SPECT/CT is Far Superior to MRI and Other Imaging in the Assessment of Implant Failures

(Joint Replacements, Osteosyntheses, and Spinal Fusions)

The MSK Radiologist Perspective

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Lucky MSK radiologist with an
opportunity to use SPECT/CT

SPECT/CT addresses all questions
orthopedic surgeons might have
in case of suggested implant failure.

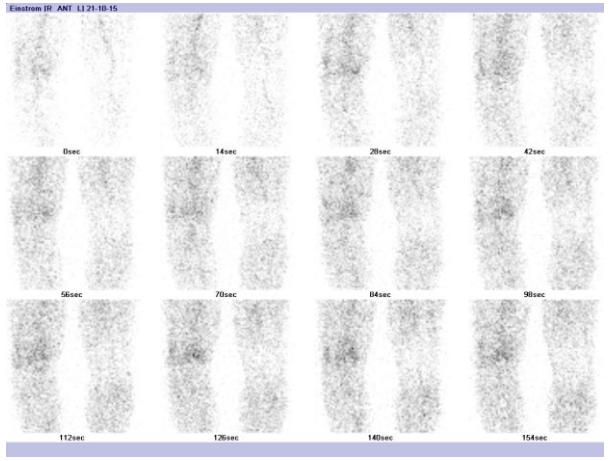
MSK radiology has nothing comparable

Lindenhof Hospitals Bern

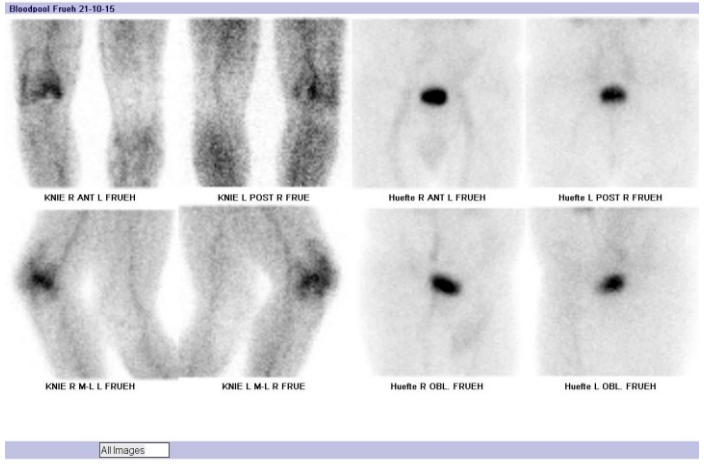
- One of the largest private hospital groups in Switzerland, largest in the Canton Bern
- One of the largest orthopedic groups in Switzerland (hip, knee, feet, spine, shoulder, hand, pediatric)
- 2018 Lindenhof Orthopedic Surgery replaced more hips than any other team in switzerland (sign of quality?)
- 6 MRI, 3 CT, 1 SPECT/CT, Rx, US, Tomo, biopsies, vascular interventions
- Largest Breast Center in Switzerland

3-phase SPECT/CT + CT alignment/rotation consists

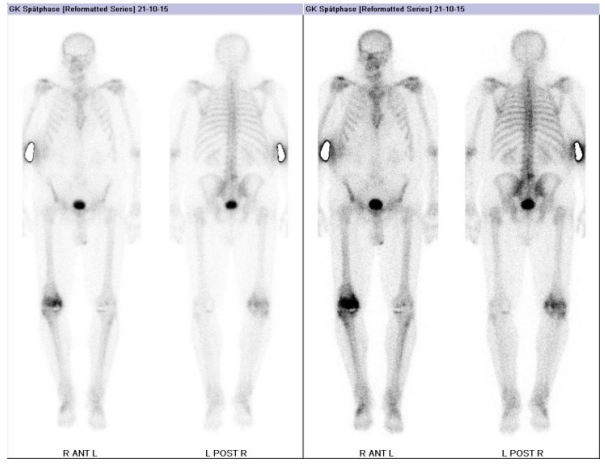
Arterial phase



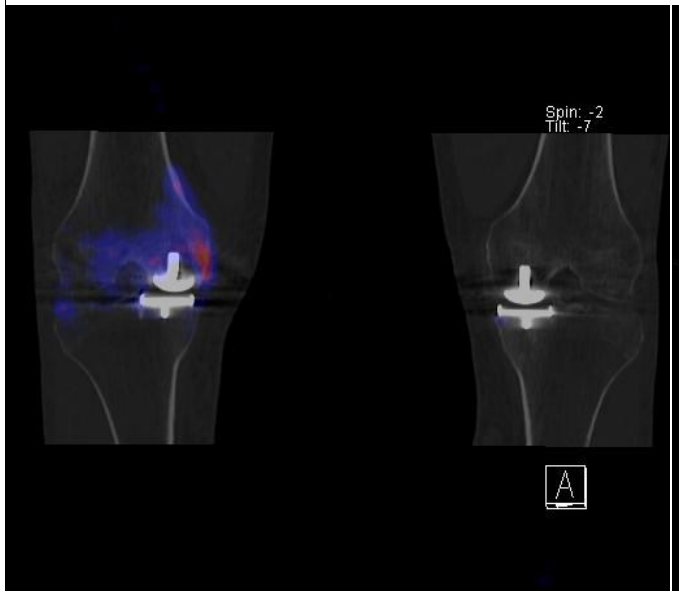
Bloodpool



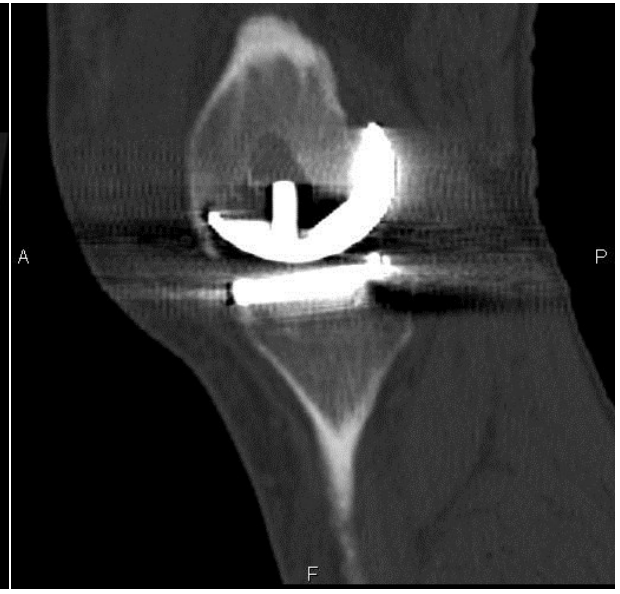
Bone remodeling WB



SPECT/CT fusion



CT bone window

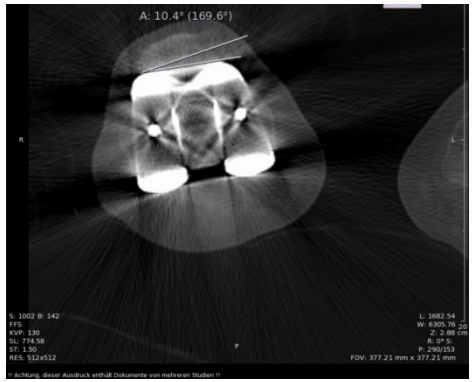


CT soft tissue window

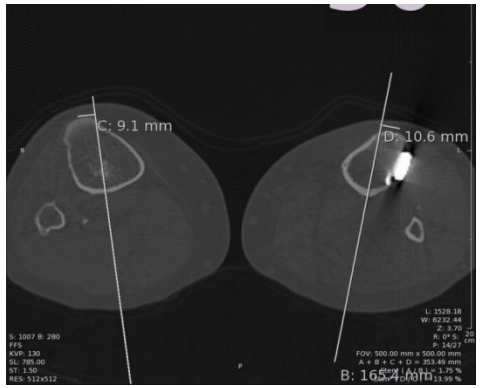
CT alignment scan/rotation
Misload to patella and implant

CT scout

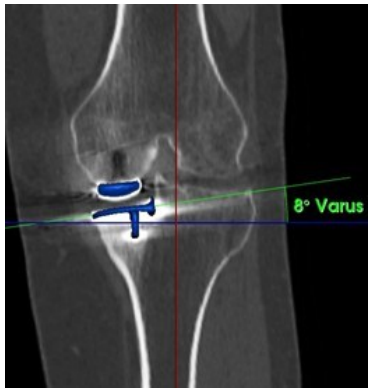
Patella tilt



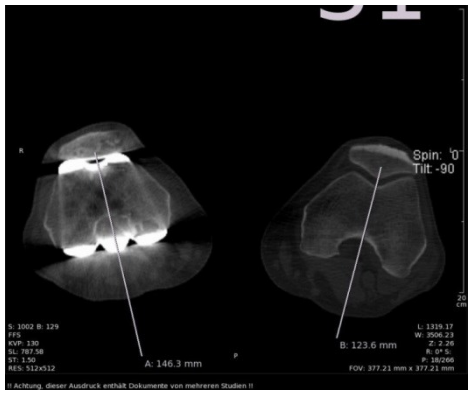
TTTG/tibial rotation



Implant rotation

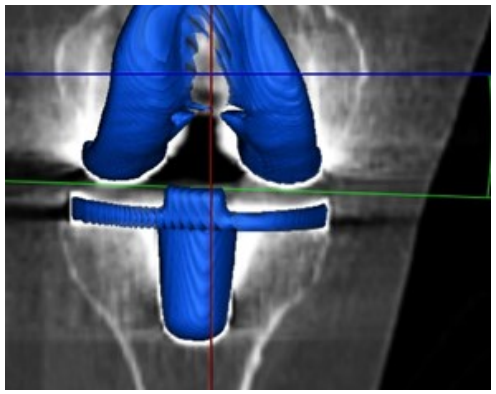


Patella shift



CT vertical position

Implant alignment



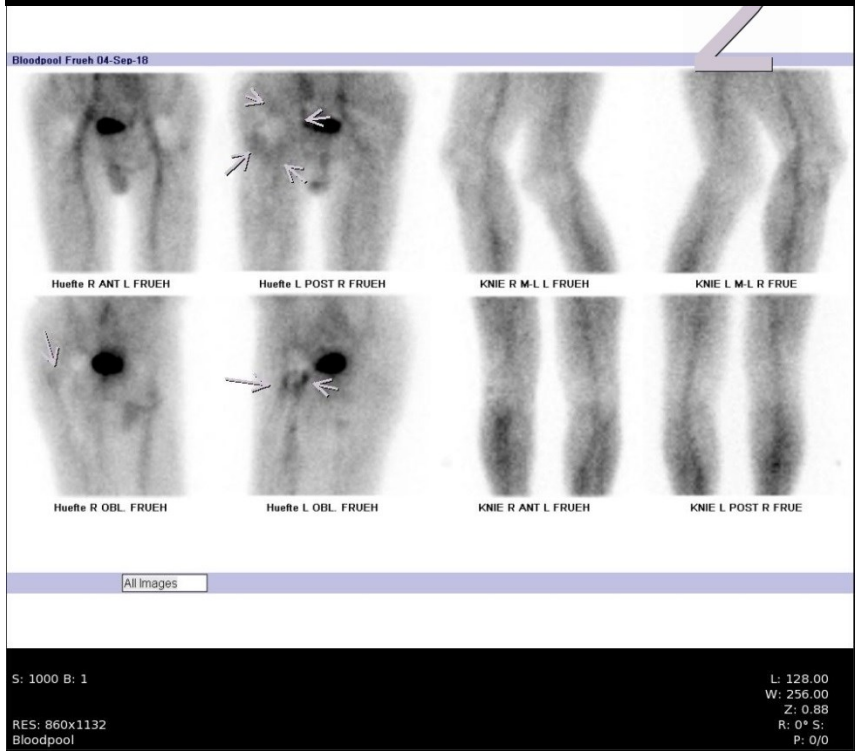
Why love? Answers…
3-phase SPECT/CT + simultaneous CT evaluation alignment offers

- Sensitive detection of soft tissue and bone hypervascularization and bone remodeling/bone stress reaction (in MRI image BML = source of pain
- Superior grading of synovitis and bone stress reaction, to MRI
- Superior evaluation bone matrix close to implant, to MRI
- Superior evaluation of imlant break and screw loosening, to MRI
- Proof of joint malalignment and patella maltracking due to large FOV
- Simultaneous assessment of extra-articular source of pain due to large FOV
- Simultaneous evaluation of muscle quality
- Simultaneous evaluation of nerve root compression in THA due to large FOV

Example of strength
M, 75Y, pain in left hip after bilateral THA

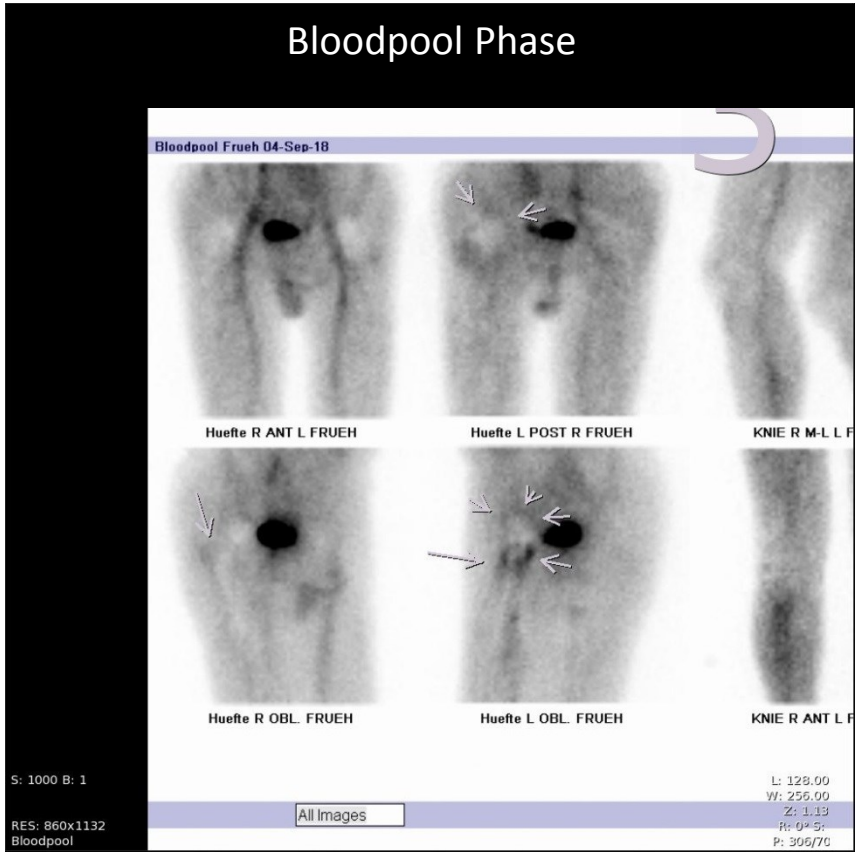
Arterial Phase

Bloodpool Phase



Slight bone hypervascularization (HV) along THA cap L
Moderate intertrochanteric bone (HV) L, grading
Knee w/o synovitis or bone HV, source of pain not knee

Intra- or extra-articular source of pain?
Grading stress reaction of soft tissue and bone



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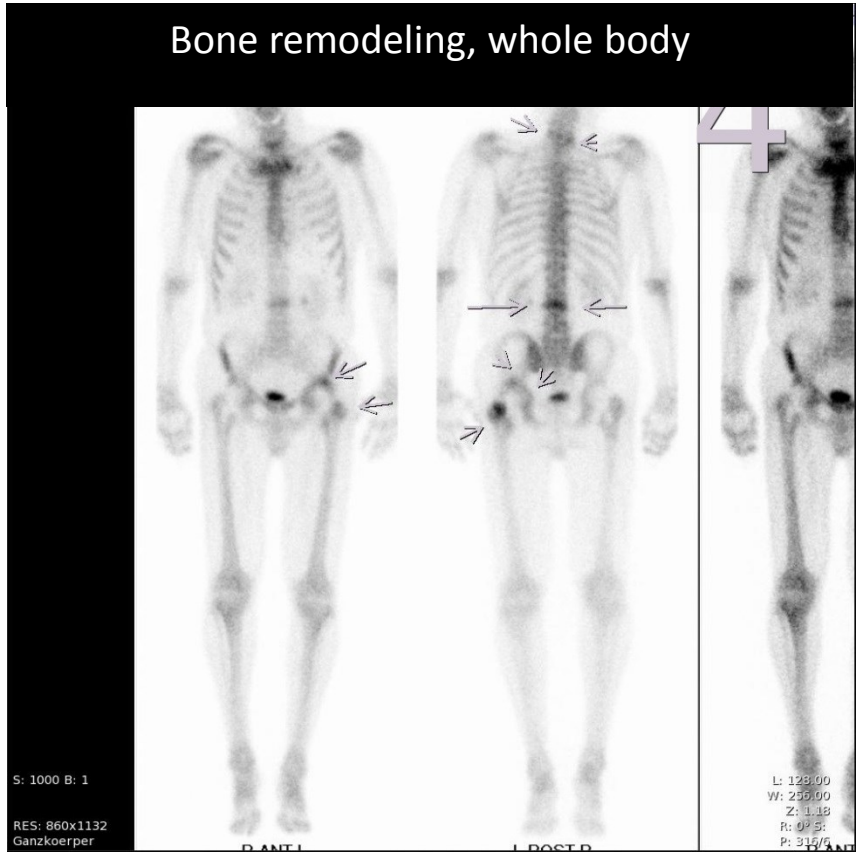


