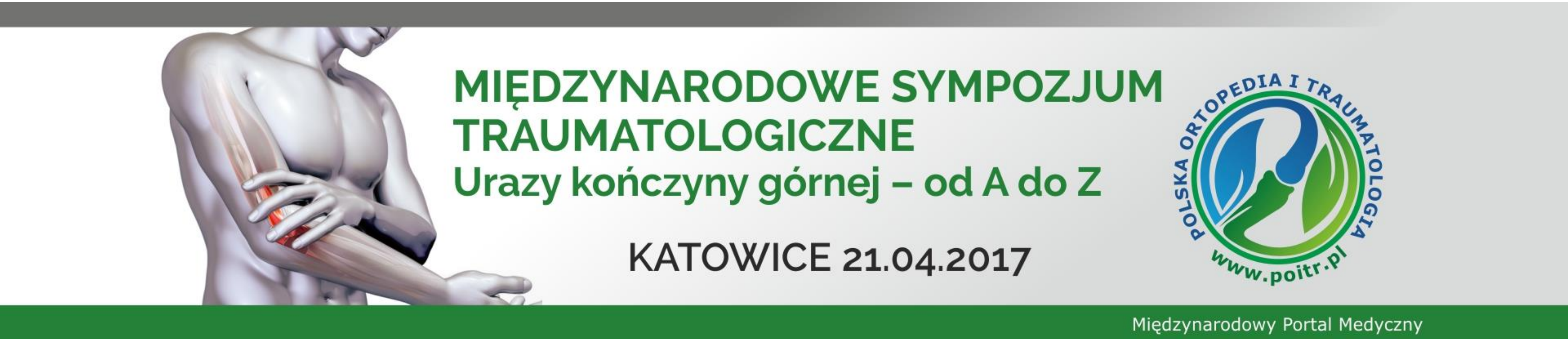

Distinct anatomical and biomechanical features of the upper limb.

DEPARTMENT OF ORTHOPEDICS AND TRAUMATOLOGY MEDICAL UNIVERSITY OF SILESIA KATOWICE
GCM

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Introduction

- shoulder anatomy & biomechanics
  - proximal humerus – blood supply
    - deep branch of radial nerve
      - olecranon fixation methods – biomechanics

Shoulder anatomy & biomechanics

❑ **4 joints** within the Shoulder Complex that work together to allow smooth shoulder function

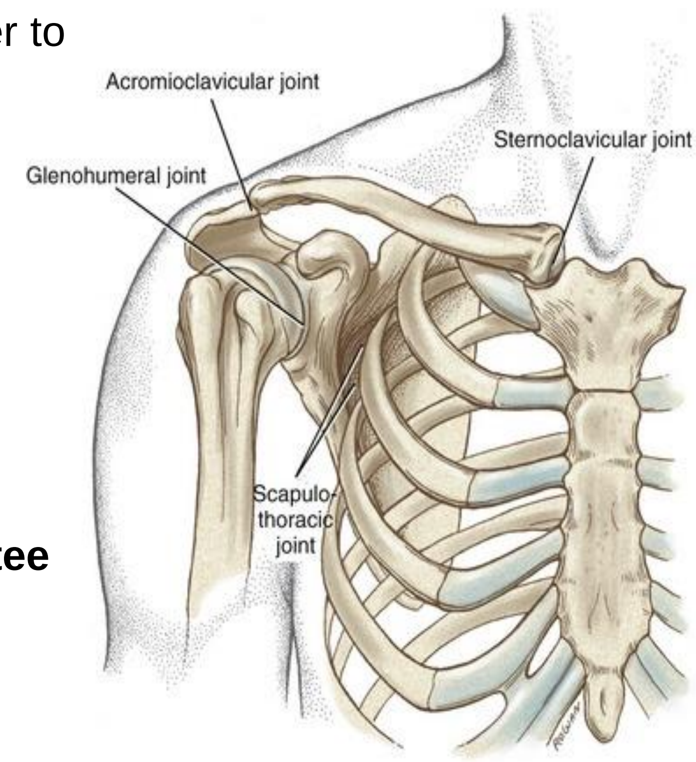
❑ **the greatest ROM** of any joint in the body

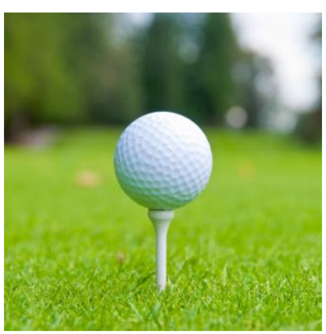
❑ balance between. **mobility and stability**

- ❑ mobility - “Large ball–small socket”

❑ bony anatomy has been compared to a **golf ball on a tee**

❑ labrum - affects the distribution of contact stresses





❑ glenohumeral joint relies on the **static and dynamic stabilizers**, especially the **rotator cuff**:

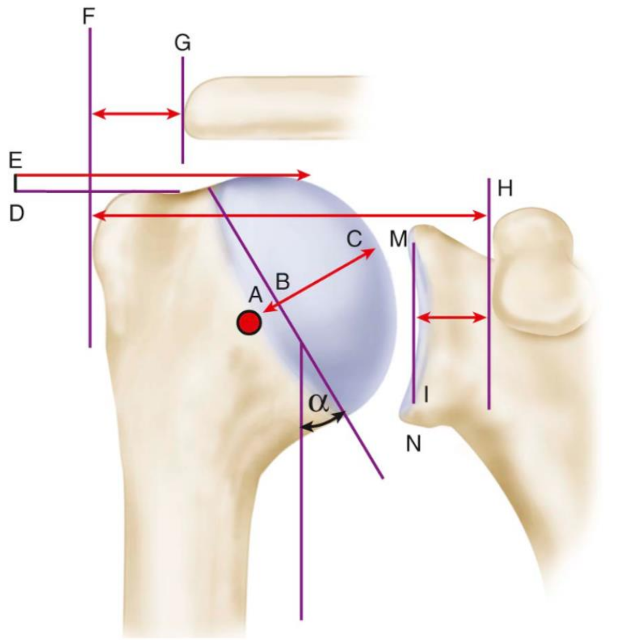
- ❑ stabilizes the glenohumeral joint while allowing great freedom of motion
- ❑ fixes the fulcrum of the upper extremity against which the deltoid can contract and elevate the humerus

S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013.
*http://clinicalgate.com/shoulder-complex/

