Managing military penetrating brain injuries in the war zone: lessons learned

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OBJECTIVE Managing penetrating military brain injuries in a war zone setting is different than managing common civilian penetrating brain injuries. Triage, i.e., deciding on which patients to treat or not treat, and which to be flown back home, is essential to avoid wasting valuable limited resources. In this study the authors aim to identify reliable predictors of mortality and poor outcome to help develop a protocol for treating their patients in the battlefield. They also demonstrate all the lessons learned from their collective experience regarding some of the controversial management issues.

METHODS This study was a retrospective review of 102 patients with penetrating military missile head injuries treated by the authors in various facilities in northern Sinai between 2011 and 2018. Patient demographics, clinical characteristics, imaging characteristics, postoperative complications, and Glasgow Outcome Scale (GOS) scores were recorded for each patient. Several variables associated with mortality and poor outcome that were derived from the literature were analyzed, in addition to variables obtained by direct observation by the authors over time.

RESULTS There were 50 patients (49%) with GOS score of 1 (death), 12 patients (11.8%) with GOS score of 2 (survivors in persistent vegetative state), and 40 survivors (39.2%) with varying degrees of disability on the last follow-up evaluation. The authors identified an anatomical danger zone that was found to predict mortality when traversed. Bilateral dilated fixed pupils and low Glasgow Coma Scale score on admission were also found to be independent predictors of mortality and poor outcome. Based on these findings, a protocol was developed for managing these patients in the war zone.

CONCLUSIONS Managing military penetrating head injuries in the war zone is different than civilian gunshot head injuries encountered by most neurosurgeons in urban cities. The authors developed a simple protocol for managing military penetrating injuries in the war zone. They also describe important lessons learned from this experience.

<https://thejns.org/doi/abs/10.3171/2018.8.FOCUS18371>

KEYWORDS military neurosurgery; penetrating brain injuries; bullet injuries; danger zone

SINCE the Egyptian revolution in 2011, the Sinai Peninsula has witnessed an insurgency that led to the undertaking of multiple military operations by the Egyptian army against terrorism. Starting in 2011 with Operation Eagle, these operations continued throughout the years until the present time. Security conditions started improving in 2018 with a major campaign, i.e., Comprehensive Operation Sinai, which has wiped out most of the militant strategic locations. Inevitably, Egyptian neurosurgeons accumulated tremendous experience dealing with military-grade penetrating head injuries.

Managing penetrating military injuries in a war zone setting is different than managing the common civilian penetrating brain injuries that we usually encounter in our practice due to a variety of factors:^{3,4,7,8} 1) technical factors

(missile caliber and velocity); 2) lack of sophisticated medical facilities in a war zone; 3) lack of equipment and supplies; and 4) lack of sufficient medical personnel and experienced neurosurgeons on site. The general rule in medical practice is to treat every human soul and as physicians we have an ethical obligation to do this. In a war zone, however, with such poor conditions, important decisions have to be made. Having a treatment protocol and algorithm is a must to avoid wasting valuable limited resources. Such a protocol will help triage, that is, deciding whom to treat or not treat, and whom to fly back home. Deciding if a patient will be treated or not is a nightmare for any neurosurgeon, as we are perfectionists and accustomed to doing the best for our patients no matter the conditions. Without evidence-based guidelines, such decisions become ethical

ABBREVIATIONS GCS = Glasgow Coma Scale; GOS = Glasgow Outcome Scale.

SUBMITTED July 25, 2018. **ACCEPTED** August 20, 2018.

INCLUDE WHEN CITING DOI: 10.3171/2018.8.FOCUS18371.

