

Penetrating cardiac trauma in children

Çocuklarda penetran kalp yaralanmaları

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BACKGROUND

Penetrating cardiac traumas in children are dramatic and fatal. Many of the patients are admitted to hospital either in a state of shock or they are dead at presentation. In this study, we aimed to present our experience in penetrating cardiac trauma in children.

METHODS

Seventeen pediatric cases of penetrating cardiac trauma were retrospectively evaluated. The effects on the results of the demographic characteristics of patients, etiology of penetrating trauma, time of presentation to the hospital, physical examination findings in the emergency department, diagnostic methods used, and the surgical techniques applied were evaluated.

RESULTS

The male to female ratio of the 17 retrospectively evaluated cases was 16:1, with an age range of 3-15 years. The patients' mean age was 12.94±3.52 years. In all patients, the penetrating cardiac trauma was due to incisive/penetrating tools. The mean Ivatury physiologic index score was 8.23±0.78, whereas the mean cardiac injury organ scale score was 5.00±0.00. The hospital mortality rate was 5.9% due to the loss of one patient.

CONCLUSION

Shock may develop in pediatric penetrating cardiac trauma in a short time due to hemorrhage and/or cardiac tamponade. The prime factors for patient survival are early diagnosis and emergency thoracotomy.

Key Words: Cardiac injuries; emergency room thoracotomy; pediatric thoracic trauma; Ivatury physiologic index score; ketamine.

AMAÇ

Çocuklarda penetran kalp yaralanmaları dramatik ve ölümcül travmalardır. Birçok olgu, hastaneye ciddi şokta veya hayatını kaybetmiş olarak ulaşır. Bu çalışmamızda penetran kalp yaralanması olan çocuk hastalarımızla ilgili deneyimimizi aktarmayı amaçladık.

GEREÇ VE YÖNTEM

Penetran kalp yaralanmalı 17 çocuk hasta geriye dönük olarak incelendi. Hastaların demografik karakterleri, yaralanmanın nedenleri, hastaneye geliş zamanı, acil servis inceleme bulguları, kullanılan tanı yöntemleri ve uygulanan cerrahi yöntemlerin sonuçlar üzerine etkisi incelendi.

BULGULAR

Geriye dönük analizleri yapılan 17 hastanın erkek-kadın oranı 16:1, yaş aralığı 3-15 yaş, ortalama 12,94±3,52 yaş idi. Tüm hastalarda yaralanma nedeni kesici delici alet yaralanması olarak tespit edildi. Ivatury fizyolojik indeks skoru 8,23±0,78 iken ortalama kardiyak yaralanma organ ölçüğü skoru 5,00±0,00 olarak bulundu. Bir olgu ile hastane mortalitesi %5,9 olarak tespit edildi.

SONUÇ

Çocuklarda penetran kardiyak yaralanmalarda kanama ve/veya tamponad nedeniyle çok kısa sürede şok gelişebilir. Erken tanı ve acil torakotomi yaralanma sonrası hastaların hayatta kalmasında temel faktörlerdir.

Anahtar Sözcükler: Kalp yaralanması; acil servis torakotomisi; çocuk toraks travması; Ivatury fizyolojik indeks skoru; ketamin.

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Penetrating cardiac traumas among children are relatively rare, and the information in the literature is insufficient. When the published case series are reviewed, it is observed that cardiac traumas in the pediatric age range are primarily due to accidents and are commonly blunt traumas. Furthermore, cardiac traumas among children due to guns have been on the rise in the United States in recent years.^[1,2]

This study discusses the effects of the etiology of the trauma, the state of presentation in the emergency department, trauma scores, and the treatment approaches on the morbidity and mortality of children with penetrating cardiac trauma treated in our clinic.

MATERIALS AND METHODS

This study retrospectively analyzed penetrating cardiac traumas treated in our clinic. The group consisted of 17 consecutive pediatric patients with penetrating cardiac trauma treated at our University Medical Faculty Hospital between January 1977 and June 2006.