Shoulder anatomy & biomechanics

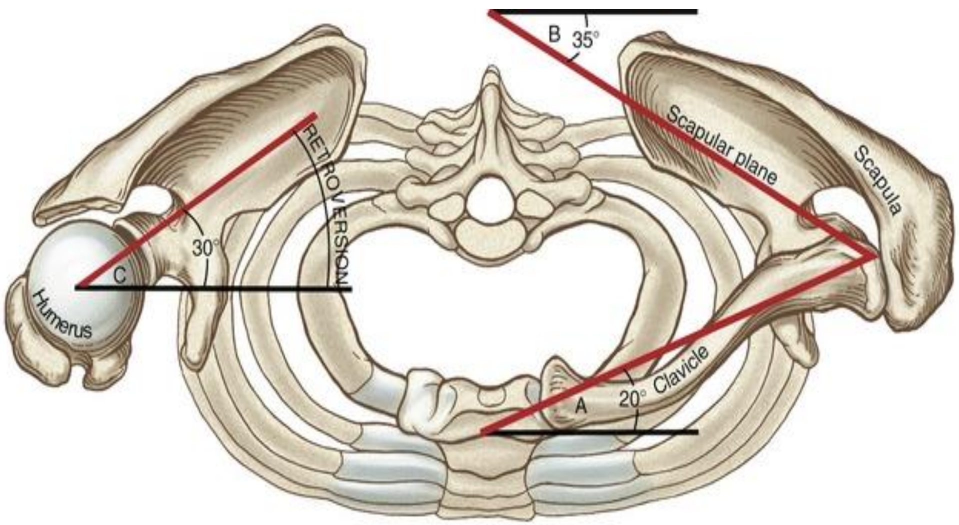
- **Humeral head:**
  - covered by **articular cartilage** with an arc of approximately 160 degrees
  - **superior position of humeral head** proximal **to greater tuberosity** by 8 to 10 mm (D-E)
  - the **radius of curvature:**
    - slightly larger in men than in women (+/- 25 mm)
    - 2 to 3 mm smaller than glenoid articular surface
    - larger in the ML than in the AP plane

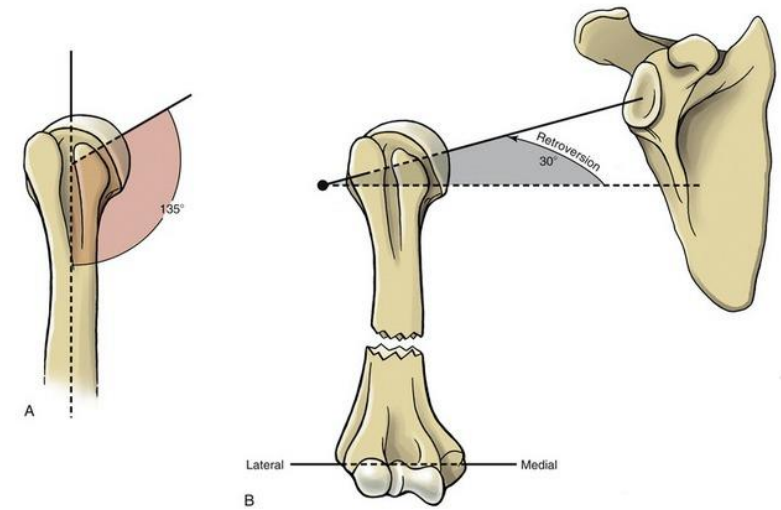
- **Lateral humeral offset** (F-H):
  - significant (distance) **increase:**
    - reduces the lever arms for the deltoid and supraspinatus muscles
    - weakens abduction
    - impairs function
  - significant (distance) **decrease:**
    - causes excessive tension on the soft tissues
    - “overstuffing” of the joint
    - impairs function



S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013.

Shoulder anatomy & biomechanics





- ❑ proximal humeral **retroversion**:
  - ❑ highly variable (from 0 to 55 degrees)

- ❑ position of the **glenoid surface in relation to the axis of the scapular body**:
  - ❑ from 2 degrees of anteversion to 7 degrees of retroversion

- ❑ average **neck-shaft angle** is 45 degrees (±5 degrees)

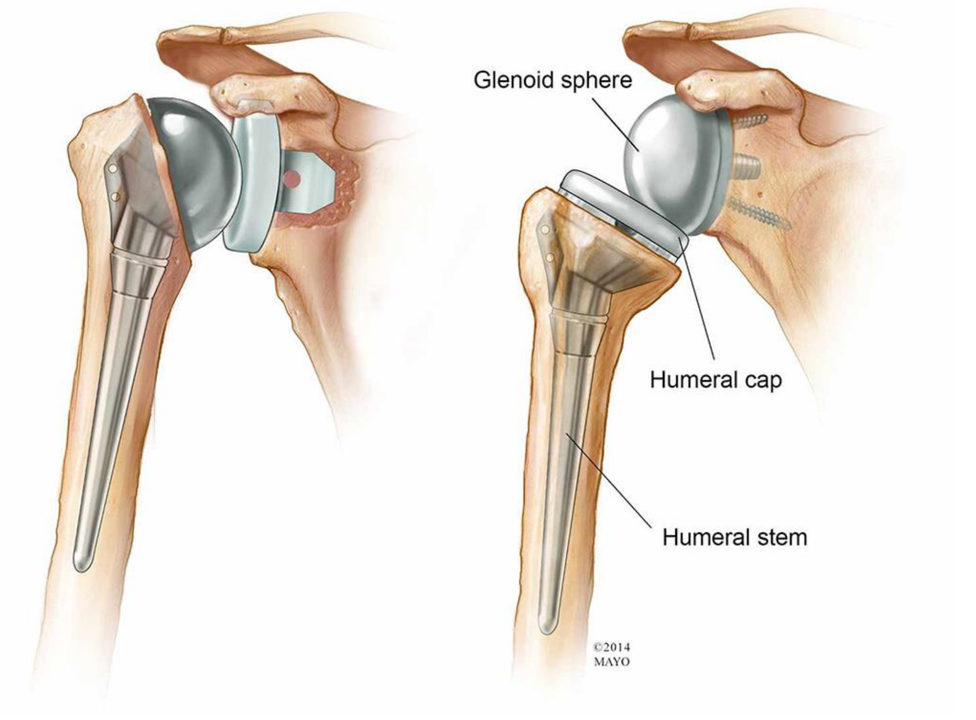
S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013.
http://clinicalgate.com/shoulder-complex/

Evolution of (reverse) shoulder arthroplasty

Goal – restoration or re-creation of functional anatomy to reduce pain and improve function.

Problems – when reconstructible tissue is lacking or not available.

