the independent t-test or Mann–Whitney U test was used to compare the values. p-value < 0.05 was considered to be statistically significant.

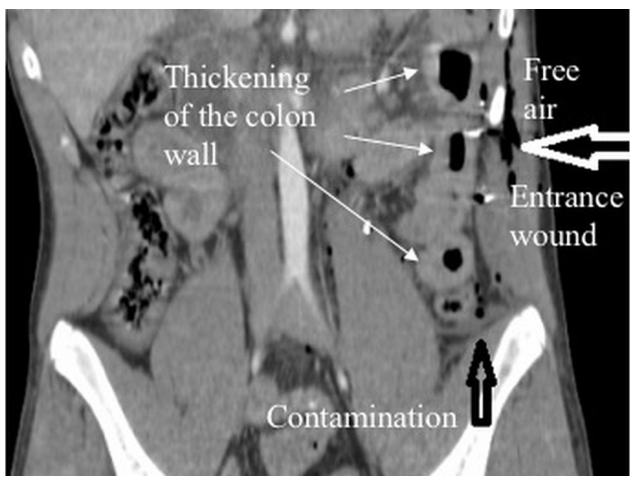

Figure 1. Coronal CT of a 15-year-old male in group I.

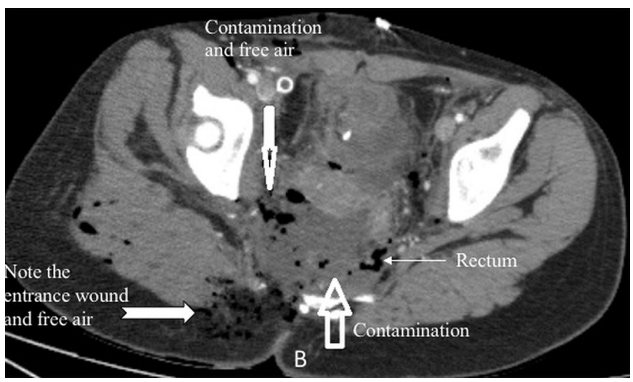

Figure 2. Axial CT of a 17-year-old female in group I.

RESULTS

We studied medical records of 302 patients who were initially admitted to the emergency department with GSW. After retrospective analysis, 30 patients (10.1%) were included in our study based on their relevance to our criteria. The mean age of our patients was 10.4±3.8 (4–16) years. Twenty-three (76.6%) were males and 7 (23.3%) were females. Seventeen (56.6%) of the 30 patients were operable and included in group I (Table 1). Thirteen (43.3%) patients were managed by NOM and included in group II. The mean time from admission to surgery was 6.4±12.5 (1–48) h. Colon perforation was found in 10 (58.8%) of the 17 patients in group I and segmental resection was performed. Seven (70%) of these 10 patients also underwent colostomy for intraperitoneal contamination or other problems. Two of these seven patients who had undergone colostomy also underwent splenectomy and nephrectomy because of grade 4–5 lacerations of the spleen and kidney. Colon perforations were primarily repaired in three (30%) of these 10 patients.

Diagnostic laparoscopy was planned 48 h after injury for one patient in the NOM group II. This patient was included in

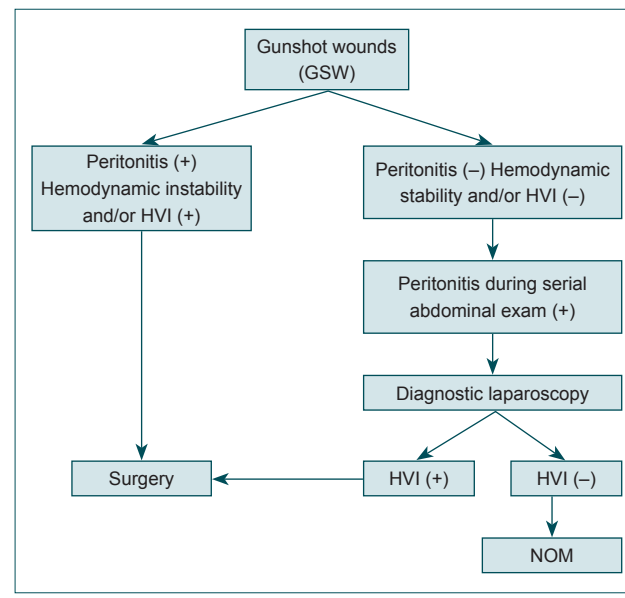

Figure 3. Flow diagram of the characteristics of the patients.

