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# Gunshot Wounds


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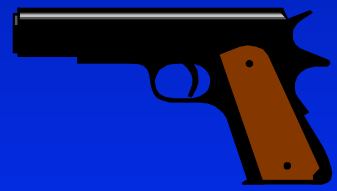


# Gunshot Wounds (GSW's) Lecture Outline

- 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

# Firearms Case Fatality Rates (CFR) Study
## (Ann. Emer. Med. March 2000 ; 35:3 ; 258-266)

- 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

- N.E.J.M. 1986 ; 314 (24): 1557-1560.
- 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

- N.E.J.M. 1992 ; 327 (7) : 467- 472.
- 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

- N.E.J.M. 1993 ; 329 (15): 1084 - 1091
- 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 missle 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)



Armorpiercer, Wikimedia Commons

**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 (W1 squared minus W2 squared) divided by 2*
- Total kinetic energy deposited in the tissue is the sum of the energy due to velocity plus the energy due to rotation

* I = moment of inertia in feet
W1 = angular velocity at impact (radions/sec)
W2 = 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

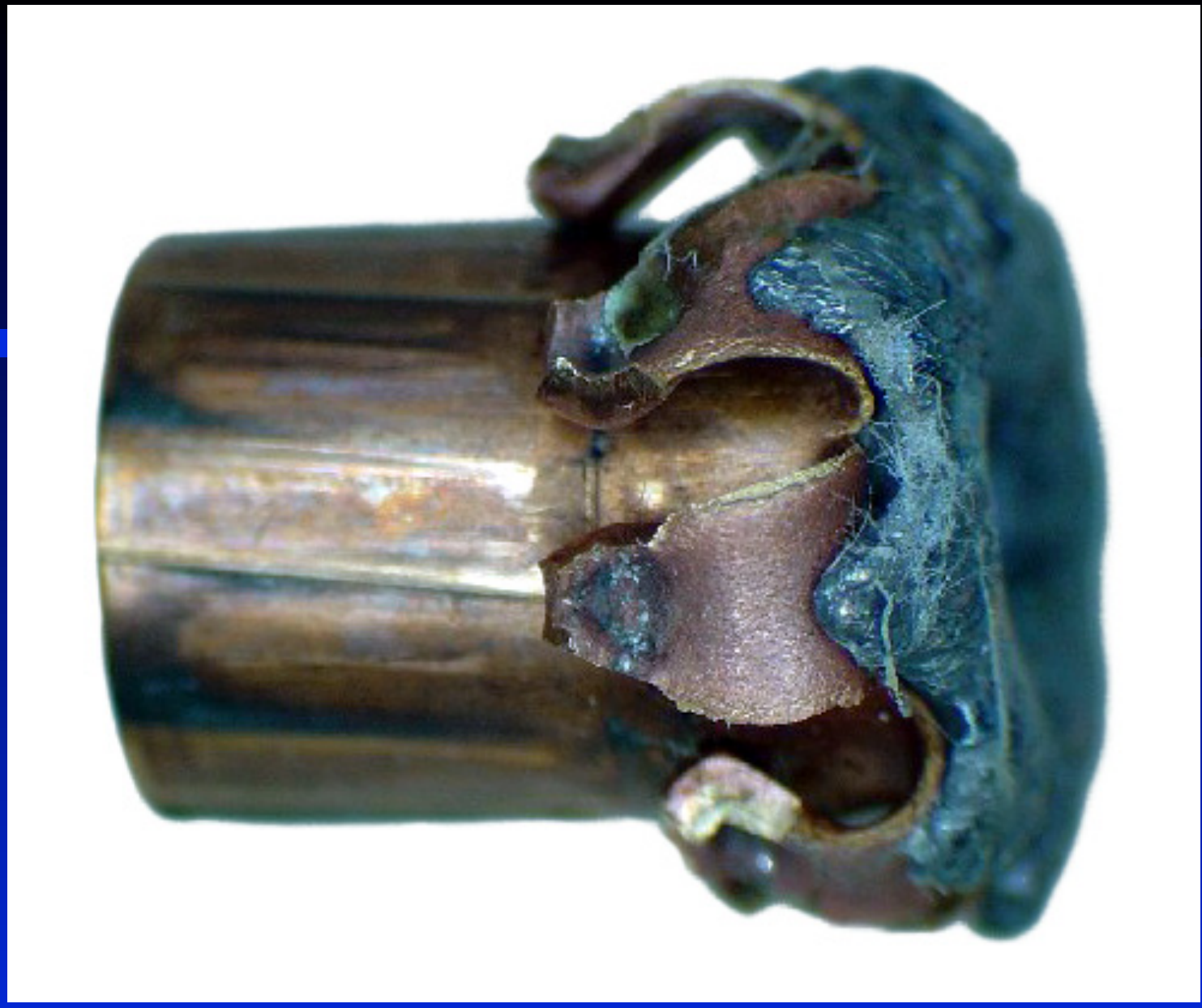
- Ballistic coefficient BC = SD divided by I (SD = sectional density or the bullet weight divided by 7000 times the diameter squared ; I = bullet ogive)
- BC is inversely related to air drag
- At > 100 meters, low BC bullets lose less velocity than high BC bullets
- Pointed bullets (high ogive value) 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**

# GSW's : Bullet Air Drag

- 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  missle 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

