Gunshot Wounds

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Ballistics

- Most bullets made of lead alloy
  - High specific gravity
    - Maximal mass
    - Less effect of air resistance
- Bullet tips
  - Pointed
  - Round
  - Flat
  - Hollow

Ballistics

- Low velocity bullets
  - Made of low melting point lead alloys
  - If fired from high velocity they melt, 2° to friction
    - Deform
    - Change missile ballistics
- High velocity bullets
  - Coated or jacketed with a harder metal
  - High temperature coating
  - Less deformity when fired

Velocity

- Energy = ½ mv^2
- Energy increases by the square of the velocity and linearly with the mass
- Velocity of missile is the most important factor determining amount of energy and subsequent tissue damage

Kinetic Energy of High and Low Velocity Firearms

Weapon	Bullet Weight		Velocity		Kinetic Energy	
	gr	g	ft/s	m/s	ft-lb	J
Civilian (low-velocity)						
.22 long rifle	40	2.6	1200	663	128	173
.38 automatic pistol	95	6.2	880	268	163	222
.45 pistol	230	14.9	850	259	369	500
Military (high-velocity)						
.22 Savage	70	4.5	2750	838	1175	1593
30/06 Springfield	150	9.7	2750	838	2519	3415
5.56-mm M-16	55	3.6	3250	991	1290	1749

Kinetic Energy of Shotgun Shells

Gauge	Shell Type	Weight of Shot			Muzzle Velocity		Kinetic Energy	
		oz	gr	g	ft/s	m/s	ft-lb	J
12	2¾-in.	1¼	546	38	1330	405	2145	2912
12	2¾-in. mag.	1½	656	43	1315	401	2519	3416
12	3-in. mag.	1⅝	701	46	1315	401	2726	3700
16	2¾-in. mag.	1¼	546	35	1295	395	2033	2761
20	2¾-in.	1	437	28	1220	372	1444	1960
20	2¾-in. mag.	1⅛	492	32	1220	372	1626	2205

Wounding power

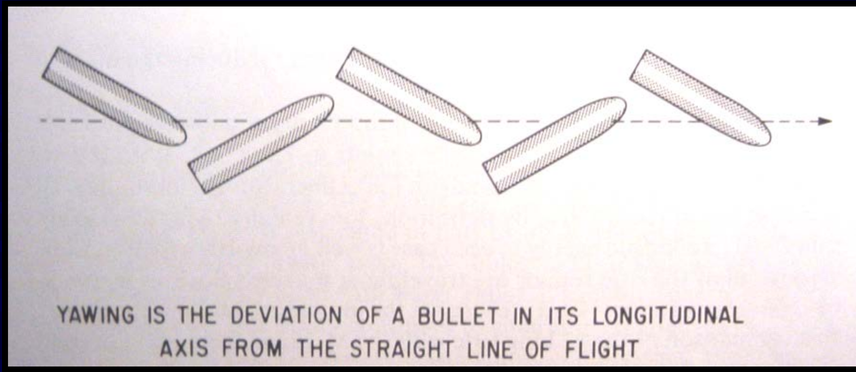
- Low velocity, less severe
  - Less than 1000 ft/sec
  - Less than 230 grams
- High velocity, very destructive
  - Greater than 2000 ft/sec
  - Weight less than 150 grams
- Shotguns, very destructive at close range
  - About 1200 ft/sec
  - Weight up to 870 grams

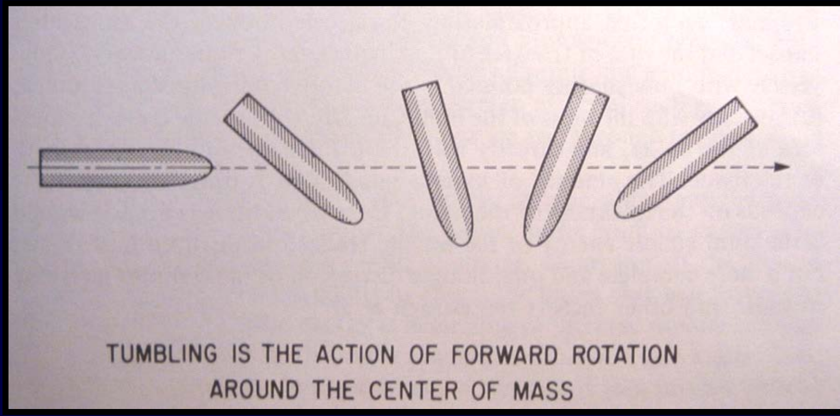
Factors that cause tissue damage

- Crush and laceration
- Secondary missiles
- Cavitation
- Shock wave

Crush and Laceration

- Principle mechanism in low velocity gunshot wounds
- Material in path is crushed or lacerated
- The kinetic energy is dissipated
- Increased tissue damage with yaw or tumble
  - Increased profile
  - Increased rate of kinetic energy dissipation
  - Increased probability of fragmentation



