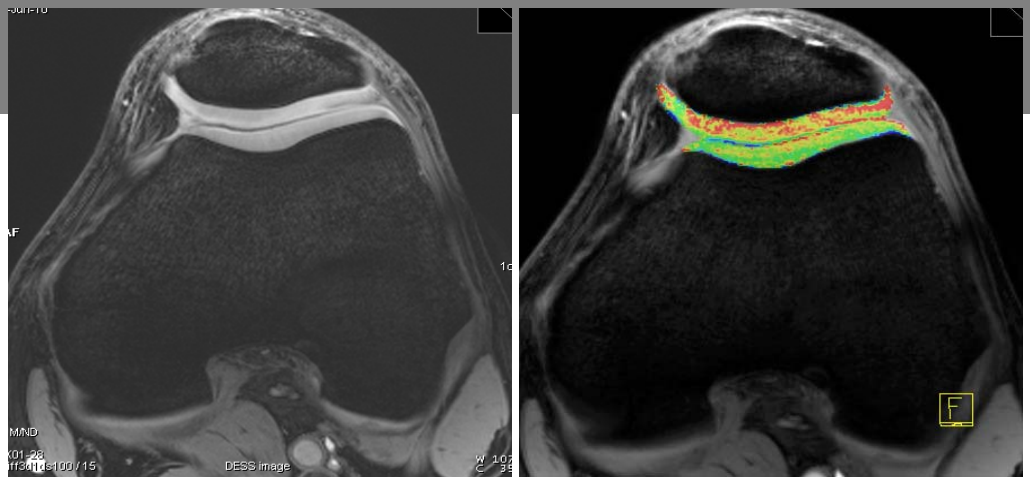
# Sodium imaging: possible clinical applications in the body at 7T

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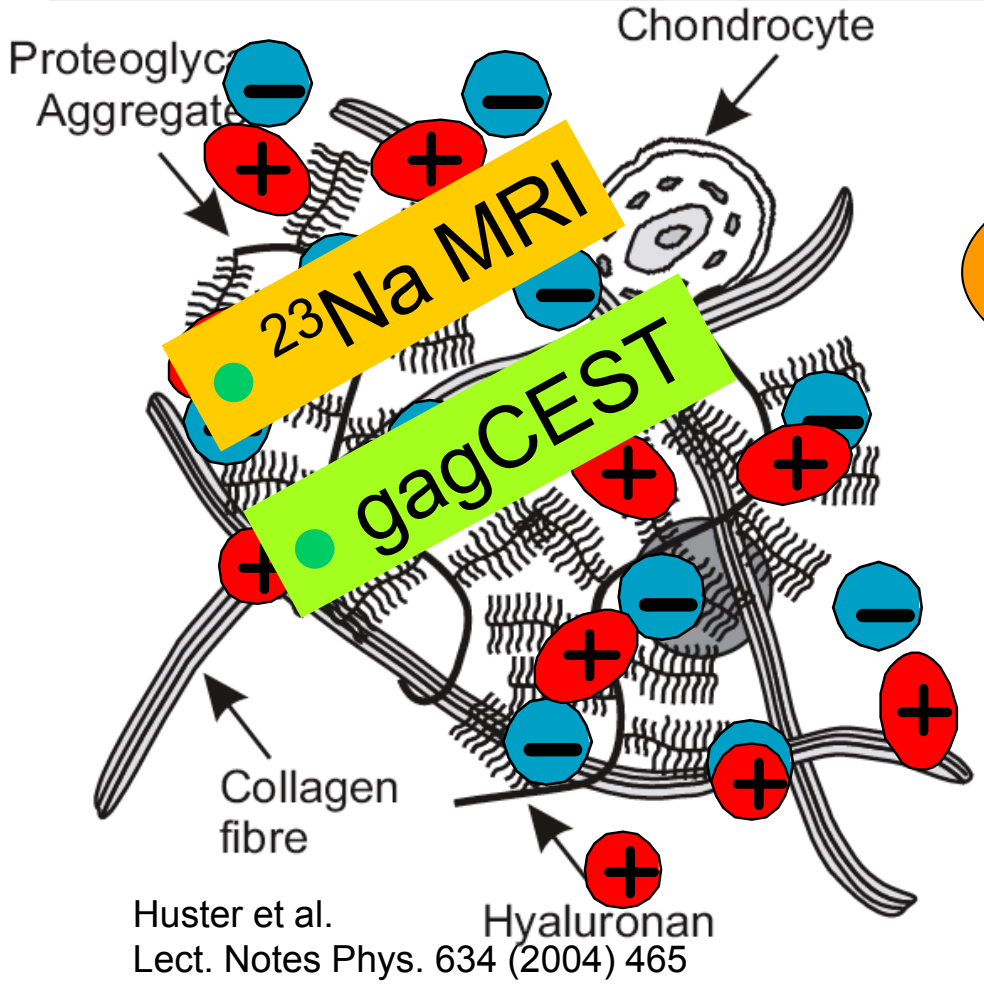
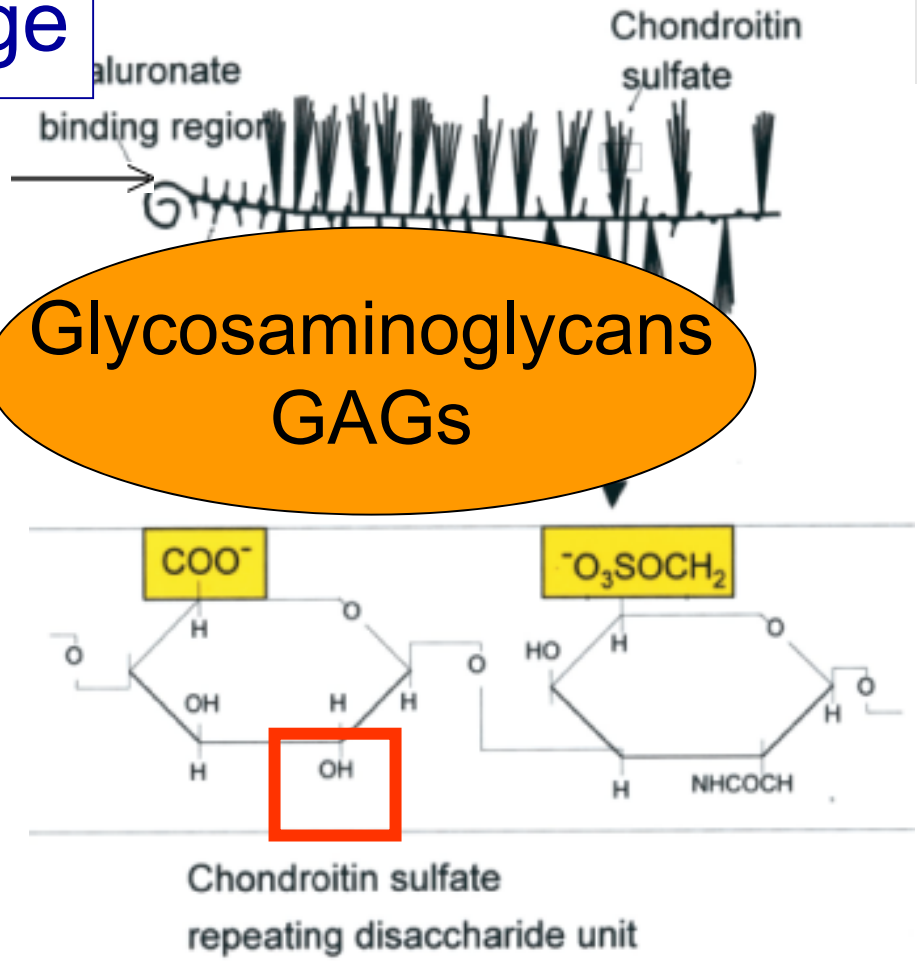
MEDICAL UNIVERSITY OF VIENNA
DEPARTMENT OF RADIOLOGY

# Sodium imaging Cartilage




Huster et al.
Lect. Notes Phys. 634 (2004) 465




Osteoarthritis: loss of [GAG]

# Sodium imaging MSK at 7T
# Clinical applications

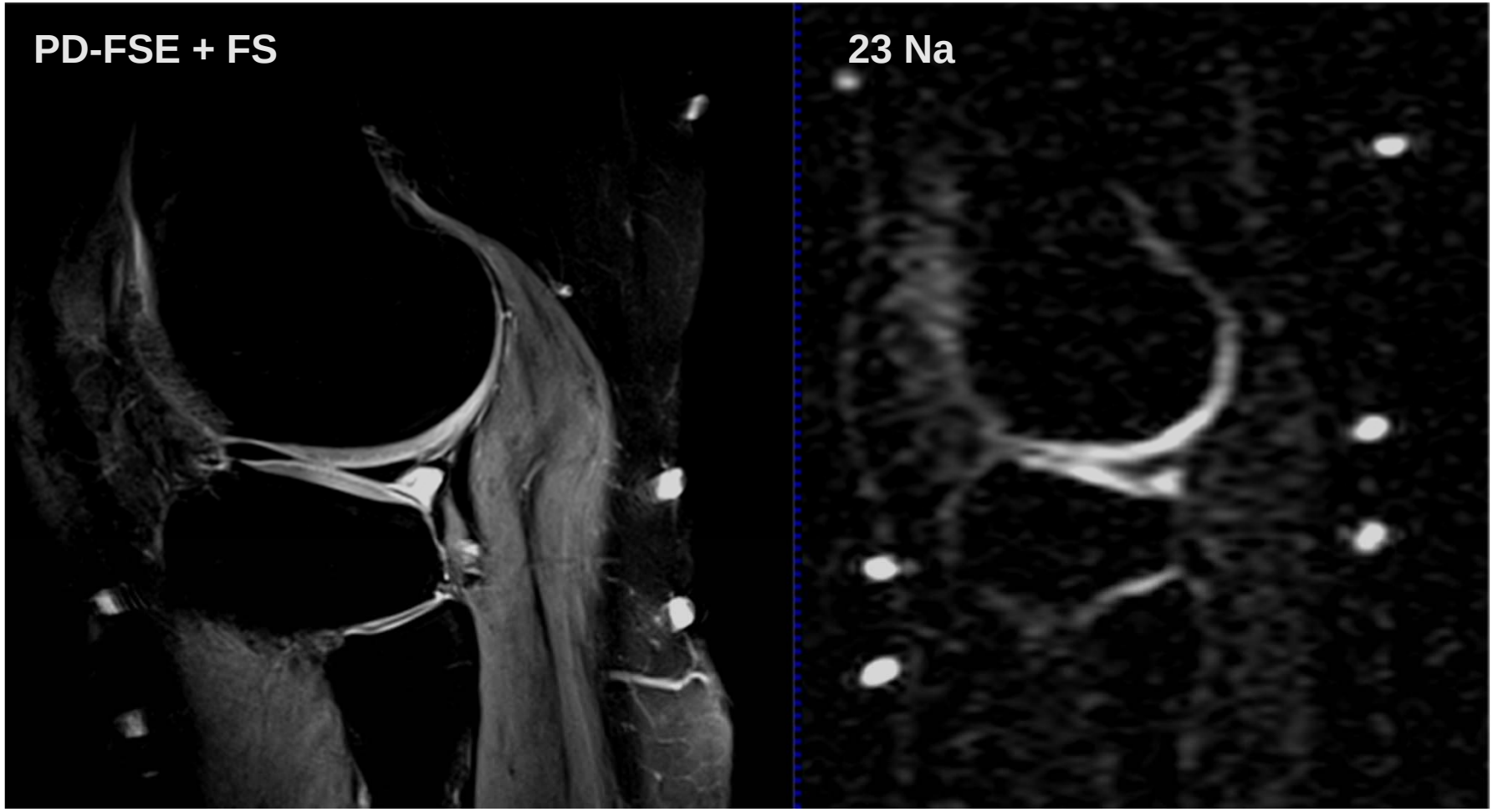
- Sodium imaging in cartilage repair (knee joint MFX, AOT, MACT)
- Sodium imaging in cartilage repair (ankle joint)
- Sodium in early osteoarthritis
  - patella dislocation
  - Cartilage adjacent to lesions
- Sodium imaging in tendons
- Sodium imaging in the intervertebral disc
- Sodium imaging – reference method for CEST

# $^{23}$Na (Sodium) Imaging in vivo at 7T

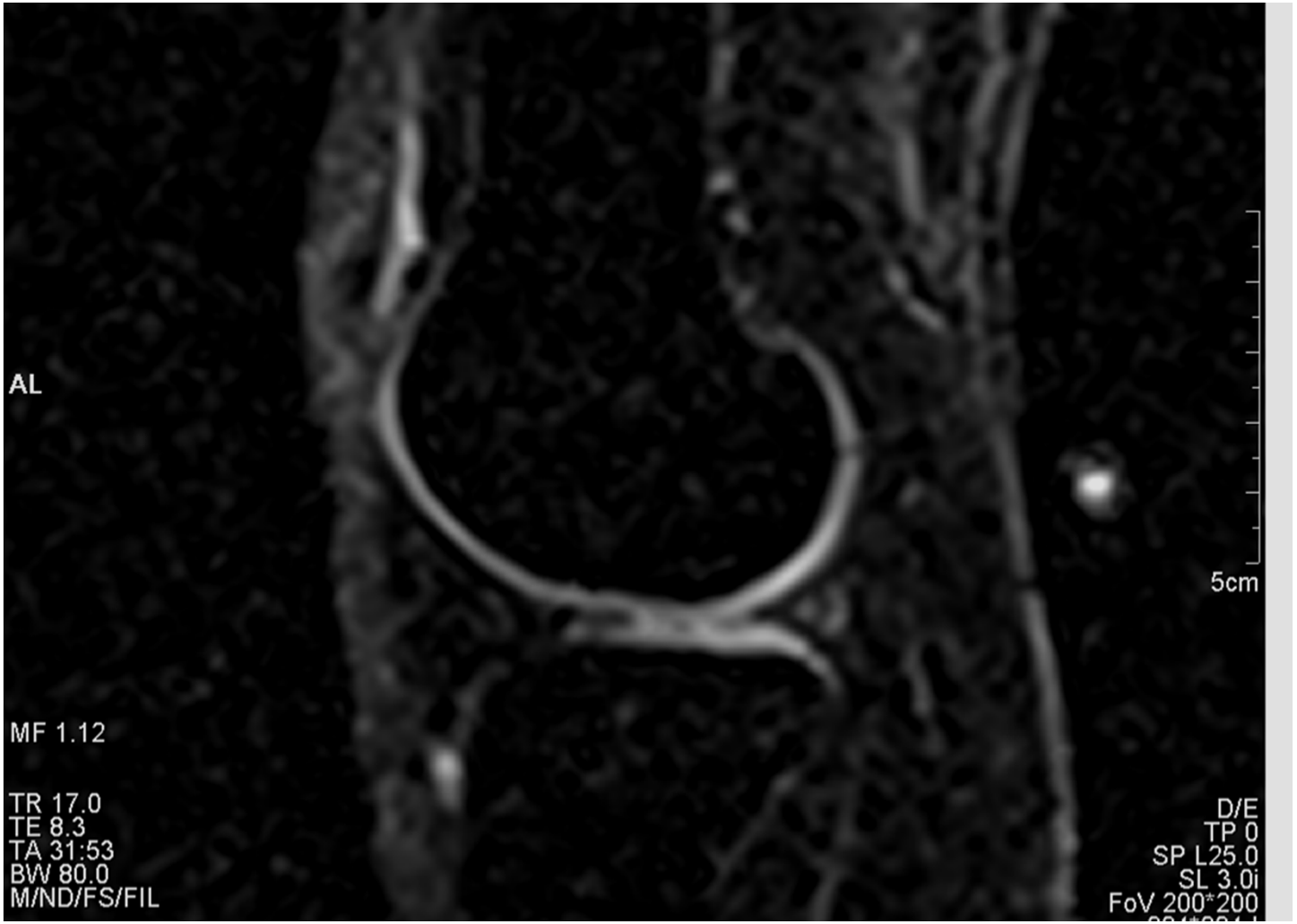
- 7T MR whole body system (Magnetom, Siemens Healthcare, Erlangen, Germany)
- Sodium measurements were performed using a $^{23}$Na-only (78.61 MHz) circularly polarized transmit/receive knee coil with an inner diameter of 19 cm (Stark Contrast, Erlangen, Germany)
- a **3D-GRE sequence optimized for sodium imaging** was employed with these parameters: TR/TE = 10.0/3.77 ms; FOV = 199x199 mm$^2$, 60 averages; 48 slices; matrix size = 64x128; resolution = 3.11x1.55x3.0 mm$^3$;