The patients who underwent trauma to topographical anatomic areas, possibly leading to cardiac trauma, and with presenting signs and symptoms of shock or tamponade were admitted urgently to the operating room. They underwent surgery on an emergency basis, primarily with anterior thoracotomy and with anterolateral thoracotomy if needed, depending on the localization of the trauma. Fluid and blood infusions were administered to the patients susceptible to shock to provide a preoperative systolic pressure of more than 80 mmHg. In those patients who were hemodynamically

stable, the diagnoses were ascertained with chest X-rays and echocardiography.

All of the surgical operations were conducted under general anesthesia with ketamine. Depending on the localization of the trauma, anterior thoracotomy between the 4th and 5th intercostal spaces was preferred for the surgical approach. Thoracotomy was continued to the lateral area in required cases. No subxiphoid drainage or pericardiocentesis was applied for diagnosis or treatment in any patient. In patients with active bleeding at this point during the operation, digital pressure to the cardiac trauma site was applied to control the bleeding, and fluid and blood replacement was given rapidly to maintain hemodynamic stability. While repairing the cardiac trauma, the "U" suture technique with 3/0 monofilament polypropylene suture material with a Teflon or pericardial pledget was preferred. Any trauma to the other organs accompanying the cardiac trauma was repaired.

In the statistical analyses, frequencies, means and standard deviations were used for the presentation of continuous variables, while a chi-square test was used to compare factors affecting mortality. A value of $p < 0.05$ was considered significant.

RESULTS

Of all the patients operated due to cardiac trauma in our clinic, 16.8% were children with penetrating cardiac trauma. The male to female ratio of the 17 retrospectively evaluated cases was 16:1, with an age range of 3-15 years. The patients' mean age was 12.94 ± 3.52 years. In all of the cases, the penetrating cardiac trauma was due to incisive/penetrating tools. The mean Ivatury physiologic index score (IPIS) was 8.23 ± 3.92 , whereas the mean cardiac injury organ scale score was 5.00 ± 0.00 (Table 1).^[3,4] The mean duration for transport to the hospital was 40.26 ± 31.29 minutes (min) if two of the cases were excluded from the analysis (Case 1: 8 hours, Case 2: 1 week). All of the patients were admitted for surgery within 30 min of their presentation. The length of the route between the emergency department and the operating room in our hospital is 15 meters, and six of the patients (35.3%) underwent thoracotomy in the emergency department.

At the initial physical examination conducted in the emergency department, six patients (35.3%) were in a state of shock, six (35.3%) were hypotensive and two (11.8%) displayed signs of tamponade. Three patients (17.6%) were found to be normal in the physical examination. When cardiac rhythm was evaluated, 16 of the patients (94.1%) displayed a sinus rhythm while one had ventricular fibrillation. Six patients (35.3%) required echocardiography as an additional method of diagnosis.

Table 1. Etiology of trauma, the state of presentation in the emergency department and trauma scores

Case	IPIS	CIOS	AT (min)	DM	T&H	HTX
1	5	5	40	ECE	+	+
2 (ex)	20	5	35	ERT	-	+
3	10	5	25	ERT	-	-
4	5	5	40	CFF	+	-
5	10	5	25	ERT	-	+
6	5	5	30	ECE	+	-
7	5	5	1 week	ECE	+	-
8	10	5	8 hours	CFF	-	-
9	5	5	44	ECE	+	-
10	10	5	25	CFF	+	-
11	5	5	35	ERT	+	-
12	5	5	30	ECE	+	-
13	5	5	150	ECE	+	-
14	10	5	45	ERT	+	+
15	10	5	25	ERT	+	+
16	10	5	20	CFF	+	+
17	10	5	35	CFF	-	+

IPIS: Ivatury physiological index score; CIOS: Cardiac injury organ scale; AT: Arrival time; DM: Diagnostic method; T&H: Tamponade & hematoma; HTX: Hemothorax; ECE: Echocardiography examination; ERT: Emergency room thoracotomy; CFF: Clinical findings on follow-up.

With regard to the surgical approach, 15 patients (88.2%) underwent left thoracotomy, while one required bilateral and one required right thoracotomy. In 10 of the patients (58.8%) who underwent thoracotomy, anterior thoracotomy was sufficient for surgical view and repair, while in the remainder, thoracotomy had to be carried out laterally.

