# Combat Gunshot Head Injury

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**ABSTRACT:**

**BACKGROUND:**

Combat Gunshot Head Injury is an increasingly important issue with all its drawbacks on the health care system .

**OBJECTIVE:**

This study presents an evaluation of traumatic brain injury caused by gunshots and discusses possible predictive factors for the outcome of surgical intervention.

**PATIENTS AND METHOD:**

A prospective study performed at Al Shaheed Mohammed Al Majed hospital, Samarra, Saladin, Iraq consisted of 60 patients who underwent surgery for penetrating TBI over a 1 year period (2015 – 2016). All injuries were caused by gunshot.

**RESULTS:**

Mean patients' age was 31.5 years. The Glasgow Coma Scale (GCS) score on admission was > 8 in 43 patients (71.7%) and ≤ 8 in 17 patients (28.3%). Commonest site of brain injury is the frontal lobe (28%). Ballistic trajectory through brain affects the post operative outcome with good outcome (50%) in the anteroposterior bullet trajectory plane. 5 patients (8.3%) died despite surgical management.

**CONCLUSION:**

Admission GCS score, bullet trajectory and ventricular involvement are the most powerful prognostic indicator with a score of more than 8, no ventricular hemorrhage, anteroposterior trajectory of bullet and lesions limited to a single lobe of the brain, have improved surgical outcomes. Early and less invasive surgery in conjunction with short transportation time to the hospital could decrease mortality rates.

**KEY WORDS:** penetrating brain injury, gunshot wounds.

## INTRODUCTION:

Traumatic brain injury (TBI) is likely as old as warfare. In modern military medicine much of the focus has been on the effects of bullets and metallic fragments upon the brain. In World War I, for example, the English neurologist Sir Gordon Holmes detailed his observations on over 2,000 cases of head injury, including a detailed analysis of 23 cases involving penetrating injury to the visual cortex.(1) Much of that work was influenced by the work of the Japanese ophthalmologist Tatsuji Inouye who created the first relatively accurate map of the primary visual cortex; the map was based on his correlational observations of visual field defects following penetrating injuries to the occipital cortex during the Russo-Japanese war of 1904.(2) In later years, Teuber made significant contributions to our understanding of the effects of penetrating brain injury in warfare by studying those injured in World War II.(2)

Alexander Luria, whose work contributed much to the beginnings of what is now known as neuropsychology, also studied injured soldiers during World War II. (3) His rehabilitation work centered on focal brain injury and how it affected cognition, language, and motor functioning. In addition, the work of Grafman et al. (4) and Carey et al. during the Vietnam era helped increase our understanding of both the acute effects and the late neurobehavioral changes of brain injuries. These contributions have allowed for further developments in modern military medicine and provided a strong foundation for our investigations today. (4)

The conflicts in Iraq and Afghanistan are different than past wars in terms of the survival rates of those injured. The current wounded-to-killed ratio in Iraq is more than 9:1,(5) compared to less than

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3:1 in Vietnam and Korea, and approximately 2:1 in World War II. [6] This increased survival of wounded personnel is related to numerous factors including advanced in-theater medical care and superb protective equipment. With these new survival rates come increased numbers of those who may have experienced a TBI. Because the most common injury mechanism in the current conflict is blast, there are possibilities for TBI either through direct blast effect or secondary or tertiary blast effects. [7][8]

There are two distinct mechanisms of ballistic injury. Crushing of tissue resulting in a permanent tract is the primary factor in wounding of most tissues and most body regions. Temporary cavitation causes radial tissue displacement and subsequent shearing, compression and especially stretching of tissue analogous to blunt trauma. In contrast to the effect in elastic tissue, temporary cavitation can contribute substantially to wounding of inelastic tissue, such as the brain. This is the case in penetrating gunshot wounds to the head. Additionally, the penetration of the bony cranium can produce secondary missiles in the form of bone or bullet fragments and a tendency of the bullet to deformation and early yaw. Most important, wounding resulting from temporary cavitation is greatly augmented by the confined space provided by the unyielding walls of the skull. (9)

The pathological consequences of penetrating head wounds depend on the circumstances of the injury, including the properties of the missile, the energy of the impact, and the location and characteristics of the intracranial trajectory. (10)

