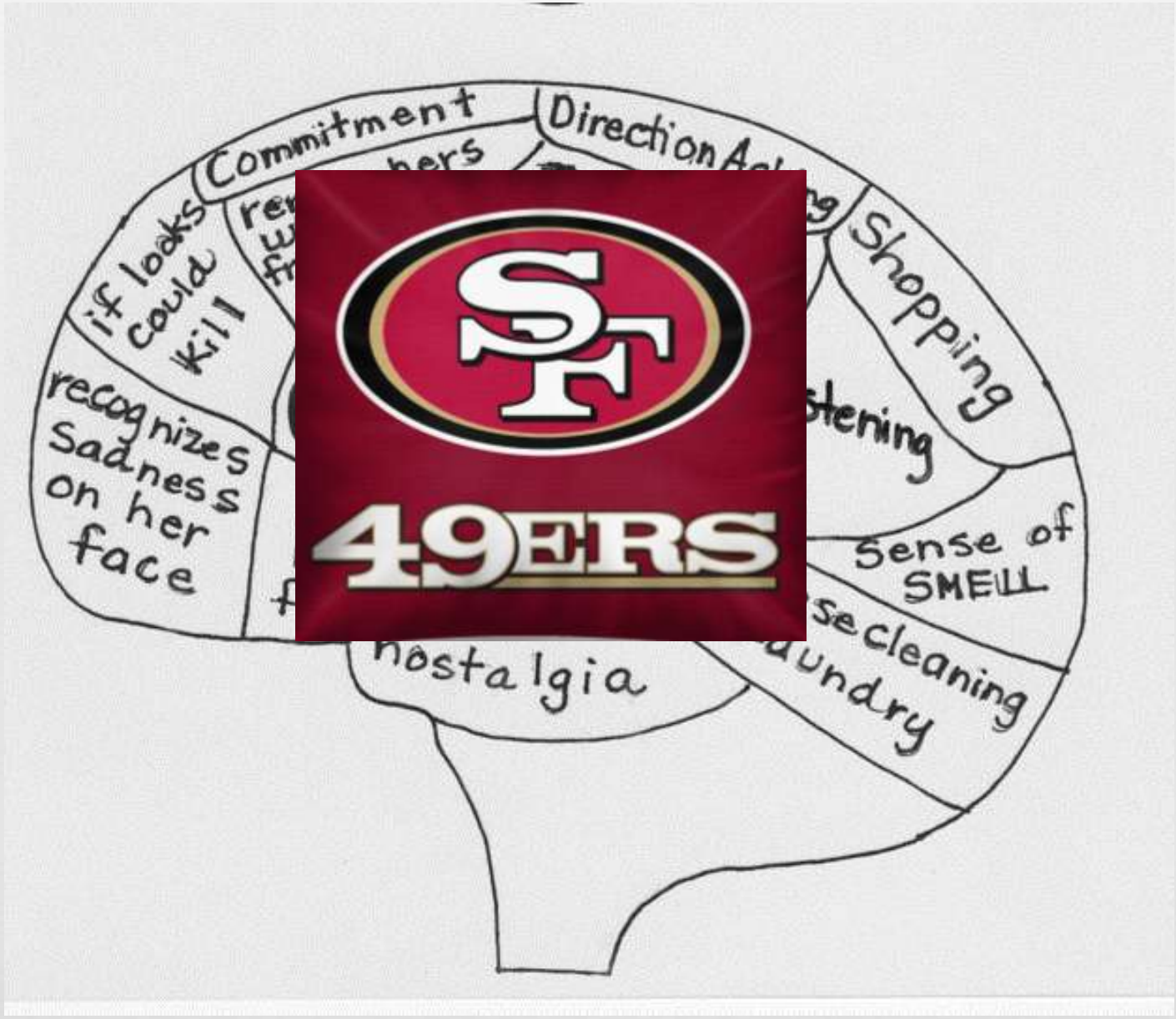
Scaphoid Bone Fractures & Assessing Fracture Fragment Viability with MR: Current Research & Pitfalls

February 7, 2013

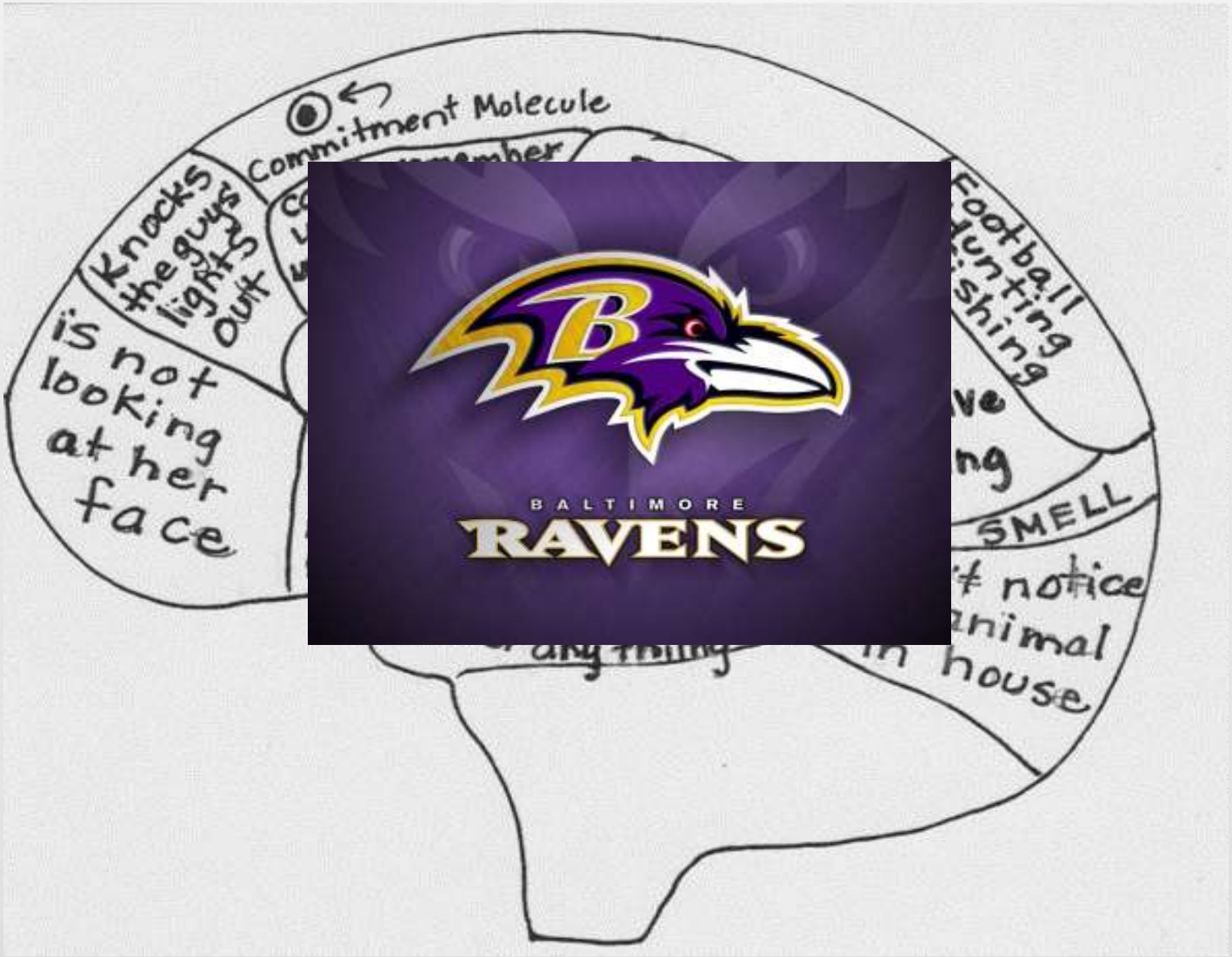
Rick Bhullar MD, FRCPC, DABR
Musculoskeletal Imaging Fellow
University of California , San Diego

