The Impact of Blast Implosions and Bullet Injury on Maxillary Air Sinus

Ahmed Fadhel Al-Quisi, BDS, FIBMS,†* *Auday M. Al-Anee, BDS, FIBMS,*‡* *and Abbas Sabah Mohammed, BDS, HDD*§*

Background: Successive waves and generations of terrorists attacked the Iraqis in the years following the fall of the regime in Iraq in 2003, after the US invasion of the country under the pretext of weapons of mass destruction. Hence, the Iraqi people enrolled in ongoing war with these armed groups which led to massive casualties due to blasts and missile injuries.

Mechanism of blasts injury can be classified into primary, secondary, tertiary, and quaternary. While bullet injuries can be classified into low and high-energy injuries, the type and severity of the injury will influence the type of management, together with facilities available in the authors' hospitals.

In this study the authors aim to compare between the effects of blast implosions and penetrating missiles on the maxillofacial air containing cavities, specifically the maxillary sinuses.

Patients and methods: Twenty-eight patients (26 male patients [92.85%] and 2 [7.14%] female patients) with maxillary sinus wall fractures were admitted to the authors' maxillofacial surgery Department in the Hospital of specialized surgeries/Baghdad Medical city from July 2014 to November 2016.

Results: Seventy-six percent of the total bullet injuries affect the left side of the face, while shell injuries tend to affect the right side of the face by 60% than the left side.

Direct maxillary sinus injuries constitute 76.9% of the injuries caused by bullets, while it constitutes only 40% of shell injuries.

Conclusion: Bullet injuries are associated with more severe comminuted fractures in addition to involvement of multiple neighboring bones and this may lead to extensive bone loss, while postoperative complications and infection are more common with improvised explosive devices injuries.

Key Words: Blast, bullets, maxillary sinus

(*J Craniofac Surg* 2019;30: 1441–1443)

From the *Oral and Maxillofacial Department, College of Dentistry, Baghdad University; †Al-Kindy Teaching Hospital; ‡Al-Shaheed Gazi Al-Hariri Teaching Hospital, Medical City; and §Almaamun Dental Care Center, Baghdad, Iraq.

Received October 23, 2018.

Accepted for publication December 22, 2018.

Address correspondence and reprint requests to Ahmed Fadhel Al-Quisi, BDS, FIBMS, Lecturer in Oral and Maxillofacial Department, College of Dentistry, Baghdad University, Baghdad, Iraq. Oral and Maxillofacial surgeon at Al-Kindy Teaching Hospital, Baghdad, Iraq; E-mail: ahmedquisi@Gmail.com

The authors report no conflicts of interest.

Supplemental digital contents are available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.jcraniofacialsurgery.com).

ISSN: 1049-2275

DOI: 10.1097/SCS.0000000000005354

Successive waves and generations of terrorists attacked the Iraqis, irrespective of their different sects and affiliations, in the years following the fall of the regime in Iraq in 2003 after the US invasion of the country under the pretext of weapons of mass destruction.

These organizations used bombed cars, antipersonnel mines, and snipers to inflict the greatest number of casualties. In addition to these methods, the direct conventional war casualties, which were the result of the armed clashes that broke out after the terrorist Islamic State took control of vast areas of Iraqi territory, add a new list of Iraqi victims.

Explosive devices of all kinds when exploding, they will convert into gas and this leading to the release of large amounts of energy.[2,4,5] This gas, in turn, will radially expand outward at very high speeds (usually greater than 5000 m/s) in a process named detonation.[1,3]

Moreover, this will lead to rapid increase in the pressure creating what is called the blast wave, these blast waves will generate winds with high velocity and it will push all surrounding objects away.[1,4,5]

The affected objects will be compressed and this will heat and accelerate the affected object molecules, creating a very high pressure called blast overpressure.[1,5] This overpressure will compress the air molecules of the blast wave into such density that resembles a solid hitting the victim.[1,6,7]

When a missile hits a living tissue, the rustled injury is related by direct relationship to the amount of energy transferred from the missile to the target tissue. This energy is expressed by the equation:

$$\text{Energy transferred} = \frac{\text{mass of missile} * (\text{velocity of missile})\,2}{2}$$

Since the velocity is squared in the formula, this is the most important factor in determining the energy transfer.[8]

The velocity of a missile striking a target is called the impact velocity and is one of the most important factors determining the extent of injury. Impact velocities of 50 and 65 m/s are required to penetrate skin and bone respectively.[8,9]

Soft tissue injuries that are associated with bullets and shells may exhibit large avulsive wounds with subsequent necrosis over days to weeks due to compromised vascularity after injury.[10]

It is important to understand the mechanism of injury for each missile and how they exert their effects on the different body tissues, as this would help to determine the pattern of injury and how to manage it. In this study we aim to compare between the effects of blast implosions and penetrating missiles on the maxillofacial air containing cavities, specifically the maxillary sinuses.