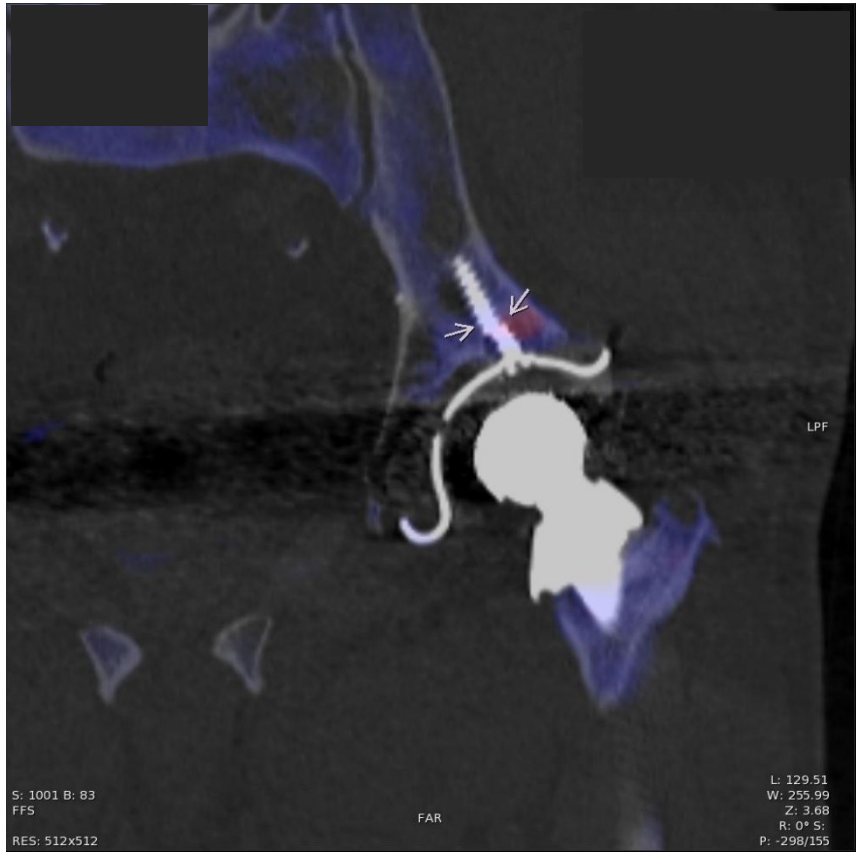
Slight bone bone remodeling (BR) along THA cap L
Severe posterior intertrochanteric BR L, grading
Lumbar spine OA or compression, source of pain?

Mild metal artefacts, screw break, loose cap, silent chronic fracture medial acetabulum

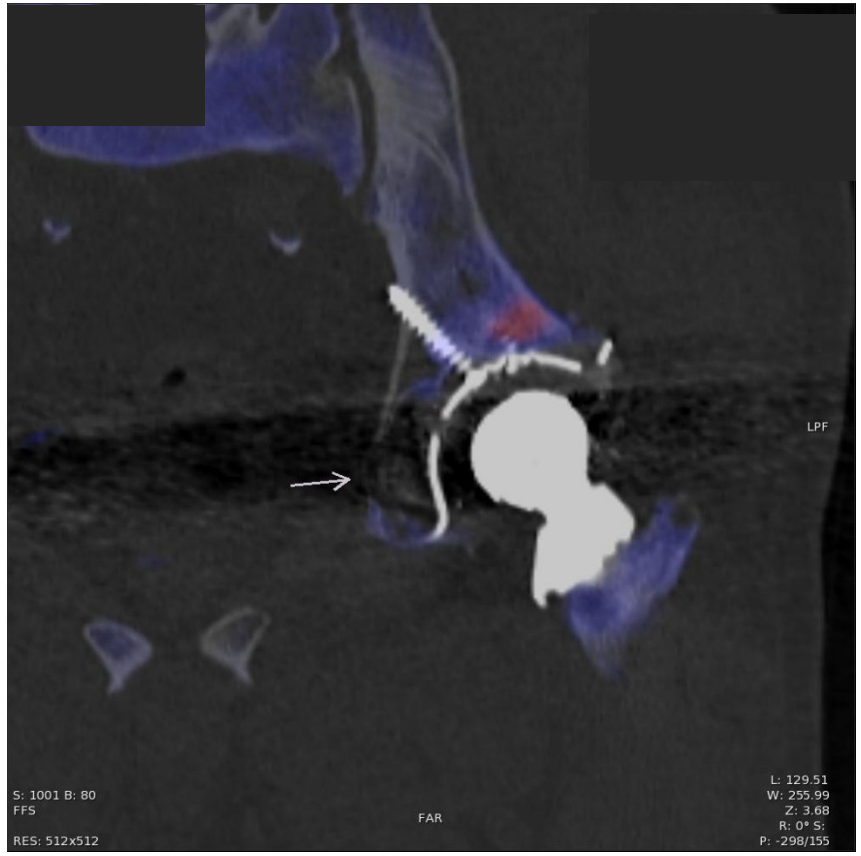
Fused SPECT/CT (xSPECT)

CT bone window

Osteolysis, particle disease, L acetabulum

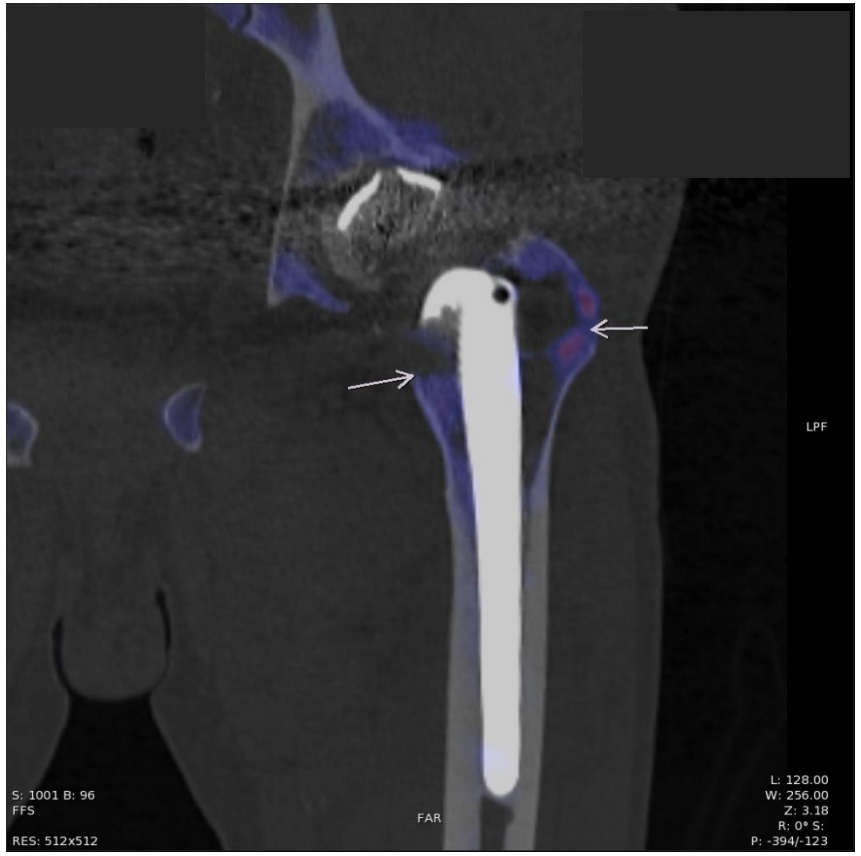


Fused SPECT/CT (xSPECT)



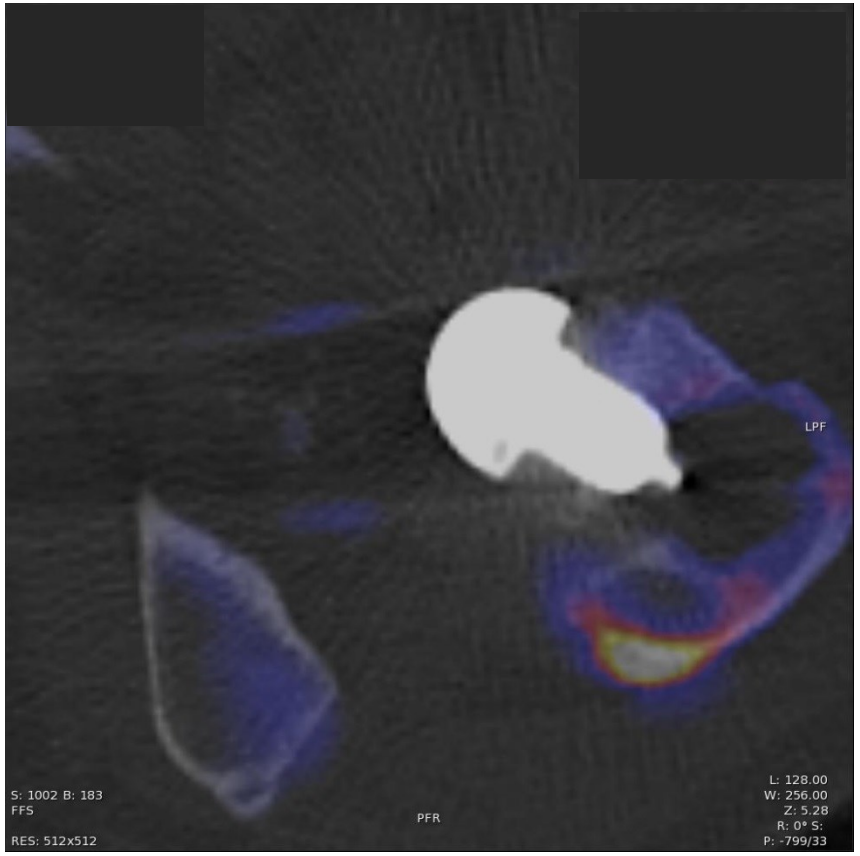
Fused SPECT/CT

Osteolysis, particle disease, L femur
w/o relevance for stability of femur component



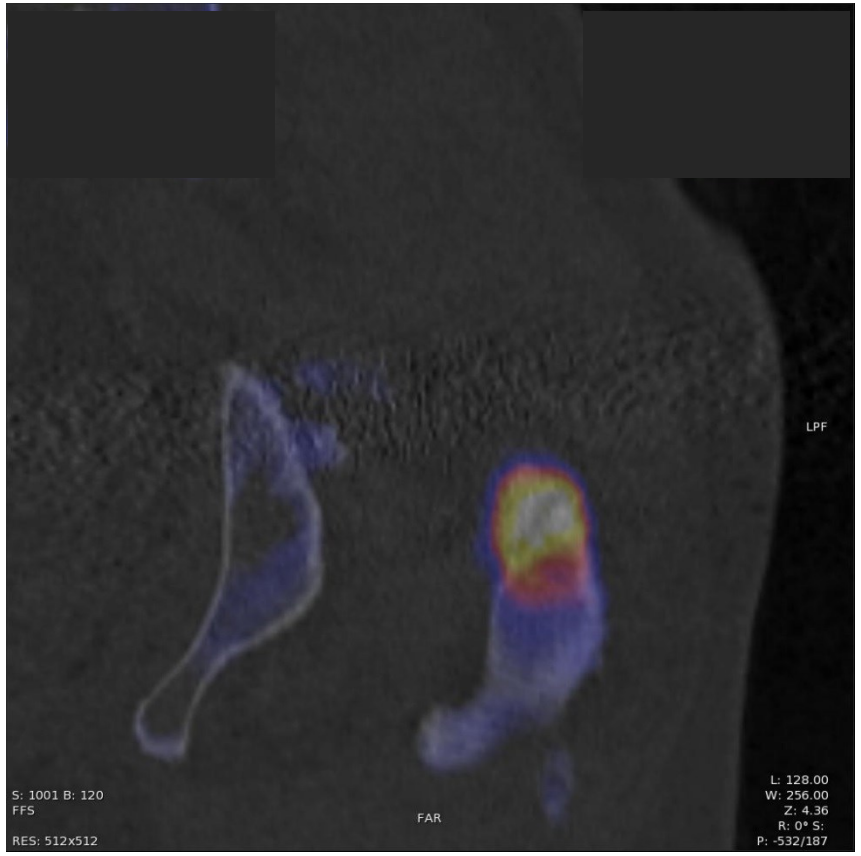
Fused SPECT/CT (xSPECT)

No BR/ stress reaction or lysis along stem



Fused SPECT/CT

Not dislocated trochanteric fracture/avulsion medial gluteus L

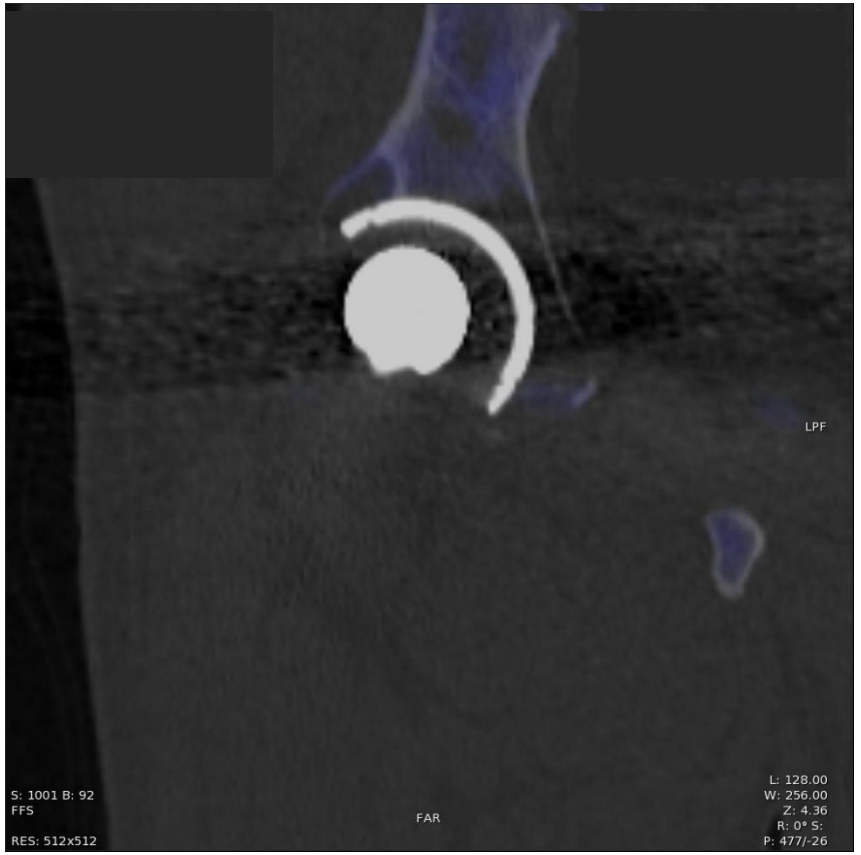


Fused SPECT/CT (xSPECT)

CT soft tissue window

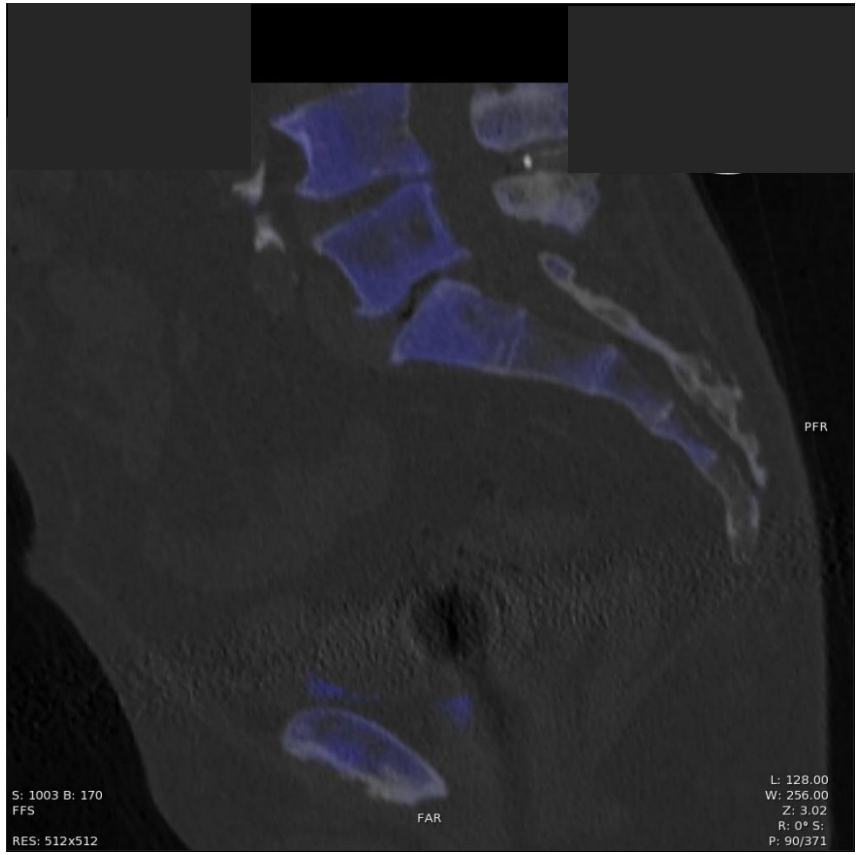
Osteolysis, particle disease, R femur + cap w/o relevance for stability of femur component

