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THE PHYSICAL BASIS AND DAMAGE MECHANISM OF BLAST INJURIES

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Abstract: Strong explosions can cause many types of damage, especially detonation pressure, which can cause very complex tissue damage. Fully understanding the physical principles and mechanisms of blast injuries will help out-of-hospital first responders, emergency physicians, surgeons and other related medical staff to effectively classify them and treat them reasonably and proactively. Therefore, the physical causes of blast injuries. A review of relevant content such as scientific principles and damage levels is provided.
Keywords: Blast injury; Physics; Damage

1 THE PHYSICS OF DETONATION

In recent years, terrorist organizations have targeted shopping malls, stations, subways, airplanes and other public places, causing a large number of civilian casualties [1], such as the 911 incident in the United States. The probability of people facing blast injuries is getting higher and higher. Most patients with blast injuries show similar typical penetrating injuries or blunt injuries, but the trauma caused by the shock wave generated by the explosion has different characteristics. The pressure caused by the shock wave mainly targets the air-containing tissues of the body, such as the respiratory system, gastrointestinal tract and auditory system. Arterial air embolism from severe respiratory trauma may cause ischemia, especially in the brain, heart, and intestines. In addition, how to accurately and effectively classify the injured and provide timely diagnosis and treatment in the chaotic scenes after the explosion should also receive great attention, because some injuries may not be obvious or the clinical manifestations may be hidden or delayed.
Detonation is caused by the rapid release of solid or liquid into the air after the explosion of an explosive. Air rapidly spreads outward from the explosion point and displaces the surrounding medium, usually air or water. The expansion of air causes a rapid increase in pressure, causing a shock wave, which then gradually dissipates with the extension of distance and time [2]. Shock waves push objects or people, causing damage. After the initial energy of the detonation disappears, the void caused by the replacement air creates a period of relatively low pressure before the pressure returns to normal. Positive pressure and negative pressure can be formed during detonation. Detonation wave front overpressure and positive pressure periods can cause blast injuries.
Four factors will affect the intensity of the detonation wave front overpressure, the propagation speed of the detonation wave and the subsequent detonation injuries. One is the medium. The surrounding medium when an explosion occurs is closely related to it. For example, water is an incompressible substance, so the propagation speed of the detonation wave in water will be higher than that of other media, but the attenuation speed is slower [3], so compared with the air medium The damage caused will be greater [4]. The second is distance. The distance between a person and the explosion point determines the intensity of the detonation wave front overpressure after the explosion. The closer you are to the explosion point, the greater the detonation wave you will endure. Due to the spread of the detonation wave, the energy dissipated by the detonation, the front overpressure and the cube of the distance from the explosion point are inversely proportional [3], so if the distance increases by 2 times, the peak front overpressure will drop to 1/ of the initial value. 8. The third is the reflective surface. When the detonation wave reflects off the solid surface, the front overpressure is amplified, increasing its force. For example, people closer to the wall will experience increased frontal overpressure, and injuries caused by blast injuries may be more severe. The fourth is the effect of the explosion location on the face overpressure [5]. In an open space, the shock wave spreads from the explosion point to the surroundings and dissipates quickly; if the explosion occurs in a narrow or closed space (such as a bus, a room or a building) the maximum pressure intensity will be significantly expanded, because the explosion force is in It cannot dissipate quickly in a confined space. Confined spaces increase front overpressure and the duration of forward pressure cycles.

2 EXPLOSIVE TYPE

The most common classification method for chemical explosives is to classify them into low-explosion velocity explosives or high-explosion velocity explosives based on the explosion velocity [6]. Low-explosive velocity explosives burn (deflagrate) rapidly, with a propagation speed of less than 1000 m/s, producing a large amount of gas, and may explode only in a confined space (such as pipe bombs). High-explosive velocity explosives will not burn, but will explode when the shock wave passes through the target at a speed exceeding 4500 m/s, followed by a front overpressure, which will produce this effect even if it is not in a confined space.
Common examples of low-explosive velocity explosives are black powder and smokeless powder, which are often used as propellants in bullets and cannonballs. Smokeless gunpowder was invented in 1864. It is made from nitrocellulose,

ether and ethanol mixed and dried [6]. There are many types of high-explosive explosives, including a variety of chemical purification substances, such as nitroglycerin, trinitrotoluene, trinitrotoluene, etc. Triacetone peroxide, trinitromethylamine, pentaerythritol and complexes (such as glycerol dynamite, ammonium nitrate fuel and plastic explosives [C4 and semtin plastic explosives]).

