

# THE 2020 BEIRUT EXPLOSION: A HEALTHCARE PERSPECTIVE

## L'EXPLOSION DE BEYROUTH EN 2020 VUE SOUS L'ANGLE SANITAIRE

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**SUMMARY.** On August 4th, 2020, at 6:07pm local time, an explosion took place in Beirut's port near the central district. This tragic event reportedly left more than 204 victims dead, more than 6,500 wounded, and displaced around 300,000 from their homes. Patients were transported to several hospitals, which became quickly overwhelmed within minutes by the large number of patient admissions. This is a retrospective chart review conducted on 292 patients, who presented to the American University of Beirut Medical Center (AUBMC) after sustaining blast-related injuries during the Beirut port explosion on August 4th, 2020. Measures including age, gender, location of the injury, mechanism of blast injury (primary, secondary, tertiary, and quaternary) and outcomes were collected. Time of arrival of the first victim was 10 minutes after the explosion. Patients across all ages presented to the medical center (age range from 3 months to 86 years) and the majority of injuries were in the upper extremity (45.6%), and head and neck region (43.2%). Most blast-related injuries were due to secondary and tertiary types, 78.4% and 24.1% respectively. This study aims to expand the literature and widen the knowledge regarding the mechanism of injury associated with the Beirut port explosion. Moreover, it could be helpful in preparing medical staff, healthcare centers and other communities to work under difficult conditions in similar disasters and improve the global response to devastating events.

**Keywords:** explosion, blast-related injuries, blast injury types, disaster, preparedness

**RÉSUMÉ.** Le 4 août 2020 à 18 h 07 locales, une explosion s'est produite dans le port de Beyrouth, à proximité du centre-ville. Cette explosion a tué 204 personnes, en a blessé plus de 6 500 et en a laissé environ 300 000 sans abri. Les blessés ont été acheminés dans plusieurs hôpitaux, vite débordés par cet afflux massif. Cet article est une revue sur dossier de 292 cas de patients blastés lors de cette catastrophe pris en charge à l'Hôpital Universitaire Américain de Beyrouth, la première étant arrivée 10 mn après l'explosion. Nous avons répertorié l'âge, le sexe, la localisation des blessures et le type de lésions de blast (primaire, secondaire, tertiaire ou quaternaire), les plus fréquents étant les blasts secondaires (78,4%) et tertiaires (24,1%) et l'évolution. Les patients étaient âgés de 3 mois à 86 ans et leurs blessures se situaient plus fréquemment au niveau de la partie supérieure du corps (45,6%) ou de la région cervico-céphalique (43,2%). Cette étude permet d'abonder la littérature sur les mécanismes lésionnels après une explosion comme celle du port de Beyrouth. Elle pourrait en outre permettre d'améliorer les réponses médicale, hospitalière et générale après une catastrophe.

**Mots-clés:** explosion, lésions de blast, catastrophe, préparation

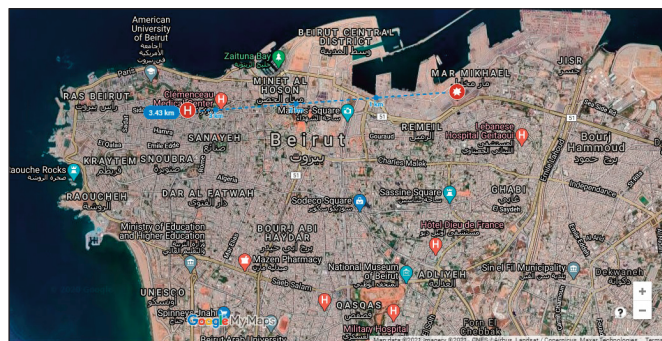
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## Introduction

On August 4th, 2020, at 6:07pm local time, an explosion took place in Beirut's port near the city central district (Fig. 1). This explosion was marked as one of the most powerful explosions in the world after Hiroshima and Nagasaki. Furthermore, the Beirut blast was ranked third in regards to the amount of ammonium nitrate involved in the explosion after the France and Texas explosions in 1947 respectively.<sup>1</sup> The blast reportedly had at least 204 fatalities and more than 6500 injured, leaving thousands of people homeless.<sup>2,3</sup> Patients were transported to several hospitals, which became quickly overwhelmed within minutes by the large number of patient admissions.