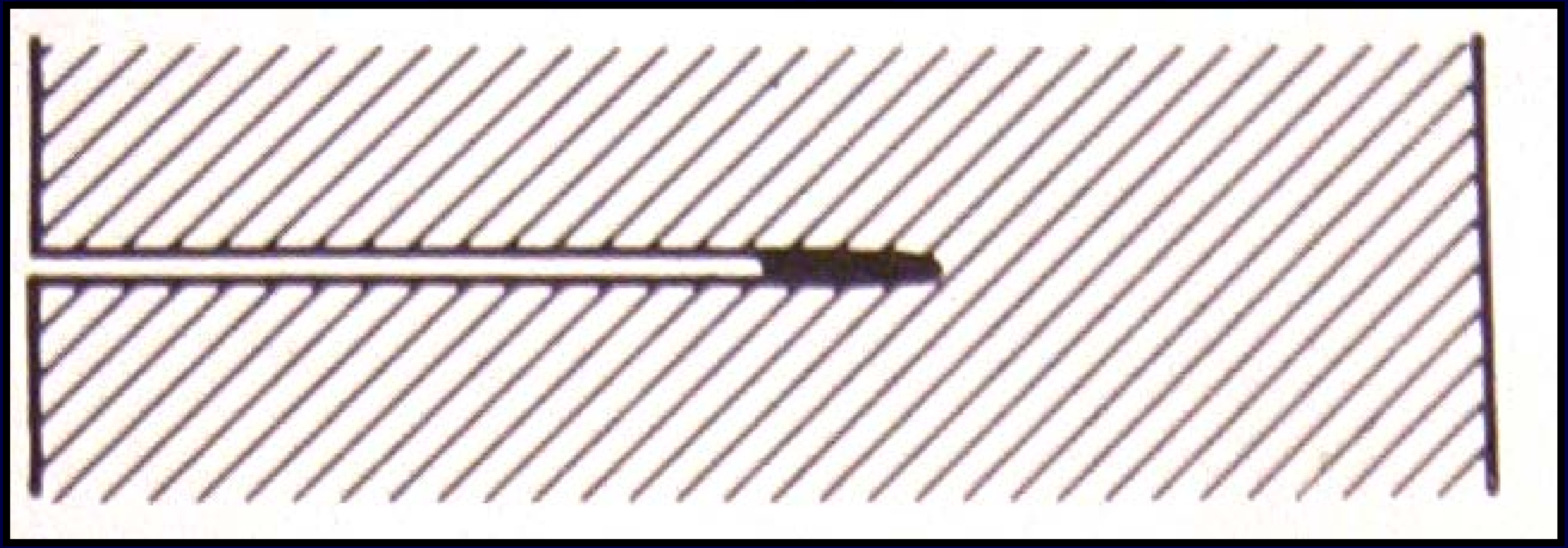


Secondary Missiles

- Bone fragments or metal fragments from helmet that move through tissue and cause damage
- Highly destructive
- Erratic, unpredictable, and unexpected courses

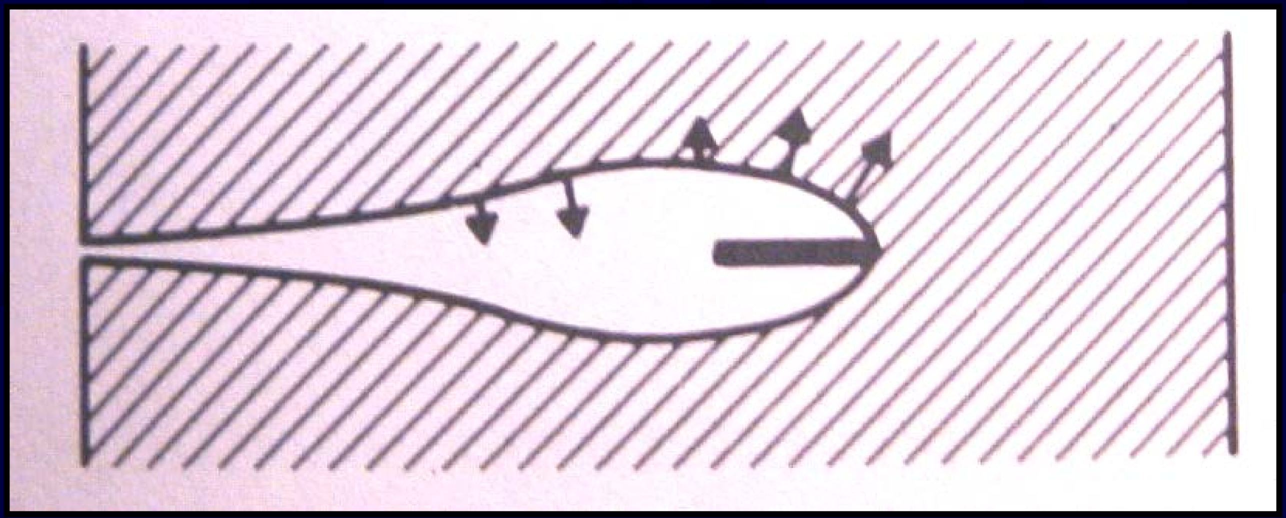
Cavitation

- Primarily with high velocity missiles
- Low velocity missiles tend to push tissue aside
  - Path of destruction only slightly larger than bullet



Cavitation

- High energy
  - Energy is dissipated forward and laterally away from the bullet and tract
  - At high velocity the cavity continues to enlarge even after bullet has passed



