# Humeral Shaft Fractures

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# Disclaimer:

Figures used with permission.  Christos Garnavos. Humeral Shaft Fractures. In: Tornetta P, Ricci WM, eds.  Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019

# Objectives

- Understand the **anatomy and surgical approaches** to the humeral shaft
- Understand the indications for **nonoperative vs operative management** of humeral shaft fractures
- Understand the use of **functional bracing** in humeral shaft fractures
- Understand the literature comparing **ORIF vs IMN**
- Understand the literature on **MIPO** technique for humeral shaft fractures
- Develop a strategy for treating **extraarticular distal 3rd humerus fractures**
- Develop a treatment algorithm for management of **radial nerve palsy** in the setting of humeral shaft fractures

# Epidemiology and Classification

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019

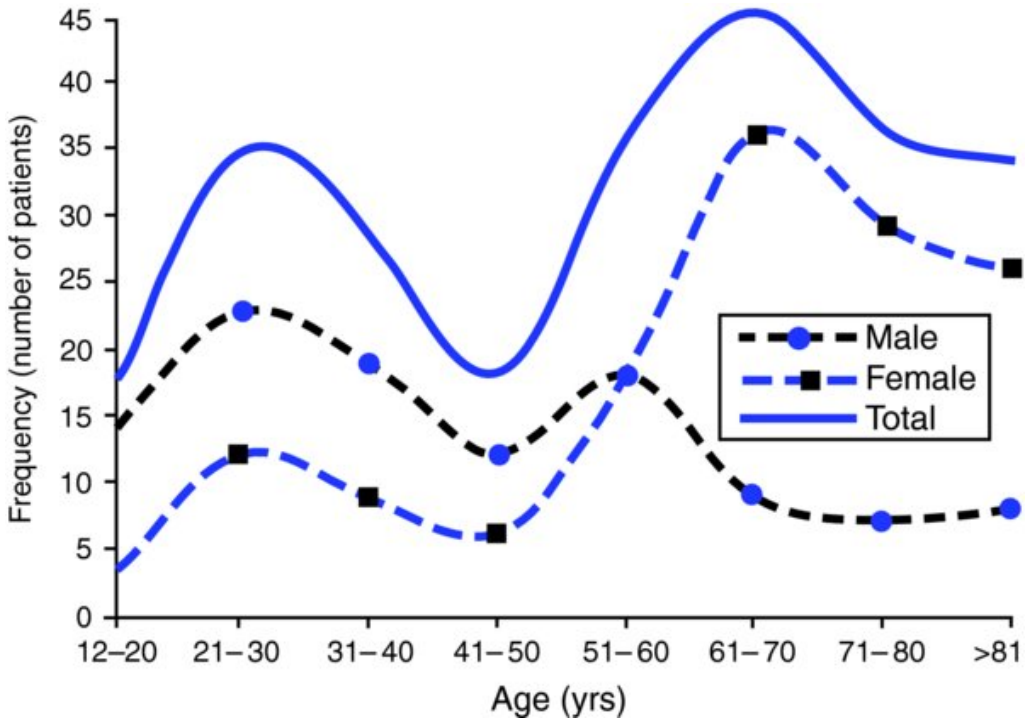
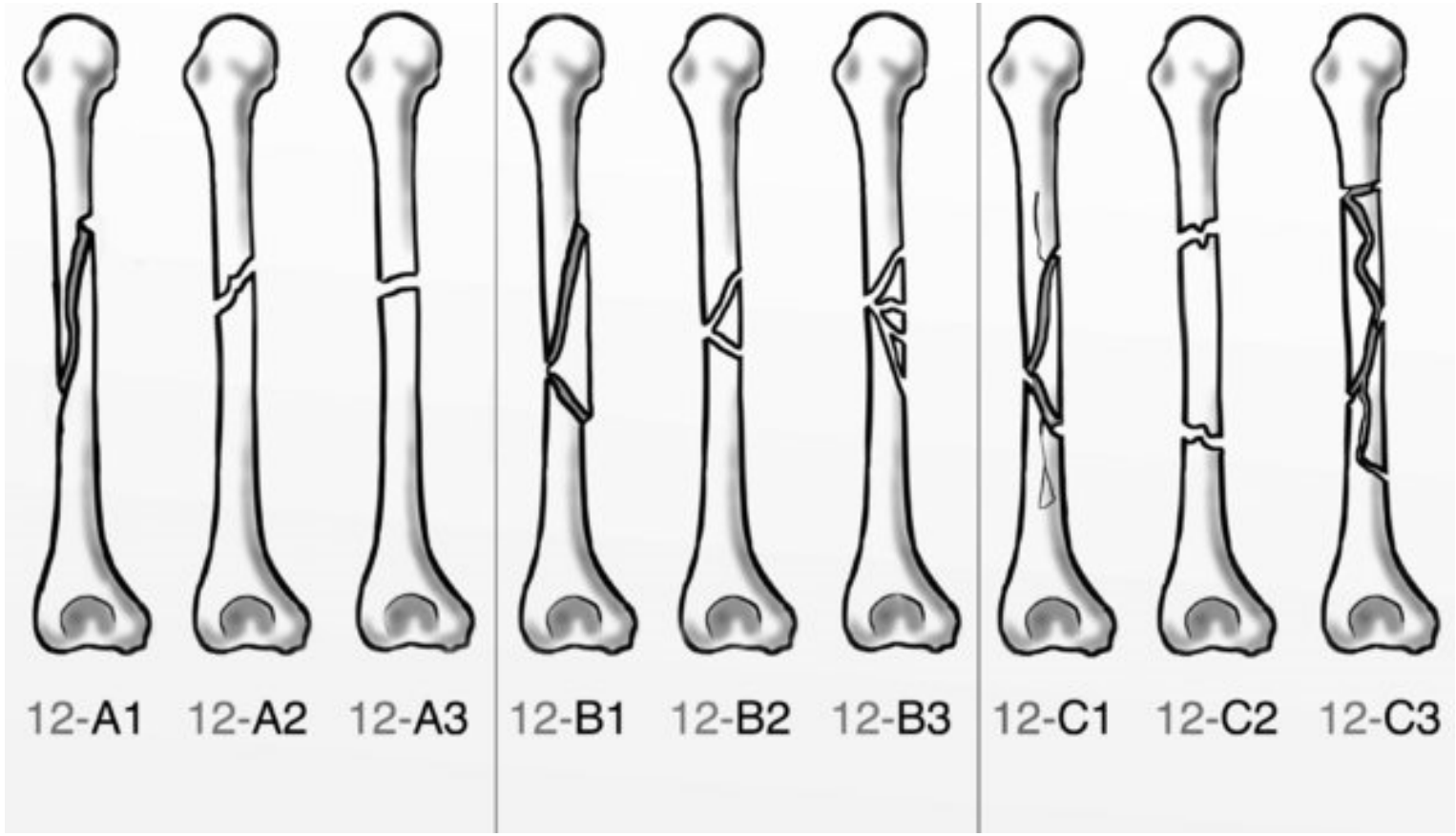



**Figure 36-1**

**Age and gender distribution of fractures of the humeral shaft in 249 patients from Edinburgh.**

(Redrawn from Tytherleigh-Strong G, Walls N, McQueen MM. The epidemiology of humeral shaft fractures. *J Bone Joint Surg Br.* 1998;80B(12):249–253.)




AO/OTA classification of diaphyseal humeral fractures.

# Anatomy

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019

- Humeral diaphysis extends from the superior border of the insertion of the pectoralis major proximally to the supracondylar ridge distally
- Medullary canal ends proximal to olecranon fossa
- Radial nerve travels from medial to lateral and is directly posterior to shaft at mid diaphysis
- Radial nerve is tethered to, and often in direct contact with, the lateral shaft distally.
- Fracture alignment is determined by the location of the fracture relative to the major muscle attachments, most notably the pectoralis major and deltoid attachments

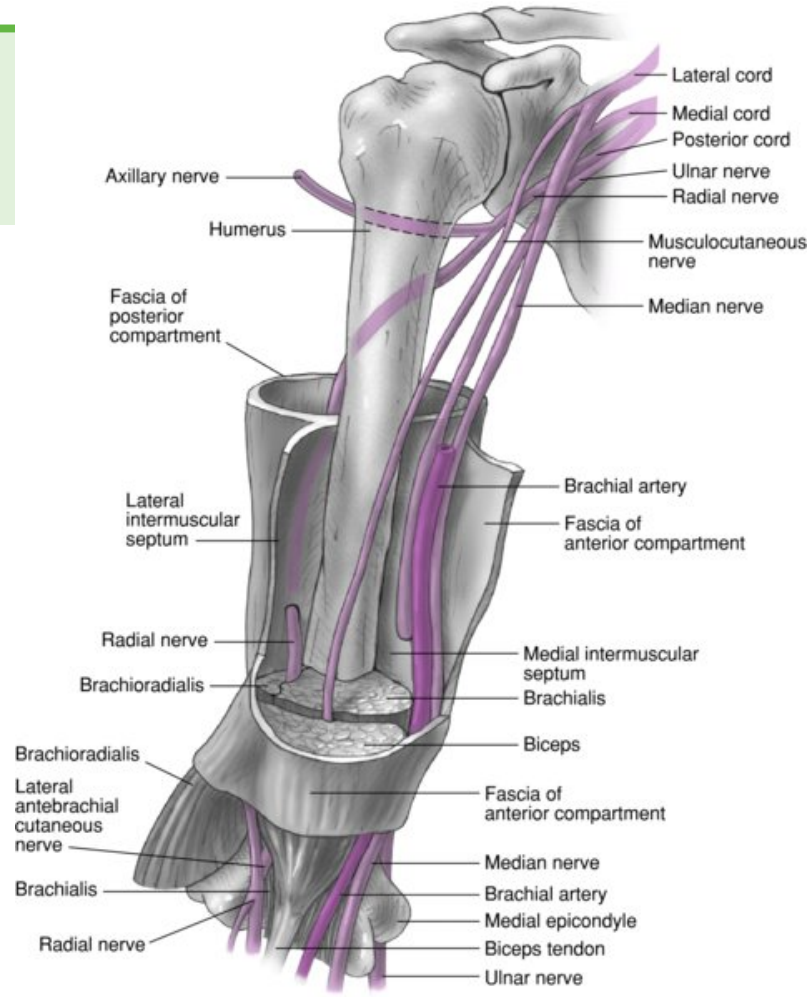
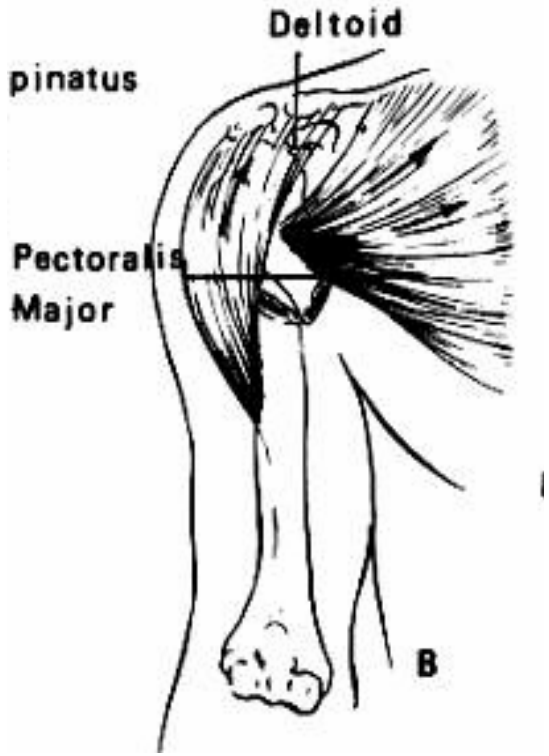



Figure 36-9

The neurovascular anatomy of the upper arm.

# Deforming Forces

- Example of a fracture distal to pectoralis major attachment and proximal to deltoid tuberosity
- This results in adduction of the proximal fragment

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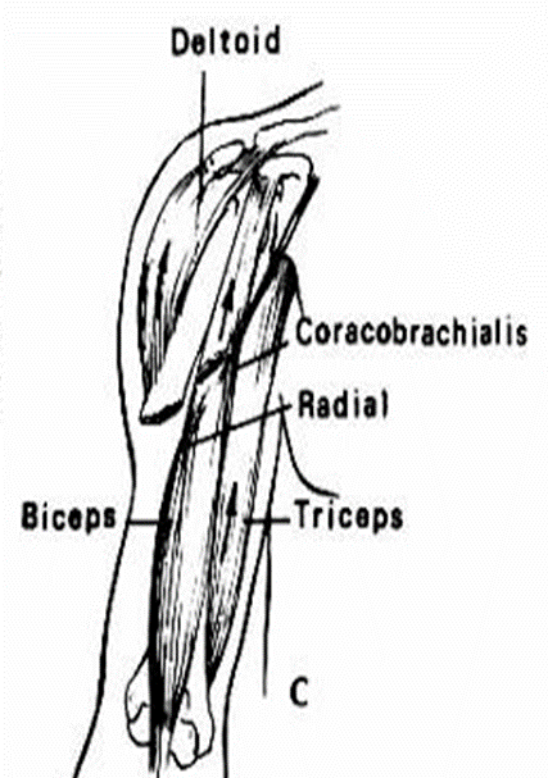
# Deforming Forces

- Example of a fracture distal to deltoid tuberosity
- The proximal fragment is abducted and shortening occurs at fracture site due to pull of biceps and triceps

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# Applied Surgical Anatomy of the Humerus

Zlotolow et al, JAAOS, 2006

Axillary nerve
- 3-7 cm distal to acromion

Radial nerve
- 16-20cm proximal to medial epicondyle
- 10-14cm proximal to lateral epicondyle

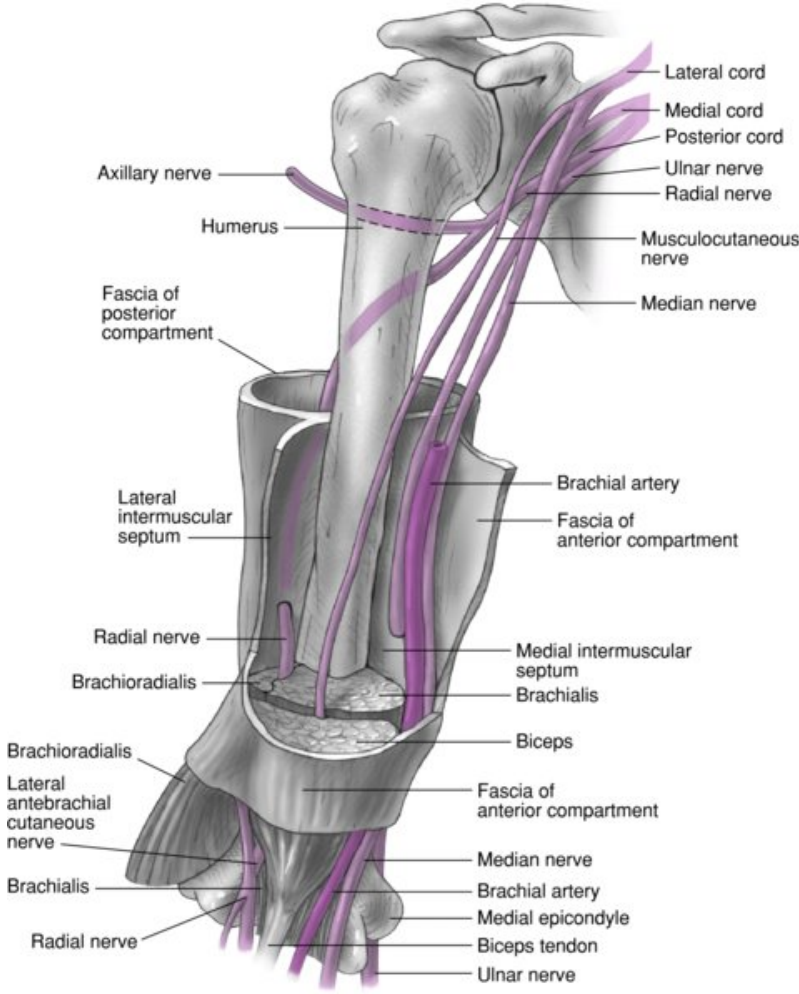



Figure 36-9

The neurovascular anatomy of the upper arm.