**Fig. 1** - Map of Beirut showing AUBMC (H) within a 4km radius from the explosion (\*)

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Until this day, local and international investigations into the events of this incident and persons responsible are still being conducted. Local and foreign testimonies reported that the blast was caused by 2,750 tons of highly combustible ammonium nitrate that was stored in the port for more than 6 years. A fire caused by a firework shipment nearby preceded the major blast, leading to the combustion of the ammonium nitrate. Experts estimated the intensity of the shockwave to be equivalent to a fifth of the size of Hiroshima.<sup>4</sup> In fact, due to its high intensity and shockwave nature, the blast damaged buildings up to 10 kilometers away and was also felt 160 kilometers across the sea in Cyprus.<sup>5</sup> The blast left a crater of approximately 405 feet in diameter and registered 3.3 degrees on the Richter magnitude scale.<sup>4</sup> With the help of NASA, experts in the field

developed a satellite map showing the extent of the blast on nearby cities and regions.<sup>6</sup> Buildings facing the port, like MTC Phone Company building, Electricity Company and other businesses were mostly affected by the blast (Fig. 2).



**Fig. 2** - Photo of destroyed buildings facing the Beirut Port explosion (Photo taken by authors on 02 January 2021)

Ammonium nitrate disasters are not rare; in fact, tens of cases have been reported all over the world throughout history. Each incident had devastating effects on the country, injuring and killing many people in the process. These incidents go back to early September 1921 in Germany, when 450 tons of ammonium nitrate combusted, killing 561 and injuring 1952 persons.<sup>7</sup> Another more recent event occurred in West Texas on April 17, 2013, in which 15 were killed and 260 were injured.<sup>8,9</sup> The West Texas blast left a crater that is 10-foot deep and 90-foot wide and registered 2.1 degrees on the Richter magnitude scale.<sup>9</sup>

In the present day, Lebanon is suffering from an unprecedented series of crises. Since October 2019, Lebanon has been experiencing a political and economic crisis, leading to many protests and demonstrations.<sup>10</sup> This was followed by the COVID-19 pandemic and subsequent lockdowns, which further deteriorated the market leading to bankruptcy.<sup>11</sup> In addition, the destruction of the Beirut port was one of many reasons behind the collapse of the Lebanese economy and financial system. Indeed, the port destruction led to a loss in revenue by preventing adequate import/export of supplies as well as reducing access and sale of goods.<sup>12</sup> Moreover, the damages caused by the explosion were estimated to be around

15 billion USD,<sup>13</sup> while also affecting workers, businesses and households leading to job loss, displacement and homelessness.<sup>14</sup> Lebanese officials and authorities are still conducting inquiries into the events that led to this unprecedented large-scale explosion. In light of the events of this tragedy and the government's failure to conduct an effective investigation, the Lebanese public considered these events as a sign of incompetency, further fueling the revolutions.<sup>15</sup>

AUBMC, a tertiary care center in Beirut, is one of the biggest and most well-known medical centers in the city and Middle East region. This center is considered to be within a 4-kilometer radius from the explosion (*Fig. 1*) and has sustained damages from the blast<sup>16</sup> (*Fig. 3*). This center is equipped with an emergency department (ED) containing 43 beds, 3 trauma bays, numerous monitors, bedside ultrasound, imaging room and advanced airway equipment. On August 4th, around 353 patients presented to AUBMC for blast-related injuries, accounting for approximately 5.5% of all injured patients.



**Fig. 3** - Photo of the damages that occurred to a patient's room on the day of the explosion at AUBMC  
(Photo taken by authors on 04 August 2020)

The aim of this study is to describe the pattern of injuries and discuss how this came to happen. While there is sufficient data on the impact of the blast on morbidity and mortality, there is a lack of documentation on how medical centers managed to work under such circumstances. Therefore, this study will also describe the different steps that AUBMC took in order to avoid crowded out effect and manage to

work under such difficult circumstances. Relating this experience to the public will add to the literature in that it will lead to a better coordination and will improve the global response to devastating events.

## Materials and methods

### *Study sample*

This retrospective study included all patients who sustained injury from the Beirut Blast on August 4th, 2020. This sample involved patients who presented to the American University of Beirut Medical Center (AUBMC) for blast-related injuries and included patients across all age groups. Patients who presented to AUBMC for non-blast related injuries or symptoms were excluded from the sample.

