Surgical Neurology International

SNI: Stereotactic, a supplement to *Surgical Neurology International*

OPEN ACCESS

For entire Editorial Board visit : http://www.surgicalneurologyint.com

Image guided surgery in the management of craniocerebral gunshot injuries

Tarek Elserry, Hesham Anwer, Ignatius Ngene Esene

Department of Neurosurgery, Faculty of Medicine, Ain Shams University, Cairo, Egypt

E-mail: *Tarek Elserry - elserry@yahoo.com; Hesham Anwer - hishambando@yahoo.com; Ignatius Ngene Esene - esenengene@yahoo.co.uk
*Corresponding author

Received: 16 March 13 Accepted: 06 September 13 Published: 20 November 13

This article may be cited as:
Elserry T, Anwer H, Esene IN. Image guided surgery in the management of craniocerebral gunshot injuries. Surg Neurol Int 2013;4:S448-54.
Available FREE in open access from: http://www.surgicalneurologyint.com/text.asp?2013/4/7/448/121642

Abstract

Background: A craniocerebral trauma caused by firearms is a complex injury with high morbidity and mortality. One of the most intriguing and controversial part in their management in salvageable patients is the decision to remove the bullet/pellet. A bullet is foreign to the brain and, in principle, should be removed. Surgical options for bullet extraction span from conventional craniotomy, through C-arm-guided surgery to minimally invasive frame or frameless stereotaxy. But what is the best surgical option?

Methods: We prospectively followed up a cohort of 28 patients with cranio-cerebral gunshot injury (CCHSI) managed from January to December 2012 in our department of neurosurgery. The missiles were extracted via stereotaxy (frame or frameless), C-arm-guided, or free-hand-based surgery. Cases managed conservatively were excluded. The Glasgow Outcome Score was used to assess the functional outcome on discharge.

Results: Five of the eight "stereotactic cases" had an excellent outcome after missile extraction while the initially planned stereotaxy missed locating the missile in three cases and were thus subjected to free hand craniotomy. Excellent outcome was obtained in five of the nine "neuronavigation cases, five of the eight cases for free hand surgery based on the bony landmarks, and five of the six C-arm-based surgery.

Conclusion: Conventional craniotomy isn't indicated in the extraction of isolated, retained, intracranial firearm missiles in civilian injury but could be useful when the missile is incorporated within a surgical lesion. Stereotactic surgery could be useful for bullet extraction, though with limited precision in identifying small pellets because of their small sizes, thus exposing patients to same risk of brain insult when retrieving a missile by conventional surgery. Because of its availability, C-arm-guided surgery continues to be of much benefit, especially in emergency situations. We recommend an extensive long-term study of these treatment modalities for CCGSI.

Key Words: Bullet/pellet extraction, craniocerebral gunshot wound, craniocerebral injury, gunshot injury, neuronavigation, stereotactic surgery

Access this article online
Website: www.surgicalneurologyint.com
DOI: 10.4103/2152-7806.121642
Quick Response Code:

INTRODUCTION

A craniocerebral trauma caused by gunshot is a complex injury with a broad spectrum of symptoms and high rates of morbidity and mortality.[2,34] Gunshot wounds to the head, the most lethal of all firearm injuries, rank among the leading causes of head injury in the United States and carry a fatality rate of more than 90%, with at least two-thirds of the victims dying before reaching a hospital.[21]

A gunshot injury may result in a perforating (from high velocity) or penetrating (from low velocity) head injury. Primary and secondary brain insults are usual accompaniments and their management is often demanding.[22] The most intriguing part in the management of craniocerebral gunshot injuries (CCGSI) is the decision to remove the bullet/pellet: When, why, and how?.[11]

In considering the management of intracerebral bullets in salvageable patients, the first question that arises is that of the site of the bullet and the second is the whether the presence of the bullet is symptomatic, rendering its removal desirable. The third question is can its removal be successfully effected? The latter depends on the position it occupies. Undoubtedly, when the bullet lies at the base of the skull, its removal may be impossible.[11] Otherwise, a bullet is foreign to the brain and, in principle, it should be removed.

