Surgical Management of Penetrating Intracranial Bullet Injuries

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Objectives: This study aimed to determine the outcome after gunshot wounds (GSWs) to the head and to evaluate the impact of prognostic factors mentioned in the literature on the outcome.

Methods: This prospective study included 30 patients; 24 males and 6 females with a mean age of 31 years. All with penetrating GSWs to the head admitted to the emergency department of Cairo University Hospitals from January 2008 till June 2011. Shotgun was the most common injury in this study, whereas bullet injury was in only 3 patients (10%). Preoperatively, patients were categorized according to their Glasgow Coma Scale (GCS) into mild, moderate, and severe penetrating head injury. Upon admission, all patients underwent a complete physical and neurological examination together with a computed tomography of the brain without contrast. Initial management included a variety of the following according to indications; resuscitation, prophylactic antiepileptics, antibiotics, control active bleeding from wounds, and measures to decrease intracranial pressure. Surgical intervention ranged from simple debridement to hematoma evacuation and/or bullet extraction. Outcome was assessed after surgical interference using GCS and Glasgow Outcome Scale.

Results: Fifteen (50%) patients had mild penetrating head injury (GCS 13 to 15), 12 patients (40%) were severely injured (GCS 3 to 8), and only 3 patients (10%) were moderately injured (GCS 9 to 12). Eighteen patients (60%) were found to have isolated intracranial injury, whereas 40% had other associated injuries. Twelve patients (40%) had an associated intracranial hematoma on their initial computed tomography scan. The average follow-up period was 16 months. The most common systemic complications were urinary tract infection (12 patients) and chest infection (12 patients), whereas the most common local complications were wound infection (10 patients), cerebrospinal fluid fistula (8 patients), and hydrocephalus (5 patients). At the follow up, The GCS of 10 patients (33.3%) was (13 to 15), 6 patients (20%) were (9 to 12), 5 patients (16.7%) showed persistent vegetative state (<3), and 9 patients (30%) died. Postoperative outcome was significantly correlated with the preoperative one ($P < 0.001$). According to Glasgow Outcome Scale, 33.3% of patients had good recovery and 30% of the patients died. The others suffered from various degrees of disability.

Conclusions: The prevalence of GSWs to the head is increasing dramatically as private ownership of weapons and gang-related urban violence increases. Most of the irreversible brain damage from a GSW is sustained at impact and can be understood in terms of a missile's trajectory and the pattern of energy transfer to brain tissue. Treatment is aimed at preventing subsequent brain injury that might further limit recovery. One third of patients obtain a good recovery.

Key Words: intracranial bullet, shotgun, Glasgow Outcome Scale

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Development of firearms in the 16th century produced profound changes in the art of warfare and raised new problems for the physician—surgeons. Old assumptions and wrong interpretations delayed the rational approach to the head injuries inflicted by missiles. Evolution of thought and increased experience over the century ultimately led to a surgical practice that can be regarded as the possible solution allowed by contemporary knowledge and technology.[1]

Gunshot wounds (GSWs) of the head are on the increase. The easy availability of handguns, revolvers, shotguns, and rifles and the continued and increasing armed struggle in various parts of the world demand a renewed and serious interest in and a better understanding of both the ballistic characteristics of missiles and the surgical pathology of missile wounds. Simple adherence to the general surgical principles of wound care leaves much to be desired when the neurosurgeon is confronted with a missile or GSW of the brain.[2]

TABLE 1. Patients Characteristics and Preoperative Data

Data	Value
Age (y)	31 (12-58)
Sex	
Male:female	4:1
Weapons used	
Shotgun	18
Machine guns	9
Handgun	3

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TABLE 2. Severity of Head Injury According to GCS

Severity	GCS
Mild head injury	13-15
Moderate head injury	9-12
Severe head injury	3-8
Persistent vegetative state	< 3
Death	—

GCS indicates Glasgow Coma Scale.

TABLE 3. Glasgow Outcome Score

Glasgow Outcome Score	
5	Good recovery
4	Mild disability
3	Moderate disability
2	Severe disability
1	Persistent vegetative state
0	Death

The extent of civilian firearm injury has reached epidemic proportions in many countries across the world, developed and developing alike. Firearm injuries are among the top 10 causes of accidental death and the top dozen causes of all death in the United States, with numbers since World War II exceeding those killed in the wars of Vietnam and Korea combined. Sadly, there seems to be preponderance of adolescent and young adult victims, the majority of whom do not survive to receive treatment.[3]

As GSWs to the head remain a significant problem in the civilian population, any information that can be extrapolated from war injuries is valuable. War injuries are unique in being secondary to the higher velocity and higher kinetic energy of the projectile. Military bullets remain intact without undergoing fragmentation or deformation. The increased force of the blast associated with a wartime injury creates a larger volume of devitalized brain tissue, with a greater chance of a retained intracranial bone fragment.[4]

This study aimed to determine the outcome after GSWs to the head and to evaluate the impact of prognostic factors mentioned in the literature on the outcome.

