UPDATES IN MSK IMAGING

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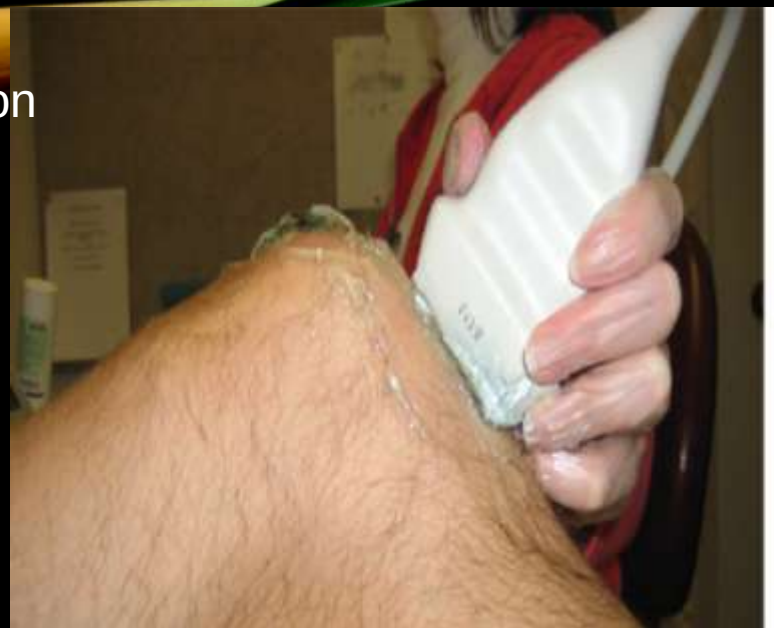
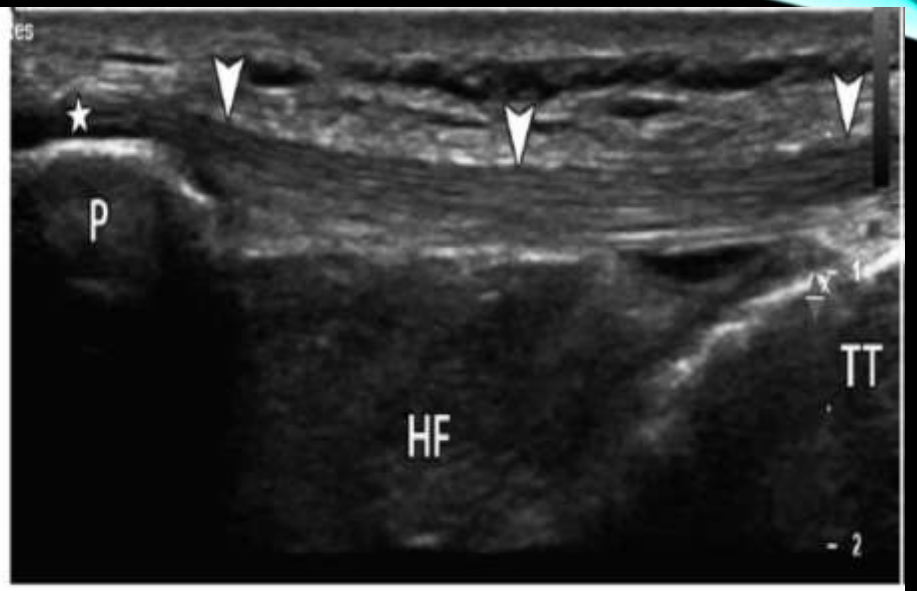
INTRODUCTION

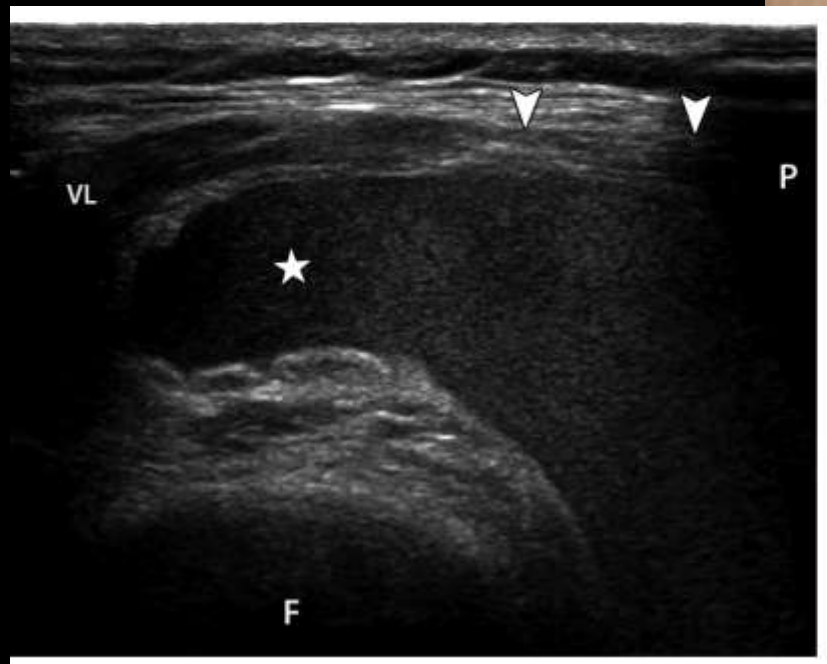
- Many musculoskeletal imaging advancements have been made within the past decade.
- This updates include many imaging modalities as US,CT & MRI.
- We will focus on most recent advances, including an update on shear wave sonoelastography, MRI parametric mapping and peripheral nerve imaging.

UPDATES IN US

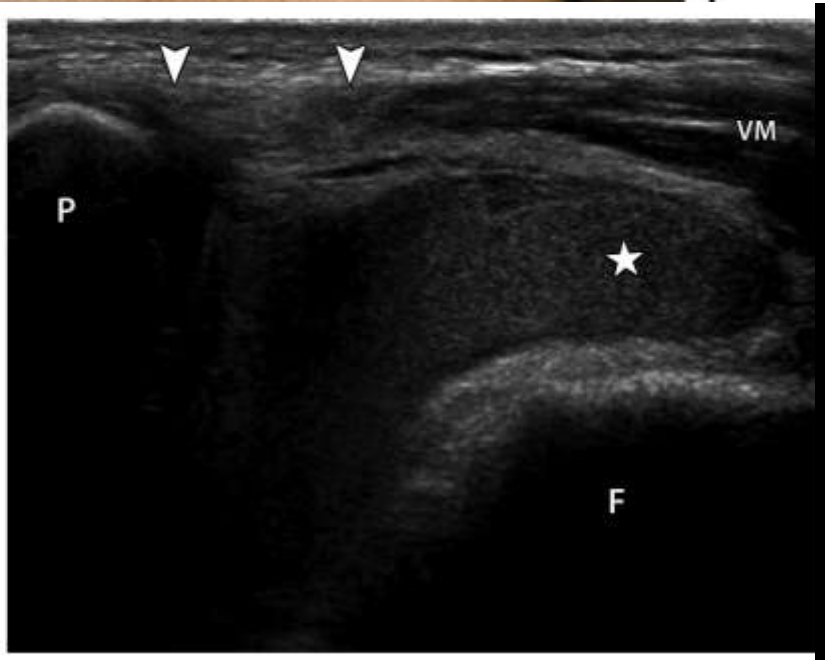
US evaluation of the patellar tendon





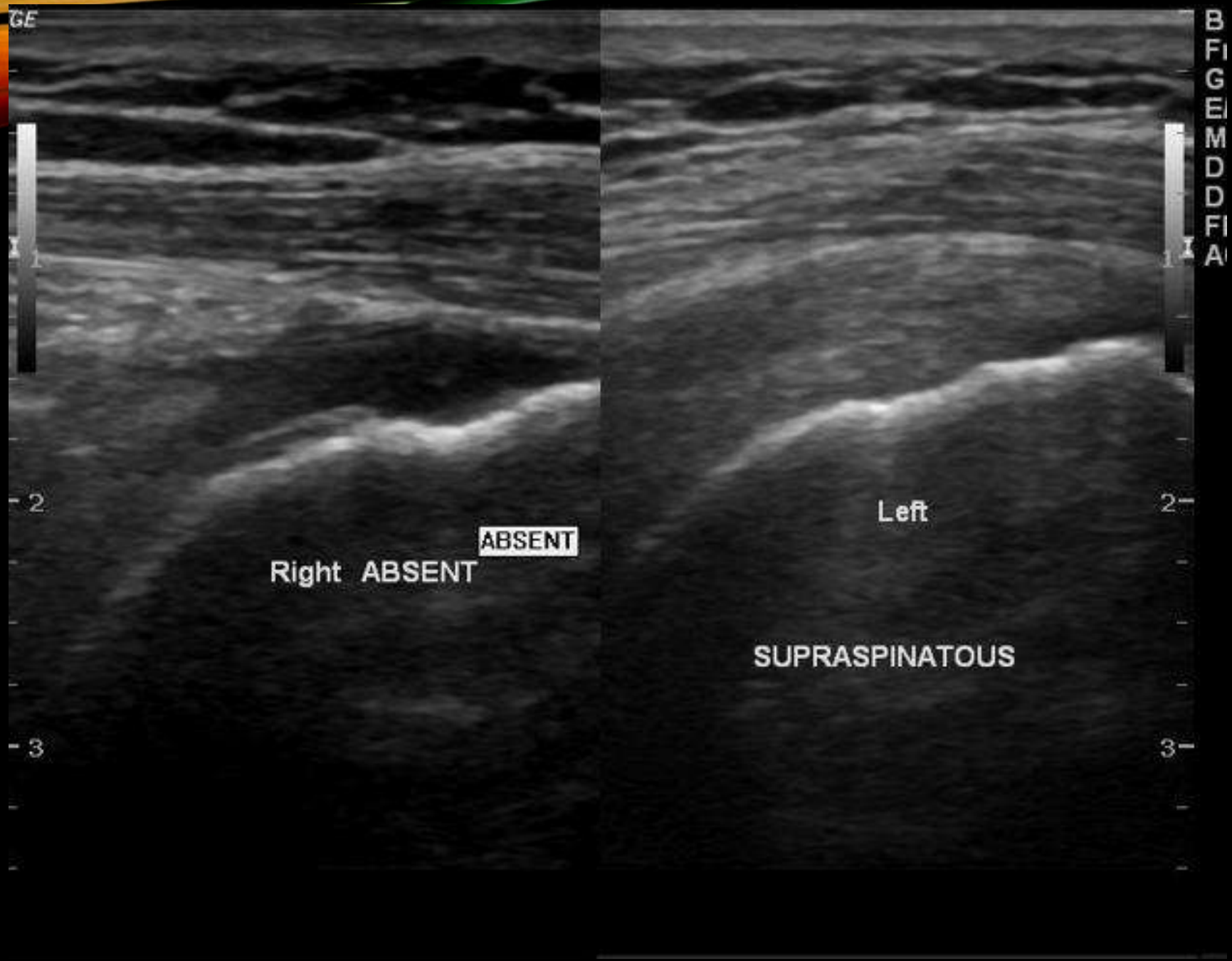


c.



d.

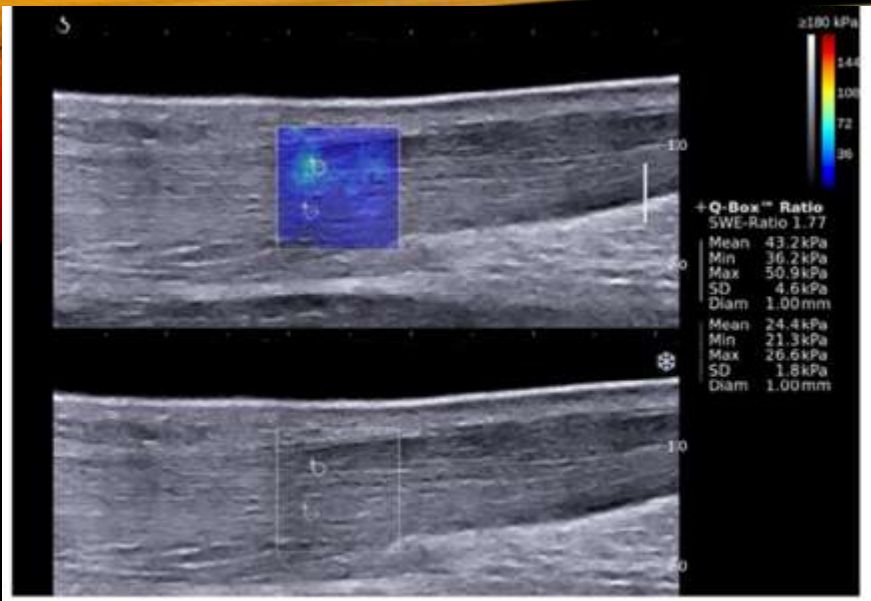
knee joint effusions at US



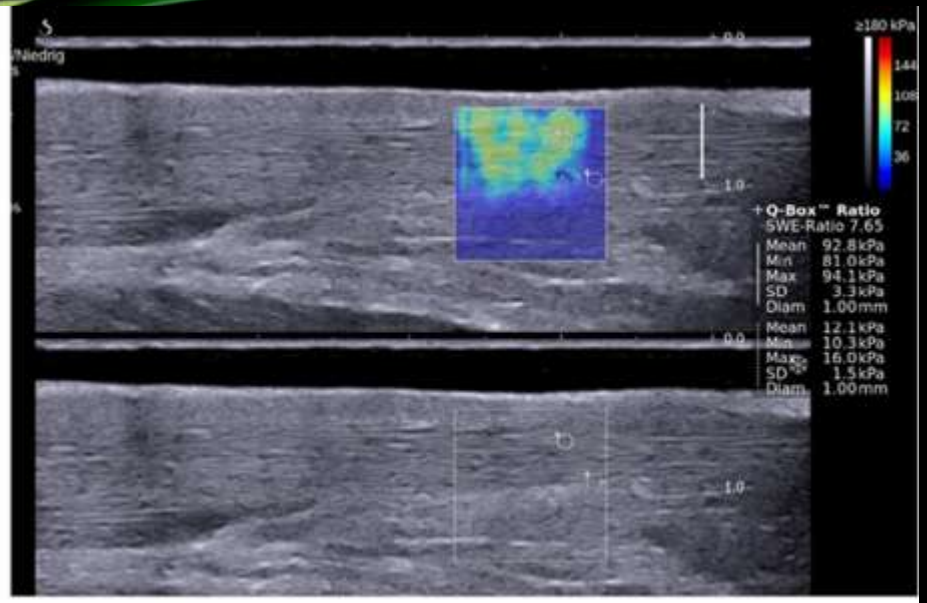
Right shoulder US shows supraspinatous tendon tear