# Surgical Approaches

Anterolateral

IMN

MIPO

Posterior

Lateral

Medial

# Anterolateral Approach

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019

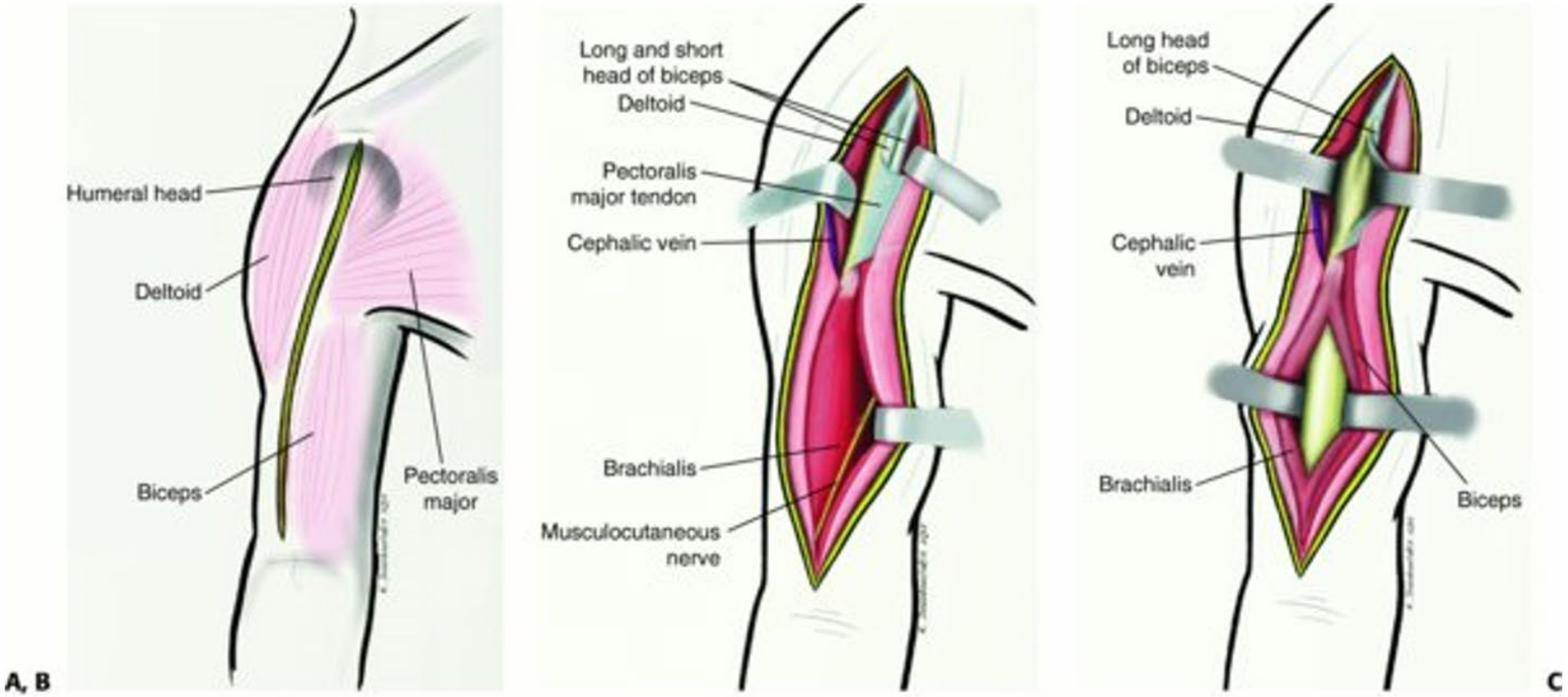
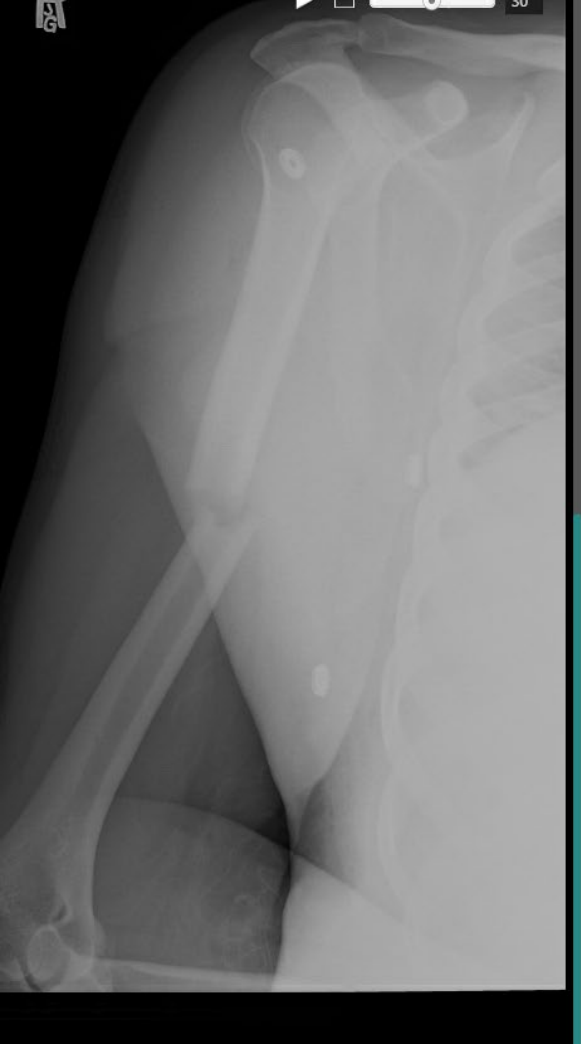
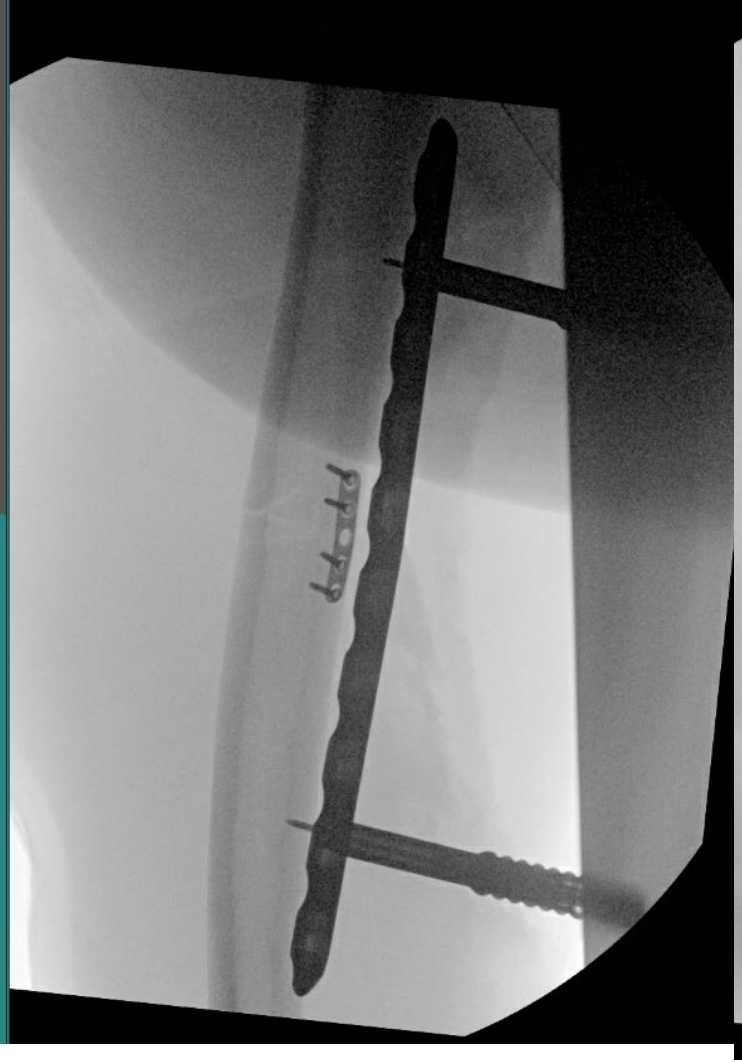



**Figure 36-11**

**Anterolateral approach to the right humerus.**

**A:** Incision. **B:** Retraction of the deltoid laterally and the long head of biceps medially will reveal the tendon of pectoralis major proximally and brachialis more distal. **C:** Partial detachment of the tendon of pectoralis major and split of brachialis will expose the anterolateral humeral shaft.





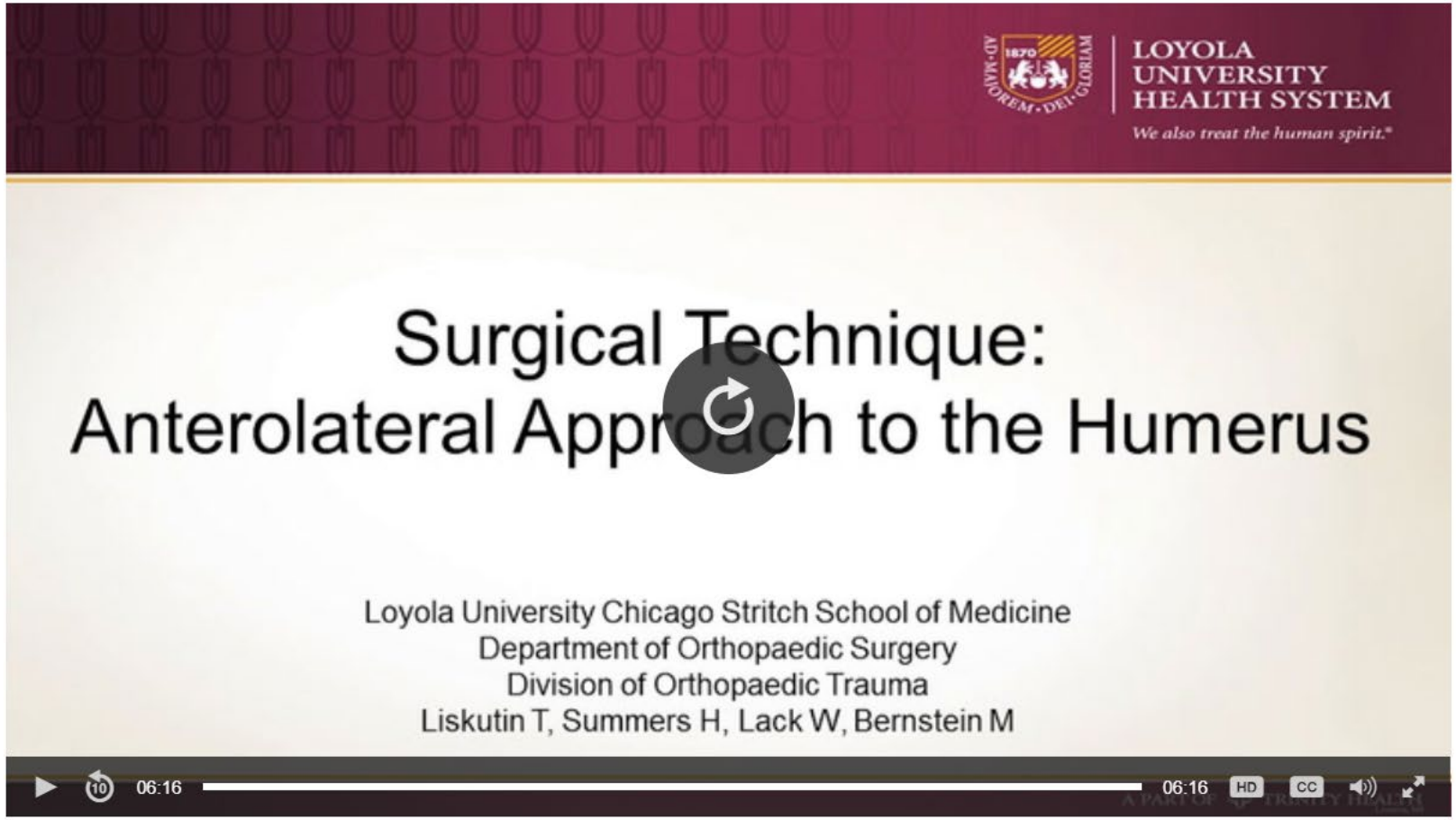
Healed at 6 months postop

51M, RHD, transverse humeral shaft fx. Pt elected for surgery

Anterolateral approach, brachialis split, mini frag assisted reduction

Compression plating (plate undercontoured) placed anterolateral between deltoid/pec insertions

https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16731323/surgical-technique-anterolateral-approach-to-the




## Surgical Technique – Anterolateral Approach to the Humerus ☆

Mitchell Bernstein, William Lack, Tomas Liskutin, Hobbie Summers

Presented in this video are surgical techniques of an anterolateral approach to the humerus, illustrated in the case of a humeral shaft fracture treated with Open Reduction and Internal Fixation. Additionally, we demonstrate the use of a Verbrugge to achieve axial compression across the fracture plane.

# Posterior Approach

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019

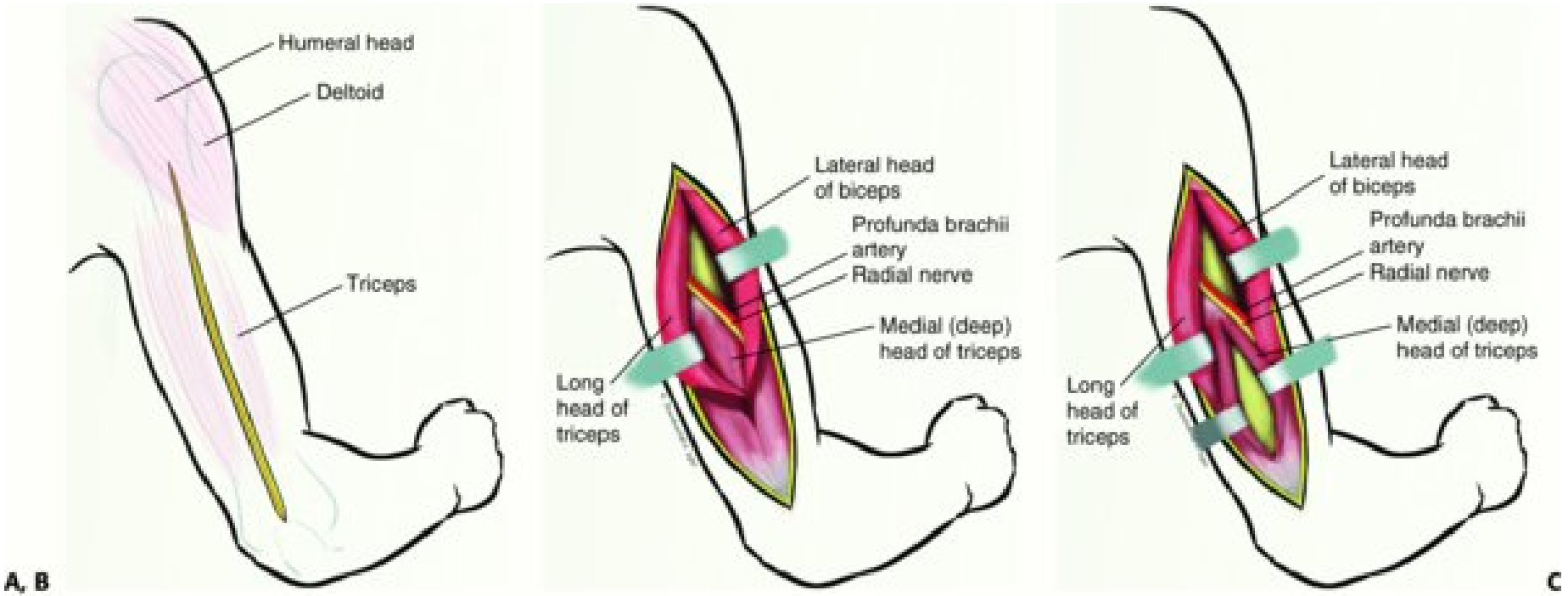



**Figure 36-12**

**Posterior approach to the distal humerus.**

**A:** Skin incision. **B:** Development of the interval between the long and lateral heads of triceps will reveal the radial nerve as it emerges within the spiral groove. **C:** Longitudinal midline dissection of the medial head of triceps will reveal the periosteum of the posterior humeral shaft.

