



Penetrating Chest Wounds: 24 Years Experience

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Abstract. Thoracic and thoracoabdominal penetrating wounds are frequently encountered in urban medical centers in the United States. This study was undertaken to determine the clinical characteristics and in-hospital outcome of these injuries. This was a longitudinal, nonblinded study using the established standard of care of patients with penetrating chest trauma. It consists of an analysis of a consecutive series of 3049 patients treated at one trauma center between April 1972 and March 1996. There were 1347 stab wounds and 1702 gunshot wounds. Antibiotic prophylaxis was administered to patients who underwent laparotomy or thoracotomy or who had lung contusion with hemoptysis (41.6%, 1296/3049). Of 3049 patients, 196 had cardiac injuries. All of them underwent thoracotomy, and the mortality was 21.9%. In contrast, among 2853 patients without cardiac injuries, only 257 (9%) required thoracotomy; the mortality in this group was 1.5%. Patients with thoracoabdominal injuries (899/3049) had a mortality of 4.3% compared to 2.1% among those who had isolated chest injuries. The overall mortality was 2.8%. Of 1702 patients with gunshot wounds, 85 (5%) sustained transaxial injuries, with an overall mortality of 36.5%. The complication rate among the survivors was 6% with only 2.5% being infectious. We conclude that the mortality for noncardiac penetrating injuries of the chest is low. The presence of associated abdominal injuries increases the mortality twofold. More than one-third of the patients with transaxial wounds die. Gunshot wounds of the heart result in higher mortality than stab wounds to the heart. The infection rate is low.

Penetrating wounds of the thorax and thoracoabdominal areas are frequently encountered in urban medical centers in the United States. In civilian practice, such wounds are most often the result of injury with guns, knives, or other sharp objects. King-Drew Medical Center serves the urban population of South Central Los Angeles. In this article we have reviewed our experience with penetrating thoracic and thoracoabdominal injuries to evaluate our cumulative results with the management of these patients over the past 24 years.

Materials and Methods

Between April 1972 and March 1996 a total of 3049 patients were treated at the King-Drew Medical Center. Patients who were not hospitalized were excluded. At our institution all patients who required a chest tube for a pleural space abnormality were hos-

pitalized, in contrast to some other institutions that kept these patients in the emergency room and discharge them subsequently. Among these patients the only evidence suggestive of cardiac injury was the presence of precordial wounds, with varying degrees of shock and cardiac tamponade or elevated central venous pressure. These patients were taken directly to the operating room for immediate or urgent thoracotomy. Patients who were received in the emergency room without blood pressure, pulse, or respiration and with pupils fixed and dilated were excluded. Thus none of the patients with emergency room thoracotomy for cardiac injury were included.

There were 2733 men and 316 women, with ages ranging from 19 to 90 years (average 23.6 years). The injuries were inflicted by knife in 1347 and by gun in 1702. Altogether, 196 patients had cardiac injuries: 97 (83 males, 14 females) from stab wounds and 99 (90 males, 9 females) from gunshot wounds. Of the 3049 patients, 453 patients (196 with cardiac injuries, 257 with noncardiac wounds) required thoracotomy. The remaining 1752 patients were managed by tube thoracostomy (Table 1). Among the 257 patients with noncardiac injuries, 155 had isolated chest injuries, and the remaining 102 had associated abdominal injury. Of the 453 patients undergoing thoracotomy, 392 underwent the procedure within the first 24 hours of hospitalization, and the other 61 patients 24 to 72 hours after admission. A total of 899 laparotomies were performed for thoracoabdominal injuries; 102 of these patients also required thoracotomy. Among the 102 patients with thoracoabdominal injuries, 31 had stab wounds and 71 had gunshot wounds (Table 1). Antibiotic prophylaxis was administered to the 1269 patients who underwent laparotomy or thoracotomy or who had pulmonary contusion with hemoptysis.

Results

Of the 3049 patients, 86 died for an overall mortality rate of 2.8% (Table 2). The injuries among the 86 patients who died are listed in Table 3. The mortality rates for patients with cardiac and noncardiac wounds of the chest were 21.9% (43/196) and 1.5% (43/2853), respectively. The mortality rate was lower among the stab wound victims in both instances (Table 4).

Among the 899 patients with concomitant abdominal injuries, an average of 1.7 abdominal organs were wounded. The intraab-

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Table 1. Types of treatment for 3049 patients with penetrating wounds of the chest.