TABLE 1. Demographics

Variable	No. of Patients (%)
Sex	
Female	2 (2.0)
Male	100 (98.0)
Age (yrs)	
10–20	16 (15.7)
21–30	76 (74.5)
31–40	6 (5.9)
41–50	2 (2.0)
51–60	2 (2.0)
Mean age $\pm$ SD	25 $\pm$ 1.8
Admission GCS score	
3–5	37 (36.3)
6–12	32 (31.4)
13–15	33 (32.3)
Type of hospital	
Inside war zone	41 (40.2)
Civilian hospital	61 (59.8)
Type of injury	
Bullet	60 (58.8)
Blast	42 (41.2)
Entry wound	
Frontal	27 (26.5)
Temporal	17 (16.7)
Parietal	22 (21.6)
Occipital	13 (12.7)
Posterior fossa	12 (11.8)
Face	11 (10.8)
Surgical procedures	
None	28 (27.4)
Debridement	70 (68.6)
Hematoma evacuation	22 (21.6)
Bullet extraction	47 (46.1)
Decompressive craniotomy	18 (17.6)
GOS score	
1	50 (49.0)
2	12 (11.8)
3	18 (17.6)
4	10 (9.8)
5	12 (11.8)
Median FU $\pm$ SD (range), mos	17 $\pm$ 3.2 (3–27)

FU = follow-up.

dilemmas, especially with an inexperienced young neurosurgeon in the field. Moreover, in those whom we decide to treat, certain surgical and management controversies arise, such as indications of decompressive craniectomy,^{3,7,11} bone reconstruction,¹¹ dural closure,^{2,11} and indications to extract bullets.^{2,8,9}

The authors of this paper have a collective experience of treating more than 100 patients with military missile

head injuries since 2010, managed in various war zone medical facilities. In this study, a retrospective review of these patients aided by guidelines from the literature has led to the identification of reliable predictors of mortality and poor outcome and thus assistance in deciding which patients to treat and how to treat them in the battlefield. We also demonstrate all the lessons learned from our collective experience regarding some of the previously stated controversial management issues.

Methods

This is a retrospective review of 102 patients with penetrating military missile head injuries treated by the authors in various war zone facilities in northern Sinai between 2011 and 2018. Patients with extracranial penetrating injuries were excluded from the study as they may affect the outcome and survival. Patient demographics, clinical characteristics, imaging characteristics, missile trajectories and paths, and surgical data were recorded for each patient. Glasgow Coma Scale (GCS) scores were obtained and recorded at admission and before and after the initial resuscitation; however, for our analysis, we decided to define the term “admission GCS score” as the postresuscitation GCS score. During the hospital stay, GCS score continued to be recorded as part of our hourly neurological examinations until the patient’s condition improved and he or she was discharged home or to a rehabilitation center. Glasgow Outcome Scale (GOS) score was recorded at the point of discharge, and subsequently during follow-up clinic visits at 1 month, 3 months, and then 6-month intervals. Our primary outcome measure was the GOS score at the 1-year follow-up or the last available follow-up visit. Secondary outcome measures were all the complications that occurred in our patients during the hospital stay and after discharge, up to the last follow-up available.

The variables studied in order to identify the predictors of mortality for penetrating military head injuries were mainly derived from the literature,^{1,5,6,10} in addition to direct observation by the authors over time, who are all experts in the field of military head injuries.

SPSS software (version 20, IBM Corp.) was used for statistical analysis. Data were presented as mean and range for numerical variables (e.g., age) and as frequency for categorical variables (sex, GCS score, complications, etc.). Mortality and poor outcome in our study were defined as GOS score 1 and 2, respectively. In the univariate analyses the chi-square test, Fisher’s exact test, and Student t-test were used to identify variables associated with mortality. Any variable with a p value < 0.10 was included in a forward stepwise logistic regression model to determine the independent predictors of mortality. These predictors were used to develop a protocol for management.