None of the patients required cardiopulmonary bypass surgery. Cardiac damage was limited to the right ventricle in 11 cases (64.7%), while in six cases (35.3%), there was left ventricular damage. The mean length of cardiac damage was 1.05 ± 0.5 cm (0.5-2). Hemothorax was observed in seven patients (41.2%), while dense hematoma inside the pericardium was observed in 12 (70.6%).

Fourteen patients (82.4%) had isolated cardiac trauma, whereas three (17.6%) had trauma to other organs accompanying the heart. Two of these patients (11.8%) had damage to the lungs, whereas left and right internal mammary artery (LIMA+RIMA) damage was observed in one patient. No damage to the coronary arteries was observed in any of the patients.

Four patients (23.5%) developed atelectasis of the left lower lobe and two developed left pleural effusion during the postoperative period. One patient had to be reoperated during the postoperative period due to hemorrhage. The hospital mortality rate was found to be 5.9%, with one case. The death of this patient was caused by prolonged shock and hypoxic edema of the brain.

The age, sex, duration of presentation to the hospital, and accompanying trauma status of the patients had no statistically significant effect on mortality. However, the localization of the trauma differed significantly with the state of presentation ($X^2=10.43$, $DF=3$, $p=0.015$). The IPIS was more effective in determining the prognosis than the cardiac injury organ scale. The mortality was higher in patients with a lower Ivatury score ($X^2=17.00$, $DF=2$, $p=0.000$), whereas the difference between the IPIS and the length of myocardial damage was significant ($X^2=12.69$, $DF=6$, $p=0.048$). No significant difference was found between the localization of trauma in the patients and the presence of hemothorax and length of myocardial damage. Accompanying traumas differed significantly with the state of initial presentation ($X^2=18.82$, $DF=6$, $p=0.004$). The cardiac rhythm of the patients at presentation was significantly related with mortality ($X^2=17.00$, $DF=1$, $p=0.000$). In addition, the difference between the length of damage and emergency room thoracotomy (ERT) and other diagnostic procedures was significant ($X^2=12.57$, $DF=6$, $p=0.030$).

DISCUSSION

It is a race against time to save children who suffer penetrating cardiac trauma. Although this area is

anatomically well protected, doctors are faced with this kind of trauma in ever-increasing frequencies due to the increase in violence in society and the developments in first aid prior to hospitalization and in transport of the patients to the hospital. Delay in the diagnosis or treatment of these patients may lead to irreversible consequences.^[2,5]

Many studies show that a rapid and effective approach leads to an increase in survival rates. Articulated alternatively, unless hemorrhage is limited, death is inevitable in penetrating cardiac traumas. The existence of tamponade plays an important role in limiting the hemorrhage and allowing patients to reach the hospital. Tamponade limits hemorrhage in damage to the right ventricle. If damage to the heart is limited to only one chamber and there is no pleural wound, tamponade can keep the patient alive.^[1] On the other hand, tamponade after trauma leads to an increase in intrapericardial pressure, hindering cardiac filling. This leads to a decrease in cardiac output volume. The increase in ventricular filling pressure leads to coronary hypoperfusion, culminating in cardiac arrest. These statements show that the protective effect of tamponade is limited and related to time.^[6] Although Asensio and colleagues^[7] and Buchman and colleagues^[8] reported that the presence of tamponade does not affect mortality, Moreno and colleagues^[9] emphasized its role as a determining factor. We observed signs of tamponade in 11.8% of our patients clinically, whereas we detected a dense hematoma inside the pericardium in 70.6% during the operation. However, we did not detect a statistically significant relation between the presence of tamponade and/or dense hematoma and mortality. Regarding these findings, it can be argued that, because the duration to reach the hospital and undergo surgery in our presented cases was short and mortality was low, the presence of tamponade in patients with cardiac trauma may have increased survival rates depending on time. Furthermore, the presence of tamponade is difficult to detect in children. Therefore, we think that the presenting situation of the patient is the prime determinant for choosing the diagnostic method. Patients with signs of shock or tamponade should be operated on promptly without further evaluation ($p=0.040$).

Continuing hemorrhage between the time of trauma and that of arrival at hospital damages the physiological compensation mechanisms of patients. The most important cause of anatomically uncontrollable bleeding in these patients due to pleural or diaphragmatic ruptures is bleeding into the thoracic and/or abdominal space.^[10] Although we did not detect a statistically significant relationship with localization of trauma and hemothorax, we noted the presence of hemothorax in 41.2% of patients retrospectively analyzed. Of these

patients, 66.6% displayed damage to the left ventricle. All patients with hemothorax were in a state of shock and were hypotensive.