Fused SPECT/CT (xSPECT)
No BR/ stress reaction or extended lysis along stem



Fused SPECT/CT
No BR/ stress reaction or extended lysis along cap

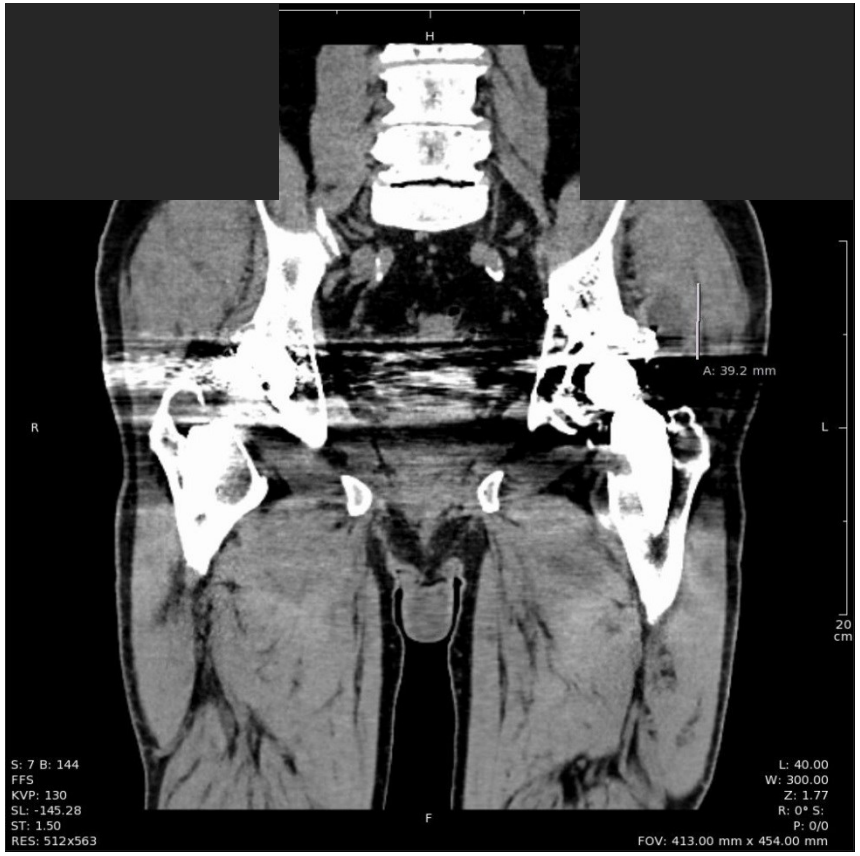
Simultaneous exclusion of nerve root compression, spine instability, activated facets



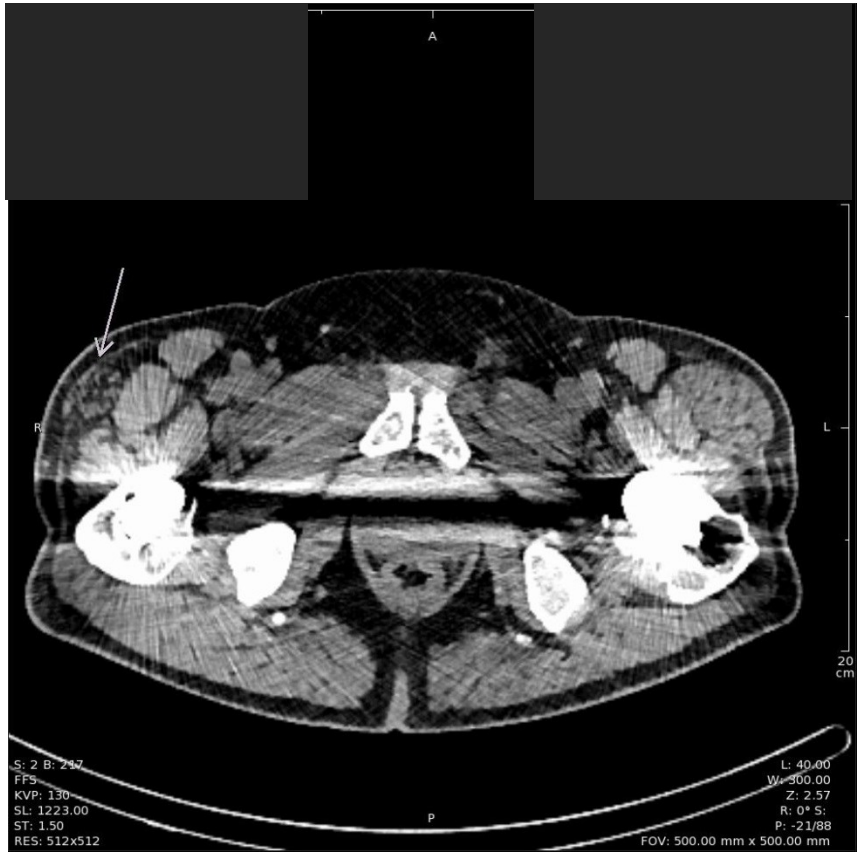
Fused SPECT/CT (xSPECT)
No BR/ stress reaction, no instability

CT soft tissue window
Moderate stenosis of neural foramen, nerve root compression possible

Ganglion cyst after THA L
Fatty degeneration of M. tensor faciae latae R



CT soft tissue window
4 cm ganglion cyst between gluteus medius and minimus



CT soft tissue window
Moderate fatty degeneration M. tensor faciae latae

Interpretation/Results

- **Acute, not dislocated trochanteric avulsion L**, likely the source of acute pain (grading of hypervascularity and bone remodeling, grading of stress)
- **Loosening of THA cap** with mild hypervascularity and mild bone remodeling, screw break, and less bone medial acetabulum (difficult surgical situation)
- **Effusion left hip without signs of acute infection** (grading of hypervascularity, low grade infections always possible), and **4 cm ganglion into gluteal muscles** (source of pain)
- **No loosening of right THA**, no misload, no periprosthetic fracture, and no signs of acute infection
- **Intertrochanteric foreign body granuloma** without evidence of instability of femoral protheses
- **Retrolisthesis of L5 with moderate neural foraminal stenoses** L4-S1 both sides, neurocomression possible. No spine instability because no activated facets.

A lot to do for the surgeon, needs to fix all, otherwise pain stays

How does MRI image the source of pain?
Imaging BML/pain

T2 (fs) effusions and muscle or bone marrow edema bright, screening pathology

Considered to show the best anatomy, best signal-to-noise

MRI and SPECT/CT image the same
BMLs = hypervascularity, bone remodeling

- **BML**/osseous stress edema **histologically** a mixture of different findings
  - bone marrow necrosis
  - fibrosis
  - vascular ingrowth, hypervascularity (bloodpool)
  - microfractures
  - bone remodeling (phosphonate hypermetabolism)

1. Link TM, Li X. Bone marrow changes in osteoarthritis. Semin Musculoskelet Radiol 2011;15:238-46
2. Hunter DJ, Gerstenfeld L, Bishop G, et al. Bone marrow lesions from osteoarthritis knees are characterized by sclerotic bone that is less well mineralized. Arthritis Res Ther 2009;11:R11.
3. Felson DT, Niu J, Guermazi A, et al. Correlation of the development of knee pain with enlarging bone marrow lesions on magnetic resonance imaging. Arthritis Rheum 2007;56:2986-92.
4. Yusuf E, Kortekaas MC, Watt I, Huizinga TW, Kloppenburg M. Do knee abnormalities visualised on MRI explain knee pain in knee osteoarthritis? A systematic review. Ann Rheum Dis 2011;70:60-7.

BMLs = source of pain?

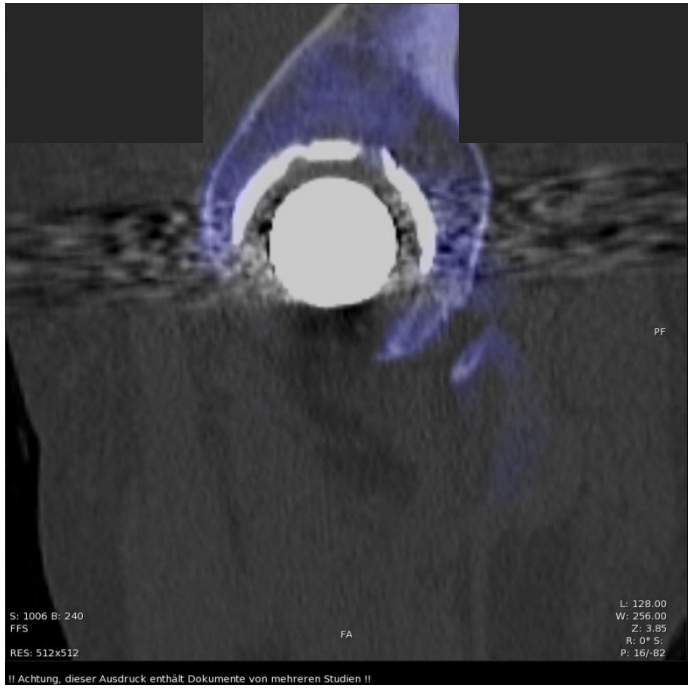
- Yes, bone marrow edema-like lesions (BMELs) are strongly associated with pain = stress reaction
- BMELs in patients with progressive OA
- BMELs in asymptomatic population predict an increased risk of OA. BMLs = osseous overload
- Subchondral bone cysts (SBCs) develop in pre-existing regions of BMELs, bone reaction to overload
- 40% of patients with OA with BMLs have worsening of joint surfaces within 1 year

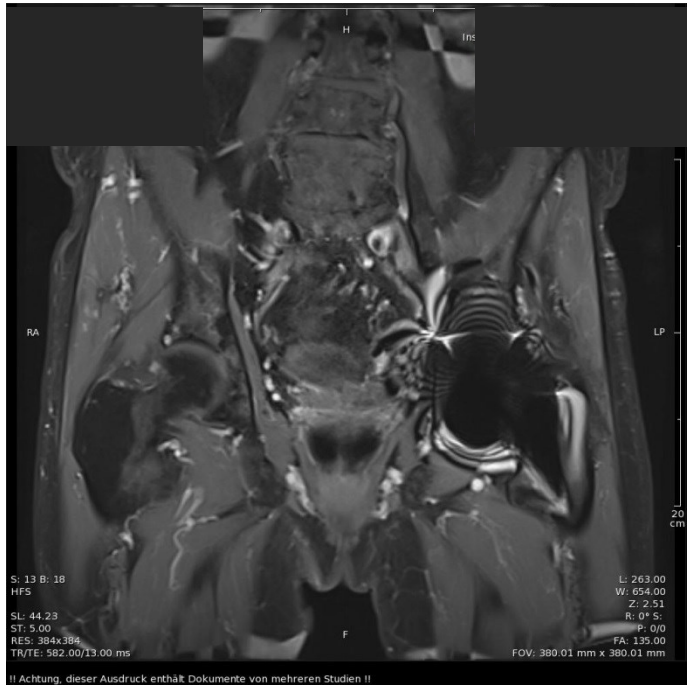
1. Link TM, Steinbach LS, Ghosh S, Ries M, Lu Y, Lane N, Majumdar S. Osteoarthritis: MR imaging findings in different stages of disease and correlation with clinical findings. Radiology. 2003;15:373–381
2. Wluka AE, Hanna F, Davies-Tuck M, Wang Y, Bell RJ, Davis SR, Adams J, Cicuttini FM. Bone marrow lesions predict increase in knee cartilage defects and loss of cartilage volume in middle-aged women without knee pain over 2 years. Ann Rheum Dis. 2009;15:850–855.
3. Carrino JA, Blum J, Parellada JA, Schweitzer ME, Morrison WB. MRI of bone marrow edema-like signal in the pathogenesis of subchondral cysts. Osteoarthritis Cartilage. 2006;15:1081–1085.

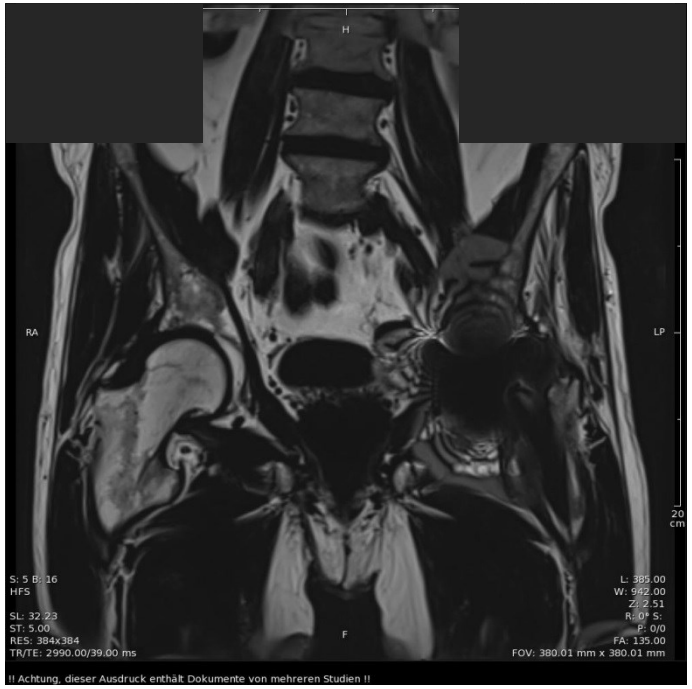
Limitations of MRI

- Limited mostly to one joint per session
  - Simultaneous evaluation of malalignment **not possible**
  - Simultaneous evaluation of outer-articular source of pain **not possible**

- Suffers from metal artefacts, even with MARS







<u>SPECT/CT (xSPECT):</u>

Evaluation of stress reaction and **bone matrix close to implant possible**

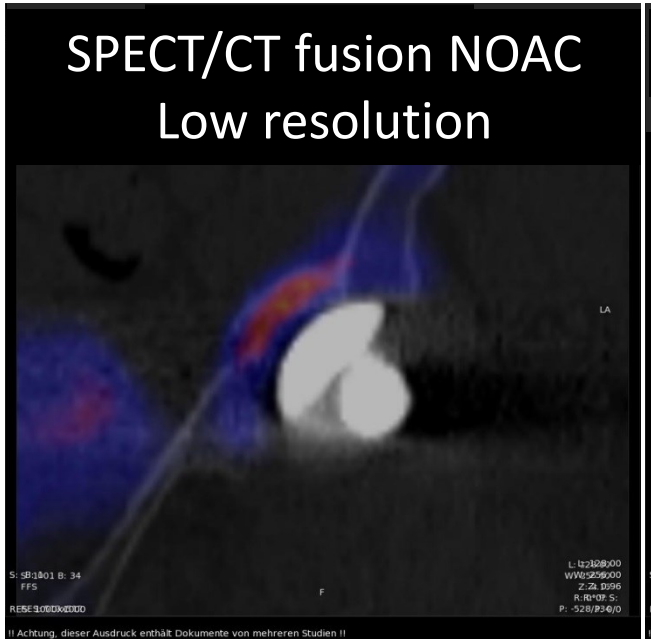
- No misload
- No lysis
- No fracture

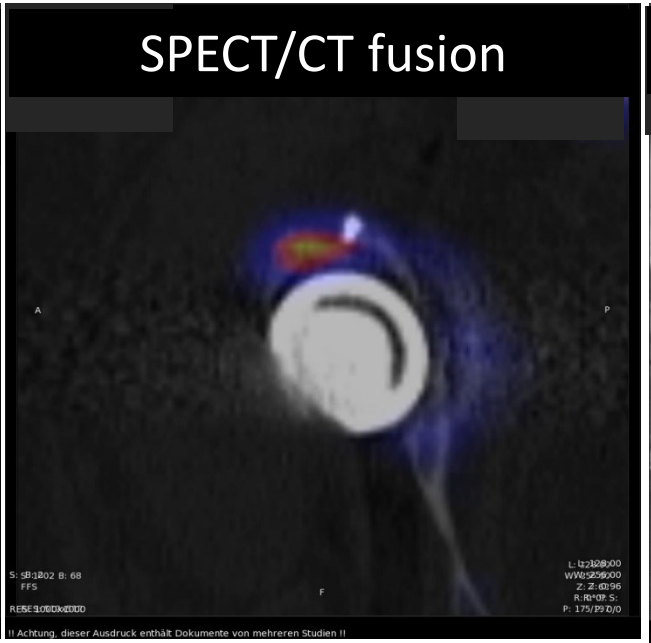
High resolution due to xSPECT reconstruction software