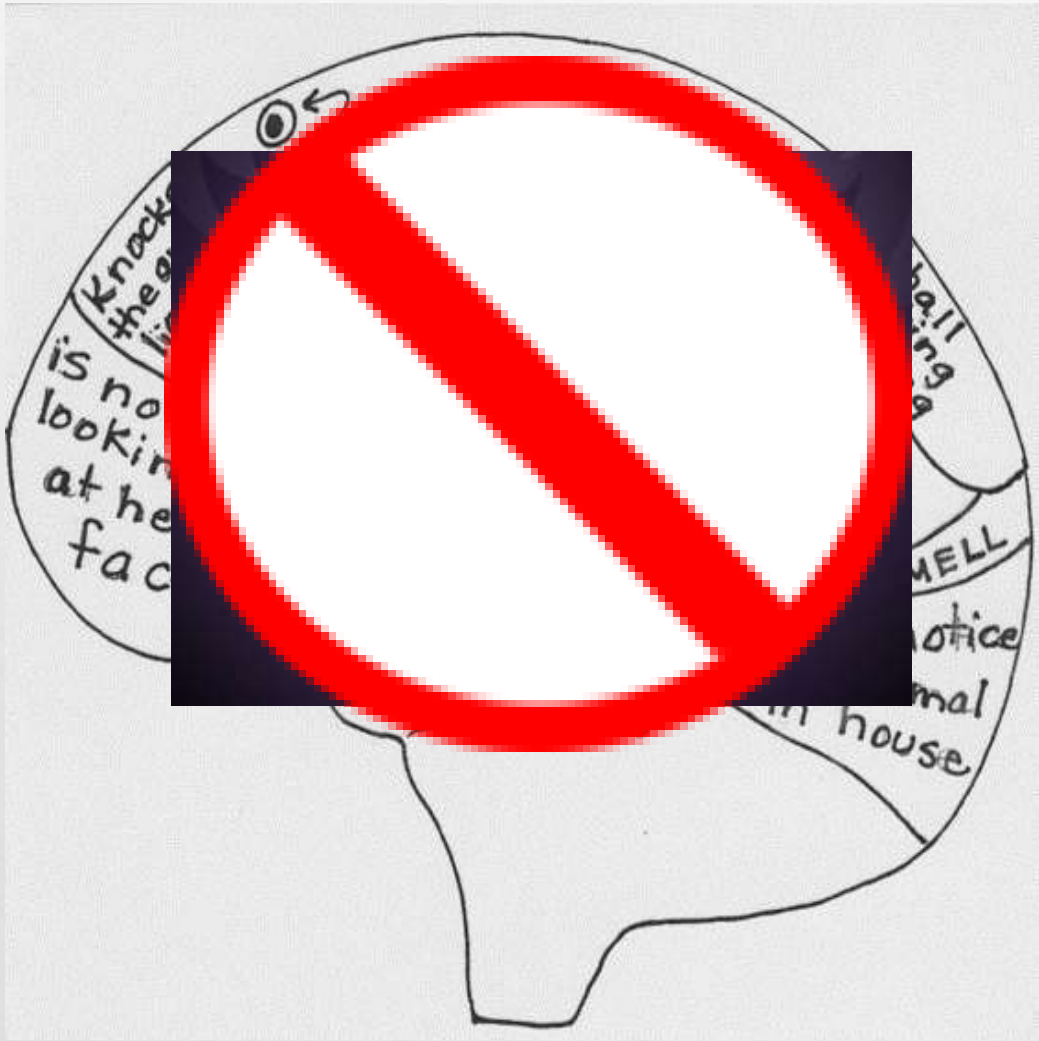
Public Service Announcement

This is your brain:



This is your brain on drugs:





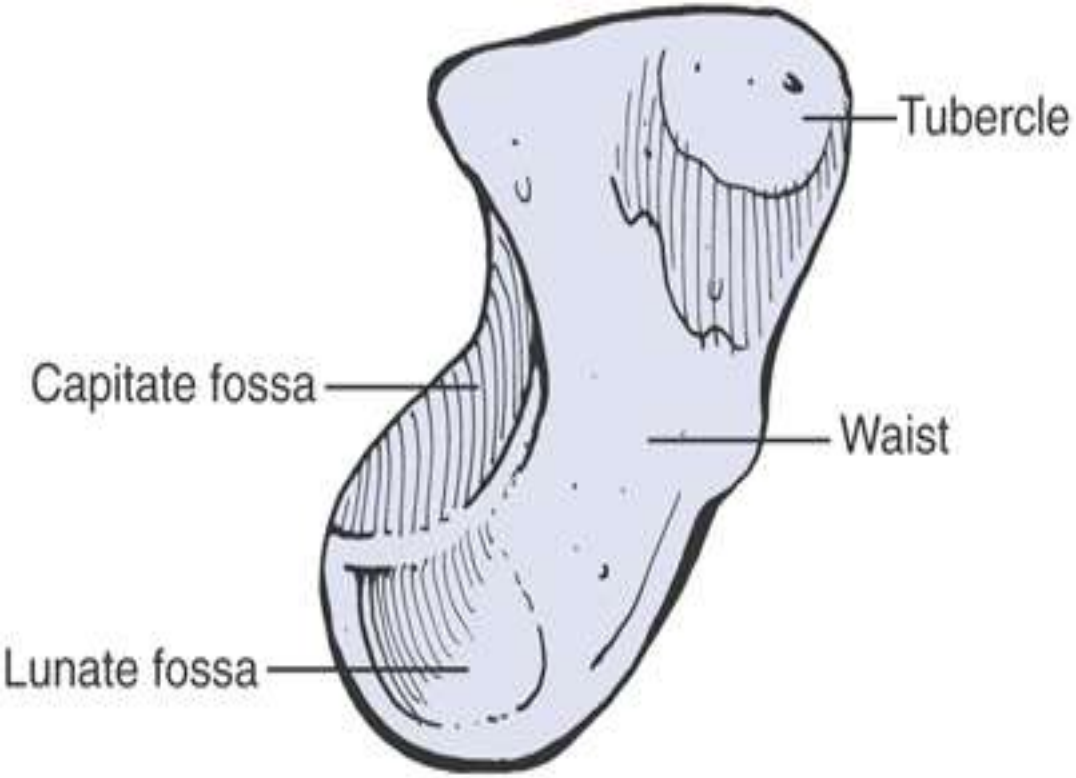
Friends don’t let friends cheer for the Baltimore Ravens….

Game Plan

- Scaphoid Anatomy & Vascularity
- Scaphoid Fractures
- Complications
- Review of 2 recent articles
- Conclusions

Scaphoid Bone Fractures

Scaphoid Anatomy



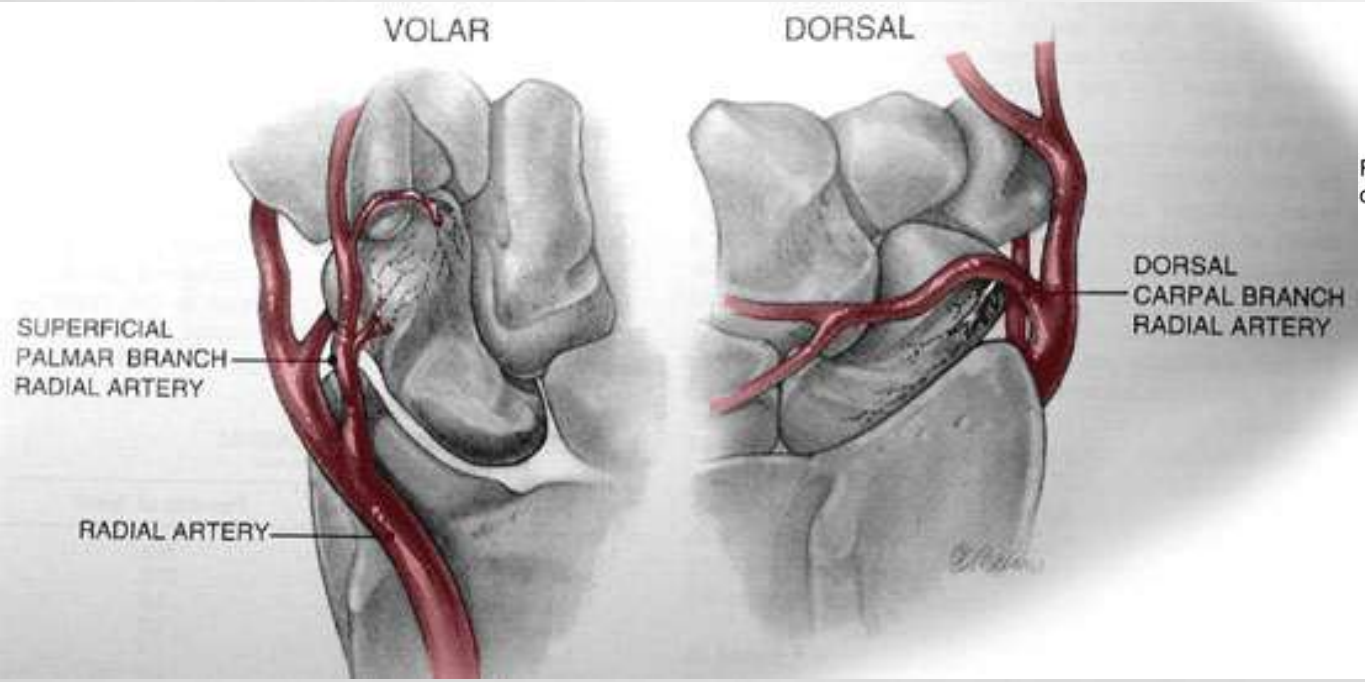
- >80% of surface covered by articular cartilage: decreases its capacity for periosteal healing, increases chance of delayed union & nonunion

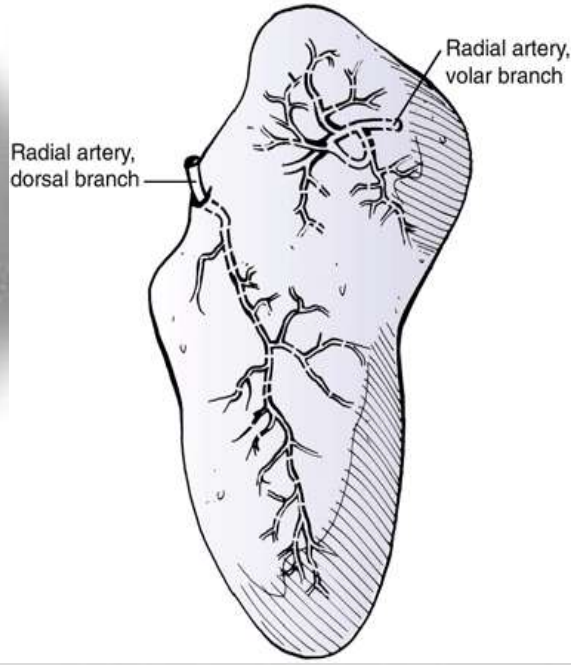
http://www.msdlatinamerica.com/ebooks/RockwoodGreensFracturesinAdults/sid680495.html