ULTRASOUND ELASTOGRAPHY

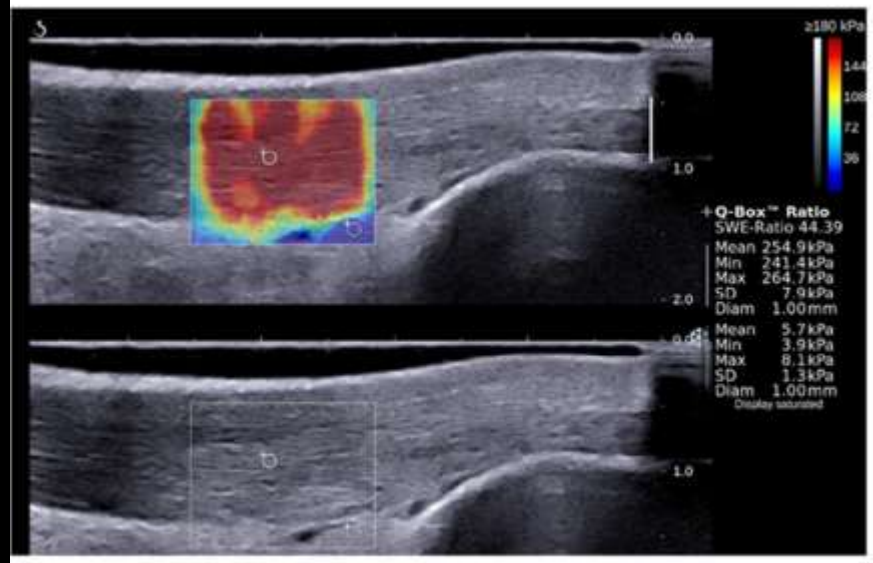
- Shear wave elastography (SWE) is a real-time diagnostic imaging technique that uses US to quantitatively assess differences in tissue stiffness.
- More recently, studies showed that SWE is useful tool in musculoskeletal imaging, especially for characterization and differentiation between normal and abnormal tendons.
- SWE enables assessment of tendon elasticity and detects early tendinopathies by demonstrating reduced tendon stiffness.
- Quantitative SWE data were measured in kilopascal (kPa; Young modulus) and in meters per second (m/s; shear wave speed).



(a) Blue = low / soft tissue rigidity

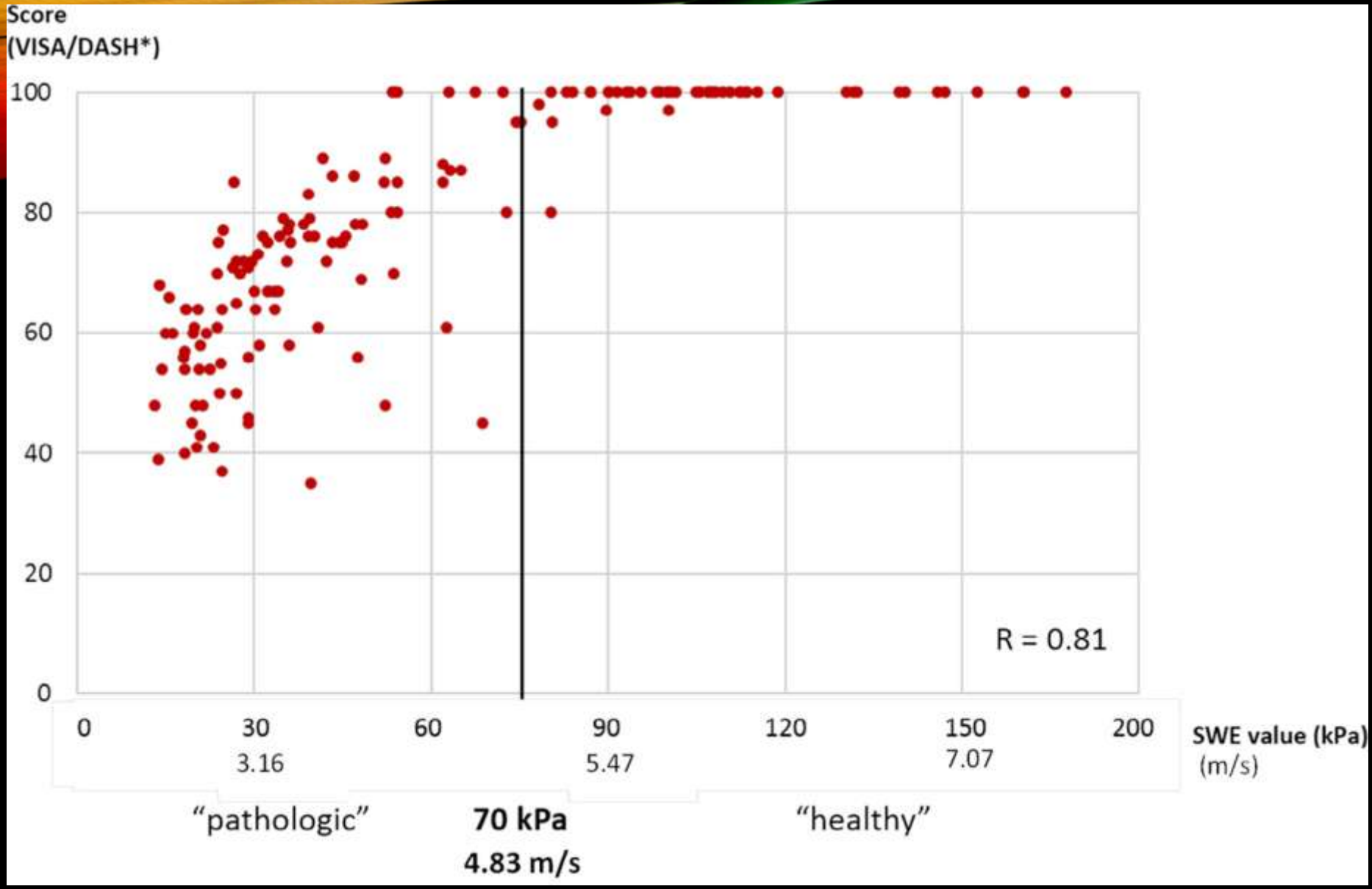


(b) Turqouise = intermediate tissue rigidity

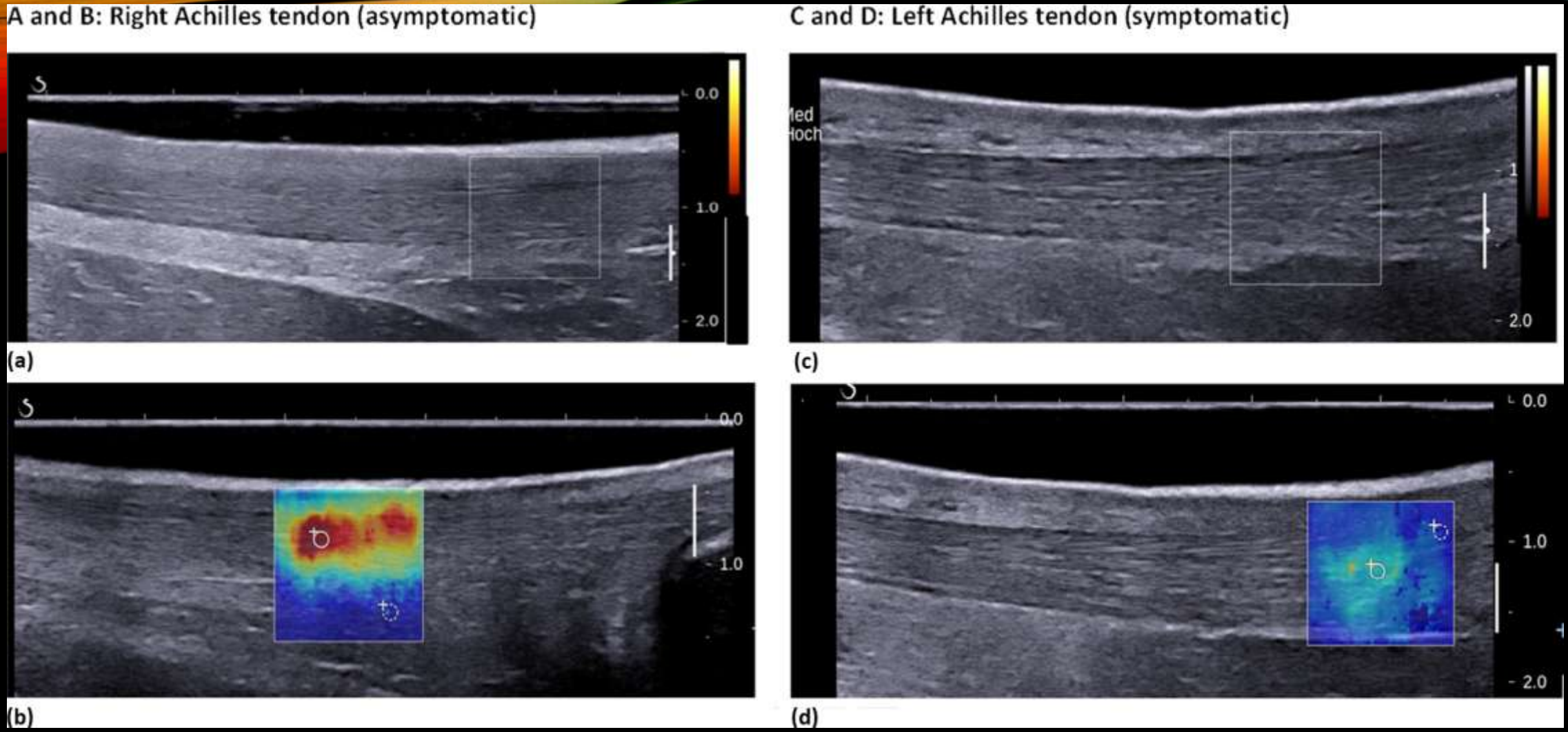


(c) Yellow to red = high / hard tissue rigidity

Semiquantitative evaluation of tendon stiffness by shear wave elastography (SWE). Tissue rigidity of tendons was assessed semiquantitatively by color charts (a–c). In every tendon, three equal Q-box measurements (1 cm2) were performed in the proximal, mid-and distal tendon parts (sagittal view). If tendon changes were visible at B-mode, at least one of these SWE measurements was performed
in the most conspicuous area seen at B-mode ultrasound (US). Tendon stiffness then was grouped into “soft” (a), “intermediate” (b), or “rigid” (c), according to SWE color chart. (a) Blue: low/soft tissue rigidity, (b) turquoise: intermediate tissue rigidity, (c) yellow to red: high/hard tissue rigidity.

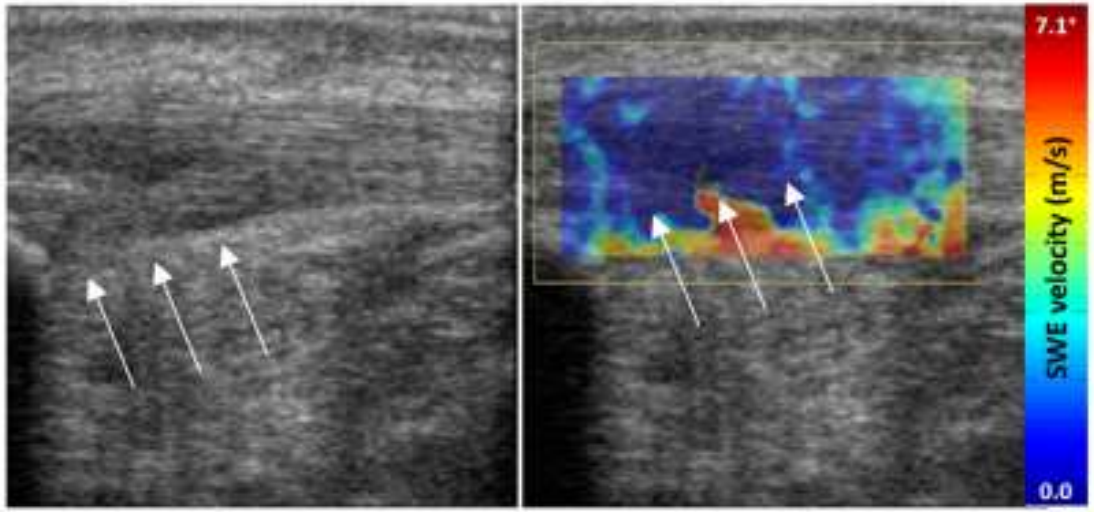


Correlation of shear wave elastography (SWE) mean values and clinical symptoms (score values) (*n* = 140).*Initial Disabilities of the Arm, Shoulder and Hand (DASH) score (0–100) was inverted to 100–0 to make it comparable to the VISA score.



