Ballistics:
The Physics Behind the Tragedy

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Disclosures

I have no financial disclosures…

…but I wish I did!

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Political Disclosures

1. This is not a talk for or against gun ownership
2. This is not a discussion about 2nd amendment rights
3. It is to look at the physics and effects of bullets and bullet-related injuries

……Therefore……
Please do not ask any questions related to items 1 or 2.
I will ignore you…..

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Definitions:

- A gunshot wound (GSW), also known as a ballistic trauma, is a form of physical trauma sustained from the discharge of arms or munitions.
- Trauma from a gunshot wound varies widely based on the bullet, velocity, entry point, trajectory, and affected anatomy.

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Start with a Question?

- If given a choice would you rather be stabbed or shot?
- I would prefer neither……but by the end of the lecture you will make a clear choice.

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Characteristics of Bullets

- Talk about:
  - Energy transfer
  - Mass of the bullet
  - Velocity of the bullet
  - Type of ammunition used

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Speed and Size Matters

- Energy of kinetics
- KE = $1/2MV^2$
- Kinetic energy transfer
  - KE = 1/2M [(V entering)^2- (V exiting)^2]
  - Assume that the bullet does not "waste" significant energy on deforming
  - Notice worst case scenario is when the V exiting is zero. You absorbed all the energy
  - Larger bullets have more mass = more KE
  - Faster bullets have higher velocity = more KE

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Velocity of Different Bullets

Gunshot wounds are classified according to the speed of the projectile:

- Low-velocity: < 1,100 ft/s (340 m/s)
- Medium-velocity: 1,100 ft/s (340 m/s) to 2,000 ft/s (610 m/s)
- High-velocity: 2,000 ft/s (610 m/s) to 3,500 ft/s (1,100 m/s)
- Hyper velocity: > 3,500 ft/s (1,100 m/s)
- Bullets from handguns are sometimes less than 1,000 ft/s (300 m/s) but with modern pistol loads, they usually are slightly above 1,000 ft/s (300 m/s), while bullets from rifles exceed 2,500 ft/s (760 m/s)
- M 16 (AR 15 civilian equivalent) 3,250 fps (990 m/s)

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Types of Ammunition

- Expanding Ammunition
- Armor Piercing Ammunition
- Tumbling Ammunition
- Why do we have different types of ammunition?
  - ➡ **To increase lethality**

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Expanding Ammunition

- When a hollow-point hunting bullet strikes a soft target, the pressure created in the pit forces the material (usually lead) around the inside edge to expand outwards, increasing the axial diameter of the projectile as it passes through.
- This process is commonly referred to as *mushrooming*, because the resulting shape, a widened, rounded nose on top of a cylindrical base, typically resembles a mushroom.

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Expanding Ammunition

- The greater frontal surface area of the expanded bullet limits its depth of penetration into the target, and causes more extensive tissue damage along the wound path.

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Expanding Ammunition

- Many hollow-point bullets, especially those intended for use at high velocity in centerfire rifles, are *jacketed*, i.e. a portion of the lead-cored bullet is wrapped in a thin layer of harder metal, such as copper, brass, or mild steel.
- This jacket provides additional strength to the bullet, increases penetration, and can help prevent it from leaving deposits of lead inside the bore.
- In controlled expansion bullets, the jacket and other internal design characteristics help to prevent the bullet from breaking apart; a fragmented bullet will not penetrate as far.

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Expanding Ammunition

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Non Jacketed Bullet

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Steel Jacketed Bullets

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Armor Piercing Bullets

- Teflon was added
- Soft outer layer
- Prevents muzzle wear on weapons
- Soft outer layer allows the bullets to “grip” hardened surfaces for greater penetrating ability
- The bullet trajectory is not changed or deflected

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Teflon Coated Ammunition

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Tumbling Bullets

- They cause greater permanent cavities in tissues
- Slows rapidly
- Tissues absorbs more energy

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What Make Bullets so Lethal?