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

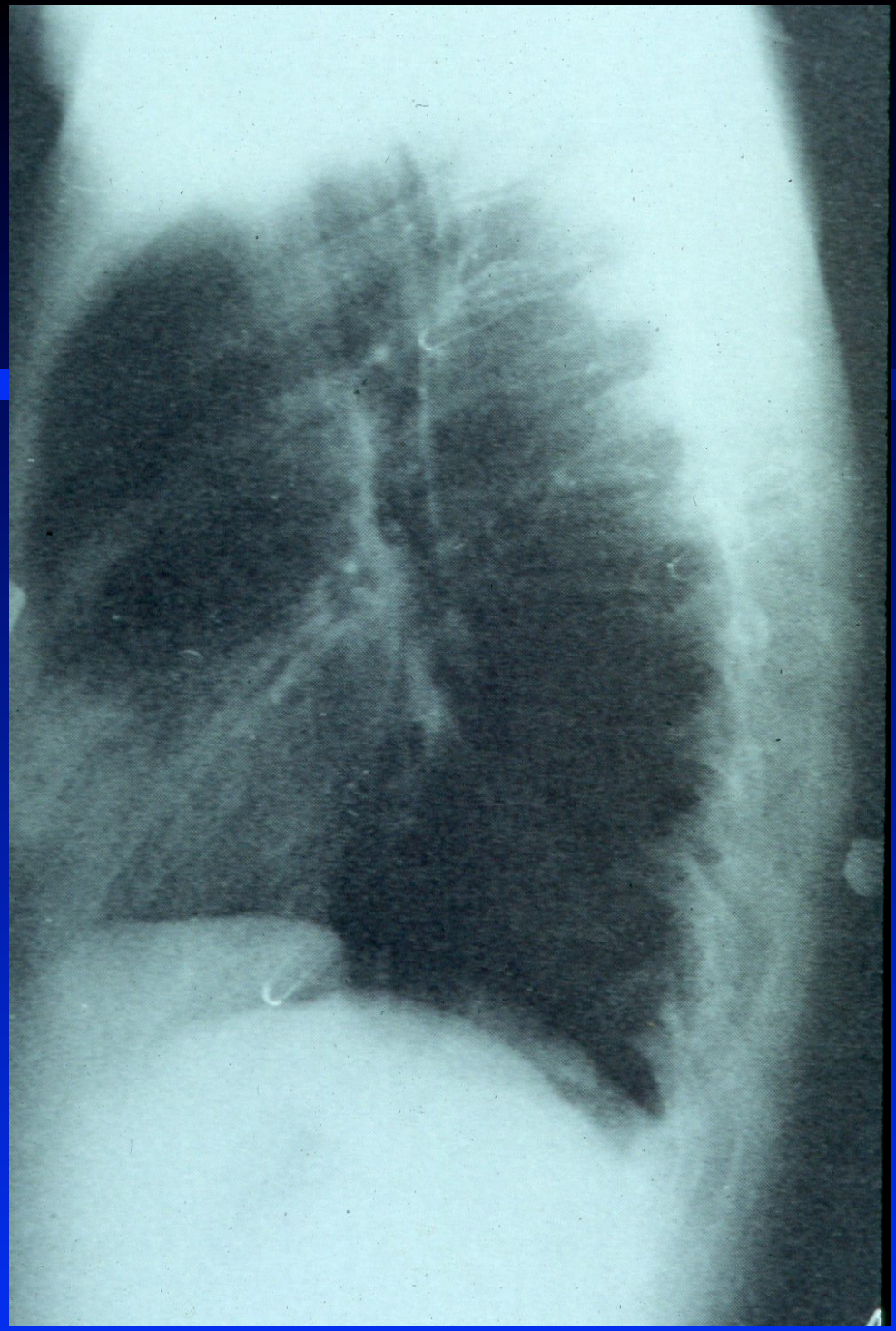
(one "grain" = 62.5 mg ; to convert fps to meters per sec.: divide by 3)

# 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)

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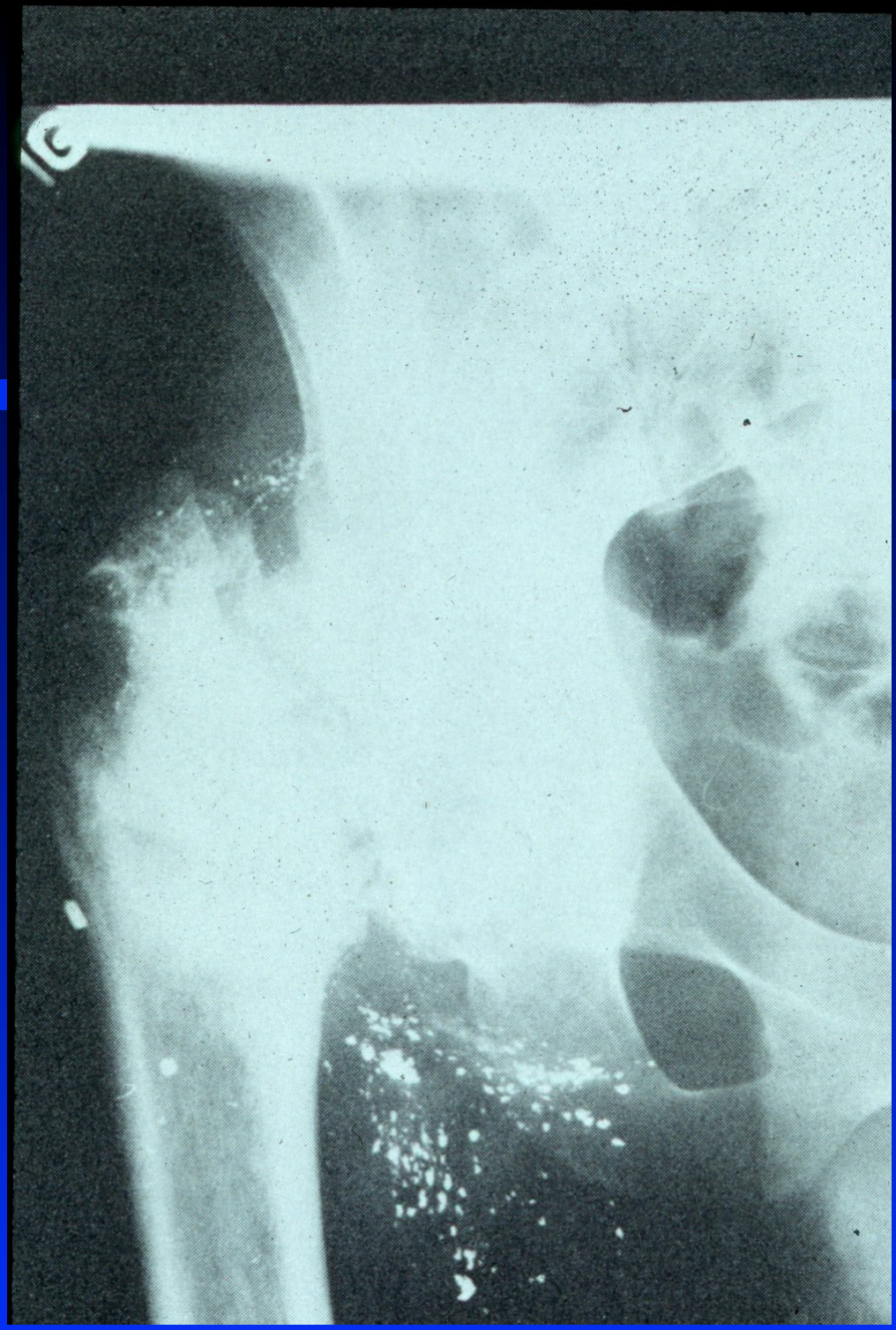
Source Undetermined