Scaphoid Anatomy

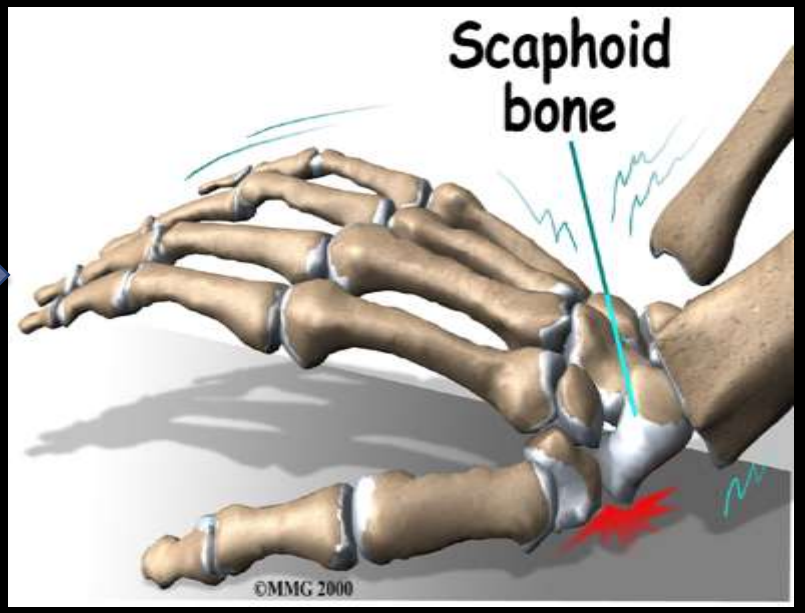
Vascular Supply: 2 major vascular pedicles

- Volar branch of radial artery: enters scaphoid tubercle, supplies distal 20%
- Dorsal branch of radial artery: enters scaphoid waste, supplies remaining 80% in retrograde fashion





Mechanism of Injury


Scaphoid
bone
©MMG 2000

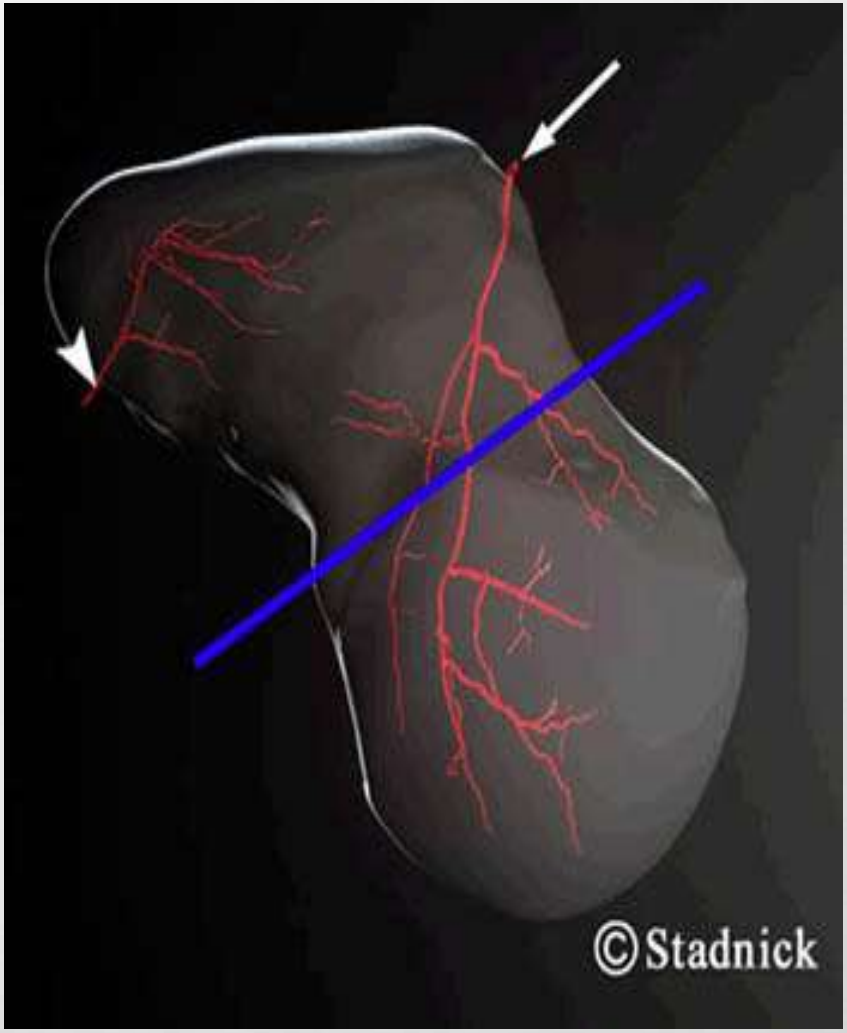

1
2

Clinical

- "Snuffbox tenderness":
  - Radial border: abductor pollicis longus & ext. pollicis brevis tendon
  - Ulnar border: ext. pollicis longus tendon

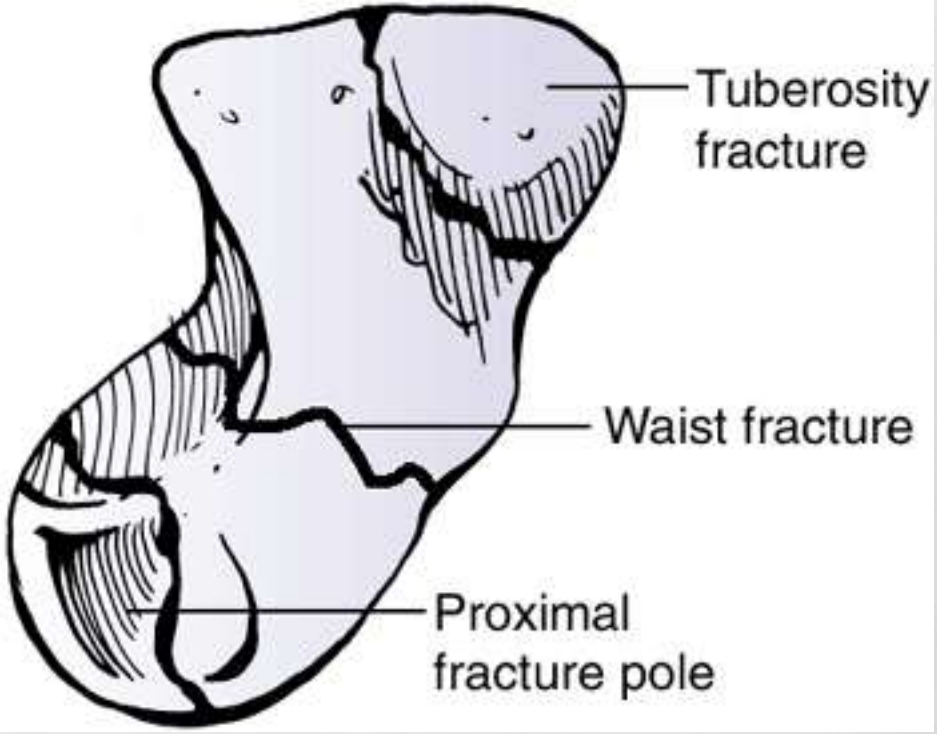
Scaphoid Fractures

- Scaphoid = most commonly fractured carpal bone
- 10%: assoc. w. # of other bones
  - Often radial styloid
- Prox pole vulnerable d/t retrograde blood supply from distal -> proximal



Scaphoid Fractures

- 70% involve scaphoid waste
- 10-20% distal pole
- 5-10% proximal pole
- Kids: scaphoid tubercle most often fractured



Scaphoid Fractures

Complications:

- Malunion: angular/"humpback" deformity
- Delayed union: # still present >4months of immobilization
- Nonunion: # lines smooth and sclerotic, >6 months after injury
  - Develop OA of radiocarpal joint, SNAC (scaphoid nonunion advanced collapse)
- AVN: more common in scaphoid d/t blood supply
  - Radiographic hallmark: collapse & fragmentation
- Scapholunate ligament injury
  - Widening of scapholunate interosseous interval
- 10%: malunion or nonunion

Scaphoid Fractures

- May progress to AVN if:
  - Chronic nonunion
  - Failed surgery
  - Prox 1/3 #
  - Occult # not treated
- 13-50% scaphoid fractures develop AVN

- Increased density & partial collapse of prox pole
- Smooth sclerotic fracture margins suggesting nonunion
- Increased SL interosseous distance

http://www.learningradiology.com/archives06/COW%20229-AVN%20Scaphoid/avnscaphoidcorrect.html

Scaphoid Fractures: Tx

- 90% of all acute #'s heal if treated early
- Casting (3-6 months!): [90% union rate]
  - stable, nondisplaced fractures of mid/distal scaphoid
- Surgery (operative fixation +/- bone graft): [95%]
  - Unstable or displaced #
  - Delayed union
  - Symptomatic malunion/nonunion
  - AVN
  - Successful surgery more likely if vascularity of prox pole maintained

Article 1

Assessment of Scaphoid Viability With MRI: A Reassessment of Findings on Unenhanced MR Images

Michael G. Fox[1], Cree M. Gaskin[1], A. Bobby Chhabra[2] and Mark W. Anderson[1]

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This Article
doi: 10.2214/AJR.09.4098
AJR October 2010 vol. 195 no. 4 W281–W286

Abstract Free
Figures Only

Assessment of Scaphoid Viability With MRI: A Reassessment of Findings on Unenhanced MR Images