In total, 353 charts were reviewed, out of which 52 patients were excluded because they left without being seen or examined after triage, nine patients were excluded because they arrived dead to the emergency room and did not have any notes, lab test or imaging done. Statistical analysis was therefore conducted on 292 patients. Oral consent was waived in order to avoid inflicting psychological harm to patients and families. Investigators obtained permission from injured victims to take photographs of their injuries and use them for educational purposes.

### *Measures*

Data collected from chart review included general characteristics of the sample, including age, gender, location of the injury, mechanism of blast injury (primary, secondary, tertiary, quaternary) and outcome (admitted to the floor, ICU, discharged, taken directly to the operating room, left against medical advice or death). Mechanism of blast injury was divided into 4 categories: primary injury refers to damage of air-filled organs such as eardrums, lungs and bowels; secondary denotes injury from penetrating wounds; tertiary results from being thrown away by the blast wind; finally quaternary includes other injuries such as burns, exposure to toxic gases, fumes and smoke.<sup>17-19</sup> Each patient can have more than one type of injury.

During the chart review, all personal identifiers were removed and all patients were de-identified hence there was no potential harm to subjects. The uni-



versity's institutional review board (IRB) approved the study protocol and design [IRB ID: BIO-2020-0413].

### Statistical analysis

Percentages and mean  $\pm$  standard deviation were carried out for different quantitative variables. Data collection and analysis occurred in September 2020. SPSS version 24 was used for analysis.

## Results

*Table I* summarizes the characteristics of the sample. Mean age of sample was 40.2 years (SD=17.9), with ages ranging from 3 months old up to 86 years of age. Twenty-one patients (7.6%) were younger than 18 years, one hundred sixty five (59.4%) were between 18 and 45 years old, fifty-nine (21.2%) were between 45 and 65 years old, and thirty-three patients (11.9%) were elderly above 65 years. More males (162, 55.7%) than females presented to the medical center. Time of arrival of the first victim was 10 minutes after the explosion.

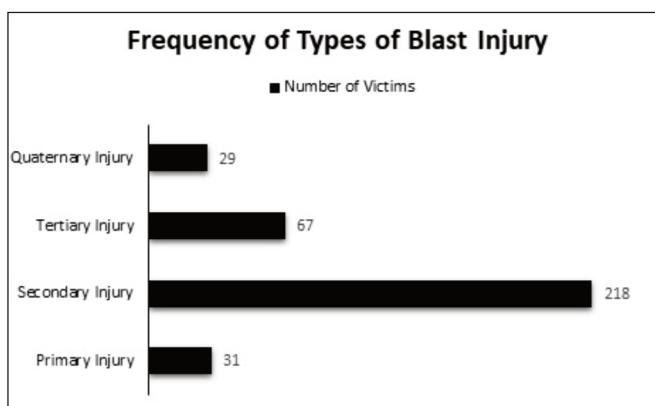
Regarding injury characteristics, the majority of the sample sustained injuries in various locations as 209 (71.6%) were injured in the extremities out of which 134 (45.9%) were in upper and 95 (32.5%) in lower extremities, 126 (43.2%) in the head and neck, 40 (13.7%) in the chest and abdomen and 32 (11%) in the back or spine. When it comes to mechanism of blast injury, 31 (11.2%) had damage of hollow organs with primary injury, 218 (78.4%) had penetrating injuries or secondary type of injury, 67 (24.1%) had tertiary injury due to being thrown away by blast wind, and 29 (10.4%) had quaternary type of blast injury (*Graph 1*).

Concerning outcomes, 199 (68.2%) of patients were discharged, 63 (21.6%) were admitted to regular floors, 16 (5.5%) were taken directly to the operating room, 10 (3.4%) were admitted to the intensive care unit (ICU), four (1.4%) left against medical advice (AMA), and five patients (1.7%) died after receiving care at the center (*Table I*). It is worth mentioning that nine other patients arrived dead to the emergency room, and were excluded from the study for the above-mentioned reasons in the methods section.