**45 caliber low velocity wound but with increased tissue damage due to bullet fragmentation and comminuted bone fragments**



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**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

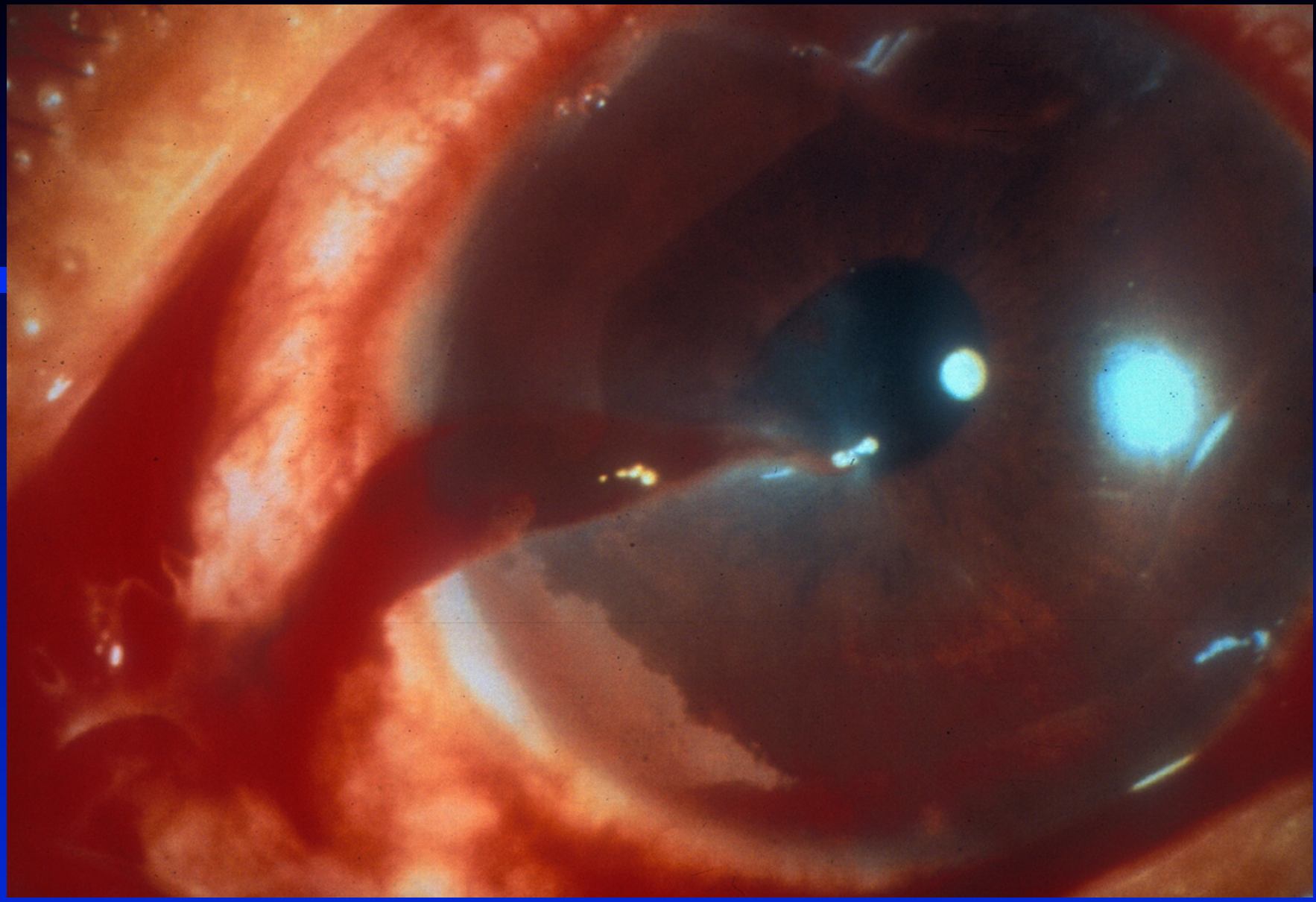
- Brain wounds in patients reaching the hospital alive have > 30 % mortality
- Often will need CT after initial skull films
- All intracranial fragments should usually be removed surgically
- May be appropriate to resuscitate obviously non-survivable head injury patient to be an organ donor
- Usually large bullet with lateral impact & track crossing the midline results in fatal injury