PATIENTS AND METHODS

Twenty-eight patients (26 male and 2 female) with maxillary sinus walls fractures were admitted to our maxillofacial surgery Department in the Hospital of specialized surgeries/ Medical city of Baghdad from July 2014 to November 2016.

All these injuries were caused by either explosion shells that came from (improvised explosive devices [IED], mortars, or bumped cars) or bullets of high-velocity rifle.

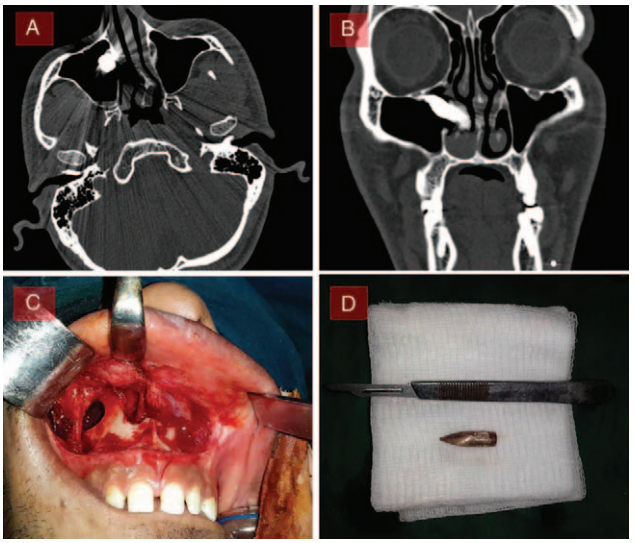

FIGURE 1. Retrieval of the foreign body that lodged in the maxillary sinus by Caldwell–Luc approach. (A) Axial view of computed tomography scan show foreign body lodged in the right maxillary sinus. (B) Coronal view of computed tomography scan. (C) Caldwell–Luc approach for bullet extraction from the maxillary sinus. (D) Bullet after its removal from the maxillary sinus.

Patients were assessed both clinically and radiographically by Occipitomental "waters" view and computerized tomography (CT) scan that have most commonly been used, for the diagnosis of the presence of foreign bodies and if there is any fracture/s.

Mechanisms of blast injury have been classified into primary (caused by implosion blast waves and affects mainly air-filled cavities), secondary (caused by the direct contact between the shrapnel and the body tissue), tertiary (results when victims being thrown by blast wind), and quaternary (include all complications that occur after injury).

While bullet injuries are classified into low and high-energy injuries, the type of injury could be primary (direct transfer of kinetic energy from the bullet to the tissue), secondary (fragmentation of the bullet and/or bone lead to formation of numerous secondary projectiles), tertiary (results when victims being thrown to hard object), and quaternary (include all complications that occur after injury).

Two lines of management were applied to the comminuted fractures of maxillary air sinuses walls which include:

1. Open technique: which includes open reduction and fixation of the complex fractures if present or only extraction of the foreign body from the sinus through the inlet wound or by using Caldwell–Luc approach if no associated fractures are present (Fig. 1).
2. Close technique used only for isolated closed comminuted fractures of the sinus walls that are mostly associated with blunt trauma (tertiary type of injury).

Statistical analysis of this study was done by SPSS. 24 Program (independent paired *t* test).

Due to the retrospective nature of this study, it was granted an exemption in writing by the University of Baghdad/Dentistry College IRB.

RESULTS

A total of 28 patients with maxillary sinus walls fractures due to war injuries were enrolled in this study. All these patients were managed from July 2014 to November 2016 at Medical City of Baghdad. There were (26 male [92.85%] and 2 female [7.14%]) patients.

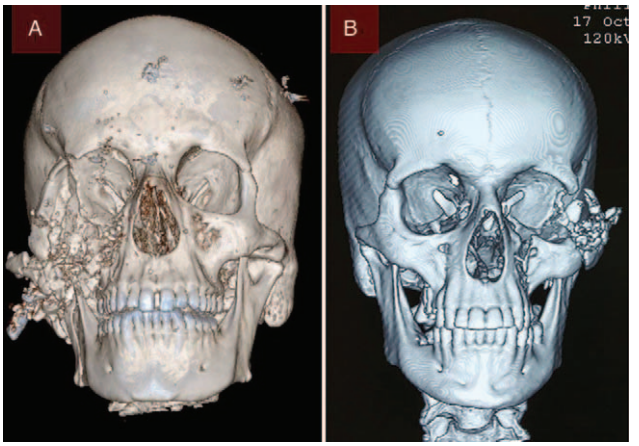

FIGURE 2. Three-dimensional computerized tomography (3D CT) showing comminuted fractures associated with bullets and blast injuries: (A) bullet injury, (B) blast injury.