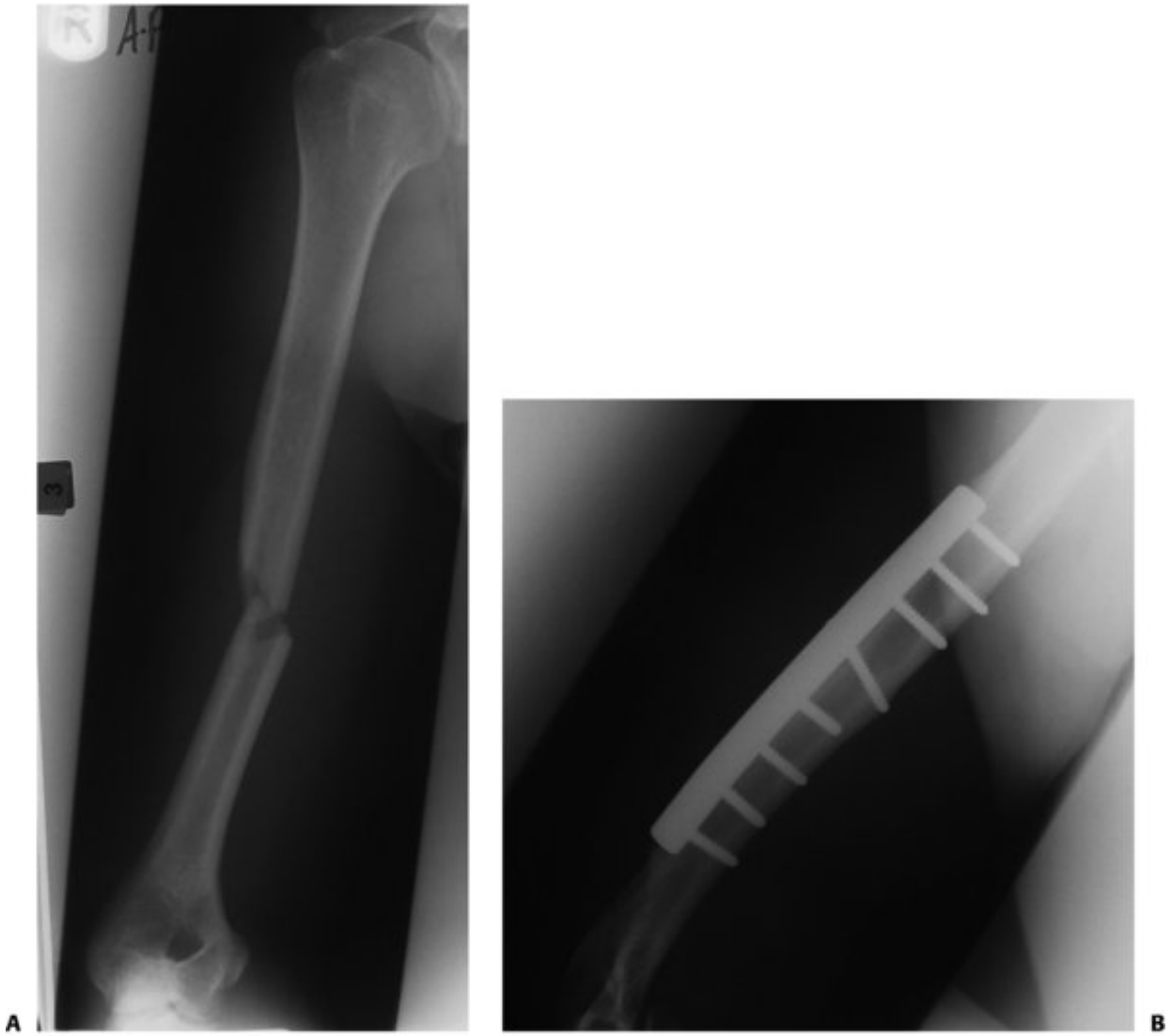
# Posterior Approach to Humerus

Gerwin et al, JBJS 1996

**Triceps split approach** will expose 55% of the posterior humeral diaphysis

**Triceps split, release of lateral intermuscular septum, and mobilization of radial nerve** will expose 76% of the posterior humeral diaphysis

**Triceps split, mobilization of radial nerve, and elevation of medial and lateral heads of triceps** will expose 96% of the posterior humeral diaphysis




A: Transverse fracture of the mid-distal humeral diaphysis.

B: Fixation with traditional plating technique through a posterior approach.

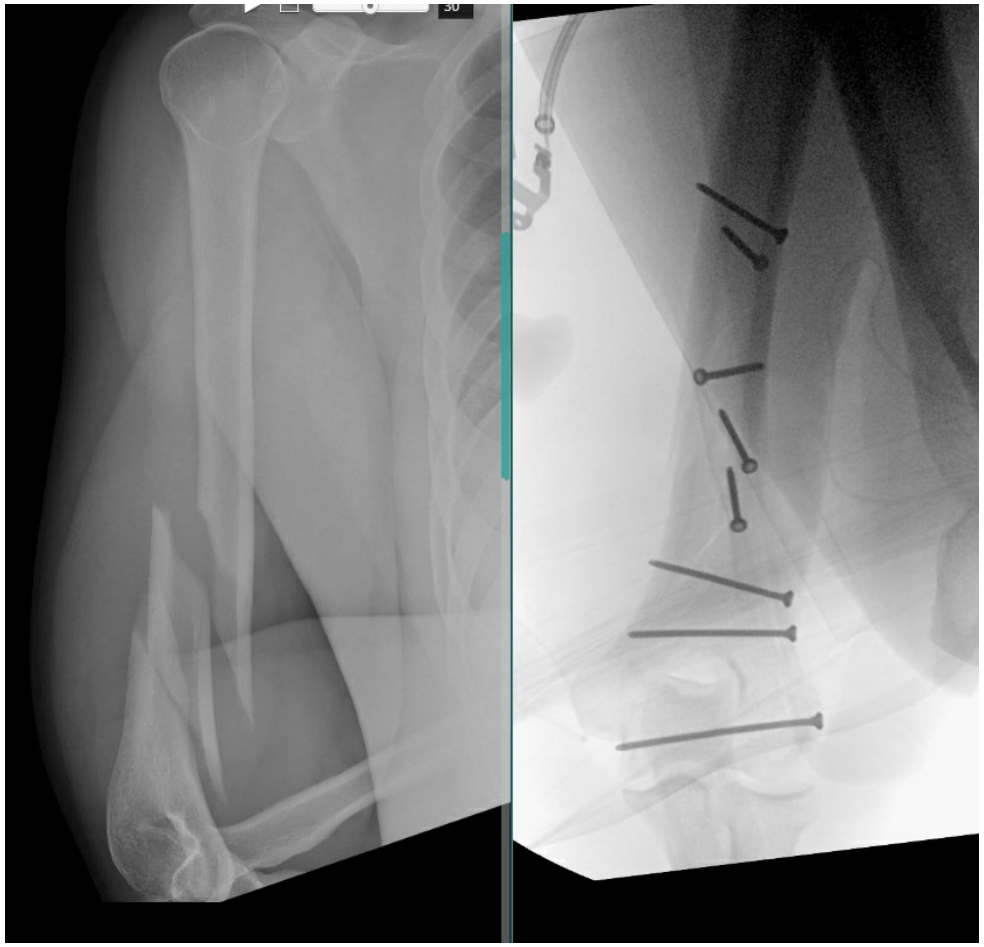
From: **36 Humeral Shaft Fractures**

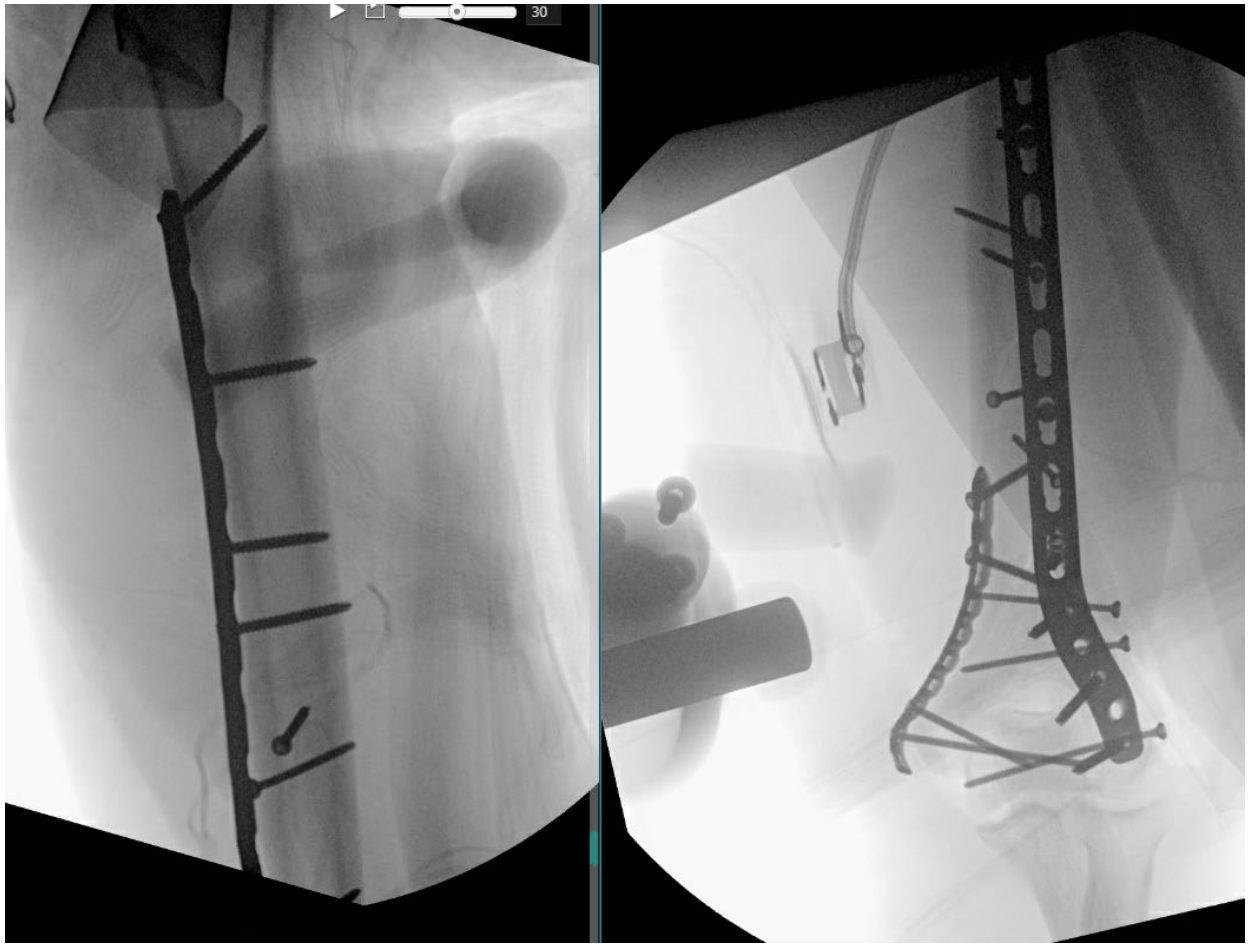
Rockwood and Green's Fractures in Adults, 9e, 2019


A: Fracture of the distal humeral diaphysis.

B+C: Fixation with a posterolateral plate that allows screw fixation of the lateral column.

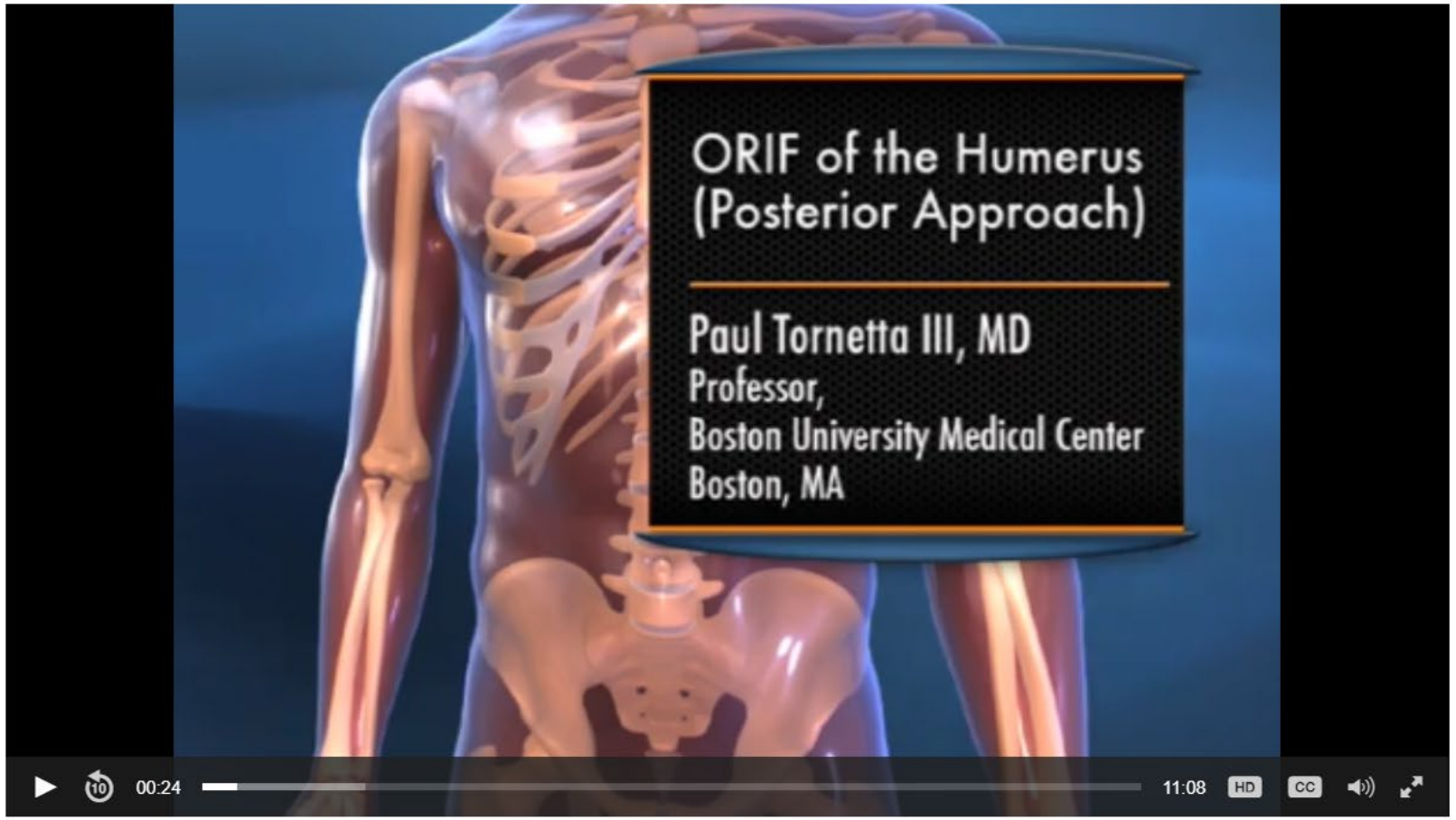
# 34M, RHD, segmental R distal 3rd humeral shaft fx w/ nondisplaced intraarticular extension





Posterior approach, lag screw fixation
Neutralization plate + supplementary med plate

https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16776523/orif-of-the-humerus