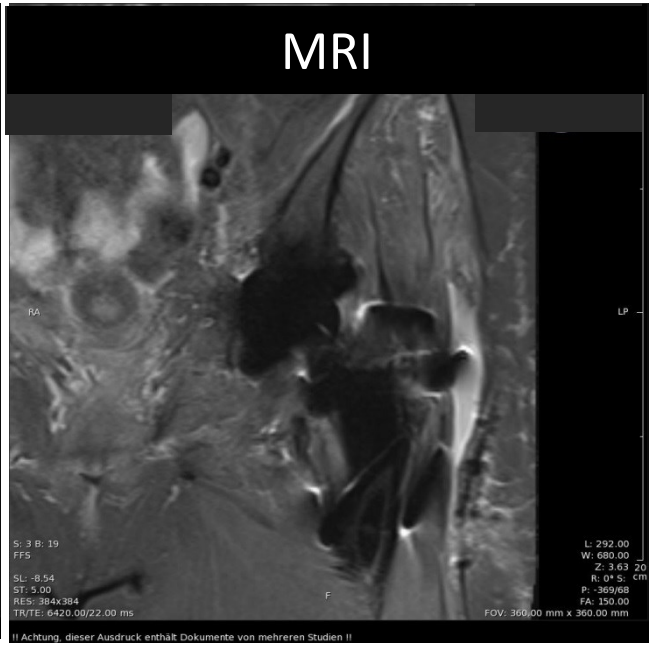
<u>MRI:</u>

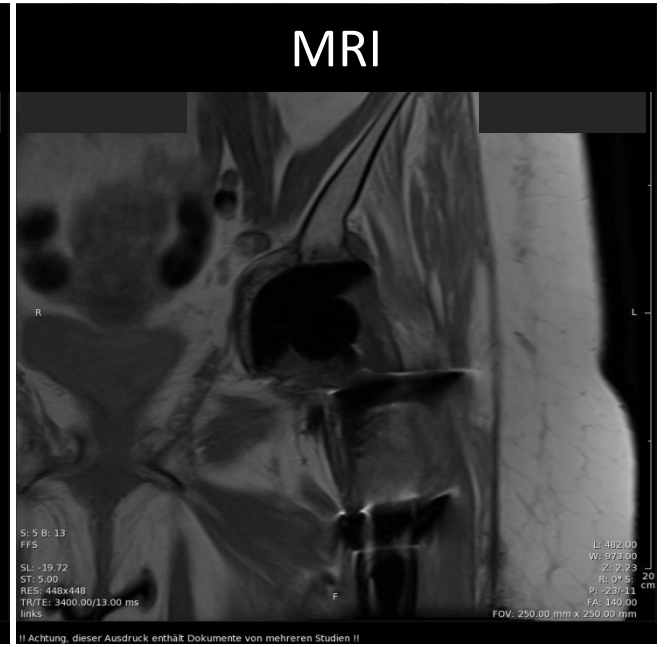
Evaluation of BML and bone matrix close to implant limited
(depending on the composition of the implant)

Metal artefacts mask BML and fracture









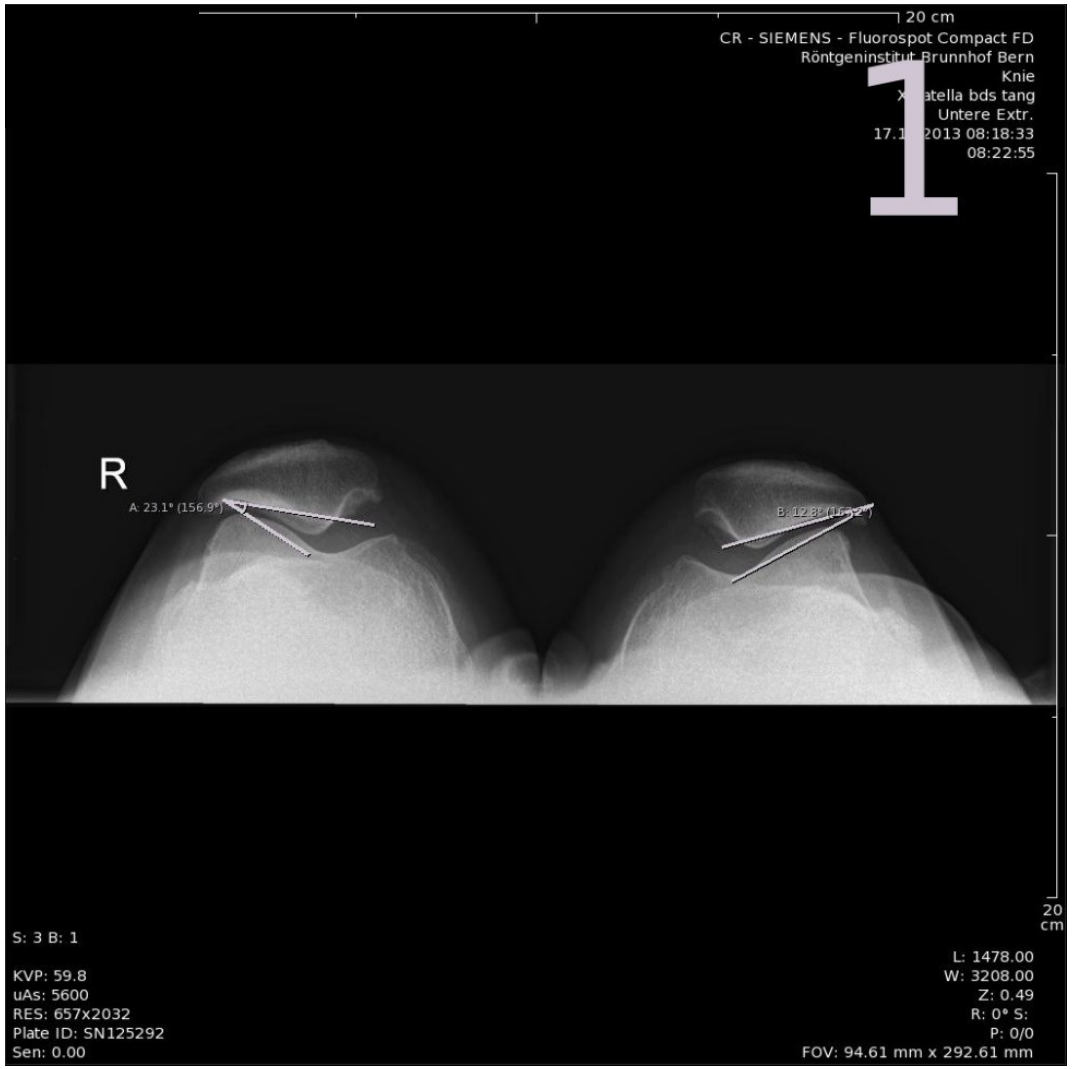
Reasons for implant failures

- Mostly caused by **mechanical overload due to malalignment**
  - Mechanical loosening
  - Periprosthetic fracture
  - Implant fracture
  - **Important issue. Patellofemoral overload after TKA (many not know impact)**
- Infection
- Osteolysis due to implant debris (particle disease)
- Pain due to **lumbar spine degeneration**. Source of the pain hip or spine?
- Abductor tendon defects and fatty atrophy of the **gluteal muscles (many not know impact)**

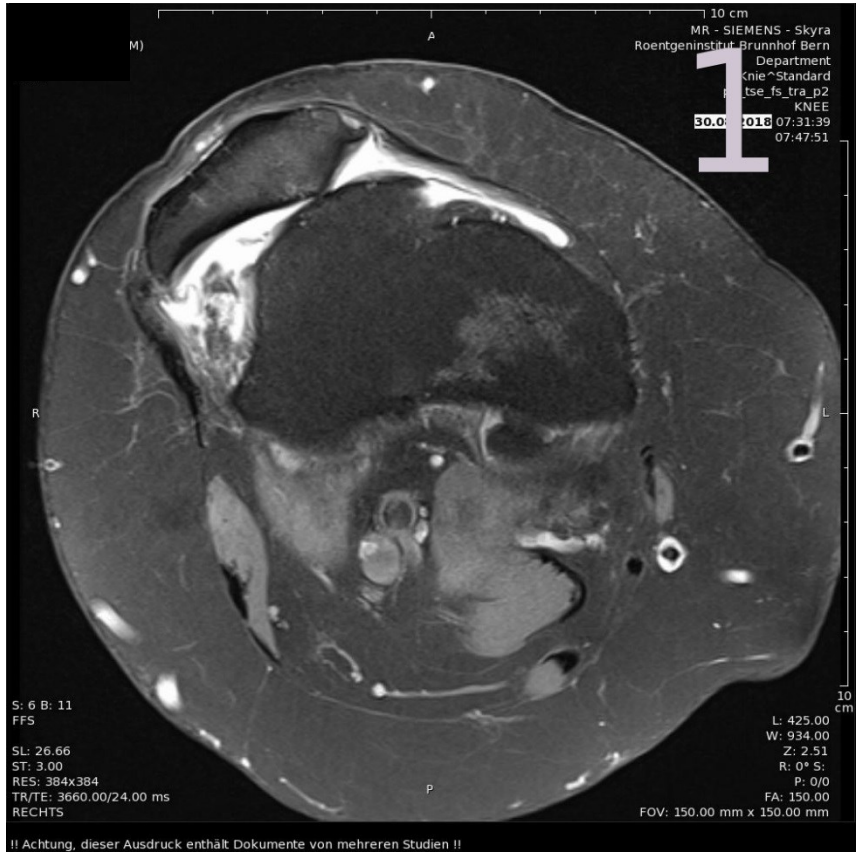
1. Ulrich SD et al. Total hip arthroplasties: What are the reasons for revision? Int Orthop. 2008 Oct; 32(5): 597–60
2. Pfirrmann CW, Notzli HP, Dora C, Hodler J, Zanetti M. Abductor tendons and muscles assessed at MR imaging after total hip arthroplasty in asymptomatic and symptomatic patients. Radiology. 2005 Jun;235(3):969-76. Epub 2005 Apr 28.
3. Javad P. et al. Back Pain and Total Hip Arthroplasty: A Prospective Natural History Study. Clin Orthop Relat Res. 2010 May; 468(5): 1325–1330.
4. Fehring TK, Odum S, Griffin WL, Mason JB, Nadaud M. Early failures in total knee arthroplasty. Clin Orthop Relat Res. 2001;(392):315–318.
5. McTighe T, Clarke I. Failure mechanism on total knee arthroplasty [Internet] Chagrin Falls, OH: Joint Implant Surgery Surgery & Research Foundation; 2009

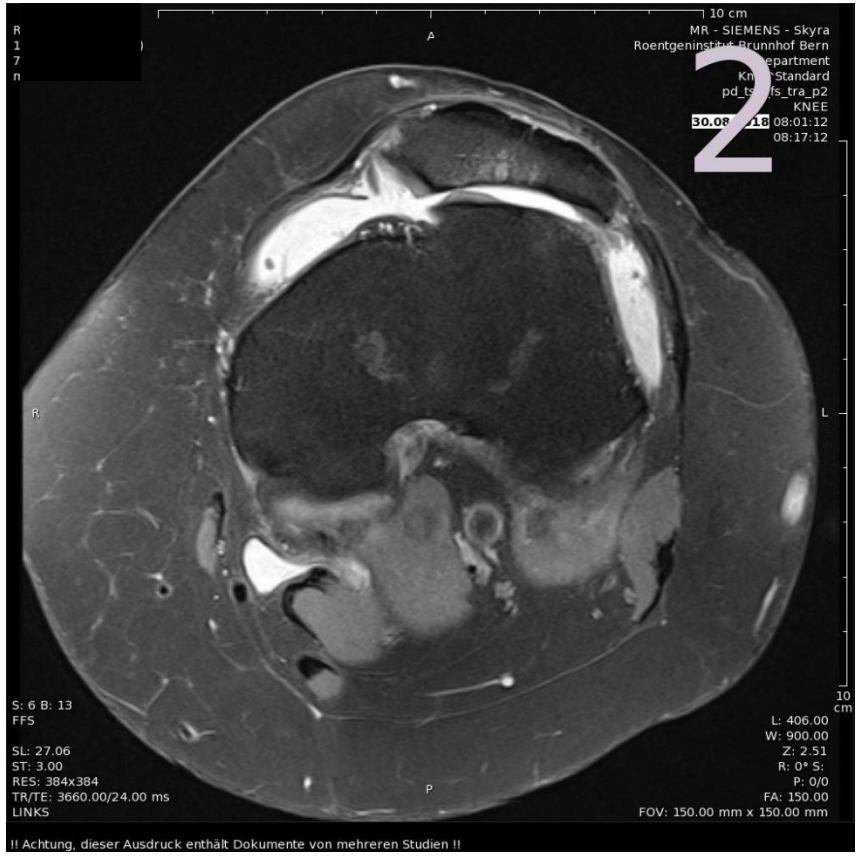
Malalignment/maltracking matters?

Lateral patella shift, mild pathologic patella tilt 2013



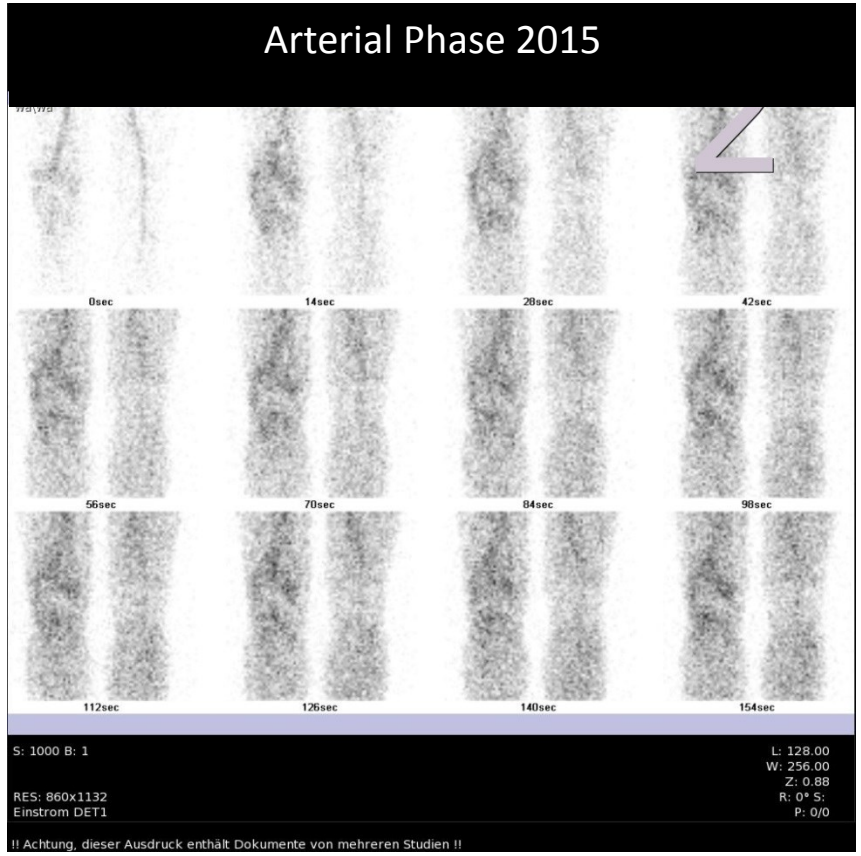
Untreated malalignment 2018
Maltracking of the patella (patella not riding correctly along trochlea)