Since the 20th century, a variety of high-explosive explosives have been developed, including trinitrotoluene, trinitromethylamine, and pentylenetetranitrate. Plastic explosives are made by mixing a high-explosive explosive (such as nitroglycerin or trinitromethylamine) with a plasticizer. This unique clay-like quality makes it widely used in blasting and military purposes [7]. What's more, there are records showing that plastic explosives are difficult to detect by security experts, so they are very popular with terrorists. They were used in the Pan American flight held in the United Kingdom in 1988 and the USS held in Yemen in 2000. Cole warship and the 2002 terrorist bombings on a train in Mumbai, India.

Triacetone triperoxide and hexamethylene triperoxide are representatives of high-explosion velocity liquid explosives. The 2005 London Underground bombing was a peroxide-based explosive; another high-explosion velocity explosive uses ammonium nitrate and fuel. 94:6 ratio mix, commonly used in the mining industry and construction industry. The use of such explosives by terrorists raises particular concerns because ammonium nitrate (fertilizer) and fuel are readily available.

High explosives can be further divided into primary explosives (which can be detonated by mechanical impact, friction or thermal energy) and secondary explosives (which require a secondary detonation).

The penetration caused by the conical charge and the explosion can directly increase the front overpressure. The conical charge has a linear hollow structure at the bottom, which can focus most of the energy of the explosive in a specific direction. This focusing improves controllability. , increasing the likelihood of destruction, making them favored by terrorists. High-density inert metal explosives (dense inert metal explosive (DIME) application. This explosive is composed of a single high-explosive explosive (such as trinitromethylamine) and inert small metal fragments (such as tungsten). The successful development of these explosives has made the bomb smaller and more effective. The explosion radius. This explosive is said to have a low additive damage capacity because the large amount of inert metal causes the pressure to decay more quickly. When it explodes, the shell of DIME breaks into small fragments. These shrapnel and the impact of the explosion are fatal at a closer range. Survivors after the explosion often have limb amputation, and heavy metal shrapnel remains in the body, which is related to the formation of tumors. And received much attention.

An improvised explosive device refers to any improvised explosive device that can replace a bomb and cause damage or disability after use. It is often used for multiple attacks or to divert the opponent's attention. A variety of devices can be used to detonate these improvised explosive devices, including electron launchers, tip switches, thermal switches, motion detectors, pressure sensing rods, and trip wires. Although the detonation mechanism is complex, the remaining parts (such as the pressure device made from a calculator switch, a washing machine timer, and a trip wire) are easily hidden and difficult to detect. Occasionally, devices to prevent dismantling or deactivation are installed on improvised explosive devices.

Improvised explosive devices using vehicles as carriers are vehicles loaded with explosives that rush towards high-value targets or government departments to detonate. The terrorist attack on the World Trade Center in New York, USA, in 2001, was carried by a temporary explosive device carried by a vehicle. Residential-loaded improvised explosive devices place a large amount of explosives inside a residence and detonate when the target is present. These explosive devices using vehicles and residences as carriers release huge direct frontal overpressure to people who are not protected by vehicles or carriers.

To increase the power of an improvised explosive device, and thus the damage from the explosion, the manufacturer may use a cone-shaped charge or add material fragments such as ball bearings, gravel or scrap metal. In addition, feces may also be added, which can cause contaminating penetrating fragments. What's more, explosive devices combined with chemical weapons may also be detonated, such as chlorine tanks, which can release toxic chlorine gas. In addition, these bomb devices were also used in terrorist bombings in Madrid, London and Mumbai [8].

3 MECHANISM OF BLAST INJURY

Explosion damage models are divided into primary, secondary and tertiary injuries. The later proposed fourth-level damage is mainly used to describe complex or mixed injuries. Recently, a fifth-level damage model has been proposed. People injured in explosions often have multiple injuries, which makes it impossible to clearly distinguish the boundaries of these injury modes, thus giving rise to the concept of multidimensional injury.

3.1 Primary Blast Injury

When the frontal overpressure reaches the human body and acts on it, primary blast injury occurs, causing direct damage to tissues. In 1950, Schardin described three types of explosions capable of causing damage Forces: rupture force, implosion force and inertia force. These forces have a concentration effect at the air-tissue interface, and are stronger in confined spaces than in open spaces, resulting in a higher probability of injury. However, the true magnitude of the force causing the injury is unknown.