Results

Study Population

The study population and demographics are listed in Table 1. Of the 102 patients included in this study, the mean age was 25 years. There were only 4 patients over 40 years old, and these were civilians who were shot during

TABLE 2. Complications in survivors (GOS score 2–5)

Complication	No. of Patients (%)
CSF leakage*	3 (5.8)
Infection	9 (17.3)
Brain abscess	2 (3.8)
Meningitis	3 (5.8)
Wound infection	4 (7.7)
Disability	
GOS 2 (vegetative)	12 (23.1)
GOS 3	18 (34.6)
GOS 4	10 (19.2)
GOS 5	12 (23.1)
Epilepsy	11 (21.1)
Hydrocephalus	13 (25.0)
Pseudoaneurysm	3 (5.8)
Lead toxicity	0 (0)

* All cases of CSF leakage were due to underlying hydrocephalus and were treated with CSF diversion.

terrorist attacks. There were 100 males and only 2 females, a common pattern in penetrating military injuries. The brain injuries in 60 patients were bullet-related while 42 were blast injuries from various explosive devices. Forty-one patients were managed in a warzone medical facility, while 61 were only resuscitated in the war zone and then transferred for management in a nearby civilian hospital in the Sinai cities. Admission GCS score (postresuscitation) was categorized into 3 groups, in which 37 patients presented with scores of 3–5, 32 presented with scores of 6–12, and 33 presented with scores of 13–15. There were 50 patients (49%) with a GOS score of 1 (death), 12 patients (11.8%) with a GOS score of 2 (survivors in persistent vegetative state), and 40 survivors (39.2%) with varying degrees of disability on the last follow-up (Table 2). The GOS scores of these patients according to their admission GCS score are listed in Table 3. The follow-up period ranged from 3 to 27 months. Seventy-four patients had undergone a surgical procedure,⁹ including one or a combination of debridement, bullet extraction, hematoma evacuation, and/or decompressive craniotomy, while 28 patients had no surgical intervention (other than cleaning of wounds and simple suturing of a scalp wound). Those 28 patients had either one or more of the following scenarios: 1) one or more foreign objects from a blast injury,

but of very tiny size and in deep and/or inaccessible locations, so we decided to leave them and only do simple skin debridement and closure; 2) a high risk of mortality and poor outcome, which discouraged us from operating on them; and 3) a traversing bullet or explosive fragment, with an inlet and exit (no retained foreign body) and no other surgical conditions.

Complications in Survivors

There were 52 survivors in this study (GOS score 2–5). Table 2 lists all the complications that occurred on the last follow-up. Of the 52 survivors, there were 12 patients (23.1%) in a persistent vegetative state who never improved. There were 3 patients (5.8%) with CSF leakage from their wounds, which in all 3 cases was due to hydrocephalus and treated with CSF diversion. Various CNS infections such as meningitis, brain abscess, and deep wound infections occurred in 9 patients (17.3%) and were all treated surgically. Eleven patients (21.1%) continued to have epilepsy and needed long-term antiepileptic therapy. Lead toxicity did not occur in any of our patients with retained fragments.

Variables for Mortality

The variables for mortality were chosen based on previously analyzed variables in the literature,^{1,5,6,10} in addition to our own personal observations. For our initial univariate analysis, we included 8 patient-related variables and 10 imaging-related (CT scan) variables (Table 4). One of the imaging-related variables (danger zone) was a direct observation by our team during the period of the study in which we found that there is a certain midline zone that when traversed will almost always cause mortality or poor outcome. This zone was named the “danger zone” (Fig. 1). It is worth noting that all previously described mortality zones in the literature, such as the posterior fossa⁵ and zona fatalis,² were also found to lie within our discovered danger zone.

On univariate analysis, patient-related variables that were found to affect outcome were: admission GCS score, bilateral dilated fixed pupils, hypotension on admission, and diabetes insipidus. Age, sex, and wound entry point did not show statistical significance (Table 4). Imaging-related factors that had a significant association with outcome were: fragments or bullets traversing the danger zone, zona fatalis, posterior fossa, or XYZ planes; and tram track appearance on CT scans (tram track sign is a track of hypodensity surrounded by 2 hyperdense lines and was described by Rosenfeld et al.⁸). Intracerebral

TABLE 3. Relationship between GCS score on admission and GOS score at last follow-up