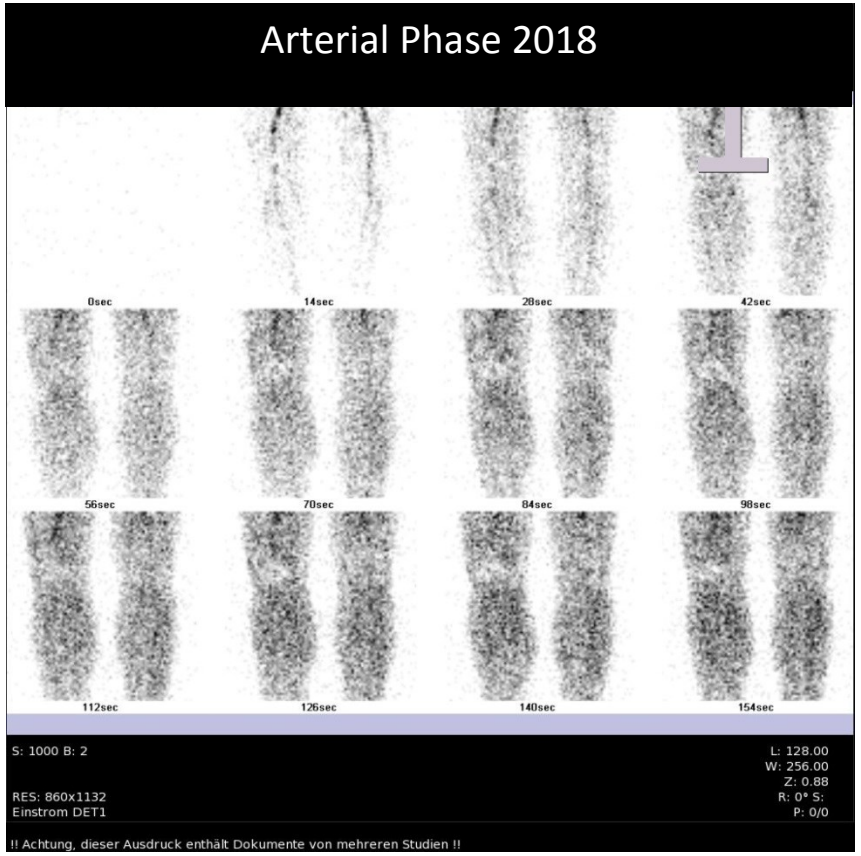


Example of grading disease intensity and patella overload

M. 59Y. TKA R 2013. Patellofemoral pain due to patella misload 2015. Treatment of patella maltracking 2015 (transfer of tibial tuberosity). Pain initially improved but still exists and worsens in 2018



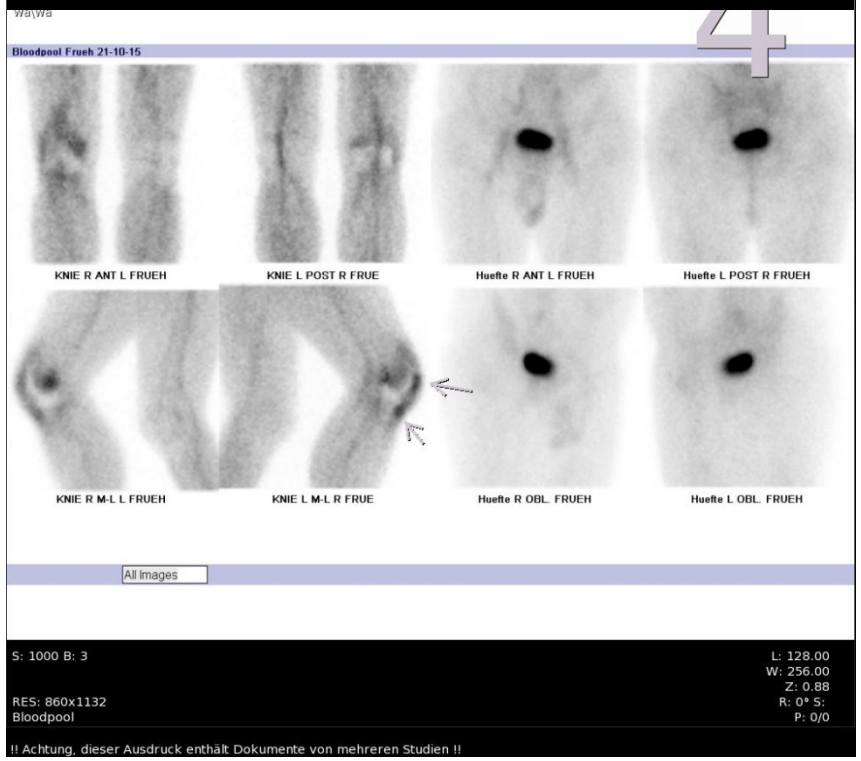
Mild to severe synovitis 2015



Mild synovitis 2018

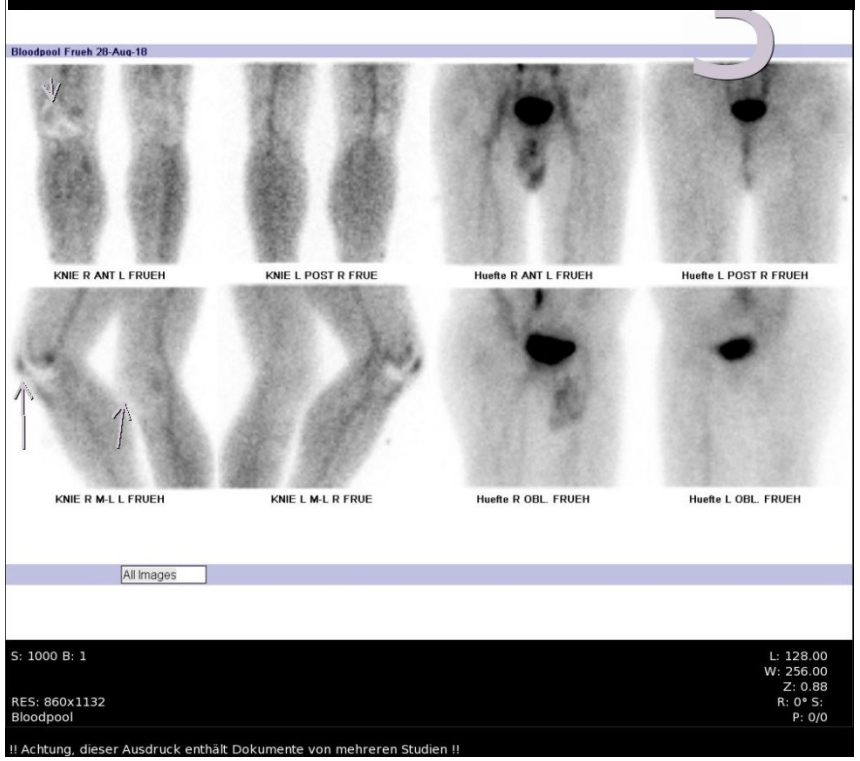
Imaging maltracking of patella (patella hypervascularity, alignment)

Bloodpool 2015



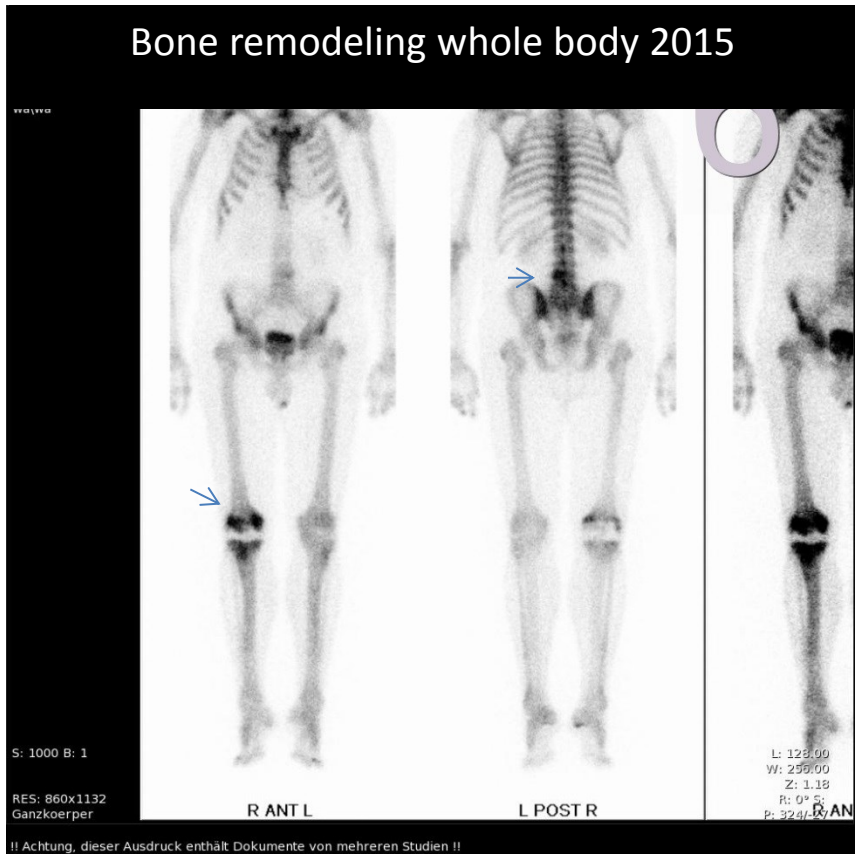
Moderate osseous hypervascularity patella R and tibial tuberosity R
Moderate synovitis, L and hip OK

Bloodpool 2018

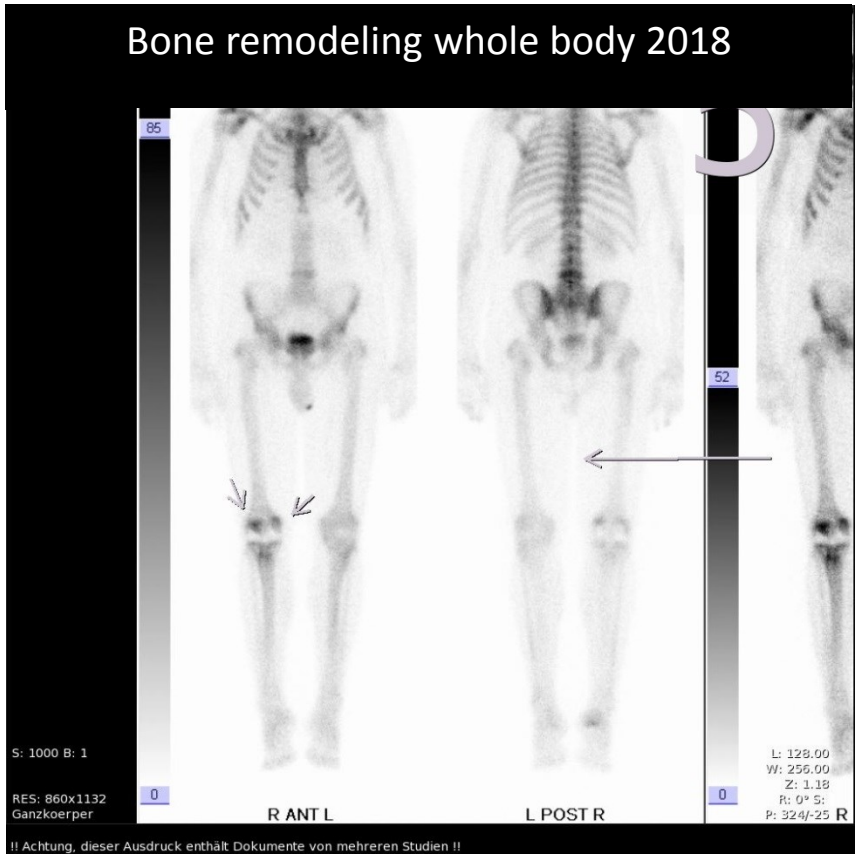


Impoved. Mild osseous hypervascularity patella R and tibial tuberosity R, Mild synovitis, L and hip OK

Improvement of osseous stress in patella R after transfer of tibial tuberosity 2015 but still existing

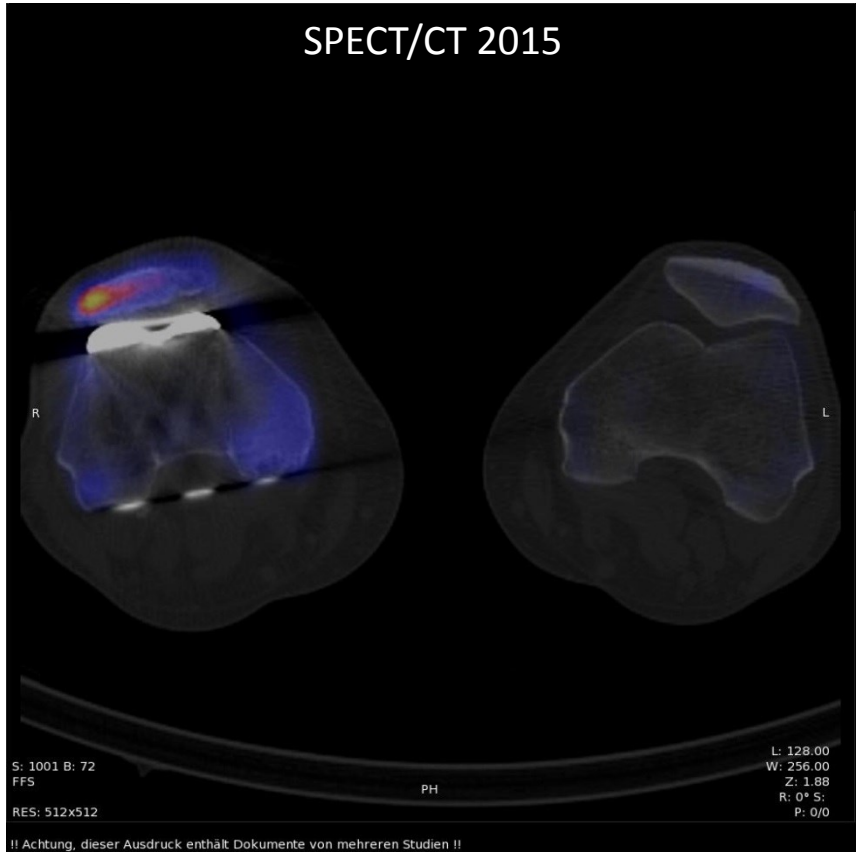


Intense bone remodeling of patella R
Lumbar degeneration
If knee w/o pathology, check lumbar spine

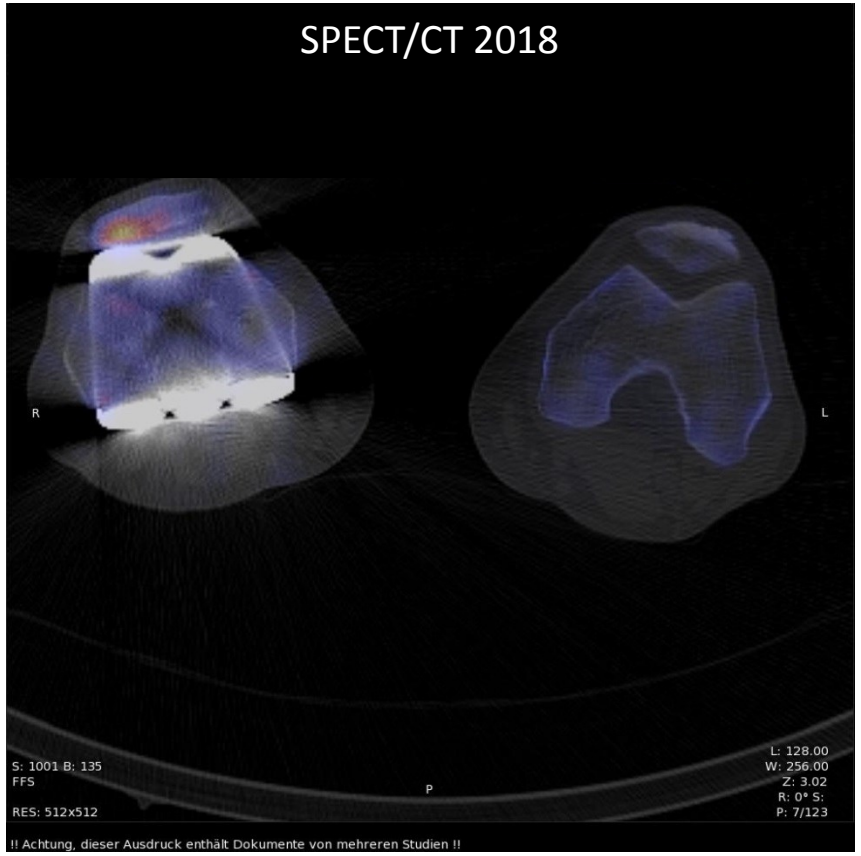


Moderate bone remodeling of patella R
Lumbar degeneration
If knee w/o pathology, check lumbar spine

Chronic lateral patella overload
due to persistent pathologic patellar tilt > 10 degree
Plane angle should open laterally