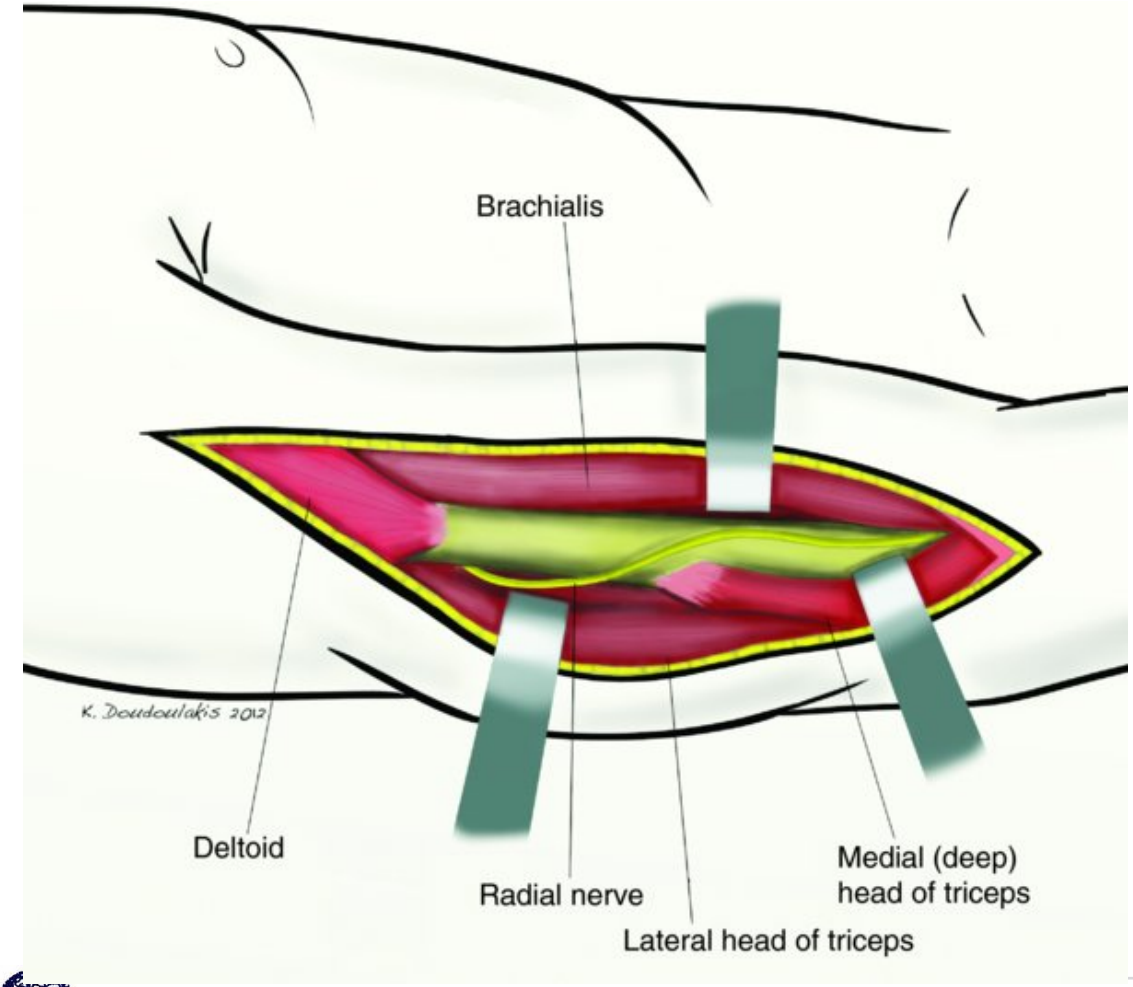



## ORIF of the Humerus ☆

This video discusses the open reduction and internal fixation (ORIF) of the left humerus through a posterior approach technique. The preoperative radiographs show a displaced left humerus bone. The operative plan is to perform an open reduction followed by internal fixation of the displaced humerus bone. The standard incision is made along the midline of the triceps without causing any damage to the radial nerve. The fractured fragments are reduced and fixed using reduction clamps. Screws of appropriate length are drilled along the posterior border of humerus.. The fractured fragment is stabilized using precontoured plates of appropriate length and fastened with screws. Multi-layer wound closure is done. Postoperative radiographs show the plate covering the entire length of the humerus.

# Lateral Approach

# Lateral approach to the distal humerus




- Allows exploration of radial nerve through length of incision.
  - carries a higher risk of iatrogenic damage
  - But in some cases is the best option.

- Supine positioning
- Muscle splitting not required
- Plate placement Ant/Lat/Post
- Extensile proximally and distally

Zlotolow et al, JAAOS, 2006

# Medial Approach

- Nearby neurovascular structures at risk
- Difficult exposure of shaft
- Rarely used for fracture fixation

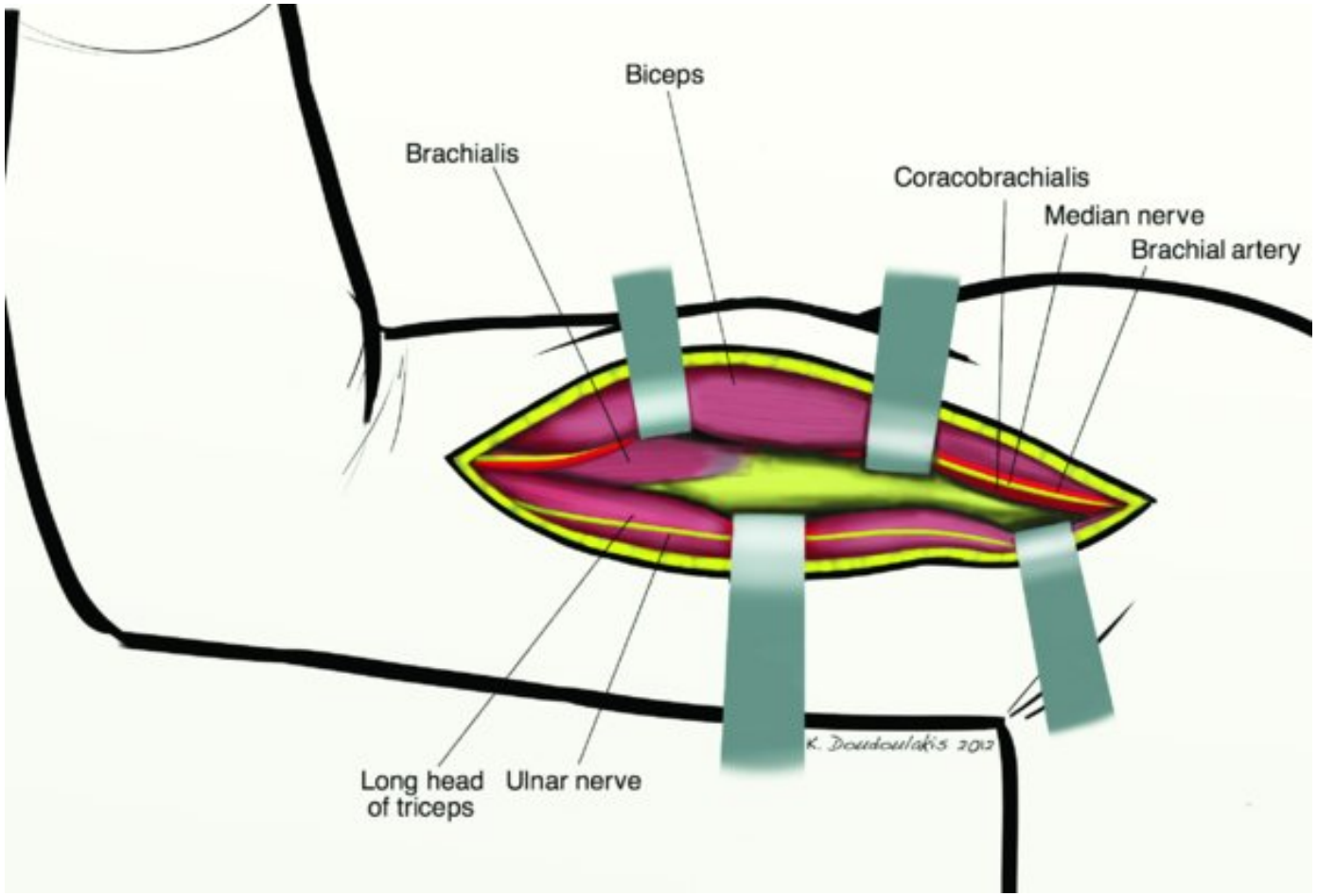



Figure 36-14

The anteromedial approach to the humeral diaphysis.

# Intramedullary Nail

Antegrade

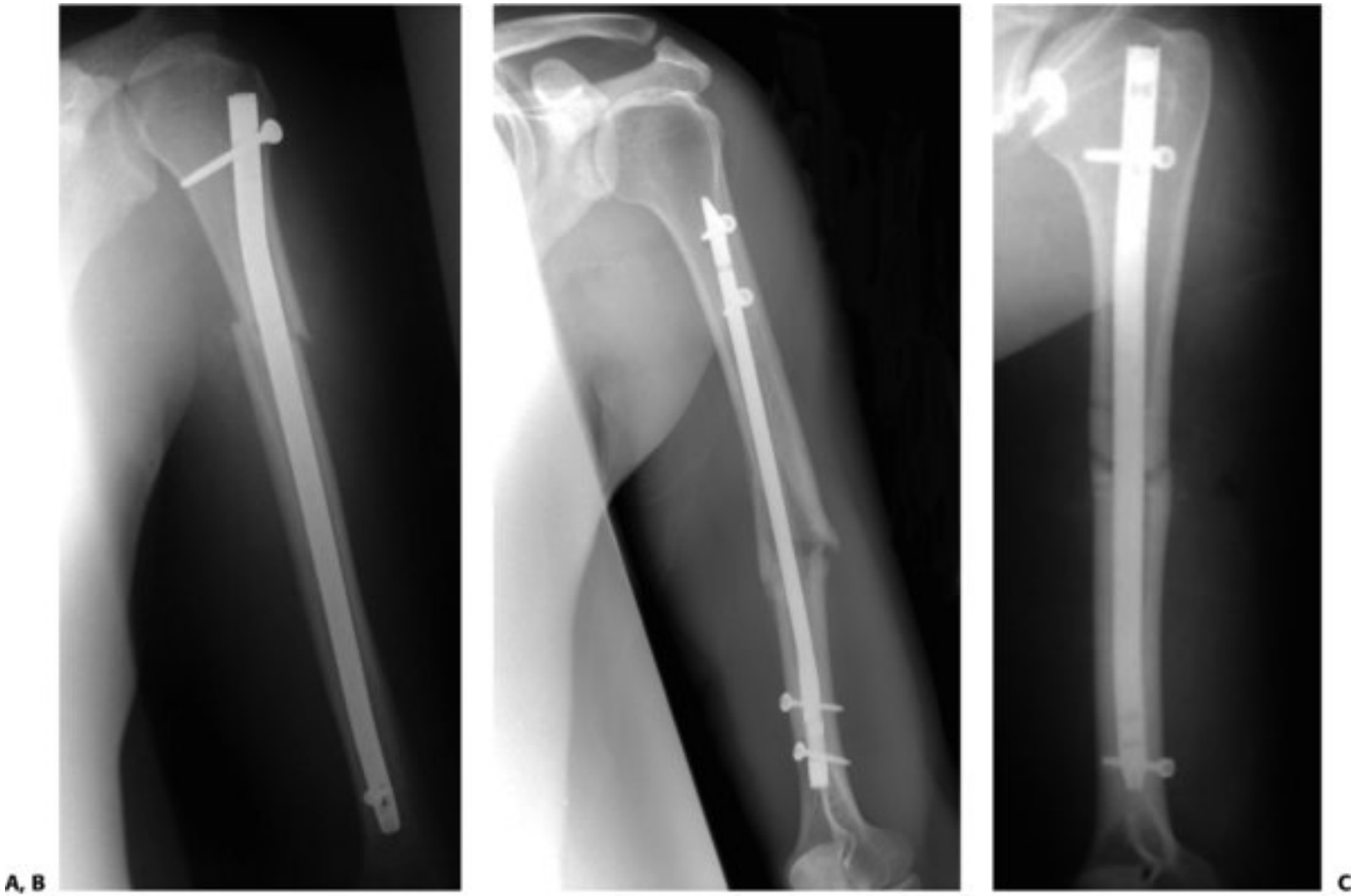
Retrograde

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019


Nails with interference fit

a. Seidel nail
b. Fixion nail
c. Marchetti-Vincenzi nail
d. True-Flex nail
e. Garnavos nail

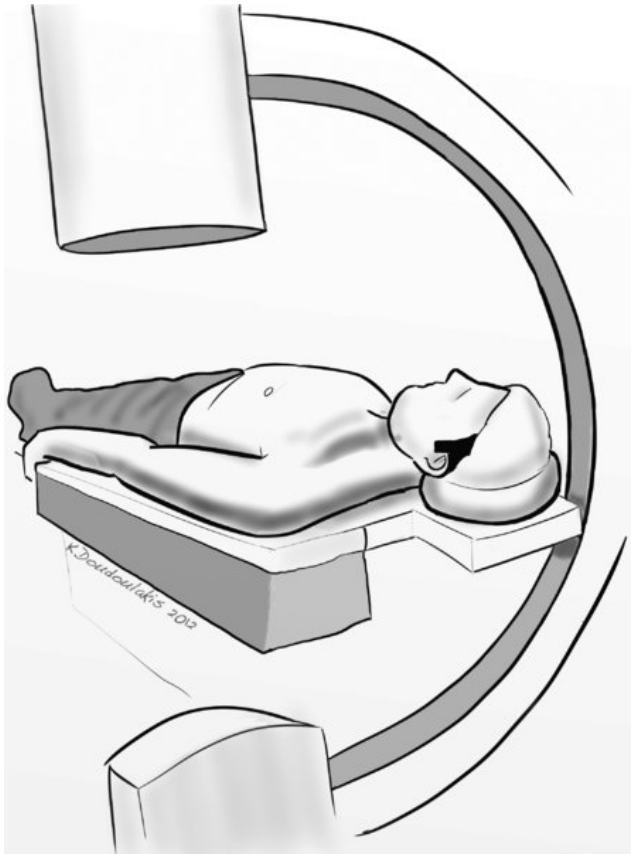



Nails with both proximal and distal interlocking screws

a. Russel-Taylor Nail
b. Unreamed Humeral Nail
c. T2 Nail

From: **36 Humeral Shaft Fractures**

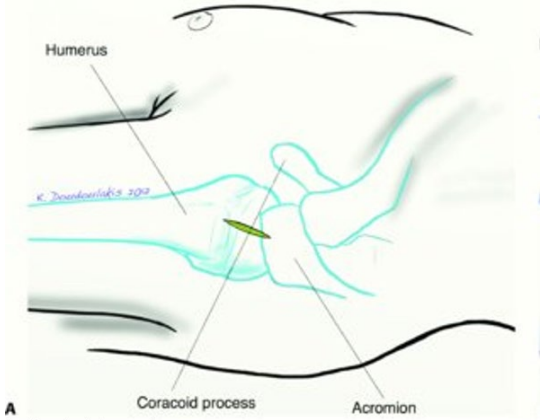
Rockwood and Green's Fractures in Adults, 9e, 2019

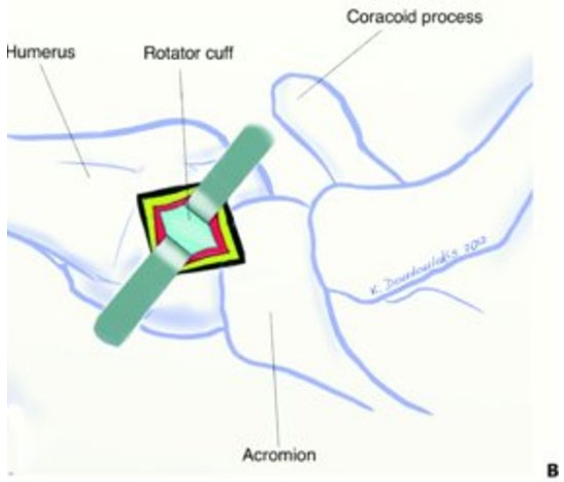


- Radiolucent table
- In this set-up, C arm is positioned on opposite side

# Antegrade Intramedullary Nailing Technique

1. Expose rotator cuff
2. Verify position with blunt radiolucent object
3. 1 cm incision to rotator cuff as medial as possible at the apex of the head
4. open cortex with hand awl
5. Reduce fracture using fluoroscopic guidance
6. Pass guidewire across fracture
7. Ream canal
   a) begin reaming with reamer inside bone
   b) do not ream across fracture in order to prevent radial nerve injury
   c) Stop reaming when reamer is within humeral head
   d) Be sure to remove all reaming debris from shoulder joint
8. Maintain fracture reduction during nail insertion
9. Do not allow fracture distraction
10. Be sure nail is not prominent
11. Lock nail proximally
12. Lock distally (always)
13. Cautious distal interlocking to prevent neurovascular injury



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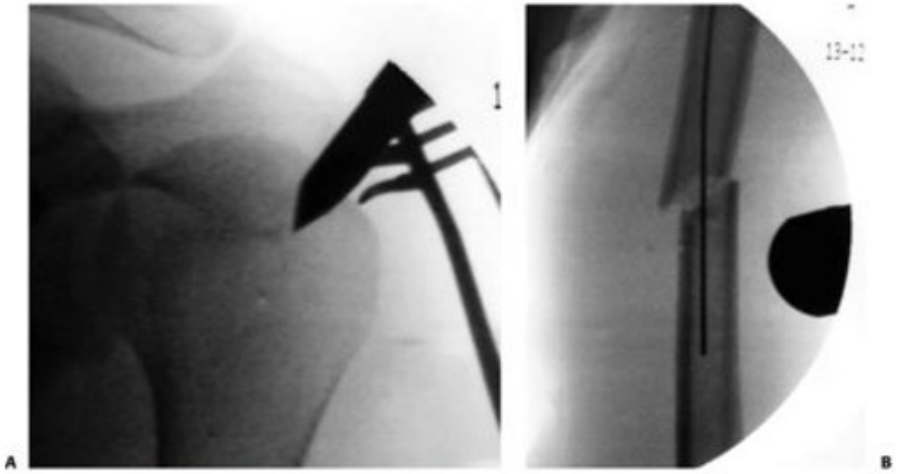