**Trattnig et al Radiology 2010 Oct;257(1):175-84**

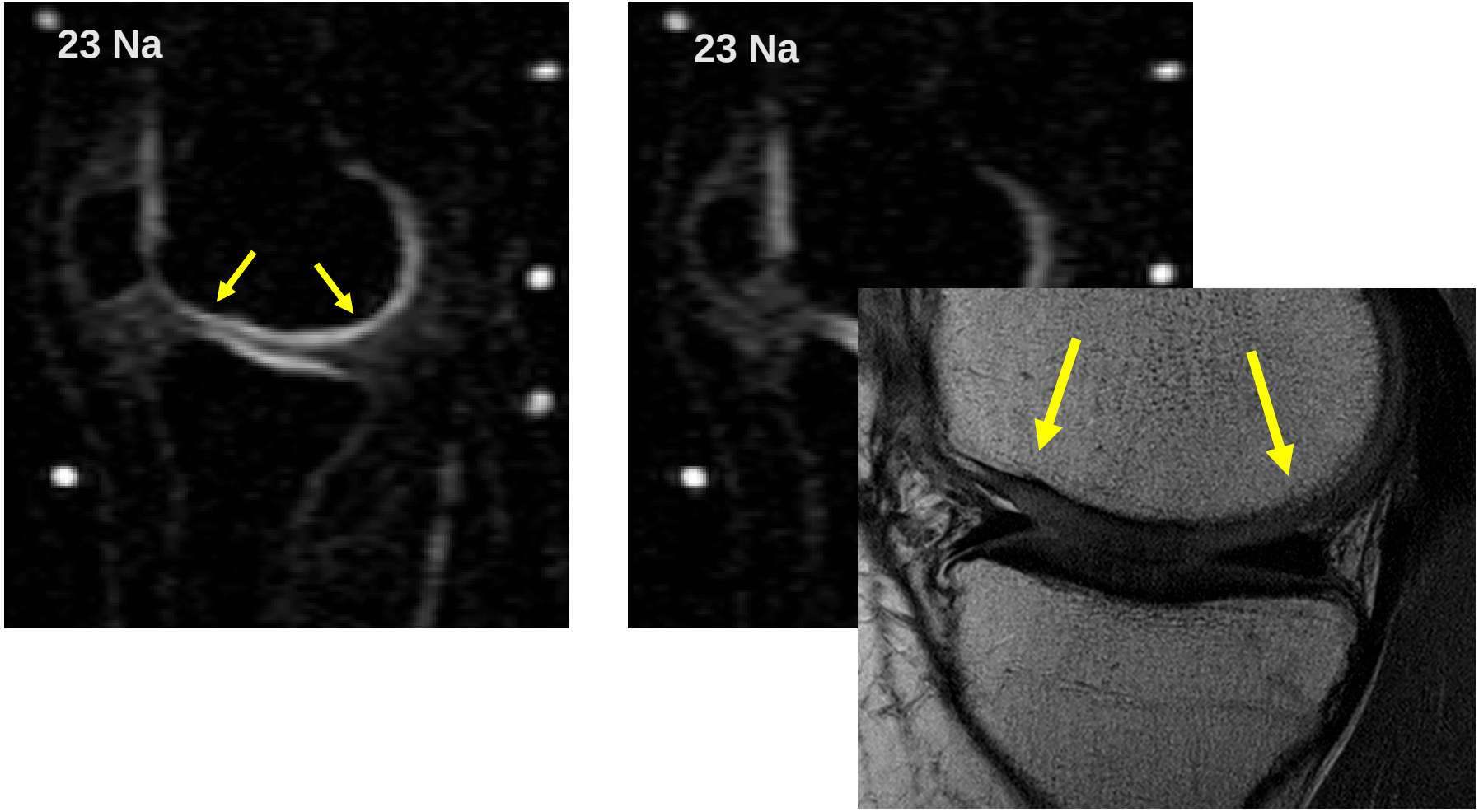
# $^{23}$Na (Sodium) Imaging in vivo auf 7T