Their age ranged from 22 to 45 years, with the largest number of the patients present in the 21- to 30-year-old age group (see Supplemental Digital Content, Table 1, http://links.lww.com/SCS/A628).

Improvised explosive devices affect 15 patients and this constitutes (53, 57%) of the total injuries 76% of the patients with bullet injuries presented with injuries affecting the left side of the face, while in shell injuries 60% of the patients presented with injuries affecting right side of the face.

In all patients, we have fond that anterior wall of the maxillary sinus fractured more frequently than the other sinus walls.

It has been found that the orbital walls injuries constitute higher percentage of fractures associated with maxillary sinus injuries in both groups (see Supplemental Digital Content, Table 2, http://links.lww.com/SCS/A629).

While isolated maxillary sinus fractures are seen in only 3 (10.7%) patients in this study.

The associated fractures of adjacent bones (bones participate in the formation of maxillary sinus) to the maxillary sinus are more (25 fracture) with IEDs injuries while it is only (18 fracture) with bullet injuries (see Supplemental Digital Content, Table 2, http://links.lww.com/SCS/A629). Bullet cause comminuted fractures in 92.3% of the cases, while IEDs cause comminuted fractures in only 73.33% of the cases (Fig. 2).

Management of those patients varied according to hospital resources and to the presence of the other injuries affecting neighboring bones to the maxillary sinus walls. Open reduction and fixation utilized in 76.92% of the fractures were caused by bullets, while in patients with comminuted fractures the open technique was used in 73.33% of the cases (see Supplemental Digital Content, Table 3, http://links.lww.com/SCS/A630).

Open reduction and fixation with miniplates and microplates only have been utilized when there were fractures affecting zygomatico-maxillary or naso-orbito-ethmoidal complexes.

In close reduction cases, Gillies approach (for reduction of the zygomatic fractures) and arch bars (for maxillary dentoalvealor fractures) have been used.

The most common postoperative complication founded in the study was infection, and this managed by wound cleaning, irrigation with normal saline, and packing of the maxillary sinus with iodoform pack.

Patients with mini-plate that exposed intraorally managed by wound debridement and irrigation by normal saline followed by packing of the wound with iodoform gauze or by using platelet-rich fibrin (2 clots of PRF, 1st one placed inside the wound to provide a

support for the 2nd one which used as a membrane that's sutured over the wound).

Poor esthetic result (flattened face) occurred in 2 patients, in the first one we had to operate the patient without a CT scan (we used only plain radiographs), because CT machine stopped working at that time due to a large number of causalities.

In the second patient who had massive comminution of the right zygomatico—orbito—maxillary complex with loss of vision of the left eye. (Patient refused to do surgical reduction and fixation for the facial bones fractures because of the risk to the right eye).

If we consider the type of management used and its relation to the complications, there was a statistically significant difference between the complications of the open and close techniques in IED injuries group only with a *P* value of 0.0101 (see Supplemental Digital Content, Table 4, http://links.lww.com/SCS/A631).

DISCUSSION

The patterns of the maxillary sinus war injuries of the cases who managed by our surgical team during 2 years period of fight against terrorist armed militia that used all kinds of weapons against our security forces such as bombed cars, improvised explosive devices, mortars, snipers, suicide bombers, et cetera.

Most of these injuries affecting men with Age group between 21 to 30 years and this result is in agree with previously published studies.[10–13] And it can be explained simply if we know a large number of this age group have volunteered to fight against the terrorist armed militias (ISIS).

About 76% of the patients with bullet injures had inlet wound on the left side of the face, this probably because of the right handed people turning as they ran from the attack and this may expose their left side to the trauma.[14,15]

Orbital floor and medial walls have close relation to the maxillary sinus and both of them consist of relatively thin bones, thus may explain why most of the maxillary sinus walls fractures associated with orbital walls injuries.[16]

Since the IEDs typically contain multiple shrapnel, metal fragments or glass, bolts or steel balls that will be propelled at high or ultra-high velocity and therefore cause ultra-high kinetic energy injuries at broad-focused area with more diffused injuries.[10]

This may explain why number of the associated fractures with the IEDs are more (25 fracture) than these with the bullet injuries (18 fracture). This difference is statistically highly significant with *P* value of (0.0001).