Cavitation

- Cavity is sub atmospheric
  - (negative pressure)
  - Sucks air and debris from both ends
- Initial cavity is temporary
- Collapse and reforms repeatedly with diminished amplitude
- Results in greater tissue damage to inelastic tisse (liver, spleen) than elastic tissue (e.g. lung)
- Missile path that remains is permanent cavity

Cavitation

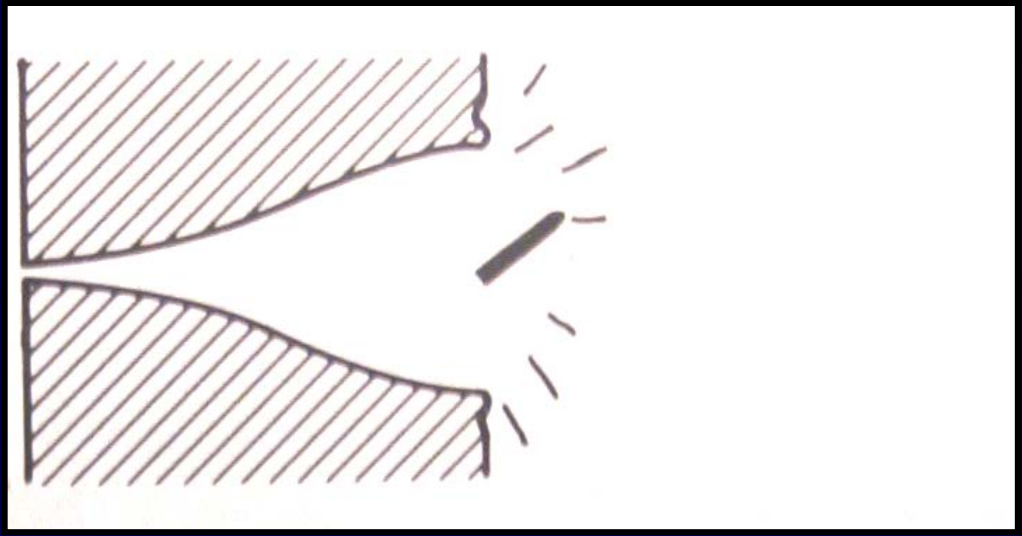
- Vessels, nerves, and other structures that were never in contact with bullet may be damaged
- In tissues with low-tensile strength (organs), cavitation develops more rapidly and extensively
- Muscle is intermediate in tensile strength
- Bone and tendon have high-tensile strength

Cavitation

- At higher velocity
  - Entrance wound may be larger than bullet
- If bullets yaws, deforms, fragments, tumbles, cavitation may be extensive and asymmetric
  - Entrance wound may be modest
  - Maybe no exit wound if entire energy of bullet is dissipated in / absorbed by the tissue.

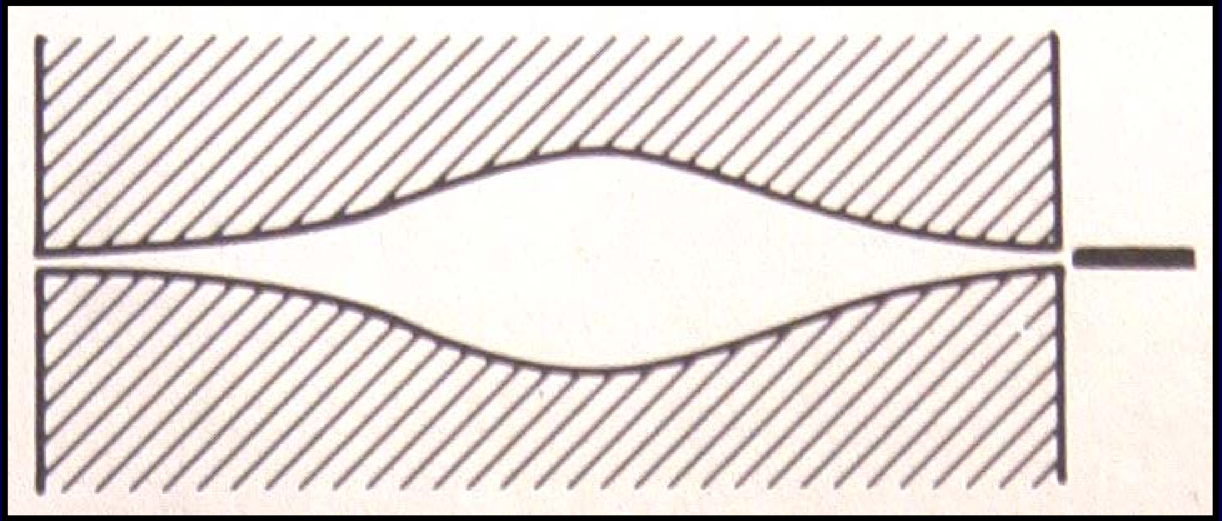
Cavitation

- If the path of the bullet is short
  - Bullet may exit as degradation of the energy is beginning to increase secondary to yaw and deformation of the bullet
  - Large exit wounds



Cavitation

- Long path of bullet
  - Energy degradation occurs deep in tissues
  - Large amount of damage through cavitation
  - Entrance and exit wounds may be small