- It is all about the energy transfer
- Bullets have a lot of energy and that rapid dissipation of energy is translated into different forms:
  - Heat
  - Permanent Cavitation
  - Temporary Cavitation
  - Pressure Wave
  - Secondary Fragmentation

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What Effects Does the Bullet Have on Tissues?

- Permanent Cavitation
  - The permanent cavity, or wound tract, is the tract of tissue directly damaged by the local forces generated as the projectile loses energy
  - It tends to be larger where the retarding forces are higher and to taper once the bullet has slowed

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What Effects Does the Bullet Have on Pliable Tissues?

- Temporary Cavitation:
  - The rapid expansion of the tissue from the radial force of the bullet
  - In elastic tissues such as lungs and muscle, where the tissue tends to spring back into place with little damage from temporary stretch
  - Most tissue damage is caused from the intense field of compressive and shear stress within a few centimeters of the bullet path
  - This intense stress field propagates outward from the retarding force between the bullet and tissue, but falls off quickly with distance

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Effects of Bullets on Tissues Temporary Cavitation

- Comparing penetrating thoracic wounds caused by stab injuries to those caused by gunshot injuries, the occurrence of lung contusions around the trajectory was 43% for gunshot injuries but only 2% for stab injuries

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Effects of Bullets on Tissues Temporary Cavitation

- The sudden expansion of the temporary cavity and/or its collapse can injure even elastic tissues
- Tissue stretches in the bullet wake due to temporary cavitation
- Small holes created by fragments cause additional permanent tears in tissue

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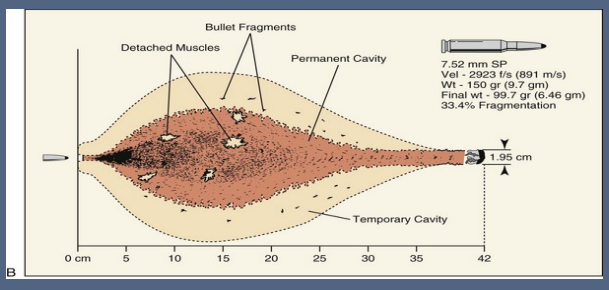

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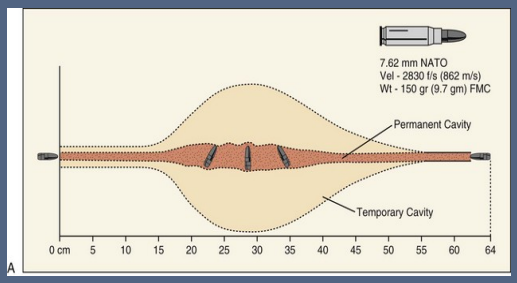
Bullet Tumbling Effect



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Trajectory of Tumbling Bullet

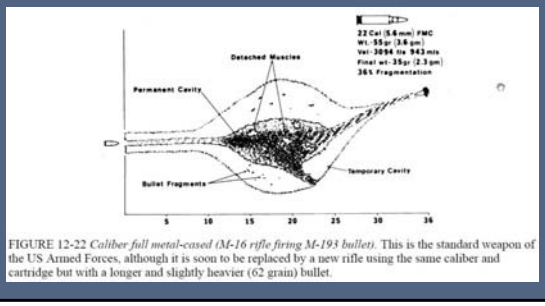

FIGURE 12-22 *Caliber full metal-cased (M-16 rifle firing M-193 bullet).* This is the standard weapon of the US Armed Forces, although it is soon to be replaced by a new rifle using the same caliber and cartridge but with a longer and slightly heavier (62 grain) bullet.