GCS Score	GOS Score					Total
	1 (Death)	2 (Vegetative)	3 (Severe Disability)	4 (Moderate Disability)	5 (Mild or No Disability)	
3–5	29 (78.3%)	6 (16.2%)	1 (2.70%)	1 (2.70%)	0 (0%)	37 (100%)
6–12	16 (50%)	6 (18.75%)	3 (9.38%)	3 (9.38%)	4 (12.5%)	32 (100%)
13–15	5 (15.15%)	0 (0%)	14 (42.42%)	6 (18.18%)	8 (24.24%)	33 (100%)
Total	50	12	18	10	12	102

TABLE 4. Univariate analysis of patient-related and imaging-related variables

Variable	Death or Vegetative/Total	p Value
Patient variables		
Age (yrs)		
10 to <20	12/16	0.231
20 to <30	42/76	0.133
30 to <40	4/6	0.612
40 to <50	2/2	0.081
50 to 60	2/2	0.142
Sex		
Male	61/100	0.093
Female	1/2	
Admission GCS score		
3–5	35/37	0.013
6–12	22/32	
13–15	5/33	
Pupils		
Reactive	1/21	
Unilateral dilated	10/30	
Bilateral dilated fixed	49/51	0.004
Wound entry point		
Frontal	10/27	0.744
Temporal	8/17	0.112
Parietal	17/22	0.532
Occipital	9/13	0.861
Posterior fossa	12/12	0.016
Face	5/11	0.443
Hypotension on admission (SBP <90)	39/46	0.037
Diabetes insipidus	18/22	0.024
Meningitis	0/3	0.511
Imaging variables		
Intraventricular hemorrhage	20/32	0.621
Bullet traversing zona fatalis	7/7	0.002
Trajectory crossing XYZ planes*	9/9	0.001
Midline shift >10 mm	11/31	0.188
Compressed basal cisterns	39/61	0.262
Large ICH >30 cm ³	17/29	0.082
SAH	38/68	0.139
Tram track sign†	16/21	0.042
Trajectory crossing posterior fossa	17/18	0.005
Danger zone	40/41	0.001

ICH = intracerebral hemorrhage; SAH = subarachnoid hemorrhage; SBP = systolic blood pressure.

Boldface type indicates statistical significance. GCS score on admission, pupils, hypotension, and diabetes insipidus were significantly associated with mortality and poor outcome. For the imaging variables, zona fatalis, trajectory crossing XYZ plane, and posterior fossa trajectory were significantly associated with outcome. Our danger zone also significantly affected outcome (which includes the previous 3 zones topographically).

* Refers to a single fragment that crosses the coronal, sagittal, and axial planes.

† Tram track sign is a track of hypodensity surrounded by two hyperdense lines and was found to be significant as well.

FIG. 1. Upper: Coronal MRI showing the lateral confines of the danger zone. A line extending through the uncus and claustrum bound the zone laterally. **Lower:** Danger zone on sagittal MRI (blue box). The boundaries of this zone are the cingulate gyrus superiorly, body of C2 inferiorly, tentorium and posterior fossa posteriorly, and the anterior commissure anteriorly. As illustrated, the zona fatalis (small red cross) and the posterior fossa (large red cross) lie within the confines of the danger zone.

hematoma, basal cistern compression, midline shift, and subarachnoid hemorrhage had no significant relationship with outcome (Table 4).

When these factors were included in further multivariate analysis (Table 5), the only factors that were found to be significantly associated with mortality and poor outcome were: 1) zona fatalis, 2) posterior fossa trajectory, 3) trajectories crossing the XYZ planes, 4) crossing the danger zone, 5) low admission GCS score (3–6), and 6)

bilateral dilated fixed pupils. Because factors 1, 2, and 3 are components of factor 4 (danger zone), both anatomically and statistically, we decided to use only the danger zone in our analysis and clinical use, as it makes no sense to describe each of them separately when there is a zone that incorporates all of them. Figure 2 illustrates some of our interesting cases.