Comminuted fracture is a fracture that consist of many connected fracture lines, which will result in multiple fractured pieces of bone.[17,18]

The severity of the injury may be determined by velocity, physical properties and shape of the missile together with the type of the injured tissue.[10,19] The IED usually affect broad focused areas with more diffused injuries unlike bullets. These previous facts may explain how bullets associated with higher incidence of comminuted fractures in the walls of the maxillary sinus (92.3% of the injuries caused by bullets, compared with 73.33% of the injuries caused by IEDs).

Regarding study complications, infection are more common with IEDs injuries than bullets and this may because shells that resulted from different explosions may have a lot of dirt carried with it to the wounds and this may lead to more severe contamination.[20]

Since severe injuries necessitate prompt intervention, this may explain why open surgical technique is associated with more complications. This comes in agreement with our findings which showed that the complications were significantly higher in open technique management for IEDs injuries while close technique used for a relatively simple cases.

In spite of these determinants, this study concludes that bullet injuries are associated with more severe comminuted fractures in addition to involvement of multiple neighboring bones and this may lead to extensive bone and soft tissue loss. In contrast postoperative complications and infection tend to occur more frequently with improvised explosive devices injuries. Isolated maxillary sinus walls fractures do not need any intervention, conservative management would be enough.

REFERENCES

1. Cohen MA, Shakenovsky BN, Smith I. Low velocity hand-gun injuries of the maxillofacial region. *J Maxillofac Surg* 1986;14: 26–33
2. Stuhmiller J, Philips YI, Richmond D. The physics and mechanisms of primary blast injury. In: Bellamy R, Zajtchuk R, eds. *The Textbook of Military Medicine-Conventional Warfare: Ballistic, Blast and Burn Injuries.* Washington, DC: Department of the Army, Office of the Surgeon General; 1991
3. Davis T. *The Chemistry of Powder and Explosives.* Los Angeles, CA: Angriff Press; 1972
4. Wolf SJ, Bebarta VS, Bonnett CJ, et al. Blast injuries. *Lancet* 2009;374:405–415
5. Mayorga MA. The pathology of primary blast overpressure injury. *Toxicology* 1997;121:17–28
6. Shuker ST. Facial skin-mucosal biodynamic blast injuries and management. *J Oral Maxillofac Surg* 2010;68:1818–1825
7. Abu-Sittah GS, Ghanem OM. Biodynamics of blast injuries. In *Reconstructing the War Injured Patient*. Cham: Springer; 2017:7–17
8. Bartlett CS, Bissell BT. Common misconceptions and controversies regarding ballistics and gunshot wounds. *Tech Orthop* 2006;21:190–199
9. Rozen N, Dudkiewicz I. Wound ballistics and tissue damage. In *Armed Conflict Injuries to the Extremities*. Berlin, Germany: Springer; 2011;21–33
10. Powers DB, Delo RI. Characteristics of ballistic and blast injuries. *Atlas Oral Maxillofac Surg Clin North Am* 2013;21:15–24
11. Perry M, Brown A, Banks P. *Fractures of the Facial Skeleton.* New York: John Wiley & Sons; 2015
12. Sadda RS. Maxillofacial war injuries during the Iraq–Iran War. *Int J Oral Maxillofac Surg* 2003;32:209–214
13. Ugboko VI, Odusanya SA, Fagade OO. Maxillofacial fractures in a semi-urban Nigerian teaching hospital: a review of 442 cases. *Int J Oral Maxillofac Surg* 1998;27:286–289
14. Singh V, Malkunje L, Mohammad S, et al. The maxillofacial injuries: a study. *Natl J Maxillofac Surg* 2012;3:166–171
15. Ghazal G, Jaquiery C, Hammer B. Non-surgical treatment of mandibular fractures—survey of 28 patients: To Prof. Dr. J. Prein on the occasion of his 65th birthday. *Int J Oral Maxillofac Surg* 2004;33:141–166
16. Abreu ME, Viegas VN, Ibrahim D, et al. Treatment of comminuted mandibular fractures: a critical review. *Med Oral Patol Oral Cir Bucal* 2009;14:E247–E251
17. Jones DE, Evans JN. "Blow-out" fractures of the orbit: an investigation into their anatomical basis. *J Laryngol Otol* 1967;81:1109–1120
18. Al-Assaf DA, Maki MH. Multiple and comminuted mandibular fractures: treatment outlines in adverse medical conditions in Iraq. *J Craniofac Surg* 2007;18:606–612
19. Bede SY, Ismael WK, Al-Assaf D. Characteristics of mandibular injuries caused by bullets and improvised explosive devices: a comparative study. *Int J Oral Maxillofac Surg* 2017;46:1271–1275
20. Holleran RS, ed. *Air and Surface Patient Transport: Principles and Practice.* Mosby Incorporated; 2003