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Ballistic Pressure Waves

- Ballistic pressure waves can cause vascular and visceral injuries and indirect bone fracture.
- Thrombosis and intimal shearing in arteries
- When repairing these injuries it is important to resect further than you think, as there will be unseen intimal injury up to 5 cm or more from the injured area (personal experience).
- The higher the velocity injury the higher the index of suspicion of distal injury.
- Ballistic pressure waves have also been implicated in focal, delayed perforation of intestines without direct penetration following abdominal gunshot wounds

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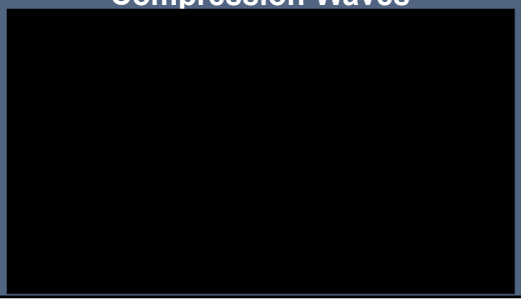
The Effect of Cavitation and Compression Waves



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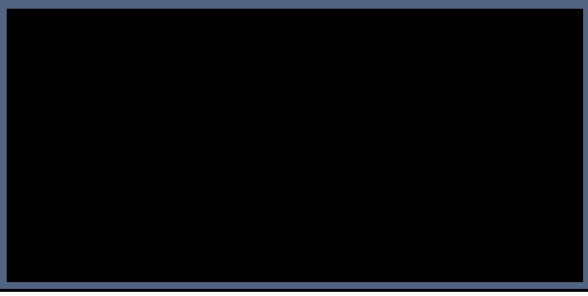
High Velocity Round



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Effects of Bullets on Non-Elastic Tissues

- Tissues can not expand and contract
  - Fracture
  - Splintering
  - Secondary Fragmentation that can cause additional injury

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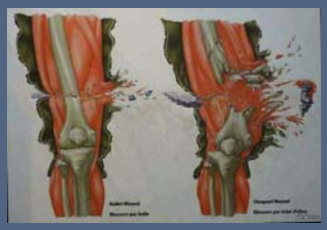
Effect of Bullet on Non-Elastic Tissue



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Effect of Bullet on Non-Elastic Tissue

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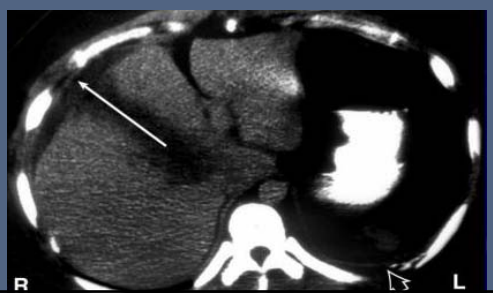
Liver Injury



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Shot Guns

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Shot Guns

Shotgun injury severity can be divided basically into four categories in relation to the distance from the shotgun:

- Type 0 – range of 20–50 m (maximal), usually only skin penetration.
- Type I – range of 7–20 m (long range), usually causes scattered low-energy injuries and does not penetrate deep to fascia.
- Type II – range of 3–7 m (close range), usually causes severe damage and does penetrate deep to the fascia.

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Shot Guns

- Type III – range of 0–3 m (point blank), causes complete destruction when transferred kinetic energy exceeds the elastic limits of the tissue, mainly to the muscles.
- Injured muscle fibers swell up to five times their normal size. It can be noted that there is clotting of muscle cytoplasm, loss of striations, and interstitial extravasation of blood. These are accompanied by a six times increase of lactate levels and depletion of adenosine triphosphate

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Survivability

- GSW to heart - all comers is about 4% survivability
  - In comparison, stab wounds to the heart - all comers is 30% survivability
- There was only a 0.3% increased risk of death for each additional GSW
- Patients with a single GSW versus multiple GSWs had no difference in mortality (9.1 vs 8.4%, P = 0.8).
- A single GSW to the head carried a 50% mortality
- Internal triage and management of gunshot victims should not be affected by the categorization of patients as having a single versus multiple GSWs.

Am Surg. 2009 Jan;75(1):44-7; discussion 48.
The number of gunshot wounds does not predict injury severity and mortality. Cripps MW1, Ereso AQ, Sadjadi J, Harken AH, Victorino GP.**Author information**1
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The Answer to the Question

- If given a choice would you rather be stabbed or shot?

Stabbed of course

Why?

- Less energy
- No temporary cavitation
- No ballistic compression wave
- No secondary fragmentation

There is only a permanent tract where the weapon went and no damage beyond that area.

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Questions

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The End…..

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