Following the primary injury or impact, secondary injuries may develop. Secondary injury mechanisms are defined as pathological processes that occur after the time of the injury and adversely affect the ability of the brain to recover from the primary insult. A biochemical cascade begins when a mechanical force disrupts the normal cell integrity, producing the release of numerous enzymes, phospholipids, excitatory neurotransmitters (glutamate), Ca, and free oxygen radicals that propagate further cell damage. (10)

Missiles range from low-velocity bullets used in handguns, as shown in the image below, or

shotguns to high-velocity metal-jacket bullets fired from military weapons. Low-velocity civilian missile wounds occur from air rifle projectiles, nail guns used in construction devices, stun guns used for animal slaughter, and shrapnel produced during explosions. Bullets can cause damage to brain parenchyma through 3 mechanisms: (1) laceration and crushing, (2) cavitation, and (3) shock waves. The injury may range from a depressed fracture of the skull resulting in a focal hemorrhage to devastating diffuse damage to the brain. (11)

A wound in which the projectile breaches the cranium but does not exit is described technically as penetrating, and an injury in which the projectile passes entirely though the head, leaving both entrance and exit wounds, is described as perforating. This distinction has some prognostic implications. In a series of missile-related head injuries during the Iran-Iraq war, a poor postsurgical outcome occurred in 50% of patients treated for perforating wounds, as compared with only 20% of those with penetrating wounds. (12)

In missile wounds, the amount of damage to the brain depends on numerous factors including (1) the kinetic energy imparted, (2) the trajectory of the missile and bone fragments through the brain, (3) intracranial pressure (ICP) changes at the moment of impact, and (4) secondary mechanisms of injury. The kinetic energy is calculated employing the formula $1/2mv^2$, where m is the bullet mass and v is the impact velocity. At the time of impact, injury is related to (1) the direct crush injury produced by the missile, (2) the cavitation produced by the centrifugal effects of the missile on the parenchyma, and (3) the shock waves that cause a stretch injury. As a projectile passes through the head, tissue is destroyed and is either ejected out of the entrance or exit wounds or compressed into the walls of the missile tract. This creates both a permanent cavity that is 3-4 times larger than the missile diameter and a pulsating temporary cavity that expands outward. The temporary cavity can be as much as 30 times larger than the missile diameter and causes injury to structures a considerable distance from the actual missile tract. (13)

A bullet wound going through the right frontal lobe tip toward the forehead and well above the base of the skull is likely to cause relatively mild clinical damage because it passes through no vital brain tissue or vascular structures. However, a similar

bullet passing downward from the left frontal lobe tip toward the temporal lobe and brainstem is likely to be devastating because it passes through eloquent brain tissue and is likely to injure important vascular structures inside the head. Outcome is poorer for those with extensive bullet tracts, those that cross the deep midline structures of the brain, or those that involve the brainstem. A bullet that damages the patient's right hemisphere can leave the victim with motor and sensory impairments on the left side, and vice versa. Many other functions such as cognition, memory, speech, and vision are controlled by both sides of the brain. As a result, damage to one hemisphere can leave a person impaired but still able to perform these functions at some level, depending on which lobes of the brain are damaged. (14)

Projectiles are customarily classified as "low-" or "high velocity", roughly corresponding to the two main categories of small arms, handguns and rifles. While low velocity is generally considered synonymous to subsonic(less than 350 m/s), the high velocity range is less well defined. In the context of wound ballistics, high velocity is considered to start approximately at 600-700 m/s, above which "explosive effects" are commonly seen. Medium or intermediate velocities (350-600 m/s) are achieved by more powerful handguns, such as those using Magnum ammunition. (15)

Intracranial hypertension is common, and may be associated with, decreased cerebral perfusion pressures (CPP), cerebral ischemia, seizures, vasospasm, arteriovenous fistula formation, or traumatic aneurysm rupture as a direct result of penetrating Traumatic Brain Injury(pTBI). Maintaining ICP <20-25mmHg and CPP >60mmHg using general measures (head mid-line, head of bed elevated to 30 degrees, control of pain and temperature) hyperosmotic therapy, sedation, neuromuscular blockade, and induced hypothermia may improve outcomes by limiting secondary injury. TCD can help monitor cerebral blood flow as well as assess for evidence of developing cerebral vasospasm in the setting of traumatic subarachnoid hemorrhage. Patients who have sustained pTBI are at higher risk for the development of non-neurologic complications as well. For example, pTBI patients are at high risk for Acute Respiratory Distress Syndrome (ARDS). Critically ill patients are at high risk for deep venous thrombosis (DVT). A number of endocrine abnormalities may present in pTBI to include hyperglycemia, diabetes insipidus, cerebral salt wasting, or syndrome of inappropriate diuretic hormone. (16)