Shock Wave

- With higher velocities damage to tissue away from are of impact can occur
- Tissue in front of projectile is compressed
  - Moves away in form of shock wave
  - At about speed of sound in water
    - 4800 ft/sec
    - Faster than bullet (except very high velocity)
  - Thus, nerve impairment with bullet wound does <u>not</u> indicate nerve transection

Shotguns

- Other factors in injury
  - Wadding
    - Plastic
    - Paper
    - Cork
  - Embeds into wound
  - Contaminates wound, infection
  - Must be identified and removed

Shotguns

- Missile
  - A few to hundreds
  - Spherical
- Relatively high muzzle velocity
  - 1000-1500 ft/sec
- Massive wounding capacity at 4 to 5 feet
- Projectiles slow down quickly

Conclusions

- High velocity gunshots may cause massive amounts tissue damage requiring debridement
- Close range shotgun wounds also cause massive tissue destruction
- Both may have large amounts of contamination
  - Secondary to negative pressure of cavitation
  - Shell casing, wading etc.
  - Thorough surgical debridement is imperative

Evaluation

- Careful inspection
  - Locate all entrance and exit wounds
- Check circulation
- Look for expanding hematoma
- X-rays of injured extremities and areas
- Angiography when necessary
  - Discrepancy of pulses

Management

- Low velocity gunshot wounds rarely need debridement
- High velocity and close range shotgun wounds always need debridement
- Most civilian gunshot wounds are low velocity and low energy

Bullets are not Sterile

- Old myth that bullet was sterile from heat
- Wolf et al:
  - Coated bullet with S. aureus and shot into sterile gelatin block
  - Positive cultures grew from gelatin

Wolf, J Trauma, 1978

Infection

- Low velocity gunshot wounds in stable fractures do not need surgical debridement
- Oral antibiotics for 72 hours as effective as IV
- IV antibiotics not indicated unless for prophylaxis for surgery *Knapp, JBJS, 1996*
- If perforate bowel and injure joint, consider irrigation and debridement

Becker, J Trauma, 1990

Distal Tibia

- Higher incidence of infection
    - Knapp et al, *JBJS*, 1996
- Consider operative debridement, especially if antero-medial wound

Vascular Assessment

- Arterial injury can occur from:
  - Direct contact
  - Cavitation
  - Associated fractures
- Evaluation
  - Physical examination
  - Non invasive doppler
  - Arteriography

Non Invasive

- Ankle-brachial index (ABI) <.90
  - 95% sensitivity

    } presence of arterial injury

  - 97% specificity
- Ankle-brachial index (ABI) > .90
  - 99% negative predictive value for arterial injury

Johansen J Trauma 1991

Vascular Injury

- Pulses absent
  - Must proceed to OR for revascularization,
  - intra op angiography helpful if location of lesion uncertain
- Discrepant pulses
  - If ABI < .90 angiography to look for lesion
  - If ABI > .90, serial documentation of limb vascularity necessary

Vascular Injury

- Vascular lesion with associated fracture:
  - Vascular repair necessitates stabilized fracture
- What should be done first?
  - Dependant on limb ischemia time
    - Temporary shunt may allow rapid revascularization and adequate redundancy to regain limb length
  - Dependant upon time needed for stabilization
    - External fixation may temporarily provide stability in a timely fashion
  - Communication among services important

Nerve Injury

- 71% with arterial injury have nerve injury
  - 39% of patients without nerve injury and vascular repair will have normal extremity
  - 7% of patients with nerve injury and arterial repair will have normal extremity

Visser, AM J Surg, 1980

Brachial Plexus

- Most show signs of recovery 2-4 weeks
- Surgical indications
  - no improvement at 3 months
- Recovery potential not related to severity of injury
  - The appearance of recovery at 4 weeks

Vrettos, J Hand Surg, 1995

Fractures

- Fractures may have significant comminution
  - These fracture heal quickly if closed reduction performed with or without internal or external fixation
  - Comminution acts almost like a bone graft to enhance healing, provided soft-tissue damage is not excessive
- Because of comminution fractures are usually very unstable
  - Difficult to maintain length with closed methods





Fractures

- Fracture lines usually propagate beyond what can be seen on traditional radiographs
  - Out of plane of radiograph
  - Non displaced cracks
- Be prepard to extending fixation beyond what traditionally would be done for fracture

  i.e.. Subtrochanteric fracture with lesser trochanter intact, use nail with neck fixation as opposed to standard nail.