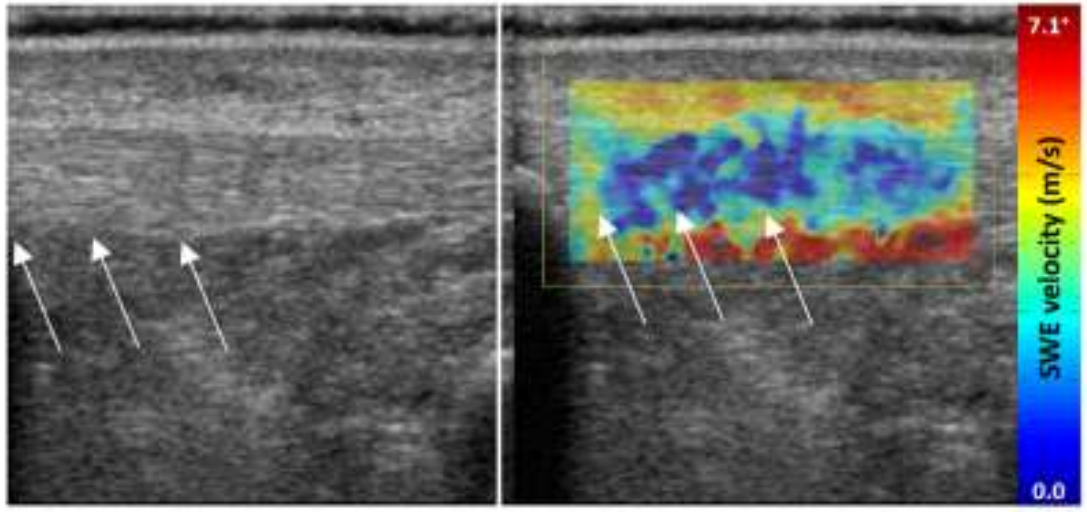
Intraindividual comparison of a symptomatic and a healthy tendon by ultrasound (US), power Doppler (PD), and shear wave elastography (SWE). Right (a, b) and left (c, d) Achilles tendons in a 35-year-old patient.. On B-mode ultrasound, no structural changes were visible, and no neovascularization was present at power Doppler (a and c) in both Achilles tendons. At SWE, the symptomatic left tendon (d) was significantly softer than the asymptomatic right tendon (b). Semiquantitative assessment of tendon stiffness by SWE revealed a red (hard rigidity) SWE color chart in the asymptomatic right tendon and a turquoise (intermediaterigidity) SWE color chart in the symptomatic left tendon.

Left Knee with Patellar Tendinopathy



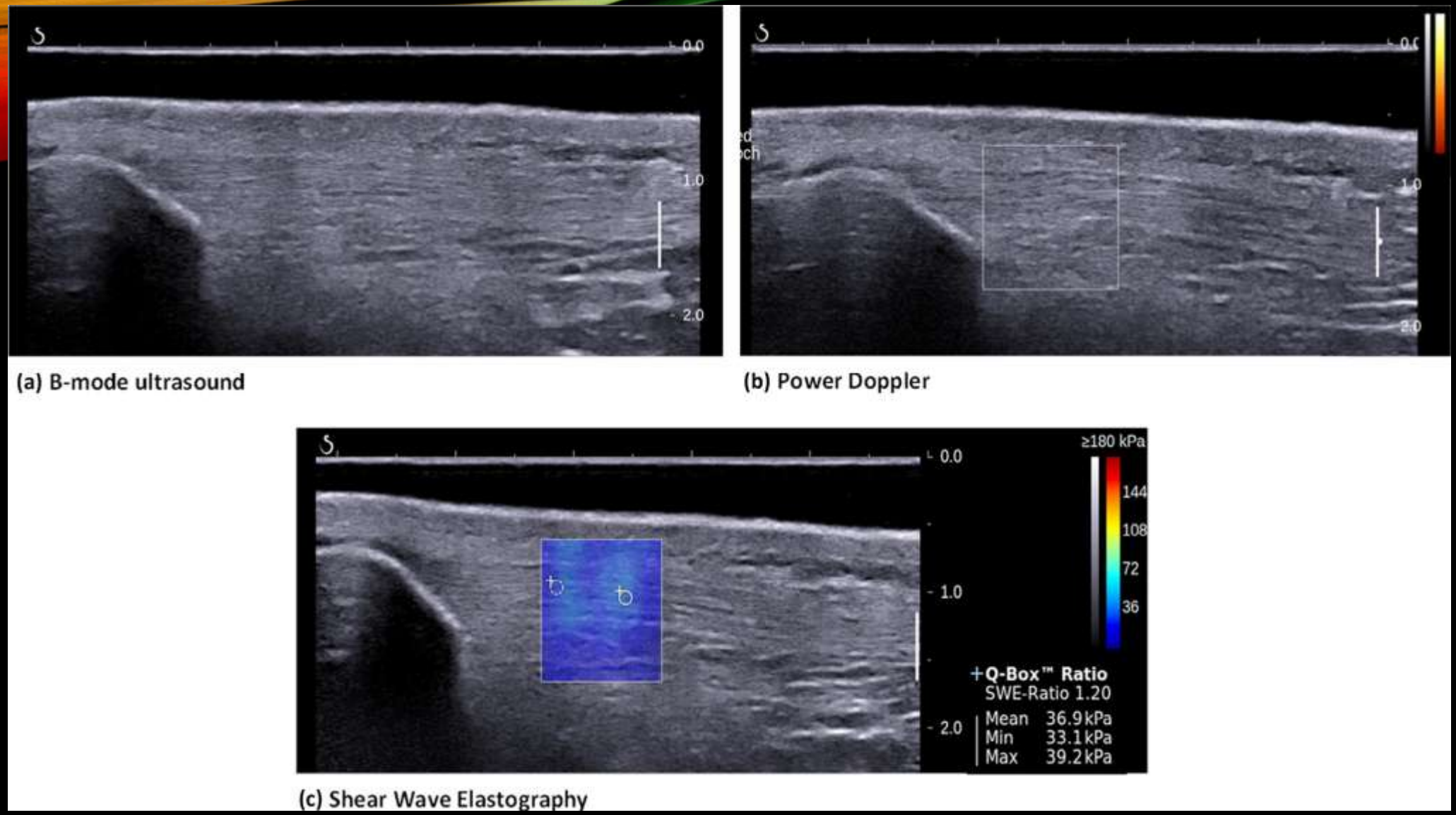
Longitudinal proximal patella tendinopathy (arrow) with decreased SW velocity

Right Knee with Normal Patellar Tendon



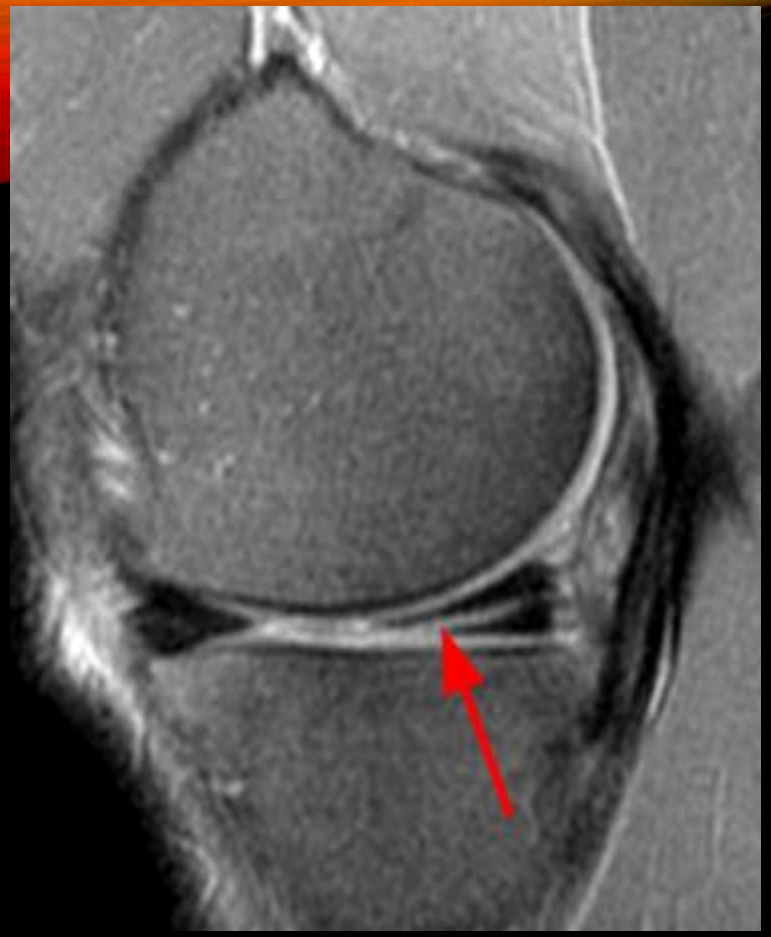
Longitudinal normal proximal patella tendon (arrow) with comparatively increased SW velocity

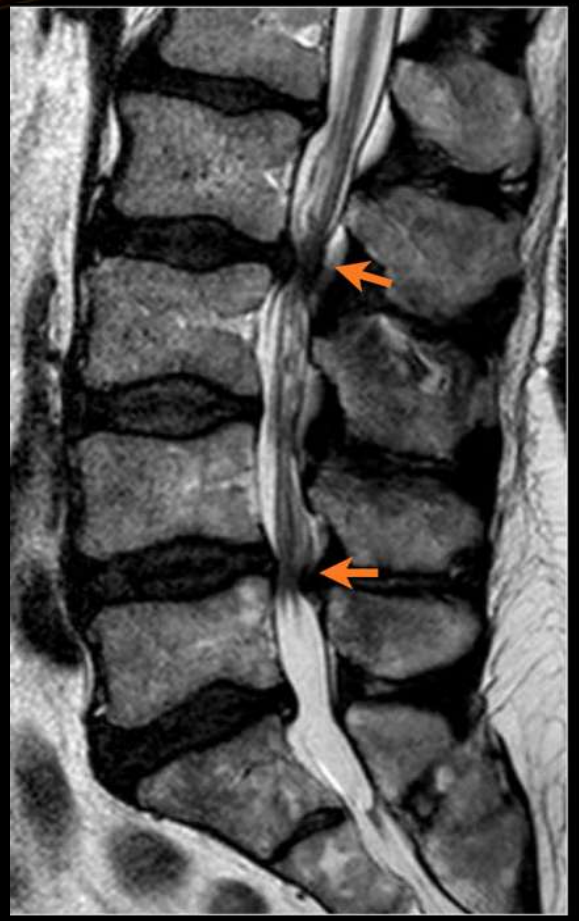
Figure 1. (a) Left knee displays patellar tendinosis and comparatively lower (deep blue) SW velocity in comparison to the contralateral (right) knee. (b) Increased (lighter blue) patellar tendon SWE velocity (m/s) demonstrated within the normal, healthy right knee of the same subject

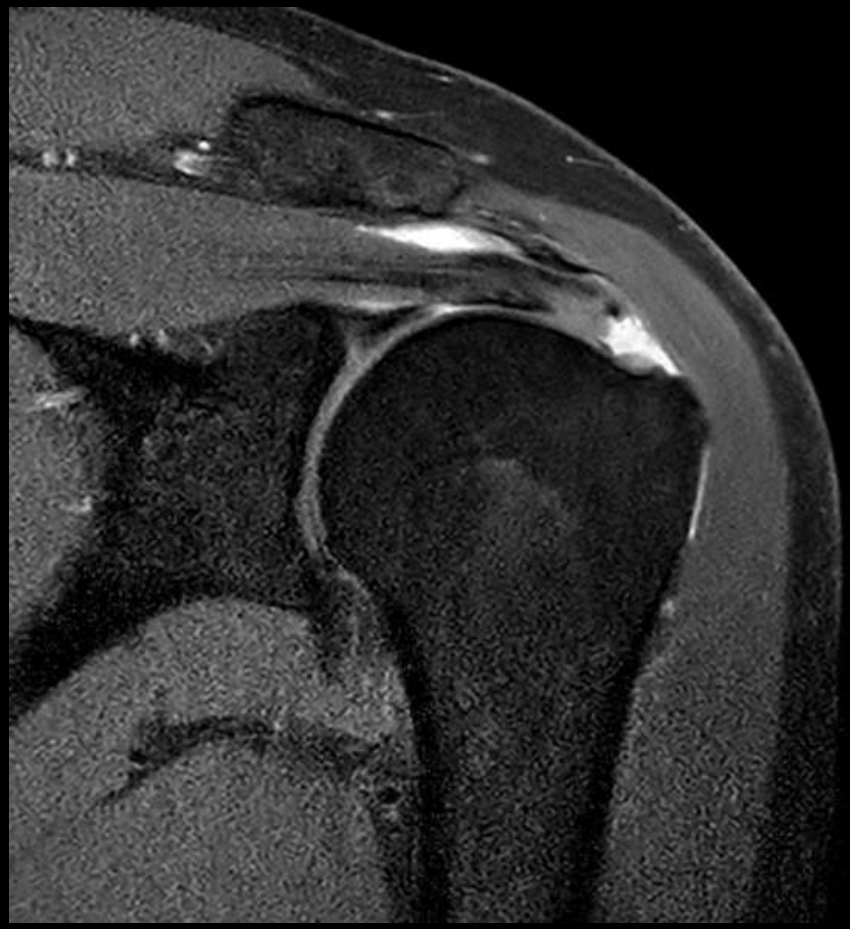


44-year-old patient with severe tendinopathy of the right patellar tendon. On B-mode ultrasound (a), no structural changes were visible, and no neovascularization was present at power Doppler (b) in the tendon. Semiquantitative assessment of tendon stiffness by shear wave elastography (SWE) (c) revealed a blue (soft-tissue rigidity) SWE color chart. Region of interest (ROI)-based quantitative assessment of tendon stiffness (c) showed a mean SWE value of 36.9 kPa (3.51 m/s), demonstrating a soft tendon. In this patient, only SWE was able to detect tendon pathology by terms of reduced tendon stiffness.