The GCS score on admission and the extent of brain injury as visualized by CT scan, such the presence of multilobar or skull base injuries, and the involvement of ventricles seem to be the most significant predictors of the outcome in craniocerebral gunshot wounds.[4,37]

Classically, options for removal of missiles include: Minimally invasive neuronavigation, stereotaxy and fluoroscopic procedures for localizing foreign body, centrifugation techniques,[27] the use of gravitational force,[12,16] and craniotomy for extraction.

Image-guided neurosurgical navigation (IGNN) has revolutionized brain surgery. Technology enables surgeons to view their surgical targets, visualize the overlying and underlying structures, assess the optimal surgical route, avoid critical structures, and perform minimally invasive surgery.

Using different image-guided systems, the bullet in the cranium can be reached accurately with precalculated precision from any point outside the skull. Thus, the bullet can be exposed and subsequently removed by a surgical approach with minimal discomfort and low risk. IGNN can improve surgical outcomes, particularly for complex surgeries. Benefits include greater accuracy, a smaller surgical incision, and reduced procedure times.

Conventional craniotomy increases brain damage by searching brain parenchyma for intracranial bullet, hence increasing morbidity and mortality.[23]

Image-guided surgery, by virtue of its techniques being minimally invasive, ought to be the most adopted method for bullet removal, but the questions that remain is how should the bullet be extracted?

Indications and techniques of surgery in the management of gunshot brain injuries remain a controversial subject in neurosurgery. Some authors stipulate that tract exploration and retrieval of bullet fragments is not indicated, as retained fragments carry a very low incidence of complications.[35]

Faced with this plethora of techniques, our study was thus conducted to assess the most suitable methods for the localization and extraction of retained missiles.

AIM

Our study aimed to assess the effectiveness and safety of different treatment modalities for the localization and extraction of retained cranial gunshot missiles and propose the best method for their management with a particular allusion to stereotactic extraction and the neuronavigation-based surgery.

METHODOLOGY

A prospective cohort study was conducted at our University Teaching hospitals and Health Insurance Hospital, from January 2011 to December 2011, a period of 12 months. A cohort of 28 consecutive patients who presented with CCGSI was classified into four groups after a staff discussion on the best management option per case, as shown in Table 4. They were then followed up and the outcome assessed using the Glasgow Outcome Score (GOS).[20]

All patients were assessed for patency of airway, breathing pattern, and circulatory status. A complete neurological assessment was also done. Local examination of the missile wound and examination of other systems was carried out elaborately. Resuscitative measures were initiated if the patient required respiratory support or was hemodynamically unstable. Patients having a Glasgow Coma Score (GCS) score of less than 8 were intubated and ventilated. X-ray of the skull and CT scan were done in all cases.

All patients were put on triple antibiotics: sodium penicillin + ceftriaxone + metronidazole. Parenteral phenytoin and ranitidine were also started. Mannitol and lasix were given if features of raised intracranial pressure were seen on imaging studies.

Depending on the preoperative clinical status and imaging findings, the patients were either considered for neuronavigation-guided surgery, stereotactic, C-arm guided, and/or microscopic craniotomy. Conservative management was the default treatment for patients with GCS of 3 and 4 irrespective of the associated lesion and these were not included in our study.

Stereotactic surgery was an option only for patients with retained intracerebral missiles. We used the Leksell frame with *x*, *y*, *z* Cartesian coordinates to stereotactically localize any point in 3D space for missile extraction. After localizing the intracerebral site of the missile, a conventional craniotomy was done. Thus, stereotaxy was used for localizing and extraction.

Neuronavigation-guided craniotomy was accomplished using image data acquired prior to surgery, integrated with fiducial registration as well as anatomical landmark-surface fitting. The patients underwent neuronavigation-assisted neurosurgical interventions with pointer-based navigational systems.

C-arm fluoroscopic-guided surgery

Three different brands of C-arm fluoroscopy machines were used Zeihm, GE, and Philips. C-arm fluoroscopic image-guided surgery was used in three cranial cases searching the brain parenchyma for the missile.

Free hand craniotomy

Patients selected for surgical treatment included patients with GCS ≥ 5 with a surgical CCGSI. Procedures were designed to remove foreign material (such as metal and bone fragments, dirt, hair, powder granules) and to evacuate extraaxial and intraaxial hematomas. Free hand craniotomy based on the anatomical bony landmark was adopted in cases in which emergency interference was mandatory and in centers where streotaxy or neuronavigation was not available.