Treatment	Total		SW		GSW	
	No.	%	No.	%	No.	%
Tube thoracostomy	1752	57.5	907	67.3	845	49.6
Thoracotomy	351	11.5	157	11.6	197	11.4
Thoracotomy and laparotomy	102	3.4	31	2.3	71	4.0
Tube thoracostomy and laparotomy	797	26.1	224	16.6	573	33.7
Thoracentesis	5	0	3	0	2	0
Pericardiocentesis	3	0	3	0	0	0
Observation	39	1.2	22	1.6	17	0.99
Total	3049		1347		1702	

SW: stab wound; GSW: gunshot wound.

Table 2. Mortality according to type of treatment.

Treatment	Total		SW		GSW	
	Deaths/patients	%	Deaths/patients	%	Death/patients	%
Tube thoracostomy	2/1752	0.11	0/907	0	2 ^a /845	0.23
Thoracotomy	45/351	12.8	15/157	9.6	30/194	15.5
Thoracotomy and laparotomy	17/102	16.6	3/31	9.7	14/71	19.7
Tube thoracostomy and laparotomy	22/797	2.8	3/224	1.3	19/573	3.3
Thoracentesis	0/5	0	0/3	0	0/2	0
Pericardiocentesis	0/3	0	0/3	0	0	0
Observation	0/39	0	0/22	0	0/17	0
Total	86/3049	2.8	21/1347	1.6	65/1702	3.8

^aQuadruplegic patient (one patient); air embolism (one patient).

dominal injuries are listed in order of frequency in Table 5. The diaphragm and liver were the organs most commonly injured. The mortality in this group of patients was 4.3% (39/899), compared with 2.2% (47/2150) in those who had isolated chest injuries. Nearly 16.6% (17/102) who required thoracotomy and laparotomy simultaneously within 24 hours of hospital admission for noncardiac thoracoabdominal injuries died (Table 2). A total of 155 patients with noncardiac isolated chest wounds required thoracotomy; two of them died (1.3%).

Transaxial injuries are defined as those where bullet entry and exit wounds were found on opposite sides of the midline or when the missile was found to be lodged across the midline from the entry site on roentgenogram or at operation. Among the 1702 patients with gunshot wounds in the present series, 85 (5%) sustained transaxial injuries (transmediastinal 25, transabdominal 60). Fifteen patients with transmediastinal and 28 with transabdominal injuries were unstable on arrival; and of those, 80% (12/15) and 68% (19/28), respectively, died; the remaining 42 patients survived. Thus the overall mortality in this group of patients was 36% (31/85). Mortality and the associated injuries of these patients are included in Tables 2 and 4. Two patients with gunshot wounds of the chest were treated only by tube thoracostomy; both died, one from spinal cord injury and the other from air embolism. The overall complication rate among the survivors was 6% (178/2963), with the infectious complications representing only 2.5% (Table 6).

Discussion

Victims of penetrating truncal injuries in civilian life usually reach the hospital alive, in contrast to those with war injuries [1]. An

Table 3. Associated injuries in 86 patients who died of penetrating wounds of the chest.

Injuries	No. of deaths		
	SW	GSW	Total
RA	0	4	4
RA + hilar vessel	1	1	2
RV	4	3	7
RV + RA	0	1	1
RV + RA + hilar vessels	3	3	6
LV + CA	4	8	12
LV + LA	0	1	1
LV + RV	4	0	4
LV + RV + VSD	0	6	6
RV + LV + SVC	0	1	1
RA + esophagus + IVC	0	3	3
RV + liver	0	1	1
Subclavian artery + vein + IJ	0	3	3
Subclavian artery + vein + IMA	0	1	1
Abdominal aorta + lungs + hilar vessels	0	5	5
Lungs + IVC + abdominal aorta	0	1	1
Thoracic aorta + lungs	0	1	1
SVC + lungs	0	1	1
Lung + hilar vessels	4	6	10
Liver + retrohepatic IVC + lungs	1	10	11
Lungs + liver + spleen + colon	0	5	5
Total	21	65	86

RV: right ventricle; LV: left ventricle; RA: right atrium; IJ: internal jugular; SVC: superior vena cava; IVC: inferior vena cava; IMA: internal mammary artery; CA: coronary artery; VSD: ventricular septal defect.

initial head-to-toe systematic examination and an awareness of the path of the penetrating object are important. This enables the physician to suspect the internal injuries and perform appropriate

Table 4. Mortality rates.

Type of wound	No. of patients	Deaths	
		No.	%
Penetrating wounds of heart			
Stab wounds	97	14	14.4
Gunshot wounds	99	29	29.2
Total	196	43	21.9
Noncardiac penetrating chest wounds			
Stab wounds	1250	7	0.6
Gunshot wounds	1603	36	2.2
Total	2853	43	1.5

Table 5. Intraabdominal organ injuries in 899 of the 3049 patients with penetrating wounds of the chest.