UPDATES IN MRI

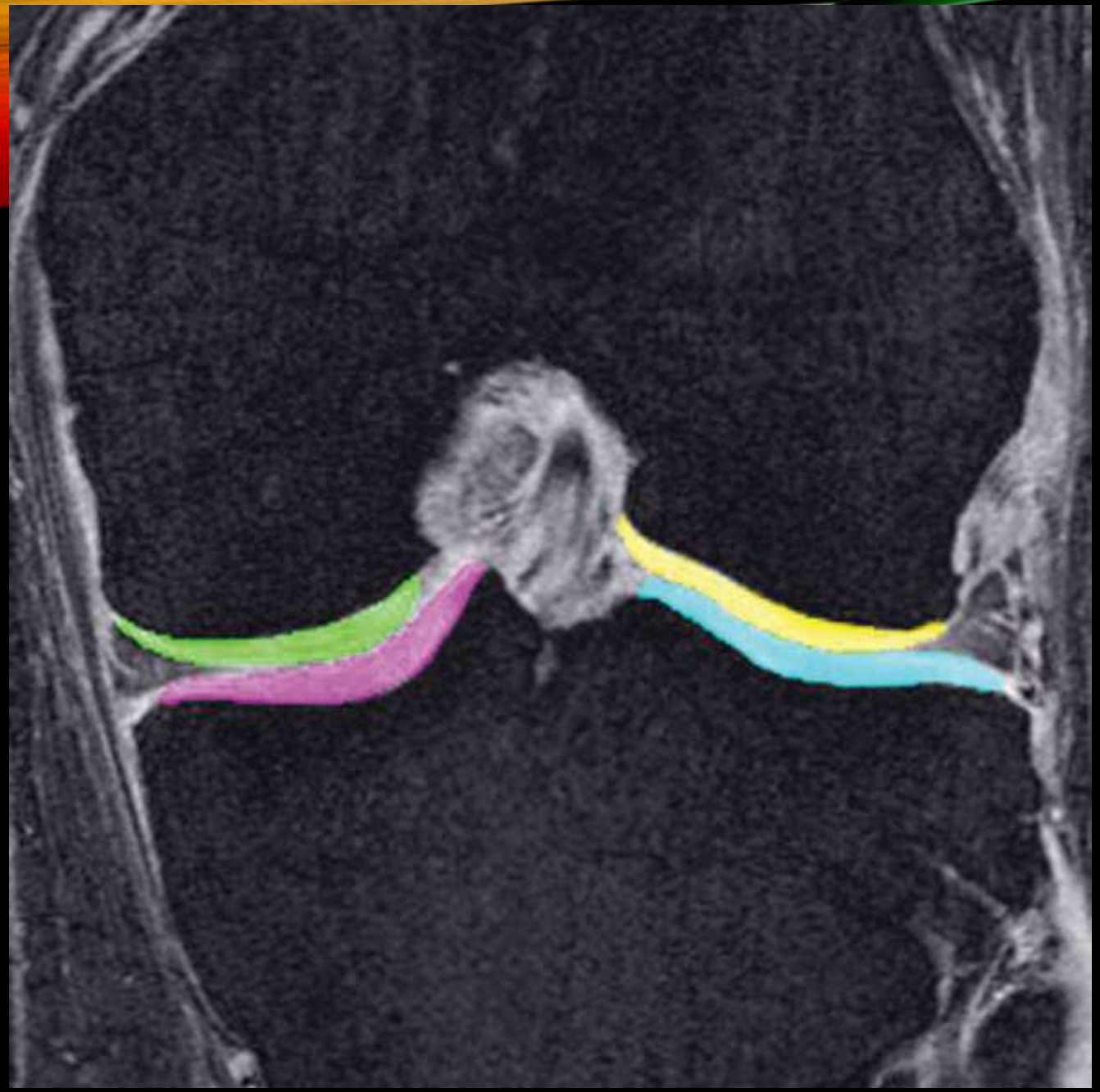






QUANTITATIVE MRI ANALYSIS OF ARTICULAR CARTILAGE

- Cartilage quantification requires segmentation of the hyaline cartilage tissue and uses the 3D nature of MRI data sets to evaluate tissue dimensions (eg, thickness, volume).
- This measurement requires high spatial-resolution 3D imaging sequences that delineate the bone-cartilage interface and cartilage surface with adequate contrast.
- These are validated in spoiled gradient-echo images and in double-echo steady-state images.
- These approaches have led to the observation that (regional) cartilage thickening, predominantly in the external medial femoral condyle, likely may be an early event in OA pathophysiology.

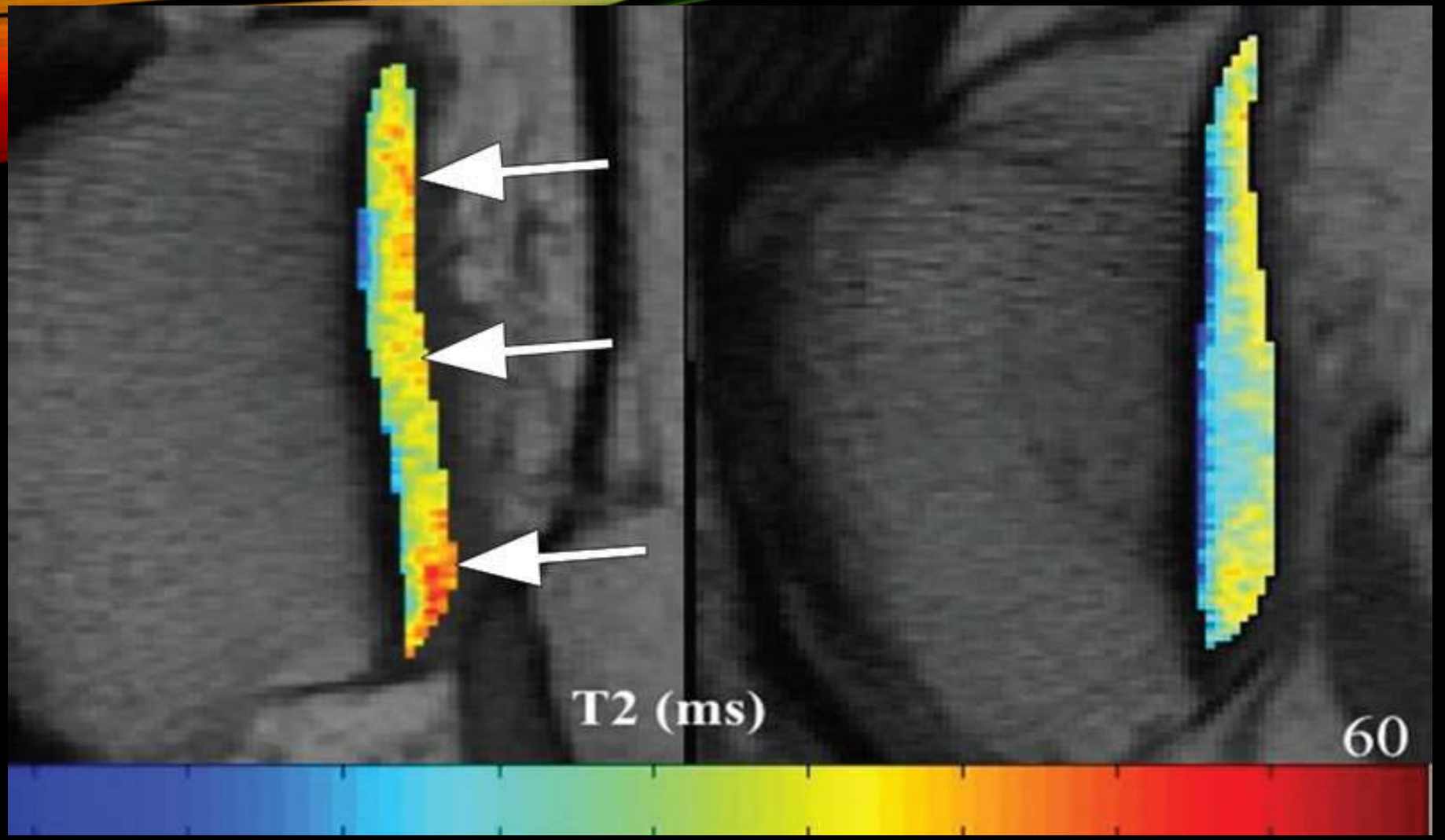


High-spatial-resolution coronal knee MRI in a 58-year-old man obtained with fast low-angle shot (repetition time, 20 msec; echo time, 7.57 msec; flip angle, 12°; field of view, 120 mm; 512 3 512 matrix) sequence with water excitation is commonly used for segmentation and quantitative morphometric analysis. Manually segmented medial tibial cartilage marked in purple, medial femoral cartilage marked in green, lateral tibial cartilage marked in light blue, and lateral femoral cartilage marked in yellow. (Figure courtesy of Felix Eckstein, MD, Paracelsus Private Medical University Salzburg and Nuremberg & Chondrometrics, Ainring, Germany.)

COMPOSITIONAL MRI

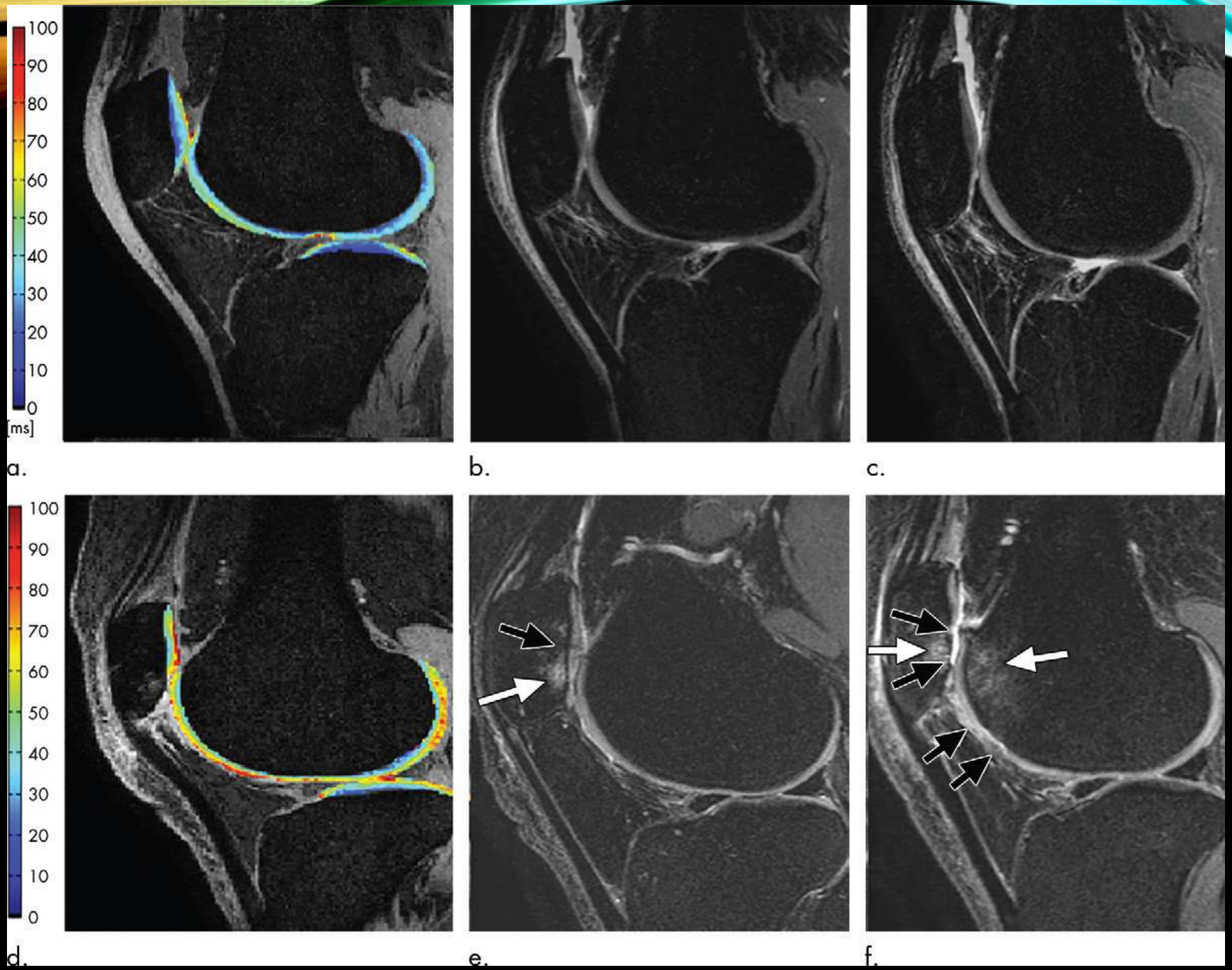
- Compositional MRI techniques have been developed to characterize the cartilage matrix quality at a stage where abnormal findings are early and potentially reversible
- Over the past 2 decades, several technologies have been developed: **T2 mapping**; **spin lattice relaxation time in the rotating frame (T1r) technique**; **delayed gadolinium-enhanced MRI of cartilage (dGEMRIC)**; **sodium imaging; and glycosaminoglycan chemical exchange saturation transfer imaging**, or gagCEST.
- Most studies have used **T2 and T1r mapping**, and these techniques are potentially the most applicable clinically.
- T2 relaxation time measurements provide information on water content of the extracellular matrix and architecture of the collagen fibers, including their orientation.

- T2 map measurements are elevated in individuals with early stages of OA and in individuals with associated risk fact for OA.
- T1r map measures the cartilage proteoglycan concentration
- T1r maps can characterize early degradation of cartilage matrix, and those areas show higher T1r values
- So, OA cartilage has elevated relaxation times (T_2 and $T_{1\rho}$) compared to healthy cartilage tissue.
- In OA, the T_1 relaxation times varied from 62 ± 5 msec to 100 ± 8 depending on the degree of cartilage degeneration.
- The T_2 relaxation times varied only from 32 ± 2 msec to 45 ± 4 msec.

