

The most common pattern of injury seen on a conventional battlefield is the patient with multiple small fragment wounds of the extremity.

Anatomical Distribution of Penetrating Wounds (%)

Conflict	Head and Neck	Thorax	Abdomen	Limbs	Other
World War I	17	4	2	70	7
World War II	4	8	4	75	9
Korean War	17	7	7	67	2
Vietnam War	14	7	5	74	—
Northern Ireland	20	15	15	50	—
Falkland Islands	16	15	10	59	—
Gulf War (UK) **	6	12	11	71	(32)*
Gulf War (US)	11	8	7	56	18+
Afghanistan (US)	16	12	11	61	—
Chechnya (Russia)	24	9	4	63	—
Somalia	20	8	5	65	2
Average	15	9.5	7.4	64.6	3.5

* Buttock and back wounds and multiple fragment injuries, not included

+ Multiple wounds

** 80% caused by fragments; range of hits 1–45, mean of 9

Mechanism of Injury

- For missile injuries, there are two areas of projectile-tissue interaction, permanent cavity and temporary cavity (Fig. 1-1).

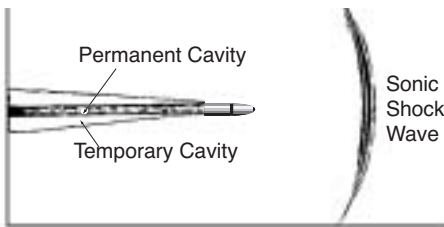


Fig. 1-1. Projectile–tissue interaction, showing components of tissue injury.

- o **Permanent** cavity. Localized area of cell necrosis, proportional to the size of the projectile as it passes through.
- o **Temporary** cavity. Transient lateral displacement of tissue, which occurs after passage of the projectile. **Elastic tissue**, such as skeletal muscle, blood vessels and skin, may be pushed aside after passage of the projectile, but then rebound. **Inelastic tissue**, such as bone or liver, may fracture in this area.
- The **shock (or sonic) wave** (commonly mistaken for the temporary cavity), though measurable, has **not** been shown to cause damage in tissue.

Explosive munitions have three mechanisms of injury (Fig. 1-2):

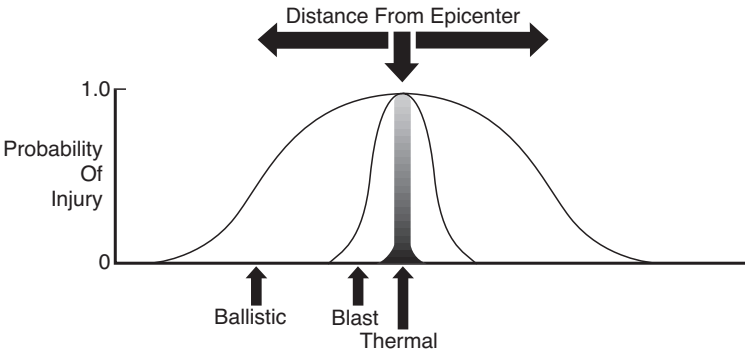


Fig. 1-2. The probability of sustaining a given trauma is related to the distance from the epicenter of the detonation.

- **Ballistic.**
 - o Fragments from explosive munitions cause ballistic injuries.
 - o Fragments are most commonly produced by mortars, artillery, and grenades.
 - o Fragments produced by these weapons vary in size, shape, composition, and initial velocity. They may vary from a few milligrams to several grams in weight.
 - o Modern explosive devices are designed to spread more uniform fragments in a regular pattern over a given area.

- o Fragments from exploding munitions are smaller and irregularly shaped when compared to bullets from small arms.
- o Although initial fragment velocities of 5,900 ft/s (1,800 m/s) have been reported for some of these devices, the wounds observed in survivors indicate that striking velocities were less than 1,900 ft/s (600 m/s). Unlike small arms, explosive munitions cause multiple wounds.
- Blast (see Fig. 1-2).
 - o The blast effects take place relatively close to the exploding munition relative to the ballistic injury.
 - o Blast overpressure waves, or sonic shock waves, are clinically important when a patient is close to the exploding munition, such as a land mine.
 - o The ears are most often affected by the overpressure, followed by lungs and the gastrointestinal (GI) tract hollow organs. GI injuries may present 24 hours later.
 - o Injury from blast overpressure is a pressure and time dependent function. By increasing the pressure or its duration, the severity of injury will also increase.
 - o Thermobaric devices work by increasing the duration of a blast wave to maximize this mechanism of injury. The device initially explodes and puts a volatile substance into the air (fuel vapor). A second explosion then ignites the aerosolized material producing an explosion of long duration. The effects from this weapon are magnified when detonated in an enclosed space such as a bunker.
 - o Air displaced on the site after the explosion creates a blast wind that can throw victims against solid objects, causing blunt trauma.
- Thermal.
 - o Thermal effects occur as the product of combustion when the device explodes. Patients wounded near exploding munitions may have burns in addition to open wounds, which may complicate the management of soft tissue injuries.