Based on this previous analysis, we have developed a simple protocol for selecting the best option for treatment in an efficient, time- and cost-effective way (Fig. 3).

Discussion

Numerous literature reviews and studies have identified predictors for mortality in gunshot injuries;^{1,5,6,10} however, this study is unique because it only identifies military head injuries. Military injuries are usually caused by large-caliber bullets and usually cause more extensive injuries than handguns. Also, there are blast injuries from explosive devices and hand grenades that are usually not seen in civilian injuries. Most studies to date mainly addressed a combination of civilian and military injuries and thus were not specific to military-grade weaponry. The significance of this can be demonstrated in the study by Gressot et al.⁵ that elegantly identified and developed a scoring system for mortality in penetrating missile head injuries, in which scores > 2 indicated a 75% chance of mortality. Because injuries in the previous study were both civilian and military injuries, we could not use its scoring system in our series of solely military injuries. In our series, this scoring system will need to be adjusted for a lower threshold for mortality as most of our patients with scores of 1 and 2 would actually have a poor prognosis due to more extensive injuries compared with civilian injuries. This highlights the importance of treating military-grade injuries as a separate entity.

A number of fatal zones have been described in the literature, such as the zona fatalis,⁶ posterior fossa,⁵ and XYZ planes.⁸ Bullets traversing these zones were significantly associated with mortality. The issue here, however, is that most of the studies were again describing penetrating brain injuries in a general sense and were not specific to the more extensive military-grade injuries. Because our study was only addressing large-caliber machine gun injuries and explosive devices, these fatal zones do not apply here and obviously need to be broader and bigger. We were able to identify a broader zone (i.e., the danger zone) that when traversed (Fig. 1), will almost always lead to a poor outcome; 40 of 41 victims with projectiles traversing this zone died or remained in a persistent vegetative state. The projectile in the only patient who survived was a tiny pellet from an explosive device traversing his posterior fossa. He survived and his GOS score was 3 on last follow-up. Our results showed that all previously described fatal zones in the literature lie within the danger zone, further supporting the significance of these zones in the literature. Projectiles passing outside this danger zone, even when crossing the midline, were not found to significantly related to mortality or bad outcomes in our series. Of the 61 victims in whom their projectiles did not traverse the danger zone, only 22 (36%) died or had a bad outcome.

TABLE 5. Multivariate analysis of variables associated with mortality

Variable	Multivariate p Value
Danger zone*	0.001
Zona fatalis	0.006
Posterior fossa trajectory	0.014
Trajectory crossing XYZ planes	0.003
GCS score 3–5	0.012
Bilateral dilated fixed pupils	0.031
Hypotension on admission	0.283
Diabetes insipidus	0.151
Tram track sign	0.082

Boldface type indicates statistical significance. Danger zone, bilateral dilated fixed pupils, and GCS score 3–6 on admission were the only factors significantly associated with mortality and poor outcome.

* The zona fatalis, posterior fossa, and XYZ plane intersection were found to be significantly associated with mortality. All 3 zones lie within the danger zone. When the danger zone is analyzed on its own, it is also a significant variable of mortality.

The other 2 variables that were significantly related to mortality in military head injuries were persistent bilateral dilated fixed pupils and low GCS score (3–6) on presentation. It is worth mentioning that these 2 variables do not lead to a 100% mortality rate, unlike the danger zone. Bilateral fixed pupils can be caused by severe hypotensive shock, and can often be reversed if the patient is quickly resuscitated. The presence of these variables alone does not preclude treatment. Based on these findings we have developed a protocol for treatment of military penetrating injuries in the warzone setting (Fig. 3). The protocol also helps identify patients who need to be transferred from the field hospital to a more sophisticated medical facility or flown back home.

It is thus important to emphasize that our protocol of management and deciding whom to treat, based on our identified predictors of mortality, is only applicable in military-grade injuries, and more importantly when treatment is in a warzone medical facility. If such injuries occurred by any chance near a large civilian hospital where supplies and personnel are adequate, then our duty is to treat everyone, and this protocol will not be applicable in this situation.