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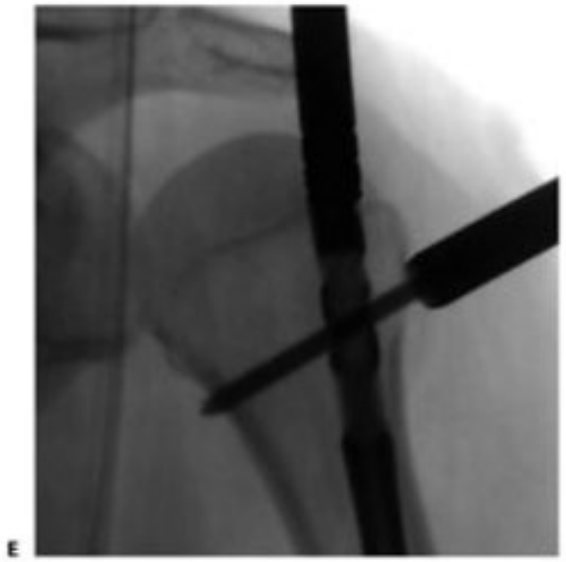
   c) Stop reaming when reamer is within humeral head
   d) Be sure to remove all reaming debris from shoulder joint
8. Maintain fracture reduction during nail insertion
9. Do not allow fracture distraction
10. Be sure nail is not prominent
11. Lock nail proximally
12. Lock distally (always) with free hand technique
13. Cautious distal interlocking to prevent neurovascular injury





# Intraoperative Pitfalls and Prevention

1. Image Intensifier Views Inadequate
   - Take time to position and check images before prepping
   - Consider location of assistants and OR table to prevent contamination

2. Leaving nail unlocked distally
   - Need some type of interference

3. Injury to rotator cuff
   - Make small (1-1.5 cm incision in cuff
   - Proper entry point for nail

4. Distal neurovascular structures at risk with distal interlocking
   - Use open incision for safe visualization

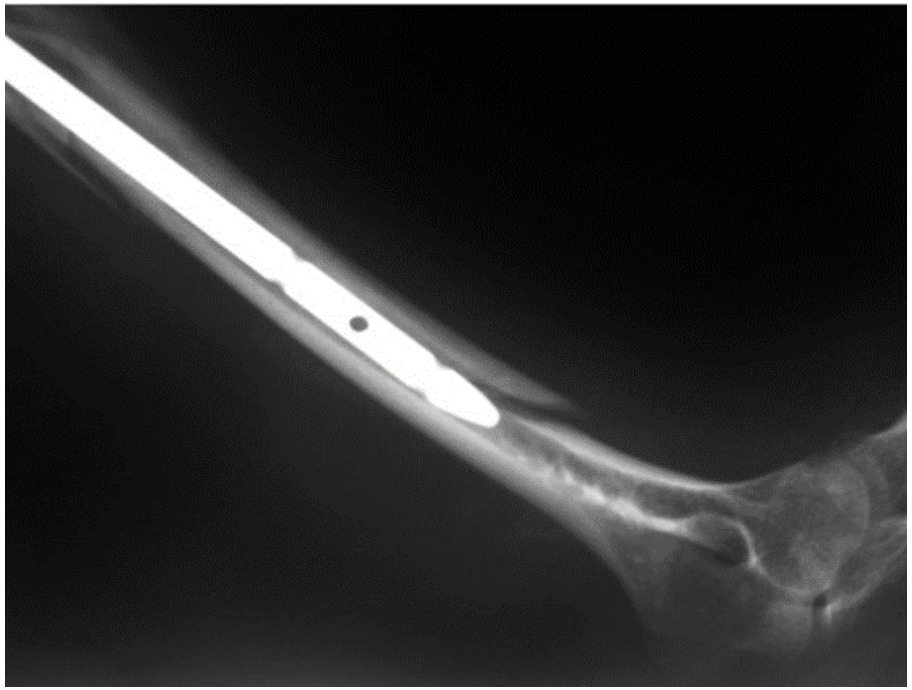


Figure 36-26

New fracture at the tip of a "fixed" nail that was inserted deliberately tight to avoid distal locking with screws.

https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16731325/humeral-shaft-fracture-intramedullary-nailing


## Humeral Shaft Fracture: Intramedullary Nailing ☆

Kenneth Egol, Nina Fisher, Sanjit R. Konda, Hesham Saleh

This case demonstrates a soft-tissue sparing technique of humeral shaft fixation using a humeral intramedullary nail. The technique is easy to perform and has significant benefits in minimizing surgical exposure, decreasing operative time and decreasing blood loss. In the correct clinical setting, humeral nailing provides an expeditious form of fixation that restores length, alignment, and rotation of the fracture humeral diaphysis.

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019

# Retrograde Nailing of Humerus: Key Steps

1. Expose Posterior supracondylar cortex
2. Open a 1x2 cm cortical home with drill holes and chisel
3. Reduce the fracture under fluoroscopy
4. Pass guidewire across the fracture
5. Hand ream the distal canal to reduce risk of fracture with nail passage
   - Beware of reaming at fracture for mid- and distal humeral shaft fractures
6. Advance nail to final position
   - Cautious advancement.
   - Ream larger canal if nail passage is difficult.
   - Maintain fracture alignment during nail placement
7. Do not allow the fracture to distract
8. Lock nail distally with targeting device
   - Larger incision for visualization and safety
9. Lock proximally with freehand technique

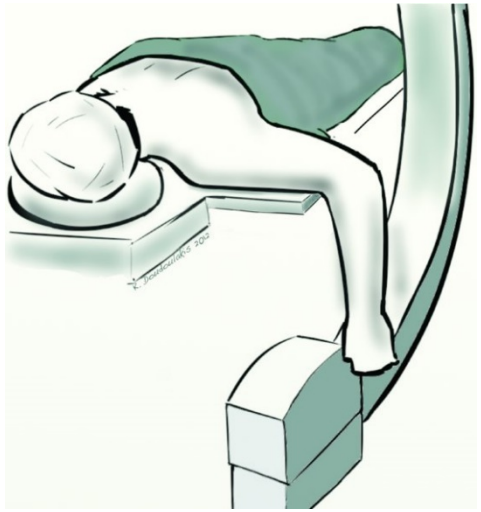


Figure 36-27
Patient positioning for retrograde nailing.

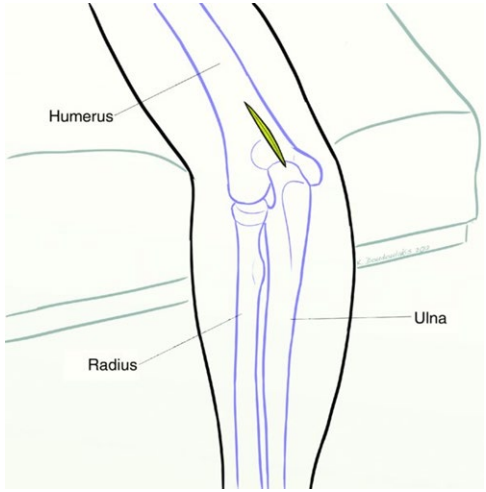
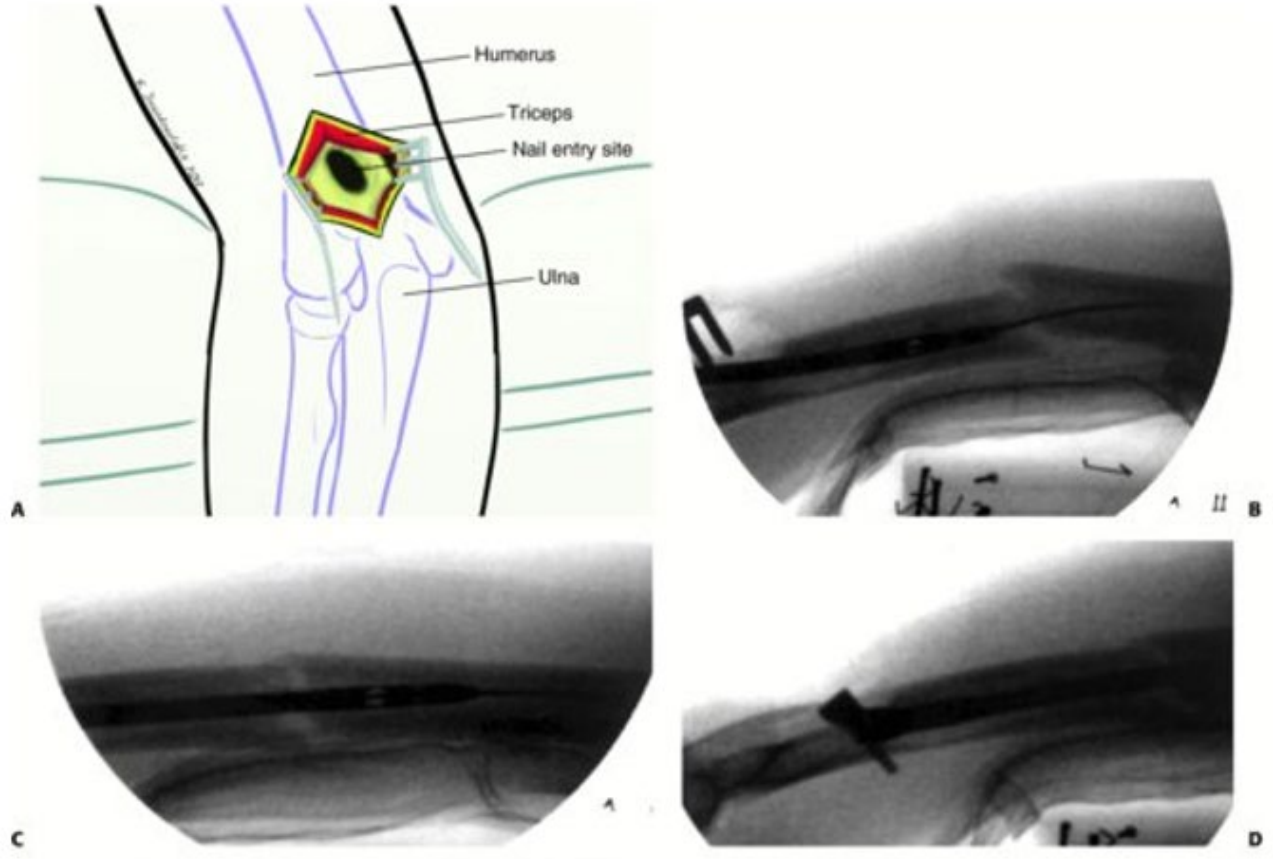
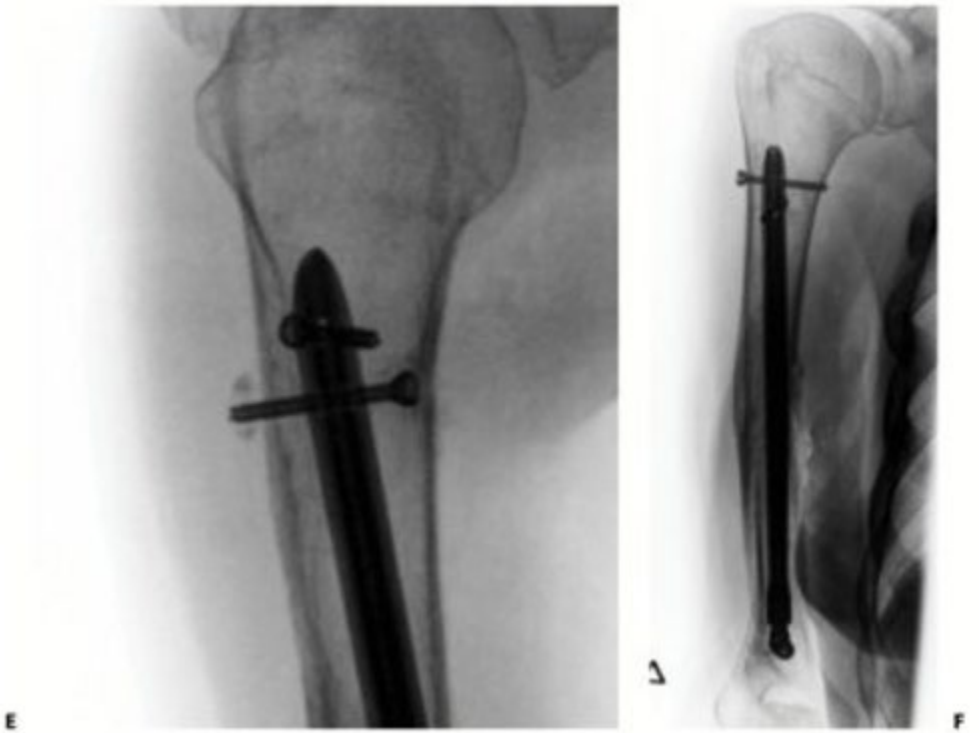



Figure 36-28
Skin incision for retrograde nailing.

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019




A. Entry portal
B. Nail insertion
C. Nail passed across fracture
D. Final position with direct visualization of distal interlocking screw

E. Proximal interlock inserted freehand technique, distal to surgical neck to avoid iatrogenic nerve injury.
F. Final AP radiograph

# Retrograde Insertion of IM Nail for Humeral Shaft Fractures: Pitfalls and Prevention

1. Problems with intra-op fluoroscopic viewing
    - Position patient to avoid metal objects that would obstruct view

2. Clear planning of positions for assistant and scrub nurse to avoid contamination of OR field.

3. Not locking proximally
    - Canal is conical in shape and widest proximally, so it must be locked proximally

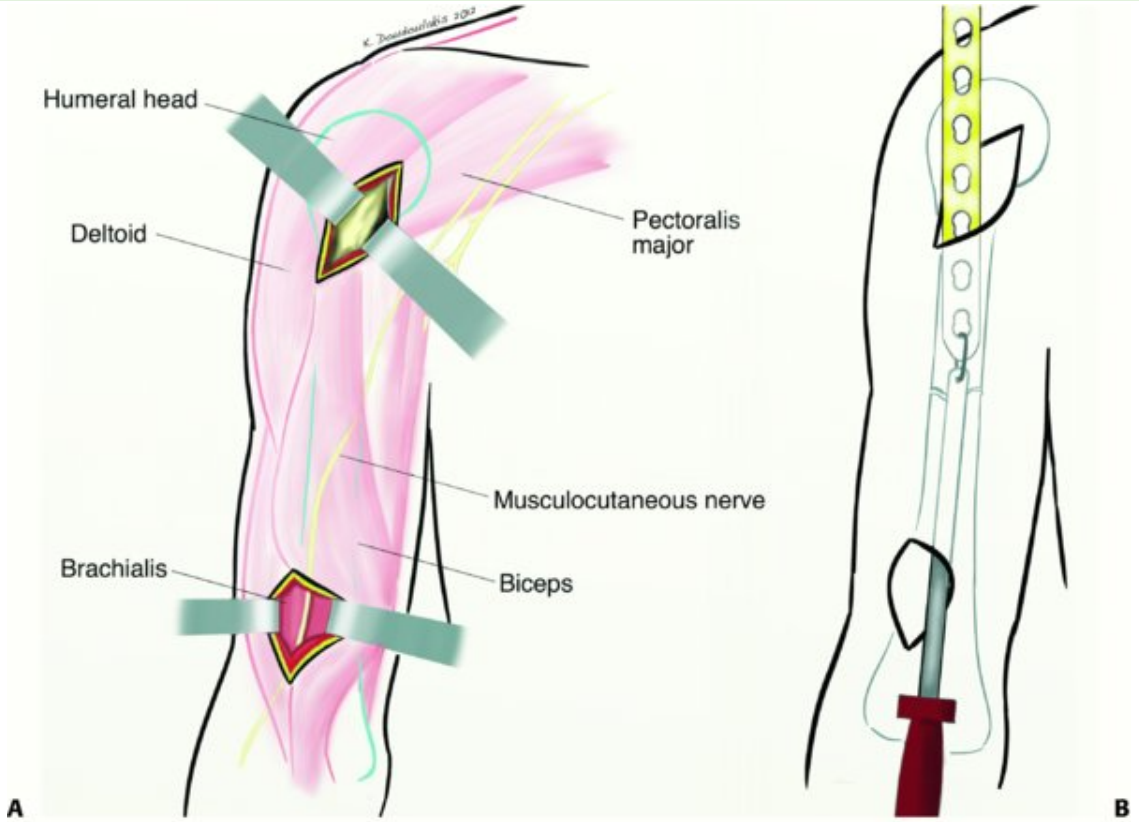
4. Underestimating risk of iatrogenic supracondylar fracture
    - Open large entry hole
    - Enlarge distal canal with careful hand reaming.