Admission GCS score, trajectory of the missile track, abnormal pupillary response (APR) to light, and patency of basal cisterns were significant determinants of patient outcome. Exclusion of GCS score from the regression models indicated missile trajectory and Afferent Pupillary Reaction to light were significant in determining outcome. (17)

## PATIENTS AND METHODS:

A prospective study at AlShaheed Mohammed AlMajed paramilitary hospital in Samarra , Saladin, Iraq for 60 military patients, with TBI caused by gunshot wounds between 2015 and 2016, mean age: 31.5 years; (age range: 18-45 years). Individuals who had gunshot wounds that did not penetrate the cranium were excluded from the study. Following initial evaluation and immediate lifesaving procedures performed by paramedics in the field, patients were transferred by emergency medical vehicle to hospital for neurosurgical management. The mean time-lapse between injury and arrival to hospital was 2.5 hours. Pre-operative computed tomography (CT) was taken in all patients .All but 3 patients were treated surgically because they died before reach to theatre due to hemodynamic compromise associated major vessel injury.

## RESULTS:

In total 60 military personnel with mean age of 31.5 years old with TBI caused by gunshot wounds had been studied over a 1 year period, all injuries happened in combat. A bullet was the wounding agent in all cases. Those in which the bullet didn't penetrate the cranium were excluded from the study. Preoperative CT. scan performed for all cases. Patients categorized according to the brain lobe injured and the bullet trajectory with respect to brain axis (Anteroposterior 43 vs. lateral 17), All but 3 patients underwent surgery. Surgical technique primarily includes craniectomy, debridement of necrotic tissues and retained fragments in and debridement in association with duraplasty using synthetic dura or fascia lata.

-Study showed that the most common site of injury to be the frontal lobe followed by multilobar brain involvement with ventricular injury. The last group had 5 patients died. $X^2$ is 13.114. The *p*-value is 0.010732. The result is significant at $p < 0.05$, these findings shown in figure I.

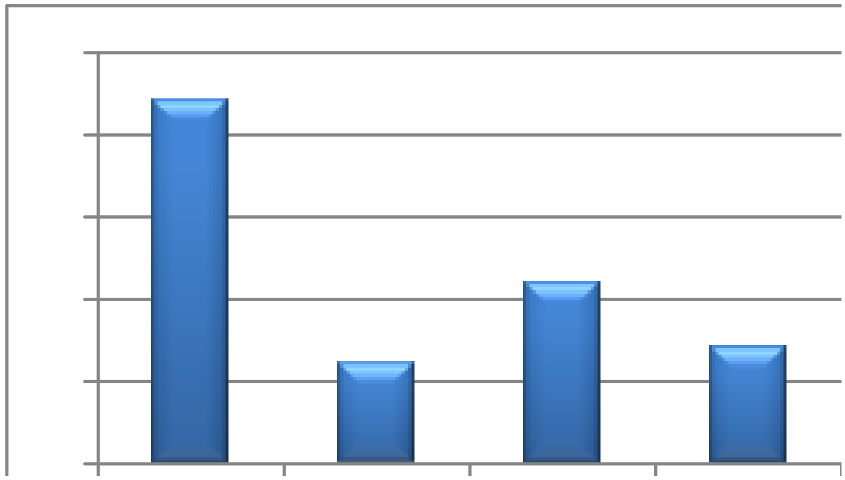

**Figure I: Distribution of patients according to the injured brain lobe and mortality.**

-CT scans of the brain were performed for all patients preoperatively; those with injuries that did not penetrate the cranium were excluded from the study. Higher admission GCS scores were associated with limited brain injury brain CT. Scan findings .The majority of our patients (66.7%) present with GCS > 8 and limited brain injury CT. finding while in those with GCS ≤ 8 we have most of the cases 20% have extensive brain injury, $X^2$ is 45.9812, *p*-value is < 0.00001. result is significant at $p < 0.05$, all that shown in Table I.