# $^{23}$Na (Sodium) Imaging in vivo at 7T



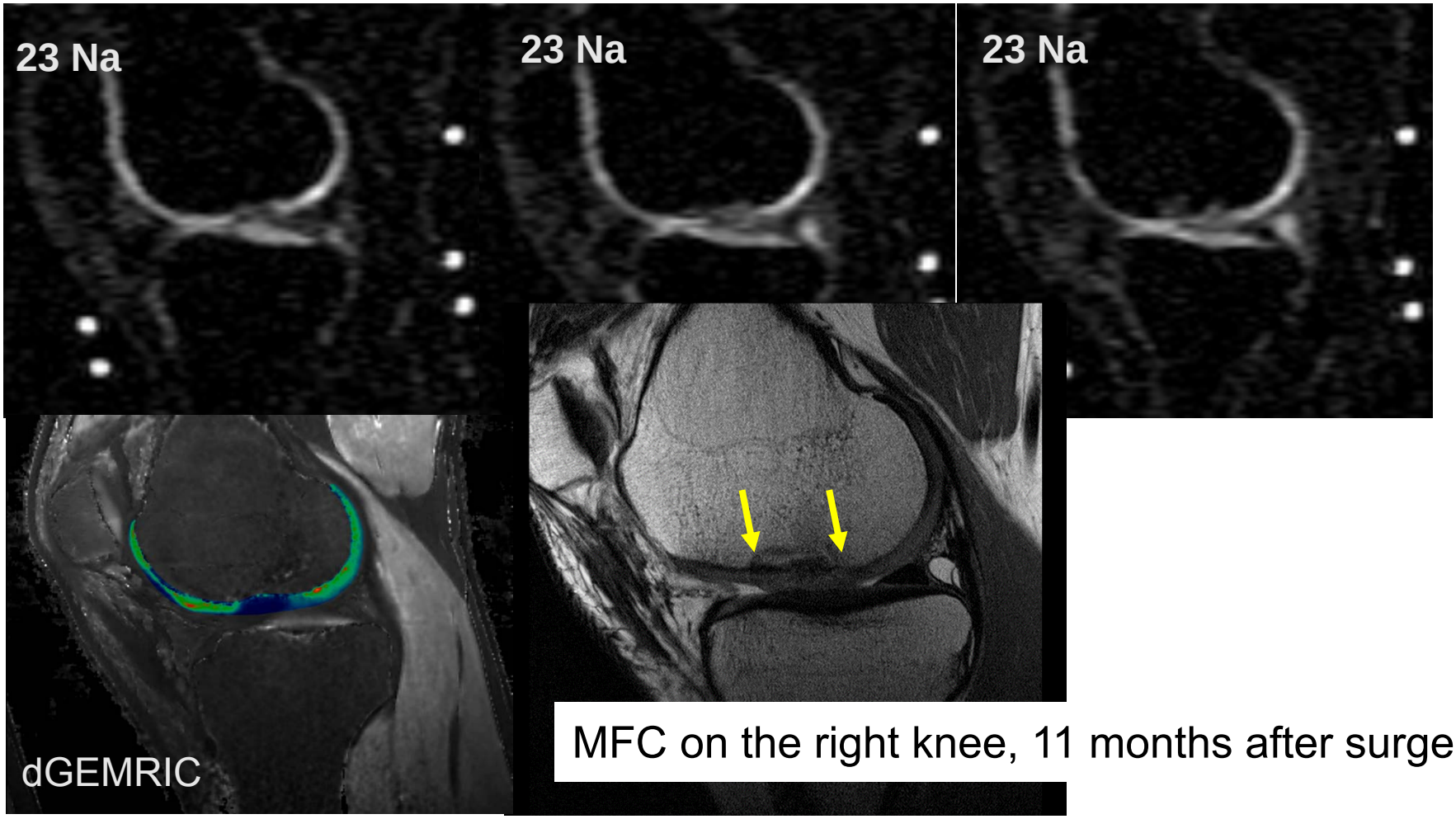
# MACT – excellent result




Matrix-associated autologous chondrocyte transplantation

MFC on the right knee, 16 months after surgery

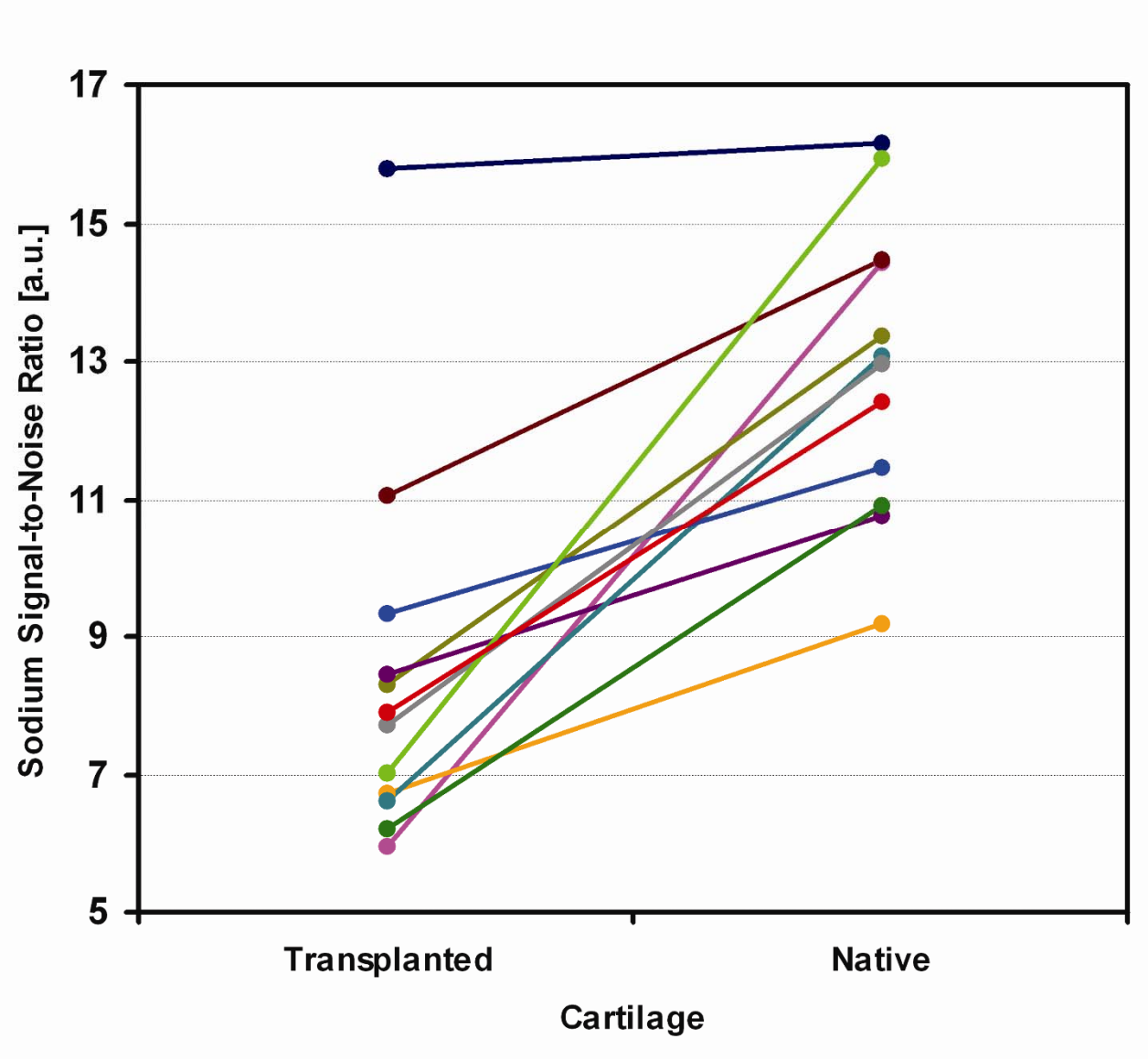
# MACT – bad outcome



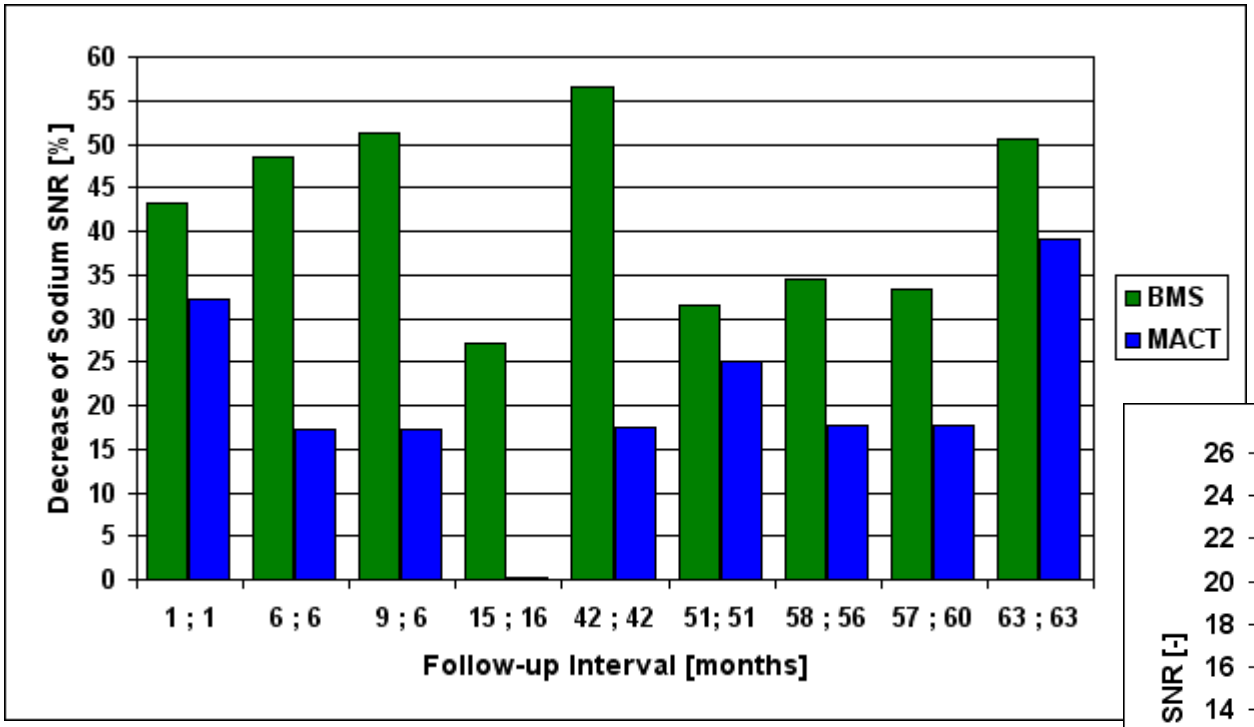

MFC on the right knee, 11 months after surgery

**Trattnig et al RADIOLOGY 2010**

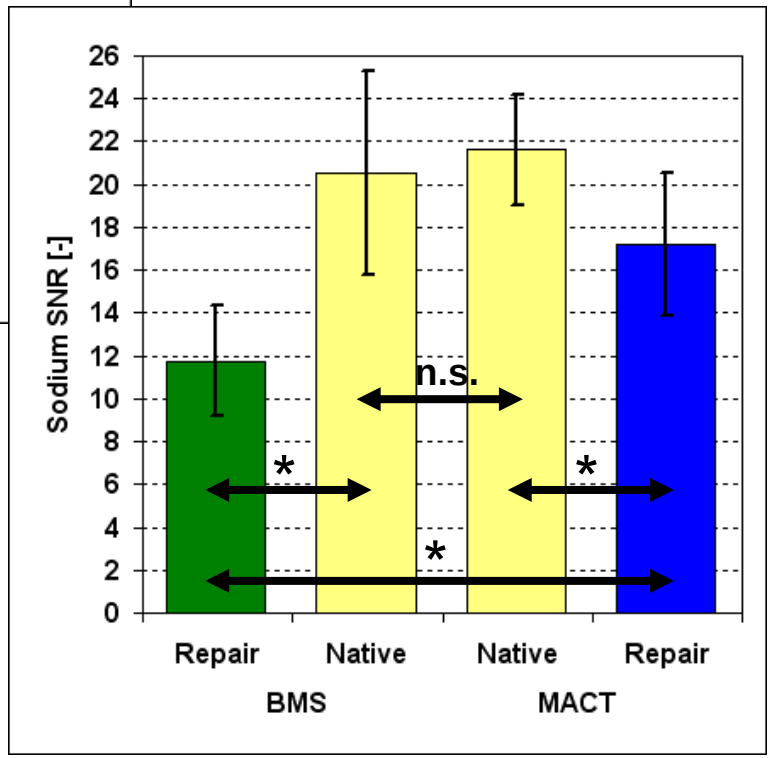
# Sodium Imaging: sodium signal to noise ratio repair tissue vs. native cartilage



# Comparison of Cartilage Repair Procedures

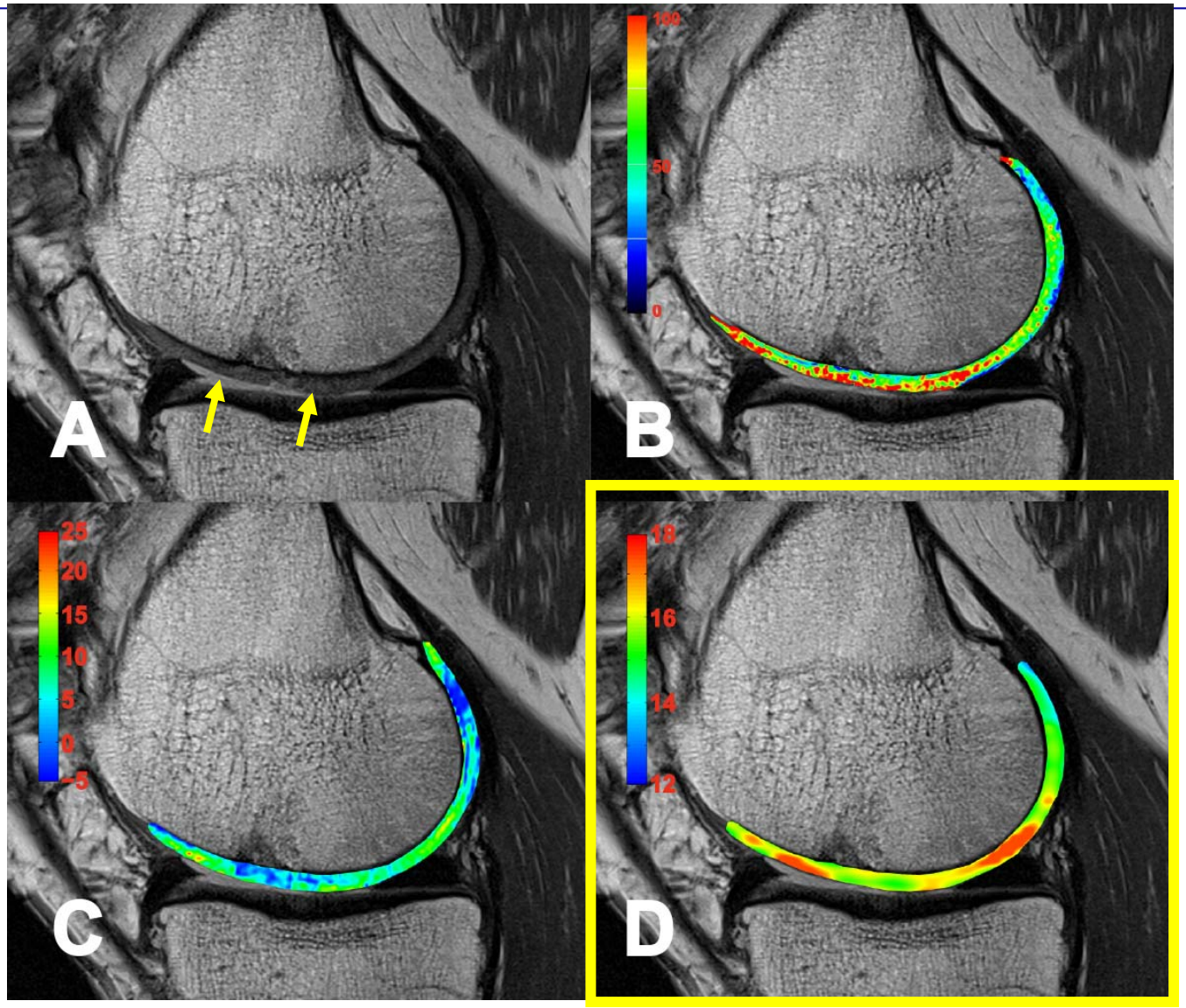



- 18 patients matched for age and post-OP interval.



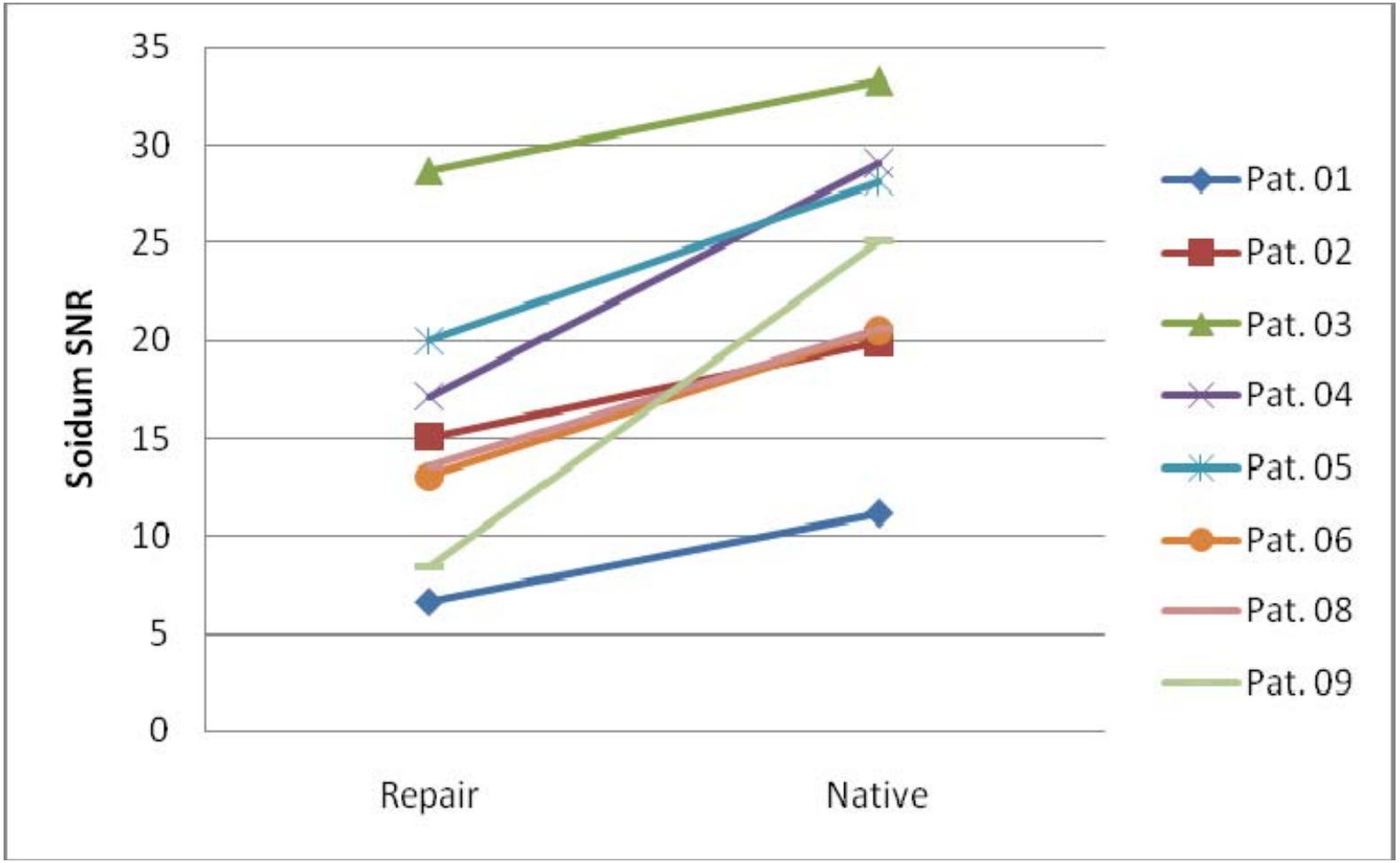

- No difference in $^{23}$Na-SNR of native cartilage ($p$=0.505).
- Significantly higher $^{23}$Na-SNR observed in MACT repair areas compared to BMS ($p$=0.002).

# Sodium imaging in patients after AOT




patient 9.4 years after AOT at the medial femoral condyle

# Sodium imaging in patients after AOT



# $^{23}$Na Imaging in early onset of osteoarthritis

- Study population:

- 9 patients (2 male, 7 female; mean age 26.4 ± 5.6) after lateral patella dislocation vs.

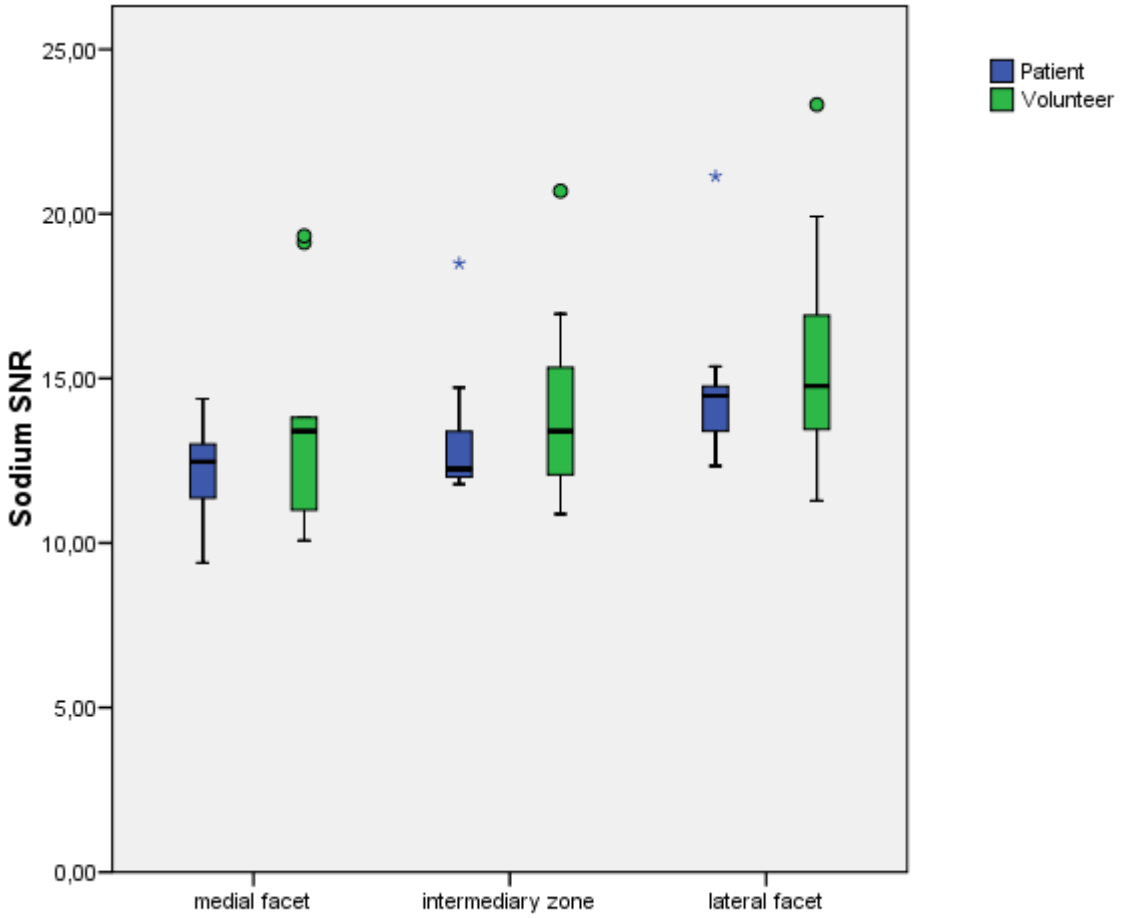
  9 healthy volunteers (2 male, 7 female; mean age 26.1 ± 5)