When pressure waves propagate from one dense carrier to a lower density carrier, fragmentation forces are generated, causing the high-density medium to displace and fragment the low-density medium. For example, an underwater explosion can cause high-density water to splash into relatively low-density air and form upward fragments of water droplets. Explosive force occurs when the gas in the tissue is suddenly compressed by the front overpressure. When the positive pressure passes, the gas expands again and releases a large amount of kinetic energy. Ho described a lung injury caused by a simple bursting and condensation force. He mapped how the detonation wave propagated through the relatively incompressible blood in the blood vessels. The condensation force destroyed the endothelium of the blood vessel wall. When the shock wave Entering the alveoli, the compressed gas in the alveoli expands again, forcing the gas to overflow into the capillaries, forming an air embolus.
Inertial forces, i.e. shear forces, are similar to the pathophysiological effects of force reduction in non-knock injuries, such as automobile collisions. Relative to the overpressure peak, tissues of different densities move at different speeds, so when overpressure passes through an organ, structural components of different densities kink together and are destroyed by these shear forces.

3.2 Secondary Blast Injury

Secondary blast injuries are mostly caused by fragments caused by overpressure on the array or shock waves. Such fragments can cause penetrating and blunt force trauma similar to peacetime trauma (eg, puncture wounds, impact injuries, visible injuries, etc.). Many civilian injuries caused by terrorist bombs are secondary blast injuries, because these bombs usually contain fragments, such as ball bearings, small hardware, gravel or scrap metal, etc., in order to achieve the maximum lethality of the weapon. Sometimes secondary blast injuries that appear as small puncture wounds on the surface of the body can obscure these fragments and severe intrinsic damage.
The distance that the debris travels in the medium and causes damage is larger than the distance that the front overpressure travels, and the damage is more serious. Therefore, fragments can cause secondary impact injuries to targets hundreds or thousands of meters away from the center of the explosion, while primary blast injuries only occur within a few tens of meters. Therefore, secondary blast injuries are more common than primary blast injuries.

3.3 Third Degree Blast Injury

When the human body is exposed to the pressure of an overpressure peak, blast injuries and blunt injuries are classified as third-level blast injuries, such as closed head injuries, blunt abdominal trauma, tissue contusions or fractures. In addition, structural collapse of buildings or attachments also increases the risk of severe third-degree blast injuries (e.g., head trauma, traumatic asphyxia, and crush injuries), with mortality rates approaching those in confined spaces that do not collapse. Knock.

3.4 Level 4 and 5 Blast Injuries

Fourth-degree blast injuries, occasionally called compound blast injuries, are caused directly by the blast, while some are classified as primary, secondary, or tertiary blast injuries, including but not limited to burns, toxic material contamination (e.g., radioactive substances, carbon monoxide poisoning, cyanide poisoning), asphyxiation and psychological trauma.
Finally, there is the five-fold damage mode. This classification is based on the observation of a highly inflammatory state in patients during the Israeli bombings. The patient presents with high fever, diaphoresis, low central venous pressure, and positive fluid balance. Continued research on trauma will likely improve understanding of this blast injury pattern.

4 CONCLUSION

In modern society, local military conflicts and terrorist incidents occur from time to time, and blast injuries can occur even in industrial and agricultural production, such as mining, building blasting, etc. The increase in these blast injuries has made it difficult for emergency rescue and Medical staff for treatment and classified management have put forward higher requirements, because they are the first to come into contact with the sick and wounded, and they should fully understand the physical principles, occurrence mechanism, and pathogenesis of blast injuries.
classification and type of tissue damage.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] de Ceballos JP, Turegano-Fuentes F, Perez-Diaz D. 11 March 2004: The terrorist bomb explosions in Madrid, Spainan analysis of the logistics, injuries sustained and clinical manage- ment of casualties treated at the closest hospital. Crit Care, 2005, 9(S1): 104-111.

[2] De Palma RG, Burris DG, Champion HR. Blast injuries. N Engl J Med, 2005, 352(11): 1335-1342.
[3] Phillips YY. Primary blast injuries. Ann Emerg Med, 1986, 15(12): 1446-1450.
[4] Stapczynski JS. Blast injuries. Ann Emerg Med, 1982, 11: 687-694.
[5] Arnold JL, Halpern P, Tsai MC. Mass casualty terrorist bombings: a comparison of outcomes by bombing type. Ann Emerg Med, 2004, 43(3): 263-273.
[6]Davis T. The Chemistry of Powder and Explosives. Hollywood CA: Angriff Press, 1972.
[7] Cooper PW. Explosives engineering. New York City, NY: Wiley-VCH, 1996.
[8] Mehta S, Agarwal V, Jiandani P. Ocular injuries in survivors of improvised explosive devices(IED)in commuter trains. BMC Emerg Med, 2007, 7(1): 16.