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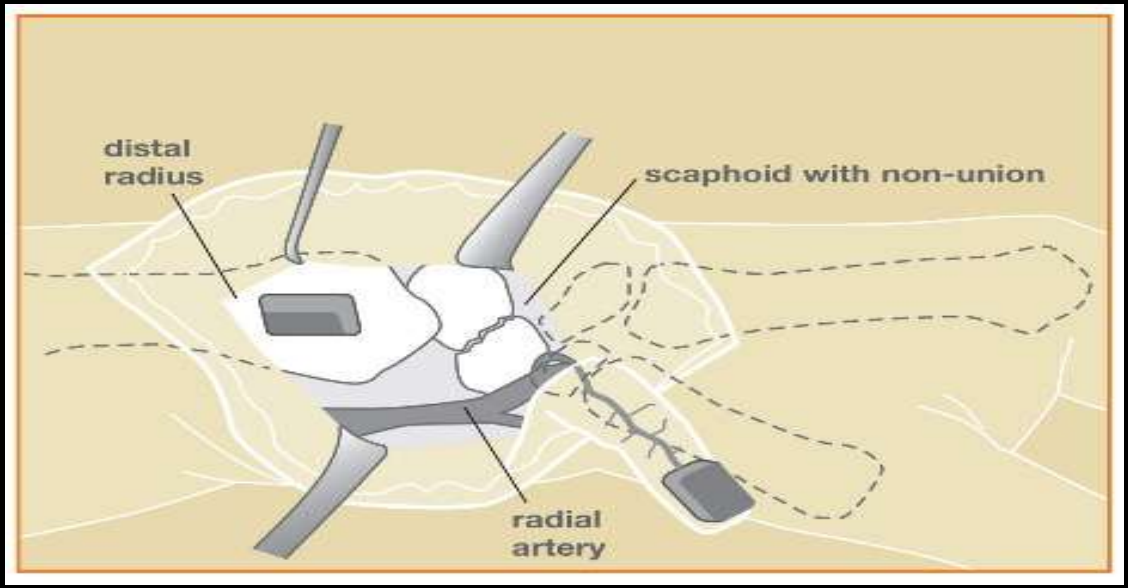
AJR October 2010 vol. 195 no. 4 W281–W286

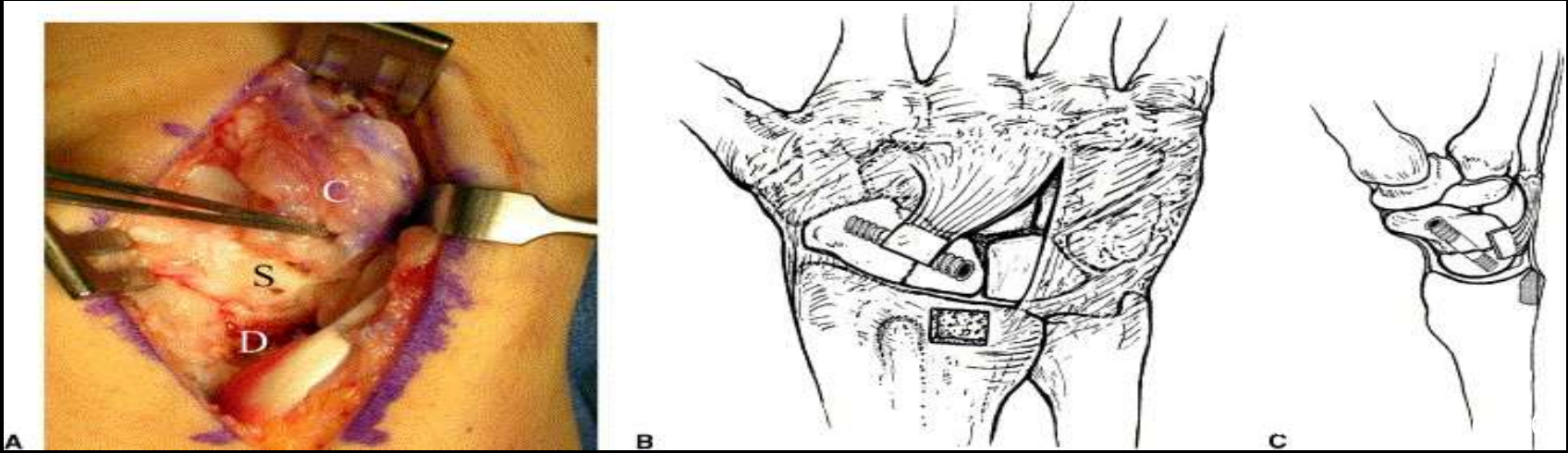
Abstract *Free*

Figures Only

- Purpose: evaluate accuracy of unenhanced T1 MR in predicting vascular status of prox pole scaphoid (in chronic scaphoid fracture nonunions)
- Why? Chronic scaphoid nonunion # needs bone grafting to heal
  - Vascular status of prox pole = vascularized vs nonvascularized bone graft
  - If preserved vasc to prox pole= can use nonvasc graft w. screw fixation to get osseous union
  - If AVN = vasc bone graft (more challenging, longer OR, uses the intercompartmental supraretinacular artery)



http://www.assh.org



- vascularized bone graft – piece of bone from radius or hand with blood supply still attached, placed at fracture to revitalize the bone

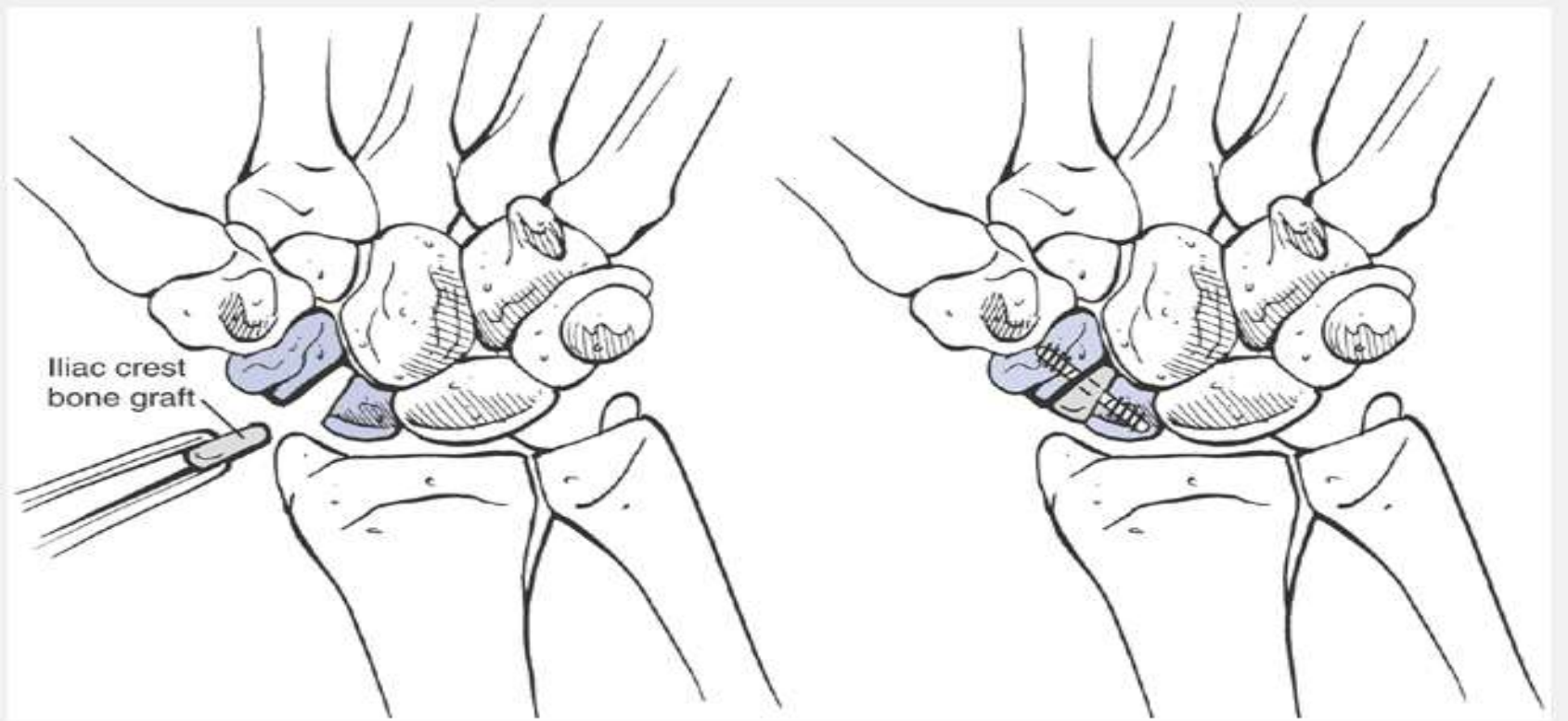


FIGURE 25-21 Insertion of an iliac crest bone graft and stabilization with a screw for treatment of scaphoid nonunions. The bone graft is wedged to correct the angulation deformity that often occurs.

- For most cases of stable nonunion, use cancellous bone graft from distal radius (for small defects) or iliac crest (preferred by some d/t superior osteogenic & mechanical properties)

http://www.msdlatinamerica.com/ebooks/RockwoodGreensFracturesinAdults/sid680495.html

Background

- Previous studies:
  - Reinus et. al (1986): T1 sensitive for detecting AVN in carpal bones but not specific
    - Therefore: use decr signal on T2 to incr specificity
  - Morgan et. al (1997): correctly dx-ed AVN in 13 of 14 pt's using decr T1 and T2 involving >50% of prox pole
  - Cerezal et. al (2000): global accuracy of –C MR for vasc status of prox scaphoid = 68% vs w. gad = 83%; more likely to see normal or incr T2 in AVN of prox pole
  - Anderson et. al (2005): used MR in postop eval of scaphoid nonunion tx'ed w. vascularized bone grafts (included data on preop MR, all had surgically confirmed AVN):
    - All 13 pt's had decr T1
    - 6 (46%) had incr signal post-gad (paradoxical enhance in necrotic bone!)