Organ involved	Incidence		
	SW	GSW	Total
Diaphragm	137	327	464
Liver	90	243	333
Spleen	45	124	169
Stomach	37	122	159
Colon	20	97	117
Small bowel	15	72	87
Kidney	12	41	53
Pancreas	7	35	42
Inferior vena cava	4	23	27
Gallbladder	0	17	17
Duodenum	4	12	16
Bladder	1	4	5
Iliac vessels	2	4	6
Aorta	0	4	4
Hepatic artery	1	2	3
Portal vein	0	2	2
Rectum	0	1	1
Uterus	0	2	2
Mesenteric vessels	1	4	5
Total	376	1136	1512

diagnostic tests. Early establishment of an airway, restoration of the intravascular volume, evaluation of pneumothorax, hemothorax, or hemopneumothorax with or without tension, and assessment of the open chest wounds are the immediate objectives in the patient with a penetrating thoracic injury [2]. In these seriously injured patients it is impossible to obtain an upright chest radiograph, but a supine radiograph provides valuable information. The most important radiographic examination is a subsequent chest film after placing an intercostal chest tube. If a chest radiograph is not instantly available, one can place an intercostal drainage tube on clinical grounds. Physical examination accurately predicts the need for tube thoracostomy with a sensitivity of 96% and specificity of 93% for a large pleural collection [3]. Most often the physical findings are normal in patients with a small pneumothorax of up to 28% and a small collection up to 800 cc [4, 5]. It should be emphasized that negative auscultation does not rule out a pleural space abnormality. Therefore patients who undergo exploratory laparotomy for penetrating wounds located at the thoracoabdominal region, even without a demonstrable pneumothorax on chest roentgenogram, we recommend preoperative tube thoracostomy (prophylactic chest tube) to prevent development of a tension pneumothorax during general anesthesia and positive-pressure ventilation.

Table 6. Complications among 2963 survivors of penetrating wounds of the chest.

Complication	Prevalence		
	SW	GSW	Total
Atelectasis	8	14	22
Pneumonia ^a	7	14	21
Empyema ^a	10	24	34
Septicemia ^a	2	8	10
Subphrenic abscess ^a	0	8	8
Mediastinitis ^a	0	3	3
Pericardial effusion	0	4	4
Bronchopleural fistula	2	0	2
Pleurobiliary fistula	0	4	4
Chylothorax	0	3	3
Delirium tremens	4	2	6
Dressler syndrome	1	2	3
Pancreatitis	2	0	2
Acute renal failure	0	11	11
Small bowel obstruction	1	0	1
Reoperation for bleeding	2	1	3
Paraplegia	2	35	37
Quadriplegia	0	4	4
Total	41	137	178 (6%)

^aInfectious complication.

Penetrating chest wounds are reported to be a major cause of death among inner city youths [6]. More than half of all homicides and suicides are committed with firearms. Firearms are the leading cause of death in African American males aged 15 to 34 years [7]. We have observed a similar trend in our series of 3049 patients: 44% had a knife wound and 56% a gunshot wound of the chest. The average age was 23.6 years, and 89.6% were male.

Thirty-nine patients (1.2%) required only simple observation for minor injuries of the pleural cavity as a result of a penetrating injury of the chest. None of these patients required delayed chest tube drainage or subsequent operation for their injury. A minor abnormality of the pleural cavity can be observed in patients with penetrating chest trauma. Thoracotomy was performed in 14.9% (453/3049) of our patients, similar to the group of 6452 patients with penetrating injuries reviewed by Jones and associates [8]. Interestingly, in our series the rate of thoracotomy with stab wounds was 13.9% (188/1347), and for gunshot wounds it was 15.6% (265/1702). The incidence of thoracotomy in both instances was similar even though gunshot wounds are generally associated with more tissue destruction. This is not true for lung tissue, because the lung with higher air content and lower specific gravity sustains significantly less devitalization than other solid organs, such as liver, kidney, and spleen. These solid organs offer greater resistance to passage of a missile and thus absorb more kinetic energy, causing more destruction and devitalization as the missile passes through them. However, reports on civic unrest in Belfast [9] and military operations in Lebanon [1] and Iraq [10] indicate that 71% to 80% required thoracotomy and the remaining 20% to 29% were managed by tube thoracostomy. The magnitude of war and civic unrest injuries caused by firearms (rifles or machine guns) is quite different from civilian handgun injuries. In contrast, only 8.1% of high velocity gunshot wounds to the chest in civilian practice were managed by thoracotomy [11].