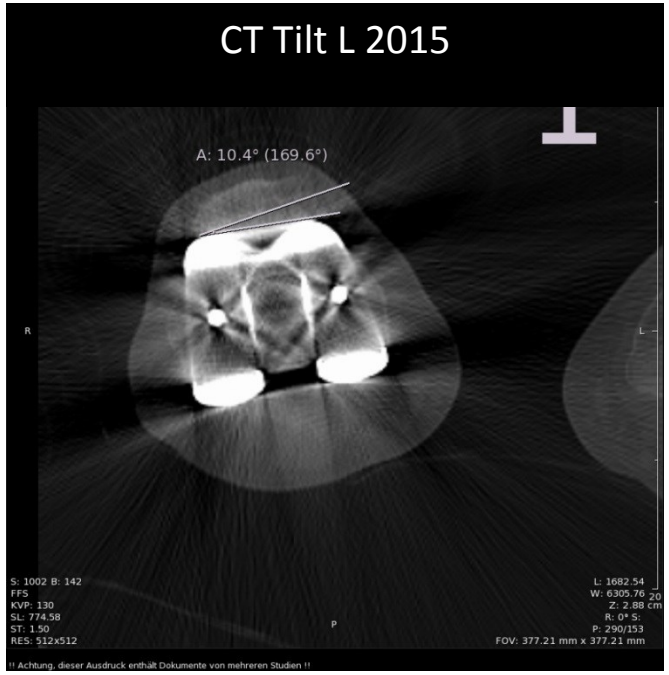


Lateral patella overload 2015

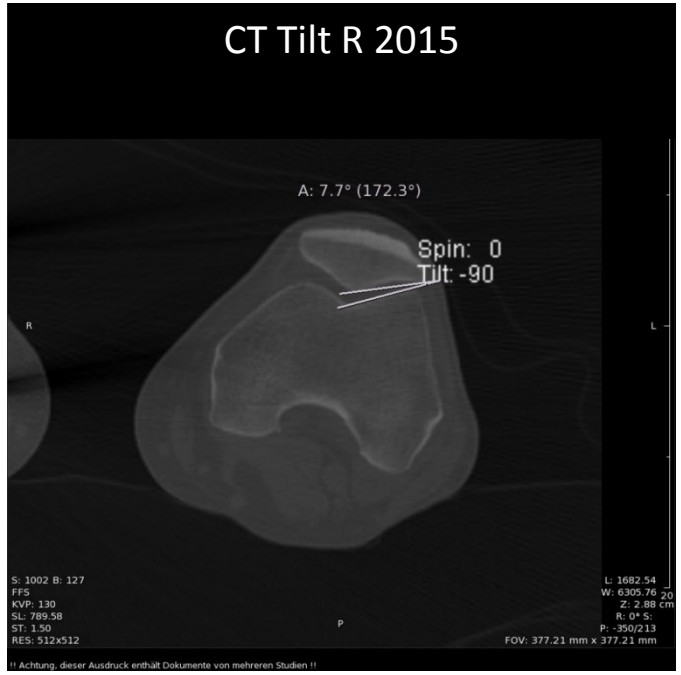


Lateral patella overload 2015

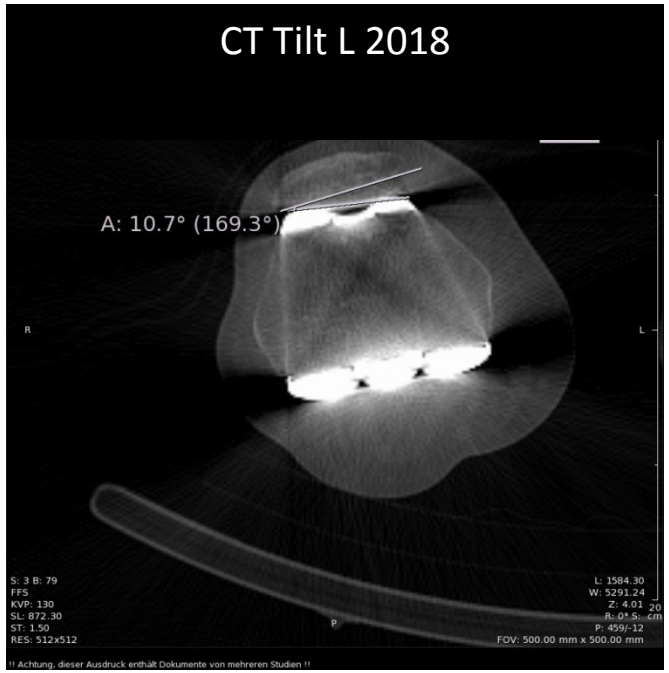
CT Tilt L 2015



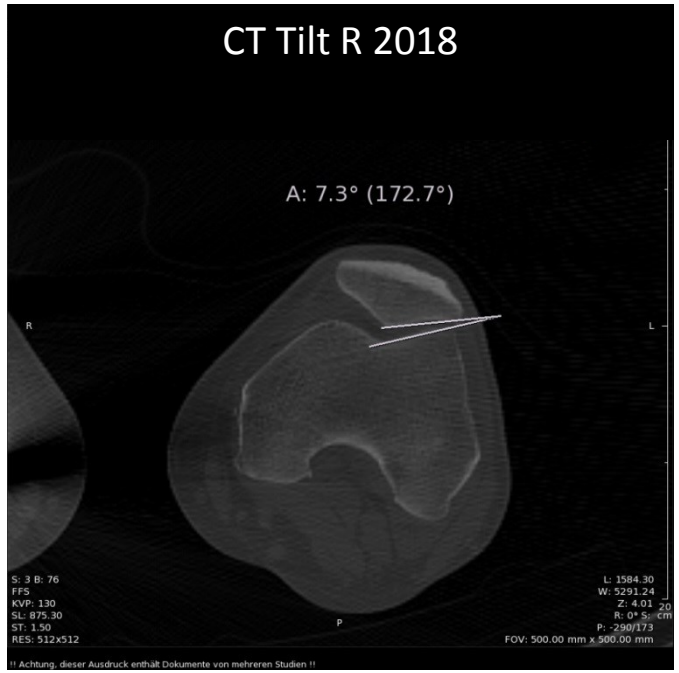
CT Tilt R 2015



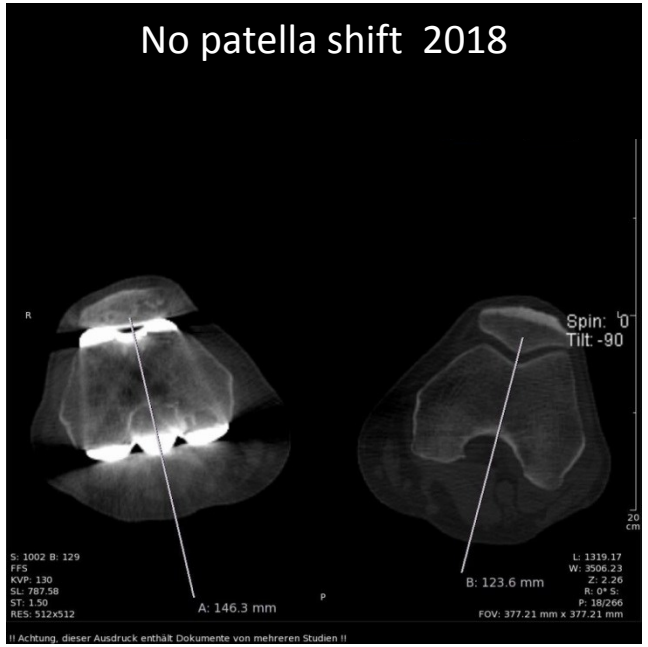
CT Tilt L 2018



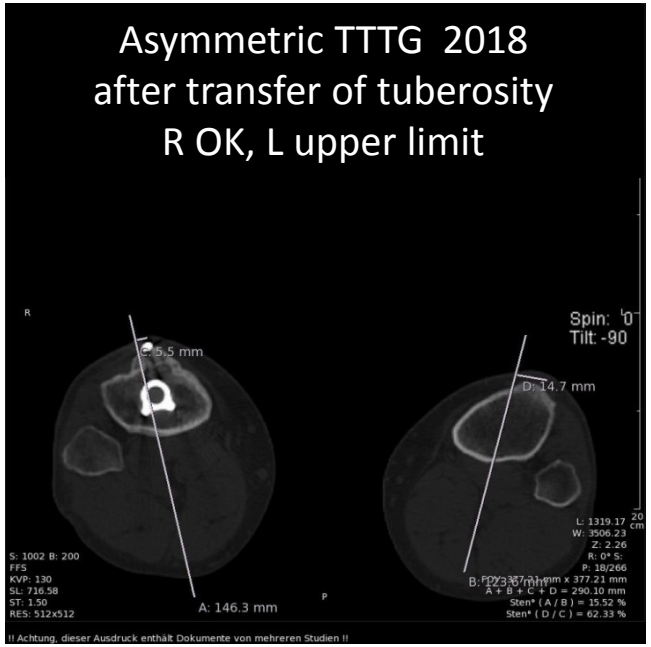
CT Tilt R 2018



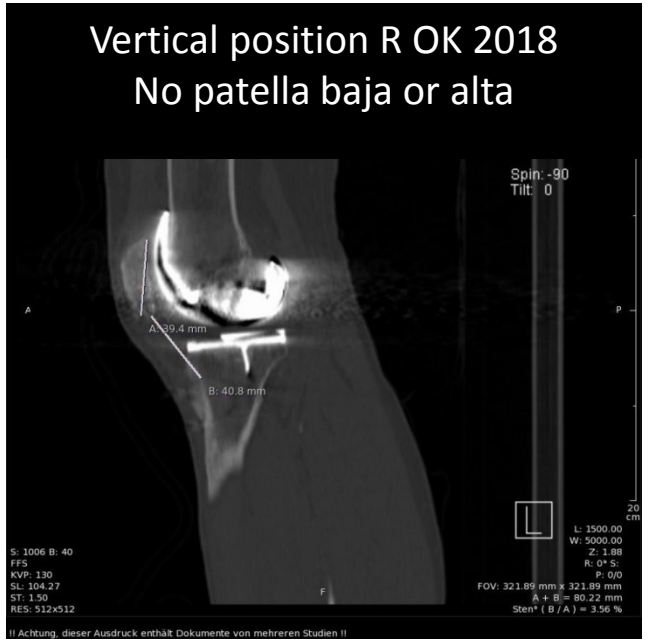
No patella shift 2018



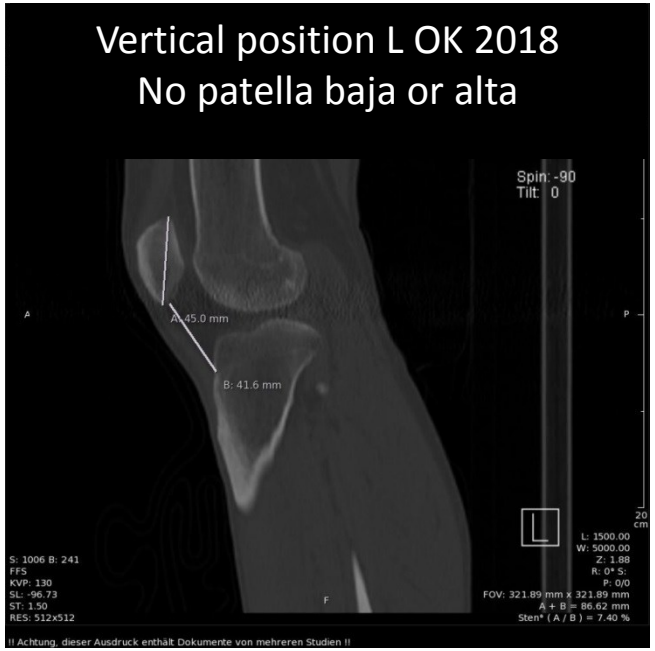
Asymmetric TTTG 2018
after transfer of tuberosity
R OK, L upper limit



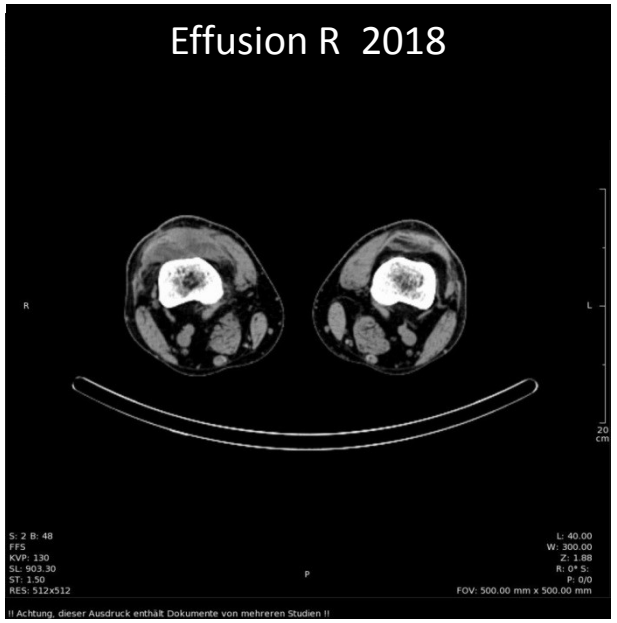
Vertical position R OK 2018
No patella baja or alta



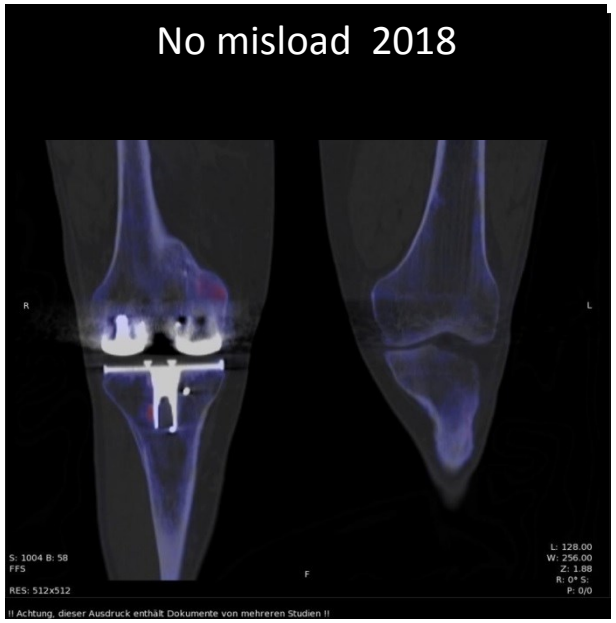
Vertical position L OK 2018
No patella baja or alta