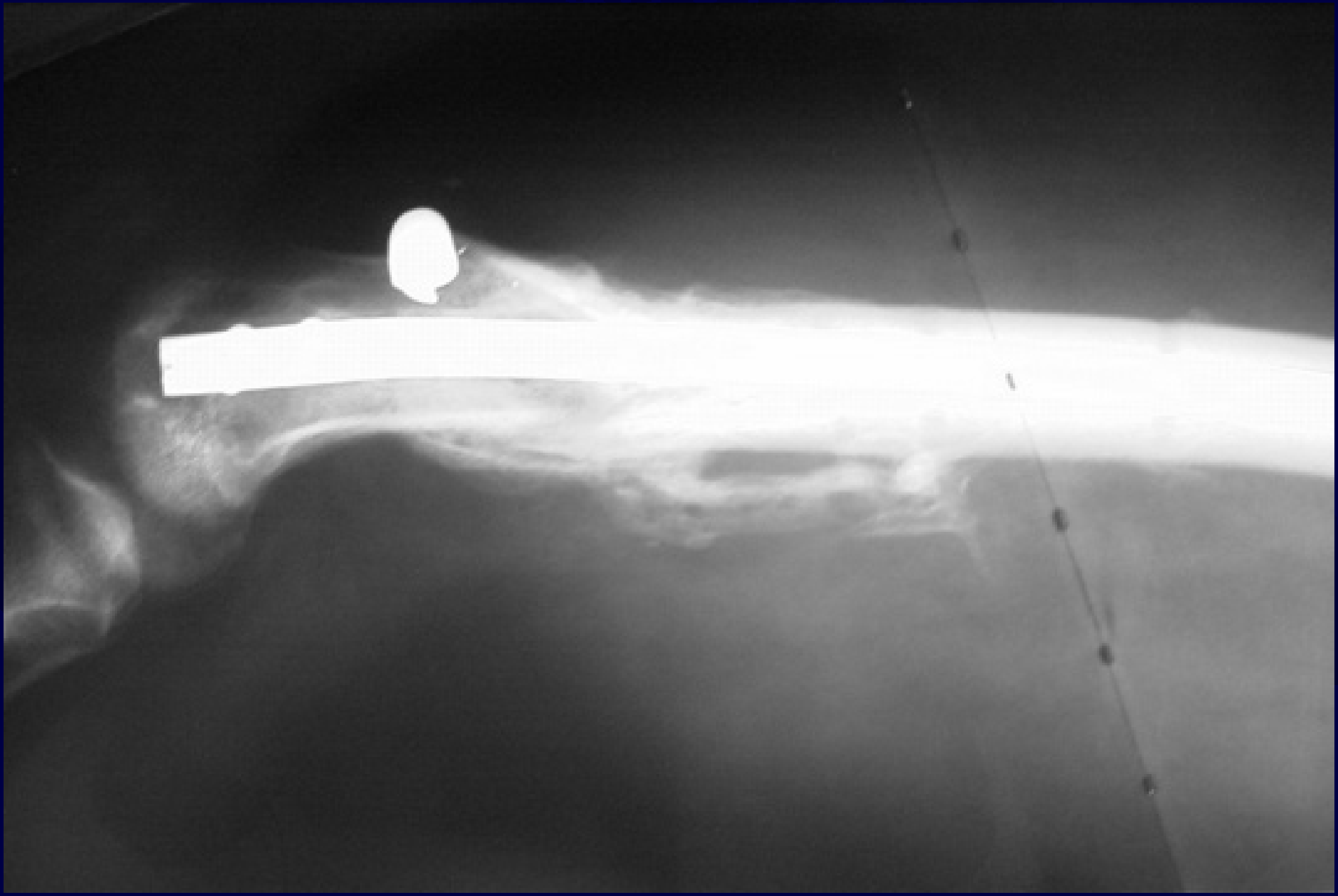
Cases

- 23 y.o. male
- Single low-energy GSW to leg
- ABI > 1.0
- Neurologically intact
- XR: Fracture of distal femur
  - Moderate comminution noted
  - Lateral condyle comminuted through articular surface
  - Not fully appreciated on plain film

Note fixation of lateral condyle for unappreciated comminution

- 27 y.o. male
- GSW to right leg
- ABI = .7
- On table angiogram
  - Laceration of popliteal artery
- Temporizing external fixator placed to stabilize length of limb
- Arterial repair performed
- Note comminution of fractured femur