The overall mortality rate among 3049 patients was 2.8%: 1.6% for knife wounds and 3.8% for gunshot wounds. The mortality rate for victims of gunshot wounds to the chest was two times

higher than that for those with stab wounds. In 1998 Inci et al. reported an overall mortality rate of 5.6%. Mortality due to stab wounds was 1.46% and that due to firearms was 8.95%. The hospital mortality rates for low and high velocity wounds were 2.9% and 11.6%, respectively [11]. The mortality rate for our patients with a gunshot wound of the heart was 29% and with a stab wound it was 14%, whereas the mortality rates for noncardiac penetrating chest injuries were 2% and 0.6%, respectively. Most of these cardiac injuries involved multiple chambers, a situation that remains difficult to treat successfully, particularly in gunshot victims.

The incidence of thoracoabdominal injuries is 10% to 30%, and the mortality associated with penetrating thoracoabdominal injuries in civilians has been reported by others to be as high as 18% [12, 13]. It is noteworthy that there were 29.5% associated abdominal injuries in this study. We have also observed that thoracoabdominal penetrating wounds tend to be more lethal. The mortality rates in patients who required both laparotomy and thoracotomy ($n = 102$) was 16.6%, whereas in patients who underwent thoracostomy and laparotomy ($n = 797$) it was only 2.8%. Of 899 patients with thoracoabdominal wounds, 39 died, for an overall mortality rate of 4.3% compared with 2.2% (47/2150) for those who sustained isolated penetrating chest wounds. Therefore patients with thoracoabdominal wounds had nearly two times higher mortality than those with isolated chest wounds. The presence of associated abdominal injuries influenced the outcome/[12,13,14]/[12–14]. Chest wounds ($n = 351$) that required thoracotomy for cardiac or noncardiac wounds comprised 12.8%. Mortality was low (1.3%, 2/155) when there was no associated cardiac or abdominal injury. The high mortality, morbidity, and missed injuries associated with both transmediastinal and transabdominal gunshot wounds is well documented [15,16]. The mortality rates for such injuries have been reported to be 36% to 42%. The overall mortality rate in the present series was 36.5%, but it rose to 80% for unstable transmediastinal and 68% for unstable transabdominal wounds.

If the patient is hemodynamically unstable, we perform thoracotomy on the side of greatest blood loss as identified by chest radiography or chest tube drainage or on the side of the major injury suspected because of the path of the transaxial trajectory. When the patient is hemodynamically stable, with or without appropriate resuscitated measures, and does not continue to bleed, diagnostic studies, such as computed tomography, esophagography, and aortography are performed. It has been advocated that esophageal injury should be evaluated expeditiously so it is repaired without unnecessary delay because of the high incidence of septic complications and suture line failures. Consequently, esophagography is performed before angiography [17]. This approach allows management of transmediastinal injuries in a more orderly and appropriate manner.

All 10 patients with transmediastinal injuries who were stable survived. Five of them required surgery, and the remaining five were managed conservatively. They did not require subsequent surgery for missed injuries or recurrent bleeding. For unstable transabdominal injury patients with massive distension of the abdomen and resistance to standard resuscitative measures, we performed anterior thoracotomy and thoracic aortic occlusion in the operating room. We then performed laparotomy through a separate incision. When laparotomy and thoracotomy are required simultaneously, a separate incision should be used to

prevent cross contamination of the pleural cavity. There were 32 patients who were stable with transabdominal trauma; they required laparotomy. There were no deaths, and all of them had intraabdominal organ injuries (Table 5).

Handguns are considered to be low velocity weapons, whereas all rifles (except the 0.22 long rifles) and any missile traveling faster than 2500 feet per second, regardless of size, are considered high velocity missiles [18]. Wounds from low velocity missiles are considered clean unless bowel penetration occurs. A high velocity missile wound must be considered contaminated because it brings a large amount of foreign material into both the entrance and exit wound sites. Those wounds must be débrided extensively and treated with appropriate antibiotic therapy. Antibiotics are not prescribed routinely unless there are specific indications, such as thoracotomy, laparotomy, pulmonary contusion with hemothysis, and extensive destruction of lung parenchyma or soft tissue by a shotgun blast [19]. We do not believe that antibiotic therapy is needed simply because the patient has a chest tube for a penetrating wound of the chest. There were infectious complications in only 2.2% of the survivors. However, a recent report advocates prophylactic antibiotics (cefazolin) prior to tube thoracostomy [20]. We believe that the most effective way to prevent infection is to place a properly functioning chest tube, discontinue the tube thoracostomy, apply a mechanical ventilator in a timely manner, and perform thoracotomy as soon as indicated.