- ❑ underlying **pathologies can alter the mechanical function of the shoulder** and create treatment dilemmas that are difficult to overcome
    - ❑ <u>inconsistent and unsatisfactory results:</u>
        - ❑ hemiarthroplasty
        - ❑ glenoid grafting with total shoulder arthroplasty

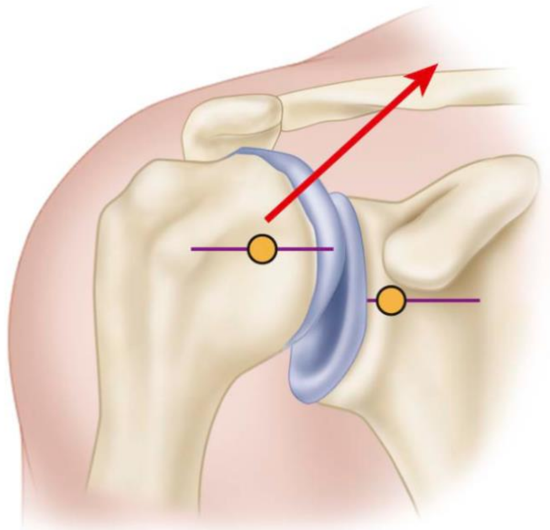


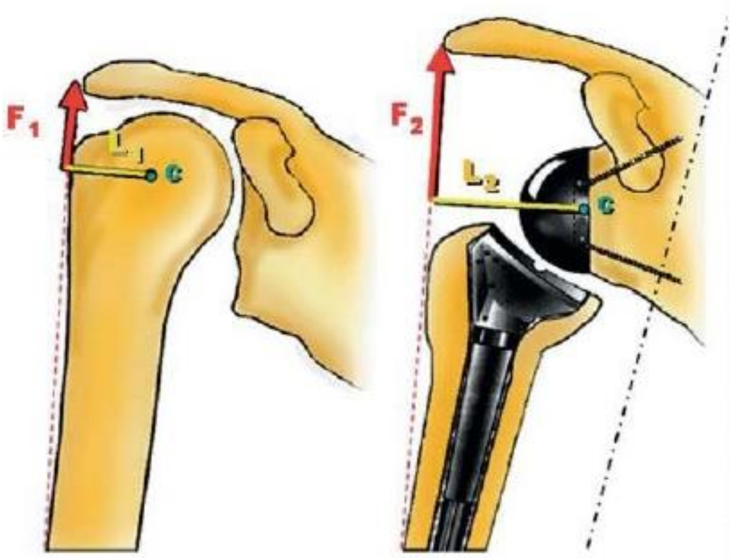
Lorenzetti AJ, Stone GP, Simon P, Frankle MA. Biomechanics of Reverse Shoulder Arthroplasty: Current Concepts. Instr Course Lect. 2016;65:127–43.

Evolution of (reverse) shoulder arthroplasty

Reverse total shoulder arthroplasty in the past decades was developed to treat complex shoulder conditions **not by specifically re-creating the anatomy** but by **using the remaining functional tissue to improve shoulder balance.**

- **no rotator cuff tendons:**
  - few restraints to **anterosuperior subluxation** of humeral head when patient attempts to raise the arm
  - pull of **deltoid muscle** worsens this by pulling **superiorly and medially**





- **reverse arthroplasty:**
  - deltoid muscle **lever arm** is restored
  - allow the **deltoid to compensate for the deficient rotator cuff**
  - deltoid **pulls the humerus** upward and outward into elevation

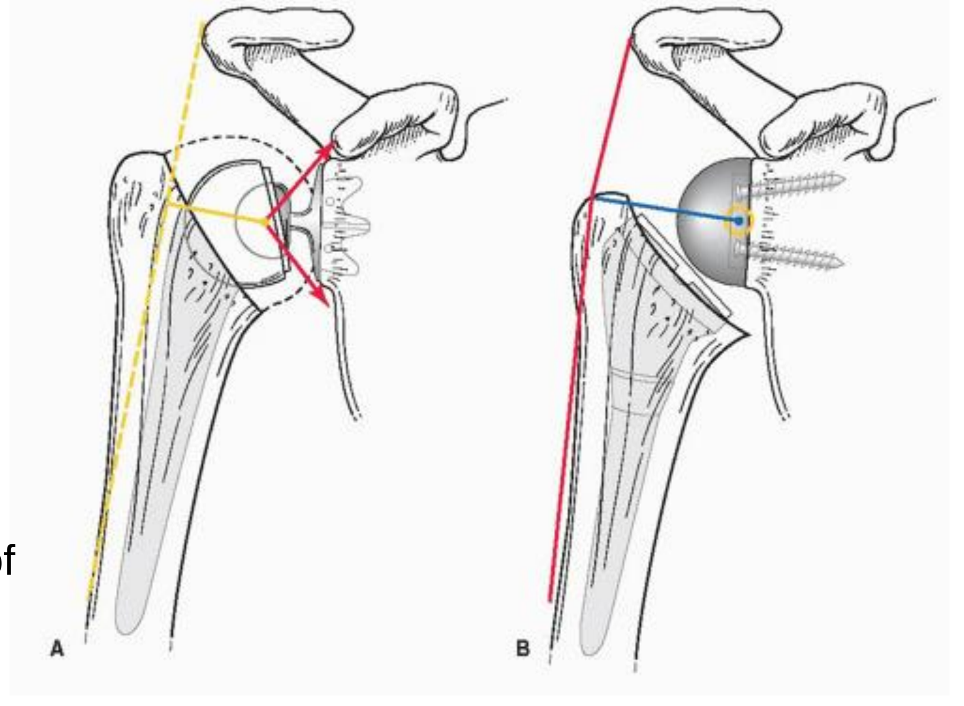
http://medapparatus.com/Ortho/Images/JointArthroplasty/Shoulder_Arthroplasty_drawing.jpg
http://musculoskeletalkey.com/rationale-and-biomechanics-of-the-reversed-shoulder-prosthesis-the-french-experience/

Evolution of (reverse) shoulder arthroplasty

Reverse total shoulder arthroplasty prostheses today **vary in certain design details**, although their intrinsic design remains based on **Grammont's principles**.

Previous types of reverse shoulder arthroplasty /biomechanical **disadvantages**/:

1) lateral center or rotation (yellow dot)
2) shear forces to the glenoid component (red arrows)
3) shortened lever arm of the deltoid (dotted yellow lines)
4) design-related limited range of motion.



Grammont type of reverse shoulder arthroplasty /biomechanical principle/:

1) inherently stable prosthesis
2) weightbearing part - convex, supported part - concave
3) lowering and medialization of the center of rotation
4) center of the sphere – at or within the glenoid neck

http://musculoskeletalkey.com/reverse-shoulder-arthroplasty-in-the-management-of-glenohumeral-arthritis-and-irreparable-cuff-insufficiency/

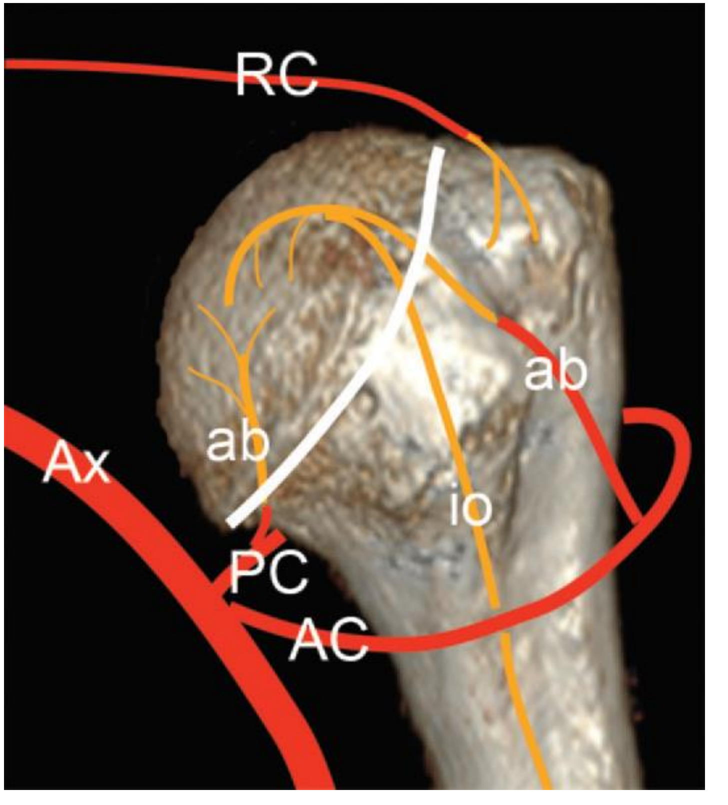
Flatow EL, Harrison AK. A History of Reverse Total Shoulder Arthroplasty. Clinical Orthopaedics and Related Research®. wrzesień 2011;469(9):2432–9.