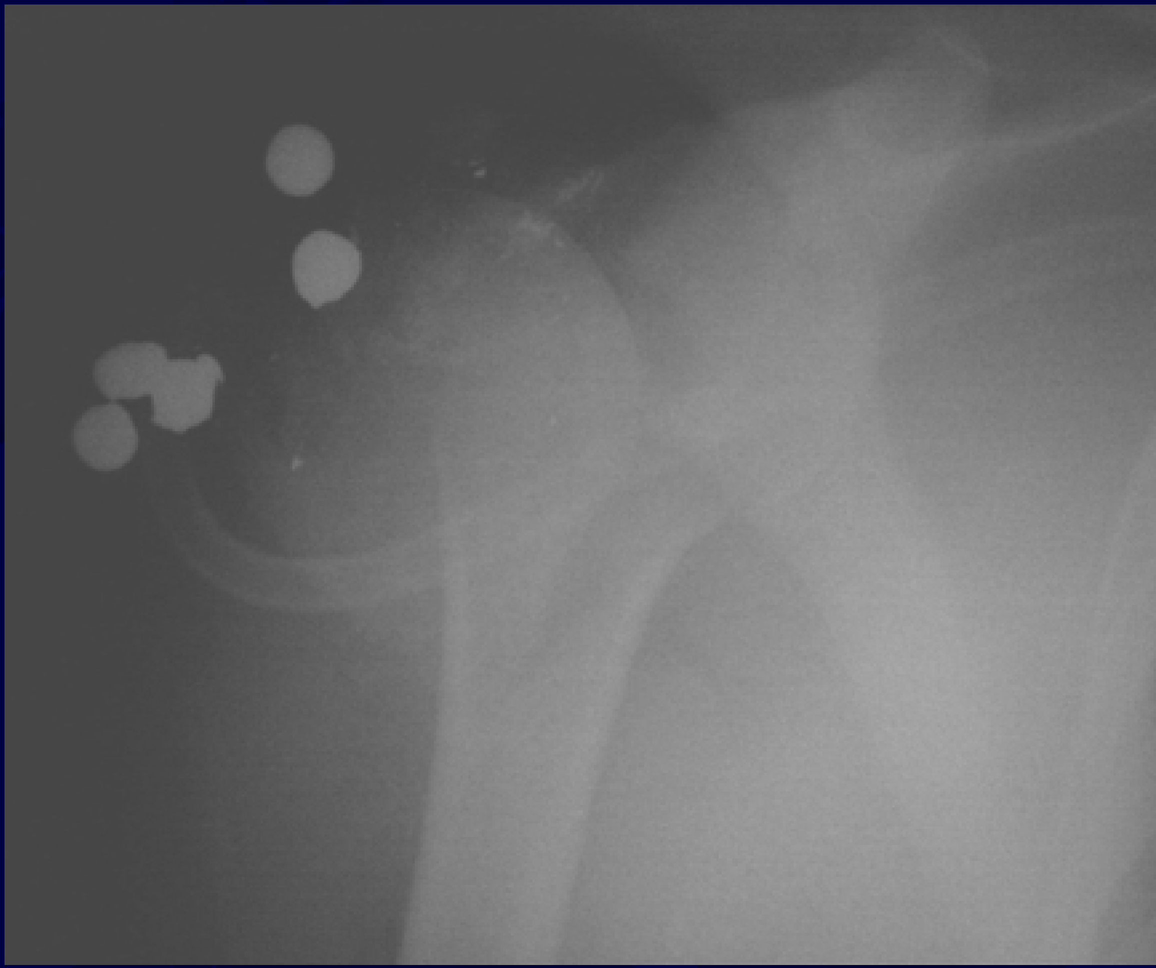
Almost Complete Healing by 3, 5 Months



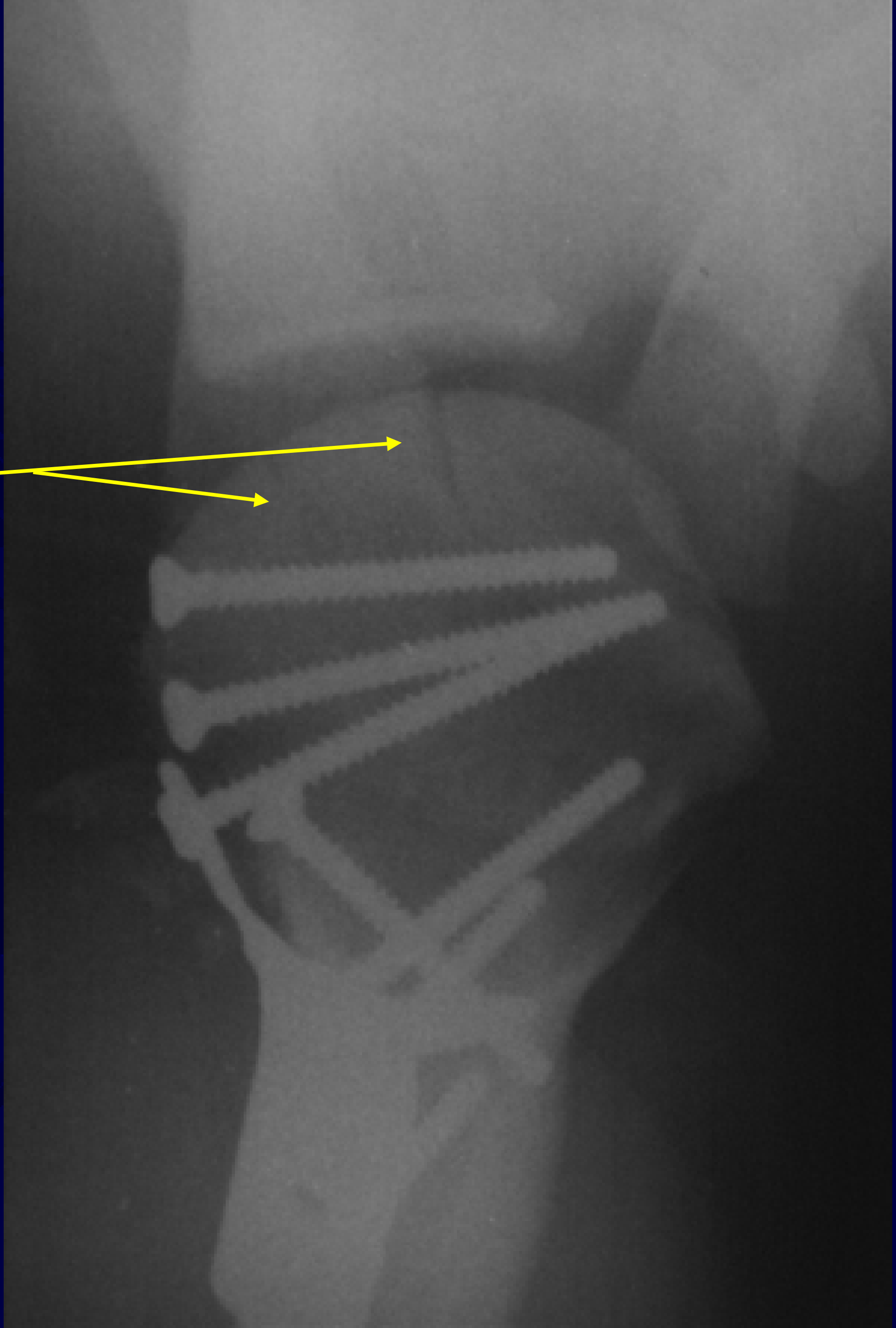
- 19 y.o. male
- GSW to leg
- ABI = .95
- Neuro intacy
- Radiographs
  - Comminuted fracture femoral shaft