# MIPO

Minimally Invasive Plate Osteosynthesis

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019




**Legend:**

The anterior approach for minimal invasive plating osteosynthesis.

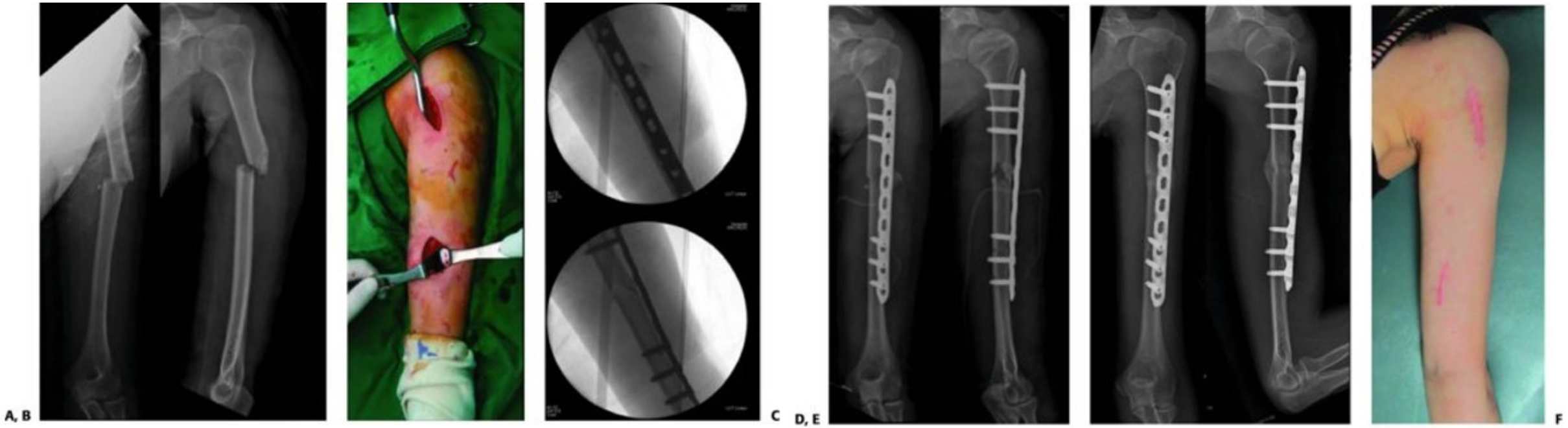
Figure 36-17

The anterior approach for minimal invasive plating osteosynthesis.

**A:** The proximal and distal windows. **B:** Insertion of the plate is facilitated with the use of a tunneling instrument.

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019




**A:** X-rays of a 21-year-old woman who sustained a fracture of the left humeral shaft (AO/OTA 12-A3 after a fall).

**B:** The fracture was treated by MIPO.

**C:** The reduction was verified under the image intensifier.

**D:** Postoperative radiographs showed an acceptable alignment.

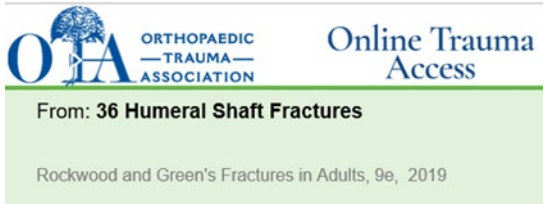
**E and F:** The fracture healed with callus formation 4 months after surgery, with small incision scar and satisfactory function.

(Reproduced with permission from Kim JW, Oh CW, Byun YS, et al. A prospective randomized study of operative treatment for noncomminuted humeral shaft fractures: conventional open plating versus minimal invasive plate osteosynthesis. J Orthop Trauma. 2015;29(4):189–194.)

Figure 36-18

# Minimally Invasive Plate Osteosynthesis (MIPO) of Humeral Shaft

1. Expose the “windows” of the approach
2. Identify and protect the neurovascular structures that are nearby
3. Reduce the fracture with longitudinal traction
4. Apply external fixator or distractor if necessary
5. Create an extraperiosteal tunnel alongside the surface of the humerus
6. Use tunneling instrument to align and position the plate on the humerus
    - Be cautious to avoid iatrogenic neurovascular injury
7. Use 4.5 mm narrow DC plate
8. Secure plate to proximal shaft and to distal shaft with one screw on each side while fracture is reduced.
9. Confirm quality of reduction, then insert remainder of screws
10. Check screw length with fluoroscopy.
11. Do not put screws in area of comminution.
12. Confirm reduction and plate length with fluoroscopy prior to closure.



# Minimally Invasive Plate Osteosynthesis: Pitfalls and Prevention

Unacceptable fracture reduction

- Use fluoroscopy
- Reduce length with traction without overdistraction

Unstable fixation

- Use 4.5 mm DCP or 4.5 mm LCP
- Aim for 3-4 screws in each fragment

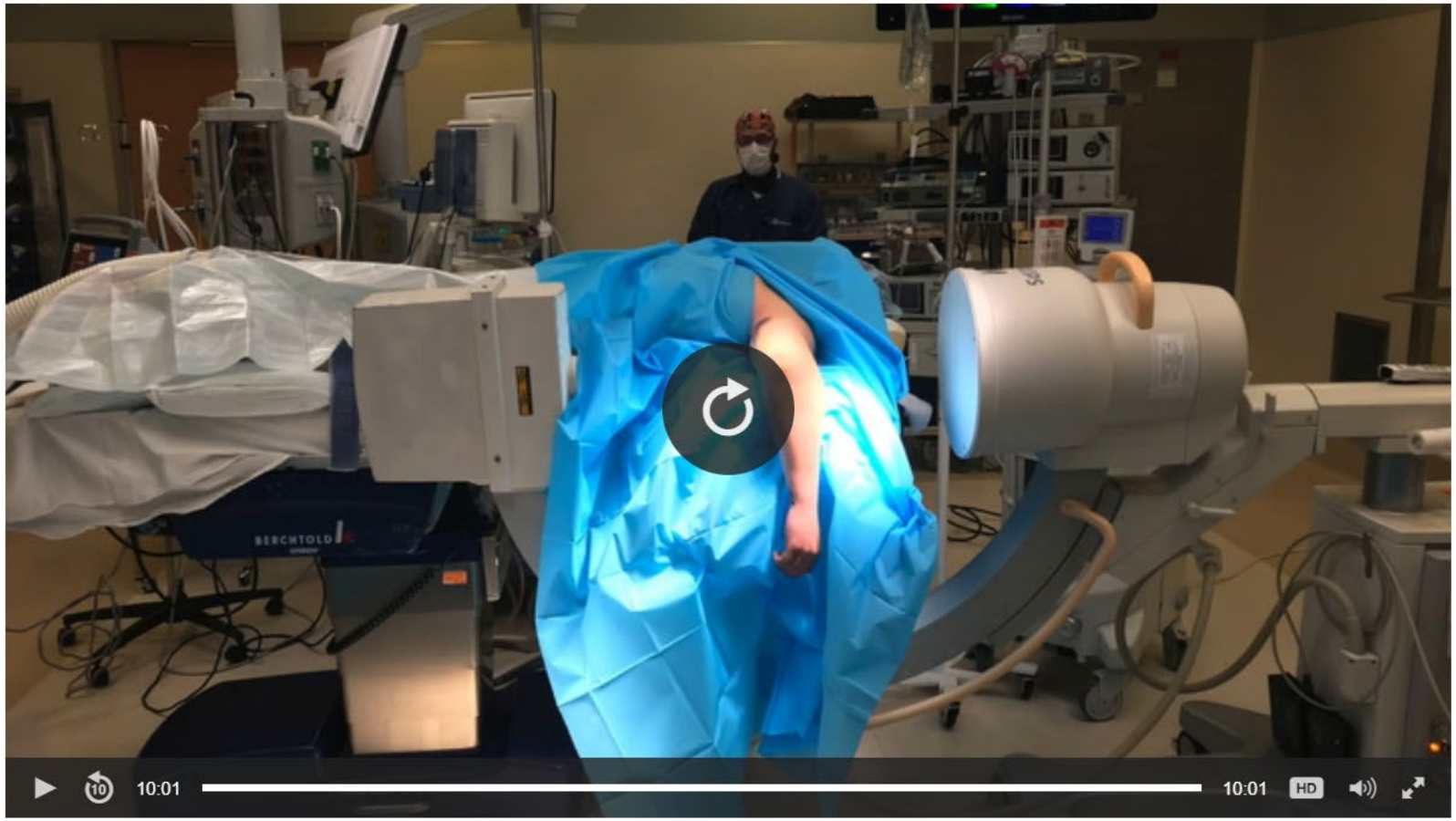
Iatrogenic nerve injury

- Avoid; or Identify and protect nerves
  - Musculocutaneous nerve with anterior approach
  - Radial nerve with lateral and posterior approaches

ORIF in presence of radial nerve palsy

- Exclude neurologic problem through clinical exam and documentation prior to surgery

https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/18420128/posterior-mipo-humerus-plating




## Posterior MIPO Humerus Plating

Arun Aneja, Thomas Krupko, Ryan Mayer, Eric Moghadamian, Alesha Scott

This video describes the minimally invasive posterior approach for fixation of comminuted meta-diaphyseal and diaphyseal humerus fractures.

# Indications

Nonoperative vs Operative management

# Indications for Nonoperative Management

**Strong Indication**
- Isolated, acute closed fracture in cooperative and ambulatory patient

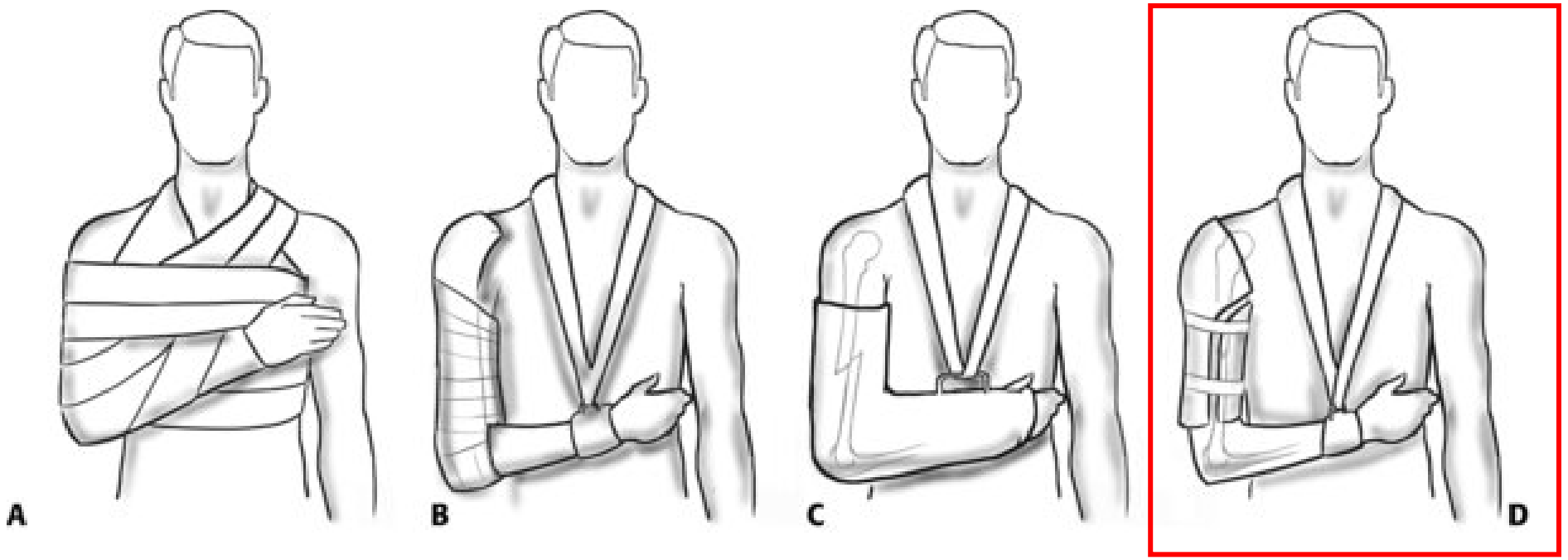
**Relative Indication**
- Type A Fracture (AO-OTA Classification)
- Proximal third, long oblique fracture
- Segmental fracture
- Low velocity gunshot fracture without neurovascular injury
- Noncompliant patient

**Relative Contraindications**
- Multiple Injuries
- Additional injuries to ipsilateral arm (e.g. floating elbow; Open fracture)
- Brachial plexus injury or increasing nerve dysfunction
- Bilateral fractures
- Periprosthetic Fractures

**Contraindications**
- Significant Vascular Injury
- Pathologic Fracture
- Nonunited fracture

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019




A: Velpeau's bandage.
B: U-slab.
C: Hanging cast.
D: Functional brace.

https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16723112/coaptation-splint-application-technique


Coaptation Splint: Application Technique ☆

R. Kiran Alluri, Geoffery Marecek

This is a technique video on how to apply a coaptation splint for a diaphyseal humerus fracture.

# Indications for Operative Management

**Indications**

- Inability to maintain satisfactory reduction
- Multiple injuries
- Bilateral fractures
- Floating elbow
- Intra-articular extension of fracture
- Progressive nerve palsy
- Significant vascular injury
- Nonunion/infected nonunion
- Pathologic fracture

**Relative Indications**

- Open fractures
- Segmental fractures
- Long oblique fracture of the proximal humerus, especially with valgus angulation
- Large soft tissue wounds or burns that require frequent care
- Noncompliant patients
- Obesity
- Periprosthetic fractures
- Type A fracture in the mid-shaft

# ORIF of Diaphyseal Humeral Fractures: Surgical Pitfalls and Preventions

Excessive stripping of soft-tissue
- Familiarity with anatomy of arm
- Careful dissection

Unacceptable reduction of fracture
- Adequate surgical exposure
- Use of fluoroscopy
- Can accept 2-3 cm shortening, but no more
- Consider staged bone grafting for larger gaps

Unstable fixation
- 4.5 mm DCP or LCP
- 3-4 screws in each fragment
- Appropriate use of lag screws
- Incorporate condyles or use 2 plates for distal fractures

Iatrogenic neurovascular injury
- Familiarity with anatomy of arm
- Careful dissection: Identify and protect nearby vessels and nerves
- Avoid excessive traction
- Avoid cerclage wiring
- Be careful with drills and screws from opposite cortex

# Functional Bracing of Humeral Shaft Fractures

- **Fractures of the Shaft of the Humerus**

Klenerman, *JBJS(Br)* 1966

- 98 patients: 87 (89%) treated nonoperatively
- 32 pts available for interview/XR after fx healing

- Sagittal deformity tolerated to **20** degrees w/o clinical impact/deformity
- Varus deformity tolerated to **30** degrees w/o clinical impact/deformity
- Shortening **3cm** w/o clinical impact/deformity

"Most fractures of the shaft of the humerus are best treated by simple splintage. The degree of radiological deformity that can be accepted is far greater than in other long bones. In this group anterior bowing of 20 degrees or varus of 30 degrees was present before it became clinically obvious and even then the function of the limb was good."

# Functional Bracing of Fractures of the Shaft of the Humerus

Sarmiento et al, *JBJS*, 1977

- 51 patents treated with functional bracing
  - Splint/cast until pain subsides (1 week) then plastic brace
  - Brace + sling x 1 week
  - Active ROM encouraged
  - Average time in brace 7 weeks

- All fractures healed and there was restoration of motion in all joints before fracture healing

"The early introduction of functional activity to the entire extremity appears to provide a desirable physiological environment conducive to rapid healing."