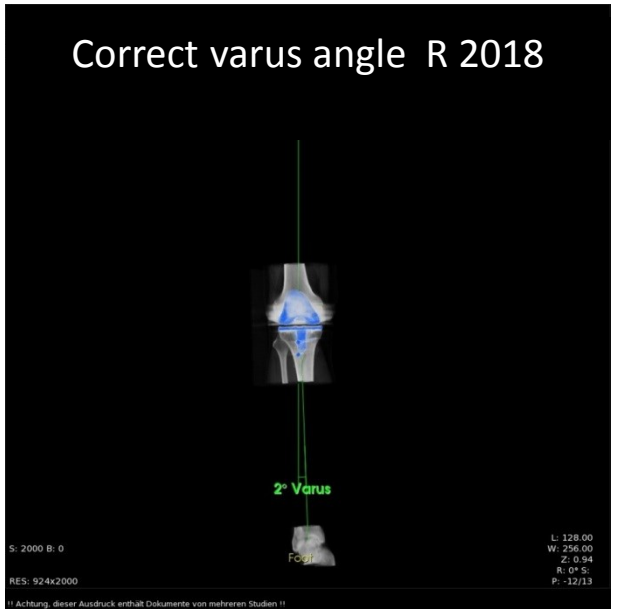
Effusion R 2018



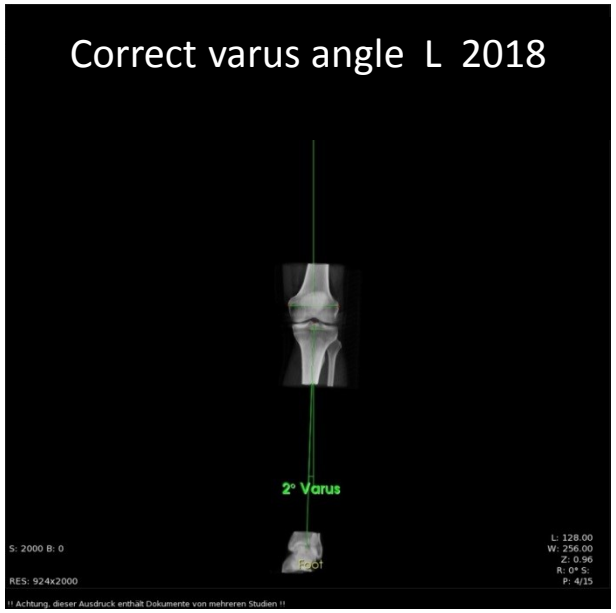
No misload 2018



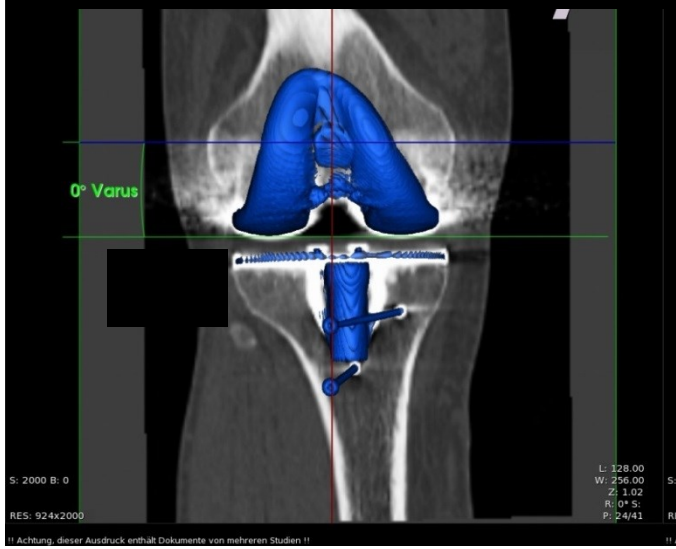
Correct varus angle R 2018



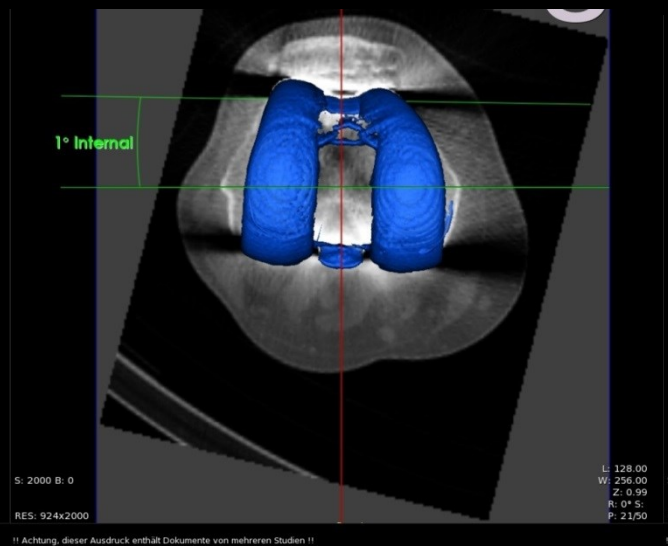
Correct varus angle L 2018



CT alignment 2018
M. Hirschmann

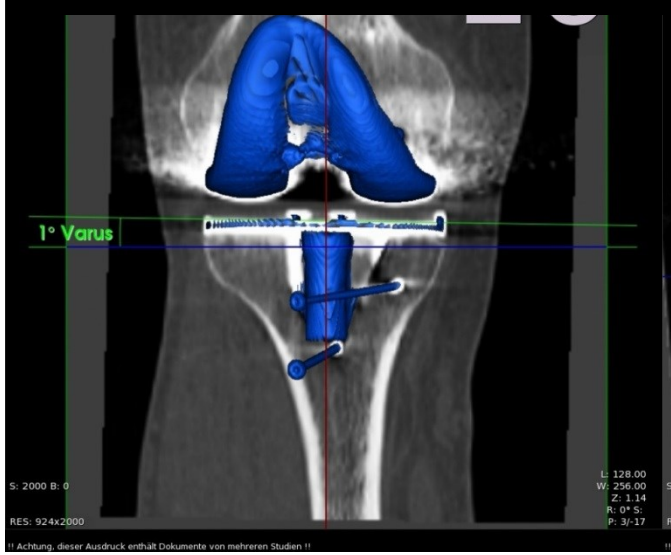


CT alignment 2018
No malrotation of prosthesis

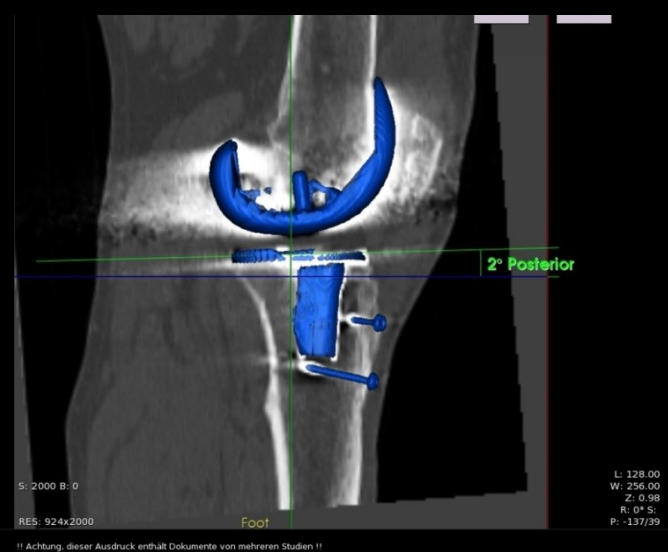


CT alignment 2018

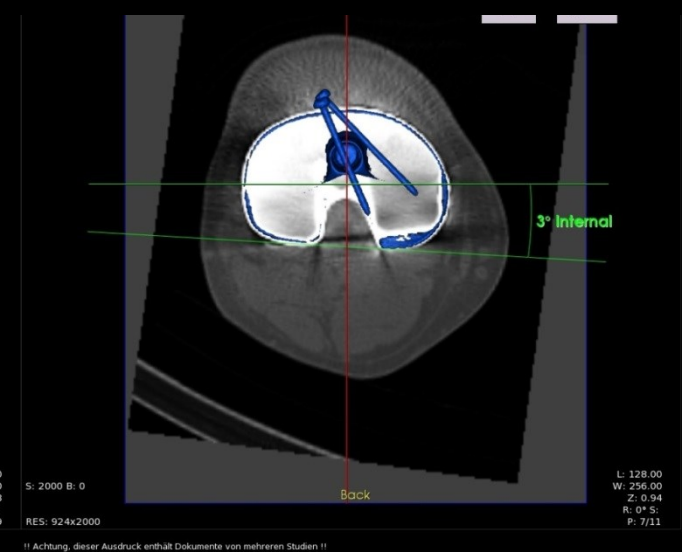
CT alignment 2018



CT alignment 2018



CT alignment 2018



Interpretation/results

1. After transfer of tibial tuberosity R persistent **lateral patella overload** due to persistent pathologic patella tilt. Concomitant mild synovitis and mild effusion.
2. Improved tibial rotation (TTTG) after transfer. No further malalignment.
3. No misload and no malalignment of TKA itself

This sentence orthopedic surgeons love to read:

No loosening of the TKA, no misload to the TKA itself, no periprosthetic fracture, no particle disease, and no signs of infection

Case

Advantages of 3 phase SPECT/CT

Simultaneous

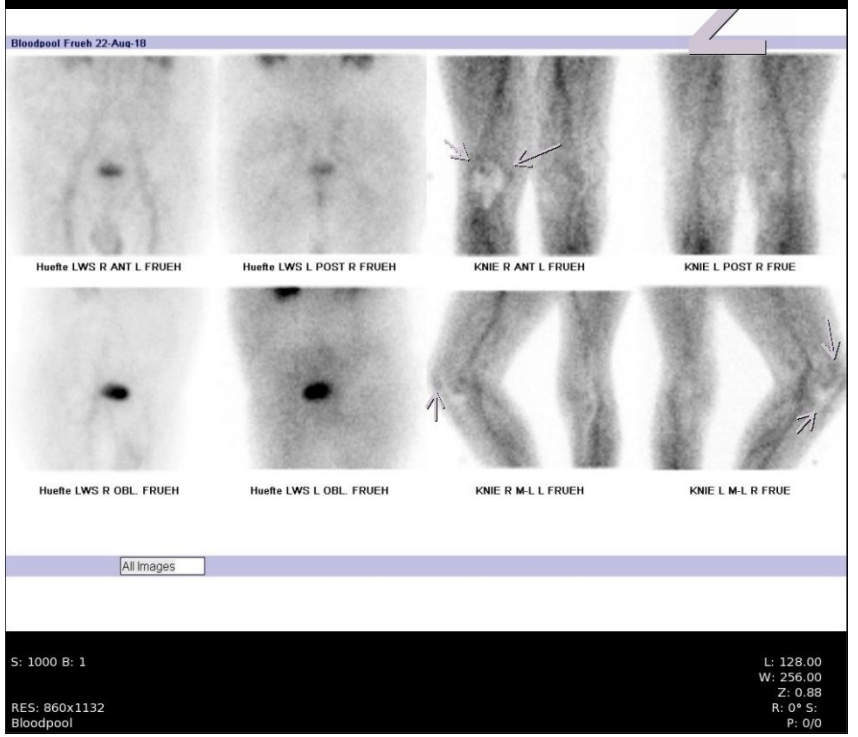
Staging pain
Evaluation of implant failure
Evaluation of malalignment

THA R 17.01.18 (6 mo). TKA R 18.11.2016. Knee arthrodesis L (years ago). Pain R lower extremity (lumbar, gluteal, hip, knee). Source of pain?

Arterial phase hips

Normal

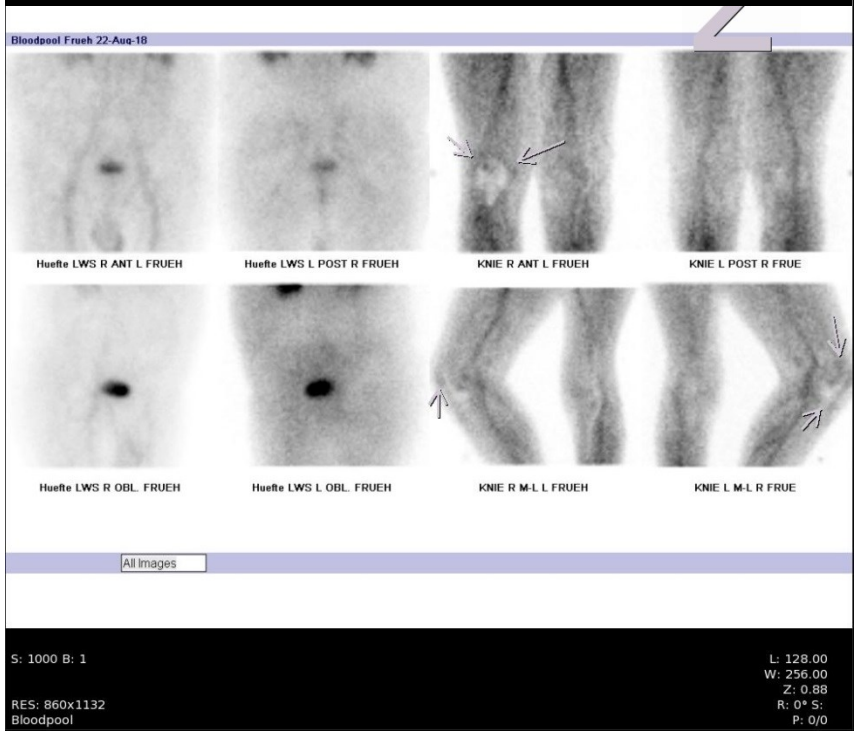
Bloodpool hips, knee



Synovitis knee R;
Mild hypervascularization patella R
No irritation knee L, hips

Staging pain
Evaluation of implant failure
Evaluation of malalignment

Bloodpool hips, knee

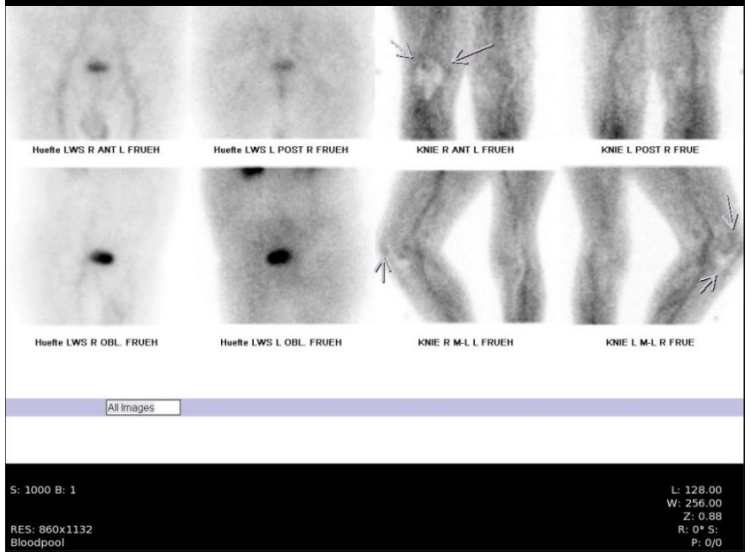


Synovitis knee R;
Mild hypervascularization patella R
No irritation knee L, patella L, hips

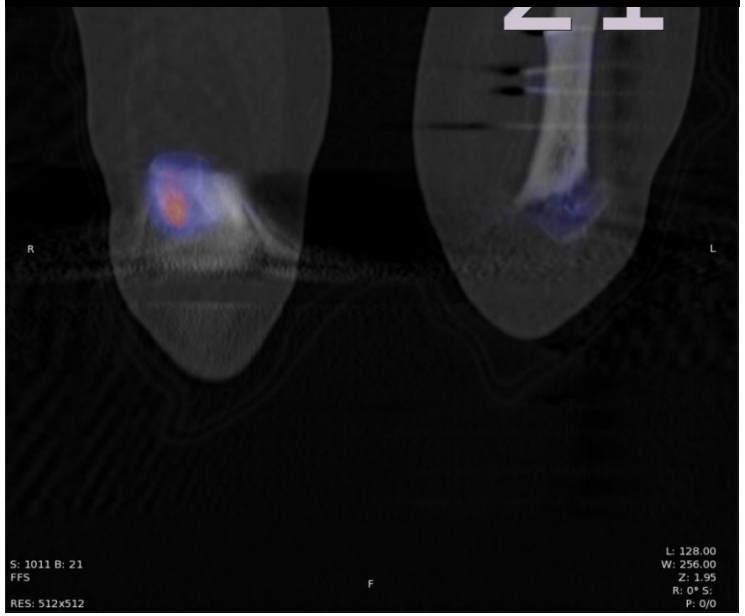
Bone remodeling, whole body

Focal moderate bone remodeling
in patella R

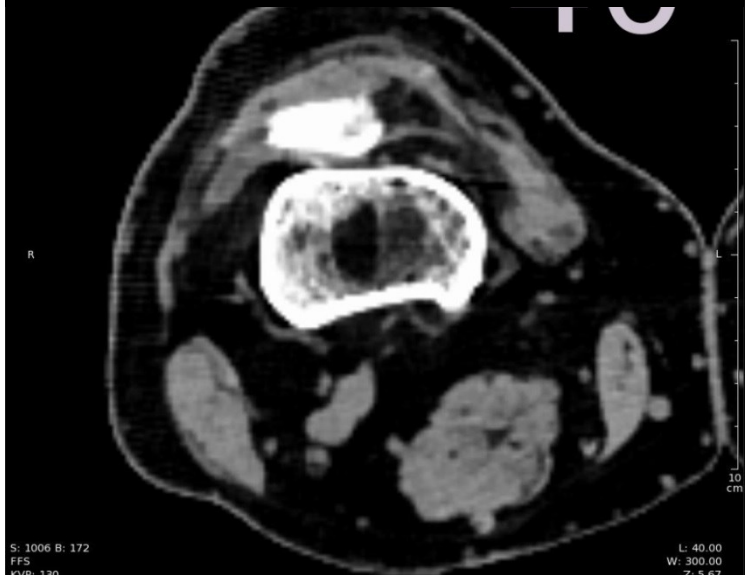
Mild synovitis R
Mild patella hypervasculaization R