- MR-protocol:

- morphological imaging ► axiale 2D-PDw-TSEfs, iso-3D-T1w-GRE

- Sodium (23Na) MR Imaging ► 3D GRE-sequence optimized for sodium imaging

# Sodium imaging in patients after patella dislocation



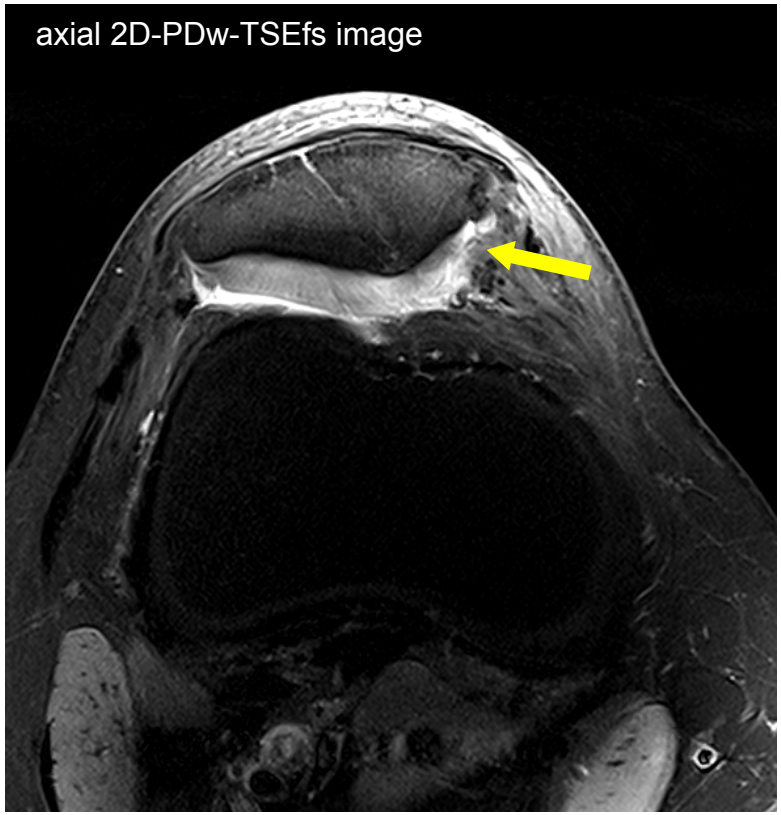

Sodium-SNR (Cartilage): different localizations within the patella in patients and volunteers

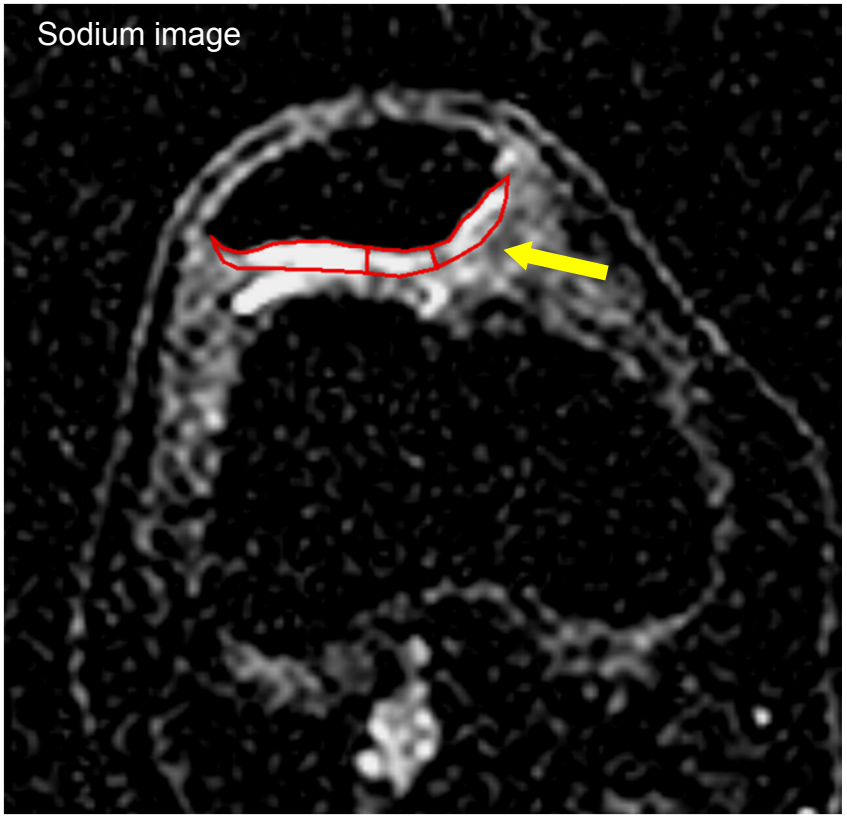
# Mean Sodium SNR-values for patients after patella-dislocation and healthy volunteers

| **Patients (N= 9)** | | | | | **Volunteers (N= 9)** | | | |
|---|---|---|---|---|---|---|---|---|
| Global Sodium SNR | | | | | Global Sodium SNR | | | P-value* |
| 13.5 (2.5) | | | | | 14.8 (3.7) | | | 0.014 |
| Medial Facet | Intermediate Zone | Lateral Facet | P-Value** | | Medial Facet | Intermediate Zone | Lateral Facet | P-Value** |
| 12.1 (1.6) | 13.3 (2.2) | 14.9 (2.5) | 0.039 | | 13.6 (3.4) | 14.2 (3.1) | 15.9 (3.8) | 0.344 |
| ICRS-Grade 0 | ICRS-Grade 1 | ICRS-Grade 2 | ICRS-Grade 3 | P-value ** | | | | |
| 14.2 (2.6) | 14.2 (2.2) | 12.0 (1.8) | 11.4 (1.1) | 0.002 | | | | |

- significantly lower global sodium-SNR in patients
- significant influence of location (medial vs. lateral) on sodium-SNR in patients (lateral patella dislocation!!!)
- significant decrease of sodium-SNR with increasing ICRS-grades
- highly significant, negative correlation between age and sodium-SNR (R= -0.382, P= 0.001)

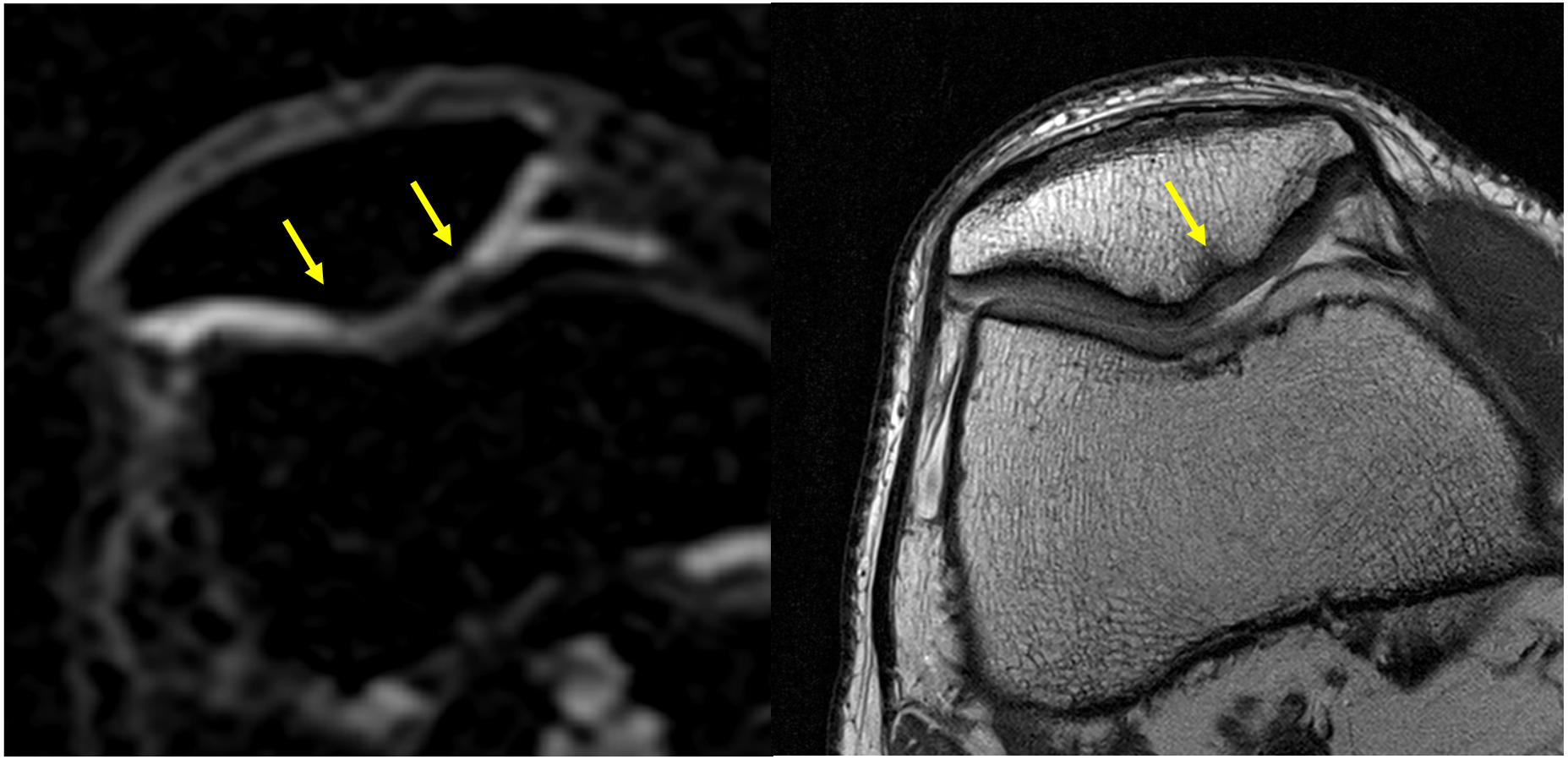
# Sodium imaging in patients after patella dislocation




visible decrease of sodium-signal corresponding to cartilage defect on the medial patella-facet

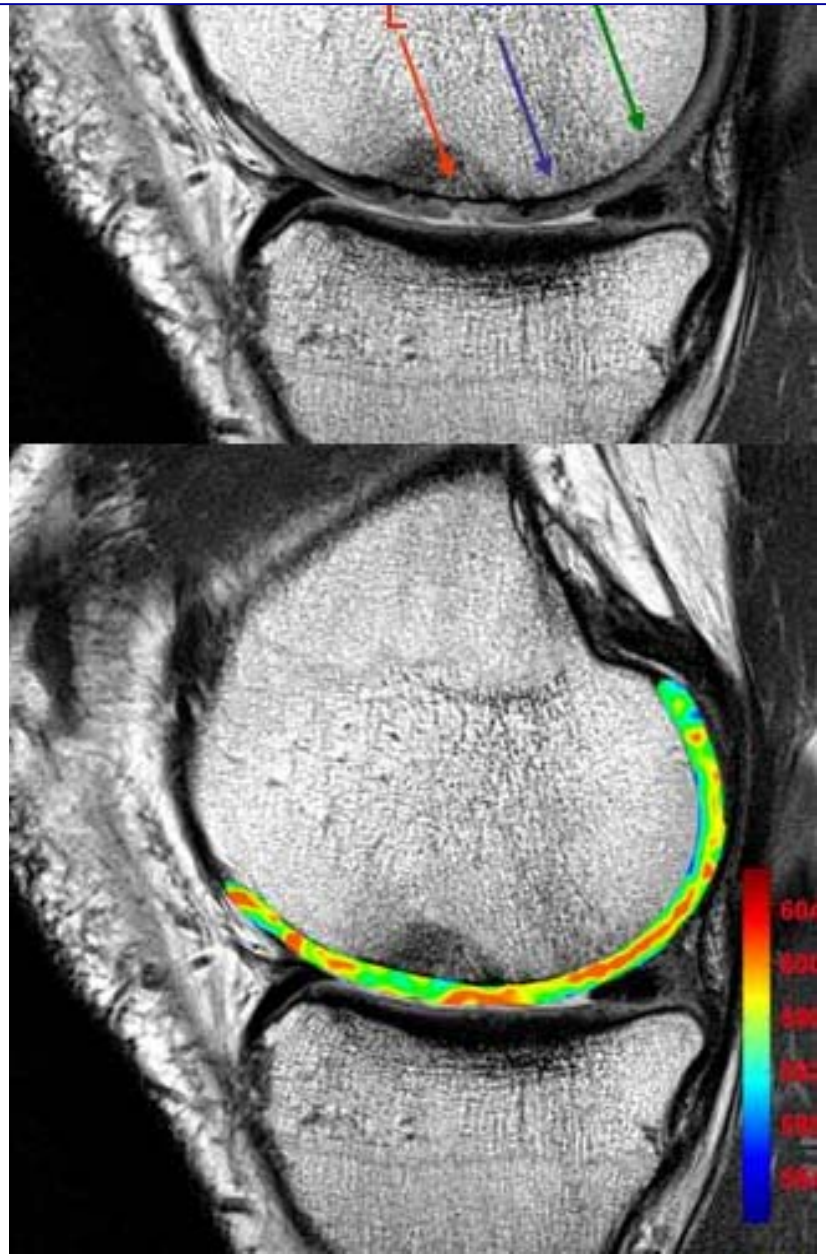
# $^{23}$Na Imaging in early onset of osteoarthritis