**Table 1** - Sample demographics and outcome summary (N=292 victims)

	Mean or n	(SD or %)	Missing values
<b>Age</b>	40.2	17.9	14
<18 years	21	7.6%	
18-45 years	165	59.4%	
46-65 years	59	21.2%	
>65 years	33	11.9%	
<b>Gender, males</b>	162	55.7%	1
<b>Location of injury</b>			0
Head & neck	126	43.2%	
Extremities	209	71.6%	
Upper extremity	134	45.9%	
Lower extremity	95	32.5%	
Chest & abdomen	40	13.7%	
Back	32	11%	
<b>Deceased patients after receiving care</b>	5	1.7%	
<b>Outcomes</b>			0
Admitted to regular floor	63	21.6%	
Admitted to ICU	10	3.4%	
Discharged home	199	68.2%	
Taken directly to operating room	16	5.5%	
Left against medical advice	4	1.4%	

SD = Standard deviation



**Graph 1** - Bar graph describing the frequency of blast injury types incurred on Beirut Port explosion victims (N=292 victims)

## Discussion

The Beirut Port tragedy is considered one of the most devastating explosions in the world. This tragic event reportedly left more than 204 victims dead and more than 6,500 wounded, and displaced around 300,000 from their homes.<sup>2,3</sup> Results showed that upper extremity, head and neck injuries accounted for a considerable amount of blast-related injuries (*Fig. 4*). In fact, 134 (45.9%) victims presenting to this tertiary care center had upper extremity injuries and 126 (43.2%) victims had head and neck injuries. These results could be explained by the fact that a large number of victims were watching the initial fireworks that ignited before the big blast, and hence were injured either directly in the face or in the ex-





**Fig. 4** - Photo of a hand injury in a patient suffering from a penetrating trauma caused by the blast  
(Photo taken by authors on 04 August 2020)

tremities after trying to shield their face from the big blast. In addition, the study's findings suggested that there was a substantially high number of patients suffering from penetrating and blunt trauma as 218 (78.4%) of this sample had secondary type of blast injury. These findings could be explained by the close proximity of patients to windows while watching the initial fireworks. Moreover, AUBMC is considered to be within a 4-km radius from the blast (*Fig. 1*) and therefore a great amount of victims transferred to AUBMC were at a larger distance from the blast and suffered from penetrating and blunt trauma caused by shrapnel, glass and projectiles. Investigators have studied the mechanics of explosive equipment thoroughly throughout the literature; explosions can cause the formation of a blast wave made of compressed high-pressure air that moves at supersonic speeds followed by a blast wind that pushes air outward.<sup>19,20</sup> Indeed, the Beirut Port explosion was a very powerful blast that led to the formation of massive blast wave and blast wind that displaced victims causing tertiary injury. In fact, tertiary blast injury was the second most common

type of injury in this sample, accounting for 67 (24.1%) victims. Hollow organs such as the middle ear, lungs and gastrointestinal tract are prone to injury depending on the distance from the blast as well as the magnitude and duration of the peak pressure.<sup>20</sup> Damage to hollow organ is considered part of primary blast injuries and has been reported in the literature.<sup>21-25</sup> In this study, primary blast injuries accounted for 31 (11.2%) of all injuries. Finally, the data showed that quaternary injury was the least common among all types, with only 29 (10.4%). This category largely consists of burns, toxic gas inhalation and worsening of existing conditions.<sup>25</sup> It is possible that severe burn patients were very close to the explosion and died at the scene. Other patients suffering from moderate or low severity burns and from toxic gas inhalation could have been admitted to closer hospitals. The aforementioned reasons could explain the lower rates of quaternary injuries at this tertiary care center.

The events of this catastrophic day took everyone by surprise; due to its high intensity and shock-wave nature, the blast damaged buildings up to 10 kilometers away,<sup>5</sup> including the tertiary care center where the authors work (*Fig. 3*). The first victim arrived to AUBMC only 10 minutes after the explosion; soon afterwards, the emergency rooms became crowded and full of injured victims requiring assistance and care. At first, the hospital staff were shaken by the events and found it difficult to work, nevertheless they were able to overcome these challenges and tend to the patients' needs by following protocol. As a response to the large number of critically ill patients, the ED director activated the code D full activation call list. Code D is an alert message that is activated during emergencies leading to the mobilization of hospital leadership, essential staff and other personnel. Upon activation of code D, the Medical Center Director and Chairmen of the Emergency, surgery, anesthesia, patient access, security and nursing departments were called for action. In the triage area, admitting clerks received, identified and distributed casualties by following a color-coded system based on severity of injury. In addition, emergency surgeries were performed (*Fig. 5*), all elective surgeries were cancelled, all regular non-blast related admissions were stopped, and pro-