Common Misconceptions About Missile Wounds

Misconception	Reality
Increased velocity causes increased tissue damage.	Velocity is one factor in wounding. An increase in velocity does not per se increase the amount of tissue damage. The amount of tissue damage in the first 12 cm of a M-16A1 bullet wound profile has relatively little soft tissue disruption, similar to that of a .22 long rifle bullet, which has less than half the velocity.
Projectiles yaw in flight, which can create irregular wounds.	Unless a projectile hits an intermediate target, the amount of yaw in flight is insignificant.
Exit wounds are always greater than entrance wounds.	This is untrue and has no bearing on surgical care.
Full metal-jacketed bullets do not fragment, except in unusual circumstances.	The M-193 bullet of the M-16A1 rifle reliably fragments at the level of the cannulure after traversing about 12 cm of tissue in soft tissue only.
All projectile tracts must be fully explored, due to the effects of the temporary cavity.	Elastic soft tissue (skeletal muscle, blood vessels, and nerves) generally heals uneventfully and does not require excision, provided the blood supply remains intact. Temporary cavity effects are analogous to blunt trauma.

Antipersonnel Landmines

- There are three types of conventional antipersonnel landmines available throughout the world: static, bounding, and horizontal spray.
 - **Static** landmines are small, planted landmines (100–200 g of explosive) that are detonated when stepped on, resulting in two major areas of injury (Fig. 1-3).

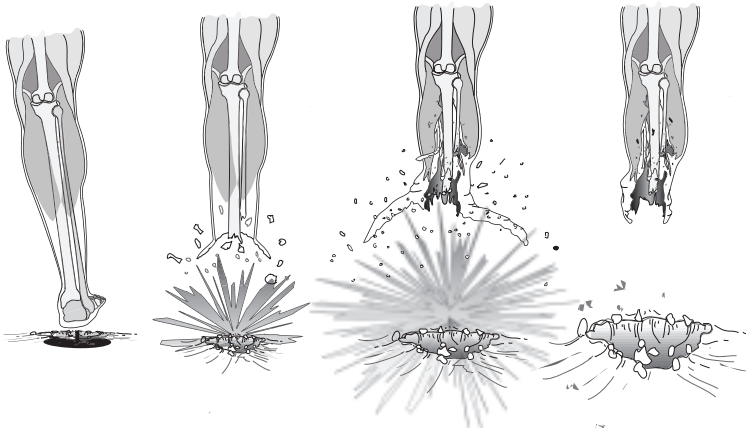


Fig. 1-3. Mechanisms of injuries caused by antipersonnel land mines.

- ◆ Partial or complete traumatic amputation, most commonly at the midfoot or distal tibia.
- ◆ More proximally, debris and other tissue is driven up along fascial planes with tissue stripped from the bone.
- ◆ Factors influencing the degree of injury include size and shape of the limb, point of contact with the foot, amount of debris overlying the mine, and the type of footwear.
- **Bounding** mines propel a small explosive device to about 1–2 m of height and then explode, causing multiple small fragment wounds to those standing nearby. These landmine casualties have the highest reported mortality.

- o **Horizontal spray** mines propel fragments in one direction. This land mine can be command-detonated or detonated by tripwire. The US Claymore mine fires about 700 steel spheres of $\frac{3}{4}$ g each over a 60° arc. Horizontal spray mines produce multiple small-fragment wounds to those nearby.
- An unconventional weapon (improvised explosive device, or IED) is a fourth type of antipersonnel landmine. Either another piece of ordnance is used, such as a grenade or a mortar shell, or the device is completely fabricated out of locally available materials.

