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Original Article

Complications and risk factors for mortality in penetrating abdominal firearm injuries: analysis of 120 cases

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Abstract: Due to the high kinetic energy, of bullets and explosive gun particles, their paths through the abdomen (permanent cavity effect), and the blast effect (temporary cavity effect), firearm injuries (FAI) can produce damage not only in the organ they enter, but in the surrounding tissues as well. Since they change route after entering the body they may cause organ damage in locations other than those at the path of entry. For example, as a result of the crushing onto bone tissues, bullet particles or broken bone fragments may cause further damage outside of the path of travel, For these reasons it is very difficult to predict the possible complications from the size of the actual injury in patients with penetrating abdominal firearm injuries. The factors affecting the mortality and morbidity from firearm injuries have been evaluated in various studies. Insufficient blood transfusion, long duration of time until presenting to a hospital and the presence of colon injuries are common factors that cause the high complication rates and mortality. A total of 120 cases injured in the civil war at Turkey's southern neighbouring countries were admitted to our hospital and evaluated in terms of: development of complications and factors affecting mortality; age, gender, time of presentation to the hospital, number of injured organs, the type of injuring weapon, the entrance site of the bullet, the presence of accompanying chest trauma, the amount of administered blood, the penetrating abdominal trauma index (PATI) and the injury severity score (ISS) scores were determined and evaluated retrospectively. The most significant factors for the development of complications and mortality include: accompanying clinical shock, high number of injured organs, numerous blood transfusions administered and accompanying thoracic trauma. It has also been observed that the PATI and ISS scoring systems can be used in predicting the complication and mortality rates in firearm injuries. Consequently, reducing the mortality and complication rates from firearm injuries is still a serious problem. Despite all of these efforts, there is still a need to determine the optimum treatment strategy to achieve this end goal.

Keywords: Firearm injury, penetrating abdominal trauma, complication, morbidity, mortality

Introduction

Due to the high kinetic energy of bullets and explosive gun particles, their paths along abdomen (permanent cavity effect), and the blast effect (temporary cavity effect), firearm injuries (FAI) can produce damage not only in the organ they enter, but in the surrounding tissues as well. Since they change their routes after entering the body, they may cause organ damage in locations away from the path of entry. For these reasons, they still carry high mortality and morbidity rates in spite of the improvements in both diagnosis and treatment [1-3].

As a result of the crushing onto bone tissues during their course inside the abdomen, bullet particles that change direction (primary fragmentation) can produce significant damage. As a result of the bullet's crushing onto the bone tissue, broken bone fragments may also cause organ damage (secondary fragmentation). For these reasons, it is very difficult to predict the possible complications from the size of the actual injury in patients in penetrating abdominal firearm injuries, [1, 4].

The factors affecting the mortality and morbidity from firearm injuries have been evaluated in various studies. Insufficient blood transfusion, the long duration until presenting to a hospital and presence of colon injuries are factors that cause high complication rates and mortality [5, 6]. Elapsed time between the trauma and the presentation greater than 6 hours, presence of shock upon admission to the hospital, surgery lasting more than 6 hours, PATI (penetrating abdominal trauma index) score higher than 25, presence of more than 2 injured intra-abdominal organs, presence of more than 2 extra-abdominally injured organs and administration of multiple blood transfusions are all risk factors that increase the complication rates in penetrating abdominal traumas [1].

A number of scoring systems have been developed over the last several decades to evaluate the severity of trauma and predict the mortality and morbidity of the patient. The penetrating abdominal trauma index (PATI) [1] and injury severity score (ISS) [8] are the two most commonly used scoring systems. However, new studies are needed in order to improve the approach and care of the trauma cases and to predict the possible results [7-9].

In this study, we retrospectively evaluated patients operated for penetrating abdominal firearm injuries, who were brought to our hospital during the conflicts of the civil war in Turkey's southern neighbouring countries. We aimed to determine the factors related to morbidity and mortality, and to determine the threshold values and the predictive powers of PATI and ISS scoring systems.