Proximal humerus – blood supply

- ❑ **axillary artery**:
  - ❑ **anterior circumflex artery**
  - ❑ **posterior circumflex artery**
    - ❑ both gives **ascending branch** that enters the humerus and flows retrograde (distal to proximal) into the anatomic head as the **arteria arcuata**.

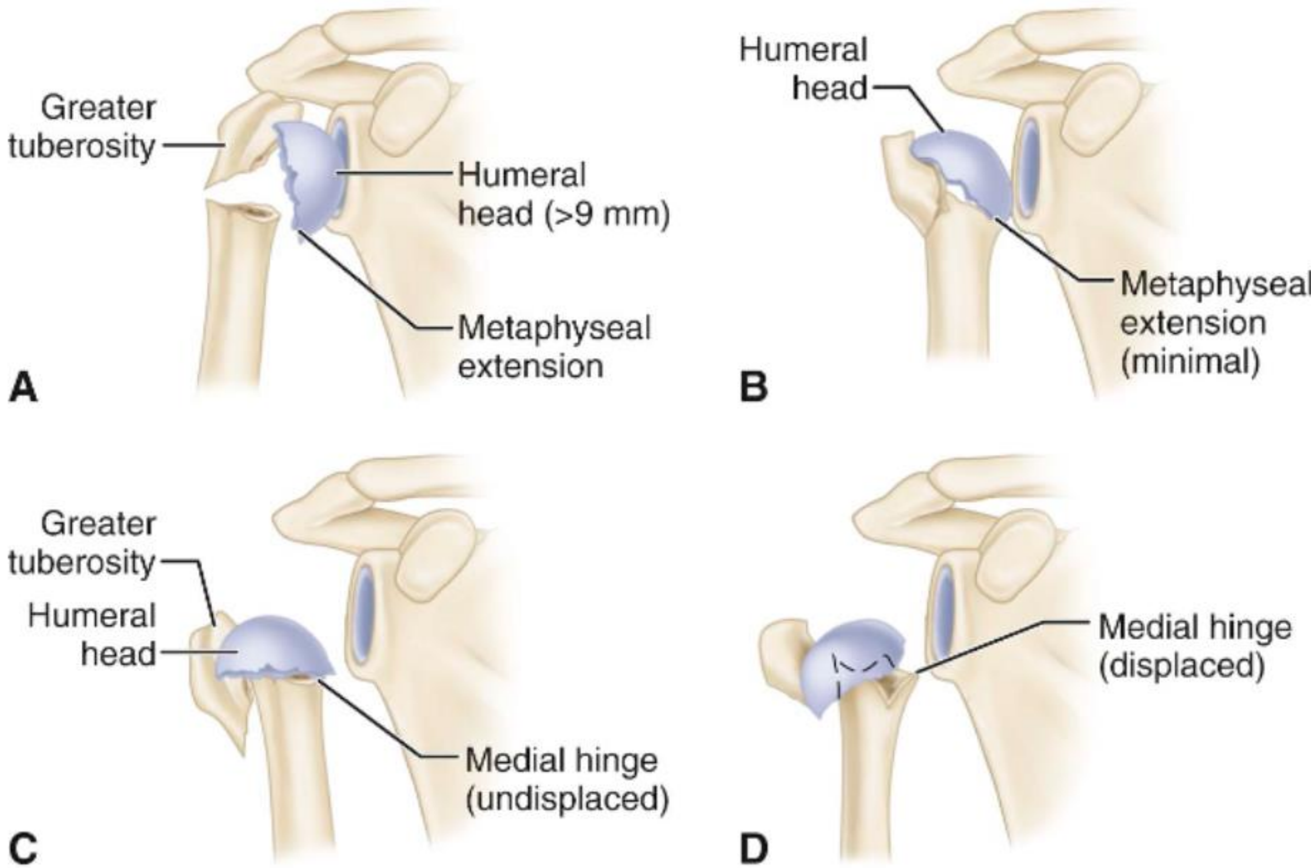
- ❑ **arteries of the rotator cuff**
  - ❑ minimal additional arterial contribution

- ❑**intraosseous metaphyseal artery**
  - ❑ via the humeral shaft



Sandstrom CK, Kennedy SA, Gross JA. Acute Shoulder Trauma: What the Surgeon Wants to Know. RadioGraphics. marzec 2015;35(2):475–92.

