

## Gunshot Injuries



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## Epidemiology

- The CDC estimated >52,000 deliberate and >23,000 accidental non-fatal GSW injuries in the United States in 2000.
- Suicide is the #1 reason for gun-related deaths in the U.S. (~17,000) in 2004.
- Almost 24,000 fatalities from GSW in 2004.



## Ballistics

### Bullets

- made of lead alloy  
high specific gravity,  
minimal wind  
resistance
- variety of tips  
pointed, round, flat,  
hollow point
- jacketed  
prevents softening or  
deformation



## Ballistics

### Velocity used to categorize firearms

- low velocity  $\leq 1000$  ft/s
- high velocity  $\geq 2000$  ft/s

.45 caliber handgun	869 ft/s
9mm automatic	955 ft/s
.357 magnum handgun	1393 ft/s
AK-47 military rifle	2340 ft/s



## Ballistics

$$KE = \frac{1}{2} mv^2$$

Velocity relates exponentially to the energy of the injury



## Ballistics

### Shotguns

- velocity 1100 - 1350 ft/s
- high mass
- KE dissipates quickly
- most injuries at close range
- complicated by wadding of felt, paper, cork and plastic casing
- range of wadding 20-30 yds

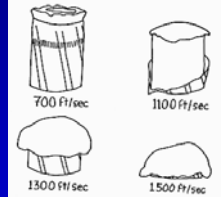


## Ballistics

### Tissue Injury

Three mechanisms:

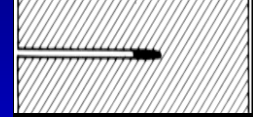
- laceration and crushing
- shock waves
- cavitation



## Ballistics

### Laceration and Crushing

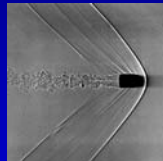
- tissue is crushed and forced apart
- principal mechanism in low-velocity injuries
- Low velocity bullets, such as handguns, that travel less than 1000 fps do virtually all their damage via crushing



## Ballistics

### Shock Waves

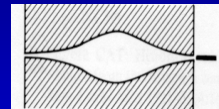
- seen with high velocity missiles
- caused by compression of tissue medium on impact – travels ahead of bullet, as well as, sides
- energy disseminates in a spherical pattern
- travels faster than the bullet itself (4800 ft/s)



## Ballistics

### Cavitation

- particles pushed aside by missile
- continue moving due to inertia
- expand track of missile
- create temporary and permanent cavity
- Cavitation is significant with projectiles travelling in excess of 1000 fps.



## Ballistics

### Yaw

- deviation from the longitudinal axis of the line of flight



### Tumbling

- forward rotation around the center of mass



## Ballistics

### Secondary Missiles

- bone
- bullet fragments
- clothing (buttons, buckles)

These elements are erratic and unpredictable and may cause more damage than the primary missile



## Ballistics

The principals of shock waves, cavitation, yaw, tumbling and secondary missiles are all important in consideration of the **zone of injury**.



## Wound Characteristics

- **Penetrating**  
bullet enters and does not exit
- **Perforating**  
bullet passes completely through an object



## Wound Characteristics

4 categories based on range

- **contact**  
muzzle against skin
- **near-contact**  
muzzle short distance away,  
skin tattooed



## Wound Characteristics

4 categories based on range

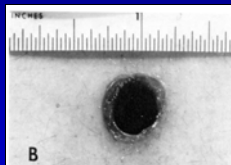
- **intermediate**  
powder tattooing 10mm in  
diameter for handguns
- **distant**



## Wound Characteristics

### Entrance Wounds

- reddish zone of abraded skin - "the abrasion ring"
- oval or circular, punched clean out lesion
- moist and fleshy when fresh
- stellate in palm and sole



## Wound Characteristics

### Exit Wounds

- larger
- more irregular
- no abrasion ring
- may be stellate, slit-like, crescent, or circular



## Wound Management

- Most civilian injuries are **low velocity** with negligible cavitation
- Tissue damage is **local** = only along the missile path
- Deep infection and osteomyelitis are **rare**
- Surgical debridement not necessary, only superficial debridement ± antibiotics
- Heat from missile **does not** sterilize



## Wound Management

Multiple studies have demonstrated the efficacy of **non-operative** management of gunshot fracture wounds.



## Wound Management

- 148 patients w/ superficial I&D, IV antibiotics x 3 days → 2 infections (1 large crush, 1 treatment delay)  
*Brettler, et al, CORR, 1979*
- 34 of 42 patients with non-op gunshot fx's, I&D, no antibiotics → 1 infxn  
*Howland and Ritchey, JBJS, 1971*
- 78 gunshot fx's → fewer infections w/ cephalosporin  
*Patzaki's, et al, JBJS, 1974*



## Low-Velocity GS-induced Fractures

- Low-velocity gunshot-induced fractures
    - Local irrigation and debridement
    - Tetanus prophylaxis
    - Long-acting, intramuscular cephalosporin
    - Splinting or casting of fractured extremity
- Above protocol equivalent to local debridement and 48 hours of abx