Small Arms

- Pistols, rifles, and machine guns.
- Trends for small arms since World War II include rifles that have increased magazine capacity, lighter bullets, and increased muzzle velocity.
- Below are some examples of the characteristics of commonly encountered firearms seen throughout the world. The illustrations are of the entire path of missiles fired consistently at 5–10 m in range into ordnance gelatin tissue-simulant blocks. Variations of range, intermediate targets such as body armor, and body tissue will alter the wound seen.
 - o The AK-47 rifle is one of the most common weapons seen throughout the world. For this particular bullet (full metal jacketed or ball) there is a 25 cm path of relatively minimal tissue disruption before the projectile begins to yaw. This explains why relatively minimal tissue disruption may be seen with some wounds (Fig. 1-4).

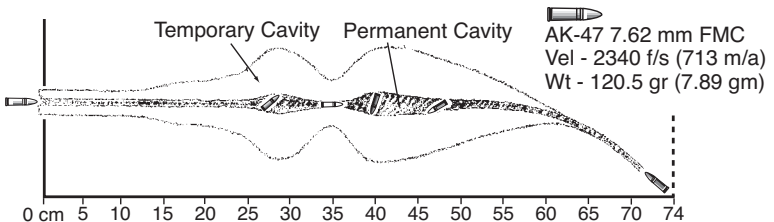


Fig. 1-4. Idealized path of tissue disruption caused by an AK-47 projectile, (10% gelatin as a simulation).

- o The AK-74 rifle was an attempt to create a smaller caliber assault rifle. The standard bullet does not deform in the tissue simulant but does yaw relatively early (at about 7 cm of penetration).
- o The M-16A1 rifle fires a 55-grain full metal-jacketed bullet (M-193) at approximately 950 m/s. The average point forward distance in tissue is about 12 cm, after which it yaws to about 90°, flattens, and then breaks at the cannalure (a groove placed around the mid section of the bullet). The slightly heavier M-855 bullet used with the M-16A2 rifle, shows a similar pattern to the M-193 bullet (Fig. 1-5).

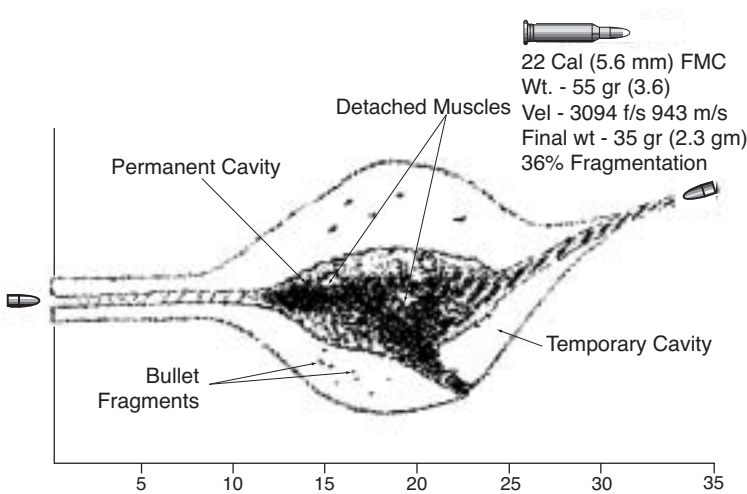


Fig. 1-5. Idealized path of tissue disruption caused by an M-193 bullet fired from the M-16A1 rifle (10% gelatin as a simulation).

- o The 7.62 mm NATO rifle cartridge is still used in sniper rifles and machine guns. After about 16 cm of penetration, this bullet yaws through 90° and then travels base forward. A large temporary cavity is formed and occurs at the point of maximum yaw (Fig. 1-6).

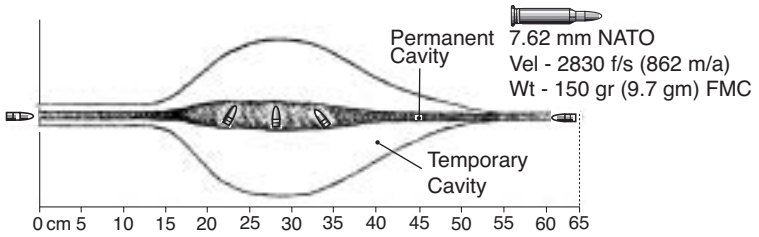


Fig. 1-6. Idealized path of tissue disruption caused by the 7.62 mm projectile, (10% gelatin as a simulation).