$^{23}$ Na

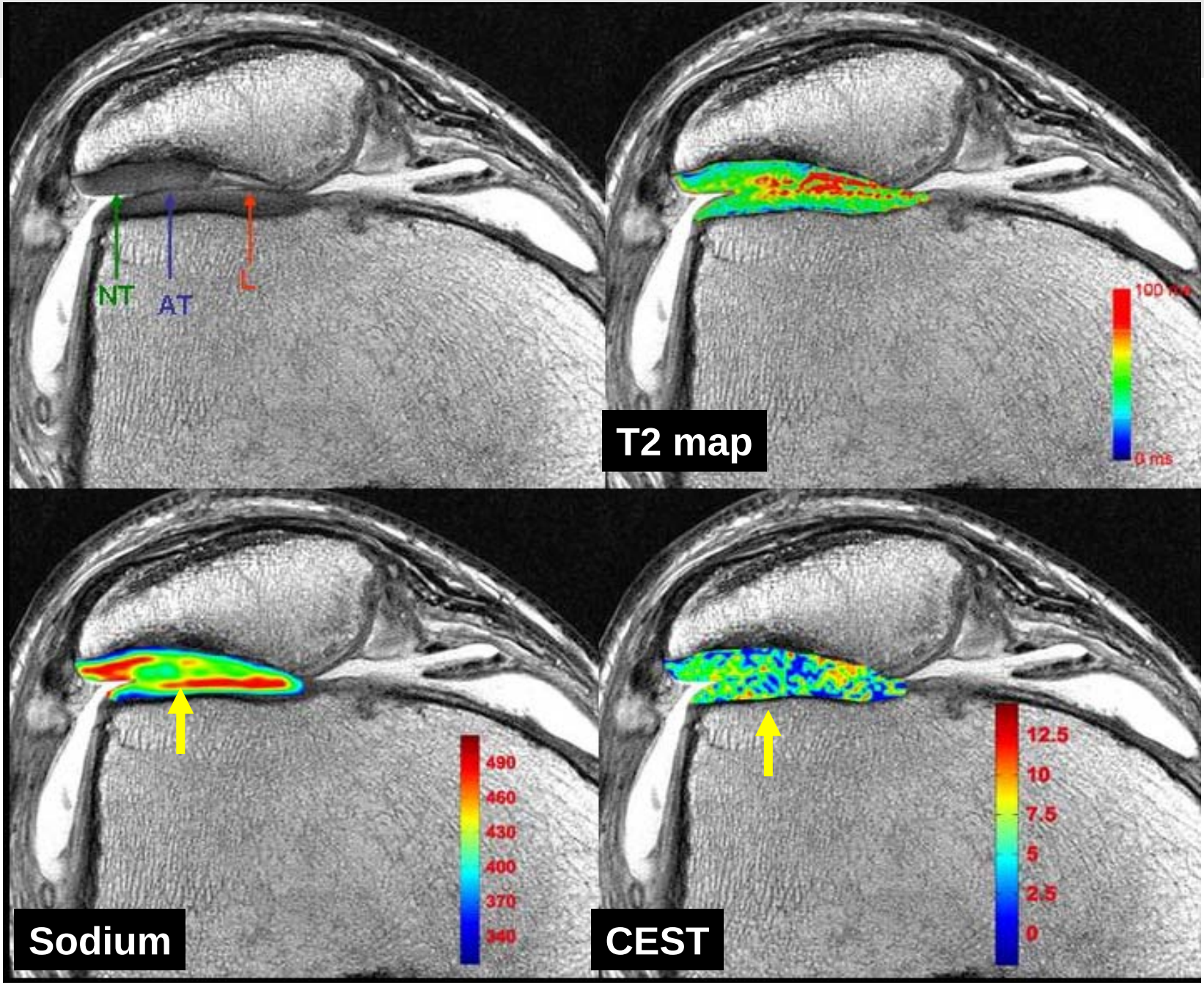
PD-FSE

# $^{23}$Na Imaging in early onset of osteoarthritis

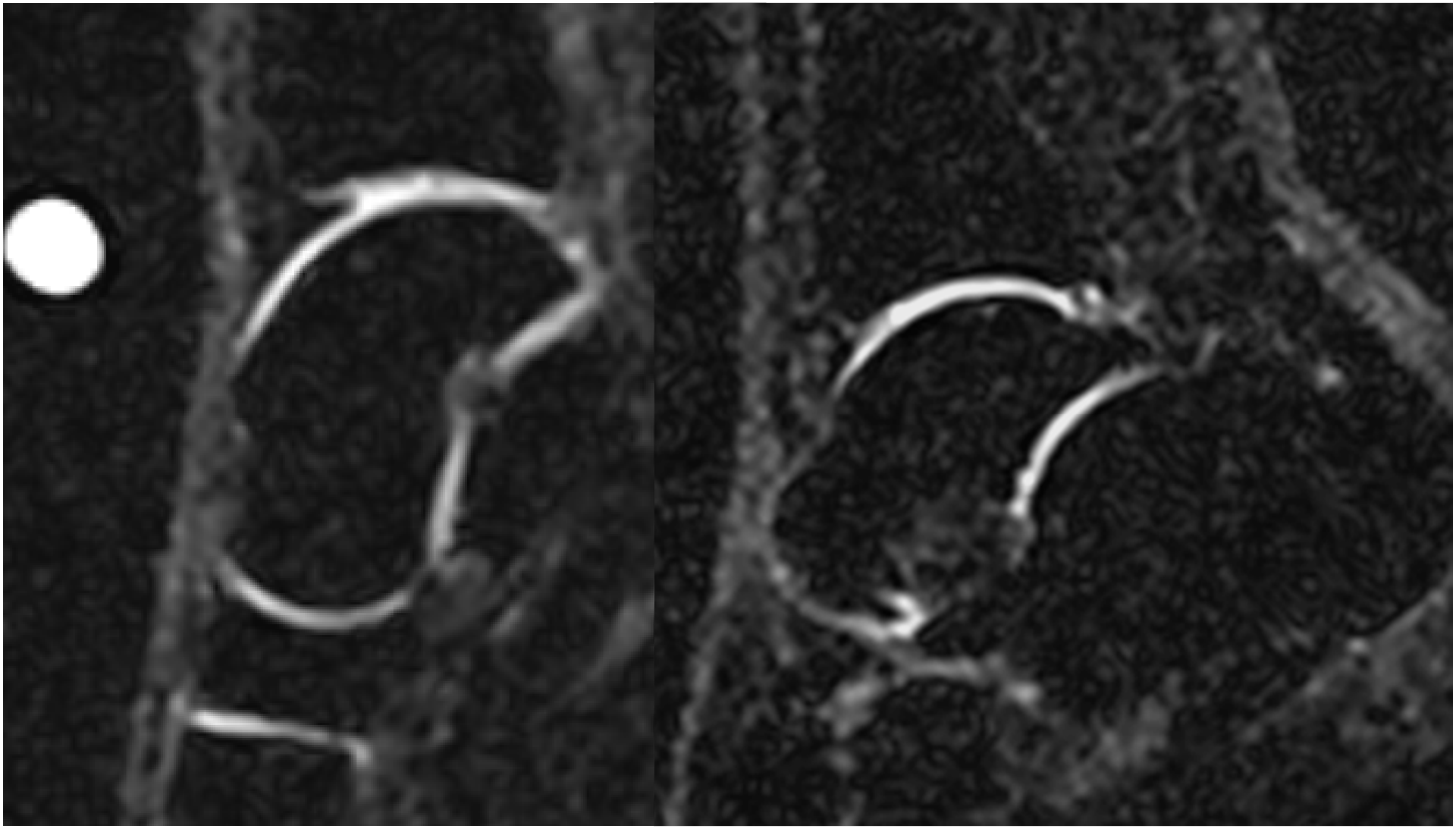



**The central part of the lesion (L) can be delineated in morphologic PD**

**sodium image shows a larger extent of signal loss compared to normal reference tissue (NT), which affects cartilage tissue adjacent to the apparent lesion (AT)**


NT
AT
L
T2 map
100 ms
0 ms
Sodium
490
460
430
400
370
340
CEST
12.5
10
7.5
5
2.5
0

# 7 Tesla Ankle joint: sodium



# Sodium (23Na) at 7T in Patients after Two Cartilage Repair Procedures in Ankle Joint

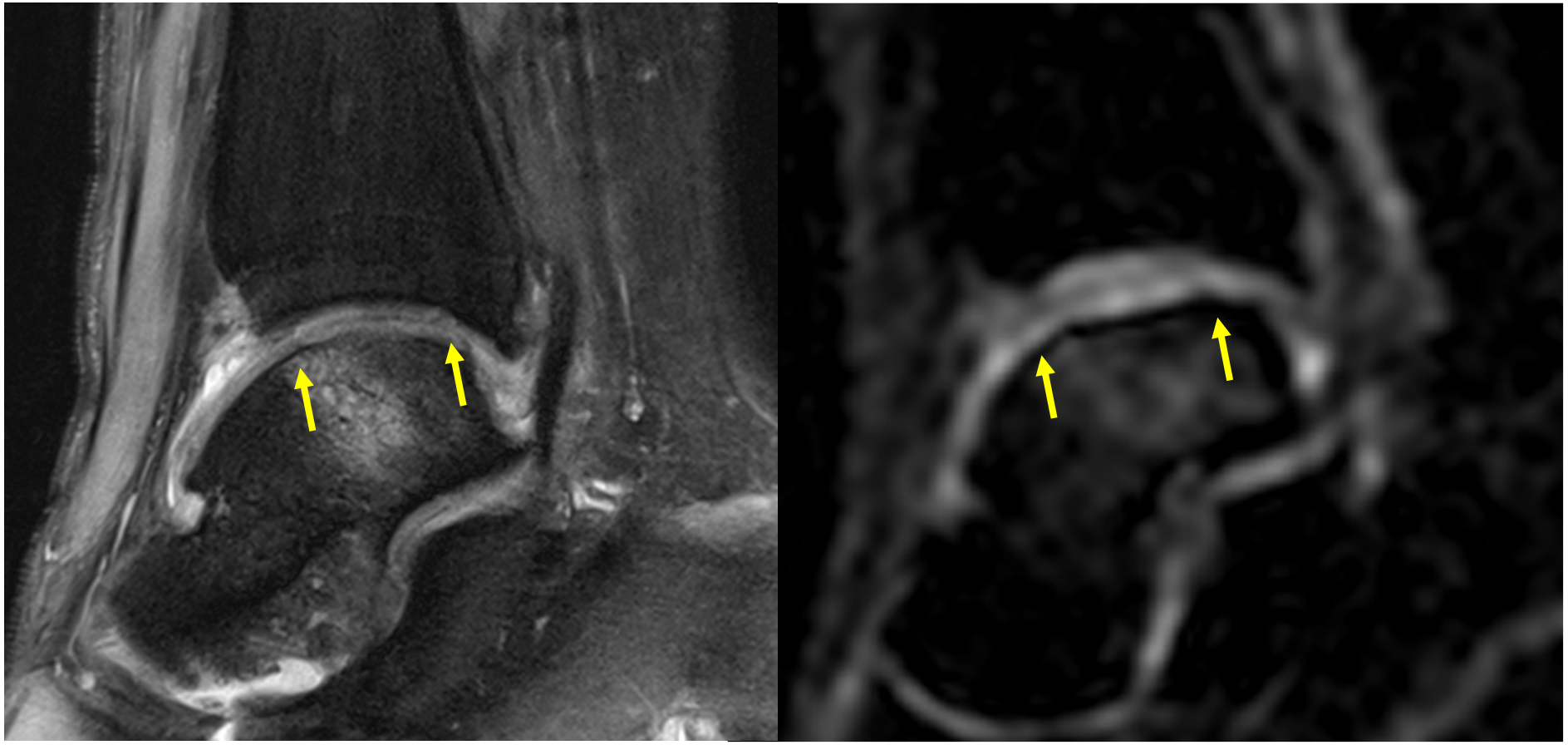
## Patients

- 14 patients (4 MFX and 10 MACT patients; 9 females, 5 males) with a mean age of 35.1±8.7 years and a mean postoperative interval of 85.6±36.9 months

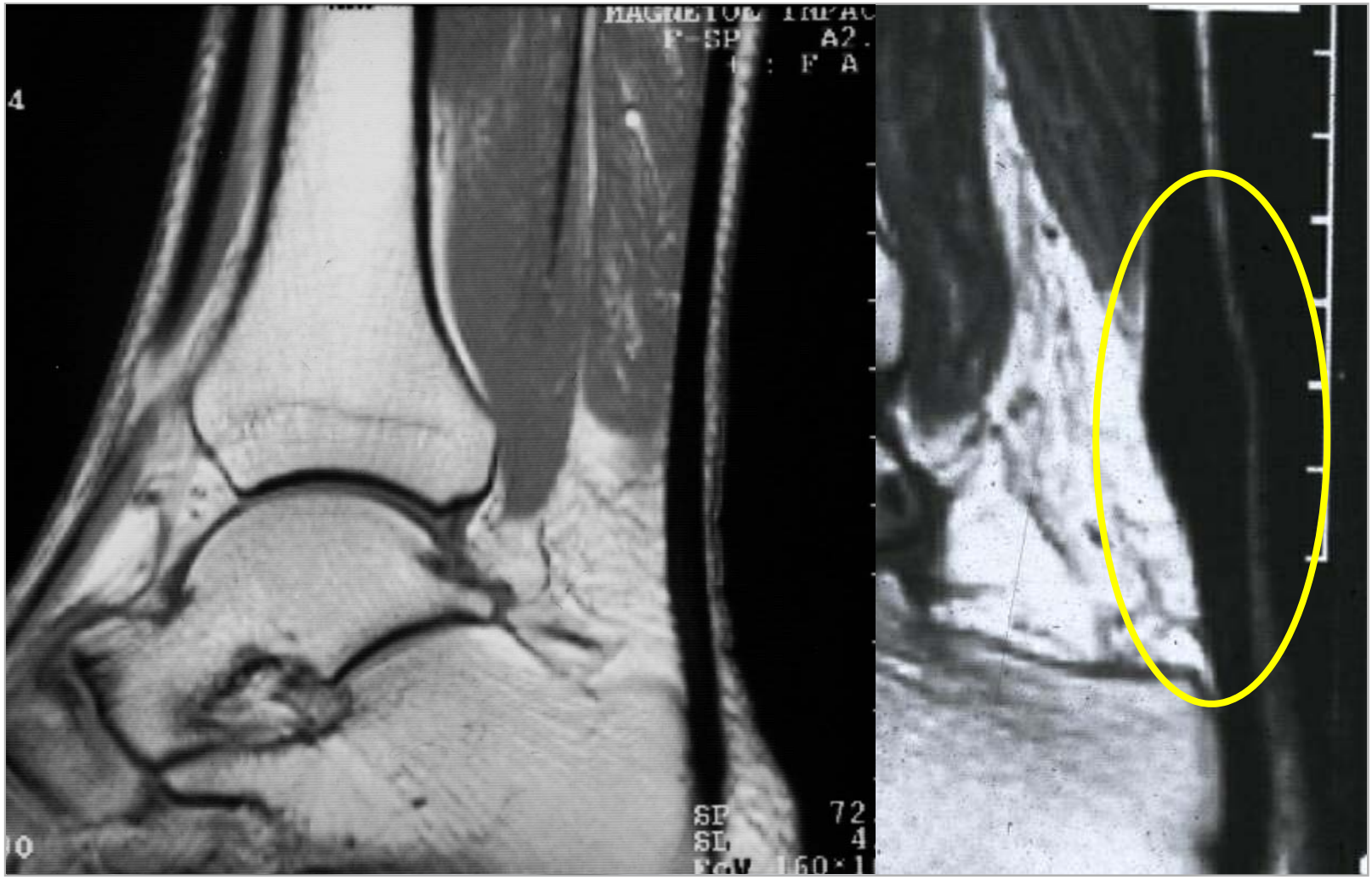
## Results

- Sodium SNR was significantly lower in repair tissue when compared to reference cartilage ($p$=.024).
- However, sodium SNR was not significantly different between MACT and MFX repair tissue ($p$=.731), and also not between the reference cartilage in MACT and MFX patients ($p$=.280). Practically no correlation was observed between the MOCART score and sodium repair tissue SNR ($r$=-.150)