Background

- Based on prev studies, MR classification for viability was created based on T1 and T2
  - Viable = normal T1 and T2
  - Ischemic = decr T1 and incr T2
  - Necrotic = decr T1 and T2

- Use of gad:
  - Viable = homogeneous enhance
  - AVN + viable bone together = inhomogeneous enhance
  - Necrotic = no enhance

Background

- Cerezal et. al (2000): directly compared accuracy of unenhanced and +C MR to intraop findings in 30 pts
- 4 groups based on T1/T2 FS:
  - 1: norm-min ischemia: norm signal
  - 2: mod ischemia: slight decr T1, homo incr T2
  - 3: severe ischemia: low T1, hetero T2
  - 4: AVN: low T1 and T2

With gad:

Homo enhance >80% of prox pole

50-80%

20-50%

0-20%

Assigning percentages is very subjective!

Background

Cerezal et. al (2000):

- Concluded: unenhanced MR not reliable for assessing DEGREE of ischemia/viability
- If just placed pt's in 2 groups (viable (gr. 1-3) vs AVN (gr. 4)):
  - Unenhanced MR: 71% sens, 74% spec, 73% accuracy
  - Contrast-enhanced MR: 86%, 96%, 93%

Background

- Anderson et. al (2005): 13 pt's w. confirmed AVN, all had decr T1 but 6 (46%) had enhancement post-contrast
  - Uncertain why necrotic bone might enhance
  - ?in-growth of viable fibrous mesenchymal tissue in necrotic bone
  - ?diffusion of contrast throughout ST's, incl bone since most routine +C-MR done in late vascular phase (4-9 min after contrast admin)
  - Bowlus et. al (2008) animal study: +C-MR: some normal femoral heads did not enhance vs avascular fem heads showed inhomogeneous enhance

Article 1

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Abstract Free
Figures Only

Materials & Methods

- 29 pt's w surgical repair of chronic scaphoid # nonunion using vasc or nonvasc bone graft

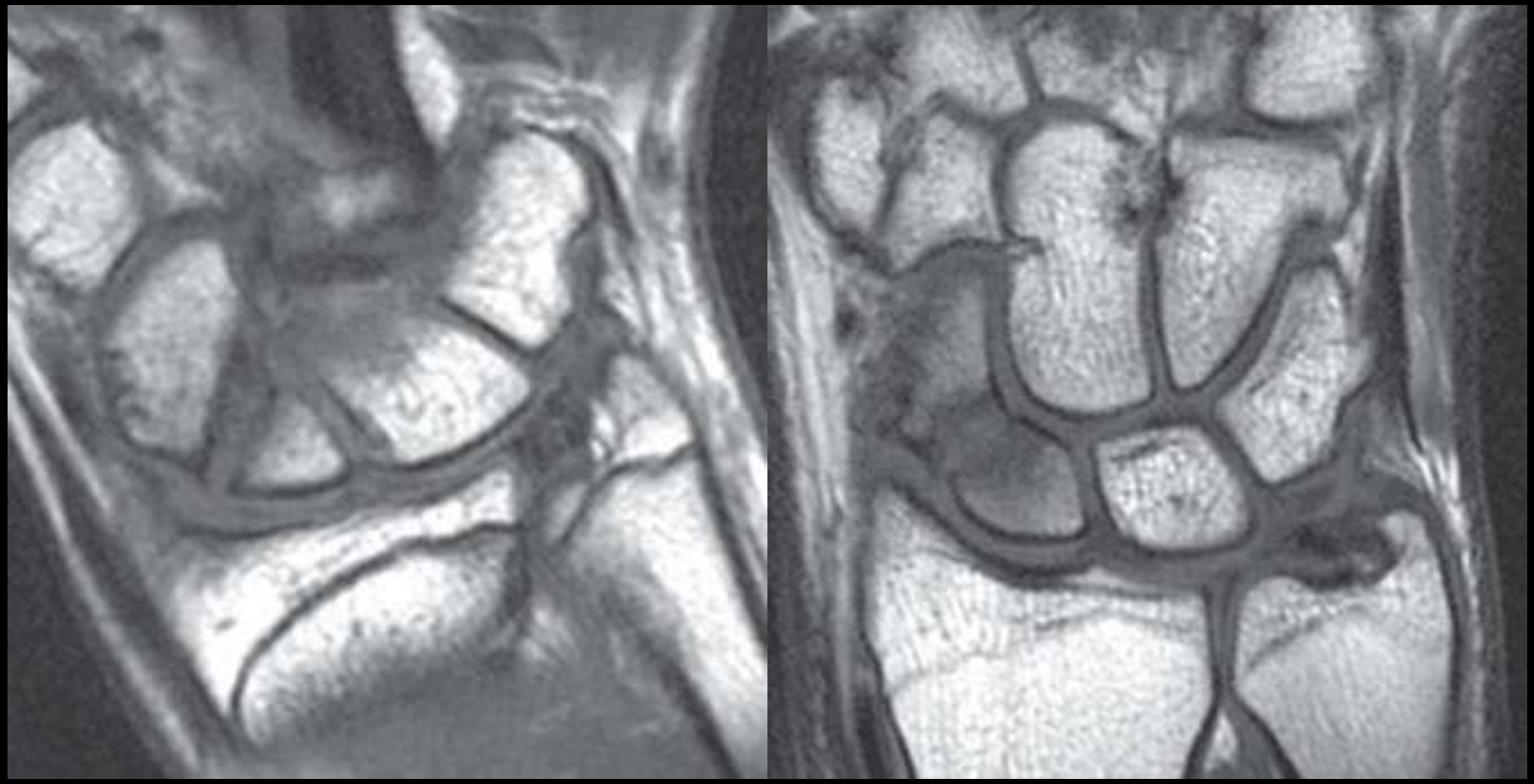
Inclusion criteria:

- Preop 1.5 T MR
- Surgical documentation of intraop vasc status of prox pole
- Number days b/w MR and surgery noted

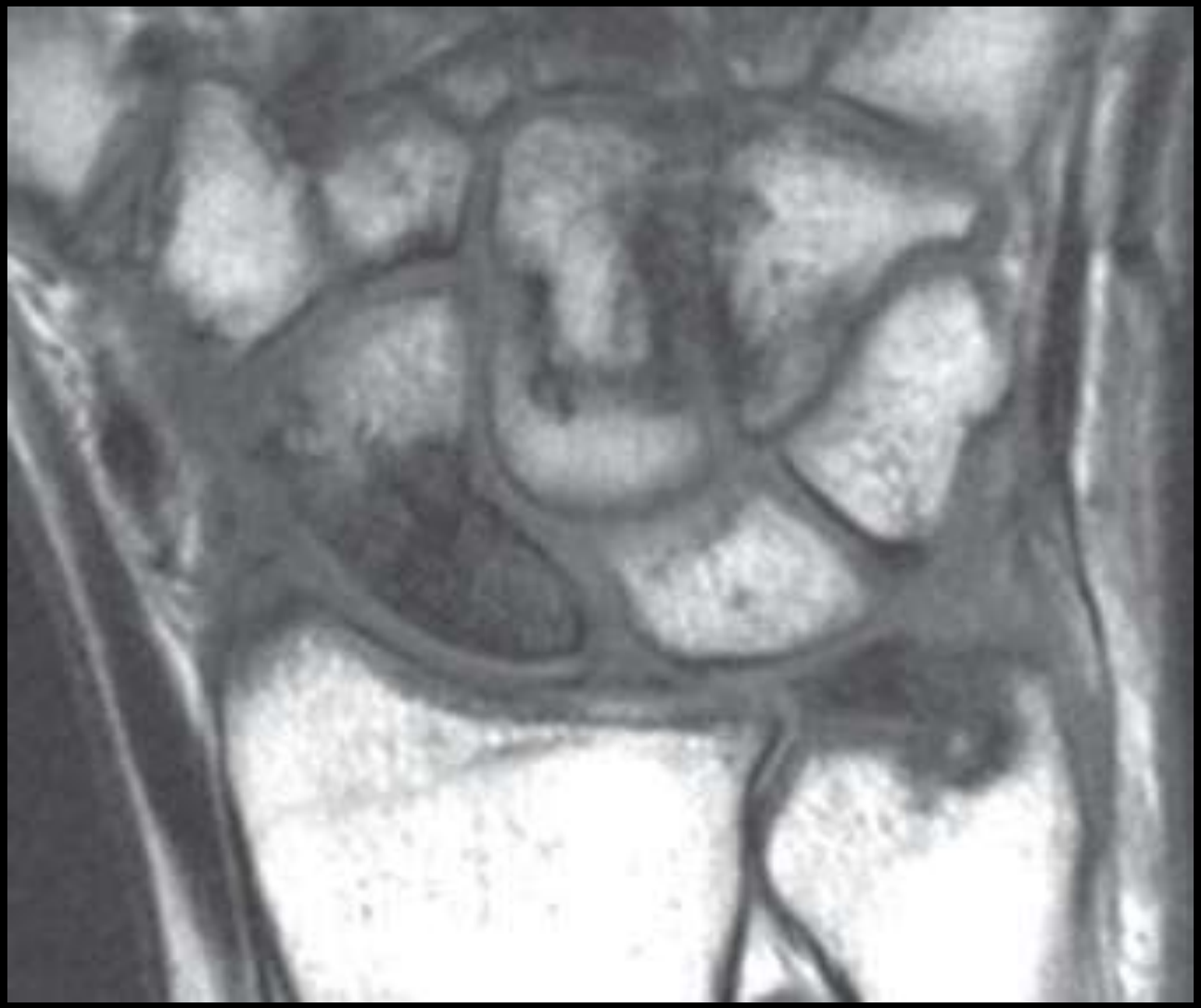
Materials & Methods

- Retrospective review of MR's by 2 MSK radiologists (blinded to original MR report and OR findings)
- Patients placed in 2 categories based ONLY on T1 of prox scaphoid pole:
  - Diffuse (entire prox pole) decr T1 (WRT skeletal muscle) = mod-to-high risk for AVN
  - Normal or heterogeneous decr T1 = viable-to-low risk
- >2 months after pt's were classified based on T1, MR's again reviewed by same 2 radiologists: look at STIR and classify as:
  - Mod-to-marked diffuse incr signal
  - Minimal diffuse incr signal
  - Incr signal only around fracture margin w. rest isointense to other carpal bones