Armored Vehicle Crew Casualties

- Since the first large scale use of tanks during WWI, injuries to those associated with armored vehicles in battle have been a distinct subset of combat casualties.
- Tanks, infantry fighting vehicles, armored personnel carriers, armored support vehicles, and “light armored vehicles.”
 - Light armored vehicles tend to use wheels rather than tracks for moving and have lighter armor. The main advantage for these vehicles is to allow for greater mobility.

Compared to infantry, injuries to those inside or around armored vehicles are characterized by:

- Decreased overall frequency.
 - Increased severity of injury and mortality (up to 50%).
 - Increased incidence of burns and traumatic amputations.
- There are three main types of antiarmor weapons on the battlefield today.
 - **Shaped charge** (Fig. 1-7a).
 - ◆ The shaped charge or high explosive antitank (HEAT) round consists of explosives packed around a reverse cone of metal called a melt sheet or a liner. This is the principle behind the warhead of the RPG.

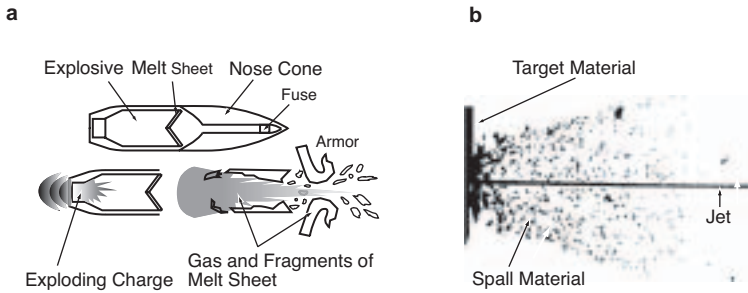


Fig. 1-7. (a) Disruptive mechanisms of the shaped-charge warhead, (b) diagram taken from photograph of an actual detonation of shaped-charged warhead against armor plate caused by antitank land mines.

- ◆ Shaped charges range in diameter from the 85 mm RPG-7 to the 6-in diameter tube launched, optically tracked, wire guided (TOW) missile.
- ◆ If the armor is defeated by the shaped charge, there are two areas of behind-armor debris.
 - ◇ First, there is the jet of the shaped charge itself. This may cause catastrophic wounds to soldiers who are hit, or it may ignite fuel, ammunition, or hydraulic fluid.
 - ◇ There is a second type of debris, called spall, which is material knocked off from the inside face of the armored plate. This produces a spray of small, irregularly shaped fragments inside of the compartment (Fig. 1-7b).

o Kinetic energy round.

- ◆ The kinetic energy (KE) round contains an aerodynamically shaped piece of hard metal (such as depleted uranium or tungsten) shaped like a dart. The metal is usually encased in a carrier or sabot that falls away from the projectile after it leaves the barrel. Fragments of depleted uranium should be treated during initial wound surgery as any retained metal foreign body should. There is a hypothetical risk, over years, that casualties with retained depleted uranium fragments may develop heavy metal poisoning. This concern by itself does not justify extensive operations to remove such fragments during initial wound surgery.

- ◆ Injuries to those inside a vehicle are due to the direct effects of the penetrator or from fragments knocked off the inside face of the armored plate. The range of fragment masses may be from a few milligrams to over a kilogram.
- o **Antitank landmines.**
 - ◆ Blast mines are those with a large explosive filler of 4–5 kg. Injuries are often from blunt trauma due to crewmembers being thrown around inside the vehicle after it detonates the mine.
 - ◆ Closed fractures of the upper and lower extremities and spine are common (Fig. 1-8).
 - ◆ A modification of the shaped charge is the Miznay-Schardin antitank mine that creates a projectile or large metal slug to cause damage to the vehicle. This is less likely than a conventionally shaped charge to be broken up by intermediate targets.

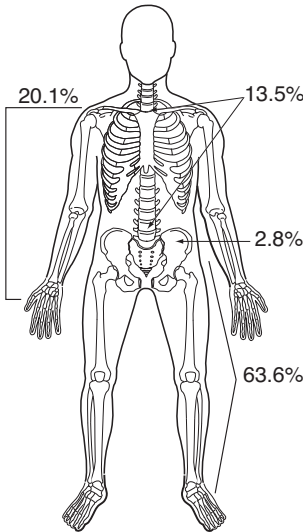


Fig. 1-8. Distribution of fracture sites sustained within an armored vehicle that had detonated a land mine (Soviet data from Afghanistan, early 1980s).