# Functional Bracing for Treatment of Fractures of the Humeral Diaphysis

Sarmiento et al, **JBJS**, 2000

922 patients treated with functional bracing
- Excluded polytrauma, high velocity GSW

67% follow-up (620 pts)
- 155 (25%) Open fractures (mainly low-velocity gunshot wounds)
- 67 had radial nerve palsy

Nonunion:
- 1.5% (closed)
- 5.8% (open)
- 3% required operative intervention

Angulation
- Varus: $>10^0$ (24%); $>25^0$ (2%)
- Sagittal: $>10^0$ (14%); $>15^0$ (7%)

Motion loss
- Shoulder: $>10^0$ (11%)
- Elbow: $>10^0$ (8%)

# Outcome after Closed Functional Treatment of Humeral Shaft Fractures

Ekholm et al, *J Orthop Trauma*, 2006

- 78 pts with isolated humeral shaft fxs
- 50 pts available for functional outcome assessment @ avg 26 months
- 90% union
- 10% radial nerve palsy
  - 50% full recovery in healed fx
  - 0% full recovery in fx that went on to nonunion and required ORIF

- The authors recommended **Randomized Clinical Trial** to compare brace vs ORIF

# Outcome of Nonoperative vs Operative Treatment of Humeral Shaft Fractures: A Retrospective Study of 213 Patients

Denard et al, *Journal of Orthopaedics*, 2010

- 213 pts
- 2 trauma centers

- Significant difference in:
  - **Nonunion**
  - **Malunion**

| | Brace | ORIF |
|---|---|---|
| ***Nonunion*** | ***20%*** | ***8%*** |
| ***Malunion*** | ***12%*** | ***1%*** |
| Infection | 3% | 4% |
| Radial nerve palsy | 9% | 2% |
| Time to Union | 4.7 months | 4.8 months |
| Elbow ROM | 136 deg | 130 deg |

# Fracture Site Mobility at 6 Weeks After Humeral Shaft Fracture Predicts Nonunion Without Surgery

Driesman et al, *J Orthop Trauma*, 2017

- 84 pts with humeral shaft fractures treated nonoperatively
- 87% healed at 6 months postoperatively

- Fracture mobility 6 weeks post injury predicted nonunion
  - 82% sensitive, 99% specific

**FIGURE 2.** A 65-year-old female with a displaced OTA/AO 12A humerus fracture treated in a functional brace. **Editor's Note:** A color image accompanies the online version of this article.

# Treatment of Diaphyseal Fractures of the Humerus Using a Functional Brace

Rutgers and Ring, *J Orthop Trauma*, 2006

- 52 pts nonop  humeral shaft fxs
- 90% union

- Nonunion
  - ***Prox 3rd*** – 29%
  - Mid 3rd – 4%
  - Dist 3rd – 0%

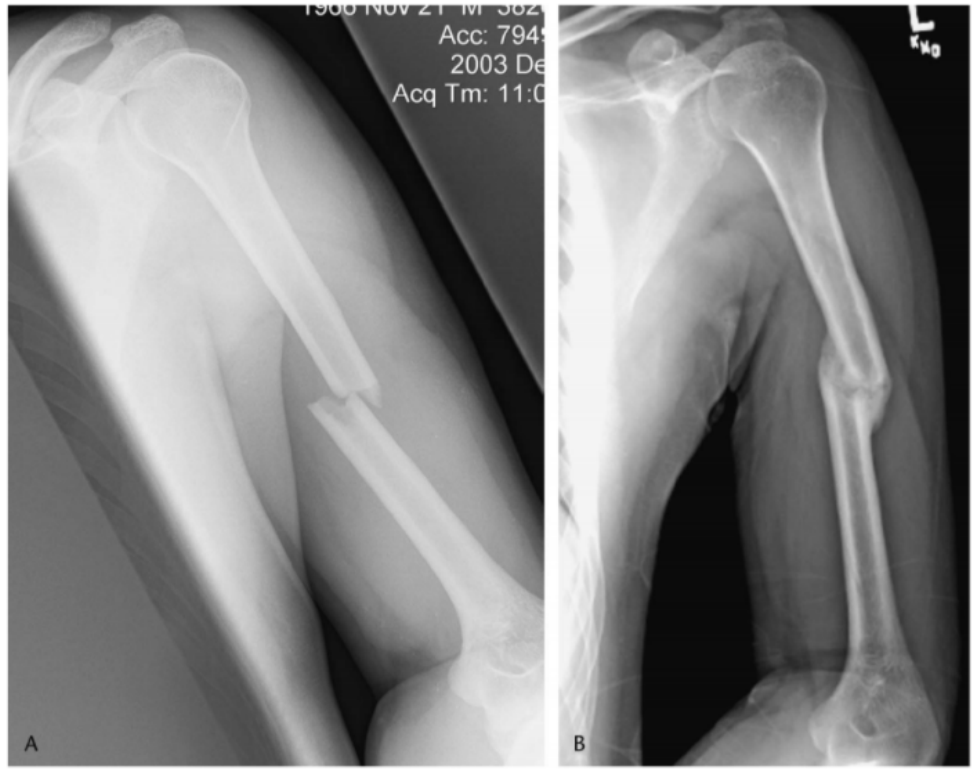



**FIGURE 2.** Transverse fractures healed in 11 of 12 patients in this series. A, An anteroposterior radiograph in a 30-year-old man with a transverse fracture of the middiaphysis demonstrates more than 50% loss of apposition. B, Three months later, solid union is apparent, and the patient has full shoulder and elbow motion.

- Motion – no greater than $15^0$ loss of shoulder/elbow motion

# Effect of Surgery vs Functional Bracing on Functional Outcome Among Patients With Closed Displaced Humeral Shaft Fractures - The FISH Randomized Clinical Trial

Rämö et al, *JAMA*, 2020

Finland, RCT, 2012-2018, 82 pts

- 30% nonop group crossed over to surgery
- 25% nonunion in nonop group

- Functional outcome
  - 6 wks = ORIF improved scores
  - 3 months = ORIF improved scores
  - 12 months = no significant difference (DASH)

# Modern Results of Functional Bracing of Humeral Shaft Fractures: A Multicenter Retrospective Analysis

Serrano et al, *J Orthop Trauma*, 2020

- 9 institutions, 2005-2015
- 1182 fractures initially treated nonoperatively with a functional brace

- **29% (344) ultimately required surgery**
  - 60% nonunion
  - 24% malalignment
  - 12% inability to tolerate brace
  - 4% persistent radial nerve palsy warranting exploration

# Conservative vs. operative treatment for humeral shaft fractures: a meta-analysis and systematic review of randomized clinical trials and observational studies

Van de Wall et al, *J Shoulder Elbow Surg*, 2020

- 12 studies
- 1262 pts

- **Nonunion**
  - Brace 15%
  - Surgery 6%

- No difference
  - Radial nerve palsy
  - Time to union
  - DASH

# Operative Treatment of Humeral Shaft Fractures

# Treatment of Humeral Shaft Fractures: A Critical Analysis Review

Attum and Obremskey, *JBJS Reviews*, 2015

**Recommendations for care with Grade of Supporting Evidence**

- Most humeral shaft fractures will heal with nonoperative management
  - Grade B
- When indication for operative treatment is met, plate fixation is reliable and safe
  - Grade A
- Nail fixation may be helpful in pathologic or highly comminuted fractures, but routine use of nails is associated with more shoulder dysfunction
  - Grade A
- Radial nerve palsy in closed fractures usually resolved without surgical intervention
  - Grade B

# ORIF vs IMN

# Treatment of Humeral Shaft Fractures: A Critical Analysis Review

Attum and Obremskey, *JBJS Reviews*, 2015

- **ORIF** (multiple series) – 547 pts
  - Iatrogenic radial nerve palsy - 3%
  - Time to union – 21 wks
  - Infection – 4%
  - Nonunion – 5%
- **IMN** (multiple series) – 240 pts
  - Iatrogenic radial nerve palsy - 3%
  - Time to union – 13.5 wks
  - Infection – 2%
  - Nonunion – 5%

# ORIF vs IMN

- **<u>Shoulder impingement/Problems</u>**
  - IMN 28% (McCormack, 2000)
  - IMN RR 7.3;  (Ouyang, 2013)
  - IMN 15%; RR 6.8; (Wang, 2013)
  - Plate 4% (McCormack, 2000)
  - Plate RR 0.1 (Bhandari, 2006)

# Early post-operative outcomes of plate versus nail fixation for humeral shaft fractures

Putnam et al, *Injury*, 2019

- National Surgical Quality Improvement Program (NSQIP) data 2005-2016
- 2009 patients
  - 1418 ORIF
  - 591 Intramedullary nail
- 30 day mortality ORIF 0.8% vs IMN 5.4%
- Patients selected for IMN had more comorbidities
    - "Suggests that surgeons may be choosing IMN for patients who may not be ideal surgical candidates"
    - "Nail fixation may not be a safer option in patients with multiple co-morbidities and low-energy humeral shaft fractures".

- LOS, complications and readmission rates did not differ after propensity score adjustment.

# Length of stay and 30-day readmissions after isolated humeral shaft fracture open reduction and internal fixation compared to intramedullary nailing

Merrill et al, Injury, 2020

- Nationwide readmissions database query, 2015-2016
- 406 patients propensity matches IMN vs ORIF
- 30 day readmission = no difference
  - 6.4% IMN
  - 4.9% ORIF

- LOS = 3 days for both groups

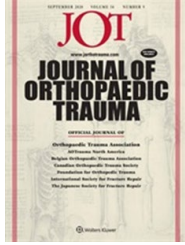
# MIPO technique

(Minimally invasive plate osteosynthesis)

# A Prospective Randomized Study of Operative Treatment for Noncomminuted Humeral Shaft Fractures: Conventional Open Plating Versus Minimal Invasive Plate Osteosynthesis

*Ji Wan Kim, MD,* Chang-Wug Oh, MD,† Young-Soo Byun, MD,‡ Jung Jae Kim, MD,§ and Ki Chul Park, MD‖*

(*J Orthop Trauma* 2015;29:189–194)



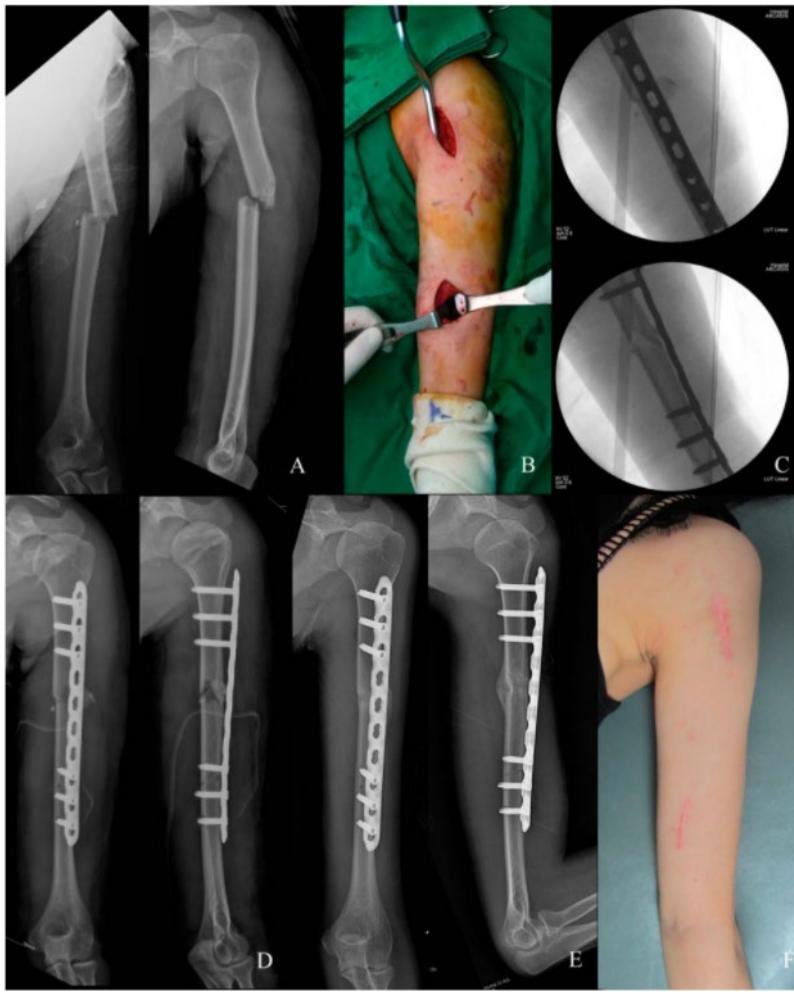

- RCT, 2010-2011, 5 trauma centers, Korea
- 68 pts, simple humeral shaft fxs
- ORIF v MIPO
- Large frag plate (4.5mm)

- **ORIF 97% healed**
- **MIPO 100% healed**

- No significant difference
  - OR time
  - Complications
  - functional outcomes
  - union

**TABLE 2.** The Results of Patients With Humeral Shaft Fractures

| | COP | MIPO | Statistics |
|---|---|---|---|
| Operative demographics | | | |
| Operation time (min) | 116 | 105 | 0.106 |
| Radiation exposure (s) | 0 | 68 | <0.001 |
| Union time (wk) | 15.8 | 14.6 | 0.588 |
| Functional outcomes | | | |
| UCLA shoulder score (35) | 33.9 | 33.1 | 0.264 |
| Mayo elbow performance index (100) | 98.9 | 96.4 | 0.798 |
| Radiologic outcomes | | | |
| Angulation on sagittal plane (degrees) | 0.6 | 1.5 | 0.276 |
| Angulation on frontal plane (degrees) | 0.9 | 0.8 | 0.494 |
| Complications | | | |
| Malunion | 0 | 0 | |
| Nonunion | 0 | 0 | |
| Delayed union | 1 | 0 | 0.471 |
| Postoperative radial nerve injury | 1 | 0 | 0.471 |
| Infection | 0 | 0 | |



# Minimally Invasive Osteosynthesis with a Bridge Plate Versus a Functional Brace for Humeral Shaft Fractures:

## A Randomized Controlled Trial

Matsunaga et al, JBJS, 2017

- RCT, 2012-2015, single center, Brazil
- 110 patients, **MIPO vs brace**
  - Large frag plate (4.5mm)

- DASH @ 6 months
  - **MIPO** – 10.9 (better)
  - Brace – 16.9
- Nonunion
  - **MIPO** – 0%
  - Brace – 15%
- Sagittal alignment
  - **MIPO** – 2 deg
  - Brace – 10 deg

- MIPO Complications
  - 2% superficial infection
  - 4% radial nerve palsy (transient)
  - 8% hypertrophic scarring

- No difference
  - SF-36, pain
  - Constant-Murley
  - Coronal displacement

# Minimally Invasive Plate Osteosynthesis of Humeral Shaft Fractures: Current State of the Art

Tetsworth et al, *JAAOS* 2018

- MIPO review
  - 24 studies, 581 pts

- Nonunion – 2.6%
- Infection – 1.5%
- Nerve injury – 2.8%

# Antegrade intramedullary nail versus plate fixation in the treatment of humeral shaft fractures

Wen et al, Medicine, 2019

- Meta-analysis
- 15 trials, 839 pts
- Similar results in operative time, ASES score, nerve injury, delayed union, and reoperation rate.
- Blood loss
  - Plate = 183 mL
  - **IMN** = 105 mL
- Infection
  - MIPO = 7%
  - **IMN** = 2%
- Nonunion
  - **MIPO** = 5%
  - IMN = 17%

# Extraarticular distal 3rd humeral shaft fractures

# Extra-Articular Distal-third Diaphyseal Fractures of the Humerus: A Comparison of Functional Bracing and Plate Fixation

Jawa et al, *JBJS* 2006

- Retrospective comparison
  - 2 trauma centers, 2000-2004
  - 51 pts, 6 month f/u
- ORIF
  - Loss of fixation – 5%
  - Iatrogenic radial nerve palsy – 15%
  - Loss of shoulder/elbow motion – 5%
- Brace
  - Converted to ORIF – 10%
  - Malunion >30 deg – 5%
  - Skin breakdown – 10%
  - Loss of elbow/shoulder motion – 10%

# Extra-Articular Distal-third Diaphyseal Fractures of the Humerus: A Comparison of Functional Bracing and Plate Fixation

Jawa et al, *JBJS* 2006

Conclusions for extraarticular distal humerus fxs:

**Operative management**

Provides more predictable alignment, potentially quicker return to function

But risks iatrogenic nerve injury, infection, need for reoperation

**Bracing**

Can cause skin issues and varying degrees of angular deformity

But function and ROM are usually excellent

# Are two plates necessary for extraarticular fractures of the distal humerus?

Watson et al, *Current Orthopaedic Practice*, 2014.