Diffuse decr T1 proximal pole. No bleeding at surgery



Normal & heterogeneous T1: Viable at surgery



False + : diffuse decr T1, viable at surgery

Materials & Methods

Surgical Side:

- "Gold std" for AVN dx = OR findings
- 1 surgeon did 28 of the 29 surgeries
- Viable if any punctate bleeding upon:
  - debridement of fracture margin
  - curetting of any sclerotic bone
  - probing prox pole OR
  - Creation of groove for bone graft
- If no bleeding after extensive debridement = AVN

Results

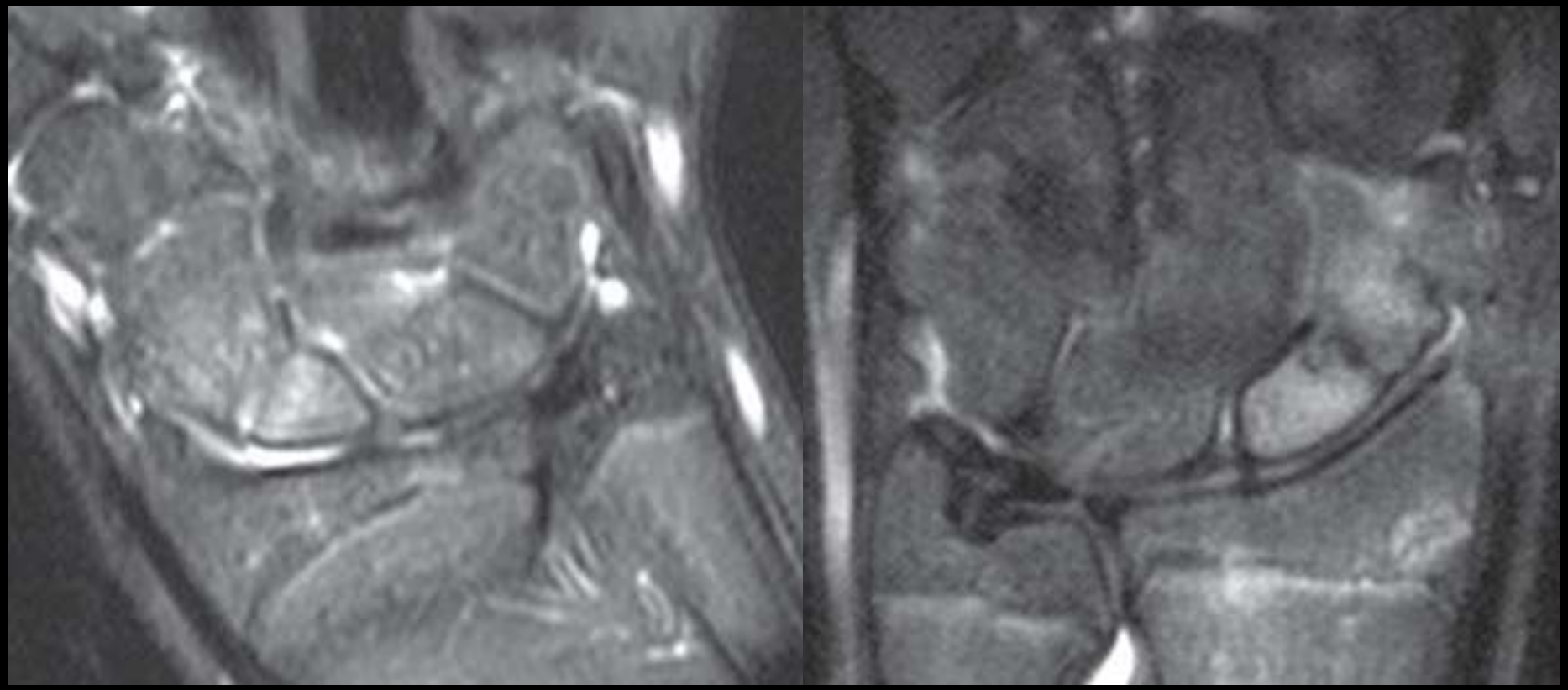
- 11 surgical AVN, 18 viable prox poles
- 13 fractures in prox pole or prox-mid third junction
  - 8 (62%) had AVN
- 16 fractures more distal
  - 3 (19%) had AVN
- Mean interval from MR to surgery = 54 days

Results

- Using T1 only:
  - 7 mod-to-high risk AVN
  - 22 viable-to-low risk AVN
- Comparing MR to OR findings:
  - 6 TP
  - 17 TN
  - 1 FP
  - 5 FN
- Sens 55%, Spec 94%, PPV 86%, NPV 77%, Accuracy 79%

Results

- STIR:
  - 15 mod-to-marked diffuse incr signal
  - 2 minimally diffuse incr
  - 12 incr signal around # margin but otherwise iso [6 of these had normal T1, 5 of these 6 (83%) had viable pole]
- 7 (64%) of 11 pt's with AVN = diffuse incr STIR
- 10 (56%) of 18 without AVN = diffuse incr STIR



Varying STIR signal. Viable

Varying STIR signal. AVN

Discussion

- This study: only required diffuse decr T1 to dx AVN
- Only 1 false positive result
- 5 false negatives: 2 may be d/t delay > 2 months b/w MR and surgery (i.e viable on MR, AVN at surgery)
- Other cause of FN: mummified fat
- Cost and time of +C-MR higher than unenhanced
- Limitations: couldn't blind the surgeons (used MR to plan OR), no direct comparison with +C-MR on the patients

Discussion

- Using contrast is confusing since some necrotic bone enhances & assigning % enhance is subjective
- Using diffuse decr T1 (< skeletal muscle) to dx AVN = simpler w high spec, high PPV and moderately high accuracy
- STIR / T2 FS not helpful in determining vasc status

TABLE 2: Comparison With Other Recent Studies Addressing MRI Evaluation of the Proximal Pole of the Scaphoid

Study	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
Cerezal et al. [7][a]					
Unenhanced, low T1/ T2-weighted image	71	74	73	45	89
Enhanced image	86	96	93	86	96
Anderson et al. [8]					
Low T1-weighted image	100	NA	NA	NA	NA
Enhanced image	54	NA	NA	NA	NA
Present study	55	94	79	86	77

Note— PPV = positive predictive value, NPV = negative predictive value, NA = not applicable.
[a]For the study by Cerezal et al., images were analyzed whether or not avascular necrosis was present.

Article 2

Radiology

Expand

Is Dynamic Gadolinium Enhancement Needed in MR Imaging for the Preoperative Assessment of Scaphoidal Viability in Patients with Scaphoid Nonunion?

Olivio F. Donati, MD, Marco Zanetti, MD, Ladislav Nagy, MD, Beata Bode, MD, Andreas Schweizer, MD and Christian W. A. Pfirrmann, MD

This Article

Published online before print June 28, 2011, doi: 10.1148/radiol.11110125

Abstract
Figures Only
» Full Text

- Classifications

Original Research
Musculoskeletal Imaging

Services

Radiology

Is Dynamic Gadolinium Enhancement Needed in MR Imaging for the Preoperative Assessment of Scaphoidal Viability in Patients with Scaphoid Nonunion?

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Abstract
Figures Only
» Full Text

- Classifications

Original Research
Musculoskeletal Imaging

Services

- Compare accuracy of dynamic +C-MR w. std MR to assess viability of prox pole in scaphoid nonunion

Materials & Methods

- 28 pt's
- Dynamic gad-enhanced MR < 90 days before surgery
- MR protocol: 1.5T
  - -C MR w. T1, intermediate-wt FS, SSPR ("std MR")
  - Dynamic post-gad: 10 ml gad, 1ml/sec followed by saline. COR image q1.5 sec x 60 sec.
  - Then COR T1 FS (post-gad, considered part of "std MR")

Materials & Methods

- Image analysis of “std MR”: 2 MSK radiologists
  - Signal of prox pole on T1 and intermediate-wt: iso, hypo, hyperintense to adj bone
  - Area of gad uptake judged to be: 80-100% of pole, 50-79%, 20-49%, <20%
  - Rate viability using 5 point scale: 1=definite viable, 2=probably, 3=indeterminate, 4=prob nonviable, 5=definitely nonviable

Materials & Methods

- Image analysis of dynamic +C-MR: 3rd reader
  - 3 ROI's: entire prox fragment, prox pole of scaphoid, radius styloid
- Time-signal intensity curves obtained
- Steepest upslope value (SSV) and difference in signal intensity calculated

- Gold Std: OR bleeding of bone surfaces
- 11 of 28 pt's: histology of scaphoid specimen, categorized as vital bone, necrotic, bone w. callus