Surgical details

Our target was to debride necrotic brain and soft tissue and to achieve an adequate closure of the dura and soft tissue layers. The goals were to mitigate intracranial pressure excursions, to prevent infection, and to establish a climate for maximum neurologic recovery. The operative procedure comprised debridement of the scalp wound and then “U” or “S” extension of the scalp wound depending on the requirement of the skull exposure or closure of scalp wound. A craniotomy was performed centered on the skull penetrance. The margins of the missile tract in the bone were minimally debrided. The size of the craniotomy was dictated by the underlying brain damage. A craniectomy was performed if there was extensive contamination of the skull bone or if the wound was badly contaminated as well as in cases where the site of craniotomy corresponded to the site of entry. The dural wound was completely exposed and its shredded margins trimmed. The dural opening was then enlarged with further extensions as required. Surgical techniques included, mainly, irrigation, debridement of devitalized tissues, removal of space-occupying hematoma, in-driven bone, and accessible bullet fragments. Superficial necrotic brain tissue was removed with suction and the missile tract was washed with saline using a catheter. No suction was introduced into the missile tract. Missile or bone fragments that presented themselves into the wound were picked up with forceps and removed. Hemostasis was achieved with bipolar coagulation and gel–foam or multilayer surgicel (fibrillar). The missile tract was finally washed with hydrogen peroxide and saline. The dural defect was repaired with a pericranial graft or temporal fascia to achieve a watertight closure. The bone flap was replaced and fixed with speedy-flap stables or mini plates screw system. The scalp was closed in a double or single layer with a subgaleal drain. Postoperatively, antibiotics were continued for 2 weeks and antiepileptics continued even thereafter. Cerebral decongestants (mannitol, furosemide, or glycerol) were continued as dictated by the extent of the injury. Postoperative ventilation was instituted if required. Each patient’s outcome was assessed at discharge using the GOS.

RESULTS

A total of 28 patients were included in our study; all victims of civilian firearm injury to the head. The mean time from injury to admission in the hospital was 4 ± 1.5 hours (min. 1 hour and max. 40 hours).

Sociodemographic data and ballistic characteristic

The mean age was 30.8 ± 12.8 years (min. 11 years and max. 57 years). The male-to-female sex ratio was 2.8:1.

In 25 cases (89.2%), the firearm used was reported to be a home-made gun, but details were usually not available. In 19 cases (67.9%), the missile type was a pellet [Table 1].

Clinical data

All the 28 cases presented on emergency basis to our trauma unit. The mean GCS on admission

Table 1: Sociodemographic data and ballistic characteristic

Variable	*N*=28	%
Age group		
≥50	3	10.7
<50	25	89.3
Sex		
Male	20	71.4
Female	8	28.6
Weapon		
Homemade	25	89.2
Hand gun	3	10.7
Missile		
Bullet	9	32.1
Pellet	19	67.9

was 13 ± 3.3 (min. 5 and max, 15). Most of our patients [17 cases (67.9%)] presented with mild head trauma (GCS = 14–15) and 4 patients (14.2%) presented with severe head injury (GCS ≤ 8).

Five cases (17.9%) presented with a disturbed vital status (hypotension from bleeding and airway obstruction from secretions), and all were rapidly corrected in the Emergency Room (ER).

Twelve patients (42.9%) had a neurologic deficit on admission; 13 (46.43%) with weakness, 2 (7.1%) with dysphasia (one had aphasia and weakness), and one blind because of associated ocular injury [Table 2].

Regarding the wound ballistics

The most frequent entry site was frontal in 16 cases (57.1%) [Table 3].

Imaging findings

All the 28 cases had initial CT scans (bone and soft tissue windows) and plain radiographies.

The entry site of the missile was confirmed on the CT and corresponded to the clinical entry sites [Table 3]. In 9 cases (32.1%) the missile was a bullet and in 19 cases (67.9%) it was a pellet.

Most of the missiles were retained in the temporal lobe [8 cases (28.6%)]. Interestingly, one was retained in the anterior body of the corpus callosum [Table 3].