- Biomechanical cadaveric study
- Extraarticular supracondylar humerus fx
  - Single precontoured posterolateral locked plate is biomechanically similar to Orthogonal dual plates

| | Stiffness | Cycles to failure | Force to failure |
|---|---|---|---|
| Single plate | 1072 N/mm | 3586 | 428 N |
| Dual plate | 722 N/mm | 2772 | 380 N |

- Thus, single plating can be used
- This offers the potential for: decreased exposure, shorter surgical time, less medial dissection, decreased ulnar nerve irritation, improved outcomes

# A paradigm shift in the surgical reconstruction of extra-articular distal humeral fractures: Single-column plating

Meloy et al, *Injury*, 2013

- Multicenter retrospective comparative study, 2 trauma centers
- 105 pts
  - Dual column plating (triceps split)
  - Single column precontoured posterolateral plate (paratricipital approach)

- Similar Results
  - Union (dual 100%,  single 97%)
  - Alignment (97% w/in 5 deg anatomic)

- Single column plating
  - Improved ROM (10 deg)
  - Fewer complications (hardware irritation, radial nerve injury)

“Patients treated with single-column plating had similar union rates and alignment. However, single-column plating resulted in a significantly better range of motion with less complications.”

# Review Article: Best care paradigm to optimize functionality after extra-articular distal humeral fractures in the young patient

Ayoub and Tarkin, *J Clin Orthop and Trauma*, 2018

## Sarmiento

- 85 pts w/ distal 3rd fx in original series
- 33% lost to f/u
- 96% union rate w/ brace
- Varus malunion 81%
- Elbow motion
  - Decreased flex/ext in 25%
- Shoulder motion
  - Decreased ER in 45%
  - Decreased abduction in 15%

## Post-Sarmiento bracing studies

- Nonunion rates 10-15%
- Not fully recovered 50%
- Excellent outcomes 50%

# Review Article: Best care paradigm to optimize functionality after extra-articular distal humeral fractures in the young patient

Ayoub and Tarkin, *J Clin Orthop and Trauma*, 2018

## Brace inconvenience

- 10% skin breakdown
- Compliance issues
- 4+ wks of fx motion/pain, limited arm function

## Intervention after failed brace treatment

- Higher complications
- More difficult surgery
- Scarring from partial healing
- Radial nerve palsy 4-20%
- Lost productivity, excess time off work, stiffness, muscle wasting – all of these are especially concerning for the young active pt who would otherwise be active/productive

# Review Article: Best care paradigm to optimize functionality after extra-articular distal humeral fractures in the young patient

Ayoub and Tarkin, *J Clin Orthop and Trauma*, 2018

## Surgical treatment

- Less stiffness
- Decreased malunion rates
- Faster return to ADLs/normalcy
- Consider pt characteristics
  - job/work needs
  - Caregivers for others
  - polytrauma
  - dominant arm
  - walker use
  - age, medical comorbidities
  - pt desires
  - obesity, pendulous breasts
  - compliance w/ bracing

- Radial nerve injury
  - Consider entrapment of nerve at fx site – better to dig it out fresh or scarred in?
  - Nonunion surgery following humerus fx: Iatragenic radial nerve palsy 4-19%

# Review Article: Best care paradigm to optimize functionality after extra-articular distal humeral fractures in the young patient

Ayoub and Tarkin, *J Clin Orthop and Trauma*, 2018

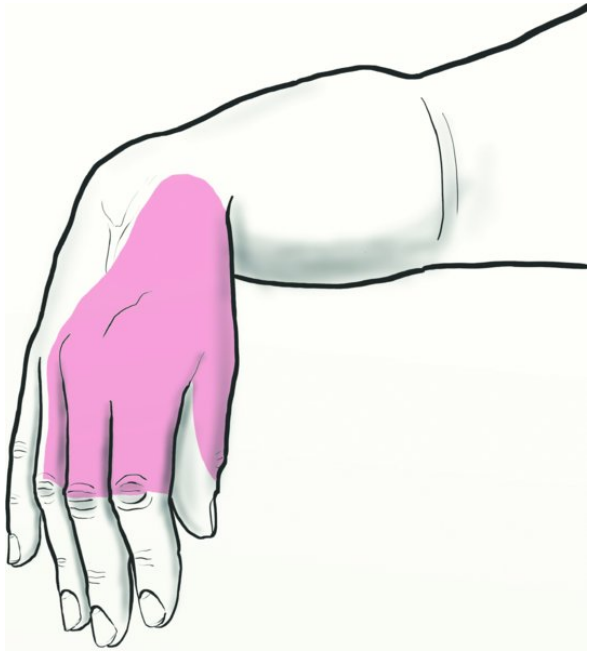
- Triceps split
  - "Falling out of favor"
- Paratricipital
  - Better proximal exposure
  - Less muscle trauma, scarring
  - Improved elbow ROM/triceps strength
  - Low incidence of radial nerve palsy

- **Single plating** vs dual plating
  - Decreased ulnar nerve irritation
  - Improved ROM
  - Less periosteal stripping, blood loss, surgical time

# Radial nerve palsy

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019



**Legend:**

The clinical picture of a radial nerve palsy.

Figure 36-2

The clinical picture of a radial nerve palsy.

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019

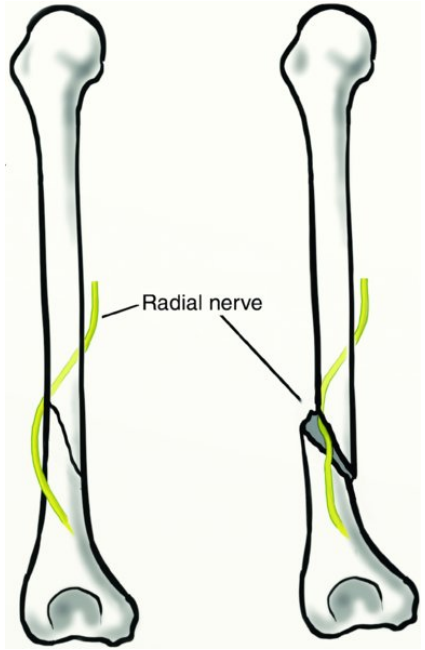



Figure 36-3

The Holstein–Lewis fracture.

# Radial nerve palsy associated with fractures of the shaft of the humerus: A SYSTEMATIC REVIEW

Shao et al, *JBJS(Br),* 2005

- 1964-2004, 21 papers, 4517 patients
- **11.8%** radial nerve palsy
- Increased frequency
  - Mid shaft, mid-distal
  - Transverse, spiral fractures
- <u>Recovery</u>
  - Spontaneous – 70%
  - Overall – 88%

# Iatrogenic Nerve Palsy Occurs with Anterior and Posterior Approaches for Humeral Shaft Fixation

Streufert et al, *J Orthop Trauma*, 2020

- Retrospective study, 2 trauma centers
- 261 pts, ORIF extraarticular humerus fx
- Preop radial nerve palsy
  - 74% resolved, avg 5.5 months
  - 22% required tendon transfer/wrist fusion
- Iatrogenic rad nerve palsy
  - 95% resolved, avg 4.1 months
  - 0% required tendon transfer/wrist fusion

**TABLE 2.** Injury-Related Nerve Palsy by Fracture Location

| | Radial | Median | Ulnar | Any Palsy* |
|---|---|---|---|---|
| Proximal 1/3 | 14% (7/49) | 4% (2/49) | 6% (3/49) | 14% (7/49) |
| Middle 1/3 | 19% (15/79) | 0% (0/79) | 3% (2/79) | 19% (15/79) |
| Distal 1/3 | 20% (26/133) | 2% (2/133) | 2% (3/133) | 20% (27/133) |
| Total | 18% (48/261) | 2% (4/261) | 4% (8/261) | 19% (49/261) |

**TABLE 4.** Iatrogenic RNP by Surgical Approach and Fracture Location

| | Approach | | | |
|---|---|---|---|---|
| | Anterolateral | Posterior Triceps Sparing | Posterior Triceps Splitting | Total |
| Fracture location (by third) | | | | |
| Proximal | 0% (0/42)* | — | — | 0% (0/42) |
| Middle | 14.2% (6/42)* | 25% (2/8) | 14.2% (2/14) | 15.6% (10/64) |
| Distal | — | 17.1% (12/70) | 10.5% (4/37) | 15.0% (16/107) |
| Totals | 7.1% (6/84) | 17.9% (14/78) | 11.7% (6/51) | 12.2% (26/213) |

*$P = 0.0258$.

# Radial Nerve Palsy Recovery with Fractures of the Humerus: An Updated Systematic Review

Ilyas et al, *JAAOS*, 2020

- 2000-2017
- 23 articles
- 7,262 humerus fxs
- **12%** radial nerve palsy

- **77%** spontaneous recovery

- Nerve exploration > 8wk
  - 68% recovery

- Nerve exploration < 3 wk
  - 89% recovery

Early exploration is associated with better recovery of nerve function, but it is not clear if there was causation.

# Nonunion

# The **R**adiographic **U**nion **S**core for **HU**meral fractures (RUSHU) predicts humeral shaft nonunion

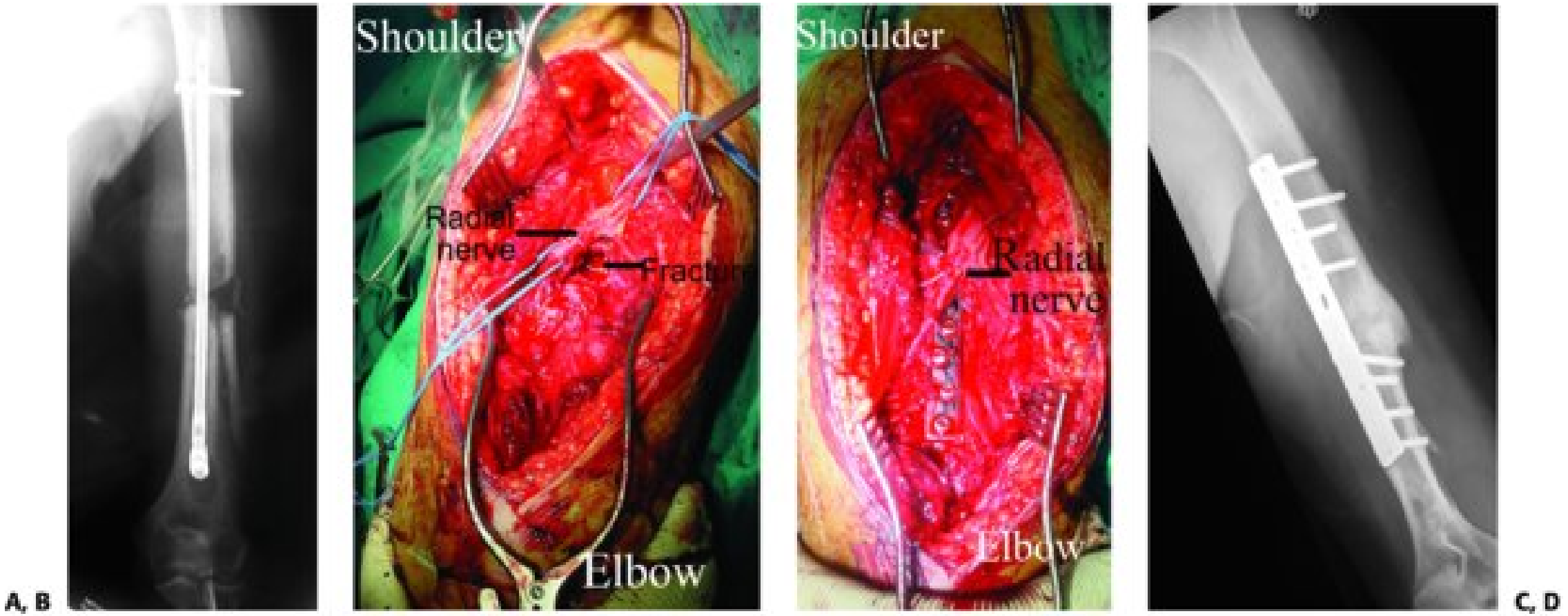
Oliver et al, Bone Joint J, 2019

- Modification of RUST score (used for **T**ibias)
- Each cortex scored from 1-3 on callus and “bridging”

- Fractures with RUSHU <8 @ 6 wks were 12 times more likely to develop nonunion
- NNT = 1.5 (to avoid one nonunion)

From: **36 Humeral Shaft Fractures**

Rockwood and Green's Fractures in Adults, 9e, 2019



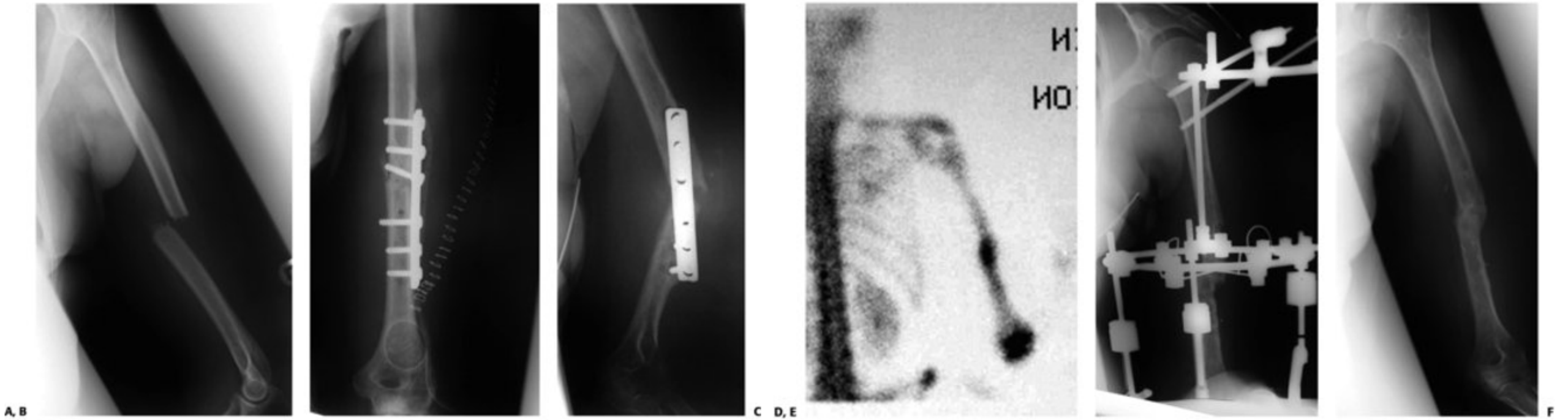

A: Nonunited fracture in a polytrauma patient who was treated with intramedullary nailing 4 months after the accident and the nailing operation.

B: Intraoperative picture (posterior approach) showing the nail removed, the radial nerve identified, and the nonunion debrided.

C: The plate and bone graft has been applied and all screws tightened.

D: Six months later, there was sound union of the fracture.

From: **36 Humeral Shaft Fractures**
Rockwood and Green's Fractures in Adults, 9e, 2019




A: A transverse fracture of the middle third of the humeral diaphysis, treated with functional bracing, as appeared on the follow-up 3 months post-accident.

B: Open reduction and internal fixation with a six-hole plate.

C: Three months later, the fixation became painful, and the arm was swollen and warm. The x-ray showed loss of reduction and nonunion.

D: The bone scan confirmed the clinical diagnosis of infected nonunion.

E: The plate was removed, the nonunion site was debrided thoroughly, IV antibiotics were administered, and Ilizarov-type external fixator was applied.

F: Six months later, the infection was eradicated and the fracture healed.

# Summary

- Most uncomplicated humeral shaft fxs will do well with nonoperative management in a functional brace, but recent studies report nonunion rates 10-25%, which is in different from Sarmiento's stellar results
- Anterolateral approach = prox/middle third fxs
- Posterior approach = distal third fxs

- Plates/IMN offer similar outcomes with the exception of increased shoulder issues with antegrade IMN, 15-30%

- MIPO plating is evolving as an attractive alternative treatment

- Single column precontoured plate is a safe treatment option for extraarticular distal third humeral shaft fxs

- Radial nerve palsy = 12% incidence in humeral shaft fxs. 77% spontaneous recovery.
- Iatrogenic radial nerve palsy = 12% with operative intervention

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