**Fig. 5** - Photos of hand injury after debridement, external fixation and K wire placement  
(Photos taken by authors on 04 August 2020)

tection services limited access of visitors and family members to prevent crowding. The pharmacy department prepared the pharmaceutical emergency response cart and transported it to the ED. Moreover, in order to decrease emergency department overcrowding, physicians opened their private surgery clinics and regular floors to receive casualties. Finally, when the influx was controlled, a surgical team started rounding on the floors for triage of primary and secondary trauma surgeries. Other measures were also taken: in fact, operating rooms were booked for the next 3 days for emergency surgeries and for cold cases post the blast. The hospital administration and the public relations office handled media news and updates.

While injury and death are major determinants of the physical burden caused by this tragic event, this is only the tip of the iceberg. The long-term impact of community disasters should not be neglected as it can negatively affect the quality of life of victims. Traumatic events can have devastating effects on patients' physical and mental wellbeing, and have been associated with increased morbidity, mortality and disability.<sup>26</sup> Indeed, patients exposed to traumatic events might undergo numerous procedures requiring multiple hospital admissions and longer hospital stays, worsening the quality of life.<sup>27,28</sup> Moreover, studies show that witnessing disasters is associated

with behavioral changes, higher levels of anxiety, post-traumatic stress, depression as well as alcohol and substance use.<sup>29-31</sup> The scourge of community disasters is heartless: unfortunately, families might lose loved ones, and children might lose one or both of their parents, which is capable of causing long-lasting psychological sequelae.<sup>32,33</sup> Furthermore, the increased number of hospital admissions, imaging and lab tests ordered, surgical procedures, revisions, length of stay, psychiatric and physiotherapist visits all add to the financial burden associated with traumatic events.<sup>34-36</sup>

This study highlights the physical burden instigated by the powerful impact of the blast on victims of this tragic event. Results show that the pattern of injury in such disasters can be unpredictable with a variety of injury mechanisms in multiple different locations. This study also emphasizes the importance of proper staff training, planning and organization to deal with such difficult situations. Future studies can benefit from detailed assessment of the mental wellbeing of victims, and on how they managed to cope with the hardships that are associated with this tragedy.

### *Limitations*

This study should be interpreted in the light of several limitations. First, it is a retrospective chart review and hence it was not possible to get other data such as cause of death and trauma severity scores from victims at the scene. Second, the sample used does not account for all of the patients that presented to AUBMC; in fact, some victims presented to the emergency department for checkup with only minor superficial bruises and injuries. Medical personnel examined and reassured these patients unofficially without writing notes or registering their presentation. Third, examiners might focus on major traumatic injuries and underreport other minor injuries; therefore, these results might underestimate the actual harm caused by the explosion. Fourth, some patients were not severely affected by the incident and could have been discharged home, however were admitted to regular floors as per patient preference. Finally, some patients had missing data or incomplete notes due to the heavy patient load.

## Conclusion

Our findings suggest that the majority of casualties had penetrating injuries to the head and the upper extremities. Most patients who presented to AUBMC were treated in the emergency room and then discharged home. Although many victims presented to AUBMC in a short period, hospital staff were capable of preventing overcrowding while

tending to patients' needs. Proper preparation, planning and utilization of resources are essential for proper management of patients under such conditions in that it can reduce time to treatment and improve morbidity and mortality in disasters. The tragic events of August 4th, 2020 still haunt the Lebanese public until this day, leaving many individuals with physical and mental scars that will take time to heal.