Lessons Learned

Based on the previous analysis, there are 3 variables that were directly related to mortality in military penetrating injuries. The presence of these 3 variables in a patient presenting in the war field will have an almost 100% poor outcome. The general rule obviously is to treat everyone and do our best, but in the war field where facilities are limited and mass casualties are common, it makes sense to choose whom to treat. Thus, from our experience, any patient presenting with a GCS score of 3–6 with a bilateral dilated fixed pupil and bullet trajectory crossing the danger zone is better left untreated (Fig. 2). Our protocol is described in Fig. 3 and also helps in selecting the best option for treatment in an efficient, time- and cost-effective way.

FIG. 2. **A:** Sagittal CT scan of a 15-year-old male victim shot accidentally. Bullet is shown resting at the foramen magnum. The patient presented with a GCS score of 3, lost brainstem reflexes, and died after 48 hours. **B:** Coronal CT scan of a 26-year-old male victim. The bullet trajectory can be seen passing through the danger zone. The patient died within days in the intensive care unit. **C and D:** Axial CT scans, 2 days apart, of one of our first patients in the series, a 22-year-old male victim. The scans show a bullet migrating from the right parietooccipital region to a midline intraventricular location. We have learned to immediately extract large-caliber bullets as early as possible to prevent such complications.

We seldom perform a watertight dural closure in these patients due to the time factor. CSF leakage, however, occurred in only 3 patients and was found to be from hydrocephalus in all 3. We suspect this to be from the heat of the missile causing gliosis and fibrosis in the brain tract and arachnoid. Although we still have no proof of this theory and previous reports¹¹ emphasized its importance, the fact remains that CSF leakage almost never occurred in our patients and when it did, it was usually from hydrocephalus. A watertight dural closure is thus not required from our experience.

In patients in whom decompressive craniectomy is indicated,^{3,7} or aggressive bone debridement is performed, we cover the brain and dura with an extra layer of temporalis fascia, fascia lata, or any thick reinforcing layer. These patients will require future cranioplasty and reconstruction, so these layers will prevent the brain from being directly in contact with the skin and will aid in the surgical dissection of the skin from the brain during the future cranioplasty surgery.

Decompressive craniectomy was performed in 18 patients and 10 survived to the last follow-up evaluations, requiring future cranioplasty. In addition, 14 other patients were aggressively debrided and had large defects also requiring future cranioplasty. These 24 surviving patients underwent cranioplasty 8–12 months later with bone cement, titanium mesh, or their own bone flap implanted in the abdomen with no infection or complications thus far. It appears that 8–12 months is optimal timing for performing cranioplasty and avoiding complications from too early or too late operations. This timing is also consistent with the study by Stephens et al.,¹¹ who performed 108 cranioplasties and had a 12% infection rate, most of them occurring in the time frame of 6–9 months. Further study is necessary to determine whether this timing can be generalized to all populations.

Infection occurred in 17% of the survivors (9 patients), proving to be a not uncommon complication after penetrating military injuries in our series. Of the 9 patients, only 1 patient had a bullet injury while the other 8 had blast in-

FIG. 3. Suggested protocol for managing military penetrating brain injuries in the war zone. Asterisk (*) = perform emergency surgical procedures, such as hemorrhage evacuation or decompressive craniectomy, promptly before transfer because these cannot wait until the patient is transferred. Caret (^) = the few victims with this specific scenario who survived became vegetative with the exception of only 1 patient. This patient in our series suffered his injury from a small pellet from an explosive device. On last follow-up his GOS score was 3. Dollar sign (\$) = this scenario did not occur in our series.

injuries from nails and other foreign bodies. We have thus learned to take infection more seriously in blast injuries and administer (intravenous) antibiotics for 2 weeks followed by oral therapy for another 2 weeks. We tried this protocol on the last 11 patients with blast injuries in the series and none of them have developed an infection of any kind so far. Moreover, we recommend aggressively debriding any superficial fragments or loose bone in any military-grade penetrating injury given the high incidence of infection.