There wasn't any predilection for the side of the retained missile. Fourteen (50%) were left. The most common associated lesions to the retained missiles were brain contusion in four cases (14.3%) and acute subdural hematoma in three cases (10.7%). One case presented with a brain abscess in the anterior body of corpus callosum [Table 3].

Treatment

The missiles were extracted using four different methods. Frameless stereotactic-guided extraction (neuronavigation) was used in 9 (32.1%) cases, frame-stereotaxy guided surgery in 8 (28.6%) cases, C-arm guided search and extraction in 3 (10.7%), and free-hand craniotomy based on anatomical land marks was used in 8 cases (28.6%) [Table 4].

The trajectory of the missile was tracked in 22 cases (78.6%), virgin track was planned in 6 cases (21.4%).

OUTCOME

The mean hospital stay was 29 ± 6 days (min. 1 day and max. 140 days). The mean duration of follow-up: 18 ± 3.5 weeks (min. 3 weeks and max. 37 weeks).

The Glasgow Outcome Score (GOS was used to assess the patients' recovery after missile extraction [Table 5]. Eighteen cases (64.3%) had a good recovery (GOS = 5) while four (7.1%) died. Disability was in the form of dysphasia in one case, motor deficit in three cases, visual

Table 2: Clinical data on admission

Variable	*n*	Percentage	Mean±S.D.
Admission GCS	28		13±3.3
Mild	19	67.9	-
Moderate	5	17.9	-
Severe	4	14.2	-
Vital status			
Disturbed	5	17.86	-
Stable	23	82.14	-
Neurologic status			
Deficit	12	42.86	-
No deficit	16	57.14	-
Entry wound			
Frontal	16	57.1	-
Parietal	2	7.1	-
Temporal	9	32.1	-
Occipital	0	0	-
Orbit	1	3.6	-

SD: Standard deviation, GCS: Glasgow coma score

Table 3: Missile location and associated lesions

Missile location	*n*	Percentage
Cranial	28	
Frontal	6	21.4
Parietal	5	17.9
Temporal	8	28.6
Occipital	6	21.4
Frontal+occipital	1	3.6
Corpus callosum	1	3.6
Cerebellum	1	3.6
Associated lesions		
Contusion	4	14.3
Acute sub-dural hematoma	3	10.7
Extra-dural hematoma	2	7.1
Contusion+edema	2	7.1
Contusion+acute sub-dural hematoma	2	7.1
Compound depressed fracture+contusion	1	3.6
Contusion+intraventricular hemorrhage	1	3.6
Brain swelling	1	3.6
Hemorrhagic contusion	3	10.7
Abscess*	1	3.6
None	8	28.6

*Patient had visited many hospitals before referral to us

Table 4: Method of missile extraction

Method of missile extraction	Frequency	Percentage
Neuronavigation	9	32.1
Stereotactic guided	8	28.6
C-Arm guided	3	10.7
Free hand craniotomy	8	28.6

impairment (left homonymous hemianopia) in one case, and aphasia plus right hemiplegia in one case.

There was no statistically significant difference in the GOS with the different treatment modalities [Table 6].

The morbidity, mortality, and infectious complication in treatment groups are as shown in Table 7.

DISCUSSION

Gunshot wounds to the head have a high morbidity and mortality. The mortality rates in the literature range from 23% to 92% and are considerably higher (87–100%) in patients admitted in a poor neurologic state.[29] The management of cerebral gunshot injuries has changed considerably since Cushing's (1916) and Matson's (1948) classification schemes, developed during World War I and World War II, respectively, from the long-time dictum of "aggressive debridement" through "conservative debridement" to now "aggressive decompression," "conservative debridement," and watertight dural closure.[18]

Looking at the question of removability of retained bullets and fragments, the study results are mixed. It had been documented that retained bullet fragments could lead to infective complications on the basis of foreign body reaction and missile migration.[41] Jamjoom *et al.* advised that removal of the missile is desirable only if easily accessible.[19] Armonda *et al.* put forth a number of criteria for removal of intracerebral fragments; namely, migrating fragment, abscess formation, contact or compression of a vessel, and symptomatic intraventricular missiles.[3] Kazim *et al.* outlined that the recent trend is toward a less aggressive debridement of deep-seated bone and missile fragments and a more aggressive antibiotic prophylaxis in an effort to improve outcomes.[23]