## BIBLIOGRAPHY

- Guglielmi G: Why Beirut's ammonium nitrate blast was so devastating. *Nature*, 2020.
- Qiblawi T, Balkiz G: Lebanon's prime minister charged over deadly Beirut blast. 10 December 2020; <https://edition.cnn.com/2020/12/10/middleeast/lebanon-pm-indicted-beirut-explosion-intl/index.html>. Accessed 20 December 2020.
- Qiblawi T: Lebanon's caretaker Prime Minister calls Beirut port explosion 'suspicious'. 30 December 2020; <https://edition.cnn.com/2020/12/29/middleeast/diab-beirut-port-explosion-intl/index.html>. Accessed 1 January 2021.
- White D, Holloway H: Hell on earth Beirut explosion - blast a fifth the size of Hiroshima kills 100 as 'welder ignites 2,700 tons of explosive chemicals'. *The Sun*, 2020, <https://www.thesun.co.uk/news/12311215/beirut-explosion-huge-blast-lebanon-capital-hiroshima/>. Accessed 10 December 2020.
- Regan H, Qiblawi T, Balkiz G, Wedeman B et al.: Ammonium nitrate stored in a warehouse linked to catastrophic Beirut explosion. *CNN* 2020, <https://edition.cnn.com/2020/08/05/middleeast/beirut-port-explosion-ammonium-nitrate-intl-hnk/index.html>. Accessed 10 October 2020.
- Howell E: NASA maps Beirut explosion damage from space with satellites. August 12, 2020, <https://www.space.com/nasa-maps-beirut-explosion-damage-with-satellites.html>. Accessed 10 October 2020.
- French Ministry of Environment: Explosion in a nitrogenous fertiliser plant, 21 September 1921 Oppau – [Rhénanie] Germany. March 2008.
- Arnold C: A strong case for prudent school siting: the West Fertilizer Company explosion. *Environ Health Perspect*, 124(10): A187, 2016.
- Metzger K, Akram H, Feldt B, Stone K et al.: Epidemiologic investigation of injuries associated with the 2013 fertilizer plant explosion in West Texas. *Disaster Med Public Health Prep*, 10(4): 583-590, 2016.
- Reuters: Timeline - Lebanon's ordeal: economic and political crises since civil war. 13 May 2020, <https://www.reuters.com/article/us-lebanon-crisis-turmoil-timeline-idUSKBN22P1K5>. Accessed 2 January 2021.
- Mroue B, Karam Z: Coronavirus delivers tough blow to Lebanon's dying economy. 26 March 2020, <https://www.timesofisrael.com/coronavirus-delivers-tough-blow-to-lebanons-dying-economy/>. Accessed 2 January 2021.
- Abdullah M: Beirut port, a major shipping point under rubble. 5 August 2020, <https://www.aa.com.tr/en/middle-east/beirut-port-a-major-shipping-point-under-rubble/1932218>. Accessed 2 January 2021.
- Morris L: Beirut needs billions of dollars it doesn't have to rebuild after massive blast. 21 August 2020, [https://www.washingtonpost.com/world/middle\\_east/beirut-needs-billions-of-dollars-it-doesnt-have-to-rebuild-after-massive-blast/2020/08/20/d30a1440-de4e-11ea-b4f1-25b762cbbf4\\_story.html?hpid=hp\\_hp-more-top-stories\\_beirutreconstruction-1145am%3Ahomepage%2Fstory-ans](https://www.washingtonpost.com/world/middle_east/beirut-needs-billions-of-dollars-it-doesnt-have-to-rebuild-after-massive-blast/2020/08/20/d30a1440-de4e-11ea-b4f1-25b762cbbf4_story.html?hpid=hp_hp-more-top-stories_beirutreconstruction-1145am%3Ahomepage%2Fstory-ans). Accessed 2 January 2021.
- United Nations Development Programme: Rapid socio-economic assessment in the neighborhoods affected by the blast. 16 November 2020, <https://www.lb.undp.org/content/lebanon/en/home/library/rapid-socio-economic-assessment-in-the-neighbourhoods-affected-b.html>. Accessed 2 January 2021.
- Amnesty International: Lebanon: Only an international investigation can set the course for justice for Beirut blast victims. 7 September 2020, <https://www.amnesty.org/en/latest/news/2020/09/lebanon-only-an-international-investigation-can-set-the-course-for-justice-for-beirut-blast-victims/>. Accessed 10 December 2020.
- World Food Programme: Beirut explosion radius distances, Pop. density, Primary Health Care Centers. 7 August 2020, <https://reliefweb.int/map/lebanon/beirut-explosion-radius-distances-pop-density-primary-health-care-centers>. Accessed 11 October 2020.
- Kirkman E, Watts S, Cooper G: Blast injury research models. *Philos Trans R Soc Lond B Biol Sci*, 366(1562): 144-159, 2011.
- Jorolemon MR, Lopez RA, Krywko DM: Blast Injuries. In: *StatPearls* [Internet]. Treasure Island (FL): StatPearls January 2020; <https://www.ncbi.nlm.nih.gov/books/NBK430914/>.
- Singh AK, Ditkofsky NG, York CJD, Abujudeh HH et al.: Blast injuries: from improvised explosive device blasts to the Boston Marathon Bombing. *Radio Graphics*, 36(1): 295-307, 2016.
- Dick EA, Ballard M, Alwan-Walker H, Kashef E et al.: Bomb blast imaging: bringing order to chaos. *Clinical Radiology*, 73(6): 509-516, 2018.
- Gan RZ, Leckness K, Nakmali D, Ji XD: Biomechanical measurement and modeling of human eardrum injury in relation to blast wave direction. *Military Medicine*, 183(suppl\_1): 245-251, 2018.
- Ballivet de Régloix S, Crambert A, Maurin O, Lisan Q et al.: Blast injury of the ear by massive explosion: a review of 41 cases. *J R Army Med Corps*, 163(5): 333-338, 2017.
- Scott TE, Kirkman E, Haque M, Gibb IE et al.: Primary blast lung injury - a review. *Br J Anaesth*, 118(3): 311-316, 2017.
- Wani I, Parray FQ, Sheikh T, Wani R et al.: Spectrum of abdominal organ injury in a primary blast type. *World J Emerg Surg*, 4: 46-46, 2009.