Résumé

Les plaies pénétrantes thoraciques et thoracoabdominales sont fréquentes en milieu urbain aux Etats-Unis. Cette étude, longitudinale, non-aveuglée, utilisant le standard de soins des patients victimes de plaie pénétrante du thorax, avait comme but de déterminer les caractéristiques cliniques et l'évolution de ces lésions en analysant 3049 cas consécutifs traités dans un seul centre de trauma entre avril 1972 et mars 1996. Il y avait 1347 plaies par arme blanche et 1702 plaies par arme à feu. Une prophylaxie antibiotique a été administrée aux patients qui ont eu une laparotomie, une thoracotomie ou une contusion pulmonaire avec hémoptysie (41.6%, 1296/3049). Parmi les 3049 patients, 196 avaient une lésion cardiaque. Tous ont eu une thoracotomie avec une mortalité de 21,9%. En revanche, parmi les 2853 patients sans lésion cardiaque, seulement 257(9%) ont nécessité une thoracotomie avec une mortalité de 1.5%. Les patients ayant une lésion thoraco-abdominale (899/3049) avaient une mortalité de 4.3%, comparée à 2.1% parmi ceux qui avaient des lésions isolées du thorax. La mortalité globale a été de 2.8%. Parmi les 1702 patients ayant une plaie par arme à feu, 85 (5%) avaient des lésions en rapport avec un projectile traversant le corps («transaxial») avec une mortalité globale de 36,5%. Le taux de complications parmi les survivants a été de 6% avec seulement 2.5%) infectieuses. Nous concluons que (1) la mortalité des plaies pénétrantes non cardiaques est basse (2) la présence de lésions abdominales associées augmente la mortalité par deux fois (3) plus d'un patient sur trois ayant une lésion «transaxiale» décède (4) la mortalité des plaies du coeur par arme à feu sont plus graves (plus de mortalité) que les plaies cardiaques par arme blanche, et (5) le taux d'infection est bas.

Resumen

En los centros médicos de las áreas urbanas de los Estados Unidos de Norteamérica las heridas penetrantes torácicas y toraco-abdominales son frecuentes; este estudio se realizó para determinar las características clínicas de las mismas y los resultados terapéuticos al alta hospitalaria. Se trata de un estudio longitudinal, no ciego, utilizando el tratamiento estándar establecido para los pacientes con heridas penetrantes de tórax; se efectuó un análisis de 3,049 pacientes tratados en un sólo centro de traumatología entre abril de 1972 y marzo de 1996. Se registraron 1,347 heridas por arma blanca y 1,702 por arma de fuego. Se administró antibiótico-profilaxis en los pacientes que hubieron de ser laparo/toracotomizados y en aquellos que presentaban contusión pulmonar con hemoptisis (41.6%, 1,296/3,049). De los 3,049 pacientes, 196 presentaron un traumatismo cardiaco, todos fueron toracotomizados y la mortalidad alcanzó el 21.9%. Por el contrario, de los 2,853 pacientes sin trauma cardiaco sólo 257 (9%) requirieron una toracotomía, siendo la mortalidad en este grupo del 1.5%. En los traumatismos toraco-abdominales (899 de 3,049) la mortalidad fue del 4.3%, mientras que en los traumatismos torácicos aislados fue del 2.1%. La mortalidad global fue del 2.8%. De los 1,702 pacientes heridos por arma de fuego, 85 (5%) sufrieron heridas transaxiales y la mortalidad global en este grupo fue del 36.5%. La tasa de complicaciones en los supervivientes fue del 6% y sólo un 2.5% fue de etiología infecciosa. Conclusiones: (1) La mortalidad de los traumatismos torácicos penetrantes, excepción hecha de los que afectan al corazón, es baja. (2) Su asociación con traumatismos abdominales multiplica la mortalidad por dos. (3) Más de un tercio de pacientes con heridas transaxiales por bala murieron. (4) Las heridas de corazón por bala cursaron con una mortalidad más elevada que las heridas de corazón por arma blanca. (5) La tasa de infecciones fue baja.

Acknowledgments

We thank Dr. N.S. Datta for skillful advice and for editing the manuscript. Our thanks go also to Ms. Mina Mandal, M.L.S. for her assistance with our literature search and for processing the manuscript.

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