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Gunshot Wounds

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Gunshot Wounds (GSW's) Lecture Outline

- Epidemiology and social effects
- Definitions of terms
- Ballistics
- Clinical management
Gunshot Wounds: Alarming Statistics

- Currently in the U.S. there are:
  - Over 30,000 deaths / year from GSW's
  - Over 100,000 nonfatal GSW's per year
- This is the equivalent of all the U.S. casualties in the Vietnam War every 2 years
- During the decade of the 1980's, three times more people died of GSW's than died of AIDS in the U.S.
Gunshot Wounds: Statistics

- 1991 U.S. Data
  - Total firearm deaths 38,317
  - GSW suicides 18,526
  - GSW homicides 17,746
  - Accident / unknown 2045

- So roughly 50% of GSW's are suicides, 45% homicides, and 5% accidental
Gunshot Wounds: Statistics

- 1992 U.S. Data:
  - 22,540 homicides (all causes)
  - 15,377 firearm homicides
  - 12,489 handgun homicides
  - So handguns caused 55% of all homicides, 80% of all firearm homicides, and 81% of all firearm deaths (because handguns are used in about 80% of firearm-caused suicides)
  - Only 308 of the firearm homicides were "justifiable" (self-defense or police action)
Gunshot Wounds: Additional Statistics

- 1990's firearm death rate in the U.S. was 1 per 6500 per yr., or 15 per 100,000 per year
- In 1992, 1004 people were shot to death at their place of work (this represented 17% of all workplace deaths that year)
- During the 1991 Persian Gulf War, the Martin Luther King - Drew Medical Center in Los Angeles admitted more gunshot victims than the number of Americans killed or wounded in the war itself
Gunshot Wounds:
Effects on Youths in the U.S.

- GSW's are now the leading cause of death in teenage boys
- Over 700,000 years of potential life are lost each year due to gunshot homicides
- Suicide is the third leading cause of death among children & adolescents in the U.S., and this rate has doubled in the last 30 years with this increase almost solely due to firearms
Relative Death Rates from GSW's Versus MVC's

• In 1990 Texas became the first state in which GSW deaths (3443) exceeded motor vehicle crash (MVC) deaths (3309)
• This has subsequently occurred in at least six more states
• If these trends continue, GSW deaths for the entire U.S. could exceed MVC deaths sometime before the year 2004
Gunshot Wounds: International Comparisons

- Overall homicide rate in the U.S. is 6 to 10 times higher than for other developed nations.
- U.S. 1991 male homicide rate for ages 15 to 24 (37 / 100,000) is nine times higher than the next closest nation (Italy) & 40 to 80 times higher than for other western countries & Japan.
Gunshot Wounds: International Comparisons

- In 1990 handguns killed:
  - 22 in Great Britain
  - 68 in Canada
  - 87 in Japan
  - 10,567 in the U.S.

- A 1980 to 1986 study showed a 2 fold increased homicide rate in Seattle, Washington, relative to Vancouver, Canada, and this increase was almost solely due to handguns.
Encouraging Statistics: Decline in GSW's in the Later 1990's

- GSW deaths in the U.S peaked in 1993, then gradually somewhat declined
- However there still were 32,436 deaths from firearms in the U.S. in 1997
- Paralled the decrease overall in major crimes over same time period
Factors Perhaps Accounting for the Decline in GSW's Since 1993

- Increased urban police patrols
- Tougher gun dealer licensing requirements (# of dealers decreased from 244,000 in 1993 to 90,000 in 1998)
- Denial of felons obtaining guns via background checks related to the Brady Handgun Violence Prevention Act
- Increase in number of incarcerated felons
- Few advances however in gun safety features

- Cases reviewed from 1992 to 1995
- Overall CFR: 31.7%
- CFR for persons arriving alive at an E.D.: 11.3%
- CFR for assaults:
  - 28.7% for females
  - 20.6% for males
- CFR for intentional self-inflicted:
  - 77.7% for males
  - 69.1% for females
Numbers of Firearms in the U.S.

- Currently there are over 200 million guns in circulation in the U.S.
- Estimates are that 60% of these are handguns, 20% rifles, 15% shotguns, and 5% antiques & others.
- Only Switzerland has a higher per capita gun ownership (because of required reserve military duty).
Kellerman's First Study on GSW's in the Home

- Looked at all deaths from a firearm in a home from 1978 to 1983 in King County, WA
- 398 deaths identified
  - 84 % suicides
  - 10 % criminal homicides
  - 3 % accidental
  - 2.5 % police action
  - 0.5 % (2 cases) justifiable self-protection
Kellerman's 1986 Study (cont.)