- 25 Jahangiri K, Ghodsi H, Khodadadzadeh A, Yousef Nezhad S: Pattern and nature of Neyshabur train explosion blast injuries. *World J Emerg Surg*, 13: 3, 2018.
- 26 Finlay SE, Earby M, Baker DJ, Murray VS: Explosions and human health: the long-term effects of blast injury. *Prehosp Disaster Med*, 27(4): 385-391, 2012.
- 27 Carty MJ, Caterson EJ, Caterson SA, Chun YS et al.: Why we are here: early reflections on the role of reconstructive plastic surgery in the 2013 Boston Marathon bombings. *Plast Reconstr Surg*, 132(6): 1623-1627, 2013.
- 28 Kim PS, Malin E, Kirkham JC, Helliwell NY et al.: The Boston Marathon bombings: the early plastic surgery experience of one Boston hospital. *Plast Reconstr Surg*, 132(5): 1351-1363, 2013.
- 29 Lee J-Y, Kim S-W, Kim J-M: The impact of community disaster trauma: a focus on emerging research of PTSD and other mental health outcomes. *Chonnam Med J*, 56(2): 99-107, 2020.
- 30 Neria Y, Nandi A, Galea S: Post-traumatic stress disorder following disasters: a systematic review. *Psychol Med*, 38(4): 467-480, 2008.
- 31 Yang H, Wang L, Cao C, Cao X et al.: The underlying dimensions of DSM-5 PTSD symptoms and their relations with anxiety and depression in a sample of adolescents exposed to an explosion accident. *Eur J Psychotraumatol*, 8(1): 1272789, 2017.
- 32 Song J, Floyd FJ, Seltzer MM, Greenberg JS et al.: Long-term effects of child death on parents' health related quality of life: a dyadic analysis. *Fam Relat*, 59(3): 269-282, 2010.
- 33 Stikkelbroek Y, Bodden DHM, Reitz E, Vollebergh WAM et al.: Mental health of adolescents before and after the death of a parent or sibling. *Eur Child Adolesc Psychiatry*, 25(1): 49-59, 2016.
- 34 Fu TS, Jing R, McFaul SR, Cusimano MD: Health and economic burden of traumatic brain injury in the Emergency Department. *Can J Neurol Sci*, 43(2): 238-247, 2016.
- 35 MacKenzie EJ, Castillo RC, Jones AS, Bosse MJ et al.: Healthcare costs associated with amputation or reconstruction of a limb-threatening injury. *JBJS*, 89(8): 1685-1692, 2007.
- 36 Aprato A, Joeris A, Tosto F, Kalampoki V et al.: Direct and indirect costs of surgically treated pelvic fractures. *Arch Orthop Trauma Surg*, 136(3): 325-330, 2016.

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