In case they are chosen for treatment, patients with large-caliber missile injuries (such as AK-47 7.62 × 39-mm bullets) must have their bullets extracted as soon as possible in the war zone hospital if feasible. Unlike small-caliber 9-mm bullets, these bullets tend to migrate easily because of their heavy weight (Fig. 2), so it is advisable to extract them immediately and not delay the procedure until the patient is flown back home.

The most important limitation of this study is its retrospective nature. Future prospective studies are needed to implement this protocol and continue with its development and upgrading.

Conclusions

Managing penetrating military injuries in a war zone setting is different than managing the common civilian penetrating brain injuries that we usually encounter in our practice. We identified 3 predictors of mortality and poor

outcome and used them to develop a simple protocol for managing military penetrating injuries in the war zone. We also describe important lessons learned from this experience.

Acknowledgments

We thank the medical personnel and staff of Hospitals in Northern Sinai for their support and care for our patients. We also wish to express our gratitude for the Egyptian army soldiers and physicians who continue to sacrifice their lives to defend our freedom and values in the war against terrorism.

References

1. Aarabi B, Tofghi B, Kufera JA, Hadley J, Ahn ES, Cooper C, et al: Predictors of outcome in civilian gunshot wounds to the head. *J Neurosurg* **120**:1138–1146, 2014
2. Agarwalla PK, Dunn GP, Laws ER: An historical context of modern principles in the management of intracranial injury from projectiles. *Neurosurg Focus* **28**(5):E23, 2010
3. Bell RS, Mossop CM, Dirks MS, Stephens FL, Mulligan L, Ecker R, et al: Early decompressive craniectomy for severe penetrating and closed head injury during wartime. *Neurosurg Focus* **28**(5):E1, 2010
4. Bell RS, Vo A, Neal C, Tigno J, Roberts R, Mossop C, et al: Military traumatic brain and spinal column injury: a 5-year study of the impact blast and other military grade weaponry on the central nervous system. *J Trauma* **66** (4 Suppl):S104–S111, 2009

5. Gressot LV, Chamoun RB, Patel AJ, Valadka AB, Suki D, Robertson CS, et al: Predictors of outcome in civilians with gunshot wounds to the head upon presentation. **J Neurosurg** **121**:645–652, 2014
6. Kim KA, Wang MY, McNatt SA, Pinsky G, Liu CY, Giannotta SL, et al: Vector analysis correlating bullet trajectory to outcome after civilian through-and-through gunshot wound to the head: using imaging cues to predict fatal outcome. **Neurosurgery** **57**:737–747, 2005
7. Ragel BT, Klimo P Jr, Martin JE, Teff RJ, Bakken HE, Armonda RA: Wartime decompressive craniectomy: technique and lessons learned. **Neurosurg Focus** **28**(5):E2, 2010
8. Rosenfeld JV, Bell RS, Armonda R: Current concepts in penetrating and blast injury to the central nervous system. **World J Surg** **39**:1352–1362, 2015
9. Sakr S, Azzazi A, Elsayed A, Fathalla H: Surgical management of penetrating intracranial bullet injuries. **Neurosurg Q** **26**:37–41, 2016 2014
10. Smith JE, Kehoe A, Harrison SE, Russell R, Midwinter M: Outcome of penetrating intracranial injuries in a military setting. **Injury** **45**:874–878, 2014
11. Stephens FL, Mossop CM, Bell RS, Tigno T Jr, Rosner MK, Kumar A, et al: Cranioplasty complications following wartime decompressive craniectomy. **Neurosurg Focus** **28**(5):E3, 2010

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Fathalla, El-Fiki. Acquisition of data: Ashry. Analysis and interpretation of data: all authors. Drafting the article: Fathalla. Critically revising the article: Fathalla, El-Fiki. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Fathalla. Statistical analysis: Fathalla. Administrative/technical/material support: Ashry. Study supervision: Fathalla, El-Fiki.

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