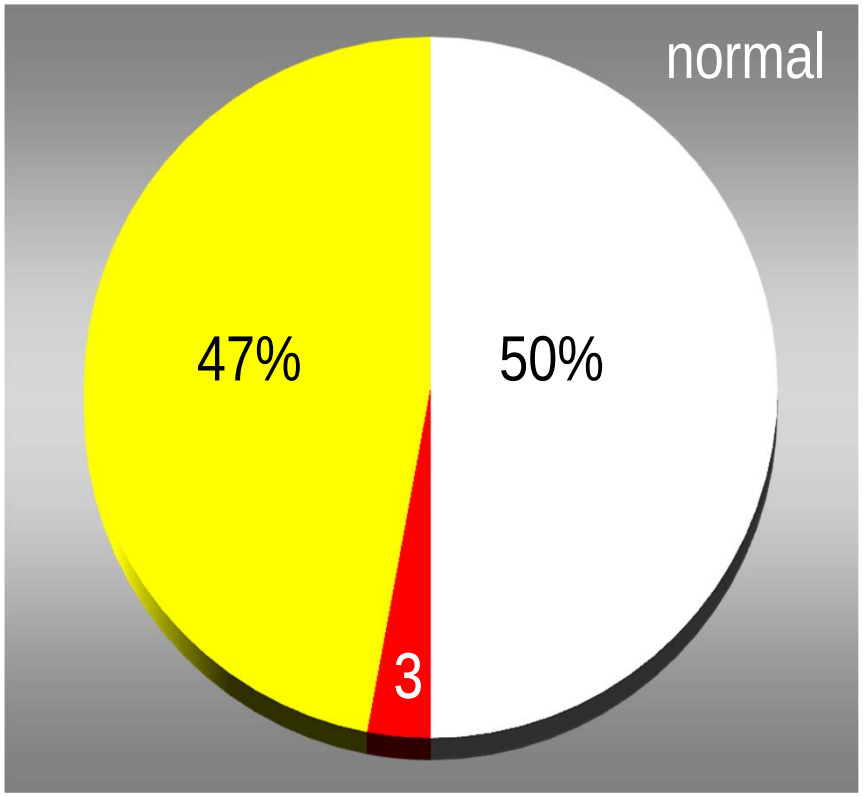
# Sodium imaging at 7T after MACT ankle joint



# Achilles tendon normal, tendinitis



# Matrix changes in chronic tendinitis

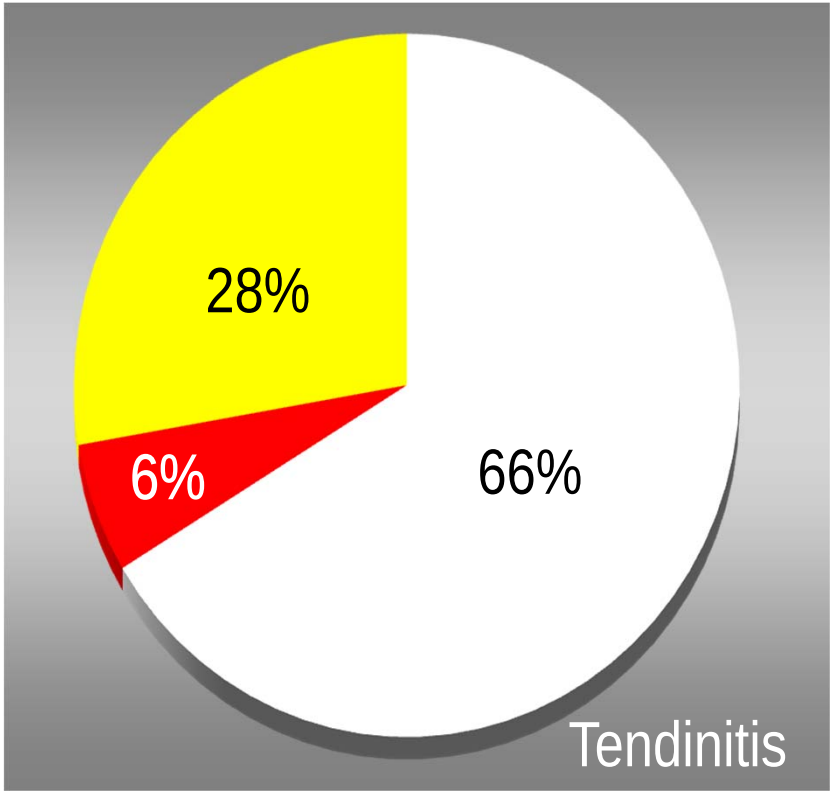



Water

Collagen

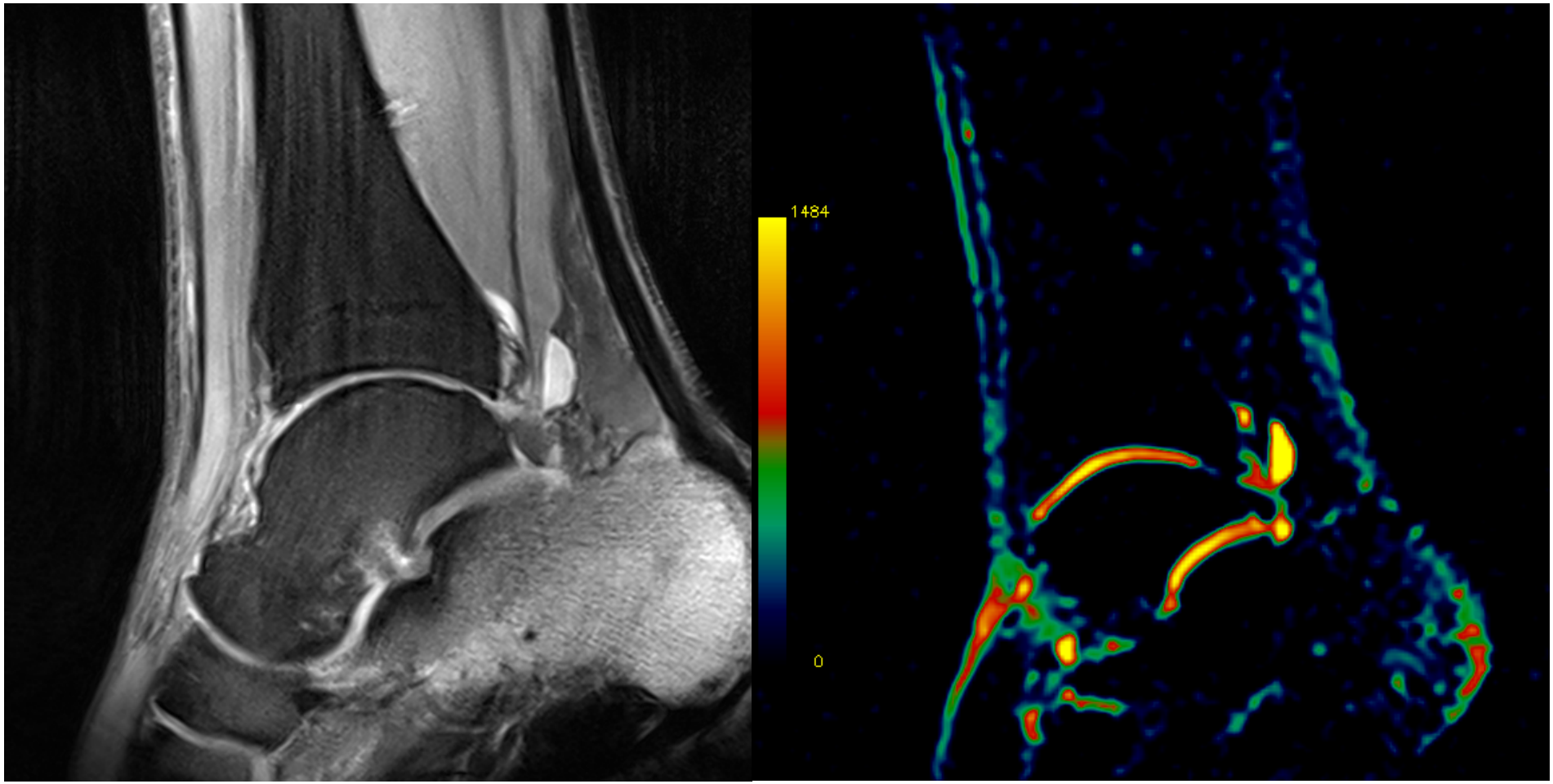
Glycosaminoglycan

Samiric et al. Matrix Biol 2009
Cook et al 2009



# Sodium MR of healthy Achilles tendon

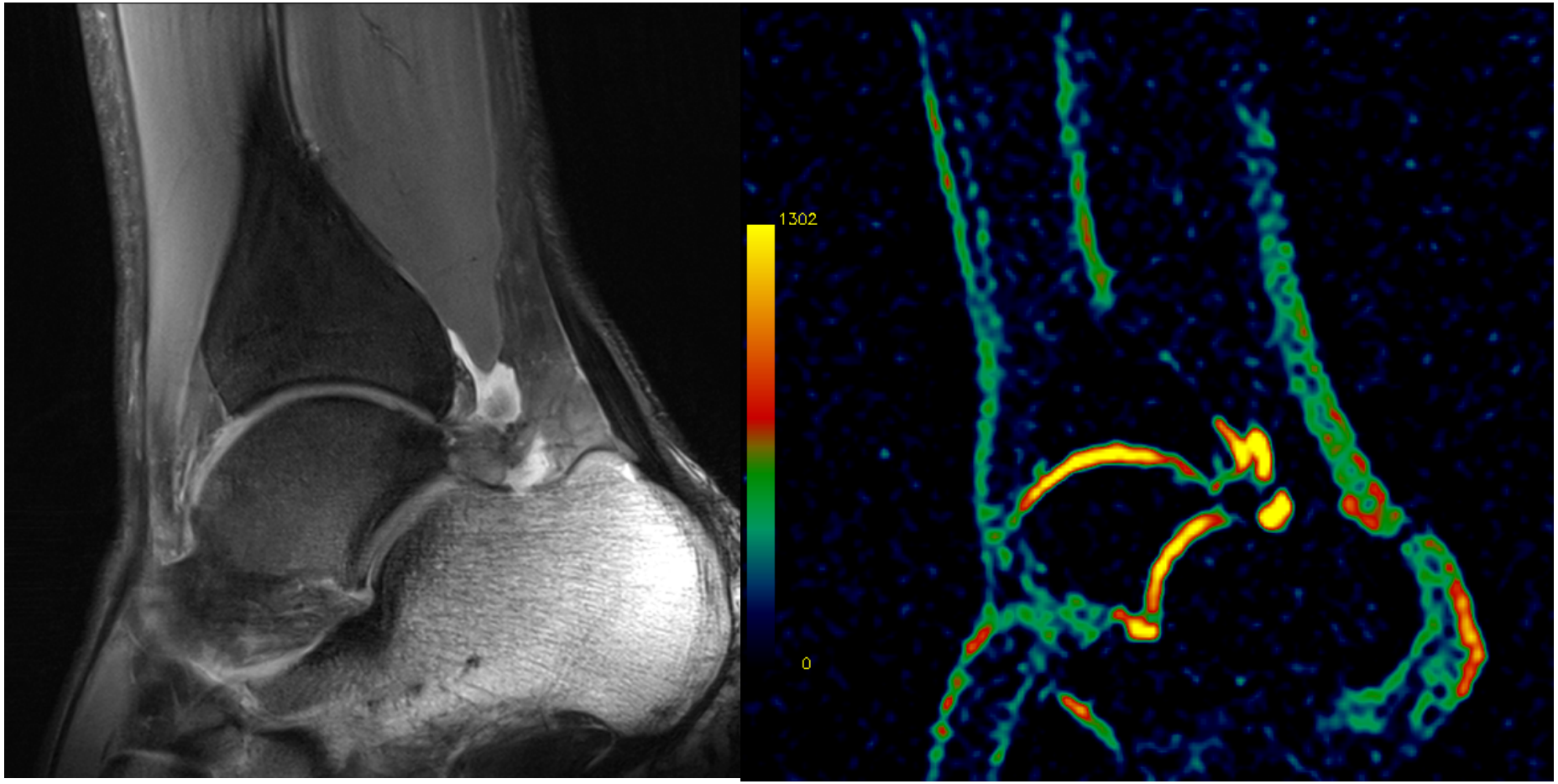
SNR of AT (insertion: 5.74, medial part: 3.09, tendon-muscle: 2.34)