- 2 months post op
- Early healing with callus forming
- Weight Bearing as tolerated, No pain

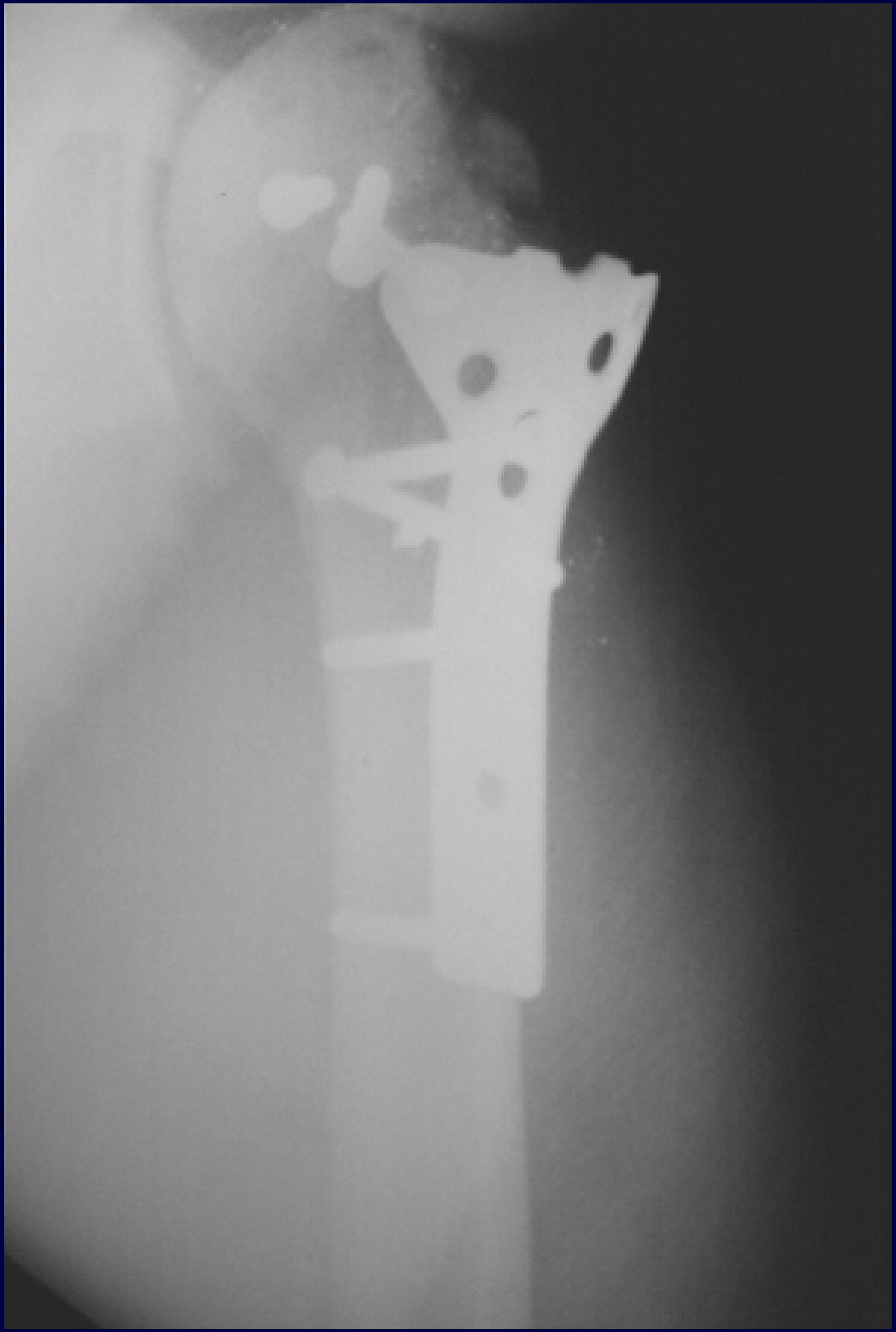
- 28 y.o. male
- Shotgun load with large pellets
- Neuro intact
- Vascular intact
- Large lateral wound from close range injury
- Exploration
  - Wadding, packing and pellets, all removed
- Repeat debridement at 72 hours



- Significant comminution not appreciated pre-op
  - Head split present
- ORIF performed