Material and methods

A total of 120 patients over 15 years of age were admitted to our hospital between February 2012 and February 2014 for high kinetic energy firearm injuries. Those who were unsuitable for conservative follow-up and in whom intra-abdominal organ injury had been detected were included in the study. Patients with negative laparotomy, cases followed non-operatively and cases with severe head injury were excluded from the study. The cases were evaluated in terms of: development of complications and factors affecting mortality; age, gender, time of presentation to the hospital, number of injured organs, the type of the injuring weapon, the entrance site of the bullet, the presence of accompanying chest trauma, and the amount of administered blood transfusion. In addition, PATI and the ISS scores were determined and evaluated retrospectively.

The general status of the cases was evaluated upon admission to the emergency unit with a rapid multi-disciplinary approach. An intravenous route was established following determination of the vital signs and having performed a detailed physical examination, and blood samples were obtained for both laboratory examinations and blood group determination. Digital rectal examinations and urethral Foley catheterization were performed on all cases. In addition, cases were monitored by prophylactic tetanus vaccination and antibiotic combination (1^{st} generation cephalosporin, metronidazole and aminoglycosides) administered by intravenous isotonic solution. Cases that were hemodynamically unstable, those with systolic blood pressure of lower than 90 mmHg and pulse rate higher than 100/minute, cases with evisceration or peritonitis symptoms, and cases when the hemodynamics deteriorated during examination under emergency conditions or in whom peritonitis had developed, were taken for emergency laparotomy. Computerized tomography, X-rays and ultrasonography were used to assistant radiological investigations and localization of the injured sites and organs to understand the course of injury and decision for surgery.

When defining the gunshot entrance site, the site between the neck and the nipples were defined as the anterior thorax, the site between the inferior scapula corners and the cervical region as the posterior thorax at the lateral mid-axillary lines, and the inferior was detrmined by taking the line between the anterior superior iliac spines as the base was expressed as: right upper quadrant-right lower quadrant, left upper quadrant-left lower quadrant. The site outside the posterior thorax and both inferior scapula corners, the cristae iliaca and between the mid axillary lines was referred to as the posterior abdomen.

Statistical analysis

Statistical analysis of the data was performed using the SPSS 15.0 for Windows package program with 95% confidence interval. The Pearson Chi Square test was used for the intergroup comparisons of the categorical data, and

Table 1. Comparison between patients with and without complication development after admission

		Complication		p Value*
		Yes	No	
Duration of hospital stay (day)		13.36 ± 14.98	12.43 ± 8.63	0.252*
Elapsed time until surgery (minute)		215.14 ± 376.05	306.27 ± 716.33	0.777*
Blood transfusions (unit)		6.24 ± 2.93	3.51 ± 2.85	0.000*
ISS score		32.12 ± 19.61	16.51 ± 13.95	0.000*
PATI score		15.54 ± 5.6	9.16 ± 4.25	0.000*
Number of injured organs (total organs)		2.77 ± 1.11	2.1 ± 1.12	0.001*
Presence of shock	Yes	11 (21.6%)	44 (63.8%)	0.000**
	No	40 (78.4%)	25 (36.2%)	
Blood transfusions (unit)	Applied	39 (76.5%)	67 (97.1%)	0.001**
	Non applied	12 (23.5%)	2 (2.9%)	
Type of weapon injuries	Bullet	28 (54.9%)	44 (63.8%)	0.327**
	Shrapnel	23 (45.1%)	25 (36.2%)	
Ostomy	Yes	19 (79.2%)	20 (76.9%)	0.848**
	No	5 (20.8%)	6 (23.1%)	
Thorax injury	Yes	8 (15.7%)	22 (31.9%)	0.043**
	No	43 (84.3%)	47 (68.1%)	

* = Mann Whitney U test; **Pearson Chi Square test; SD = Standard deviation; PATI = Penetrating abdominal trauma index; ISS = Iinjury severity score. Results are given as mean ± SD or n (%) whatever needed.

the (Kolmogorov-Smirnov P < 0.05) Mann Whitney U test was used for the intergroup comparisons of continuous variables, since the data were not suitable for normal distribution. For complications and mortality, the cut-off values of the given blood, ISS and PATI scores were determined using the ROC (receiver operator characteristics curve) analysis. Stepwise binary logistic regression analysis was used to identify the independent risk factors in our study groups. Multivariate baseline differences were ascertained after a Forward-Stepwise Logistic Regression of all the baseline variables. A *P* value of < 0.05 was accepted as statistically significant.