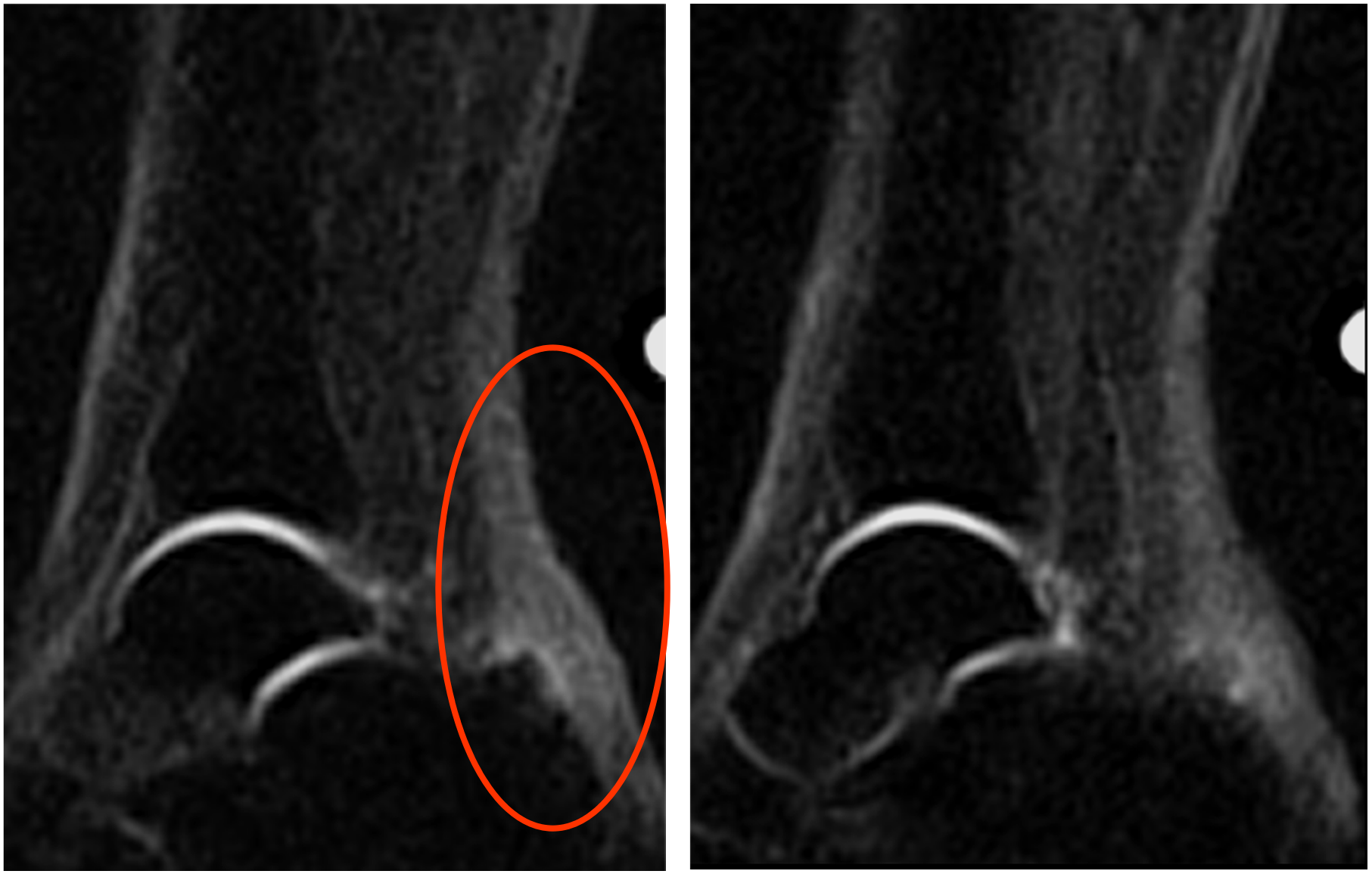

Juras et al RADIOLOGY (in press)

# Sodium MR of Achilles tendinitis

SNR of AT (insertion: 14.56, medial part: 12.59, tendon-muscle: 9.93)



# $^{23}$Na Bildgebung der Insertionstendinitis

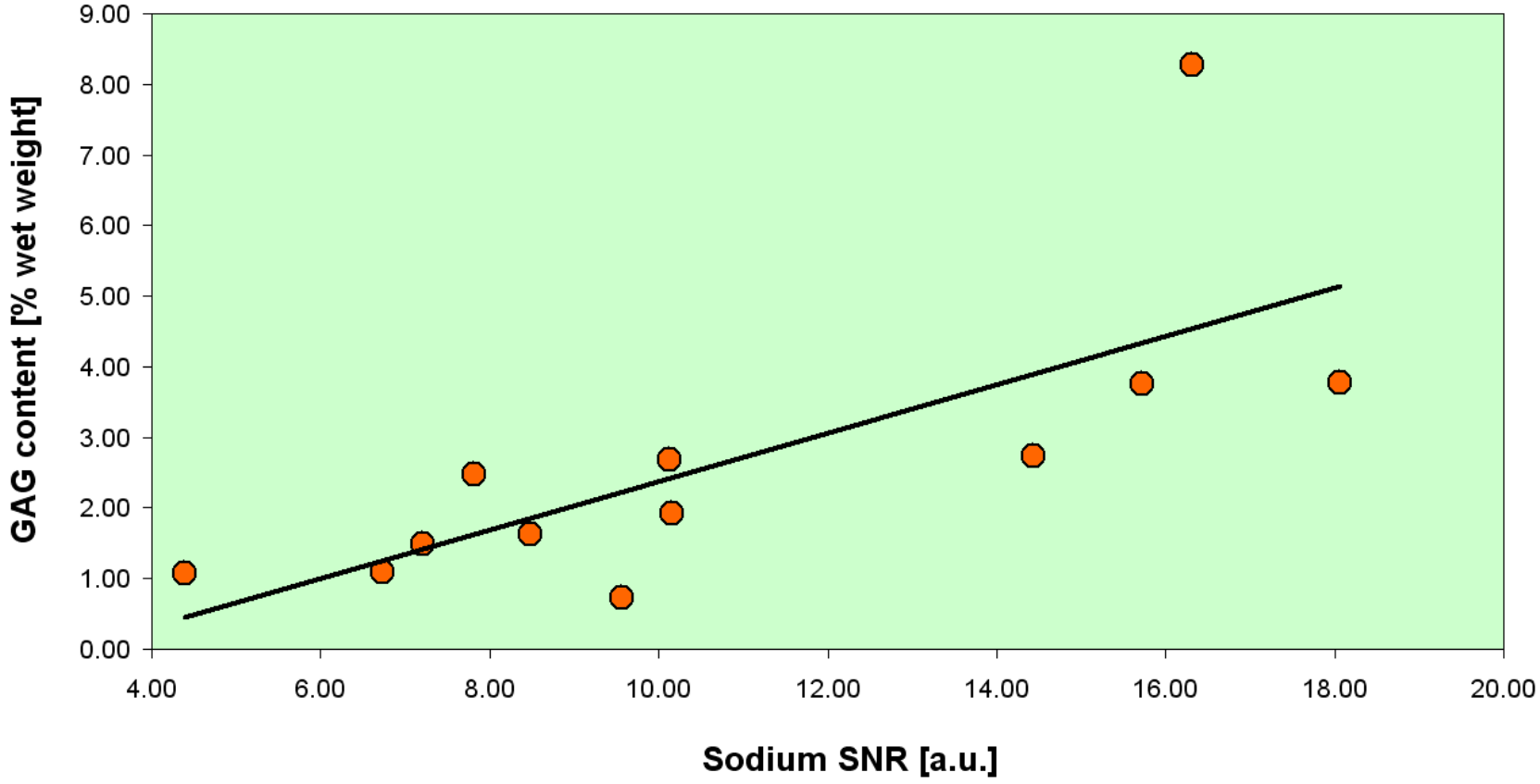


# Vergleich Natriumbildgebung normale Sehne und chronische Tendinose

| | controls | | | patients | | | |
|---|---|---|---|---|---|---|---|
| **region** | sodium SNR | Standard deviation | mean area [mm$^2$] | sodium SNR | Standard deviation | mean area [mm$^2$] | p-value |
| **INS** | 6.68 | 2.31 | 63.92 | 12.27 | 4.52 | 62.85 | 0.0081* |
| **MED** | 5.11 | 1.87 | 125.51 | 9.37 | 3.00 | 121.12 | 0.0041* |
| **MTI** | 3.88 | 1.32 | 202.20 | 6.30 | 2.21 | 216.04 | 0.0137 |
| **bulk** | 4.94 | 2.14 | 130.54 | 9.31 | 2.26 | 133.33 | 0.0006* |

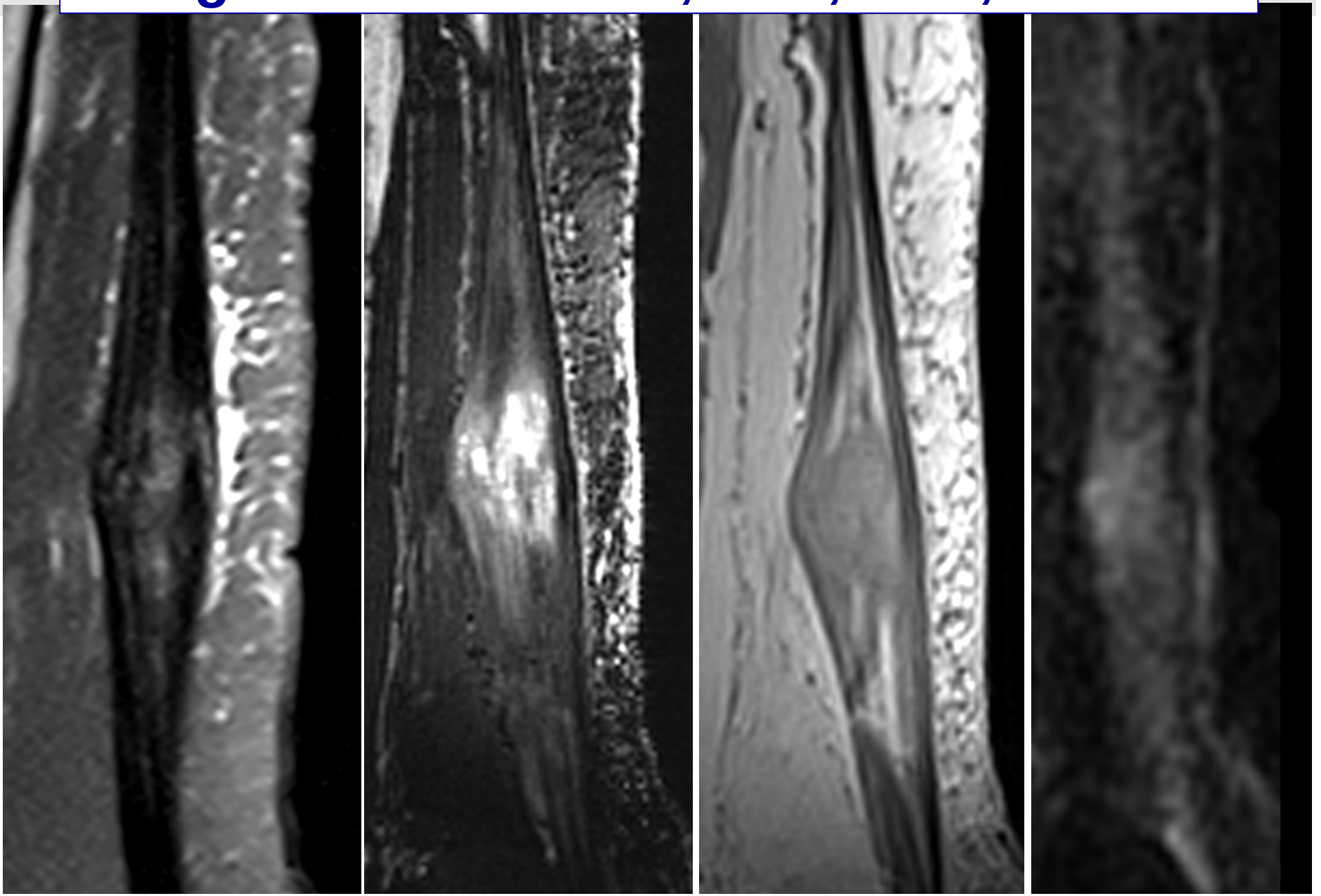
The summary of sodium SNR in different ROI locations of controls and patients with chronic Achilles tendinosis. Statistically significant differences are marked by asterisk sign

# Validierung:
# Vergleich $^{23}$Na SNR mit GAG Gehalt




The correlation between normalized sodium signal acquired from cadaver AT and histologically assessed GAG content
Pearson correlation coefficient was 0.7315

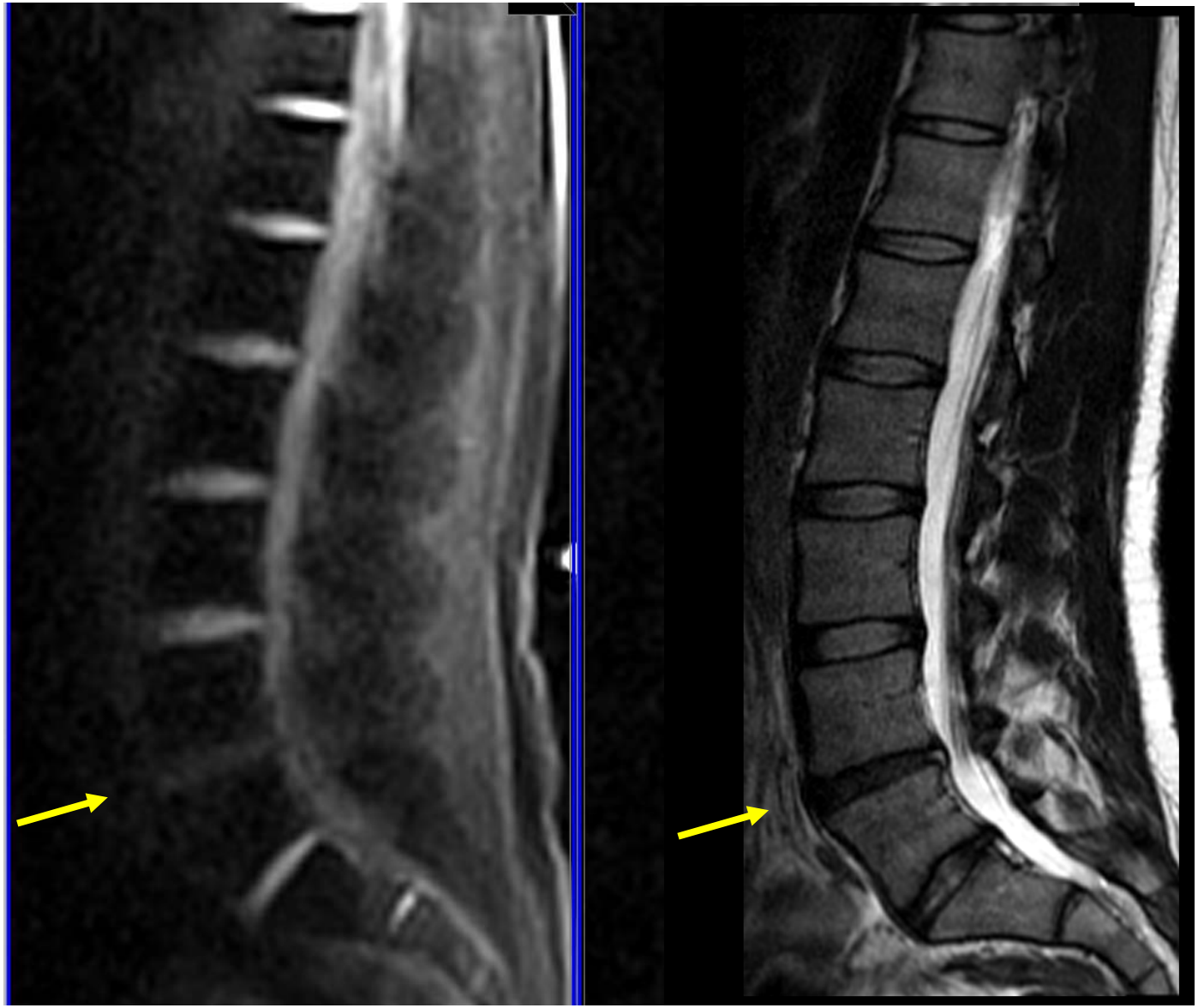
# Vergleich PD-FSE 3T, DWI, UTE, $^{23}$Na 7T