PATIENTS AND METHODS

This prospective study was conducted on 30 patients; 24 males (80%) and 6 females (20%). The age varied from 12 to 58 years with mean age 31 years. All with penetrating GSWs to the head admitted to the emergency department of Cairo university hospitals from January 2008 till June 2011. Shotgun was the weapon used in 18 patients, whereas machine guns were used in 9 patients. Only 3 patients were shot by small 9-mm handguns one of which was a suicidal attempt (Table 1).

Preoperatively, patients were categorized according to their Glasgow Coma Scale (GCS) into mild (GCS 13 to 15), moderate (GCS 9 to 12), and severe penetrating head injury (GCS 3 to 8) (Table 2).

All patients in this study were subjected to complete general and neurological examination. The history was taken from the relatives, or the ambulance aid. On admission, emergency measures were taken to maintain the air way and adequate oxygenation, endotracheal tube if GCS < 8. Associated ventilation was used when needed. Resuscitation, control of bleeding site from any wounds, fluids or blood replacements started immediately. Also examination for any associated injuries and prompt management of those who need urgent treatment, mainly chest injuries. Preoperative and intraoperative management to control intracranial tension prevent secondary injury, seizure, and infection using mannitol, hyperventilation, and prophylactic antiepileptics, antibiotics. All patients were investigated by computed tomography brain without contrast after stabilization of the general condition of the patient, correction of any preexisting shock, sedation, and hyperventilation (Fig. 1). Other imaging studies were done if indicated to assess other associated injuries.

All patients were subjected to one or more of the following surgical interventions: debridement, wound closure, removal of intracranial hematoma, removal of

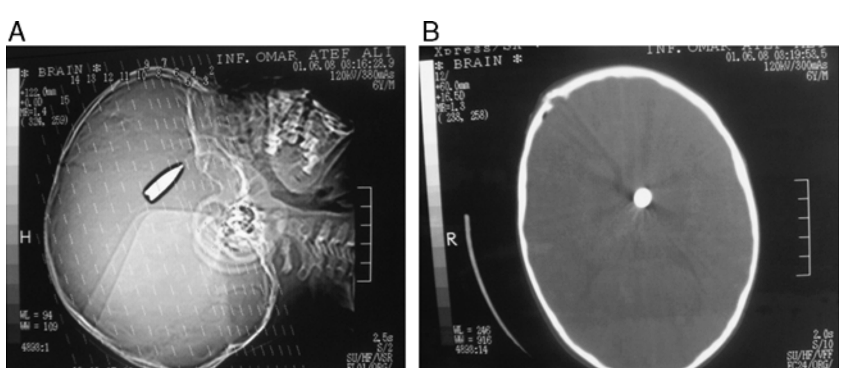

FIGURE 1. A, Computed tomography (CT) sagittal cut showing penetrating intracranial bullet. B, CT axial cut showing penetrating intracranial bullet.

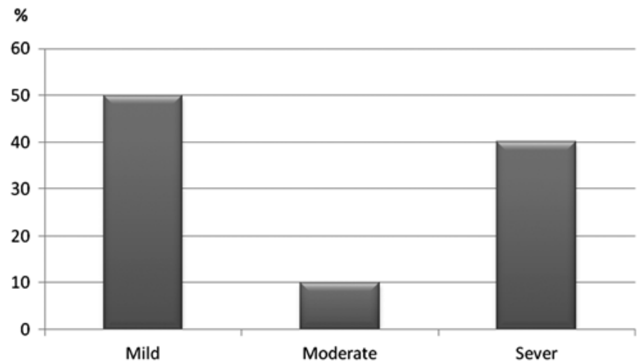

FIGURE 2. Glasgow Coma Scale of patients upon admission.

bony spicules or foreign bodies (only if easily accessible), and external ventricular drains in case of intraventricular hemorrhage.

All patients were followed up clinically and radiologically. Mean follow-up period was 16 months. The outcome of patients was categorized according to the GCS and evaluated by Glasgow Outcome Score (Table 3).