**Table I: Brain computed tomography scan findings and admission GCS score.**

| Brain CT. scan findings | Admission Glasgow Coma Scale Score | |
|---|---|---|
| | ≤ 8 | >8 |
| Limited brain injury (single-lobe / non dominant) | 2 | 42 |
| Extensive brain injury (multi lobar/ dominant / crossing midline / ventricle involvement) | 15 | 1 |
| Total | 17 | 43 |

-The relationship between the GCS score, time of transfer to hospital and the mortality is shown in Table II.

Time of transfer to hospital that is less than 2 hours associated with higher admission GCS score with better survival rate, GCS scores at admission ranged from ≤ 8 in 17 patients and > 8 in 43 patients, all mortalities 8.3% occurred with GCS < 8 and with transfer time > 2 hours, $X^2$ is 10.5871. The *p*-value is 0.001139. The result is significant at $p < 0.05$.

**Table II: Relationship between admission GCS score, time of transfer to hospital and mortality.**

| Admission GCS score | Number of patient | Time of transfer to hospital (hours) | Mortality |
|---|---|---|---|
| >8 | 43 | < 2 hours | - |
| ≤ 8 | 17 | > 2 hours | 5 |
| Total | 60 | | 5 |

-Outcome of treatment and its affection by group of factors including type of trajectory, pupil dilatation, GCS score, ventricular hemorrhage and surgical intervention, shown in table III.

*Anteroposterior ballistic trajectory* had been associated with better GCS admission score >8 (55%), 7% of cases with ventricular hemorrhage, 50% with good post operative functional outcome with just 1 death related to other major body injury, on the other hand *lateral ballistic trajectory* that had presented with worse GCS admission score ≤ 8 (23%), 18% of cases with ventricular hemorrhage, only 16.5% have well outcome despite surgical intervention.

$X^2$ is 45.5645. The *p*-value is 0.00001. The result is significant at $p < 0.05$.

**Table III: The prognostic factors affecting the outcome during the in-hospital stay of patients with gunshot wounds to the head.**

| Type of injury Trajectory through brain | GCS score on admission | | Ventricular hemorrhage | surgical intervention | | outcome of treatment | | |
|---|---|---|---|---|---|---|---|---|
| | ≤ 8 | >8 | | Surgery | No surgery | Death | Disabled | Good |
| Anteroposterior | 3 | 33 | 1 | 42 | 1 | 1 | 4 | 30 |
| Lateral | 14 | 10 | 14 | 15 | 2 | 4 | 11 | 10 |
| Total (60) | 17 | 43 | 15 | 55 | 3 | 5 | 15 | 40 |

Disabled = any mental or physical handicap that makes person independent to some degree.
Good = fully independent with daily activities with no physical or mental handicap.

-Regarding post operative complications there were 2 cases with infection meningitis confirmed by CSF study from that treated conservatively with antibiotic coverage with full resolution in 10 days without sequela.

## DISCUSSION:

TBI caused by gunshot wounds is one of the most common causes of death and disability in warfare. This is becoming an issue of growing concern in modern warfare, in which rapid surgical interventions are effective in saving the lives of soldiers with severe head injuries. According to the Defense and Veterans Brain Injury Center, a research and treatment agency run by the Pentagon and Veterans Affairs Department, 64% of injured troops have suffered penetrating brain injuries [(18),] due to advancement in combat weapons technology including sniper rifles and armor piercing bullets that will produce more lethal fire power and more damage to the delicate brain tissue.

-Mean patient age was 31.5 years in our study, similarly Smith found that gunshot causalities in both military and civilian personnel fall in between 16 to 43 years old as those more involve in conflicts and military enrolment as part of army service [(19)] as mean age of combat military personnel in service fall in this age group.

-The mean time-lapse between injury and arrival to hospital was 2.45 hours as all patients transferred by ambulance from the front field which looks to have adverse effect on outcome, as patients who received at our hospital with > 2 hours since injury were presented with GCS < 8 with 5 mortalities. Prolonged transport time affects the hemodynamic status and cerebral perfusion especially when other body system involvement especially chest or cardiovascular injuries making time crucial. This is in common with other studies that shows that peak mortality from cranio-cerebral gunshot injuries happens at the scene or within 3 hours of injury.[(20)] During the Vietnam War, the neurosurgical postoperative mortality rate was 8% to 10% . For combat casualties of the Vietnam War, resuscitation in the field by paramedical personnel, rapid transportation by helicopter to specially equipped medical facilities, bountiful supply of whole blood and sophistication of care rendered by these facilities contributed to an improved survival rate [(21)].