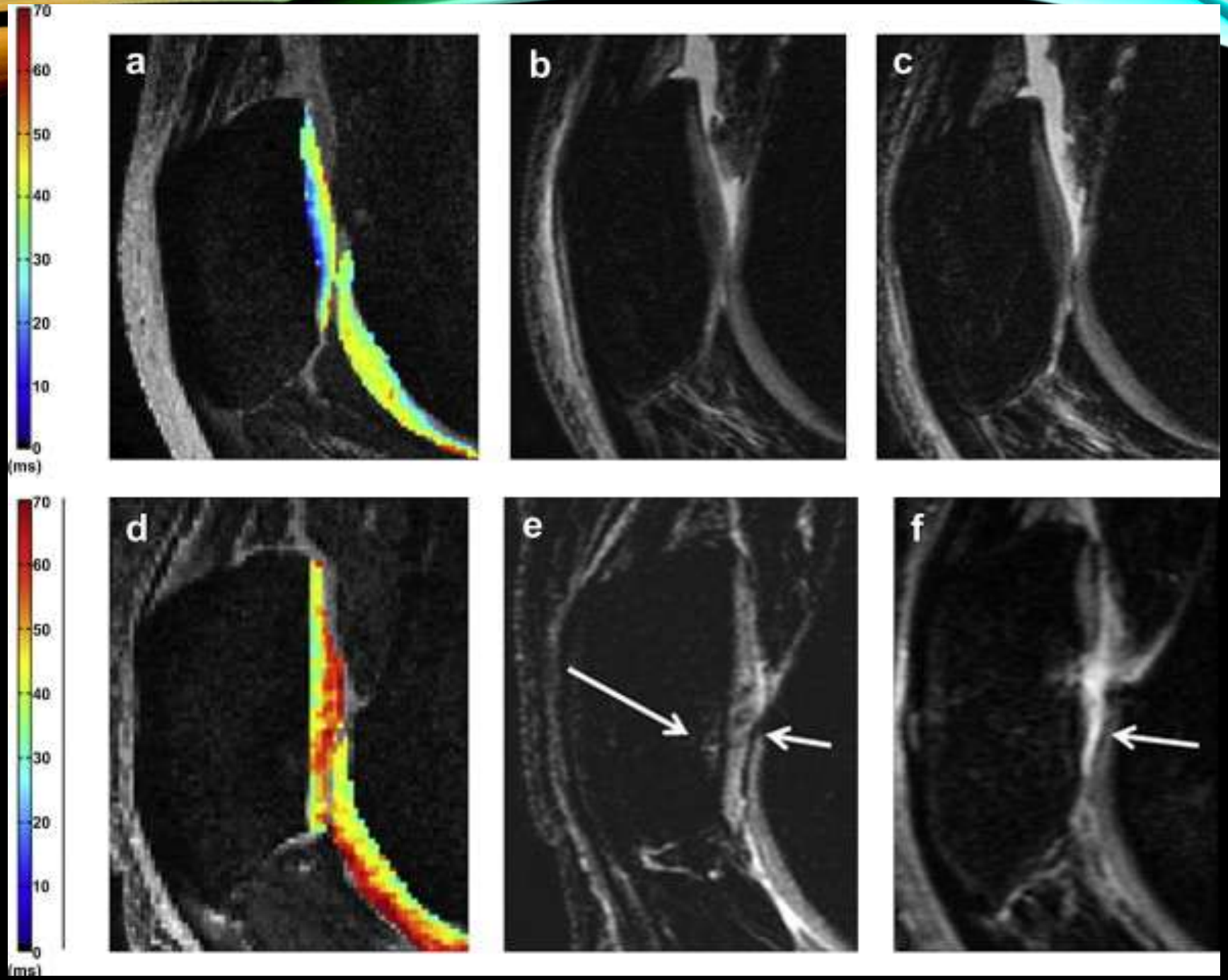


Images show T2 color maps based on sagittal T2 multiecho spin-echo sequence (repetition time, 2700 msec; echo times, 10, 20, 30, 40, 50, 60, 70 msec; field of view, 120 mm; section thickness, 3 mm; gap, 0.5 mm) of patella cartilage in a 61-year-old man with diabetes mellitus (left) and another without diabetes mellitus (right). Patella cartilage was morphologically normal in both patients, but T2 values are diffusely elevated (arrows) in individual with diabetes mellitus compared with age-matched control

Baseline T1 relaxation time in rotating frame (T1r) color maps of lateral knee joint compartment in a 56-year-old woman with progressive cartilage degeneration and another 63-year-old woman without progressive cartilage degeneration over a period of 2 years. **(a)** Sagittal segmented T1r baseline values throughout lateral joint compartment in patient without progressive disease. **(b)** Corresponding sagittal intermediate weighted fat-suppressed image obtained at same time point does not show any cartilage surface damage. **(c)** Sagittal intermediate-weighted fat-suppressed image acquired 2 years later still does not show any incident cartilage damage. **(d)** In patient with progressive cartilage damage over time, segmented baseline T1r values show diffuse elevation in entire lateral compartment compared with patient without cartilage damage. **(e)** Corresponding sagittal intermediate-weighted fat-suppressed image shows normal trochlea cartilage without surface defects. Patella cartilage shows linear hypointensity (black arrow) but no defects. Subchondral bone marrow signal abnormality underlying patella cartilage is also observed (white arrow). **(f)** After 2 years, high-grade thinning of cartilage at trochlea and full-thickness cartilage loss at patella (black arrows) is demonstrated. In addition, there is increase of subchondral bone marrow lesions at patella and trochlea (white arrows).



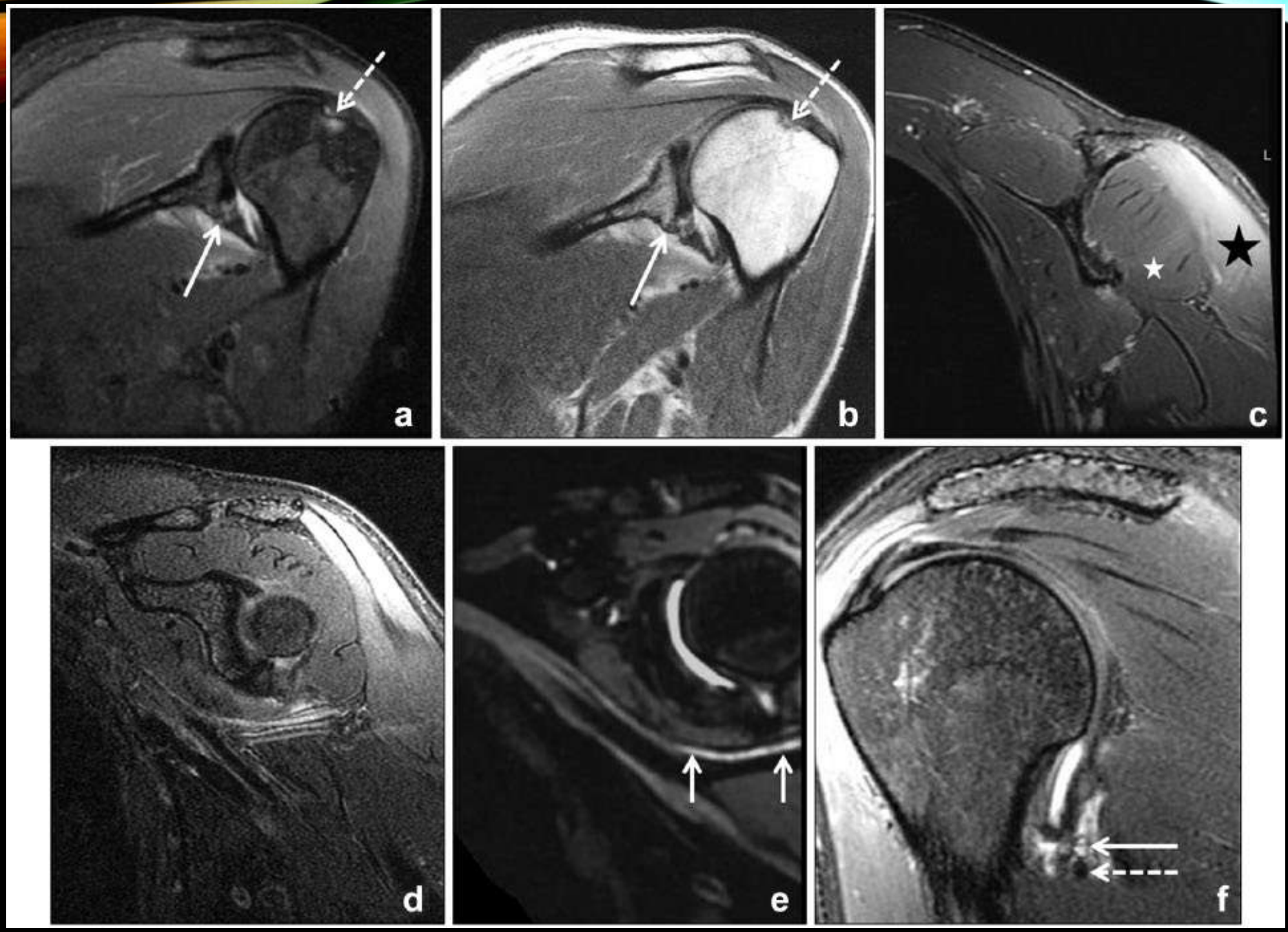
MR color T1p maps with low $T_{1\rho}$ values in a subject with non-progressive changes (a-b-c) and high $T_{1\rho}$ values in a subject with progressive disease (d-e-f).

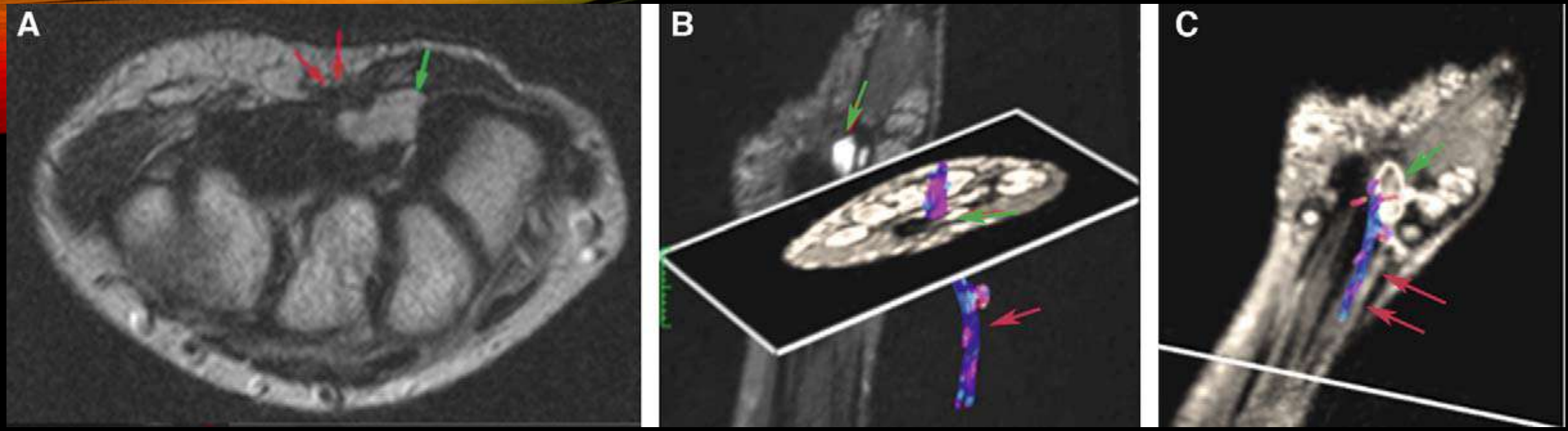


Magnetic resonance neurography (MRN)

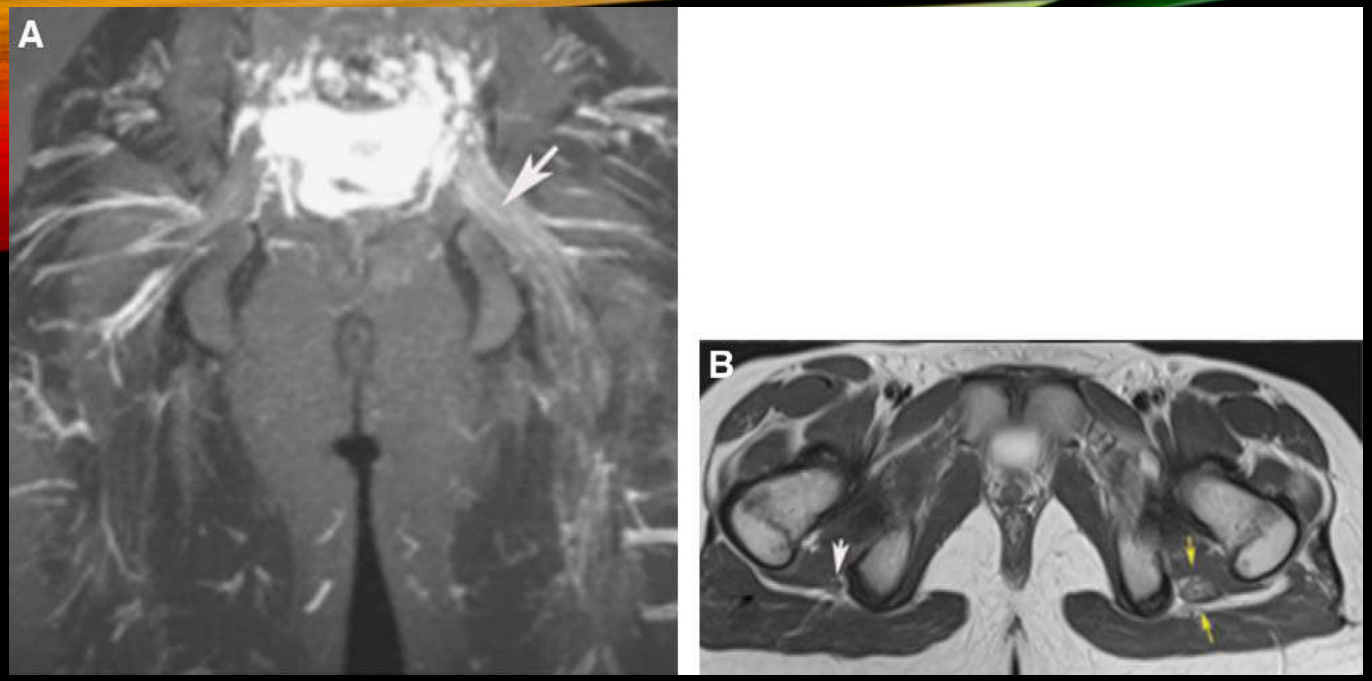
- It is non-invasive imaging technique for dedicated assessment of peripheral nerves.
- It is used to assess peripheral nerve entrapments and impingements as well as localization and grading of nerve injuries and mass lesions.
- Commonly used imaging protocols include:
  - Axial T1-weighted
  - Axial fat-suppressed T2-weighted
  - 3D STIR (short tau inversion-recovery)
  - 3D PSIF (reversed fast imaging in steady state precession)
  - Diffusion tensor imaging (DTI) and Fiber tractography (FT).
- Use of intravenous gadolinium contrast is usually restricted for assessment of infection or perineural involvement by tumor.