Data were statistically described in terms of mean ± SD, or frequencies (number of cases) and percentages when appropriate. Comparison between the study groups was done using Student *t* test for independent samples in comparing 2 groups when normally distributed and Mann-Whitney *U* test for independent samples when not normally distributed. *P* values < 0.05 was considered statistically significant. All statistical calculations were done using computer program SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL) version 15 for Microsoft Windows.

RESULTS

This study included 30 patients with penetrating gunshot and bullet wounds to the head. On admission it was found that 15 patients (50%) had mild penetrating head injury (GCS 13 to 15), 3 patients (10%) were moderately injured (GCS 9 to 12), and 12 patients (40%) were severely injured (GCS 3 to 8) (Fig. 2). All patients underwent surgical intervention ranged from simple debridement to hematoma evacuation and/or bullet extraction.

Twelve patients (40%) presented with associated intracranial hematomas including extradural, subdural, subarachnoid, or intracerebral, whereas 18 (60%) presented with penetrating intracranial injury without hematomas. Also, 12 patients (40%) had associated injuries other than cranial injuries.

During the follow-up period local and general complications were observed. The most common local complication was wound infection and was found in 10 patients (33.3%), 8 patients of them were cured by IV antibiotics and 2 patients required further debridement. Other local complications were cerebrospinal fluid (CSF) fistula and leak in 8 patients (26.6%), 4 stopped spontaneously, and the other 4 required CSF diversion, and hydrocephalus requiring CSF diversion in 5 patients (16.6%). Regarding systemic complications, the most common complications were chest infection, seen in 12 patients (40%), and urinary tract infection in 10 patients (33.3%). Other complications were bed sores in 2 patients and stress ulcer in 2 patients (Tables 4 and 5).

Patients were followed for a period of 16 months clinically and radiologically. Postoperative outcome was significantly correlated with the preoperative one (*P* 0.001). GCS of 10 patients (33.3%) was 13 to 15, 6 patients (20%) were 9 to 12, no patient was 3 to 8, and 5 patients (16.7%) showed persistent vegetative state and 9 patients (30%) died (Table 6).

Also the outcome was evaluated according to Glasgow Outcome Score which showed that 33.3% of patients had good recovery, 30% of patients died, 20% of patients were moderately disabled, and 16.7% patients were in persistent vegetative state.

TABLE 4. Local Complications Observed

Complications	N (%)
Infection	10 (33.3)
CSF fistula	8 (26.6)
Hydrocephalus	5 (16.6)

CSF indicates cerebrospinal fluid.

TABLE 5. Systemic Complications During Management

Complications	N (%)
Chest infection	12 (40)
UTI	10 (33.3)
Bed sores	2 (6.6)
Stress ulcer	2 (6.6)

UTI indicates urinary tract infection.

DISCUSSION

Traumatic GSW to the head is becoming an issue of growing concern in modern society, in which rapid surgical interventions are effective in saving the lives of victims with severe head injuries. Although much of the literature on craniocerebral gunshot injuries is derived from military experience.[5] Civilian GSWs are extremely

TABLE 6. Clinical Outcome of Patients

	Preoperative		Postoperative		
GCS	N	Ratio (%)	N	Ratio (%)	*P*
13-15 (mild disability)	15	50	10	33.3	< 0.001
9-12 (moderate disability)	3	10	6	20	< 0.001
3-8 (severe disability 12	12	40	0	—	< 0.001
< 3 (vegetative)	0	—	5	16.7	< 0.001

GCS indicates Glasgow Coma Scale.

common in certain populations.[3] Most patients do not survive to receive treatment.[5]