-Despite of diversity of approaches for the surgical management craniectomy is the standard in our neurosurgical department for this injury type. Our surgical procedures mainly included irrigation, debridement of devitalized tissues, and removal of space-occupying hematoma, in-driven bone, and accessible bullet fragments. Exploration of deep-seated bullet fragments was never done. In the only prospective study in the literature, Grahm et al, who analyzed the results of aggressive surgical treatment in 100 patients, found that none of the patients with a GCS score of 3 –5 had a good recovery [(20)].

-Regardless of whether or not clinical evidence of penetration exists, all patients with TBI should undergo CT, except in extreme cases that require immediate surgical intervention, or when the patient is clinically and neurologically moribund and there is no hope for survival as shown by Cooper et al. [22] Poor outcomes in patients with extensive brain injury indicated by CT scan have been documented previously [23] and patients with extensive brain injury in our series had similarly poor outcomes. CT scan done for all patients in our study preoperatively. 66.7% of our patients presented with GCS > 8 and shows limited brain injury picture on CT scan.

-Frontal lobe involvement was the most common site of injury to our study as majority of injuries cause between soldiers during charge phase in battle, tower guard personnel by sniper rifle or by shrapnel during combat which in common with Military wound ballistic. Chandra reports that suicide and assassinations including street gangster attacks were guns are used have more injury to temporal and to lesser degree occipital lobe involvement. [24]

-Poor prognosis associated with involvement of both cerebral hemispheres that is usually the case in the lateral trajectory injury group, whereas only one hemisphere was affected in the anteroposterior injury group, thus admission GCS score was better (>8) in the latter group so as the mortality rate was lower in comparison to the former group (2% vs. 7%). The protection of the other cerebral hemisphere contributed significantly to the prediction of the outcome in patients with anteroposterior injury. [25] This group was also associated with longer hospital stay because of minimal brain damage compared with the lateral injury group, and required more rehabilitation period.

-One of factors that have a grave effect on patient's outcome is ventricular injury. The ventricular system is susceptible to damage during lateral penetrating gunshot injury. Its delicate nature and nearness to vital structures make it a critical site [26]. Erdogan et al reported that the presence of diffuse brain damage, brain stem injury, CNS infection, or ventricular injury was associated with poor outcome. [27] It is difficult to cause a lateral injury trajectory without damaging the ventricular system, and therefore high mortality and morbidity rates are inevitable in patients with such injuries. In our series, 11 patients with lateral injury had concomitant ventricular injury, from them 4 patients died despite surgical intervention.

-Two cases with post operative meningitis confirmed with CSF study encountered in our patients, there is a debate whether the retained bony fragments, bullets is the main vector behind infection in penetrating gunshot injuries. Removal can be associated with more damage to brain tissue, extended operative time. [28] Our practice including preoperative heavy antibiotic coverage, copious saline irrigation and removal of accessible fragments with continue of antibiotic coverage in the post operative period.

## CONCLUSION:

-Rapid transportation to the hospital and urgent surgical intervention could have reduced mortality rates.

-Admission GCS score, bullet trajectory and ventricular involvement are the most powerful prognostic indicator. Low GCS score, multi lobe brain injury injuries and ventricular involvement, should not be discouraged from surgical intervention.

## REFERENCES:


1. McDonald, I. Gordon Holmes Lecture: Gordon Holmes and the neurological heritage. Brain 2007; 130: 288–98.
2. Douglas J. Lanska. Historical perspective: Neurological advances from studies of war injuries and illnesses. *Annals of NEUROLOGY* 2009;66:444–59.
3. A. R. Luria. *The Man with a Shattered World*. Boston, USA: Harvard University Press; 1987; 12:48–51.
4. Raymont, V., A. Greathouse, K. Reding, et al. Demographic, structural and genetic predictors of late cognitive decline after penetrating head injury. *Brain* 2008;131:543–58.
5. Hannah Fischer. *A Guide to U.S. Military Casualty Statistics: Operation Iraqi Freedom.* 2015; 1: 1–10.
6. Armonda RA, Bell RS, Vo AH, et al. WARTIME TRAUMATIC CEREBRAL VASOSPASM: RECENT REVIEW OF COMBAT CASUALTIES. *Neurosurgery* 2006;59: 1215–25.
7. Atul Gawande. Casualties of War — Military Care for the Wounded from Iraq and Afghanistan. *New England Journal Med* 2004; 351: 2471-75.
8. Shashank Joshi. A SURVEY OF INDIA'S STRATEGIC ENVIRONMENT. *Asian Affairs* 2016; 47: 234-36.