Results

A total of 120 cases between the ages of 15-63 years (mean age: 28 years), 5 females (4.1%) and 115 males (95.8%) were evaluated. In cases in which complications had developed, the number of blood transfusions, the ISS score, the PATI score and the number of injured organs were found to be significantly higher than those in the non-complication cases (**Table 1**). There was no significant difference between those developing complications and those not developing complications in terms of the duration of hospital stay and the elapsed time until surgery (**Table 1**).

The mortality rate of our series was determined as 39% (n = 47). The elapsed time until the surgery, the number of administered blood transfusions, the ISS scores, the PATI scores and the number of injured organs in cases that died were significantly higher than those in cases that survived (**Table 2**).

The rate of complication and mortality in cases with a clinical picture of shock or accompanying thoracic injuries were statistically significantly higher (P < 0.05). There was no significant effect on the morbidity and mortality from the type of injuring weapon, the entrance and exit sites of the bullet, and whether ostomy was opened or not during surgery (**Tables 1** and **2**).

There was no statistically significant difference determined between the groups from the complication rate and survival rate distribution (P > 0.05).

The cut-off values we determined in cases developing complications in our series were as follows: 4.5 for the number of administered blood units (AUC (Area under Curve):0.767 P: 0.001 95% CI (Confidence Interval): 0.667-

Table 2. Comparison between patients who survived and died

		Result		*p* Value*
		Survive	Dead	
Duration of hospital stay (day)		17.47 ± 13.33	5.98 ± 7.28	0.000
Elapsed time until surgery (minute)		234.04 ± 590.86	284.68 ± 473.33	0.008
Blood transfusions (unit)		4.02 ± 2.76	6.89 ± 2.97	0.000
ISS score		13.9 ± 5.04	43.47 ± 18.77	0.000
PATI score		9.04 ± 3.39	18.7 ± 3.99	0.000
Number of injured organs		2.27 ± 1.15	2.81 ± 1.12	0.008
Presence of shock	Yes	20 (27.4%)	35 (74.5%)	0.000
	No	53 (72.6%)	12 (25.5%)	
Blood transfusions (unit)	Applied	61 (83.6%)	45 (95.7%)	0.042
	Non applied	12 (16.4%)	2 (4.3%)	
Type of weapon injuries	Bullet	42 (57.5%)	30 (63.8%)	0.492
	Shrapnel	31 (42.5%)	17 (36.2%)	
Ostomy	Yes	27 (79.4%)	12 (75%)	0.728
	No	7 (20.6%)	4 (25%)	
Thorax injury	Yes	11 (15.1%)	19 (40.4%)	0.002
	No	62 (84.9%)	28 (59.6%)	
Complication	Yes	26 (35.6%)	43 (91.5%)	0.000
	No	47 (64.4%)	4 (8.5%)	

* = Mann Whitney U test; **Pearson Chi Square test; SD = Standard deviation; PATI = Penetrating abdominal trauma index; ISS = Iinjury severity score. Results are given as mean ± SD or n (%) whatever needed.

Table 3. Cut-off values (ROC analysis) in cases in which complications had developed and died

	Complication			Dead		
	Value	Sensitivity	Specificity	Value	Sensitivity	Specificity
Blood transfusions (unit)	3.50	0.79	0.62	4.50	0.78	0.62
	4.50	0.72	0.74	5.50	0.71	0.74
	5.50	0.58	0.77	6.50	0.58	0.82
ISS scores	21	0.61	0.82	21	0.93	0.90
	23.50	0.61	0.87	23.50	0.93	0.93
	27.0	0.43	0.92	27.0	0.71	1.00
PATI scores	13.50	0.66	0.90	13.50	0.96	0.92
	14.50	0.66	0.92	14.50	0.96	0.93
	15.50	0.54	0.92	15.50	0.80	0.95

ROC = Receiver operator characteristics; PATI = Penetrating abdominal trauma index; ISS = Injury severity score.

