C A S E R E P O R T

Blast injury: lessons learned from an autopsy

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Blast injury is becoming more common in the non-military population but it is still rare to see such injuries and deaths unrelated to terrorist acts. The exact mechanisms involved in blast injuries are unclear. Civilian physicians and surgeons need to have a basic understanding of the patho-mechanics and physiological effects of blast injuries. We report a case where a 31-year-old male accidentally detonated a diesel storage tank. His autopsy findings provide useful information for those who investigate explosive-related deaths.

Introduction

An explosive is any substance or device capable of creating a sudden gas expansion, releasing potential energy and thus creating a pressure wave. Compression of the air in front of the pressure wave, which heats and accelerates air molecules, leads to a sudden increase in atmospheric pressure and temperature transmitted to the surrounding environment as a radially propagating shock wave known as the blast wave.[1] Injuries directly inflicted by this sudden increase in air pressure after an explosion are referred to as primary blast injuries, and affect primary gas-containing structures (lungs, middle ear, and gastro-intestinal tract).[1-4] Secondary blast injuries result from blast-energised bomb fragments and other displaced objects causing penetrating trauma. Tertiary blast injuries occur when the body is accelerated away from the blast wave at first and is then abruptly decelerated on rigid objects, resulting in blunt force trauma.[1] Countries such as Germany, Sweden, Israel, and Iraq have greater experience investigating deaths associated with explosive devices. In the United States, forensic pathologists and death investigators have very little exposure to deaths caused by explosive devices.[5] Our country has limited experience in this field. The investigation of explosion-related fatalities can be a substantial challenge in medico-legal casework.[3] Our experience of the explosive injuries seen in this case should help surgeons and intensivists with little experience of such trauma recognise blast injuries correctly.

Case report

On 30 January 2006, a young man was discovered at 10.00 a.m. lying in a supine position in the road 2 m from a truck. The weather was very cold and it was snowing heavily. The police and Emergency Medical Services arrived at the scene and found a flame burning from the nozzle of the truck's fuel storage tank. On the anterior surface of the tank they found two holes designed to prevent propagation of a flame through a flammable vapour mixture (Fig a). There was also a burning piece of wood, one end of which was wrapped in cloth. Upon examination of the deceased young man a smell of "heavy gasoline and diesel" was noted. There were burns on his exposed body parts—the head, neck and hands. The body was then transported to the Forensic Medicine Department to undergo a medico-legal autopsy. According to the victim's friend, with whom he had worked in the same company for 4 years, "All the drivers usually do this method on their journeys. Although it is known to be very dangerous, they put extra gasoline to malt the frozen diesel. A piece of wood surrounded by a cloth is soaked in the diesel tank and flamed outside, then the frozen storage is heated from outside. The frozen diesel melts and the truck begins to work again. After the incident, I examined the storage tank. There were two holes on it. In my opinion, he caused a fire when he put the woodpiece into the storage the second time as he believed there was no fire on it. Following this, just to prevent the blast, he made these two holes".

At autopsy the victim was found to be a 31-year-old white male, who weighed almost 80 kg, and was 183 cm in height. On external examination, superficial burns were found predominantly on the head, neck and hands, suggesting his clothing had a protective effect. Some of his teeth were destroyed completely; we think that those teeth had been crowned (Fig b). There was a 5-cm laceration to his posterior scalp and he had cherry-red livor mortis. External examination of the thoracic and abdominal cavities revealed no evidence of trauma. The internal examination of the body revealed no fractures of the ribs, sternum, or vertebral column. The lungs were collapsed and the right parietal pleura had separated

Key words
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爆炸受傷的解剖案例

爆炸受傷在非軍事人員中日益普遍，而因爆炸造成的受傷或死亡，往往是由恐怖活動引起的。爆炸受傷的確切機制還未清楚，但是，非軍職的內科和外科醫生均須對爆炸受傷的病理常規和生理效應有基本的瞭解。本文敍述一名31歲男子意外引爆了柴油缸而致死的案例，死者的解剖結果有助於爆炸死亡的研究。