Figure 2

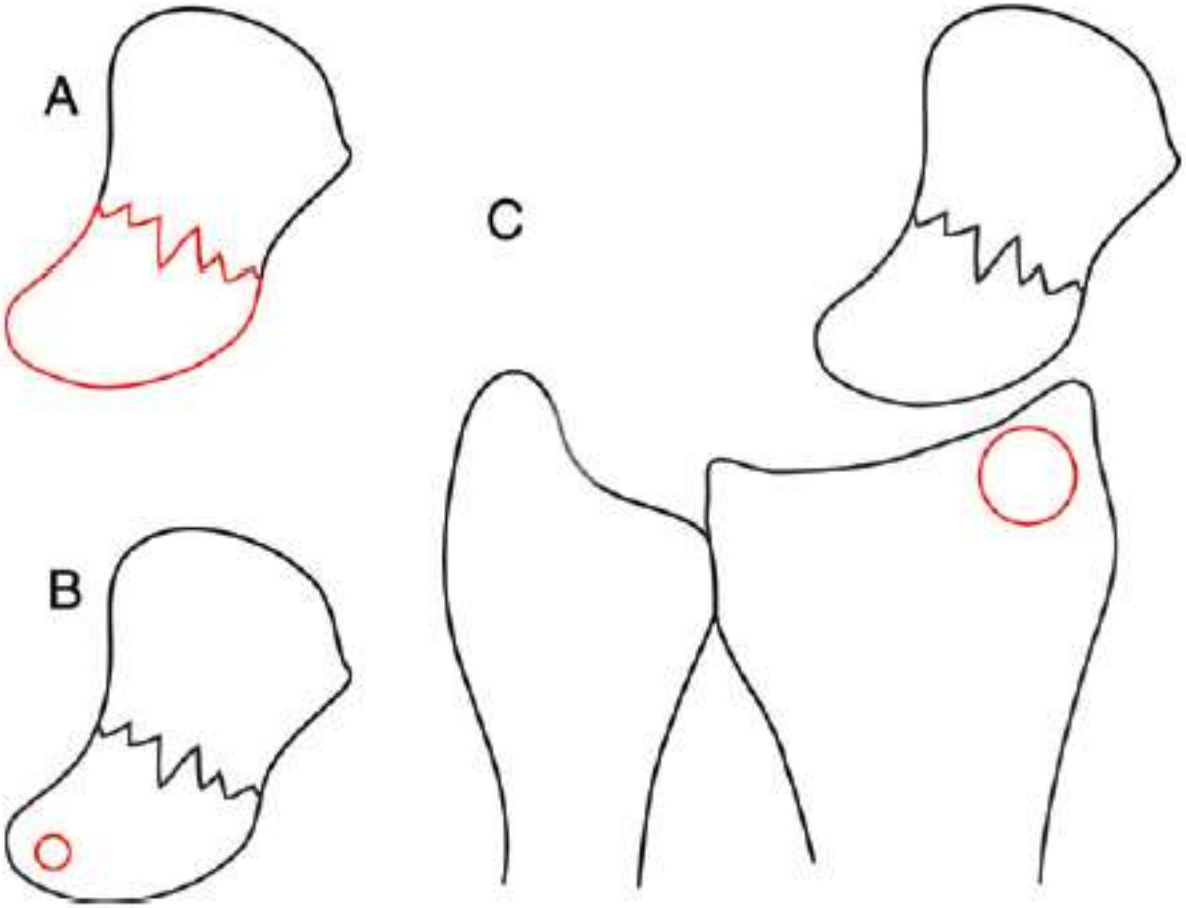


Figure 2: Diagram illustrates ROIs used to evaluate dynamic gadolinium-enhanced MR images. ROIs were placed, *A*, encircling the entire proximal fragment of the scaphoid, *B*, in the proximal pole of the scaphoid, and, *C*, at the radius styloid.

Results

- 13 (46%) of 28 pt's = nonviable prox pole at OR
  - 8 (62%)/7 (54%) judged to show gad uptake
- 15 viable prox poles
  - 13 (87%)/14 (93%) judged to show gad uptake
- Median area of gad uptake:
  - Grade 2 (20-40% of fragment) in nonviable
  - Grade 3 (50-79%) in viable

Results

- Comparing “std MR” w. OR:
  - Reader 1:
    - Sensitivity: 54%
    - Specificity: 93%
    - Accuracy: 75%
    - NPV: 70%
    - PPV: 88%

Reader 2:
62%
93%
78%
74%
89%

  - No sig difference b/w readers

Results

- Comparing values from dynamic +C MR to histologic findings = no sig correlation
  - i.e. comparing SSV &ΔSI to vital bone, necrotic bone, and callus formation: no significant correlation b/w vascularity & composition of prox. pole

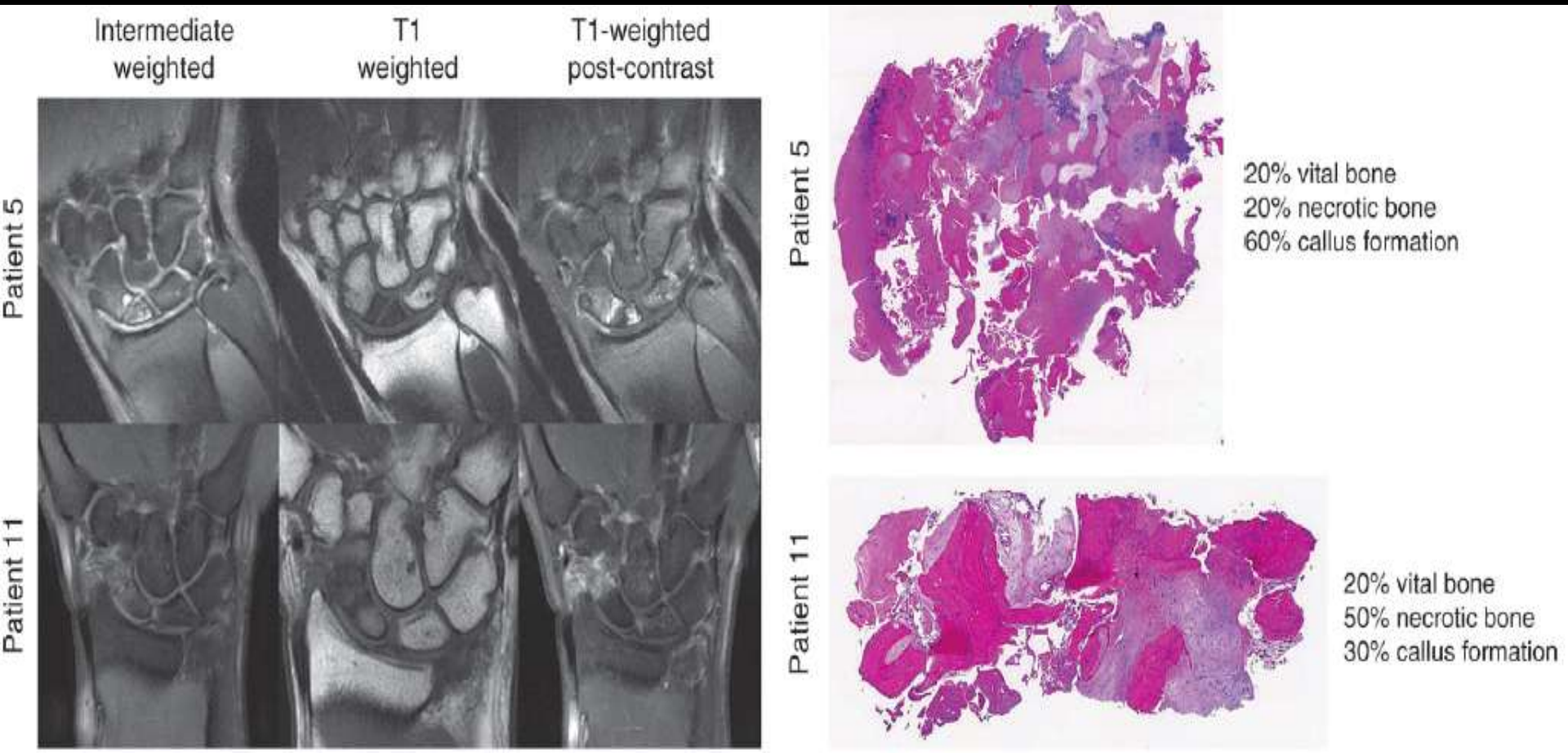
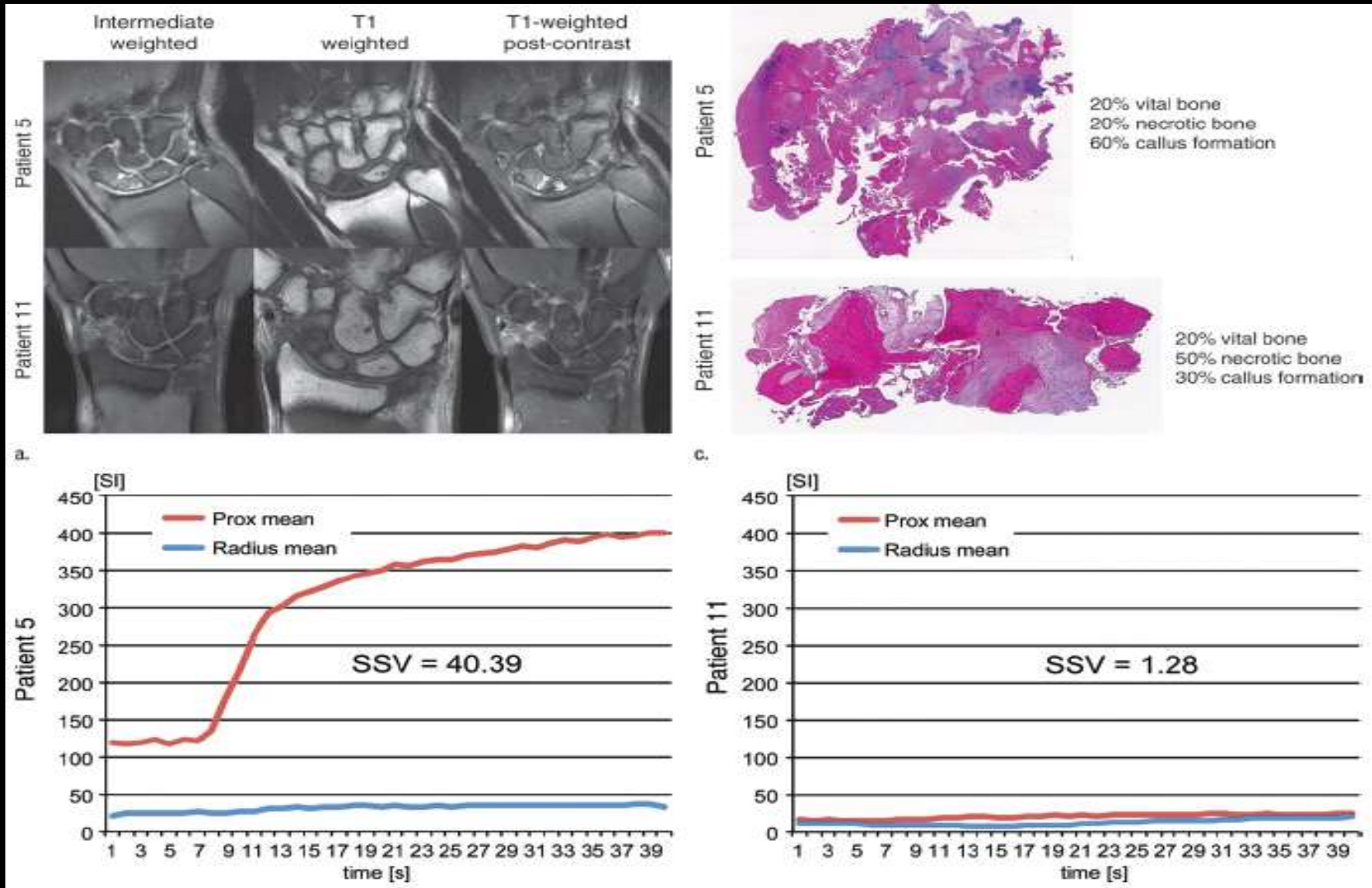