Table 5: Functional outcome of patient after missile extraction

Glasgow outcome score	Score	Frequency (*n*)	Percentage (%)
Good recovery	5	18	64.3
Moderate disability	4	2	7.1
Severe disability	3	4	14.3
Persistent vegetative state	2	0	0
Death	1	4	14.3

Table 6: Glasgow outcome score according to the treatment modality

Treatment modality	Glasgow outcome score				
	1	2	3	4	5
C-Arm	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)
Free hand	2 (25)	0 (0)	1 (12.5)	0 (0)	5 (62.5)
Neuronavigation	2 (22.2)	0 (0)	1 (11.1)	1 (11.1)	5 (55.6)
Stereotaxy	0 (0)	0 (0)	2 (25)	1 (12.5)	5 (62.5)

Fisher's exact=0.762 and $P>0.05$ Nonstatistically significant

Table 7: Morbidity and mortality in the treatment groups

Treatment	*n*	Mortality (%)	Total morbidity *n* (%)	Infection *n* (%)
Neuronavigation	9	2 (7.1)	2 (7.1)	0
Stereotaxy	8	0	3 (10.7)	2 (7.1)
C-arm	6	0	0 (0)	2 (7.1)
Free hand	8	2 (7.1)	1 (3.6)	1 (3.6)

In 22 cases (78.6%) of our cohort, the missile was associated with a bony or intracerebral lesion warranting an intervention. The remaining nine cases included four cases with bullets and five patients with pellets. Bullets have been described to migrate and to be coupled with the risk of infection. We therefore decided to intervene. As for the five cases with pellets having no associated lesions, we opted for extraction on the premise that the characteristics of the firearm or ammunition used or missiles were unspecified and unknown from the history. However, findings from physical examination suggested that they could have been from locally made guns (multiple small inlet wounds) with very high risk of infection. Intracerebral infections have been well documented, with retained bullet fragments on the basis of foreign body reaction and missile migration.[41] In our institutions, we routinely use triple antibiotics in line with the guidelines of the "Infection in Neurosurgery" Working Party of the British Society of Antimicrobial Chemotherapy, which recommended that for civilian CCGSI, antimicrobial prophylaxis should include broad-spectrum intravenous antibiotics.[5]

We did a CT Scan for all our cases. CT scans demonstrate the track of the missile, destruction of deep cerebral parenchyma, dissection of the white matter, and reactive edema. CT scan helps to choose the best therapeutic management in each case.[33] It also has a prognostic value, although patients with a GCS lower than 4 die regardless of their CT findings.[26]

To answer the question of how to remove the missile with minimal injury to the brain, we examined stereotactic surgery in localizing and extraction of these missiles. Stereotactic surgery for the extraction of retained intracerebral has been described as early as 1918 when it was used to localize cerebral foreign bodies.[30] Sugita *et al.*, in his article on "Successful Removal of Intracranial Air-Gun Bullet with Stereotaxic Apparatus" was a landmark paper describing the successful use of stereotaxy in CCGSI.[36] Later in 1979, Yoshijima described a case of successful removal of a deep-seated bullet in the brain by stereotaxic approach.[42] Despite these sporadic reports, the role of stereotaxy has not been defined, least its indications and outcome.

In our series, 17 cases (60.7%) had the missile localized and extracted via stereotaxy; 9 cases (32.1%) via frameless and 8 cases (28.6%) via frame stereotaxy. There was no statistically significant difference between the two modalities, although two of the nine patients who underwent neuronavigation-guided localization and extraction died.

Pellets extracted from our patients were of the range of 20 ± 5 mm and we know that stereotaxy has an accuracy in same range in getting to the target, which may explain why it missed the missile in three cases.

Stereotaxy, which is a minimally invasive form of surgery, is far from being a panacea for the extraction of retained intracerebral missiles. However, we support the idea of Vrankovic that in cases in which missile extraction is absolutely indicated, stereotaxy be used for localizing while adjuncts such as ultrasound be used for precise extraction.[39] Also with stereotactic guidance, deep-seated intraparenchymal lesions can be satisfactorily approached and removed endoscopically.[31]

Because of ready availability, C-arm-guided extraction was used in three cases with an associated lesion such as hematomas needing urgent intervention, thus evading the difficulties of bringing the stereotactic apparatus.