• Relationship of person committing the homicide to the victim:
  • 37% friend
  • 17% relative
  • 14% spouse
  • 9% roommate

• Conclusion: "The advisability of keeping firearms in the home for protection must be questioned."
Kellerman's Second Study on GSW's in the Home

- Case control study from Shelby County, TE, and King County, WA, for 1987 to 1990
- Concluded that presence of a firearm in the home increased the risk of suicide in the home 5 fold
Kellerman's Third Study on GSW's in the Home

- Concluded that presence of a gun in the home was associated with an overall 3 fold increased risk of homicide, with virtually all these homicides committed by a family member or intimate acquaintance
- The relative risk factor was even higher in homes with alcohol or other violence problems
GSW Statistics: Effects of Semi-automatic Weapons

- 1992 study: number of GSW's per patient increased from 1.6 in 1985 to 2.7 in 1990 (mainly due to increased use of semi-automatic pistols)
- Death rate at scene for semi-auto wounds is 3 times that of other guns
- 20% of victims had > 2 GSW's in 1988
- First bullet to hit victim will spin him, so subsequent bullets enter at much different angles: this causes more anatomic structures to be hit and more preop diagnostic tests to be needed (contributing to increased costs)
GSW's: Risks to Health Care Workers

- Being shot on duty in the hospital
  - Episode at L.A. County Hospital in 1993
- Exposure to blood with hepatitis or HIV
- Injuries from caring for wounds with bone splinters or sharp bullet fragments
- Psychologic stress
  - Not being able to "stem the flow of victims"
  - Seeing deaths & injuries in children
  - Physical exhaustion from the large caseload
U.S. National Costs of Caring for GSW's

• Direct costs estimated by CDC in 1988 as $16.2 billion
• GSW's are 2nd or 3rd most costly form of injury (after MVC's & falls)
• Death from GSW estimated to cost $373,000 per case
• GSW care spending may account for more than 3 % of all U.S. health care spending
• 90 % of costs are paid by public funds
Costs for GSW's in Pennsylvania

- Average charges for GSW cases seen at Hershey Medical Center in 1993 were $23,449 (hospital charges only; not including physician and followup fees)
- This average charge is greater than the average annual cost of prison incarceration in PA ($18,000) and the average annual cost of college tuition
Other Causes of Missle Injuries Besides GSW's

- Objects thrown by:
  - lawnmowers
  - weed whackers
  - nail drivers

- Explosions
  - truck tires
  - bombs
  - fires
GSW's: Definitions of Terms

- **Caliber**: bullet diameter in hundredths of an inch
- **Magnum**: extra gunpowder in the shell causing a 20 to 30% increase in bullet energy
- **Special**: (as in "38 Special") extra gunpowder in the shell compared to other cartridges of the same caliber
- **Dumdums**: bullets that expand & flatten upon impact
- **Muzzle velocity**: bullet velocity as it leaves the gun barrel
- **High velocity**: bullet with muzzle velocity greater than 2500 feet per second (fps) or 800 meters per second
- **Cavitation**: cavity in tissue created by bullet passage
- **Casualty criterion**: kinetic energy of a missile needed to put a soldier out of combat (U.S. definition: 58 foot pounds; Soviet definition: 174 foot pounds)
GSW's: More Definitions

- **Rifling**: grooves cut in the gun barrel to impart spin to the bullet
- **Shotgun**: weapon firing multiple pellets from a non-rifled barrel
- **Semi-automatic**: weapon firing one round and reloading with one pull of the trigger
- **Breech**: proximal end of the barrel containing chamber for the cartridge
- **Cartridge**: the bullet & gunpowder together in a container (usually metal)
Different types of projectiles fired from shotguns
GSW's: Definitions Related to Bullet Motions

- Ogive: radius of a bullet in lateral projection
- Tumbling: forward rotation about the center of mass of the bullet
- Yaw: deviation of a bullet in its longitudinal axis from straight line of flight
- Precession: wobbling around the center of mass in a spiral fashion
- Nutation: rotation in small circles forming a rosette pattern

Note: these 4 motions do not usually occur as the bullet moves through the air, but only after striking & penetrating an object.
GSW's: Ballistics