PD-INEL Source Undetermined

**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)

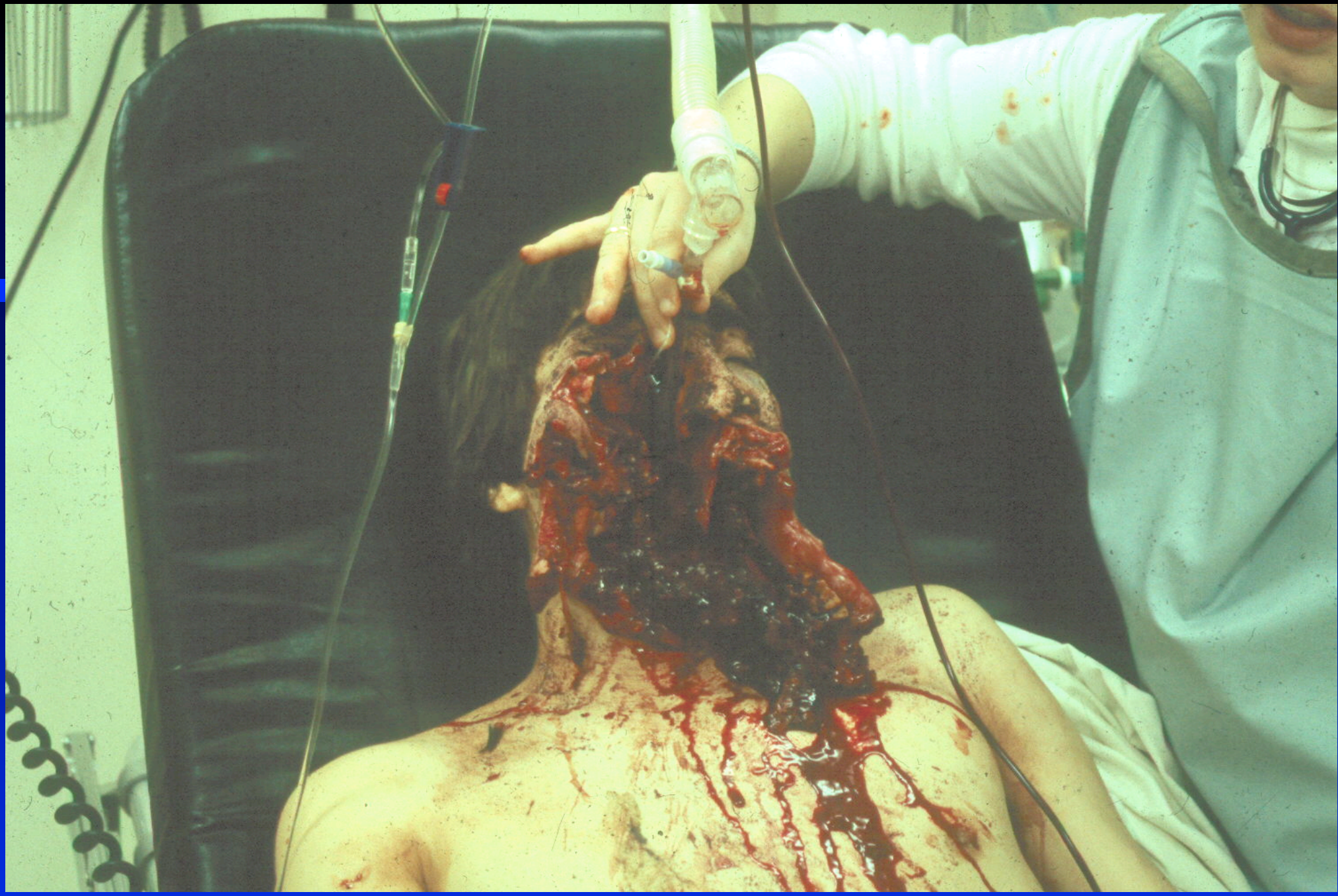




# Penetrating eye injury from a B-B pellet

# 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