Free hand craniotomy was used in eight cases. All the cases had surfacing associated lesions, including the missile that was a bullet in six of the eight cases, thus making removal easy.

While conventional craniotomy is the treatment of choice for retained firearm missiles with associated operable pathologies such as fractures and underlying hematomas, its role in the extraction of retained isolated missiles remains questionable and a subject of contention because conventional craniotomy increases brain damage caused by searching brain parenchyma for intracranial bullet increasing morbidity and mortality. In our series, of the eight cases who underwent surgical extraction of the bullet, two died from meningitis 3 weeks postoperatively while the others had contralateral hemiplegia and entry wound scalp infection.

Complications of penetrating craniocerebral injuries in CCGSI can be early (during the first week after wounding) or late (after that period). Postoperative hematomas, infections, seizures, and cerebrospinal fluid fistulas (CSFFs) are counted among the early complications, whereas foreign bodies migrating intracranially, seizures, infections, and posttraumatic hydrocephalus represent late complications. Intracranially retained foreign bodies, wound age, wound site, and operations performed outside the neurosurgical services are the main risk factors for the development of complications, which exerted a very unfavorable influence on outcomes.[38] The retention of bullet and bone fragments as well as scalp and hair tissue within the cerebral substance following CCGSI often presents a management dilemma to the neurosurgeon.

With regard to infectious complications, most of the studies, especially those related to military firearms injuries, showed that surgery has higher infection rate and the nonremoval of retained missiles is not statistically associated with an additional risk. Though a few studies had incriminated intracerebral infection to be positively associated with retained missiles,[15,28,38] an avalanche of literature from old to recent reviews with both short- and long-term follow-up have proven the contrary showing no association and concluding that retained missile fragments or bone are not the usual cause for the development of intracranial infections.[1,6-9,13,17,24,25,32,40]

Admission GCS score is a valuable prognosticator of outcome. Clark *et al*. had earlier demonstrated that patients with a GCS score of 3 invariably died, with or without surgical intervention; and the presence of intracranial hematomas, ventricular injury, or bihemispheric wounding was associated with a poor outcome.[10] This has recently been corroborated by Solmaz *et al*.[34] Nonetheless, when this comparison is made with patients with a good GCS, surgery inevitably carries a higher mortality. The point whether one should operate on a patient with a GCS of < 5 or not remains debatable. Grahm *et al*. advocated no surgery for this group of patients if they have no intracranial mass lesion as the result of surgery is usually poor.[14]

We had four cases of deaths: two from severe head injury (GCS on admission = 5), respiratory failure and meningitis.

Neurosurgeons consider neuronavigation a critical surgical tool for improved patient safety, better surgical planning, greater procedure confidence, improved appreciation of complex anatomy, precise lesion localization, and increased confidence in complete tumor resection. There is a flood of studies introducing neuronavigation with or without the integration of ultrasound for a multitude of neurosurgical topics, yet surprisingly there is no introduction of the neuronavigation as a localizing virtual image, which can be a real time with the help of intraoperative CT or MRI as a tool for extraction of foreign body in the craniospinal vicinity. The neurosurgeon should therefore opt for the ever-increasing safety, efficiency, and simplicity to remove retained craniocerebral gunshot missiles using stereotaxy.

CONCLUSION

Conventional craniotomy is not indicated in the extraction of isolated retained intracranial firearm missiles in civilian injury but could be useful when the missile is incorporated within a surgical lesion.

Stereotactic surgery, though with limited precision in identifying small pellets because of their small sizes thus exposing patients to same risk of brain insult when retrieving a missile as conventional surgery could, however, be useful for bullet extraction. Because of its availability, C-arm-guided surgery continues to be of much benefit, especially in emergency situations. We recommend an extensive long-term study of these treatment modalities for CCGSI.