0.866), 23.5 for the ISS score (AUC: 0.768 P: 0.001 95% CI: 0.672-0.864) and 14.5 for the PATI score (AUC: 0.804 P: 0.001 95% CI: 0.716-0.892) (**Table 3**).

The cut-off values for the development of mortality were determined as: 5.5 for the number of administered blood units (AUC: 0.766 P: 0.001 95% CI: 0.674-0.858), 23.5 for the ISS (AUC: 0.973 P: 0.001 95% CI: 0.946-1.000) and 14.5 for the PATI score (AUC: 0.967 P: 0.001 95% CI: 0.935-0.999) (**Table 3**).

The number of injured organs and the distribution of the complications are presented in **Tables 4** and **5**, respectively.

Logistic regression (independent variable could be with or without complication, and survival or death) was performed to find the risk factors for both complication development and survival. Correlations between continuous variables were determined nonparametrically using Spearman's rho (**Table 6**). Variables showing significant correlation with complication were

Table 4. Distribution of injured organs

Injured organs	Number of cases (%)
Small bowel	58 (48%)
Colon	50 (41.6%)
Stomach	13 (10.8%)
Liver	37 (37.8%)
Splien	12 (10%)
Pancreas	2 (1.6%)
Bladder	5 (4%)
Kidney	19 (15.8%)
Lung	23 (19.1)
Diaphragm	22 (18.3)
Major vessels	13 (10.8%)
Others	18 (15%)

Table 5. Distribution of complications

Complications	Number of cases (%)
Intraabdominal absess	6 (8%)
Leakage of anastomosis	2 (2.8%)
Bile fistula	13 (18.8%)
Wound infection	15 (21.7%)
Sepsis, septic shock	15 (21.7%)
Lung infections, acute respiratory distress syndrome	14 (20.2%)
Intraabdominal brid	3 (4.3%)
Evisseration/evantration	6 (8.6%)
Abdominal compartment syndrome	5 (7.2%)

presence of shock, PATI and ISS. Variables showing significant correlation with survival were presence of complication, time until surgery, presence of shock, PATI and ISS.

Multiple logistic regression analysis was used to explore determinants of complication development and survival (**Tables 7** and **8**). The overall significance of the model for development of complications was < 0.001 with the percentage of correctly predicted outcomes of 75%. Accordingly, it was found that 1) Risk of complication development ratio was 2.5 times (1.00/0.38) lower if shock was not present; 2) Complication development ratio was positively correlated with the rise in PATI; 3) The change in ISS was not correlated with the risk of complication development (**Table 7**). The overall significance of the model for survival was < 0.001 with the percentage of correctly predicted outcomes of 95%. Accordingly, it was found that 1) Risk of death in the presence of complication is quite high; 2) There is no significant impact of the time until surgery on the risk of death; 3) The risk of death was significantly lower in absence of shock; 4) The risk of death increases when PATI increases; 5) The risk of death increases when ISS increases (**Table 8**).

Discussion

Firearm injury, which is a type of high kinetic energy injury, is generally classified as high or low speed [10, 11]. Those below 600 meters per second (m/s) are low-speed and generally are civil injuries caused by firearms such as pistols. Firearms with an output speed of higher than 600 meters are high-speed weapons and in general are military or hunting weapons. High speed weapons are more effective than low speed weapons and their damaging powers are high [10, 11]. Generally, there is a common consensus on performing laparotomy in penetrating abdominal gunshot injuries with evisceration, hemodynamic instability and abdominal peritonitis symptoms [12, 13]. In the past, although all firearm injury cases underwent surgery, non-operative monitoring of selected penetrating firearm injuries, which are hemodynamically stable and without peritonitis, has recently gained importance [14-17]. It has been reported that the complication rates may increase up to 41% in negative laparotomies [18]. Twelve cases had been treated non-operatively during the time period in which we evaluated the cases (February 2012- February 2014); furthermore, negative laparotomies had been performed on 10 cases (7%).