*Journal of Orthopaedic Trauma. [JC:jhd] 4(1):39-41, 1990*



## Low Velocity GS-induced Fracture

- Prospective trial
  - No antibiotics vs. IV ancef Q8 hours x 72 hours
  - 67 low velocity GSW fractures
    - Not requiring operative stabilization
    - No difference in infection rates

*Dickey et al, J Ortho Trauma,3:6-10,1989*



## Low Velocity GSW Fracture

- Prospective trial
  - Acute vs Delayed IM nailing of femoral shaft fractures from low velocity GSW
    - No difference in:
      - Infection, Delayed union, or Nonunion rates

*Holmann et al, J Orth Trauma,4:64-69,1990*



## Infection Rate in Low-Velocity GSW

- 62 patients out of 3390 (1.8%) developed wound infections
- All sustained entry/exit wound; 60% of patients sustained more than one injury
- More likely to occur when there is prolonged period between injury and time of initial treatment
- **Authors recommend treatment of low-velocity GSW in: multiple injuries, gross wound contamination, signif. tissue devitalization, large wounds and in delayed treatment**

Ordog et al., Journal of Trauma 1993



## Shotgun Injuries

- Significant soft tissue wound at close range
- Note that wadding may lie underneath fascia at "far side" of wound
- Requires surgical exploration and wide debridement of devitalized tissue along with repair of associated injuries
- Management included mandatory frequent dressing changes, debridement, irrigation in the operating room, and the perioperative administration of broad-spectrum antibiotics

Hoekstra et al, Journal of Trauma 1990



## High-Velocity GSW

- High velocity GSW need to be treated like **open fractures**
- Generally requires formal operative debridement and fixation
- Consider second look to remove devitalized and necrotic tissue



## Vascular Injury

- Transection
- Laceration  
may be worse than transection due to inability to constrict
- Intimal Disruption with Thrombosis  
may cause late pseudoaneurysm and ischemia



## Vascular Injury

Palpable pulses may not exclude the presence of vascular injury  
40 pts w/ pulses → 20 false aneurysms, 12 AV fistulas, 6 delayed occlusions

*Weingartner, et al, J Trauma, 1967*

Angiography is essential if trajectory passes near a major vessel  
92% accuracy in study of 157 extremity gunshot wounds

*Snyder, et al, Arch Surg, 1978*



## Vascular Injury

- Utilize **angiography** liberally
- Be aware of the potential for bleeding to result in **compartment syndrome**
- Beware of low velocity injuries with no exit wound



## Joint Injuries

- mechanical dysfunction
- dissolution of lead by synovial fluid
- deposition of lead w/ periarticular fibrosis
- chondrolysis
- hypertrophic arthritis
- chronic lead intoxication (plumbism)



## Joint Injuries

### Management

- xrays immediately pre-op or intraop
- I & D to remove bullet, lead fragments and osteochondral debris
- I & D even if bullet traverses joint



## Joint Injuries

### Chronic Lead Toxicity (plumbism, saturnism)

- absorbed into systemic circulation
- symptoms:  
nausea, vomiting, abdominal pain,  
anemia, proteinuria, encephalopathy,  
renal failure



## Spine Injuries

- Gunshot wounds to the spine represent 14% of spinal cord injuries
- Main concerns typically relate to spinal cord injury
- Mechanical instability is rarely a problem, therefore operative stabilization is usually not necessary



## Spine Injuries

### Factors predisposing to instability

- young children (small vertebral size)
- severe comminution
- previous laminectomy



## Spine Injuries

### Spinal and Paraspinal Infections

- These are a concern when spine wounds are associated with a perforated viscus prior to entering the spinal canal
- High infection associated with perforation of pharynx, esophagus and colon
- Incidence of 5-15% for all gunshot wounds to the spine

*Romanick, et al, JBJS, 1988*



## Spine Injuries

### Management of gunshots to the spine:

- Antibiotics for 7-13 days  
*Roffi, et al, Spine 1989*
- With irrigation of missile track, 48 hours of antibiotics sufficient  
*Kihitir, et al, JOT 1991*
- No need for removal of bullet to prevent infection



## Spine Injuries

### Bullet in Disc Space

- lead poisoning  
excision versus following serum lead levels
- mechanical symptoms due to instability from disruption of motion segment  
excision if symptomatic
- disc extrusion  
excision w/ discectomy for symptomatic radiculopathy



## Spine Injuries

### Treatment for Bullet in the Canal

- cervical spine  
no change in neuro status w/ decompression  
*Kupcha, An, Cotler, Spine, 1990*
- thoracic spine  
no change in neuro status w/ decompression
- lumbar spine  
improvement of motor deficits, no change in sensation or pain  
*Waters, Atkins, Spine, 1990*



## Spine Injuries

### Treatment for Bullet in the Canal

- Treatment also indicated for deteriorating neuro status w/ radiographic evidence of compression
- Optimal time for surgery is 7 to 10 days



## Gunshot Wounds: Summary

- Ballistics  
bullets and the wounds they inflict
- Management of these wounds
- Associated vascular injuries
- Joint Injuries
- Spine injuries



## Gunshot Wounds: Summary

Gunshot wounds can have a wide range of effects on the management of orthopaedic problems; from benign injuries that don't alter their management to devastating ones that do so radically. Consequently, the proper assessment and management of these injuries is crucial.



**Thank You**