A 33-year-old woman status post left shoulder dislocation. (a) Oblique coronal inversion recovery and (b) proton density images of the left shoulder demonstrate a Hill-Sachs lesion (dashed arrow) and partial capsular detachment from the scapula (solid arrow). Dedicated magnetic resonance imaging of the left axillary nerve was acquired at 6-week follow-up to evaluate a dense axillary nerve palsy postdislocation. (c) Coronal T2-weighted Dixon fat-suppressed image confirms denervation edema of deltoid muscle (black star) and relative sparing of the teres minor (white star). (e) Axillary nerve (arrows) is better delineated from adjacent vessels on vascular-suppressed, 3-dimensional T2-weighted curved multiplanar reformatted image compared with (d) the 2-dimensional image without vascular suppression. (f) T2-weighted sagittal image confirms suspected stretch injury, with signal hyperintensity of the axillary nerve (solid arrow) adjacent to the capsule with the posterior circumflex humeral artery (dashed arrow

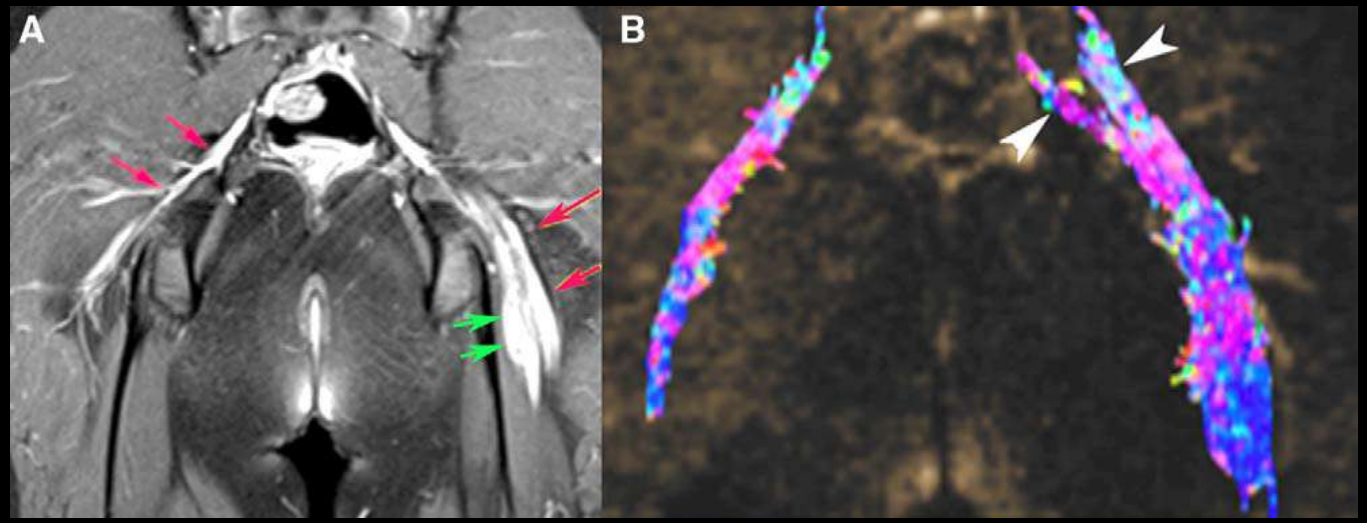




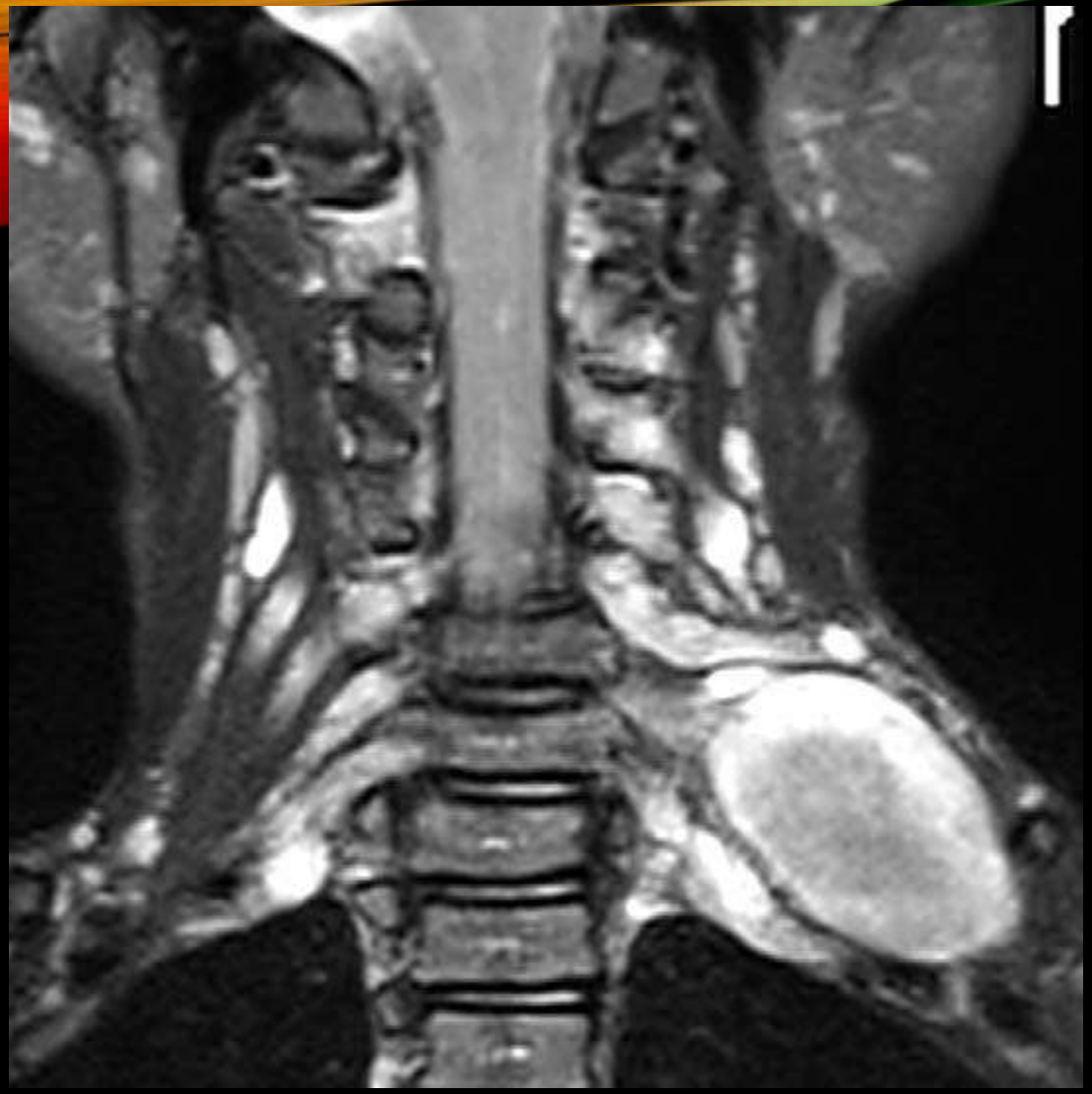
A carpal compression mass on axial 3D SPACE imaging (A) and on tractography (B, C) appears as an ovoid mass in the carpal tunnel (green arrows). The median nerve is not well visualized (red arrows). Tractography shows the relationship between the nerve (red arrow) and the mass (green arrow) which is confirmed by surgery as intraneural ganglion cyst.



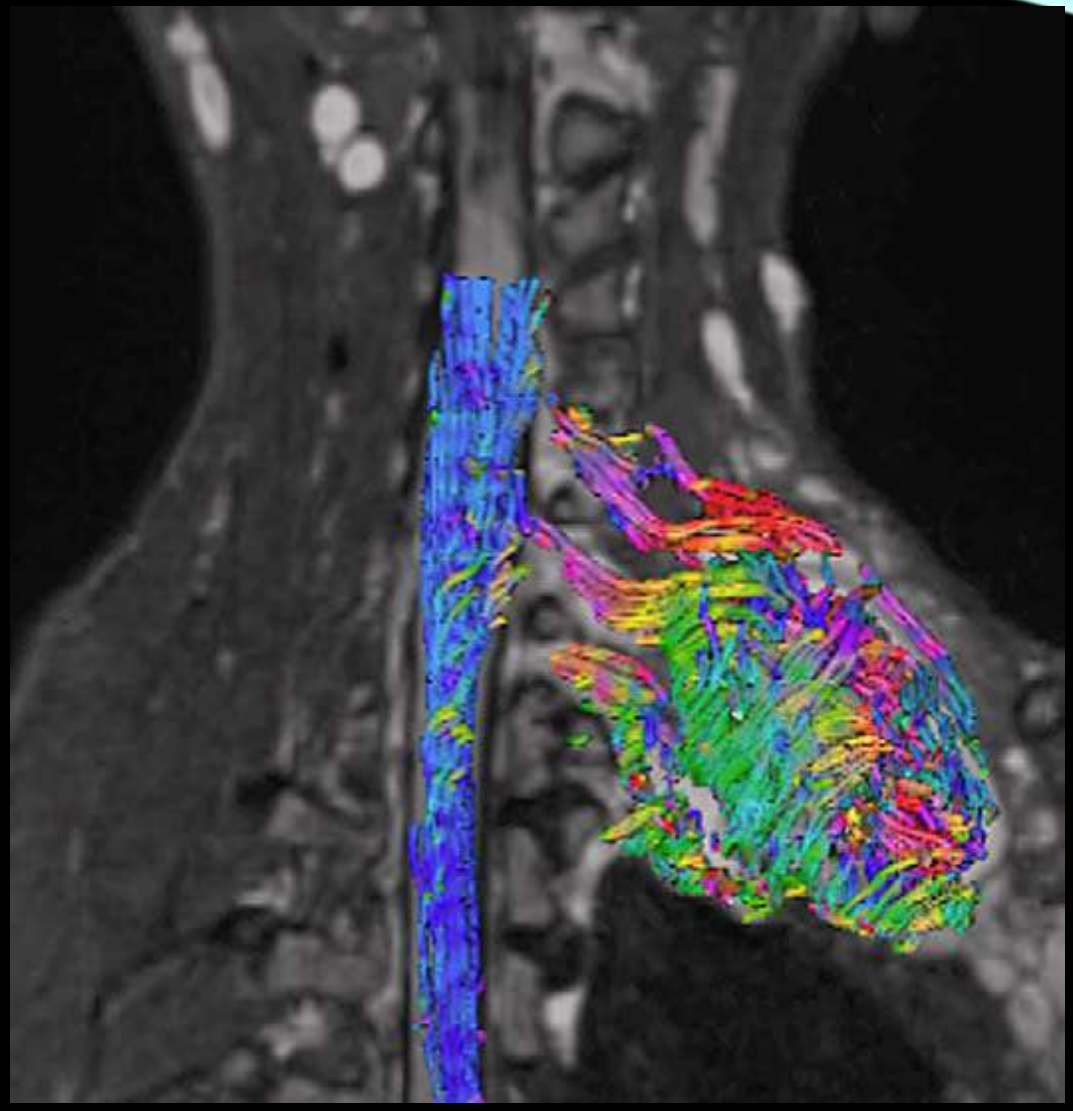
Perineurioma on 3D SPACE T2-weighted coronal reconstruction (A) and T2-weighted axial sequences (B) clearly demonstrate
hypertrophy of the left sciatic nerve (yellow arrows) compared with the contralateral side (white arrow). Nerve root involvement is not clearly visualized



coronal post-gadolinium T1-weighted fat-saturated sequences (A) reveal fusiform neural hypertrophy (green arrows), although the nerves are difficult to distinguish from vessels (pink arrows). Fiber-tracking (B) depicts not only the extent of the lesion, but also allows evaluation of spinal root involvement (white arrowheads



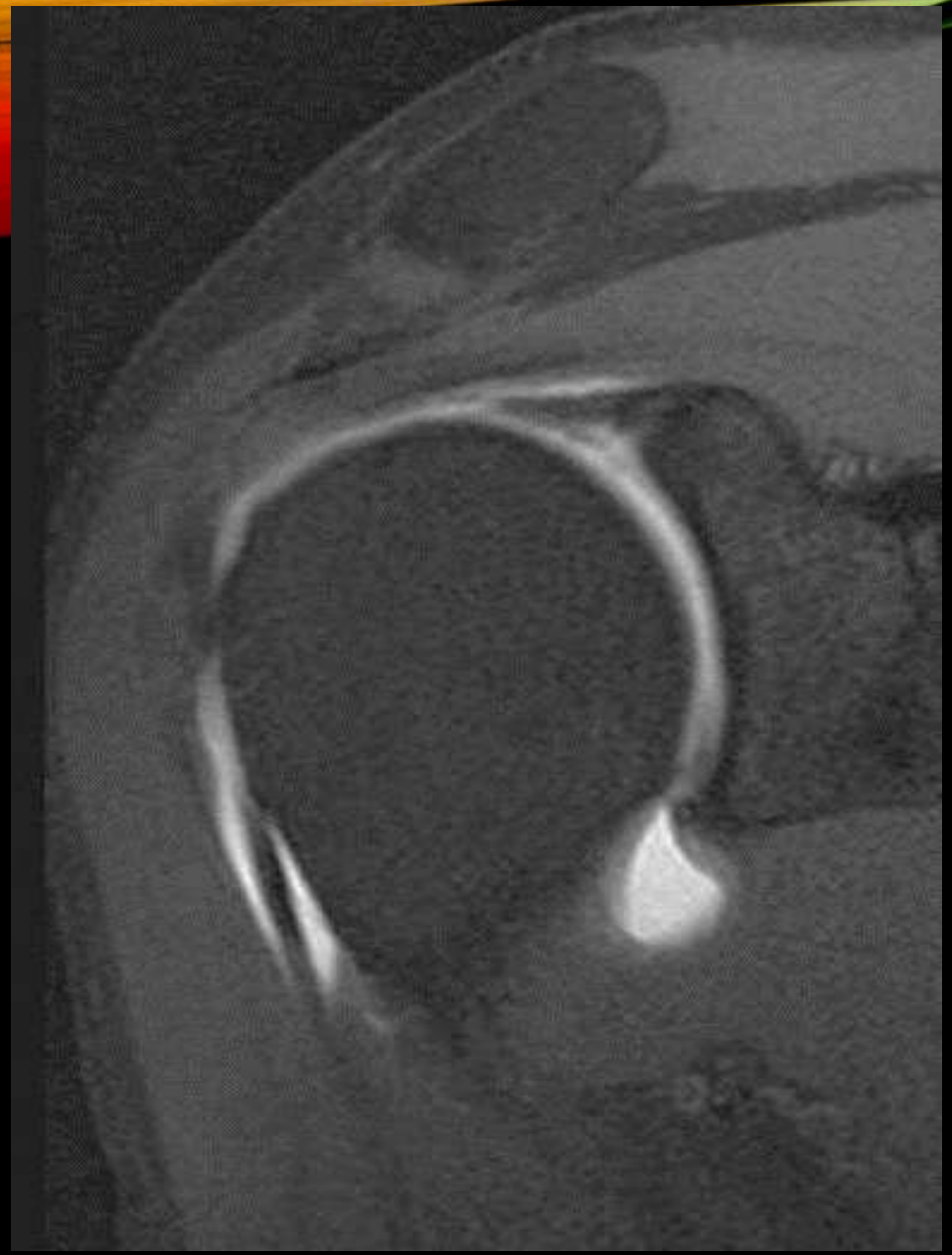
Neurofibromatosis on coronal 3D SPACE T2-weighted imaging shows diffuse involvement of the brachial plexus, and the tortuous expansion (‘bag of worms’) appearance that is pathognomonic of plexiform neurofibroma.



