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Advanced Emergency Trauma Course

Ballistics and Penetrating Trauma to the Extremities

Presenter: Carl Seger, MD

Ghana Emergency Medicine Collaborative
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Projectiles

- Any material that travels has the ability to injure
  - Glass, falling object, bullet.

- The energy within that projectile is dependent on the velocity, weight (or mass in zero gravity), and distance

- Air resistance slows an object, as do barriers, gravity can accelerate.

- Material makeup and design of a projectile can determine how energy is transferred to the target, which determines the tissue damage
Projectiles

- Can injure soft and hard tissue
- One projectile can be a multi-system trauma
- Damage is a factor of design, velocity, and distance
- Entry and exit wounds can lie!!! Projectiles do not have to follow a straight line
Introduction to Penetrating Trauma

- Mechanisms of penetrating trauma
  - Bullets, Knives, Arrows, Nails, etc

- Understanding principles of energy exchange increase the index of suspicion for associated injuries with a mechanism of injury
Physics of Penetrating Trauma

- Kinetic Energy = \( \frac{(\text{Mass} \times \text{Velocity}^2)}{2} \)

So,

- Greater the mass the greater the energy
  - Double mass = double KE
- Greater the speed the greater the energy
  - Double speed = 4x increase KE
Physics of Penetrating Trauma

- Thus, Small & Fast bullet can cause greater damage than large and slow.
  - Different objects of different weights traveling at different speeds
    - Low Energy/Low Velocity
      - Knives and arrows
    - Medium Energy/Medium Velocity Weapons
      - Handguns, shotguns, low-powered rifles
      - 250-400 mps (meters per second)
    - High Energy/High Velocity
      - Assault Rifles
      - 600-1,000 mps
Physics of Penetrating Trauma

- **Rifling**
  - Bullet spins as it travels down barrel
  - Allows bullet to travel straight with slight yaw (wobble)

- **Weapon forced backward and absorbs energy**
  - Recoil
Physics of Penetrating Trauma

- Remainder of energy propels bullet forward at a high rate of speed.
- Trajectory is curved due to gravity.
- As bullet strikes object, it slows and energy is transferred to object.
Ballistics

- Ballistics: Study of the characteristics of projectiles in motion and the effects upon that object that is impacted.
- Factors affecting energy exchange between a projectile and body tissue:
  - Velocity
  - Profile
  - Stability
  - Expansion & Fragmentation
  - Secondary Impacts
  - Shape
Ballistics

- Energy Dissipation
  - Drag:
    - Wind
  - Stability
    - Allows for straighter trajectory
    - ↓ after striking object results in tumbling
Ballistics: Definitions

- **Stability**
  - Bullet length increases bullet tumbling
    - Can reduce the accuracy of the shot
    - Reduced by Rifling in barrel (spinning)

- **Yaw**
  - Tumbling of bullet once it strikes object
    - Reduces kinetic energy but can result in greater tissue damage
Ballistics: Definitions

- **Profile**
  - Portion of bullet you see as it travels towards you
    - Larger profile = greater energy exchange

- **Caliber**
  - Diameter of a bullet (ID of gun)
    - 0.22 caliber = 0.22 inches
Ballistics

- Expansion & Fragmentation
  - Results in increased profile
  - Initial impact forces may result in fragmenting
  - Greater tissue damage
Ballistics

- Secondary Impacts
  - Bullet striking other objects can cause yaw and tumble

- Shape
  - Handgun Ammunition = Blunt = Tumble
  - Rifle Ammunition = Pointed = Piercing
Specific Weapon Characteristics

- **Handguns**
  - Small caliber, short barrel, medium-velocity
  - Effective at close range
  - Severity of injury based upon organs damaged

- **Rifle**
  - High-velocity, longer barrel, large caliber
  - Increased accuracy at far distances

- **Assault Rifles**
  - Large magazine, semi- or full-automatic
  - Similar injury to hunting rifles
  - Multiple wounds
Handgun vs. Rifle Bullet

http://library.med.utah.edu/WebPath/TUTORIAL/GUNS/GUNBLST.html
Specific Weapon Characteristics

- **Shotgun**
  - Slug or pellets at medium velocity
    - 00 (1/3”) to #9 (pin head sized)
    - Larger the load, the smaller the number of projectiles
    - Deadly at close range

- **Knives & Arrows**
  - Low-energy & low-velocity
  - Damage related to depth and angle of attack
  - Movement of the victim can increase damage
Damage Pathway