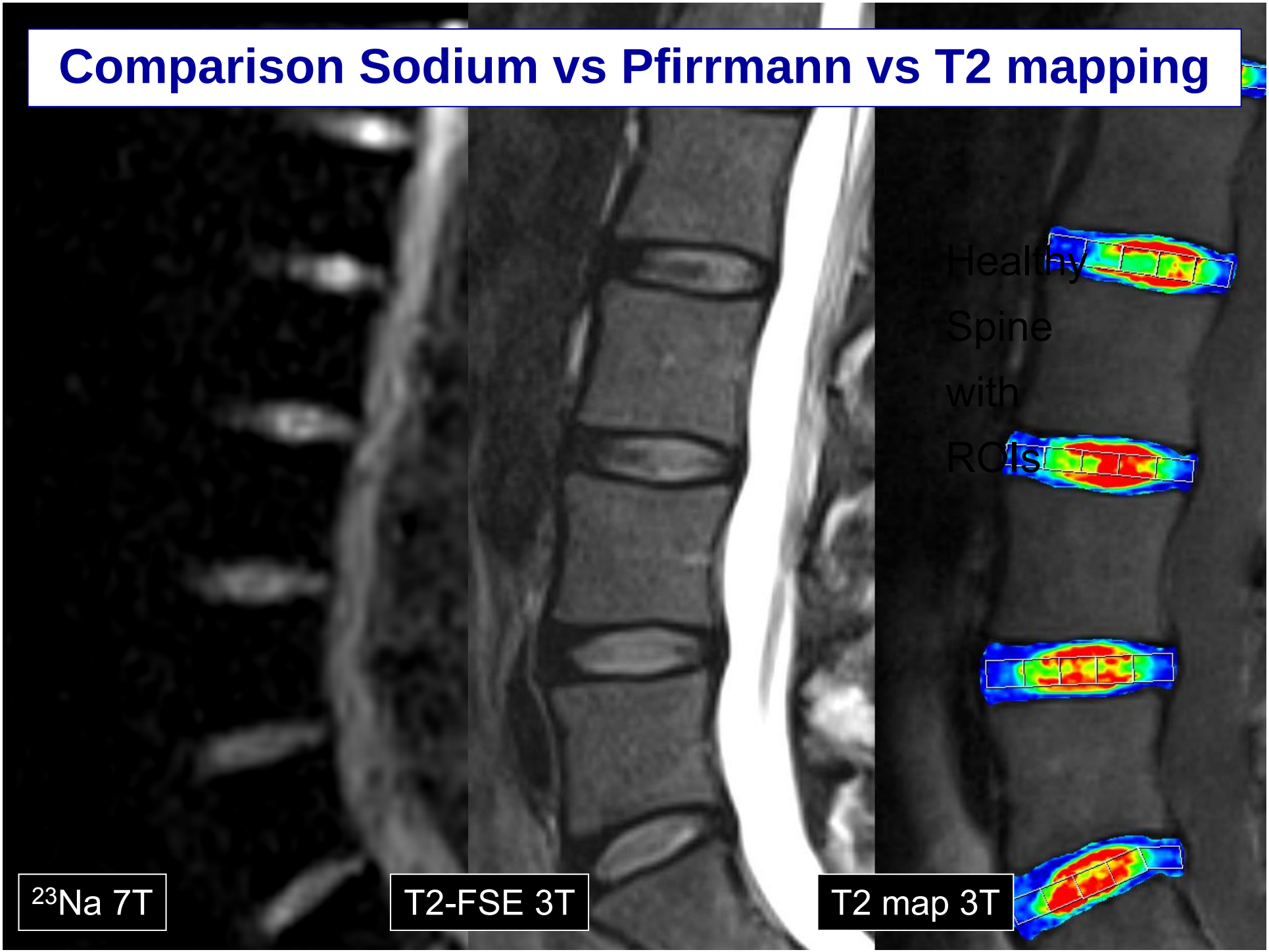
# Comparison between MR and immunhistological parameters in tendons

| | sodium SNR | T2 [ms] | FISP signal [a.u.] | PSIF signal [a.u.] | GAG [% of dry weight] | water content [%] |
|---|---|---|---|---|---|---|
| sodium SNR | 1.000 | 0.373 | **0.524** | 0.303 | **0.710** | -0.480 |
| T2 [ms] | 0.373 | 1.000 | **0.564** | **0.511** | 0.263 | -0.109 |
| FISP signal [a.u.] | **0.524** | **0.564** | 1.000 | **0.958** | 0.170 | 0.340 |
| PSIF signal [a.u.] | 0.303 | **0.511** | **0.958** | 1.000 | 0.031 | 0.330 |
| GAG [% of dry weight] | **0.710** | 0.263 | 0.170 | 0.031 | 1.000 | **0.7572** |
| water content [%] | -0.480 | -0.109 | 0.340 | 0.330 | **0.7572** | 1.000 |

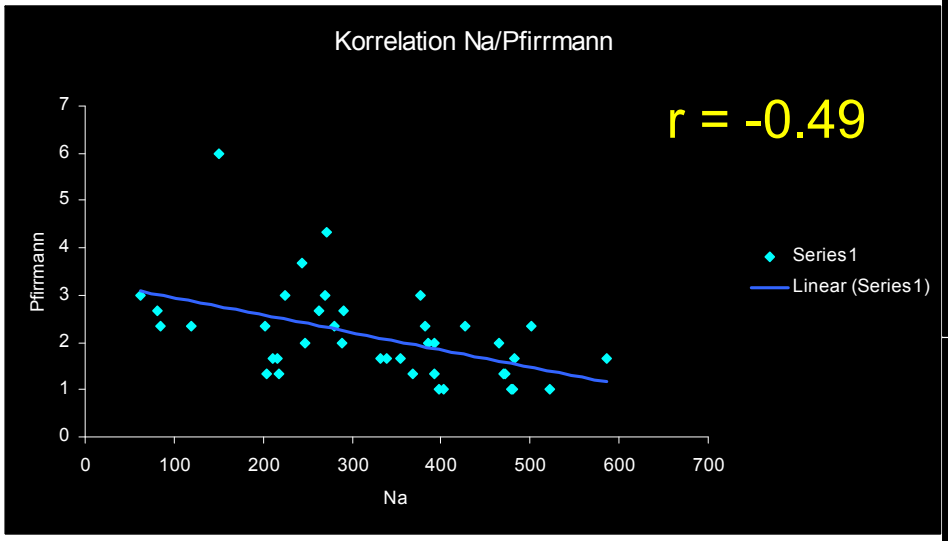
# Spine 6ch sodium coil at 7T - first results

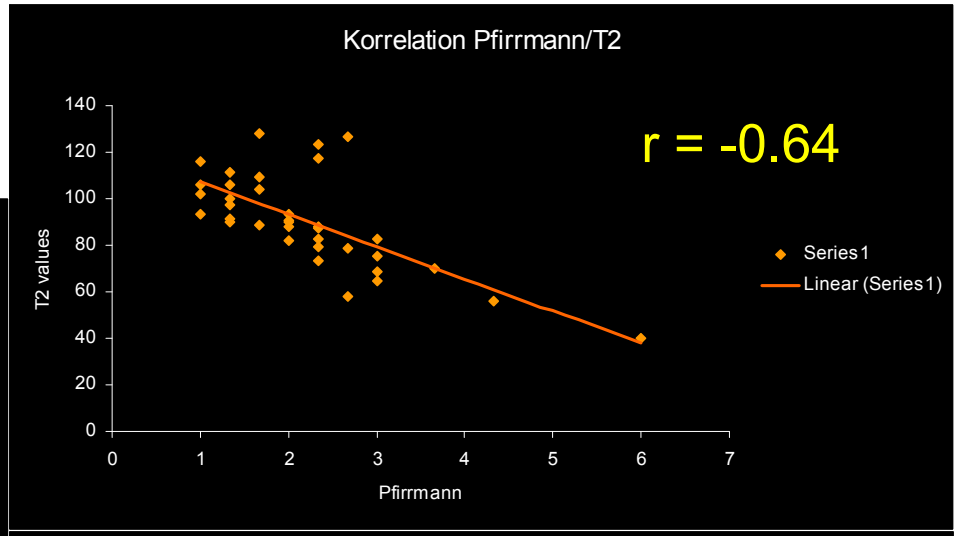


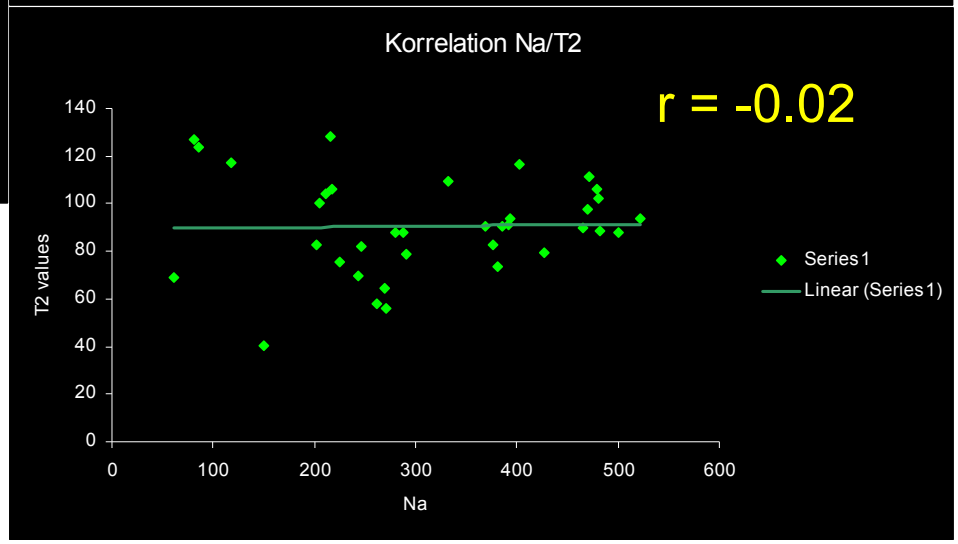
# Comparison Sodium vs Pfirrmann vs T2 mapping



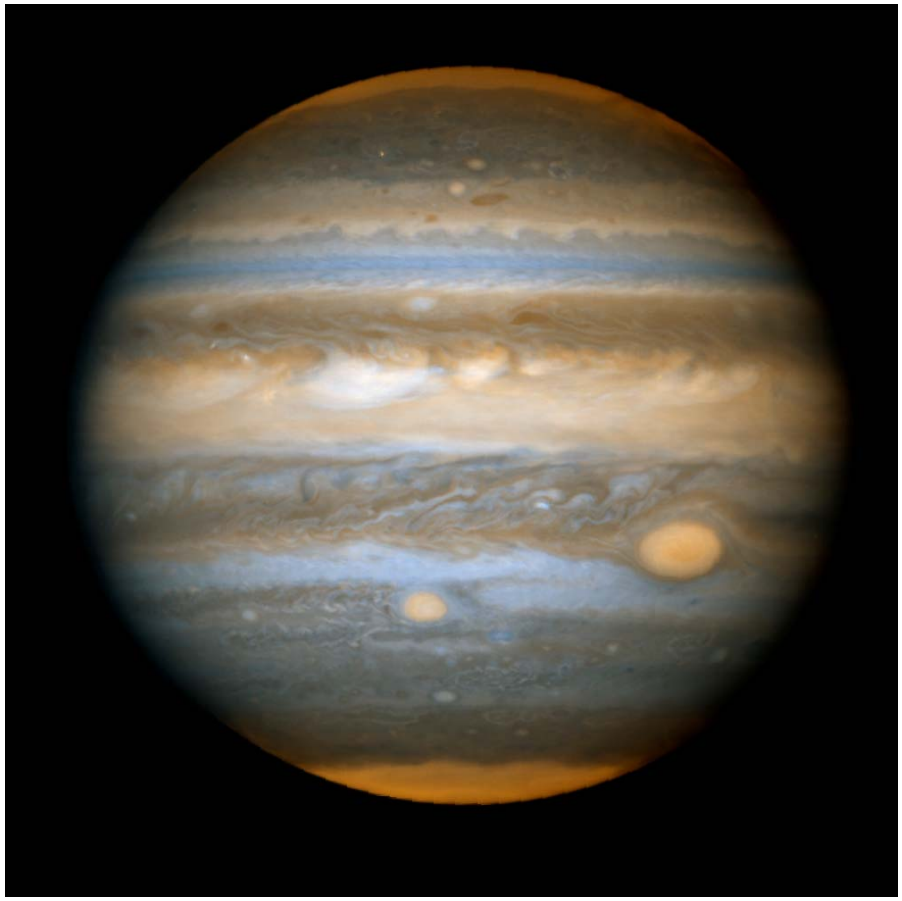
# Pearson-Correlations

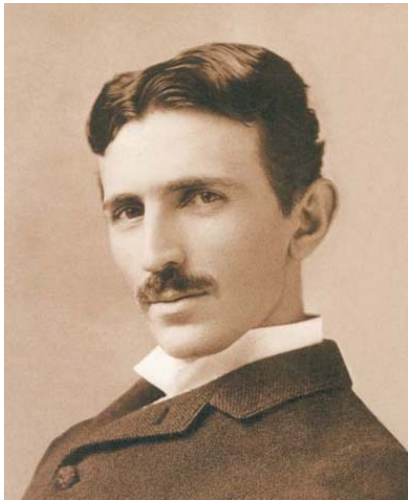


# Thanks for your attention!





1899
Nikola Tesla detects radio waves from Jupiter