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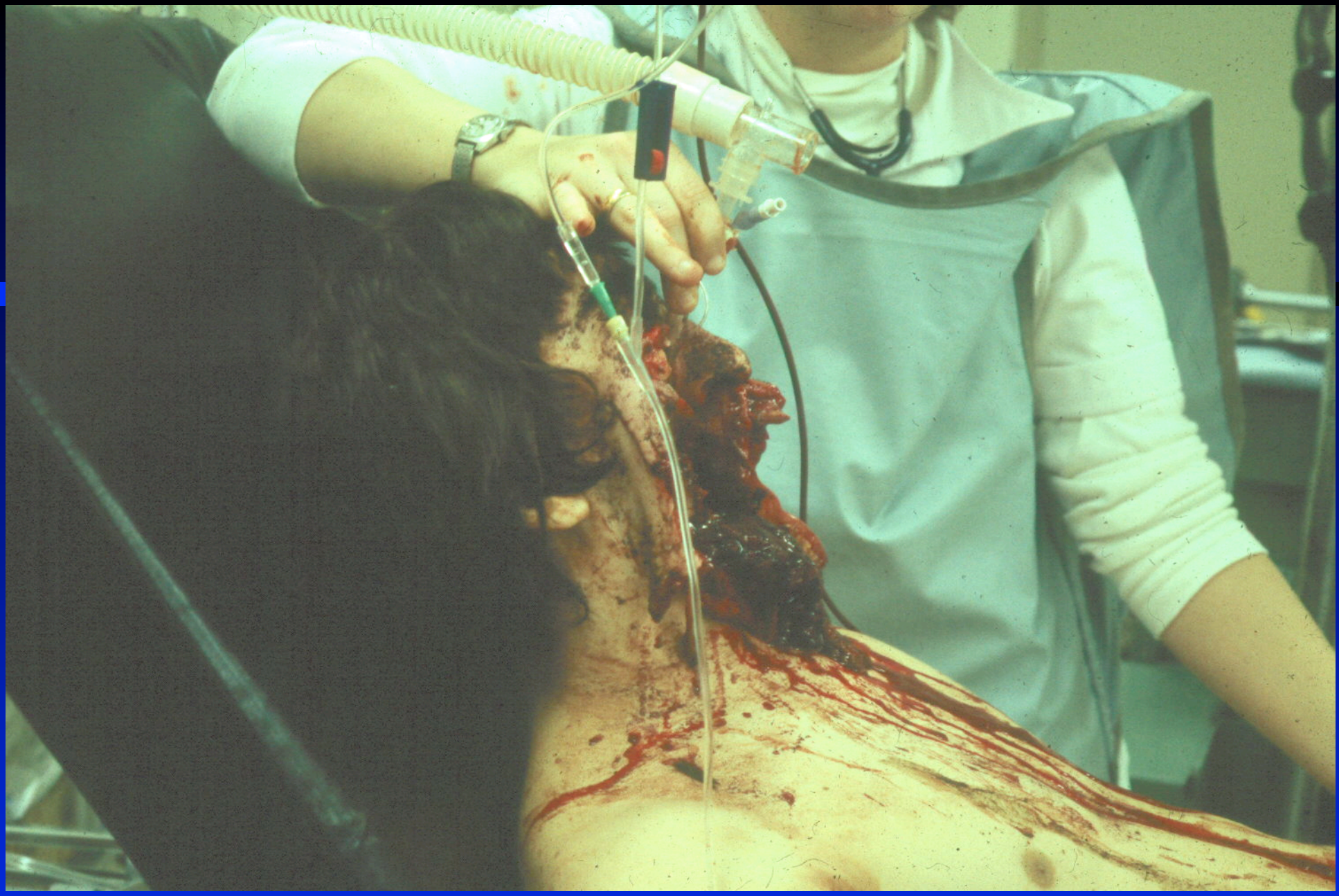
# Shotgun wounds of face



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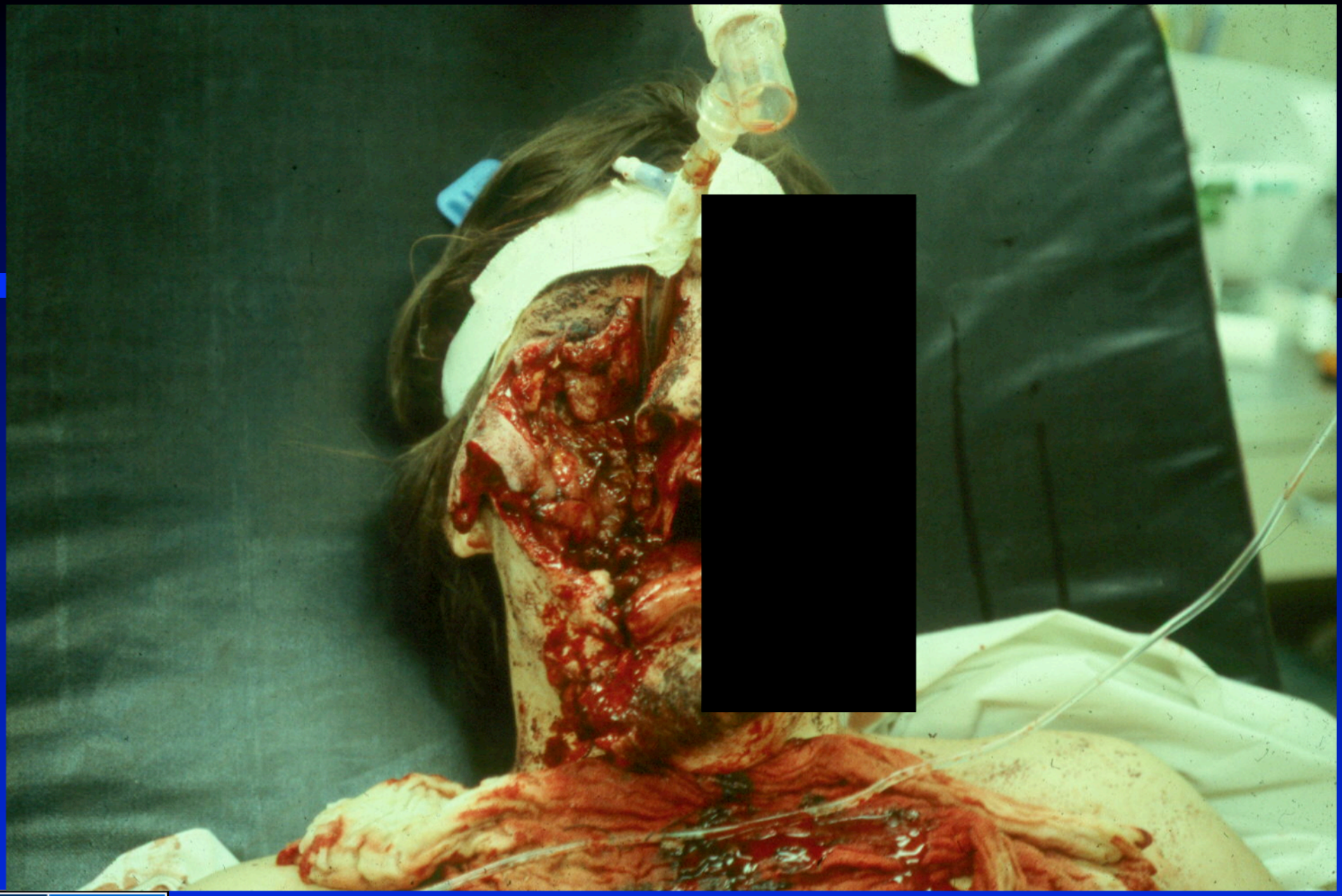
# Side view of same patient on prior slide