ACKNOWLEDGMENT

We would like to thank Dr. Ahmed Maamoun, Dr. Ahmed Hamd, Dr. Ahmed Maged, Dr. Ahmed El-Sawy, Dr. Mohamed Eid, Dr. Mohamed Abdelatey, Dr. Mohamed Helmy, Dr. Amr Galal and Dr. Mohamed Abelrahman for their assistance. We would also like to thank Prof. Dr. Emad Ghanem, Prof. Dr. Alaa Fakhr and Prof. Dr. Hossam El Husseiny for their continuous tutorship. We express our appreciation to the staff of the Department of Neurosurgery Health Insurance Hospital.

REFERENCES

1. Amirjamshidi A, Abbassioun K, Rahmat H. Minimal debridement or simple wound closure as the only surgical treatment in war victims with low-velocity penetrating head injuries. Indications and management protocol based upon more than 8 years follow-up of 99 cases from Iran-Iraq Conflict. Surg Neurol 2003;60:105-10.
2. Andrade A. Management Of gunshot injuries to the head and brain. Rev Chil Neurocirugía 2010;34:39-45.
3. Armonda RA, Bell AS, Amuel C, Alexander H Vo. Wartime Penetrating Injuries, In: Jallo J, Loftu C, editors. Neurotrauma and critical care of the brain. New York: Thieme Publishers; 2009. p. 238-53.
4. Bakir A, Temiz C, Umur S, Aydin V, Torun F. High-velocity gunshot wounds to the head: Analysis of 135 patients. Neurol Med Chir (Tokyo) 2005;45:281-7.
5. Bayston R, De LJ, Brown EM, Johnston RA, Lees P, Pople IK. Use of antibiotics in penetrating craniocerebral injuries. "Infection In Neurosurgery" Working Party of British Society for Antimicrobial Chemotherapy. Lancet 2000;355:1813-7.
6. Brandt F, Roosen K, Weiler G, Grote W. Neurosurgical management of gunshot injuries to the head. Neurochirurgia (Stuttg) 1983;26:164-71.
7. Brandvold B, Levi L, Feinsod M, George ED: Penetrating craniocerebral injuries in the Israeli involvement in The Lebanese Conflict, 1982-1985. Analysis of a less aggressive surgical approach. J Neurosurg 1990;72:15-21.
8. Cairns H. Gunshot head wounds in the acute stage. Br Med J 1944;1:33-7.
9. Carey ME, Young H, Mathis JL, Forsythe J. A bacteriological study of craniocerebral missile wounds from Vietnam. J Neurosurg 1971;34:145-54.
10. Clark WC, Muhlbauer MS, Watridge CB, Ray MW. Analysis of 76 civilian craniocerebral gunshot wounds. J Neurosurg 1986;65:9-14.
11. Drew D. Bullet wound of the motor region of the brain: Bullet retained: Successful extraction. Br Med J 1902;1:138-9.
12. Jefferson G. Removal of a rifle bullet from the right lobe of the cerebellum; Illustrating the spontaneous movement of a bullet in the brain. Br J Surg 1917;5:422-4.
13. Gonul E, Baysefer A, Kahraman S, Ciklatekerlioglu O, Gezen F, Yayla O, *et al.* Causes of infections and management results in penetrating craniocerebral injuries. Neurosurg Rev 1997;20:177-81.
14. Grahm TW, Williams FC Jr, Harrington T, Spetzler RF. Civilian gunshot wounds to the head: A prospective study. Neurosurgery 1990;27:696-700.
15. Hagan RE. Early complications following penetrating wounds of the brain. J Neurosurg 1971;34:132-41.
16. Hanieh A. Brain injury from a spent bullet descending vertically. Report of five cases. J Neurosurg 1971;34:222-4.
17. Hecimovic I, Dmitrovic B, Kurbel S, Blagus G, Vranes J, Rukovanjski M. Intracranial infection after missile brain wound: 15 war cases. Zentralbl Neurochir 2000;61:95-102.
18. Jallo J, Loftus CM. Neurotrauma and critical care of the brain. New York: Thieme Publishers; 2009.
19. Jamjoom AB, Rawlinson JN, Clarke PM. Airgun injuries of the brain. Injury 1989;20:344-6.
20. Jennett B, Bond M. Assessment of outcome after severe brain damage. Lancet 1975;1:480-4.