Figure 4: Findings in two patients with nonviable proximal scaphoid pole at intraoperative evaluation. **(a)** Intermediate-weighted turbo spin-echo images obtained with fat suppression (left column). The proximal scaphoid pole is hyperintense to adjacent bone in patient 5 and isointense to adjacent bone in patient 11. On T1-weighted spin-echo images (middle column), the proximal scaphoid pole is hypointense to adjacent bone in both patients. On T1-weighted gadolinium-enhanced images obtained with fat suppression (right column), only the scaphoid pole of patient 5 shows gadolinium enhancement. **(b)** Graphs of SSV of the proximal *(Prox)* scaphoid pole at dynamic gadolinium-enhanced MR imaging. The upslope is much steeper in patient 5 (SSV = 40.39) than in patient 11 (SSV = 1.28). **(c)** Photomicrographs show the patchy distribution of viable bone, necrotic bone, and areas of callus formation. (Hematoxylin-eosin stain; no magnification.)



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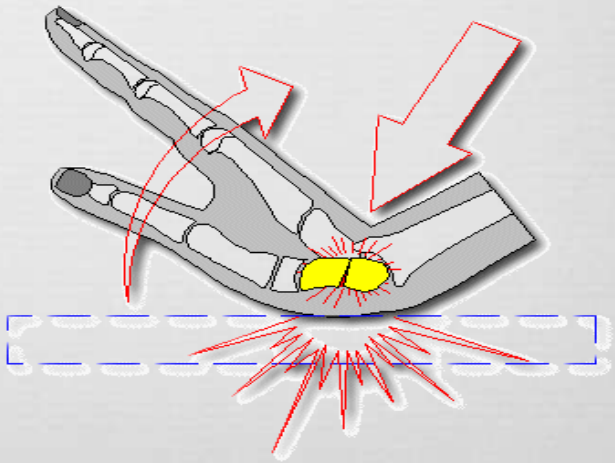
Discussion

- Other studies divided on whether gad-enhanced MR is accurate for evaluating bone viability
- Cerezal et. al (2000) = good correlation b/w degree of enhance and viability
- Others (Megerle et. al (2011), Singh et. al (2004)): no sig correlation b/w degree of enhance and healing of a scaphoid #

This Study

- Approx ½ nonviable poles showed some enhance (but smaller area than viable)

- Eventhough approx 90% viable poles showed enhance, not accurate predictor of viability



This Study

- Some studies WRT –C MR: good correlation b/w decr T1/T2 & poor vascularity
  - This study: decr T1/intermediate-wt to dx necrotic pole may not be as good as previously reported
  - 90% of viable & nonviable poles showed hypo or iso T1
    - Maybe d/t mature callus formation, which occurs in both viable and nonviable poles
  - 80-90% of both viable and nonviable: appeared hyper on fluid-sens sequences (d/t immature callus, blood vessels, edema, fibrosis)

This Study

- Dynamic gad-MR not better at predicting nonviability (in fact, inferior to std MR)
- Interesting: in the patients who had histology, no correlation b/w vascularity on dynamic MR and composition
  - Get patchy distribution of vasc bone, necrotic bone and callus on histology

My Conclusions

- Using decr T1 seems appropriate to dx AVN
- Use of gad not helpful
- T2 FS/STIR signal not useful
- Impromptu workstation brainstorm w. Dr. E. Fliszar:
  - ?Degree of decr T1 may indicate degree of nonvasc/ischemia
  - "grayish" decr T1: ?areas of still viable bone/normal marrow mixed w necrotic bone
  - "dark dark" T1: necrotic bone
  - Dark T1/Dark T2: necrotic bone

Thank you!

Disclaimer:

Hamid Torshizy was not injured in the making of this presentation.

Resources

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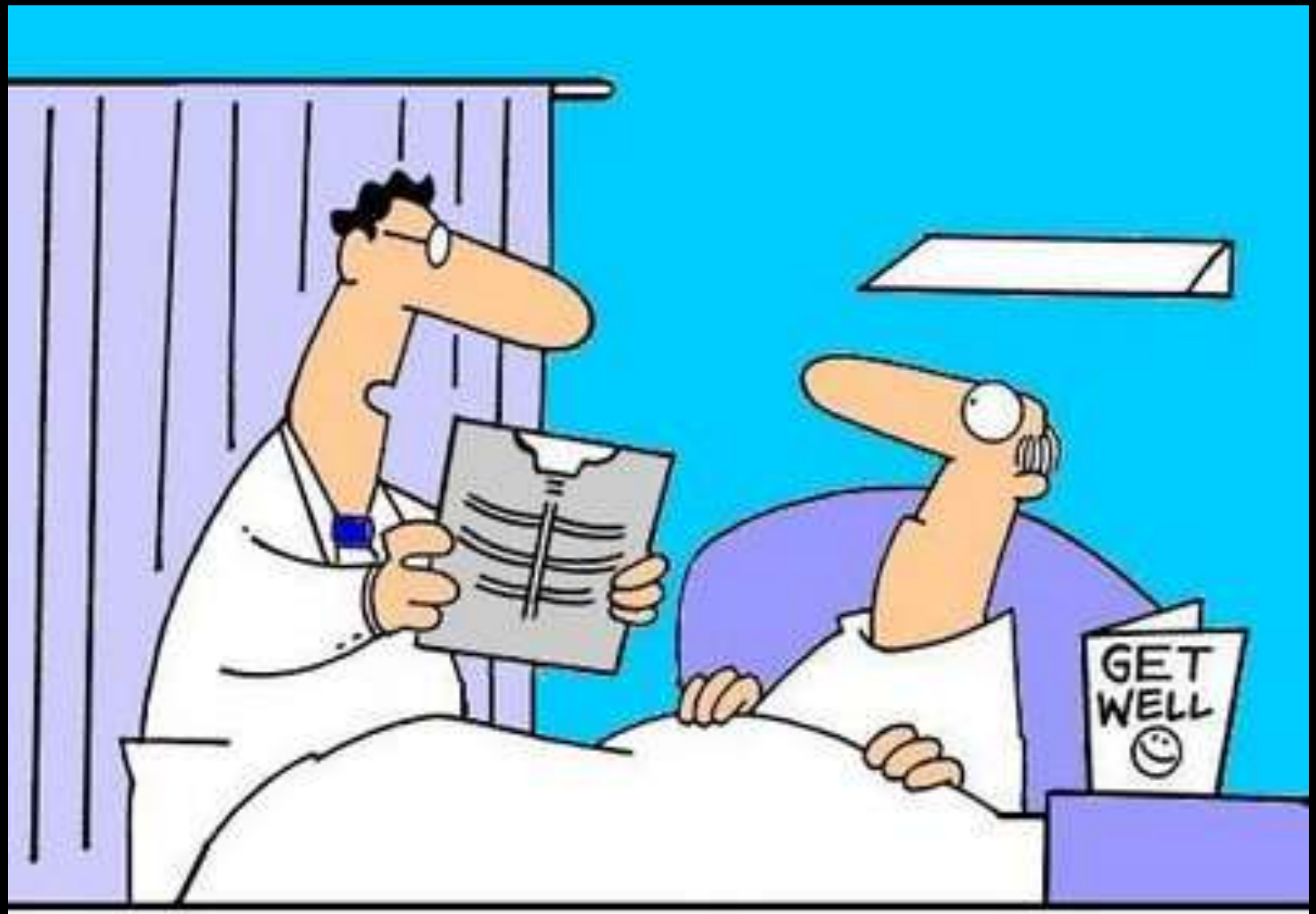
Resources

- http://www.learningradiology.com/archives06/COW%20229-AVN%20Scaphoid/avnscaphoidcorrect.html
- http://www.msdlatinamerica.com/ebooks/RockwoodGreensFracturesinAdults/sid680495.html



"Your x-ray showed a broken rib,
but we fixed it with Photoshop."