9. Breeze J, Sedman AJ, James GR, Newbery TW, Hepper AE. Determining the wounding effects of ballistic projectiles to inform future injury models: a systematic review. *J R Army Med Corps* 2014; 160:273-78.
10. Folio L, Solomon J, Biassou N, et al. Semi-automated trajectory analysis of deep ballistic penetrating brain injury. *Mil Med*. 2013. 178:338-45.
11. Stuehmer C, Blum KS, Kokemueller H, et al. Influence of different types of guns, projectiles, and propellants on patterns of injury to the viscerocranium. *J Oral Maxillofac Surg*. 2009 ; 67:775-81.
12. Kazemi H, Hashemi-Fesharaki S, Razaghi S, et al. Intractable epilepsy and craniocerebral trauma: analysis of 163 patients with blunt and penetrating head injuries sustained in war. *Injury*. 2012 ; 43:2132-35.
13. Aarabi B. History of the management of craniocerebral wounds. Aarabi B, Kaufman HH, Dagi TF, George ED, Levy ML, eds. *Missile Wounds of the Head and Neck*. Park Ridge, Ill: American Association of Neurological Surgeons; 1999;1:281-92.
14. Robert D. Ecker, et al. Outcomes of 33 patients from the wars in Iraq and Afghanistan undergoing bilateral or bi-compartmental craniectomy. *Journal of Neurosurgery* 2011; 115:124-29.
15. Gugala Z, Lindsey RW. Classification of gunshot injuries in civilians. Clin Orthop Relat Res 2003; 408: 65-81.
16. Maiden N. mechanisms of bullet wound trauma. *Forensic Sci Med Pathol*. 2009; 5:204-9.
17. Bodanapally UK, Shanmuganathan K, Boscak AR, Jaffray PM, Van der Byl G, Roy AK, et al. Vascular complications of penetrating brain injury: comparison of helical CT angiography and conventional angiography. *J Neurosurg*. 2014;121:1275-83.
18. Alisa D. Gean. *BRAIN INJURY Applications from War and Terrorism*. Philadelphia, USA: Lippincott Williams & Wilkins; 2014;1: 254-267.
19. Smith DH, Meaney DF, Shull WH. Diffuse axonal injury in head trauma. *Journal of Head Trauma Rehabilitation* 2003; 18: 307-16.
20. Tara A. Cozzarelli. Evaluation and Treatment of Persistent Cognitive Dysfunction Following Mild Traumatic Brain Injury. *Journal of Special Operations Medicine* 2010; 10: 39-42.
21. Seber N: Craniocerebral gunshotwounds. *Neurosurgery Quarterly* 2002; 12:1-18.
22. Cooper PR, Maravilla K, Cone J: Computerized tomographic scan and gunshot wound of the head: Indications and radiographic findings. *Neurosurgery* 1979; 4:373–80.
23. Yuang-Seng Tsuei, Ming-His Sun, Hsu-Dung Lee, Ming-Zer Chiang, Ching-Hsiang Leu1, Wen-Yu Cheng et al. Civilian Gunshot Wounds to the Brain. *J Chin Med* 2005;68: 126-30.
24. Chandra Sameer, Joshi H S, Joshi Gaurav, Singh Kashmir. Outcome of head injury patients based on computed tomography (CT) scan findings in a tertiary care hospital: - a cross-sectional study. *International Journal of Contemporary Medical Research* 2016;3: 610-12.
25. LD Payne Military wound ballistics: history and renaissance J R Army Med Corps, 2013;159:256–58.
26. Bizhan Aarabi, et al. Predictors of outcome in civilian gunshot wounds to the head Clinical article. *Journal of Special Operations Medicine* 2014;120: 1138-46.
27. Erdogan E, Gonul E, Seber N. Craniocerebral gunshot wounds. *Neurosurg Q* 2002; 12:1–18. Izci Y, Kayali H, Daneyemez M, Koksel T, Cerrahoglu K: The clinical, radiological and surgical characteristics of supratentorial penetrating craniocerebral injuries: A retrospective clinical study. *Tohoku J Exp Med* 2003; 201:39-46.