- Ballistics is defined as the science of the motions and impacts of projectiles.
- Wounding capacity = kinetic energy deposited in the tissue.
- Kinetic energy = mass times (V₁ squared minus V₂ squared)*

* V₁ = impact velocity
V₂ = exit velocity (it is zero if the bullet does not exit)
GSW's : Bullet Rotational Energy

- Rotational energy is due to spin of the rifled bullet
- Rotational energy = \( I \times (W_1^2 - W_2^2) / 2 \)*
- Total kinetic energy deposited in the tissue is the sum of the energy due to velocity plus the energy due to rotation

* denotes:
- \( I \): moment of inertia in feet
- \( W_1 \): angular velocity at impact (radians/sec)
- \( W_2 \): angular velocity at exit

Note that most authorities think that bullet rotational energy is of little importance or clinical relevance
GSW's: Impact Velocity

- Practically, impact velocity = muzzle velocity for:
  - Civilian weapons at ranges < 50 meters
  - Military weapons (high velocity) at ranges < 100 meters

- Clinical effects of impact velocity:
  - 150 fps (50 meters/sec.) : penetrates skin
  - 195 fps (65 meters/sec.) : breaks bone
Low velocity bullet causing leg fracture
GSW's: Ballistic Coefficient

- Ballistic coefficient BC = SD divided by I (SD = sectional density or the bullet weight divided by 7000 times the diameter squared; I = bullet ogive).
- BC is inversely related to air drag.
- At > 100 meters, low BC bullets lose less velocity than high BC bullets.
- Pointed bullets (high ogive value) have a lower BC than blunt or round-nosed bullets.
GSW's: Bullet Jacketing

- Pure lead bullets melt if velocity > 2000 fps or 700 meters/sec.
- So high velocity bullets are jacketed with another metal to maintain bullet shape
- Geneva Convention (signed by U.S.):
  - all military bullets must be fully jacketed
  - was response to greater tissue injury occurring from non-jacketed bullets
GSW's: Post-impact Bullet Expansion

- Non-jacketed bullets can expand to 3X diameter and 4X surface area.
- Non-jacketed bullet can cause exit wound 6X larger diameter than wound from jacketed bullet of same caliber.
“Mushrooming” of a partially jacketed bullet
The Winchester “Supreme Talon” bullet designed to make sharp flanges; taken off the market but many still in circulation
Causes of increased air drag (and resultant increased tissue damage) by bullets:

- hollow point
- flattened point (Dum-Dum bullet)
- cross-hatched point

However, the main increased damage from these may be due more to flattening on impact than on the air drag
Determinants of Wounding Capacity from Bullets

- Bullet velocity
- Bullet mass
  - Determines how deeply tissue is penetrated
- Bullet construction & jacketing
  - Determines whether it deforms or fragments
- Bullet shape & center of mass
  - Determines how soon it yaws in its path thru tissue
- Thickness of body part wounded
  - Determines if bullet path is long enough to yaw
- Tissue type struck
GSW's: Tissue Damage

- Retardant forces: forces that slow the missile once it enters the target (tissue)
- Kinetic energy is then turned into heat, vibration, mechanical, and vacuum forces which cause tissue damage
- The higher the specific gravity of the tissue, the greater the retardant force, and the greater the damage
GSW's: Tissue Damage

- Direct causes of tissue damage from bullets:
  - laceration
  - crushing
  - cavitation
  - shock waves
Tissue Determinants of Degree of Wounding from Bullets

• Elasticity
  • Determines how well the tissue withstands stretch & cavitation

• Density

• Specific gravity

• Internal cohesiveness

• Anatomic relationships
How Bullets of Equal Wounding Potential May Cause Wounds of Different Severity

- Heavier slower bullet crushes more tissue but causes less cavitation
- Heavier slower bullets cause relatively more severe damage in elastic tissue than do lighter faster bullets
  - In less elastic tissue (such as liver or brain) the larger temporary cavity produced by lighter faster bullets is more severe
- Penetration depth may be less with lighter faster bullets
Bullet Effects Which Increase Tissue Damage Through Crushing

- Yaw through tissue
  - If bullet yaws to 90 degrees, then entire long axis of the bullet crushes tissue, & the amount of tissue crushed is 3X greater than if the bullet keeps its long axis parallel to the tissue track
  - The earlier a bullet yaws in its tissue path, the more severe the wound (M16 bullet was designed to yaw early)