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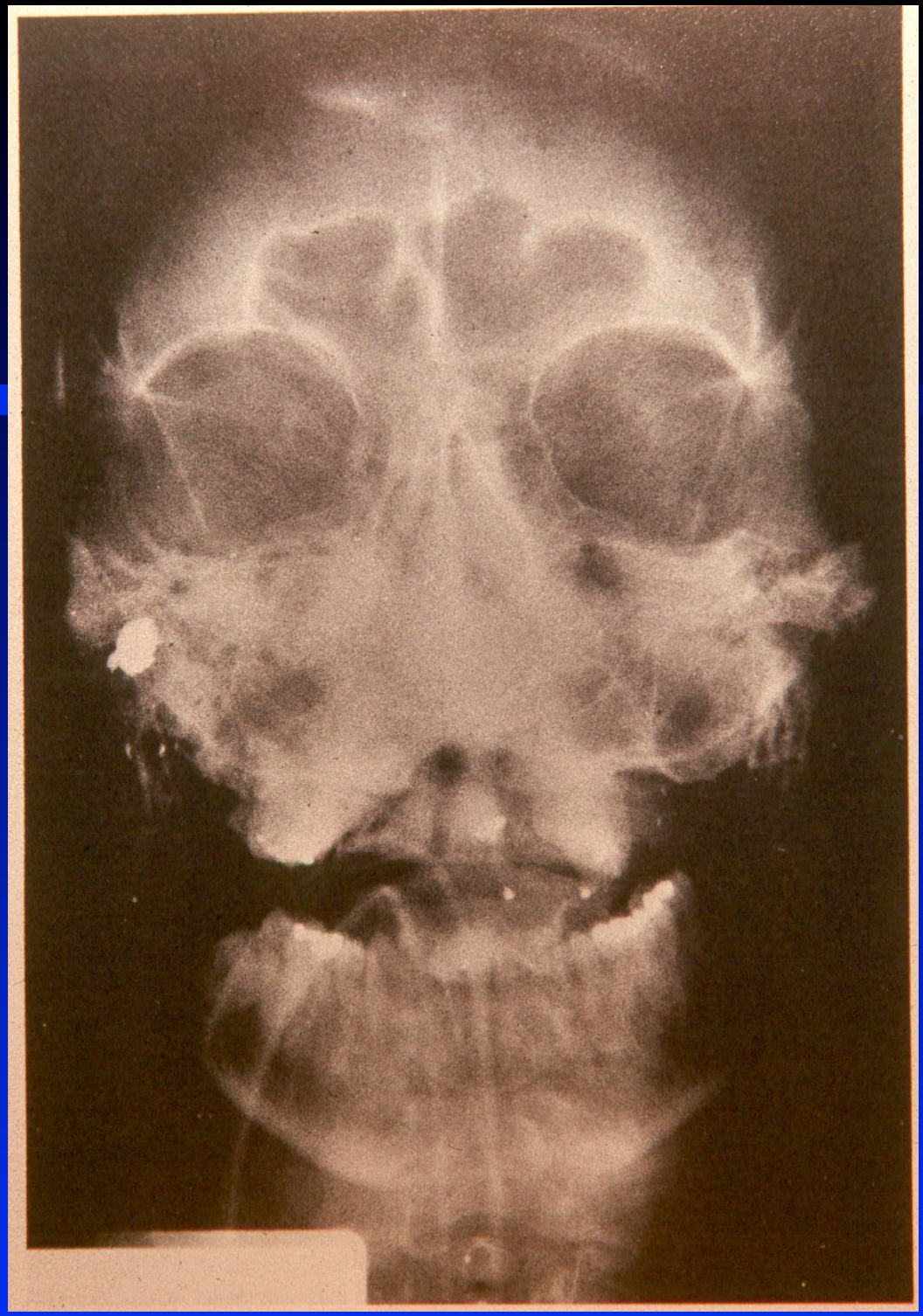
## Same patient after initial wound management