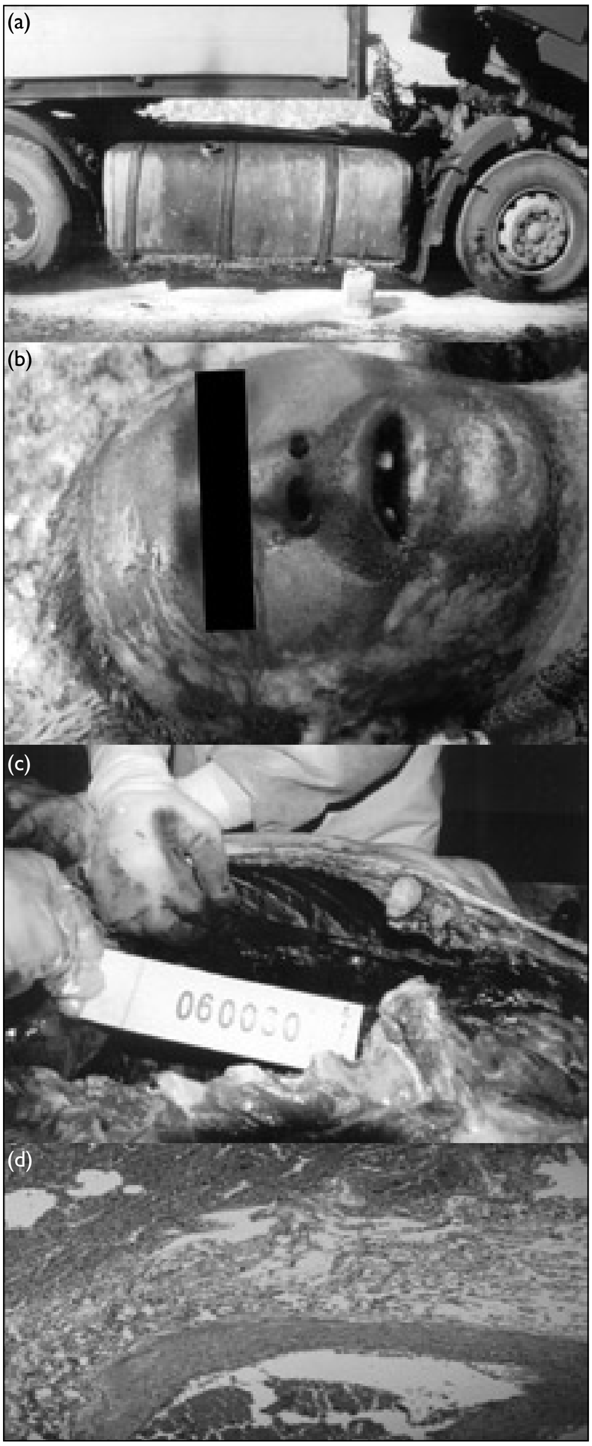

FIG. (a) Two holes on the anterior surface of the tank. (b) Some of the teeth completely destroyed. (c) Right parietal pleura separated from the chest wall. (d) Cuff-like pattern around pulmonary vessels (H&E; original magnification, x100)

from the chest wall (Fig c). Internally, the musculature and the viscera had a cherry-red colouration. The blood carboxyhaemoglobin level was measured as 30% saturation. The high carboxyhaemoglobin level in the blood was due to the flame from the explosion, which produced carbon monoxide. But there was no evidence of inhalation of other toxic gases, such as cyanide, in the blood samples or soot deposits in the airways and alveoli. A serum toxicological analysis was negative. The histopathological examination of the lungs revealed enlargement of the alveolar spaces, ruptures and thinning of the alveolar septae, interstitial perivascular haemorrhages, showing a cuff-like pattern around the pulmonary vessels (Fig d), but no evidence of air or fat embolism. Death had been caused by carbon monoxide inhalation and blast injuries to the lung.

Discussion

In the non-military population blast injuries caused by things other than terrorist acts are rare.[5-9] Explosive-related deaths fall into three categories; accident, homicide, and suicide. Accidental deaths normally occur either at the workplace or when untrained, unlicensed individuals handle legal or illegal fireworks. Accidental explosions at the workplace typically involve mines, road construction, and demolition sites.[5] We report an autopsy case of accidental death in a man who detonated a diesel storage tank. A comparative analysis of injuries inflicted in different blast incidents may be biased. The characteristic injury patterns resulting from explosions have been thoroughly discussed in the literature. Blast injuries are mediated by different mechanisms; victims usually suffer from a combination of primary blast effects to gas-containing organs, blunt force injuries, penetrating trauma, and burns. Injuries directly inflicted by this sudden increase in air pressure after an explosion are referred to as primary blast injuries and usually involve gas-containing organs such as the lungs, middle ear, and gastro-intestinal tract, which are the organs most vulnerable to extreme pressure.[1] Blast lung injuries are caused by the pressure wave. The pressure front causes chest wall displacement towards the spinal column, leading to a transient high intrathoracic pressure. The elevated intrathoracic pressure leads to tearing of the alveolar septae, stripping of the airway epithelium, rupture of the alveolar spaces with consequent alveolar haemorrhage, oedema, and alveolar-venous fistulae.[1] The size of the bomb, the nature of the explosive, and open or closed spaces may explain the increased incidence of blast lung injuries. Blast lung injuries are more common after closed-space explosions (eg in a bus) as compared with open-space explosions (eg an open market) [Table].[4,6,7] The lung injury is considered an important parameter defining mortality in those who survive the

TABLE. Effect of a blast wave in 'open spaces' as compared to 'closed spaces'

Blast wave effect	Location	
	Open spaces	Closed spaces
Mortality	Low	High
Multiple injury	Low	High
Blast lung injury	Low	High
Surgery required	High	High
Wounding potential	Low	High

explosion.[1] The postmortem examination is critical to the investigation of explosives-related deaths. In our autopsy-based study, we found a significant blast lung injury without co-existing blunt or penetrating chest trauma, along with histopathology findings expected after an open-space explosion.

Eardrums may rupture at pressures as low as 2 psi, whereas pulmonary damage should be expected in 50% of cases exposed to 70 psi.[6] In this case, we did not use an otoscopic examination as a marker for blast injury. A review of the literature of cited cases of explosives-related deaths found perforated ear drums in the majority of the cases (76-86%).[6-8] A high carboxyhaemoglobin level has not, to the best of our knowledge, been described previously in human blast injuries but we found a high carboxyhaemoglobin level in this case.

In conclusion, we present this autopsy-based investigation to provide further insight into blast injuries, which are rare events. Physicians and surgeons need to have a basic understanding of the pathophysiology of such injuries, because the major prognostic factor for favourable outcome is accessible and timely medical treatment.

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