Hertel radiographic criteria for perfusion of humeral head



A - Metaphyseal extension of humeral head greater than 9 mm

B - Metaphyseal extension of humeral head less than 8 mm

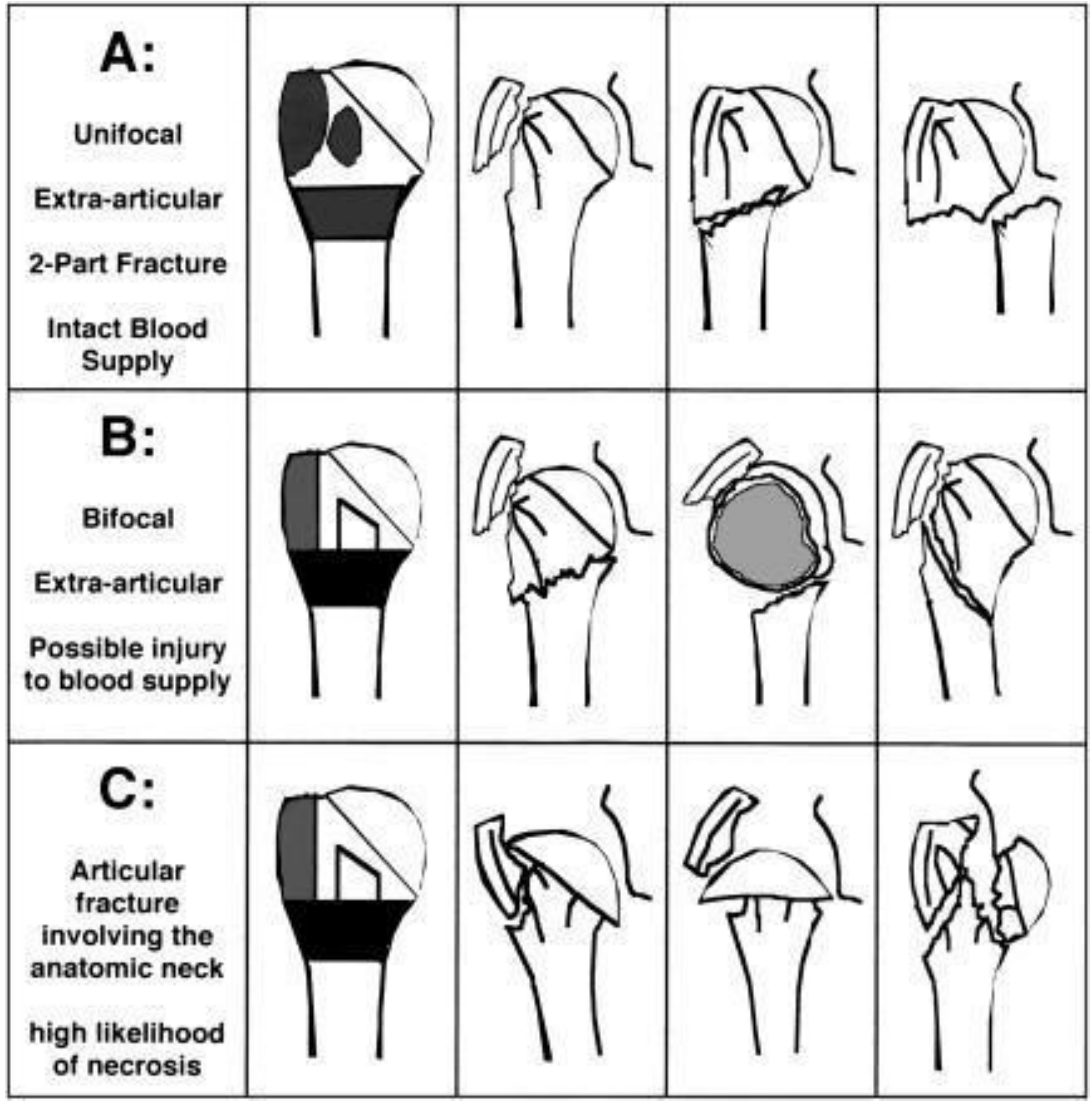
C - Undisplaced medial hinge

D - Medial hinge with greater than 2-mm displacement.

S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013

AO classification system

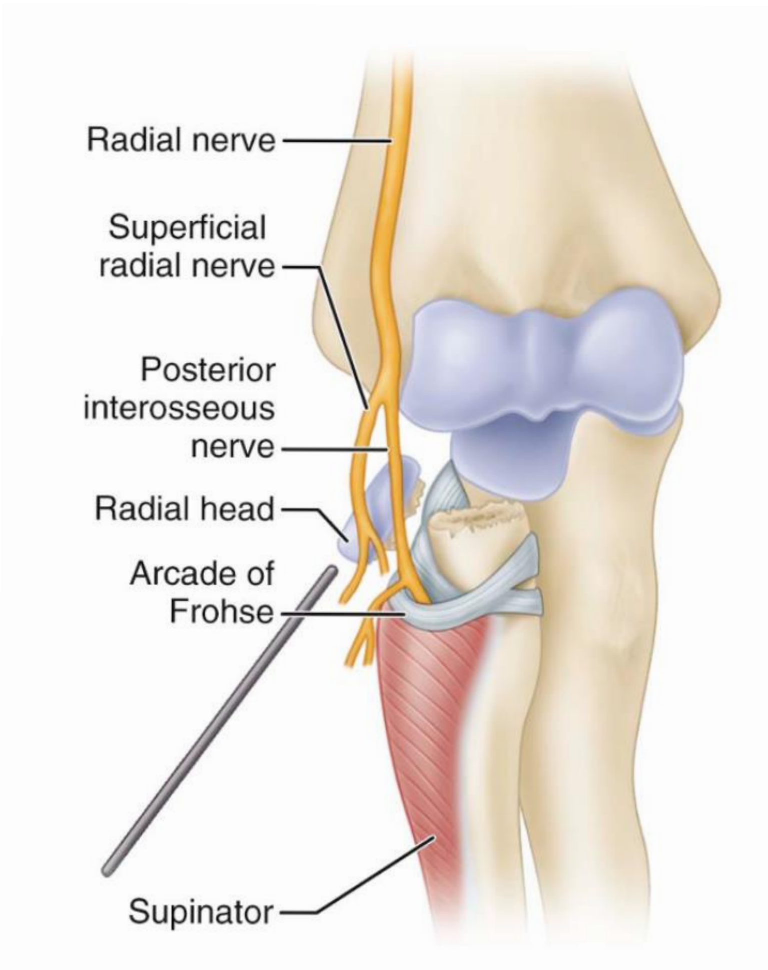
- **type A** fractures - **intact vascular supply**
- **type B** fractures - **possible injury** to the vascular supply
- **type C (**articular) fractures - **high probability of osteonecrosis**



S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013.
https://classconnection.s3.amazonaws.com/908/flashcards/414908/jpg/ota_classification_of_proximal_humerus_fractures-1457325AB9D637784ED.jpg

Deep branch
of radial nerve

Originates from the **radial nerve** at the **radiohumeral joint line.**



Course:

1) **arcade of Frosche** at radial head (dives under supinator at arcade of Frosche)

2) **forearm posterior compartment** (winds around radial neck within substance of muscle to posterior compartment of forearm)