- Mushrooming
- Fragmentation
- Creating secondary projectiles (bone, teeth, etc.)
GSW's: Tissue Damage from Cavitation

- Tissue motion continues for a few milliseconds after bullet has passed
- This creates cavity at subatmospheric pressure (oscillatory cavity)
- Permanent cavity created but smaller than the temporary cavity
- Can occur with any bullet > 1000 fps (300 m/s)
- Can rupture blood vessels, nerves, even bone
- Cavity may be 30 to 40X bullet diameter
GSW's: Tissue Damage from Shock Waves

- Generated by bullets at > 2500 fps (800 meters/sec.)
- Region of compression moves away from bullet in all directions at speed of sound (4800 fps or 1500 meters/sec.)
- Lasts only 15 to 25 microseconds
- Causes pressure > 1000 lbs. / sq. in.
- Can rupture gas-filled organs (lung, bowel)
- May cause little damage to muscle or bone
# Muzzle Velocities & Bullet Energies

<table>
<thead>
<tr>
<th>WEAPON</th>
<th>Bullet Weight (grains)</th>
<th>Muzzle Velocity (fps)</th>
<th>Bullet Energy at the Muzzle (ft. - pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pistols</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.32 cal.</td>
<td>71</td>
<td>863</td>
<td>91</td>
</tr>
<tr>
<td>.38 Special</td>
<td>158</td>
<td>1090</td>
<td>425</td>
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<tr>
<td>.357 Magnum</td>
<td>158</td>
<td>1415</td>
<td>895</td>
</tr>
<tr>
<td>.44 Magnum</td>
<td>240</td>
<td>1470</td>
<td>1150</td>
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<tr>
<td><strong>Rifles</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.22 Remington</td>
<td>40</td>
<td>1180</td>
<td>124</td>
</tr>
<tr>
<td>.223 (M-16)</td>
<td>55</td>
<td>3250</td>
<td>1248</td>
</tr>
<tr>
<td>7.62 mm (AK)</td>
<td>150</td>
<td>2750</td>
<td>2635</td>
</tr>
<tr>
<td>M-14</td>
<td>180</td>
<td>2810</td>
<td>2720</td>
</tr>
</tbody>
</table>

(one "grain" = 62.5 mg ; to convert fps to meters per sec.: divide by 3)
GSW's: Contamination

- Fired bullets are not sterile because insufficient heat is generated
- Bullets introduce secondary internal projectiles (clothing, skin, hair, etc.) that are contaminated
- So all GSW's should be treated as contaminated wounds
GSW's: Bullets Seen on X-ray

- If bullet is close to surface of body adjacent to the X-ray film, there is essentially no magnification effect (bullet size as seen on X-ray is actual bullet size)
- However, if bullet is on side of body away from film, then magnification effect is up to 25%
Low velocity, non-deformed bullets (one near sternum, the other in the back)
45 caliber low velocity wound but with increased tissue damage due to bullet fragmentation and comminuted bone fragments
High velocity gunshot wound with bullet fragmentation and extensive bony and soft tissue damage
GSW's : History Items To Determine

- Range and direction of shooter
- Bullet velocity (high or low category)
- Bullet caliber
- Number of shots
- Tetanus immunization status
- Antibiotic allergies
- Other concurrent trauma
GSW's : E.D. Treatment Priorities

- Hemorrhage control
- Oxygen
- IV access
- Type & cross
- Neurovascular exam
- Remove clothing : cut AROUND bullet holes (to preserve forensic evidence)
- X-ray to locate bullet(s) : AP & lateral
GSW's: Definitive Treatment

- For all: careful surgical wound exploration & removal of imbedded foreign bodies (clothing, etc.)
- For low velocity: consider primary closure (22 cal. wounds may not need closure)
- For high velocity: debridement and delayed closure 5 to 7 days later
- Antibiotics (usually first generation cephalosporin)
GSW's : Special Preop Dx Studies

- For GSW of chest below nipple line : peritoneal lavage (laparotomy if > 1000 RBC's per mm3)
- For multiple pellet GSW's of limb : arteriography
- GSW of neck : gastrografin swallow & arch arteriography if stable
- GSW of back : IVP or CT, routine laparotomy
- GSW of limb : monitor compartment pressures
**GSW's of the Head**