Another factor affecting whether the patients reached the hospital alive was the presence of hypotension due to hypovolemia. Hypotension may allow time for the formation of clots and spontaneously limit the hemorrhaging. Aggressive replacement of fluids may increase filling pressure temporarily and overcome tamponade. However, overzealous replacement of fluids may lead to secondary hemorrhages by displacement of the clot due to increased intracardiac pressure.^[1,11] Because of these consequences, we avoided excessive fluid replacement in our patients who were prone to develop shock, and instead infused fluid and blood were used to keep the preoperative systolic blood pressure over 80 mmHg.

Among the cases analyzed retrospectively, patients with damage to the right ventricle displayed signs of shock and tamponade generally, whereas in those with damage to the left ventricle, hypotension predominated. Moreover, patients with accompanying damage displayed more signs of shock and tamponade, whereas patients without accompanying trauma displayed either hypotension or normotension. However, no statistically significant relation was found between accompanying trauma and development of complications. Patients with a higher IPIS displayed more signs of tamponade ($p=0.025$) and required more additional diagnostic procedures ($p=0.019$). This leads to the conclusion that more time was spent in the analysis of patients with a higher IPIS. However, IPIS decreases with lengthier damage to the myocardium. As the length of myocardial damage increases, the rates of ERT and mortality increase as well ($p=0.047$).

There is no consensus regarding the surgical approach for the repair of penetrating cardiac trauma. Some authors prefer sternotomy due to the better surgical view, while many prefer to approach the site of damage via anterolateral thoracotomy.^[6,11] While both surgical approaches have their own merits and drawbacks, we primarily preferred anterior thoracotomy as the surgical approach in our patients with penetrating cardiac trauma. Thoracotomy was carried out laterally if there was a need for better visualization. Anterior thoracotomy alone was used to manage 58.8% of patients. No additional complications developed because of the choice of this surgical approach.

Anesthesia with ketamine in patients with cardiac trauma not only increases cardiac output, it also increases preload by increasing the tonus of veins.^[2] Therefore, in our clinic, we prefer to use ketamine for anesthesia in patients with penetrating cardiac trauma. Ketamine has the unwanted side effects of hallucina-

tions when used as an anesthetic, and this may also add to the considerable need for psychological support of the child and the family after the operation. However, these side effects were not observed in our case series.

In their prospective study, Asensio and colleagues^[7] showed that the existence of sinus rhythm at initial presentation to the hospital in patients with cardiac trauma increases the chance of survival. In our case series, we also found that preoperative dysrhythmia affected mortality ($p=0.000$).

Some authors recommend preoperative pericardiocentesis. However, this procedure may lead to false-negative results due to the formation of clots as well as to recurrent hemorrhages via decompression. This procedure also carries the risk of iatrogenic cardiac trauma in children. An average-sized pericardial tamponade stops the hemorrhage, and the risk of cardiac arrest is relatively decreased in these patients. Tube drainage of the thorax should also be avoided for similar reasons and because of its propensity to remove clots, leading to fatal hemorrhages.^[11] This procedure also leads to loss of time. For all of these reasons, none of our patients underwent perioperative pericardiocentesis, subxiphoid drainage or tube drainage of the thorax.

As a result, it can be concluded that rapid transport and surgery proved life-saving in our series of children with penetrating cardiac trauma. The presence of tamponade was an important factor in the survival of traumatized patients, whereas the presence of shock and/or poor vital signs and the cardiac rhythm in patients at the initial presentation determined increased mortality. Therefore, it may be prudent to promptly operate on patients displaying signs of shock and tamponade without applying additional diagnostic methods. As the length of myocardial wound increases, the rates of ERT and mortality also increase. We think that massive preoperative fluid replacement should be avoided in patients with penetrating cardiac trauma unless absolutely indicated. Furthermore, anterior thoracotomy should be primarily preferred among the surgical techniques, and preoperative pericardiocentesis should not be applied in these patients. In pediatric patients with penetrating cardiac trauma, we prefer to use ketamine for anesthesia.

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