Chapter 3
Blast and Ballistics: Types, Background, Terminology

Keywords IED · V-IED · EFP · RPG · Shrapnel · Fragment, Projectile, Missile · Ballistics, missile precession · Rifling, spinning · Wound ballistics, tumbling · Temporary, permanent wound cavity · Penetrating · Perforation · Missile embolus · Keyhole pattern

3.1 Introduction

Many combat casualties are victims of explosives, resulting in catastrophic poly-trauma with multiple types of injuries. Terrorists attack in an attempt to drain resources, injuring many, with grueling psychological effects to help get their message across. Blast injuries are not as unique to battle as we would hope, however, as they are unfortunately becoming more common worldwide outside the battlefield environment. Familiarity with imaging manifestations of blast injuries, for example, is paramount no matter the setting, country, or location. Disasters, explosions, and shootings can happen in all types of settings and can occur anywhere. Some example cases of blast and ballistic injury are highlighted to illustrate our experiences in imaging findings and surgical follow-up in combat casualties.

3.2 Types of Explosives and Types of Resultant Blast Injuries

Few providers have had the opportunity to gain experience diagnosing and treating those severely injured from blast or high-velocity missiles. Most injuries in Iraq have been due Improvised Explosive Devices (IED). With explosions becoming more common in civilian settings to include the United States, understanding types

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and effects of blast injury can familiarize the radiologist and result in increased detection of imaging findings for optimal diagnosis, prognosis, and treatment options.

There are several types of explosive ordinance seen in modern combat worthy of discussing.

IED: Improvised Explosive Device that is home-made from everyday materials. The harmful projectiles include anything from paperclips and spent bullet shells to automobile parts (especially when the car is part of the bomb).

VB-IED: Vehicle-Borne Improvised Explosive Device: Essentially an IED that is placed in a vehicle.

RPG: Rocket Powered Grenade: a grenade that is shot from a rocket to explode on impact of a human, group, or structure to inflict damage.

EFP: Explosive Formed Penetrator: a tubular container capped with concave copper plates that project the plate by mechanics of reversal of the concavity to a convexity, providing additional thrust during the explosion. See Fig. 3.1 for sequential photos of a controlled detonation of VB-EFP that acted also like an IED in that the car parts acted as projectiles. These images should show how these homemade explosive devices can be devastating.

Example cases are included that highlight some of these properties and medical effects and imaging findings in casualties suffering from blast injuries. A brief description of medical blast effects is in order. There are four types of blast injury depending on proximity, severity, type of explosive, and surrounding environment [1, 2]:

Primary: Blast wave: hollow organs essentially burst due to overpressure
Secondary: Debris vs. body (most common, IED, other blasts)
Tertiary: Body thrown against hard objects (walls, objects)
Quaternary (or miscellaneous): Fire, smoke, crushing

Basically, primary blast injury comes from a wave of blast overpressure compressing the body and hollow air-filled organs; secondary injury results from flying debris and projectiles that have ballistic properties; tertiary injury happens when the patient's body becomes the flying object and collides with other objects (walls, vehicles, etc). Quaternary (sometimes referred to as miscellaneous) injury comes from burns from the blast heat or inhalation of gases and smoke released in the explosion. Many casualties have a combination of these injury types.

There was recently a case reported that demonstrated colon perforation from the primary blast wave [3]. We have seen other primary blast effects to include lung (Blast Lung Injury or BLI). Although described for years, BLI has a lot to be discovered, however, has been shown to be a major cause of immediate death at the scene of terrorist bombing attacks [4]. Work is underway to stage severity by CT findings of BLI at Walter Reed Army Medical Center. A spectrum of blast lung injuries with proposed mechanisms will be shown in the chest imaging chapter.