- Significant bone loss and muscle damage from energy of Shotgun
- Treated as open fracture with multiple debridements



- Healed at three months
- Motion limited
  - No active Abduction due to injury to rotator cuff insertion

Joint Injuries

- Knee most common
- Ankle second
- Look for vascular injury especially around knee
- Careful evaluation for fractures
- May need CT scan especially about hip

Joint Injuries

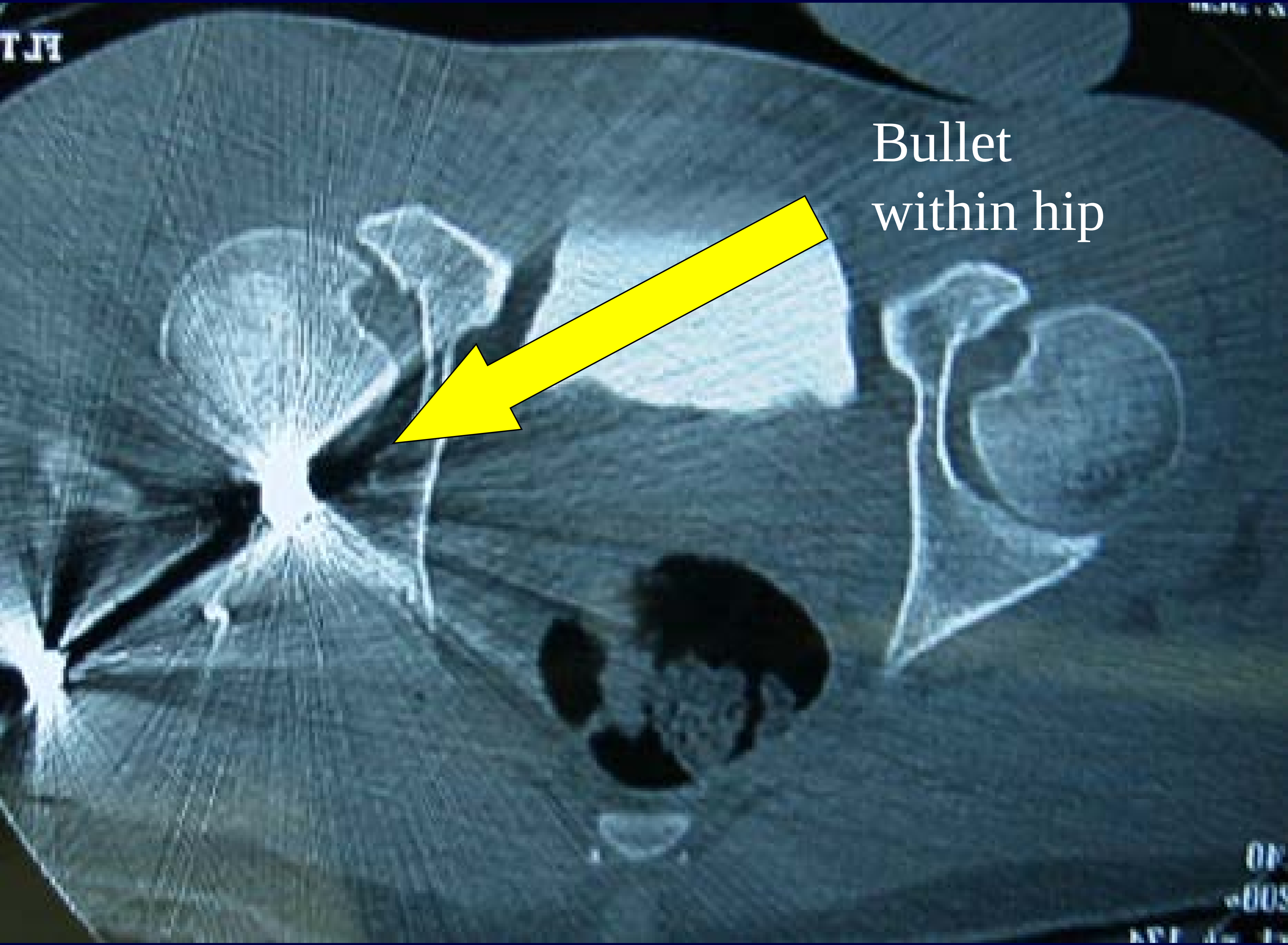
- Large amount of articular and cartilage damage, especially in knee
  - ? Significance
- Indication for surgery
  - Retained bone fragments
    - Acts as three body wear
  - Metal fragments in joints
    - Plumbism (lead poisoning)
  - Fix unstable fractures

Joint Injuries

- Hip Injuries
  - Look for association with bowel injury
  - If visceral injury, joint needs to irrigated to prevent infection

Becker, J Trauma, 1990

- Other operative indications same as other joints


Bullet
within hip

Conclusions

- Tissue damage and contamination dependant upon missile energy
- Careful vascular assessment mandatory
- High velocity and shotgun blasts require surgical debridement. Joints if retained metal or bone
- Recommend all victims treated with antibiotics
  - Route of delivery dependant on need for surgery
- fracture extension, fragmentation common
  - Many require surgical stabilization d/t instability
  - Indirect reduction, internal fixation recommended for diaphyseal injuries

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