21. Karch DL, Logan J, Patel N. Surveillance for violent deaths--National Violent Death Reporting System, 16 States, 2008. MMWR Surveill Summ 2011;60:1-49.
22. Kaufman HH. Civilian gunshot wounds to the head. Neurosurgery 1993;32:962-4.
23. Kazim SF, Shamim MS, Tahir MZ, Enam SA, Waheed S. Management of penetrating brain injury. J Emerg Trauma Shock 2011;4:395-402.
24. Kim TW, Lee JK, Moon KS, Kwak HJ, Joo SP, Kim JH, *et al.* Penetrating gunshot injuries to the brain. J Trauma 2007;62:1446-51.
25. Levi L, Borovich B, Guilburd JN, Grushkiewicz I, Lemberger A, Linn S, *et al.* Wartime neurosurgical experience in Lebanon, 1982-85. I: Penetrating Craniocerebral Injuries. Isr J Med Sci 1990;26:548-54.
26. Mancuso P, Chiaramonte I, Passanisi M, Guarnera F, Augello G, Tropea R. Craniocerebral gunshot wounds in civilians. Report on 40 cases. J Neurosurg Sci 1998;32:189-94.
27. Markham JW, Stein S, Pelligra R, Lippe P, Noyes J. Use of centrifuge in the treatment of an intraventricular metallic foreign body. Technical Note. J Neurosurg 1971;34:800-4.
28. Martin J, Campbell EH Jr. Early complications following penetrating wounds of the skull. J Neurosurg 1946;3:58-73.
29. Martins RS, Siqueira MG, Santos MT, Zanon-Collange N, Moraes OJ. Prognostic factors and treatment of penetrating gunshot wounds to the head. Surg Neurol 2003;60:98-104.
30. Mcfadden JT. Stereotactic localization of cerebral foreign bodies. Va Med Mon (1918) 1970;97:336-9.
31. Mohanty A, Manwaring K. Endoscopically assisted retrieval of an intracranial air gun pellet. Pediatr Neurosurg 2002;37:52-5.
32. Rish BL, Caveness WF, Dillon JD, Kistler JP, Mohr JP, Weiss GH. Analysis of brain abscess after penetrating craniocerebral injuries in vietnam. Neurosurgery 1981;9:535-41.
33. Shoung HM, Sichez JP, Pertuiset B. The early prognosis of craniocerebral gunshot wounds in civilian practice as an aid to the choice of treatment. A series of 56 cases studied by the computerized tomography. Acta Neurochir (Wien) 1985;74:27-30.
34. Solmaz I, Kural C, Temiz C, Secer HI, Duz B, Gonul E, *et al.* Traumatic brain injury due to gunshot wounds: A single institution's experience with 442 consecutive patients. Turk Neurosurg 2009;19:216-23.
35. Suddaby L, Weir B, Forsyth C. The management of .22 caliber gunshot wounds of the brain: A review of 49 cases. Can J Neurol Sci 1987;14:268-72.
36. Sugita K, Doi T, Sato O, Takaoka Y, Mutsuga N, Tsugane R. Successful removal of intracranial air-gun bullet with stereotaxic apparatus. J Neurosurg 1969;30:177-81.
37. Tsuei YS, Sun MH, Lee HD, Chiang MZ, Leu CH, Cheng WY, *et al.* Civilian gunshot wounds to the brain. J Chin Med Assoc 2005;68:126-30.
38. Tudor M, Tudor L, Tudor KI. Complications of missile craniocerebral injuries during the Croatian homeland war. Mil Med 2005;170:422-6.
39. Vrankovic D, Hecimovic I, Splavski B, Dmitrovic B. Management of missile wounds of the cerebral dura mater: Experience with 69 cases. Neurochirurgia (Stuttg) 1992;35:150-5.
40. Vrankovic D, Hecimovic I, Splavski B, Dmitrovic B. Management of missile wounds of the cerebral dura mater: Experience with 69 cases. Neurochirurgia (Stuttg) 1992;35:150-5.
41. Wood EH Jr. The diagnostic significance of change in position of metallic foreign bodies in brain abscess. Am J Roentgenol Radium Ther 1947;58:52-8.
42. Yoshijima S, Murayama Y, Matsumoto K. A case of successful removal of a deep-seated bullet in the brain by stereotaxic approach (Author's Transl)]. No Shinkei Geka 1979;7:989-94.