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REVIEW

Wound ballistics and blast injuries

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Ballistic protection

Summary Wounds due to gunshot and explosions, while usually observed during battlefield combat, are no longer an exceptional occurrence in civilian practice in France. The principles of wound ballistics are based on the interaction between the projectile and the human body as well as the transfer of energy from the projectile to tissues. The treatment of ballistic wounds relies on several principles: extremity wound debridement and absence of initial closure, complementary medical treatment, routine immobilization, revision surgery and secondary closure. Victims of explosions usually present with a complex clinical picture since injuries are directly or indirectly related to the shock wave (blast) originating from the explosion. These injuries depend on the type of explosive device, the environment and the situation of the victim at the time of the explosion, and are classed as primary, secondary, tertiary or quaternary. Secondary injuries due to flying debris and bomb fragments are generally the predominant presenting symptoms while isolated primary injuries (blast) are rare. The resulting complexity of the clinical picture explains why triage of these victims is particularly difficult. Certain myths, such as inevitable necrosis of the soft tissues that are displaced by the formation of the temporary cavitation by the projectile, or sterilization of the wounds by heat generated by the projectile should be forgotten. Ballistic-protective body armor and helmets are not infallible, even when they are not perforated, and can even be at the origin of injuries, either due to missile impact, or to the blast.

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Essential points

- Gunshot wounds do not cause occult injuries: wounds must be treated in the usual manner.
- Gunshot wounds are combat injuries and must be considered as being highly dirty and contaminated.
- A non-perforated ballistic protection does not mean that there are no underlying injuries: transmitted forces can be responsible for blunt injuries that are potentially serious.
- In explosion victims, isolated blast injuries are rare because injuries by projected material (secondary injury) usually predominate. These injuries are usually quite obvious.
- Triage of blast victims is particularly difficult because of the complexity of the clinical picture. Routine ear examination by otoscopy should be abandoned. All suspected blast victim should have a CT scan.
- "Treat the wound, not the weapon"

Introduction

Gunshot wounds and blast injuries are the principle causes of wounds and mortality in combat. In today's world, unfortunately, such lesions are no longer an anecdotal experience in civilian practice in France. Aside from certain highly theoretical notions necessary for the understanding of the observed phenomena, this update is essentially a review of the practical aspects and several ill-founded myths that surround ballistic wounds.

Principles of ballistic wounds: interaction between the projectile and living tissue (IPLT)

The biomechanical principles underlying ballistic injuries are simple: when a missile interacts with the human body, it transfers its energy to the human tissues, and this energy transfer determines the injuries. Thus, the greater the loss of energy as a projectile traverses the tissue, the more the damage caused. In addition to frictional energy loss during penetration, a firearm missile can transfer its kinetic energy according to three particular modalities: tumbling, mushrooming, and fragmentation (Fig. 1).

The IPLT and the severity of injuries also depend on elements related to the zone of impact. Ballistic protections (bullet-proof armor, helmet) limit the wounding effects of missiles by capturing the missile before it creates any penetrating injury. However, these protections are far from infallible; their limitations are discussed further on.

Principles of blast injuries

Victims of explosions present complex clinical pictures, either immediately or at longer term, directly or indirectly related to the shock wave (blast) of the explosion. The location and the distance from the epicenter of explosion are primordial elements for the early diagnosis of blast injury in the individual. The pressure characteristics of the shock wave generated by the explosion and the type of injuries created depend on the nature of the explosive device, its packaging, the environment in which the explosion occurs, and the location of the victim at the time of the explosion.

For an open-air explosion, the shock wave pressure profile is defined by a transient phase of hyper-pressure that decreases rapidly with distance if there are no obstacles. The risk of blast injury decreases very quickly with distance.

Any nearby obstacle (ground, wall, corridor, shelter...) can reflect, deviate, re-inforce, shunt or transfer the shock wave (for example, the floor of a vehicle hit by a land-mine). Explosions in urban areas or in confined spaces complicate and intensify the destructive power of the charge because of the compounding effect of the confining structures. Injuries are not only a function of the intensity of the explosion and the shock wave but also depend on the lesional mechanism involved. The victim usually has multiple injuries.

Projection of debris, rubble, or of the victim, contamination of the wounds, collapsing structures and burns all are causes of traumatism that influence the survival of the victim. Thus, explosions can be responsible for several different types of injuries:

- blast injuries (primary blast injuries) are related to the direct interaction between the shock wave hyper-pressure with the person;
- penetrating injuries (secondary blast injuries) result from shrapnel, originating from fragments of the explosive device itself or rubble from the environment, energized and projected by the explosion blast wind;
- closed traumatism (tertiary blast injuries) are the consequence of the projection of the victim him/her-self against nearby obstacles (ground, walls, dashboard or car cabin), somewhat similar to injuries observed in classical accidental falls or motor vehicle accidents;
- quaternary blast injuries (mostly burns) associate all the factors that, indirectly, converge to complicate, or present a particular aspect of injury specific to the explosive device or the charge: burns, dust particles, pathogenic agents, radiation.

Myths and reality

Soft tissue attrition

Along its intra-corporeal pathway, the projectile pushes and thrusts back the tissues, creating a temporary cavitation. Although this temporary cavitation can exceed 10 cm in diameter for high-velocity missiles, the tissues so driven back and compressed, are not inevitably injured. A misunderstanding of this principle and the appearance of theories stating that tissues involved in this temporary cavitation are doomed to necrosis have led to truly unnecessary mutilative procedures during surgical debridement.

All wounds, and especially combat wounds, are dirty and at high risk for infection [1]. This axiom is equally true for ballistic wounds. Effectively, first of all, even though the missile is hot, it is not "sterilized" and in any case, cannot "sterilize the wound". Next, and last, all ballistic wounds become infected secondarily; thus the axiom pronounced by Fackler: "Treat the wound, not the weapon" [2].

Limitations of the protective capacity of ballistic protections

Personal ballistic protections, whether bulletproof vests or helmets, have their limitations and particularities that medical personnel should be aware of [3].

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