Table 1. Image and examination findings of cases of group I

Group I (n=17)	n	%
The computerized tomography images criteria for evaluation		
Free air in the abdomen and/or retroperitoneum	11	64.7
Free fluid in the pelvis without solid organ injury	10	58.8
Bullet track injuries	13	76.4
Intraperitoneal contamination	12	70.5
Bowel wall thickening	9	52.9
Serial abdominal examination		
Hemodynamic instability	10	58.8
Peritonitis	17	100

group I after developing signs of peritonitis (Fig. 4a, b). A microperforation was detected in the ileum during laparoscopy. This patient underwent laparotomy, and the microperforation was primarily repaired after exclusion of additional pathologies. Small bowel perforation was found in 7 (41.2%) of 17 patients in group I and were primarily repaired. None of the cases required ileostomy.

In addition to the pathologies observed mentioned above, we also detected small bowel evisceration (n=2), bladder perforation (n=3), femoral vessel injury (n=2), vaginal injury (n=1), and eye injury (n=2). Postoperative sepsis with multiple organ failure developed in one patient. During further exploration in this patient, anastomotic leaks were detected, which were repaired primarily, and the colostomy was revised. Another patient exhibiting multiple organ failure required massive transfusion and then died (mean transfusion requirement was 8 units).

The 13 hemodynamically stable patients in group II did not show any signs of HVI during radiological imaging and

Figure 4. (a, b) A 7-year-old female with ileal microperforation.

were managed non-operatively. Liver laceration (grade I–III), splenic injury (grade II), and renal injury (grade II-III) was detected in four (30.7%), one (7.6%), and three (23%) patients, respectively. No solid organ injury or HVI was found in the remaining five (38.4%) patients. In the five patients where no solid organ injury was found, the bullet track was adjacent to the intra-abdominal area and there was high-density fluid in the pelvis, similar to that observed in the patient in whom an ileum perforation was discovered 48 h later. Because patients in group II were hemodynamically stable, no morbidity or mortality was observed.

Statistical analysis demonstrated significantly lower Hb levels and systolic blood pressure levels in patients in group I than in those in group II (p^*=0.01 and p^*=0.00, respectively). However, the pulse rate, mean ISS, and length of ICU stay were significantly higher in patients in group I than in those in group II (p^*=0.00, p^*=0.00, and p^*=0.00, respectively). Differences between the two groups with respect to the need for blood transfusions and the length of follow-up were not statistically significant (p=0.88 and p=0.11, respectively) (Table 2).

DISCUSSION

Many studies have demonstrated that NOM is safe for patients with solid organ injuries caused by blunt abdominal

Table 2. Demographic data of all patients with gunshot wounds

	Group I (Surgery, n=17)	Group II (NOM, n=13)	p
Patient age (year), (Mean±SD)	11.1±3.7 (range 4–16)	9.6±3.9 (range 4–16)	=0.297
Gender (Male/Female)	12/5	11/2	=0.510
Hemoglobin, (Mean±SD)	8.7±1.3 (range 6.43–12.1)	11±1.7 (range 8.6–13.8)	*=0.01
Systolic blood pressure (mmHg), (Mean±SD)	83.8±7.8 (range 70–95)	105±6.9 (range 90–115)	*=0.00
Pulse rate (min), (Mean±SD)	126±17.6 (range 95–148)	96±9.9 (range 78–110)	*=.000
Injury Severity Score, (Mean±SD)	19 (range 5–38)	5.6 (range 2–17)	*=0.00
Hospitalization period at ICU (days), (Mean±SD)	5.6±1.8 (range 2–8)	2.3±0.9 day (range 1–4)	*=0.00
Hospitalization period (days), (Mean±SD)	3.7±2.3 (range 0–10)	2.7±2.5 (range 1–10)	=088
Blood transfusion (IU), (Mean±SD)	1.8±1.4 (0–4)	0.5±0.7 (0–2)	=011
Mortality, n (%)	1 (5.8)	0	