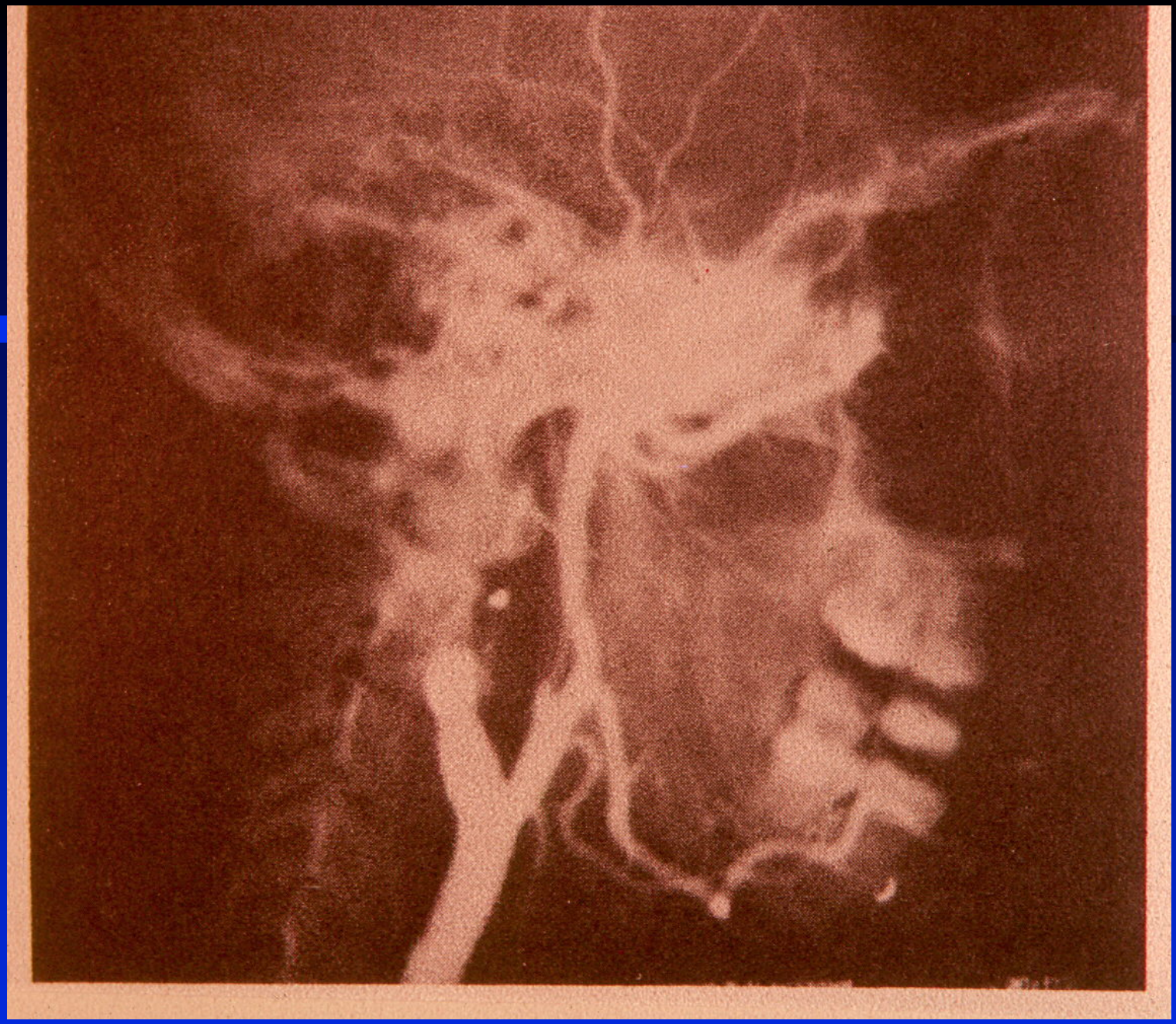
Victim sustained a 38 caliber (revolver) gunshot wound on the left side of the face. Wound entrance has been packed.



**Skull X-ray of same patient on prior slide**

# 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



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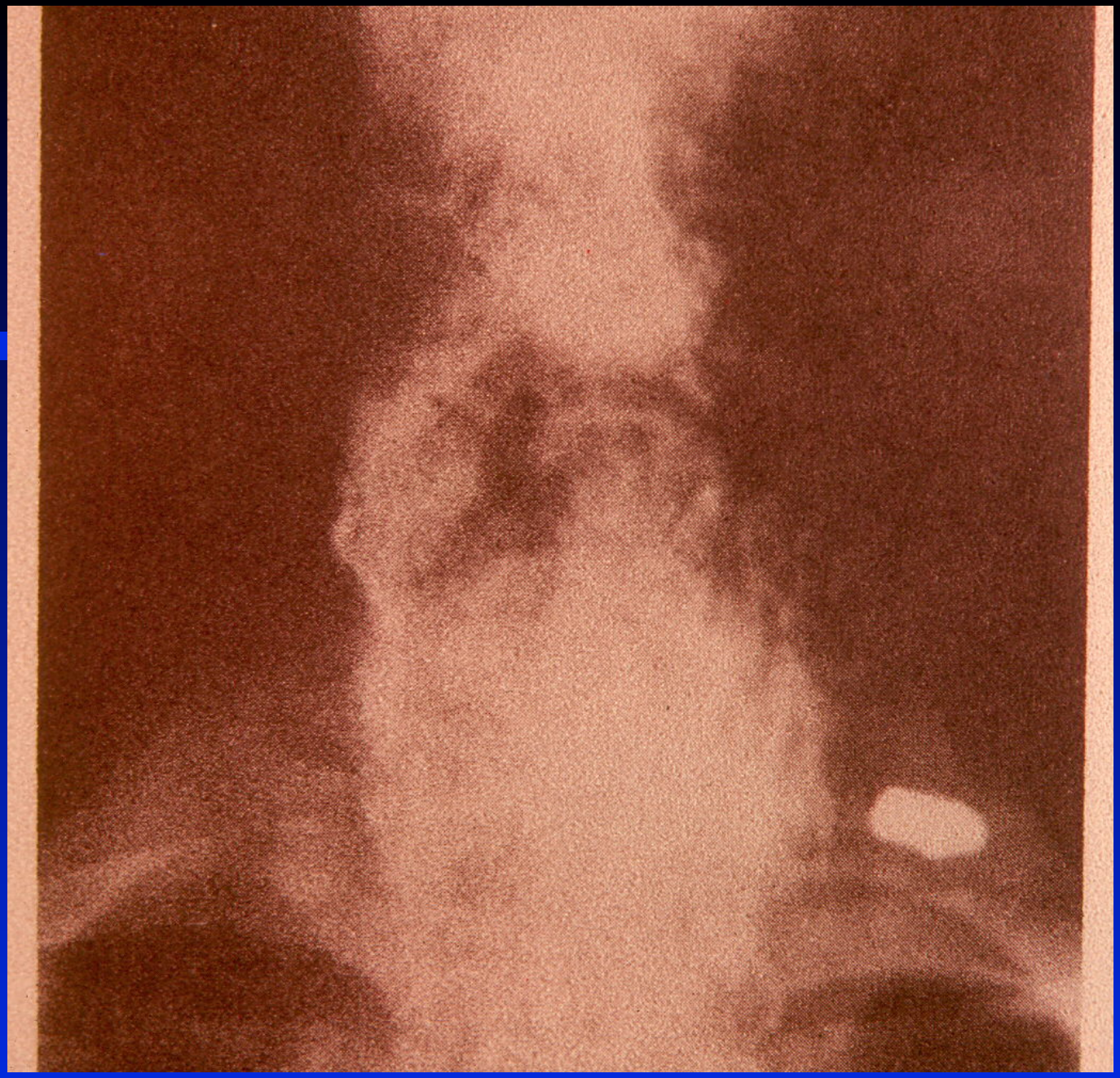
# Angiogram showing occluded carotid artery from a GSW