There are several classifications used for to predict the trauma severity in firearm injuries. In a review conducted by Tohira et al. [7], there is no single test that is superior and no new classification that combines these classifications. Although the prediction of the PATI scoring for mortality and morbidity is high when over 25 [1], some authors set this value at 15 [5]. Although there is no clear value for the ISS score, it has been reported that as the value increases, its predictability also increases [19].

Table 6. Correlations determined non-parametrically between continuous variables

		Complication	Survival	Gender	Age	Type of weapon	Time until surgery	Presence of shock	PATI	ISS
Complication	Correlation Coefficient	1.000	.552**	-.074	-.084	.089	.026	.419**	.548**	.511**
	Sig. (2-tailed)		.000	.423	.364	.331	.779	.000	.000	.000
	n	120	120	120	120	120	120	120	120	120
Survival	Correlation Coefficient	.552**	1.000	.004	-.011	.063	.243**	.461**	.801**	.817**
	Sig. (2-tailed)	.000		.969	.904	.496	.007	.000	.000	.000
	n	120	120	120	120	120	120	120	120	120

** = Correlation is significant at the 0.01 level (2-tailed); * = Correlation is significant at the 0.05 level (2-tailed); PATI = Penetrating abdominal trauma index; ISS = Injury severity score.

Table 7. Multiple logistic regression analysis used to explore determinants of complication development

Variable	Wald value	*p* Value	Odds Ratio	95% CI
Presence of shock	3.77	0.05	0.38	0.14-1.01
PATI	9.27	0.00	1.24	1.08-1.43
ISS	0.00	0.99	1.00	0.96-1.04

CI = Confidence interval; PATI = Penetrating abdominal trauma index; ISS = Injury severity score.

Table 8. Multiple logistic regression analysis used to explore determinants of survival

Variable	Wald value	*p* Value	Odds Ratio	95% CI
Complication	2.53	0.11	0.02	0.00-2.50
Time until surgery	4.4	0.04	1.00	1.00-1.01
Presence of shock	1.93	0.16	0.09	0.00-2.64
PATI	4.22	0.04	1.78	1.03-3.08
ISS	4.56	0.03	1.50	1.03-2.19

CI = Confidence interval; PATI = Penetrating abdominal trauma index; ISS = Injury severity score.

Norouzi et al. [20], found that an ISS score of over 25 is directly related to mortality. In our study, it was observed that a PATI score greater than 14.5 and the ISS score value higher than 23.5 are independently effective at predicting morbidity and mortality.

The presence of shock, as our study supports, is a parameter which is known to increase morbidity and mortality rates [21]. The relationship between the number of blood transfusions and the development of complications and mortality is known, as the number of blood transfusion increases the risk of developing complications and the mortality increases [22]. In our study, only 14 patients required blood transfusion (11.6%). Parallel to the literature, in our results, an increase in the number of blood transfusion significantly increased both the development of complications and the mortality ($P < 0.05$). We do not suggest that number of blood transfusion effectively predicts morbidity and mortality, since a high number of blood transfusions may indicate that the patient is in shock however, the question of whether or not the same result can be obtained by administering other fluids instead of blood or together with blood may be raised. Large-scale case series and studies with concrete evidence are necessary to answer this question.

Both bullets and shrapnel injuries have high kinetic energy. However, the speed and severity of shrapnel may be variable. High-speed kinetic energy has a more damaging effect. In a study evaluating the relationship between bullet injuries or shrapnel injuries and complications and mortality, injuries with bullets were related to higher complication rates and mortality than shrapnel injuries [23]. However, in our study, we did not detect any significant difference for the complication and mortality rates between bullet or shrapnel particle injuries.