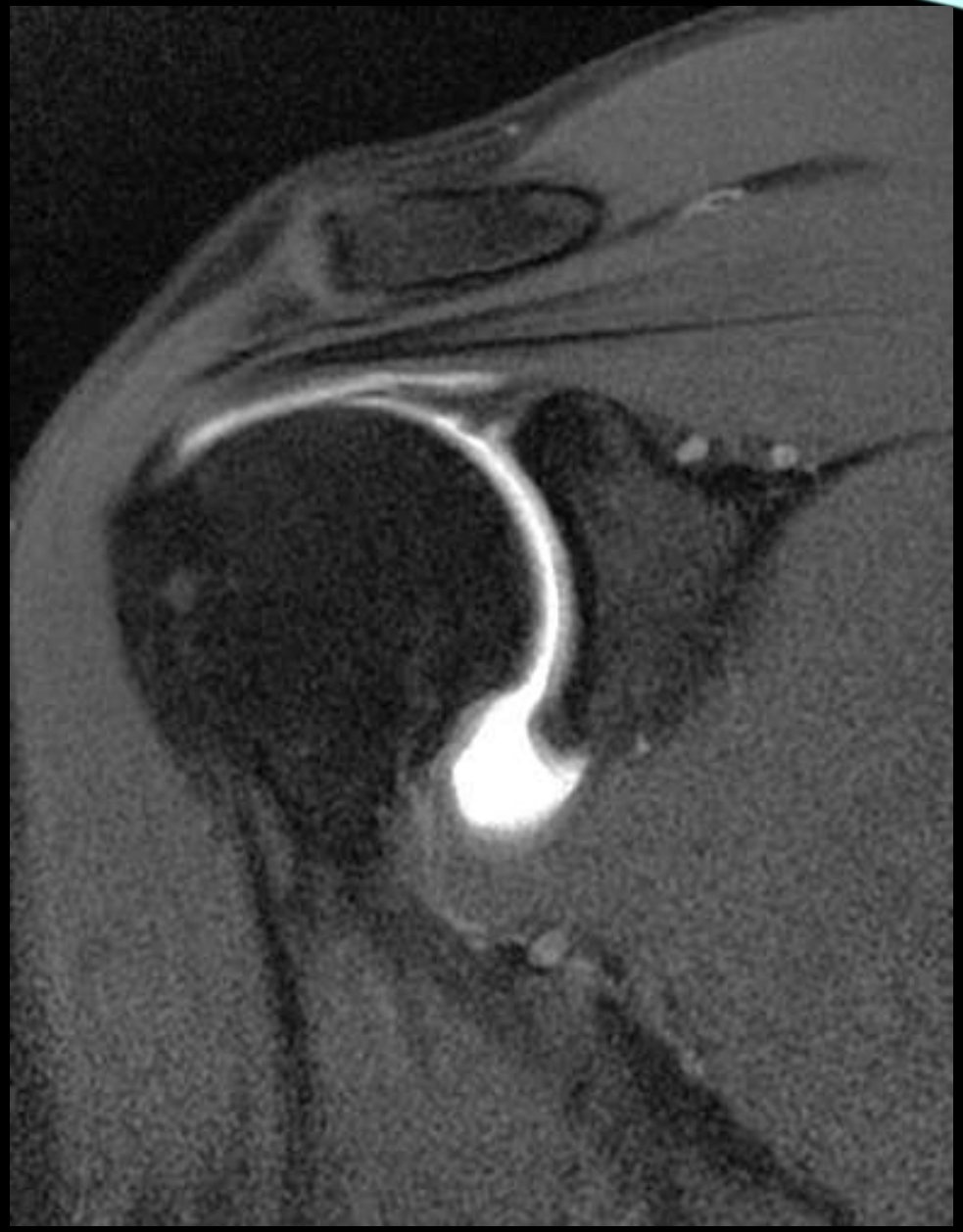
Tractography shows neural tracks within the plexiform neurofibroma. Note also the presence of cutaneous neurofibromas in this patient with NF-1.

MRI arthrogram

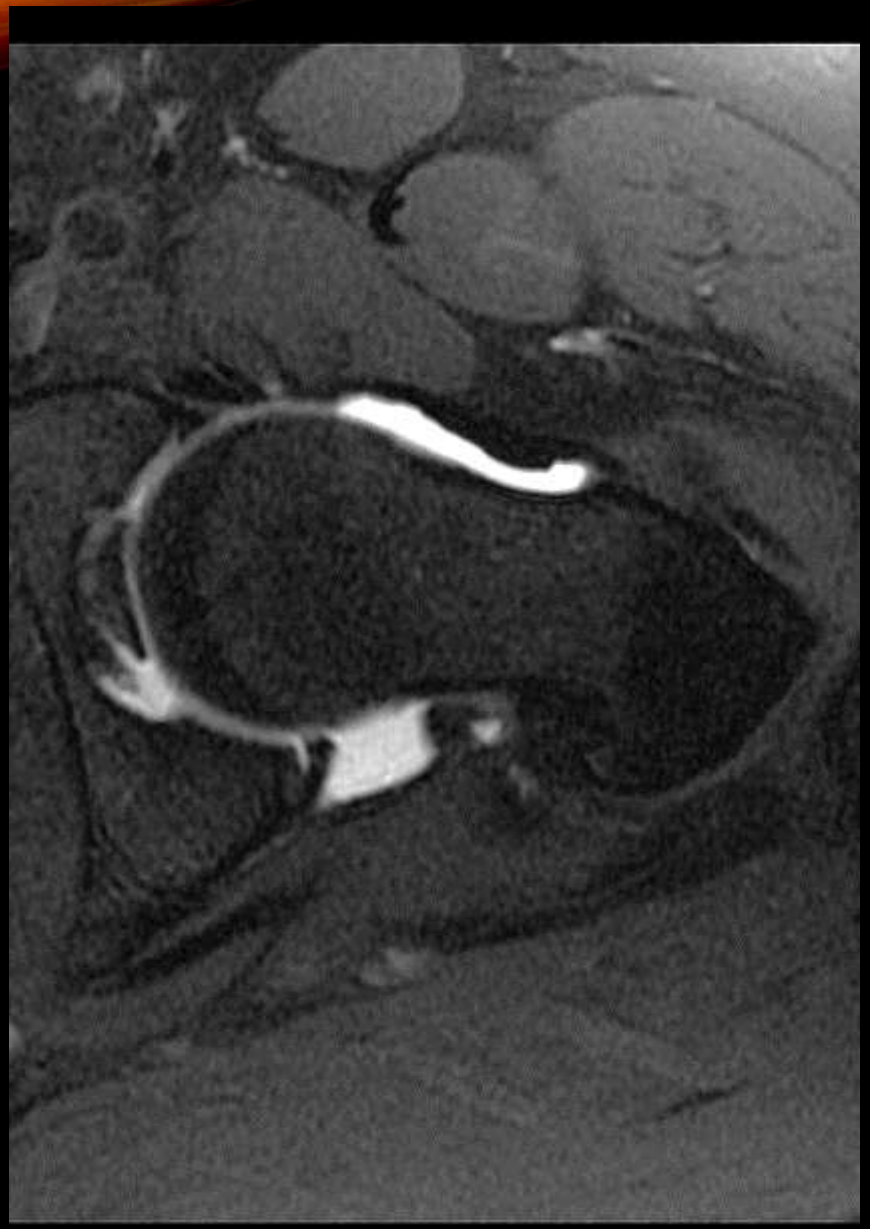
- It is injection of dilated contrast media under guidance of sonar or fluoroscopy.
- It has great role in many joints as wrist shoulder, hip and elbow.