- Brain wounds in patients reaching the hospital alive have > 30 % mortality
- Often will need CT after initial skull films
- All intracranial fragments should usually be removed surgically
- May be appropriate to resuscitate obviously non-survivable head injury patient to be an organ donor
- Usually large bullet with lateral impact & track crossing the midline results in fatal injury
Intracranial bullet fragments (if these are on the other side of the midline from the entrance wound, then are diagnostic of a non-salvageable injury)
GSW's of the Orbit

- Usually need prompt enucleation to prevent blindness from sympathetic ophthalmia
- If more stable, can do scleral evisceration only (preserving the extraocular muscles for better cosmetic effect)
Penetrating eye injury from a B-B pellet
Maxillofacial GSW's

- May need primary closure just for hemorrhage control
- May need early tracheostomy
- May need external carotid artery ligation
- Remember that the patient may have concurrent C-spine trauma
Shotgun wounds of face
Side view of same patient on prior slide
Same patient after initial wound management
Victim sustained a 38 caliber (revolver) gunshot wound on the left side of the face. Wound entrance has been packed.
GSW's of the Neck

- All should be surgically explored
- If carotid artery injured & no neuro deficit, repair with vein graft or patch
- If complete neuro deficit from carotid injury, then ligate carotid
- If jugular vein injury, prevent air embolism & OK to ligate (if both jugulars injured, must repair one)
- Verify esophagus is uninjured
Angiogram showing occluded carotid artery from a GSW
Gastrografin swallow showing esophageal disruption from GSW
GSW's of the Thorax

- Often only need treatment with chest tube
- Do thoracotomy for:
  - Blood loss > 200 cc per hour
  - Major air leak
  - if ? cardiac tamponade
  - if ? esophageal injury
  - if ? intrathoracic arterial bleeding
- May need to have transfusible blood ready before chest tube placed
- Consider autotransfusion
GSW's of the Abdomen

- All should be surgically explored (even if tangential)
- Usually only preop test needed is one-film intravenous pyelogram (IVP)
  - If patient is initially stable & spiral CT can be done quickly, this would be acceptable alternative
- Complication rate is 30 to 40 %
  - 17 % require colostomy
  - 31 % require long term open wound care
Intravenous pyelogram showing right ureteral disruption from a GSW (note bullet in right mid-abdomen)
GSW's in the Pregnant Patient

- All abdominal wounds should be surgically explored
- Preop ultrasound helps determine fetal viability
- May need C-section to allow repair of maternal intraabdominal injuries
- Alert pediatrician prior to surgery in case C-section needed and fetus is premature
Upper abdominal gunshot wound in a pregnant patient
Treatment Considerations for Patients Wearing Body Armor

• Even if no skin penetration, can still have serious internal injuries
  • If shot in chest, can have pulmonary contusion or rib Fx
  • Even if initial CXR is normal, need observation & repeat CXR at 4 to 6 hours
  • If shot over lower chest or abdomen, may need CT to evaluate for blunt intraabdominal injury
• Remember that Kevlar armor is impossible to cut with standard trauma scissors, so will need to be removed directly to examine the patient
Injuries from the "Police Bean Bag"

- This type of weapon is used by the police to non-fatally subdue violent criminals
- Is a synthetic bag filled with small lead pellets & is fired from a shotgun
- Design intent is to inflict blunt trauma from the bag to stun or knock down the victim
- Can cause life-threatening internal injuries, & sometimes penetrating injuries
One commercially available “ballistic bean bag” (the cartridge on the left contains the bean bag shown on the right)
GSW's: Late Problems

• Bullet embolus (can be either arterial or pulmonary)
  • Most occur soon after injury
  • Almost all occur in < 2 weeks
• Lead poisoning
  • Symptoms often delayed for months to years (anemia, colic, cramps, weight loss)
  • Bullets in contact with bursae, lung tissue, bone, & joint fluid are at risk
  • Most bullets are walled off by fibrous tissue & don't need to be surgically removed prophylactically
GSW's : Overall Prognosis

- GSW patients have a 10 to 20 % mortality if they survive to reach a trauma center
- Trunk GSW's cause:
  - 20 % mortality
  - 49 % chance of long term disability
  - 11 % chance of paraplegia (GSW's are now the third leading cause of spinal cord injuries nationwide, and in places like Detroit are the number 1 cause of SCI)
Gunshot Wounds
Summary

- Evaluate ABC's first
- Determine if high or low velocity (affects surgical management)
- Don't forget tetanus & antibiotic coverage
- Notify law enforcement authorities (even if accidental)
- Physicians should become involved in GSW injury prevention efforts