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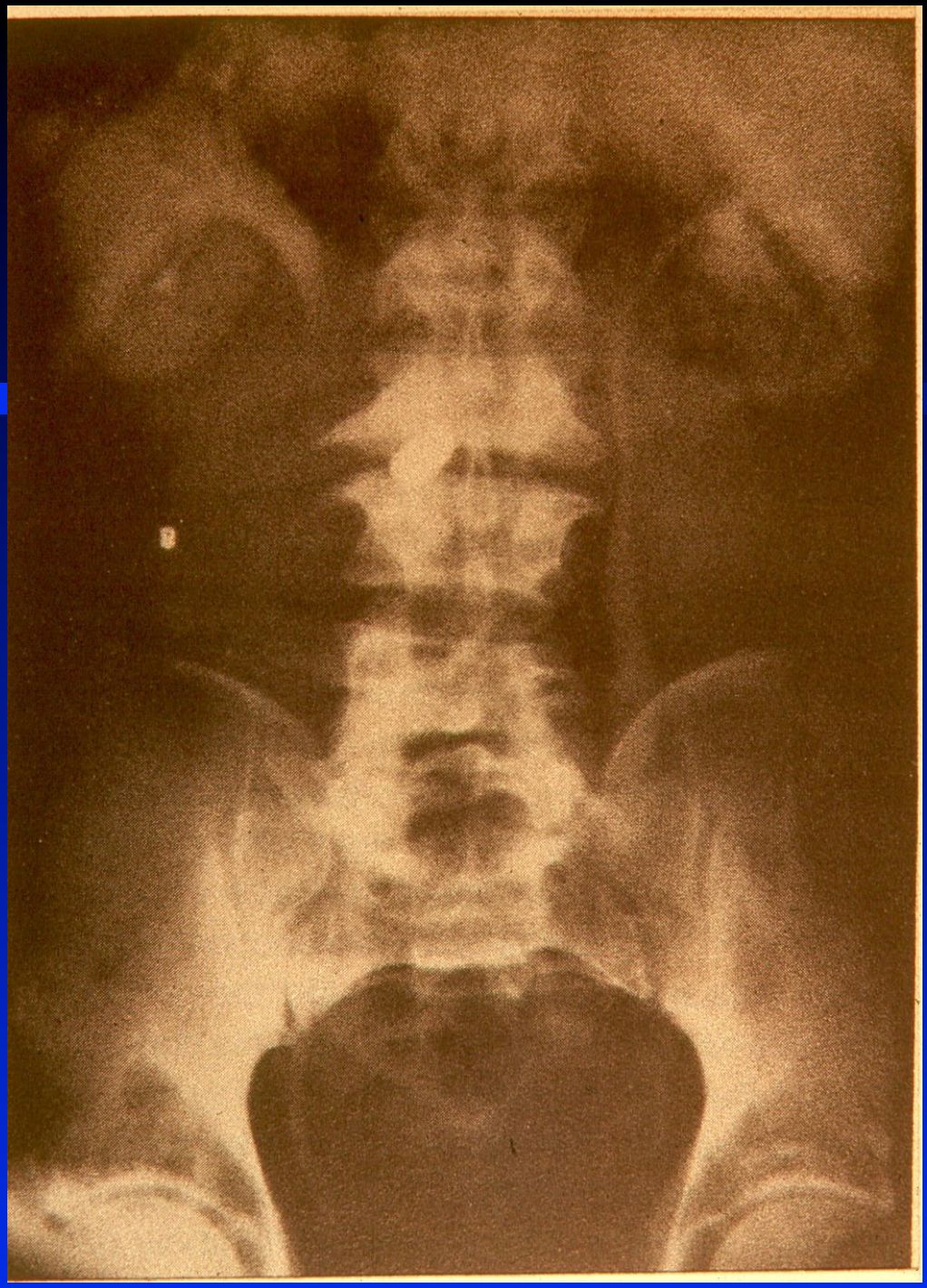
**Gastrografin swallow showing esophageal disruption from GSW**

# 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 transfusable 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



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**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

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Source Undetermined

## 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




Techjess, Wikimedia Commons.

**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