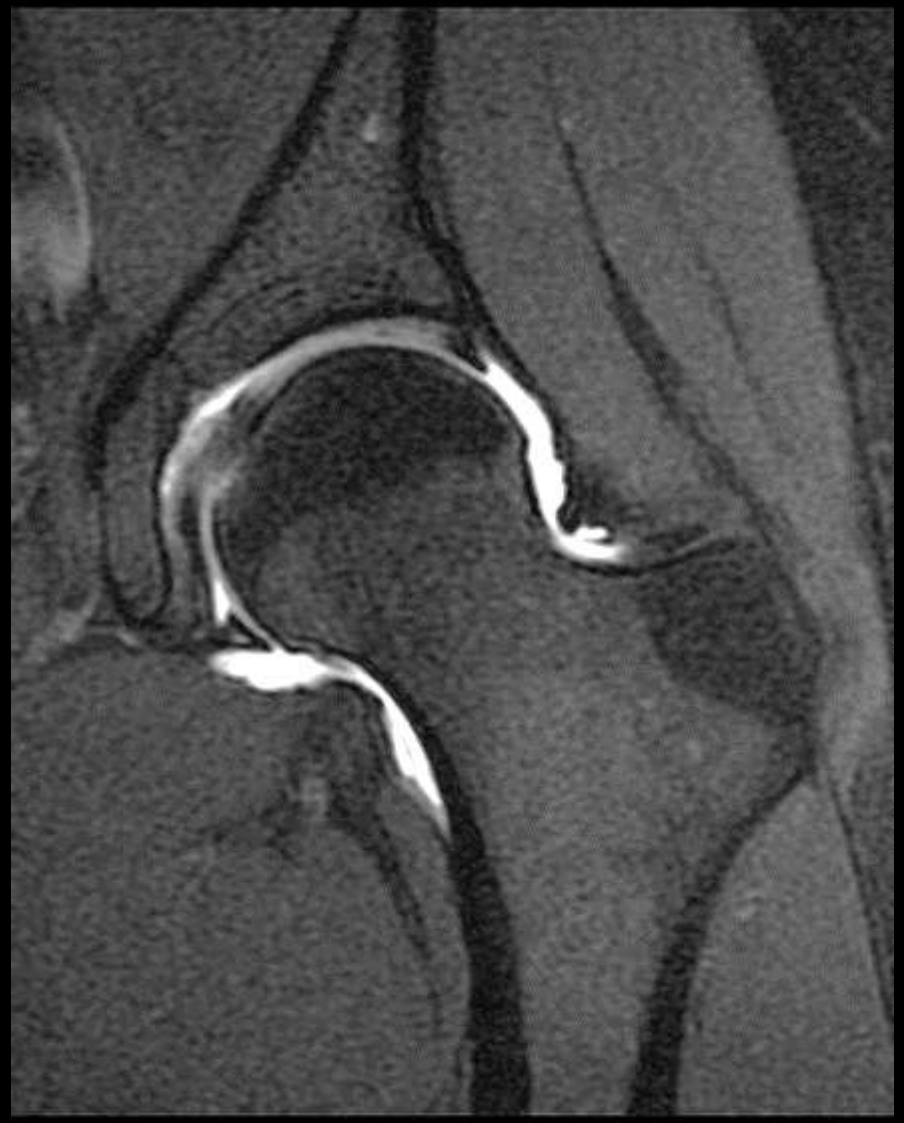


Slap tear

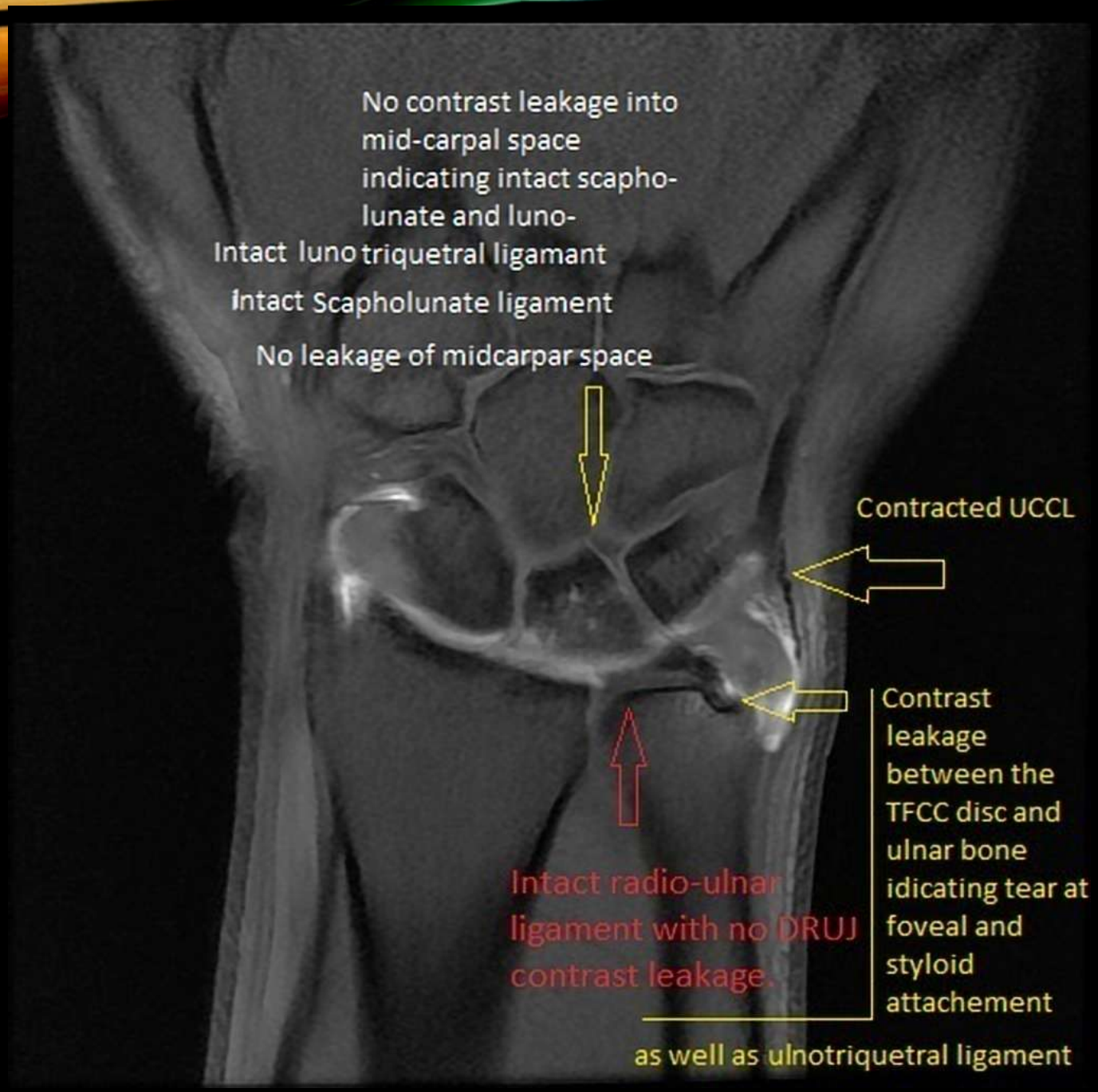


Focal chondrolabral separation



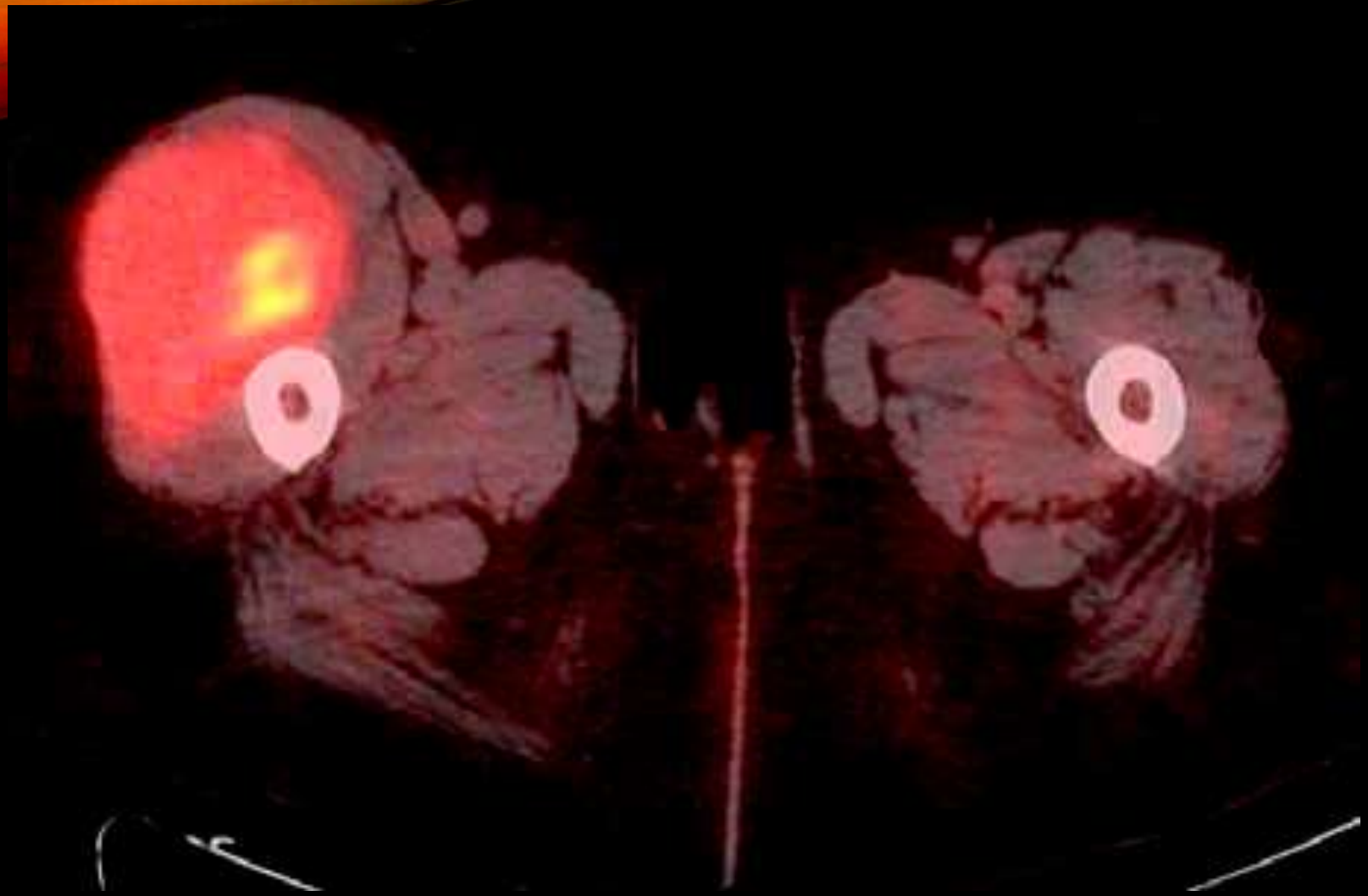


Wrist T1 fat sat with arthrogram

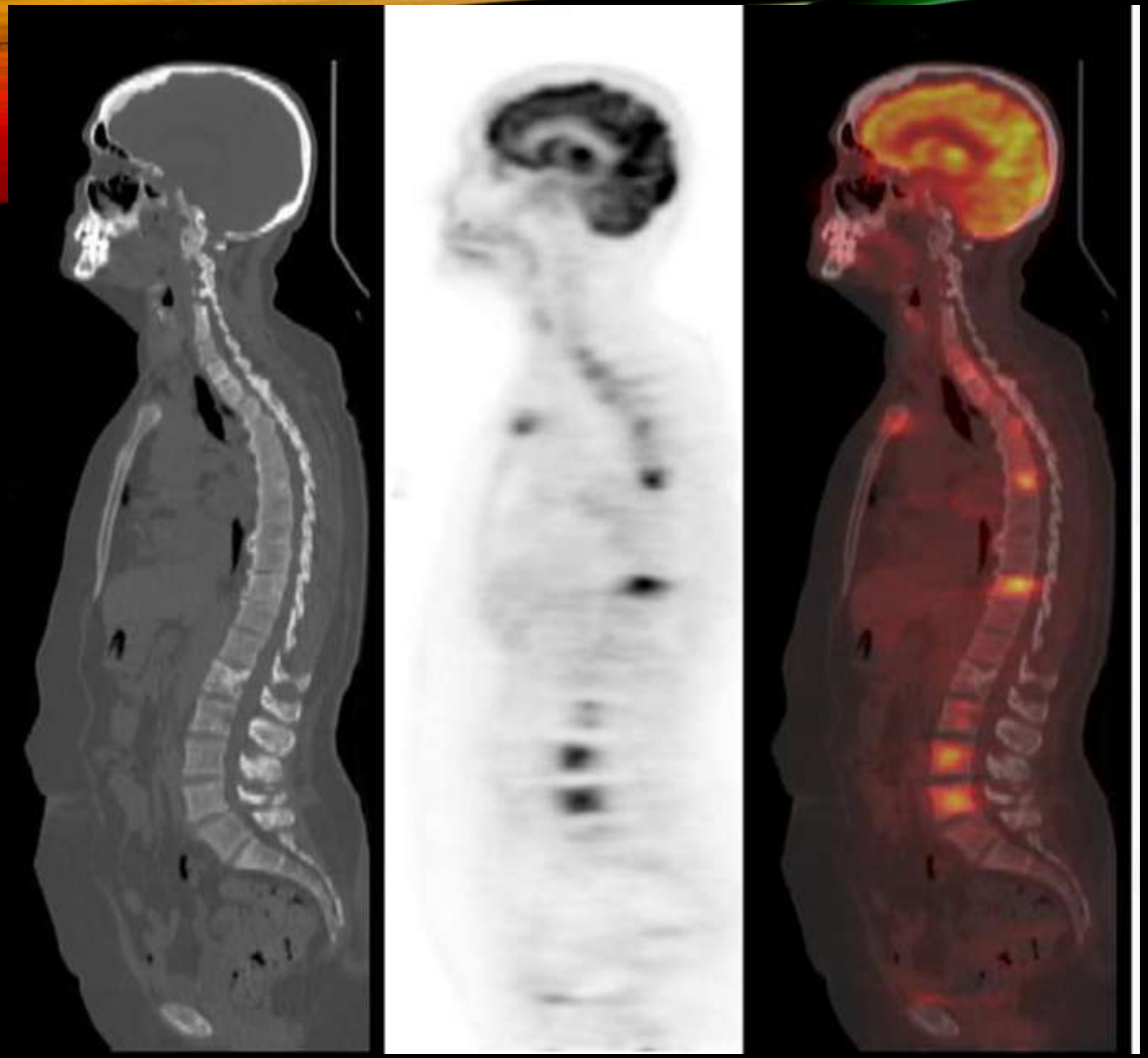


FDG PET/CT in musculoskeletal malignancy

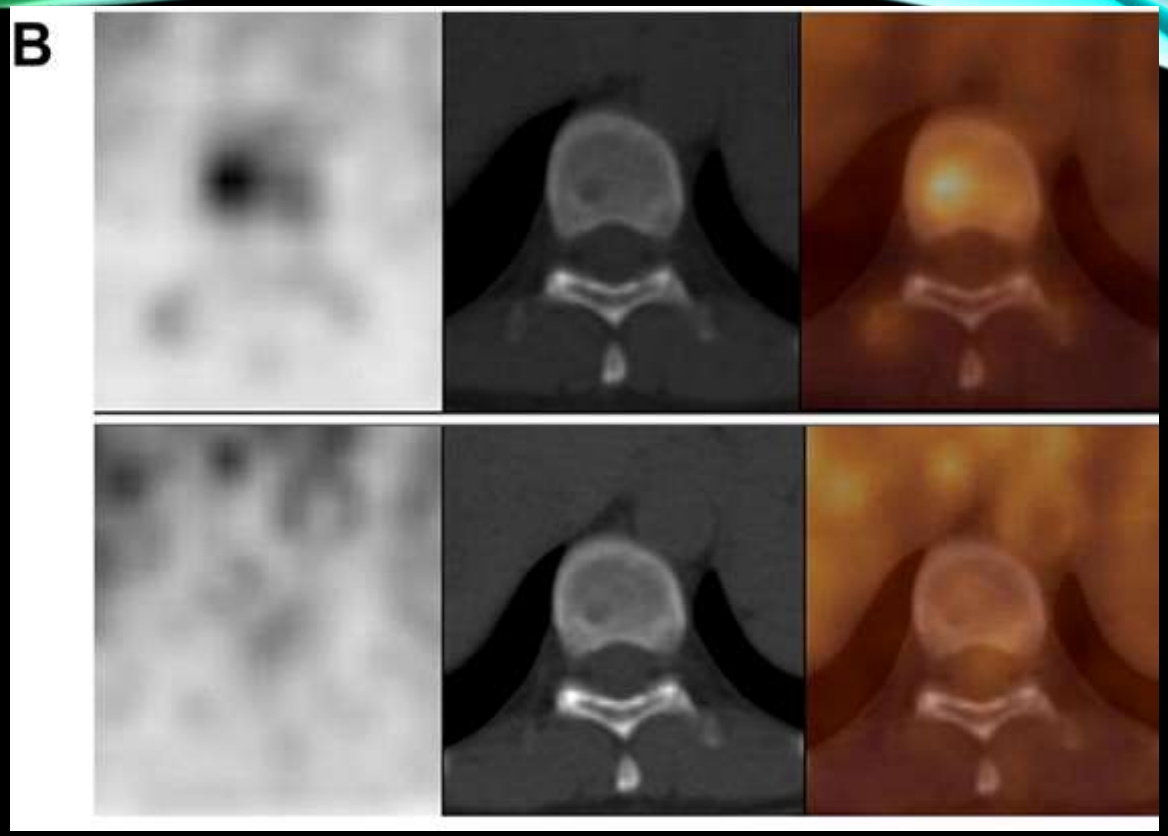
- Positron emission tomography/computed tomography (PET/CT) has several roles in the management of patients with musculoskeletal malignancy.
- Used to determine whether a lesion is benign or malignant
- To know grade of primary malignant lesions and identify metastases.
- Evaluate treatment response and potential recurrence.



59-year-old woman with a sarcoma of the anterior compartment of the right thigh. Axial fused PET/CT. The uptake is heterogeneous



A 67-year-old woman with metastatic breast cancer. PET demonstrates multiple foci of FDG uptake in the vertebrae, although there are no abnormalities at the corresponding location on CT.



FDG PET/CT performed at baseline and after 2 months of hormone therapy of pt with spinal metastasis due to breast Ca

(a) Sagittal PET/CT at baseline shows two vertebral foci in T10 and L2 (top). These foci are no longer visible on the study performed after 2 months of hormone therapy (bottom).

(b) Semi quantitative analysis of the response of the T10 lesion. The SUVmax decreases from 5.5 at baseline (top) to 2.6 (–53%) after two months of treatment (bottom), confirming the metabolic response, whereas CT shows no significant change.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