In this study, the mean age of patients was 31 years and the male to female ratio was 4:1. This implies that most of the patients are young men. Only one of the 30 patients was a suicidal attempt, denoting that suicide is not that common in the Egyptian community possibly because of strong religious and cultural beliefs. On admission, 40% of patients were severely injured (GCS 3 to 8), 10% were moderately injured (GCS 9 to 12), and 50% were mildly injured (GCS 13 to 15). In the Kim et al[6] study, which included 13 patients, 30.7% of patients were severely injured (GCS 3 to 8), 15.4% were moderately injured (GCS 9 to 12), and 53.9% where mildly injured (GCS 13 to 15). In the case of penetrating head wounds, usually that result of a high-velocity missile or handgun fired at close range, the entry wound is smaller than the exit wound, and there is variation in the degree of cavitation along the bullet's path through the brain, whose diameter is usually several times larger than that of the bullet itself. The bullet's transit is accompanied by a percussion wave that is transmitted through the brain, causing explosive skull fractures and widespread destruction of neuronal cell membranes. The shock wave may propagate as far down as the medulla oblongata, causing transient cardiorespiratory impairment, which may manifest clinically as acute respiratory arrest. The transmission of kinetic energy to the brain results in a sharp rise in intracranial pressure (ICP) upon injury, followed by a slow, slight decline, and subsequent second increase in ICP due to intracranial bleeding from torn blood vessels and progressive edema. In our study 9 patients (30%) died; 2 in the same day of injury, 4 during the first 3 days, and 3 after 2 weeks. In Tsuei et al's[7] study of 16 patients with civilian GSWs to the brain, the overall mortality rate was 31.3% (5 of 16 patients). In our series, 7 patients of the 9 who died had injuries crossing the midline which confirms that bullets crossing midline are most commonly fatal. This was agreed by Selden et al,[8] who reported in his series which included 67 patients who had sustained self-inflicted GSWs of the brain that when a missile crossing both vertical anatomic planes of the brain it was lethal in 100% of cases.[5]

Craniocerebral gunshot injuries, contusions are commonly located beneath the site of the missile impact and are caused by inward movement of the skull, with or without fracture, based on the frequent finding of cerebral contusions in superficial and tangential injuries. Violent shock waves or cavitary tissue displacement in which the skull impacts on the brain parenchyma may also cause contusions to form at sites remote from the missile tract.[9] The same forces may also result in diffuse parenchymal injury, or "diffuse axonal shear injury."[10] In our study, radiologic examination showed that diffuse parenchymal damage was present in 6 (20%) cases and that this was associated with poor prognosis in the series. Also noted that 12 patients (40%) were harboring intracranial hematomas of different types whether extradural, intracerebral, and subdural or subarachnoid. Six of the 12 patients died, denoting a mortality of 50% in case of bullet injuries with intracranial hematomas.

As of regards surgical issues, some authors have stated intracranial bone fragments that if not removed can cause infection.[11] Pitlyk et al[12] revealed that the bone fragments did not increase the infection rate itself, but that the infection rate became 10 times higher if the fragment combined with scalp or hairs. Carey et al[11] reported 2 minor complications, 1 major complication and 1 death after secondary debridement in 103 patients. Meirowsky et al[13] noticed increasing neurological deficit in 4 of 116 (3.4%) patients who underwent reoperation. However, it has also been reported that attempts to remove intracranial fragments may increase the risk of neurological defects. In our study, only accessible fragments were removed, and no attempts were made to aggressively remove them. To prevent infection, all wounds were properly washed by hydrogen peroxide and all patients received IV rocephin + IM amikacin. The rate of infection, however, remained high (33.3%), but only 2 of the 10 patients required redebridement. Tsuei et al[7] noticed complications in 11 survivors which were seizure in 2 patients (18.2%), CSF leakage in 1 (9.1%), and brain abscess formation in 3 (27.3%).

In our series, on admission 15 patients (50%) had GCS of 13 to 15, 3 patients (10%) had GCS of 9 to 12, and 12 patients (20%) had GCS of 3 to 8. At follow-up period we found that GCS of 10 patients (33.3%) was 13 to 15, 6 patients (20%) were 9 to 12, no patient was 3 to 8, and 5 patients (16.7%) showed persistent vegetative state.

Craniocerebral GSWs are associated with high mortality rates with postsurgical mortality of approximately 20%.[14,15] Mortality and morbidity in craniocerebral missile wounds are affected by many factors, including patient transport, antibiotic therapy, surgical techniques, and follow-up procedures.[14] In our study, however, the mortality was 30%, 33.3% of patients had good recovery, 20% of patients were moderately disabled, and 16.7% patients were in persistent vegetative state. Tsuei et al[7] in his study mentioned that he had satisfactory outcome in 7 of 16 patients (43.7%), 3 were in a persistent vegetative state (18.7%).

CONCLUSIONS

Penetrating cerebral trauma is predominantly GSWs to the head. Much of the irreversible brain damage from a GSW is sustained at impact and can be understood in terms of a missile's trajectory and the pattern of energy transfer to brain tissue. Treatment is aimed at preventing subsequent brain injury that might further limit recovery. Medical treatment is not particularly complicated, nor is surgical treatment technically demanding. Surgery is indicated to reduce the mass effect of an intracranial hematoma or hemorrhagic necrosis, to debride areas of gross contamination, and effect repair 33.3% of patients had good recovery.

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