NOM: Nonoperative management; SD: Standard deviation.

trauma.[6,7] Until recently, emergency laparotomy was the standard treatment for abdominal GSW.[5] However, there are an increasing number of studies demonstrating the importance of NOM of GSW.[8] Retrospective and prospective studies in adults report that the success rate of NOM in cases of anterior abdominal GSW is 30%.[9] Moreover, a previous study conducted at our center demonstrated that 10 of 30 (33.3%) patients with penetrating abdominal injuries including GSW were successfully treated with NOM.[4]

The success rate of NOM in patients with GSW depends on which solid organ was damaged.[10] Renz et al.[11] reported successful NOM in 13 patients with liver injury due to GSW. Similarly, Demetriades et al.[12] used NOM in 11 patients (7% of the liver injuries in the study) with liver injury caused by GSW. Another study by Demetriades et al.[5] reported that 28.4% of penetrating liver injuries, 3.5% of splenic injuries, and 14.9% of renal injuries were managed non-operatively. Furthermore, Bozdag et al.[13] published their 10 case series with thoracoabdominal GSW which were managed non-operatively, of which five were grade I-II liver injury. Despite many studies demonstrating successful NOM of GSW in adults, few studies have been conducted among pediatric patients.[4] In their multi-centric study, Dicker et al.[14] operated on 106 (80%) of 132 patients aged <19 years with penetrating liver injury (100 GSW and 32 stab wounds) because of the increased incidence of further organ damage alongside liver injury. On the other hand, the success rate of NOM was as high as 95% for kidneys which is a retroperitoneal organ with a rich blood supply.[15] In a previous study from our institution, the success rate of NOM was 89%, even in high-grade renal traumas.[16] There are few studies on the safety of NOM in the case of splenic injury. In a study with 225 patients with penetrating splenic injury, only 24 (10.6%) of them could be managed non-operatively.[17] In another study conducted by Böyük et al.,[18] only 3 (7.5%) of 40 patients treated with NOM had splenic injuries. The most likely reason for the higher rate of operative management in splenic injury is the higher incidence of co-HVI and diaphragmatic perforation.[19] In our study, we were only able to successfully use NOM in one of the three patients with splenic injury; the other two patients underwent splenectomy.

In addition, in our study, the incidence of HVI was considerably higher wit GSW than with blunt and stab trauma. Because GSW entail high kinetic energy which causes more extensive damage that cannot be predicted by imaging modalities, surgeons tend to manage them operatively.[20] Although CT is a commonly used and reliable imaging technique for diagnosing solid organ damage after penetrating injuries, its reliability in diagnosing HVIs is not determined.[21,22] For this reason, it is imperative to monitor hemodynamic parameters and perform serial abdominal examinations during follow-up of patients treated with NOM. If a patient develops symptoms of peritonitis or unexplained abdominal symptoms, diagnostic laparoscopy should be performed. In the literature, studies encouraging the use of NOM of penetrating abdominal trauma reported that patients undergoing surgery following delayed diagnosis of HVI did not develop any serious complications, even after an interval of 24–56 h from the time of injury to surgery.[23,24] A multi-institutional study which supported NOM investigated blunt intestinal trauma in children aged <15 years. In this study, 214 patients with HVI were divided into four groups according to the time elapsed from the time of injury to surgery (<6, 6–12, 12–24, and >24 h). Data did not demonstrate any significant difference in the development of complications or the length of stay at the hospital among the patient groups.[25]