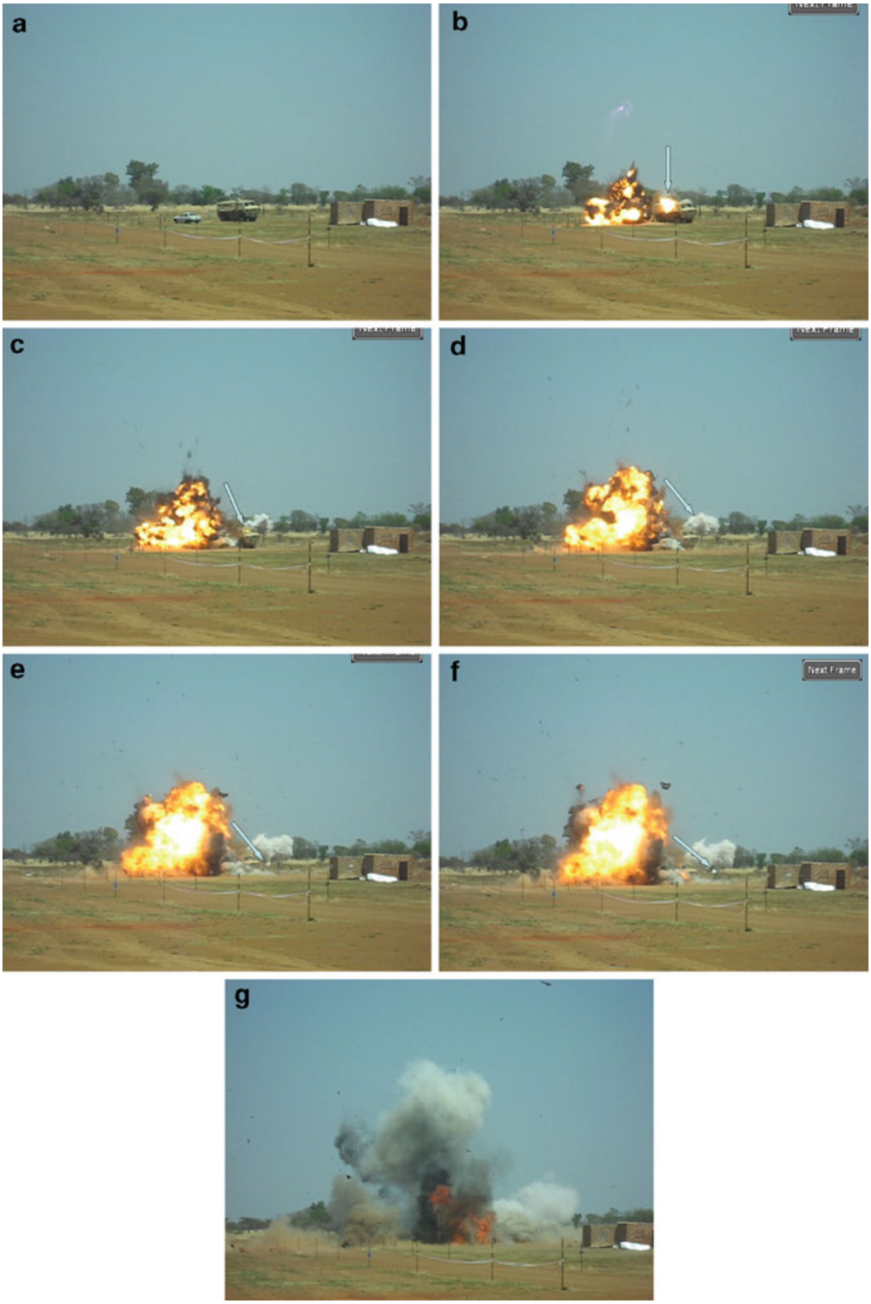

Fig. 3.1 These sequential photos demonstrate the destructive nature of an EFP. The armored vehicle was penetrated by the EFB placed into the adjacent small car. The effects of the copper plate (initial burning on entrance, burning copper in drivers compartment, smoke on exit, and resultant ash debris on exit) are seen by the arrow in each of the sequences. Photos by Dr. Les Folio

3.2.1 Blast and Ballistic Terminology

There are unique terms in the science of blast and ballistics that may not be familiar to many radiologists. Mastering this lexicon before deployment would be prudent since trauma surgeons and experienced deployers will be using this terminology regularly. For example, some still use the term “Shrapnel” however, that is a specific term reserved for the now obsolete artillery round developed by Henry Shrapnel, a young British Officer, at the end of the eighteenth century. This Shrapnel Shell, also called “case-shot” or “canister,” was a metal canister filled with lead balls set to explode after traveling a specific time or distance. It was in use by Armies for more than 100 years, and fell essentially into disuse in World War I in 1915 when replaced by the more effective high explosive artillery rounds [5]. We refer to retained metal from blasts as fragments and describe their shape, size, and location. There is research underway at Walter Reed to automatically localize all retained fragments in 3D. This will be discussed in more detail later in this book.

3.2.2 Ballistics

Bullets spin on own axis (like a spinning football) when exiting a weapon due to rifling of the barrel. There is slight precession or wobbling that often increases with distance from the weapon. Once a projectile enters the body, it tumbles and most often reverses orientation where the heavy end of the bullet eventually takes the lead. This often causes the tapered end of the bullet to face back toward the direction the bullet entered. High-velocity firearms generally create the greatest amount of trauma, however, size, shape, and consistency of the bullet (jacketed, hollow point, etc.) have influence over the extent of the wound.