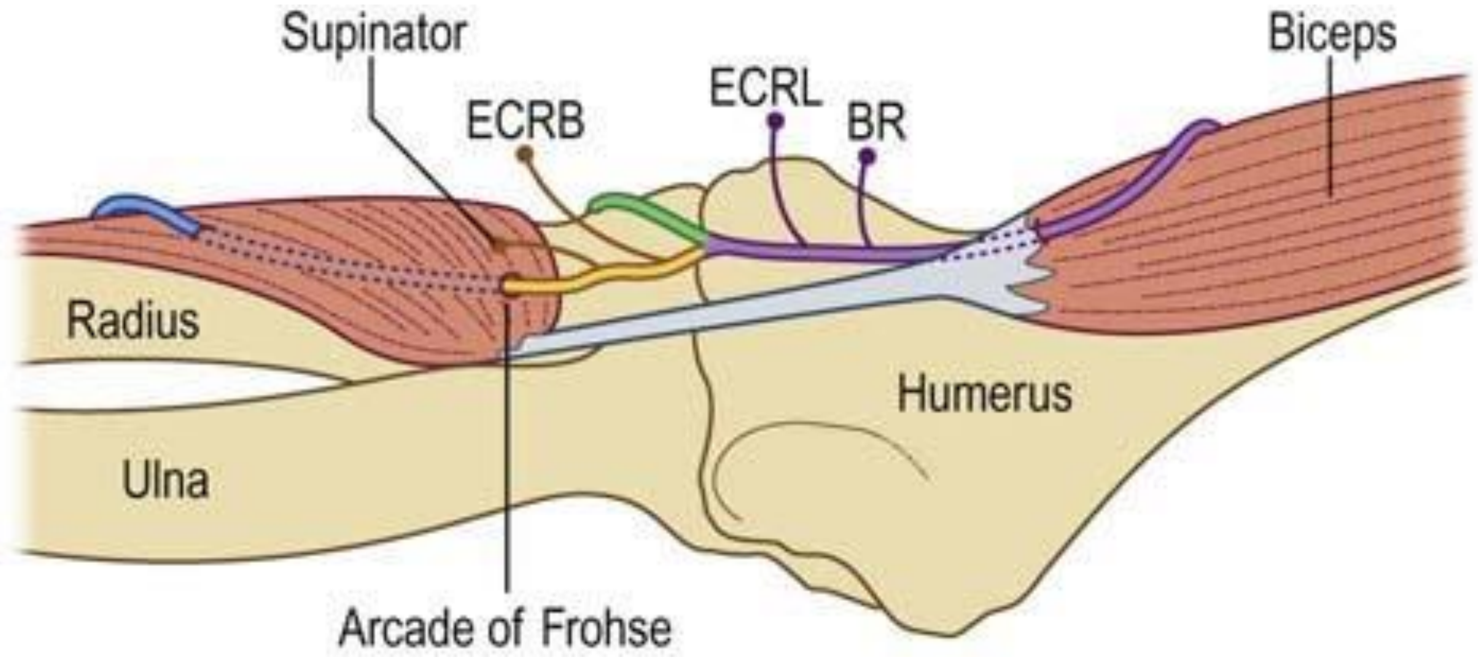
3) **interosseous membrane** (reaches interosseous membrane of forearm and ends as sensation to dorsal wrist capsule)

4) **dorsal wrist capsule**

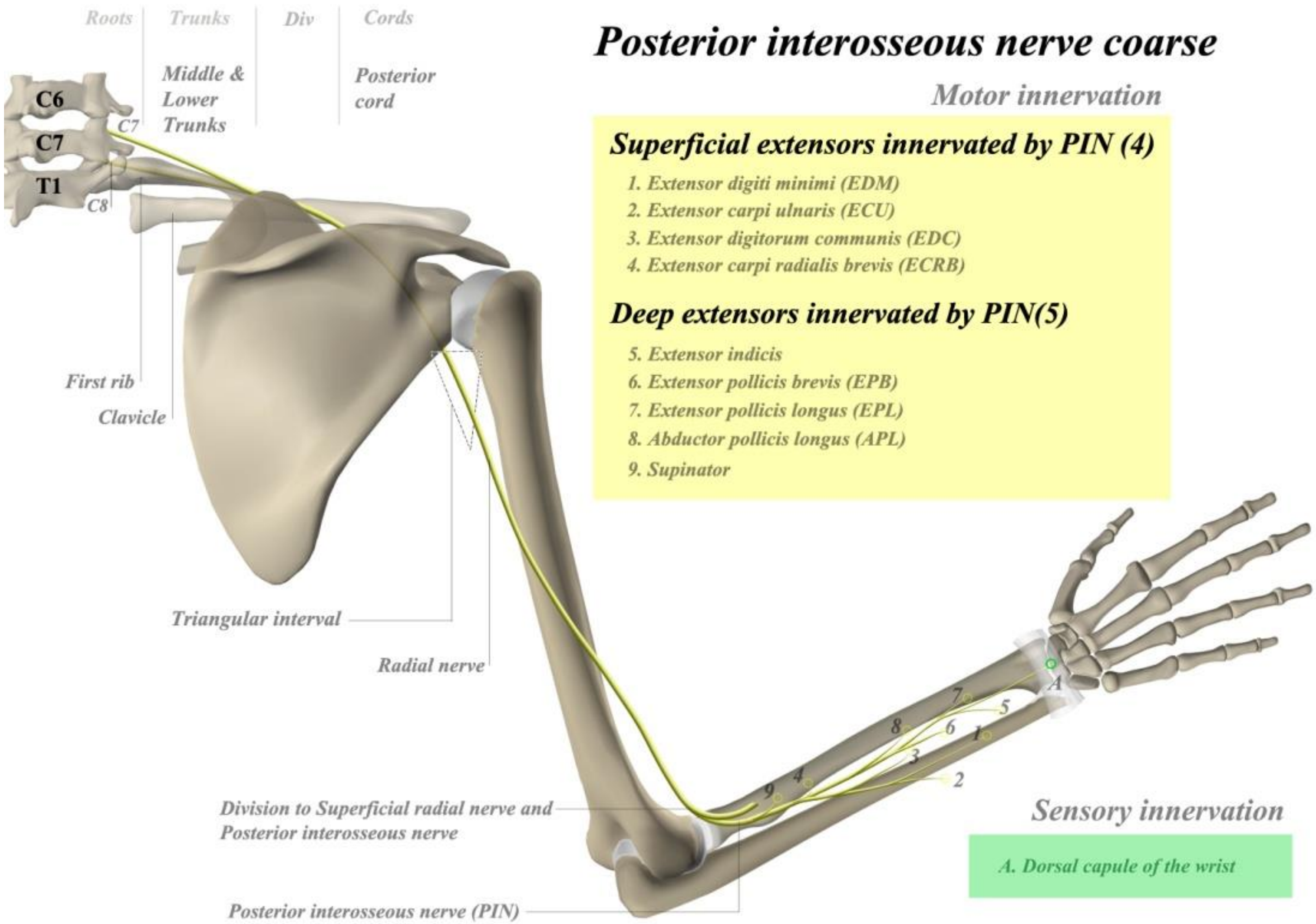
S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013.
Posterior Interosseous Nerve. W. Dostępne na: http://www.orthobullets.com/anatomy/10104/posterior-interosseous-nerve

Arcade of Frohse

- sometimes called the **supinator arch; thickened edge of between heads of supinator**
- the most superior part of the superficial layer of the supinator muscle, and is a **fibrous arch over the posterior interosseous nerve**



Arcade of Frohse. W. Dostępne na: https://en.wikipedia.org/wiki/Arcade_of_Frohse

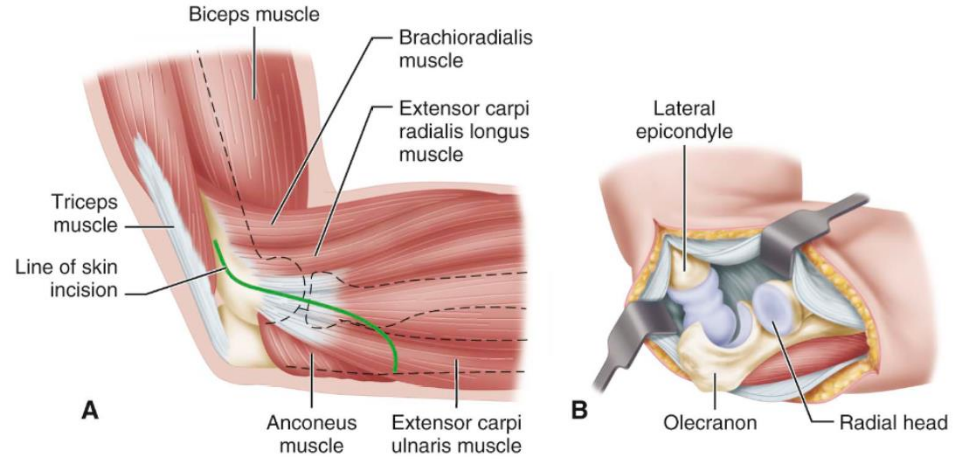


Radial nerve:

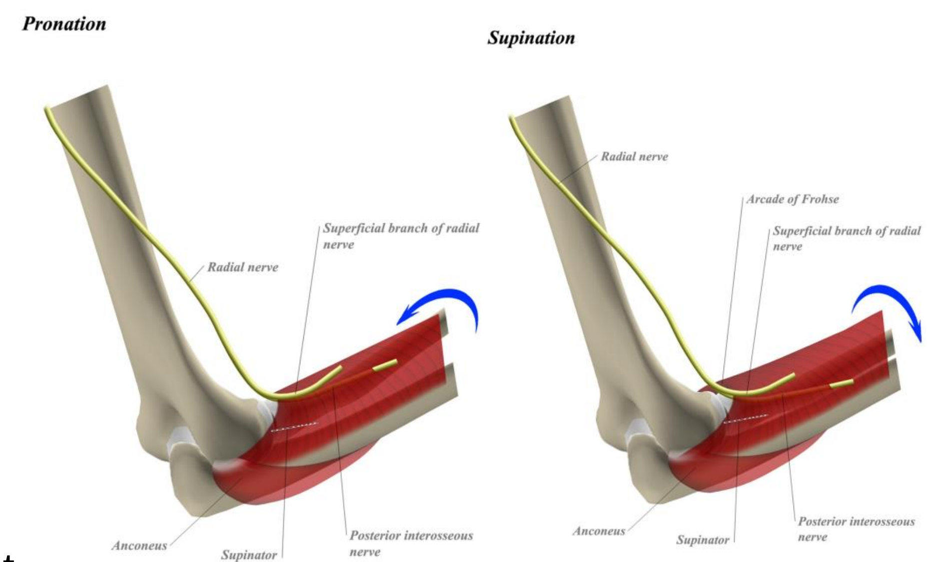
1) triceps
2) anconeus
3) ECRL
4) brachioradialis

Posterior Interosseous Nerve. W. Dostępne na: http://www.orthobullets.com/anatomy/10104/posterior-interosseous-nerve

Radial Head Lateral / Posterolateral / Kocher Approach



- ❑ Incision:
  - ❑ based off the lateral epicondyle and extending distally over the radial head
- ❑ Superficial dissection:
  - ❑ plane between ECU and anconeus distally
- ❑ Deep dissection:
  - ❑ **maintain arm in pronation to move PIN away from field**
  - ❑ split proximal fibers of supinator
  - ❑ incise capsule longitudinally

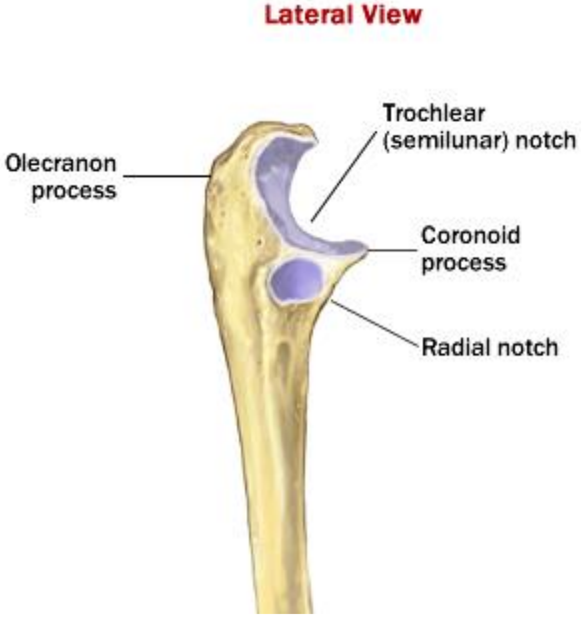


- ❑ PIN **not in danger** as long as:
  - ❑ dissection remains proximal to annular ligament
  - ❑ release supinator along posterior radius border beyond annular ligament with forearm **in full pronation**

S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013.
Posterior Interosseous Nerve. W. Dostępne na: http://www.orthobullets.com/anatomy/10104/posterior-interosseous-nerve

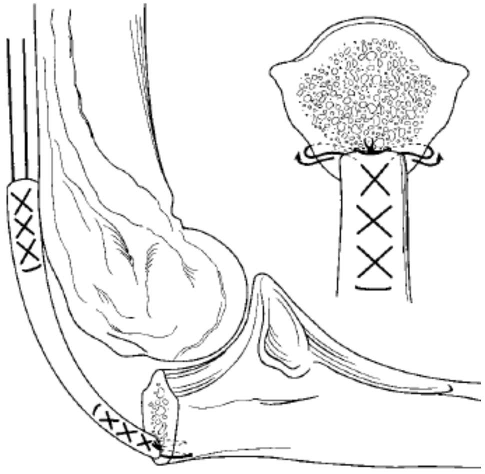
Olecranon fixation methods – biomechanics

Most olecranon fractures are displaced and require surgery.



Excision

- ❑ one study demonstrated that removal of as little as 12.5% of the olecranon is sufficient to alter joint stability
- ❑ An et al. suggested that up to 50% of the olecranon can be removed without rendering the elbow completely unstable
- ❑ however, it has also been reported that up to 75% of the olecranon can be removed without creating gross instability [1]
  - ❑if distal surface of **semilunar notch of ulna** & **coronoid** are not injured



[1] S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013.
[2] Rouleau DM, Sandman E, van Riet R, Galatz LM. Management of fractures of the proximal ulna. Journal of the American Academy of Orthopaedic Surgeons. 2013;21(3):149–160.
•https://www.studyblue.com/notes/note/n/bone-practical-part-2/deck/18091913
•DiDonna ML, Fernandez JJ, Lim T-H, Hastings H, Cohen MS. Partial olecranon excision: The relationship between triceps insertion site and extension strength of the elbow. The Journal of Hand Surgery. styczeń 2003;28(1):117–22.