Projectile Injury Sequence of Events

- Tip impacts tissue
- Tissue pushed forward and to the side
- Tissue collides with adjacent tissue
  - Shock wave of pressure forward and lateral
- Rapid compression, crushes and tears tissue
- Cavity forms behind bullet pulling in debris with suction.
Damage Pathway

- Not all projectiles are fire arms
- 3000 pound car
- 30 miles per hour (44 feet/second)
- $kE = 91,000$ foot pounds of energy to a pedestrian ($361,194$ foot pounds at 60 mph)
- Very low velocity but very high mass
Damage Pathway

- **Direct Injury**
  - Damage done as the projectile strikes tissue

- **Pressure Shock Wave**
  - Human tissue is semi-fluid
  - Solid and dense organs are damaged greatly

- **Temporary Cavity**
  - Due to cavitation

- **Permanent Cavity**
  - Due to seriously damaged tissue

- **Zone of Injury**
  - Area that extends beyond the area of permanent injury

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Wound Characteristics

- Entrance Wounds
  - Size of bullet profile for non-deforming bullets
  - Deforming projectiles may cause large wounds
  - Close Range
    - Powder Burns (Tattooing of powder)
    - 1-2 mm circle of discoloration
    - Localized subcutaneous emphysema

- Exit Wounds
  - Appears to be “Blown” outward
    - Pressure wave
Gunshot Patterns

http://commons.wikimedia.org/wiki/File:Gunshot_patterns.jpg
Close Range Wounds

http://library.med.utah.edu/WebPath/TUTORIAL/GUNS/GUNINJ.html
Penetrating Wounds to the Extremities

- Vascular Injuries
- Orthopedic Injuries
- Wound Management
Vascular injury: anatomy
Vascular injury: hard signs

- Hemorrhage
  - Pulsatile
  - Exsanguinating

- Expanding hematoma

- Bruit

- Thrill

- Ischemia ("6 P’s")
  - Absent pulse
Vascular injury: Soft signs

- History of significant hemorrhage
- Hematoma: small, non-expanding
- Neurologic deficit (non-progressive)
Vascular Injury

Complications:
- Hemorrhage
- Thrombosis / Embolism
- Aneurysm / pseudoaneurysm
- Compartment syndrome
Vascular: investigations

- Pressure Index: Ankle Brachial Index (ABI)
  - Sensitivity: 45-95% for wounds requiring OR
  - The ABI is an easy to perform non-invasive test which compares the highest systolic brachial pressure to the highest ankle pressure by dividing the ankle pressure by the brachial pressure.
  - The resulting number is the Ankle Brachial Index.
  - A number below .99 shows the presence of decreased arterial blood flow.
Vascular: Investigations

- Arteriogram
  - Sensitivity: 98%
  - Specificity: 99%
  - Too Sensitive:
    - 4% False Pos --> unnecessary OR
  - Expensive
  - Thrombosis / Allergic reaction Risk

- Duplex
  - Sensitivity: 50-60% (compared to angio)
  - Sensitivity: 100% (wounds requiring OR)
  - Specificity: 99-100%
Orthopedic injury: Bone

- **Low Velocity**
  - Drill Hole
  - Divot

- **High Velocity**
  - Complicated
  - Comminuted
  - Fragments act as 2° missiles

- Stab wounds
Orthopedic injury

- Joints
- Lead Toxicity
- Nerves
When to use Antibiotics?

- Bacterial inoculum
- Devitalized tissue
- Age of wound
- Location of wound
- Foreign bodies
- Immune compromised
GSW Wound Care: Indications for OR

- Hard signs
- Progressive neuro deficit
- Open fracture
- Unstable fracture
- Significant soft tissue damage or necrosis
- Compartment syndrome
- >8h post-injury
Prognosis for Limb Salvage

- Time- between delay in revascularization and limb loss.
- Mechanism- Blunt or high-velocity penetrating trauma has a worse outcome than simple, low-velocity penetrating trauma.
- Anatomy- Lower extremity vessels have worse prognosis of salvage than upper extremity vessels;
  - The popliteal artery has the overall single worst prognosis for salvage.
- Associated Injuries
- Age and Physiologic
Questions?
References


- Web Path: [http://library.med.utah.edu/WebPath/webpath.html#MENU](http://library.med.utah.edu/WebPath/webpath.html#MENU)