In firearm injuries, there is a 6-42% rate of associated thoracic and abdominal injuries [24]. In general, many thoracic injuries can be monitored and treated non-operatively with chest tube application [10]. In our study, there was simultaneous thoracic injury with abdominal injury in 25% (n = 30) of the cases and while chest tube was applied to all cases, only 4 cases underwent a surgical procedure with thoracotomy.

It has been mentioned in various literatures that the morbidity and mortality rates of firearm injuries are variable between 3-31.4% and 7-46%, respectively [25, 1]. Different from the literature, our study had high complication and mortality rates. Exclusion of negative laparotomies and non-operatively followed-up cases from the study increased the numerical values of complication and mortality rates. Apart from this, the main factors for our high rates were the presence of two and more organ injuries in 79% of the cases, the presence of shock in 46% of the cases, accompanying thoracic injury in 30 cases, and all cases having been injured by high kinetic energy gunshots. Furthermore, we suggest that due to the fact that the injuries had occurred outside the borders of our country, there were transportation challenges and lack of professional first aid teams in the conflict-ridden areas, and hence, the necessary first aid and resuscitations had not been provided.

In large bowel firearm injuries, there is a tendency to avoid colostomy in appropriate cases and performing primary repair or anastomosis instead. It has been advocated that 66-100% of the cases can be treated without colostomy [26]. In our series, due to the fact that the decision for colostomy was made according to intra-abdominal uncleanliness, the presence of additional organ injury and presence of shock, most of the 50 cases with colon injury were treated with colostomy. However, when compared with primary repair or cases in which anastomosis was performed, the type of colon injury was not predictive of the complication and mortality. Our study determined that the elapsed time until the hospital admission was not an effective predictor of the development of complication and mortality. However, besides the publications in the literature concluding that the time to presentation is effective [27], there are also studies that have reported the time to admission to be an ineffective predictor [1, 25]. According to our observations, the mortality rate is high in cases in which the elapsed time between the event and hospital admission is long, and in cases in which septic symptoms are detected. However, we did not determine a statistical analysis that would support this observation in our series. Better understanding of this issue may be possible with larger series, prospective studies and meta-analyses.

It has been stated in the literature that the most common intra-abdominal injury is small intestinal injury, followed by the large bowel and the liver [28]. When the injury rates in our series are considered, correlation has been observed between the small bowel, colon and liver in decreasing rates of incidence, and this is compatible with the literature [28].

The entrance site of the firearm injuries is one of the investigated issues. In the study conducted by Starling et al., it has been stated that the number of organs that require surgical treatment is high in right thoraco-abdominal firearm injuries, and for this reason, laparotomy is a safe procedure, and that physical examination is not reliable as mortalities and morbidities increase after delayed laparotomies [29]. In the study by Demetriades et al., major injuries were detected in 75% of penetrating anterior abdominal firearm injury cases; however, 30% of these could be successfully treated non-operatively [30]. Velhamos et al. emphasized that severe intra-abdominal organ injuries in posterior abdominal firearm injuries are less common than the anterior entry injuries, and that physical examination is more sensitive and specific than anterior injuries. They treated posterior abdomen injury non-operatively in 60% of their cases [31]. In our study, no relationship was determined between the site of the entry on the body, injuries occurring with bullets, and whether the bullet exited or not with development of complication and mortality. When logistic regression was performed to find the risk factors for both complication development and survival, the presence of shock and the PATI and ISS scores showed significant correlation with complication development; while presence of complication, time until surgery, presence of shock, PATI and ISS showed significant correlation with survival.

In firearm injuries, which still have high mortality and morbidity despite all of these efforts, time is required for determination of the optimum treatment strategy and decreasing these high morbidity and mortality rates.

Consequently, reducing the mortality and complication rates in firearm injuries is still a serious problem, along with the parallel development of the arms industry while medicine is developing. The most important factors for development of complication and mortality include: accompanying clinical picture of shock, high number of injured organs, numerous blood transfusions administered and accompanying thoracic trauma. It has also been observed that the PATI and ISS scoring systems can be used in predicting the complication and mortality rates in firearm injuries.

Disclosure of conflict of interest

None.

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