3.2.3 Wound Ballistics

The terms “penetrating” and “perforating” injuries, while very different, are often confused for one another. In penetrating injuries, the projectiles (or missiles) enter the body and do not exit, while in perforating injuries, they enter and exit; through and through injuries essentially. In addition, bullets, associated fragments, and blast debris may enter a vessel and embolize to the lungs or brain. This is sometimes referred to as missile embolus, and is well-documented [6–8]. Once intravascular, any migration of the bullet/fragment will be influenced by position, respiratory motion, blood flow, and gravitational forces [9, 10]. Operative manipulation alone has been described in causing fragment migration [11]. One recent documentation of missile embolus was nicely illustrated by Andrews et al. [12]. This fragment from an AK 47 round was documented with regard to the knee, then was not seen on follow-up knee plain images, then seen on a follow-up CXR that was clear hours earlier.

3.2.4 Wound Cavities

The permanent wound cavity is the damage done directly by the projectile along its immediate path. There is also a temporary wound cavity, caused by pressure waves created by and following the projectile as it passes through surrounding tissues separated from the bullet. The temporary cavity is generally larger than the diameter of the bullet [13]. This temporary wound cavity is created by deformation of tissue as it is displaced by the pressure wave. Some tissue stretch easily and are less vulnerable to damage by this mechanism, such as muscle. Other, more friable tissue, as in solid organs like liver or spleen, are more vulnerable to damage. Mechanisms of trauma are a result of crushing and stretching of tissues from the often tumbling projectile [14]. Figure 3.2 demonstrates a GSW to the chest that shows a laceration of the lung in the direct path of the bullet, with surrounding consolidation representing the local destruction of lung tissue and associated vasculature.

Fig. 3.2 This reformatted para-axial thorax CTA demonstrates the lung laceration representing the permanent cavity, and the surrounding consolidation representing contusion of the temporary cavity of the perforating tumbling projectile. C-Arm interoperative selective ICA angiogram with isolated CTA 3-D correlation (3B). Reprinted with permission from Military Medicine: International Journal of AMSUS

3.2.5 Even Number Guide

When a casualty suffers from multiple GSW, a basic guide may be helpful to account for all fragments based on wounds and imaging findings. The even number guide is based on the number entrance and exit wounds should be associated with number of fragments expected on imaging. This assumes GSWs without fragmentation and occasionally may work with blast fragments. Basically, the total number of bullets and wounds should be an even number [15]. The simplest example would be a penetrating GSW with an entrance and no exit. One entrance wound means one fragment should be expected on imaging (total of two, an even number). If a fragment is not seen on initial imaging, then more imaging may be necessary, even in remote anatomic regions. One reason for this is the possibility of a missile embolus just mentioned. Another example to highlight the even number guide would be a casualty with three entrance wounds and one exit wound. One would expect to find two bullets for a total of six – an even number. This may not seem necessary at first, however, with multiple GSW casualties, each with multiple GSWs, every tool to simplify matters can be more helpful than first realized.

There are some injuries that have characteristic imaging patterns that help determine prognosis, cause and manner of death, and may help in analysis of incident. Later in this book I will present a case of a soldier wounded in Iraq with a gunshot wound to the skull exhibiting this characteristic keyhole fracture pattern on CT [16]. Tangential gunshot wounds to the skull were originally termed "keyhole fractures" by Spitz in 1980, and the mechanics involved in the creation of the defect were later described by Dixon in 1982 [17]. Keyhole fractures exhibit entrance and exit wound defects resulting from a projectile striking the cranium or long bones tangentially. The projectile's initial impact creates a circular entrance defect as the bullet strikes the outer table of bone, and a secondary fracture is created by bone fragments propagated from the initial point of impact [18]. External examination of the wound can therefore be confusing, manifesting signs of both entrance and exit type trauma [19]. This is important information for the radiologist to provide to the ED doc urgently since the wound can seem trivial on clinical inspection. Awareness of the mechanics behind tangential gunshot wounds can help classify the type of injury and the associated trauma incurred by the patient. CT is important in the medical work up of tangential gunshot wounds as it can show the keyhole fracture of the cranium as well as any bone fragments within the calvarium.

3.3 Summary

Imaging in blast and ballistic injuries can be puzzling if not prepared or familiar with findings and/or terminology. This chapter introduced some basic lexicon to help orient the radiologist to the lingo used in combat hospitals and some busy trauma centers that see these types of injuries. Although blast injuries may not be common in most hospitals, familiarity with lessons learned in combat would be prudent for if and when a blast does occur. Even a basic understanding of blast properties and potential effects on the body can help the radiologist more effectively communicate with ED docs and trauma surgeons.

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