The success rate of NOM is higher for liver and renal injuries than for splenic injuries. Therefore, minimally invasive techniques, such as laparoscopic vascular embolization or splenography, may be preferentially performed over NOM in patients with splenic injury.[26]

Despite diagnostic difficulties, using diagnostic CT to facilitate the decision to operate in cases of GSW is quite safe in patients with hemodynamic instability and signs of peritonitis upon serial abdomen examination. GSW causes surrounding organ damage by dispersing kinetic energy throughout the track of the bullet. In cases where the decision is made to perform NOM, following up closely with serial abdominal examinations is extremely important if the bullet track does not pass intra-abdominally. In our study, one patient who was managed non-operatively exhibited peritonitis upon serial abdominal examination and required surgery. Even though the bullet track was extraperitoneal, the patient exhibited small bowel perforation. Therefore, monitoring even patients with extraperitoneal bullet tracks for signs of HVI is very important. During the follow-up of patients undergoing NOM, adequate observation, serial abdominal examinations and diagnostic laparoscopy are preferable methods for selecting patients who are surgical candidates, avoiding the repeated exposure to ionizing radiation entailed in repeat CT.

Conclusion

NOM is becoming an accepted noninvasive treatment modality for abdominal GSW in the pediatric population, and its popularity is increasing worldwide. The major drawback is the difficulty in diagnosing HVI in abdominal GSW, which usually delays the treatment. Patients with solid organ damage, who are hemodynamically stable, who exhibit no signs of peritonitis upon serial abdominal exam, and have no radiologic signs of HVI on CT may be treated with NOM. Nevertheless, more multi-centric prospective research studies are needed in this area.

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ORİJİNAL ÇALIŞMA - *ÖZET*

Batın ateşli silah yaralanması olan çocuklarda cerrahi ve cerrahi olmayan yaklaşımımız

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AMAÇ: Solid organ yaralanmalarında, bütün dünyada standart tedavi yöntemi "nonoperative management"dır (NOM). Kurşun, trakt boyunca yaydığı yüksek enerjiden dolayı oluşturmuş olduğu doku hasarının derinliği öngörülememekte ve içi boş ogan (İBO) yaralanma sıklığı yüksek olduğundan ateşli silah yaralanması (ASY) ile ilgili bir konsensüs bulunmamaktadır. Bu çalışmada, karın bölgesinde ASY olan hastaların cerrahi ve NOM kriterlerini ortaya koymayı amaçladık.

GEREÇ VE YÖNTEM: Ocak 2010–Nisan 2016 tarihleri arasında karnında ASY olan hastalar geriye dönük olarak analiz edildi. Hemodinamik instabilitesi olan, seri karın muayenelerinde peritonit bulgusu devam eden, karında serbest havası olan grup 1 (n=17) operasyona alındı. NOM ile tedavi edilen olgular ise grup 2 (n=13) idi.

BULGULAR: Grup 1 ile grup 2'yi karşılaştırdığımızda; grup 1'de hemoglobin (Hb) seviyesi ve sistolik kan basıncı istatistiksel olarak düşük iken ($p<0.001$), yoğun bakımda kalış süresi ve ortalama yaralanma şiddet skoru (ISS) ise istatistiksel olarak yüksek idi ($p<0.001$). Ayrıca Grup 1'deki olguların 10'unda kolon perforasyonu, yedisinde ise ince bağırsak perforasyonu saptadık. Grup 2'deki olgularımızın dördünde karaciğer yaralanması, birinde dalak, üçünde ise renal yaralanma var iken, beşinde ise parankimatoz organ yaralanması ve İBO saptamadık.

TARTIŞMA: Karında ASY'lerindeki problem İBO yaralanması tanısındaki zorluklara bağlı olarak tedavinin gecikmesidir. Hemodinamik olarak stabil ve seri karın muayenelerinde peritonit bulgusu olmayan parankimatoz organ yaralanmaları NOM olarak tedavi edilebilinir.

Anahtar sözcükler: Ateşli silah yaralanması; çocuklar; içi boş organ yaralanması; non-operatif takip.

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