Tension Band Wiring (TBW)

- ❑ purported to create compression at the articular end of an olecranon fracture when the dorsal cortex is tensioned under flexion of the elbow

- ❑ biomechanical studies **have not been able to demonstrate the conversion of tensile forces to compression forces [1]**

- ❑ 78% of the patients treated with **intramedullary** K-wires were found to have instability of K-wires, compared to 36% in the patients treated with **transcortical** K-wires [2]

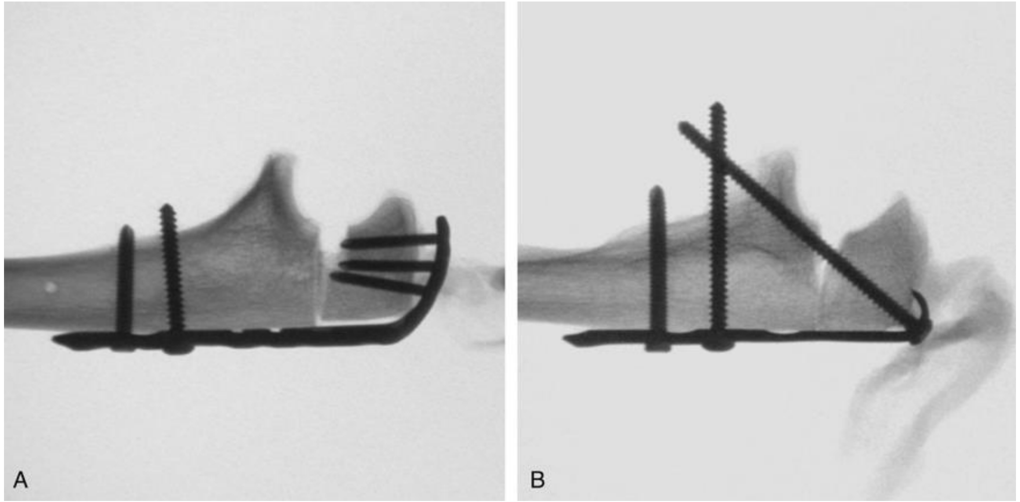
[1] S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013.
*K. J. Koval and J. D. Zuckerman, Handbook of Fractures: Third Edition, Lippincott Williams & Wilkins, 2006. ISBN: 0-7817-9009-3
[2] van der Linden SC, van Kampen A, Jaarsma RL. K-wire position in tension-band wiring technique affects stability of wires and long-term outcome in surgical treatment of olecranon fractures. Journal of Shoulder and Elbow Surgery. marzec 2012;21(3):405–11.

Plate-and-Screw Fixation

❑ provides the overall stability

LCP vs TBW
❑ **significantly greater compression** than TBW in the treatment of transverse olecranon fractures
❑ precontoured plates provide **greater compressive force** at the fracture site for transverse olecranon fractures comparing to TBW (Wilson et al.) [1]

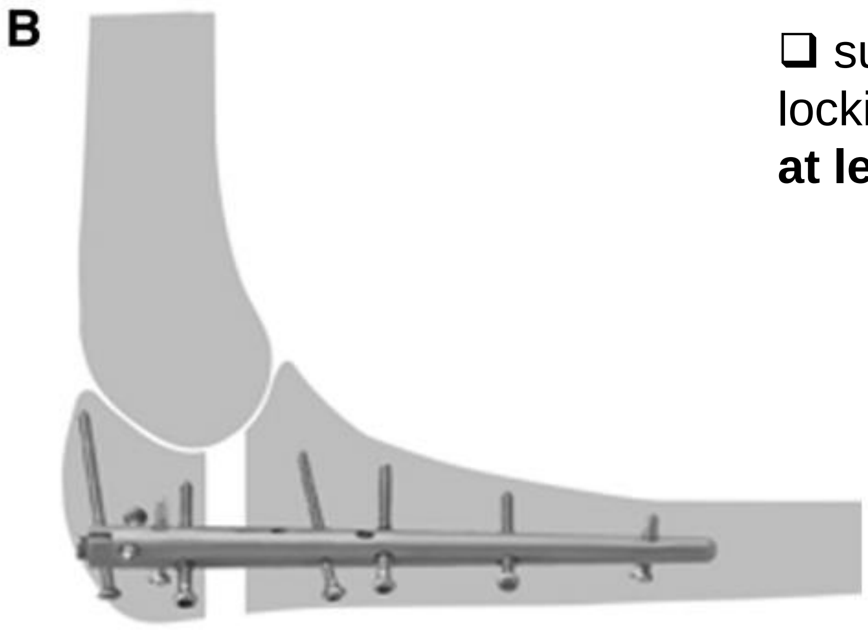
Variable Angle-LCP vs LCP Hook Plate
❑ significantly **higher biomechanical stability** in the fixation of unstable olecranon fractures



•Wagner FC, Konstantinidis L, Hohloch N, Hohloch L, Suedkamp NP, Reising K. Biomechanical evaluation of two innovative locking implants for comminuted olecranon fractures under high-cycle loading conditions. Injury. czerwiec 2015;46(6):985–9.

[1] Rouleau DM, Sandman E, van Riet R, Galatz LM. Management of fractures of the proximal ulna. Journal of the American Academy of Orthopaedic Surgeons. 2013;21(3):149–160.

Multidirectional locking intramedullary nailing



❑ sustained significantly **higher maximum loads** than the locking plates.

❑ **no significant differences** in fragment control or number of cycles survived

❑ surgeons can expect the multidirectional locking nails to **stabilize comminuted fractures at least as well as locking plates** [1]

* [1] Argintar E, Martin BD, Singer A, Hsieh AH, Edwards S. A biomechanical comparison of multidirectional nail and locking plate fixation in unstable olecranon fractures. Journal of Shoulder and Elbow Surgery. październik 2012;21(10):1398–405.

References

1. S. Terry Canale, MD and James H. Beaty, MD, Campbell's Operative Orthopaedics, 12th Edition, Philadelphia, PA: Elsevier/Mosby, 2013.

2. http://clinicalgate.com/shoulder-complex/

3. Lorenzetti AJ, Stone GP, Simon P, Frankle MA. Biomechanics of Reverse Shoulder Arthroplasty: Current Concepts. Instr Course Lect. 2016;65:127–43.

4. http://medapparatus.com/Ortho/Images/JointArthroplasty/Shoulder_Arthroplasty_drawing.jpg

5. http://musculoskeletalkey.com/rationale-and-biomechanics-of-the-reversed-shoulder-prosthesis-the-french-experience/

6. http://musculoskeletalkey.com/reverse-shoulder-arthroplasty-in-the-management-of-glenohumeral-arthritis-and-irreparable-cuff-insufficiency/

7. Flatow EL, Harrison AK. A History of Reverse Total Shoulder Arthroplasty. Clinical Orthopaedics and Related Research®. wrzesień 2011;469(9):2432–9.

8. https://www2.aofoundation.org/wps/portal/!ut/p/a1/

9. Sandstrom CK, Kennedy SA, Gross JA. Acute Shoulder Trauma: What the Surgeon Wants to Know. RadioGraphics. marzec 2015;35(2):475–92.

10. http://a0.att.hudong.com/57/86/19300001298238131047869199584_950.jpg

11. https://www.shoulderdoc.co.uk/images/uploaded/neer_parts.jpg

Thank you for your attention