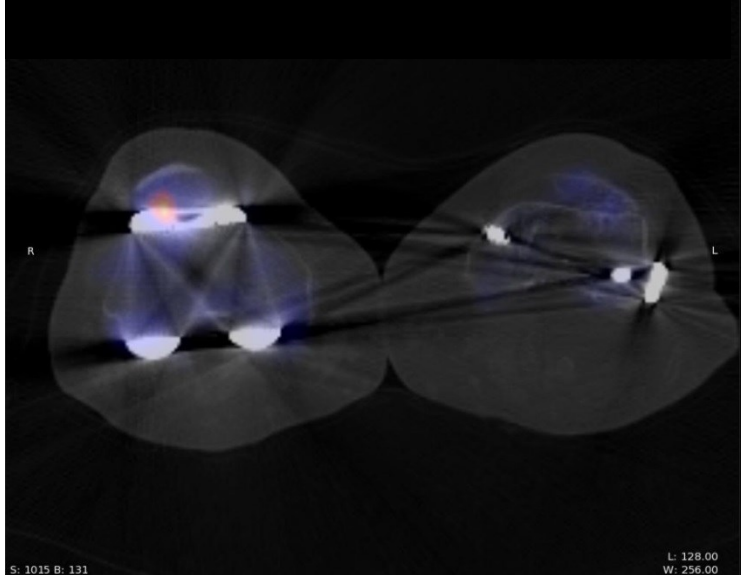
Moderate bone stress patella R



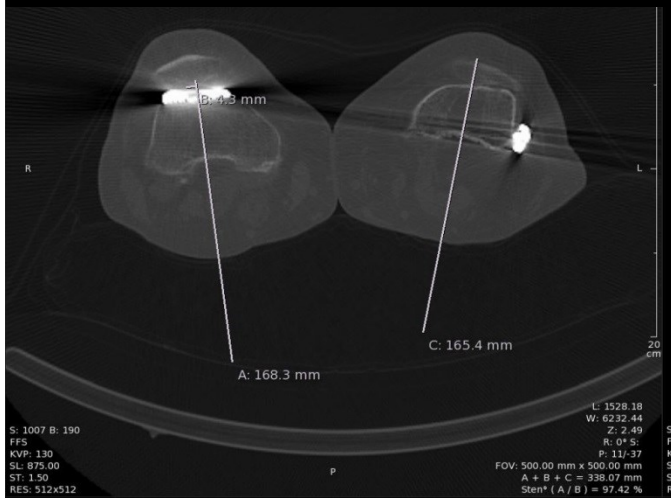
Mild effusion knee R



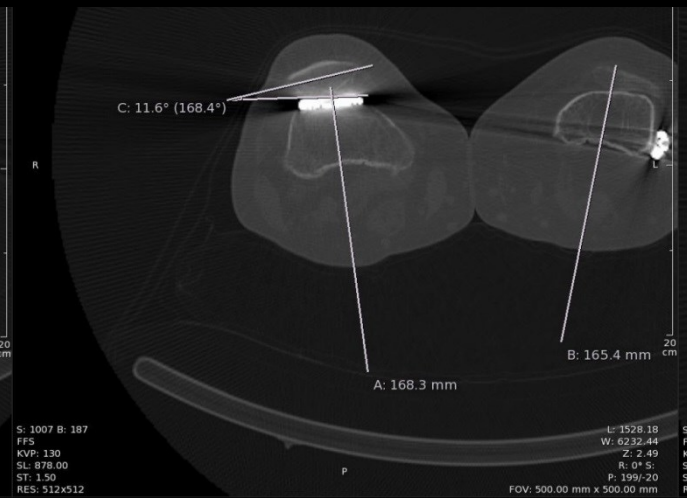
Moderate bone stress patella R



Slight lateral patella shift R

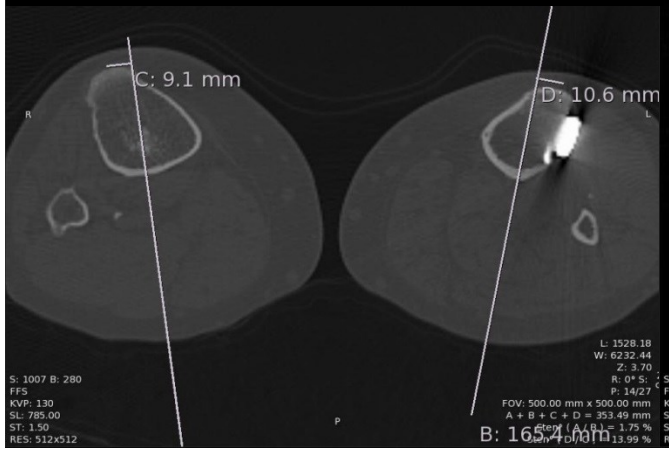


Pathologic Tilt patella R

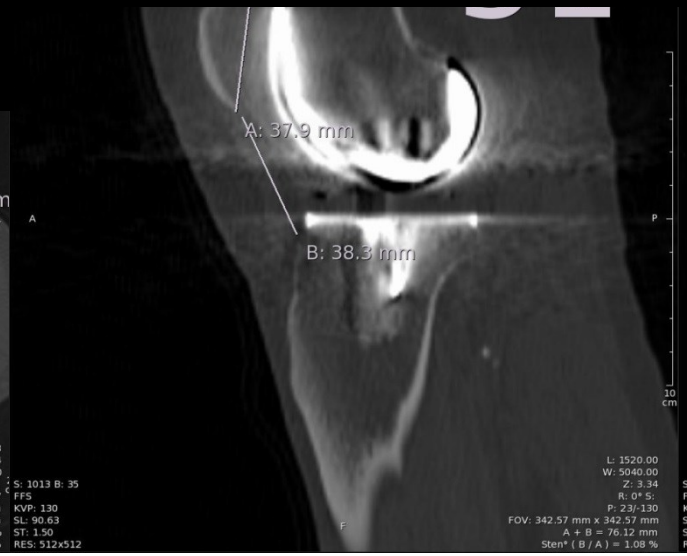


Pathologic patella R

Symmetric normal tibial rotation
TTTG

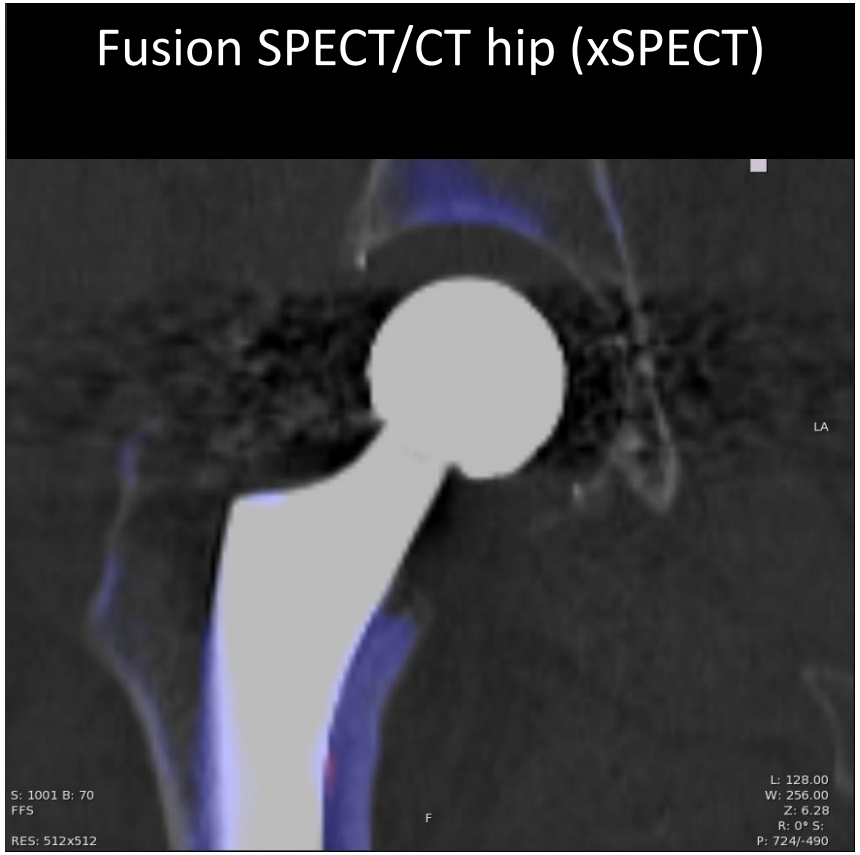


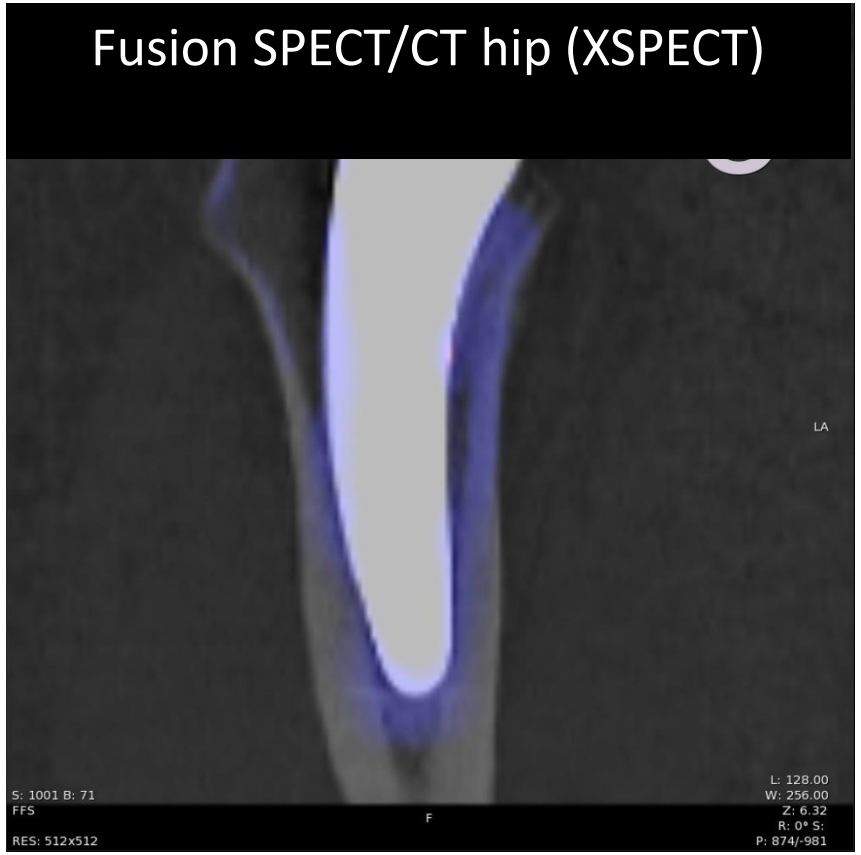
Correct vertical position patella R



Correct vertical position patella L

Staging pain
Evaluation of implant failure
Evaluation of malalignment

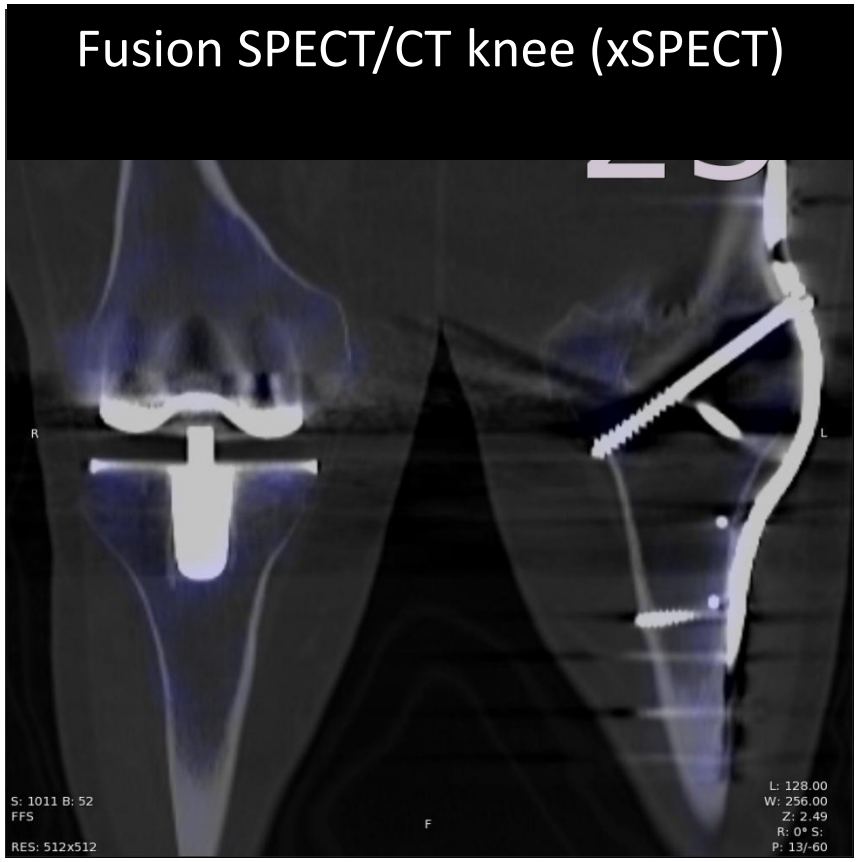




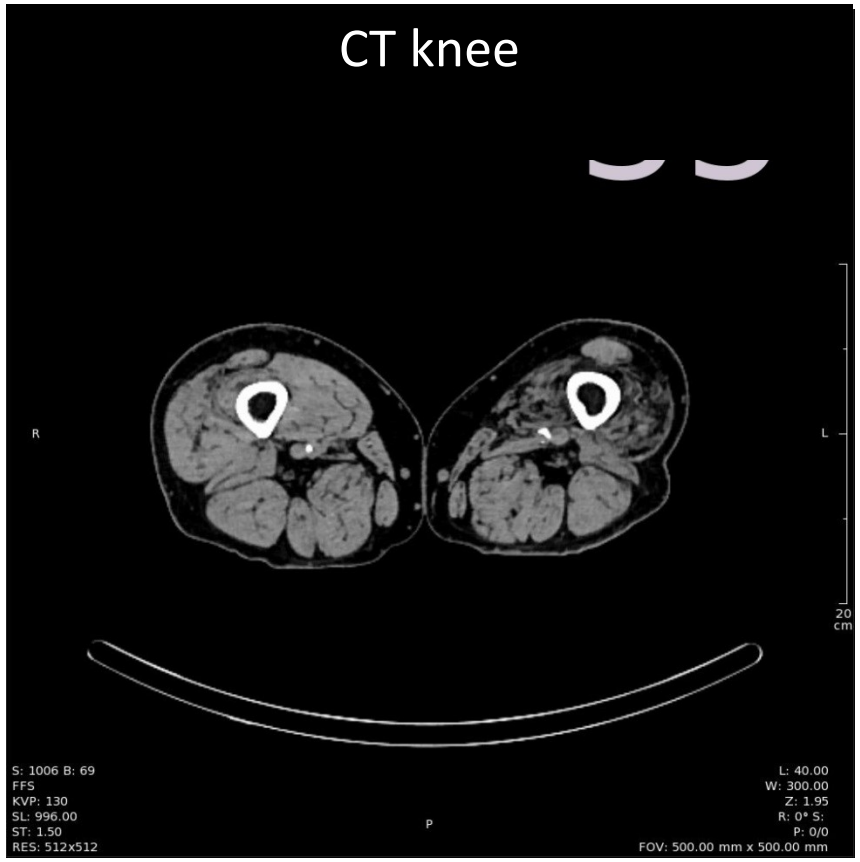
Physiologic bone stress 6 m after THA, no lysis, no fracture, no misload

Staging pain
Evaluation of implant failure
Evaluation of malalignment

Staging pain
Evaluation of implant failure
Evaluation of malalignment



No irritation of TKA R and arthrodesis L



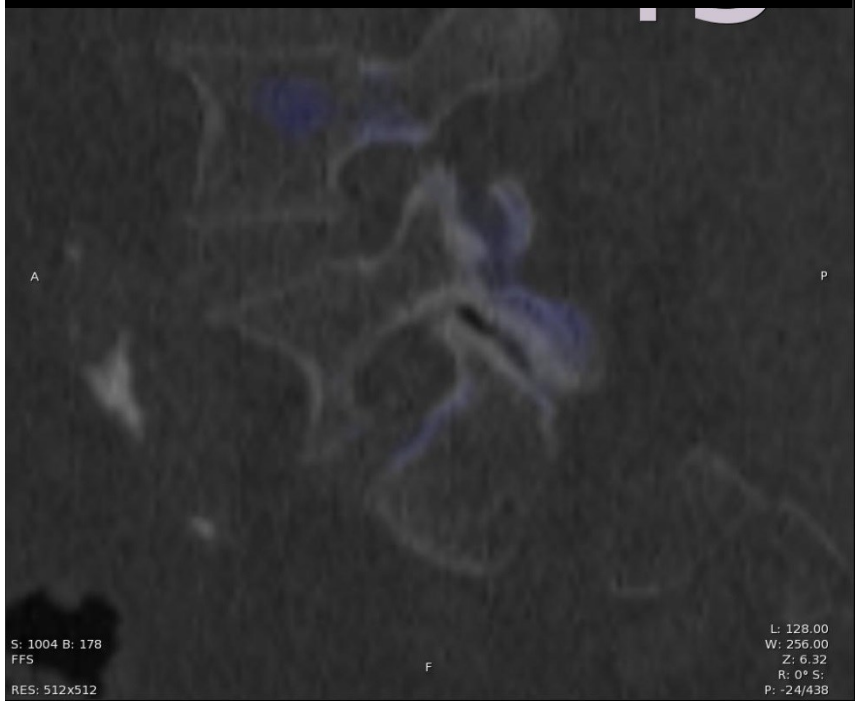
Fatty athrophy of medial and lateral Vastus

Staging pain
Evaluation of implant failure
Evaluation of malalignment

CT hips/lumbar spine/soft tissue

No instability, no spinal disc herniation, no root compression

CT hips/lumbar spine



Slightly activated facets L5/S1

Interpretation/results

1. Source of pain knee R. Lateral patella overload due to lateral patella shift and pathologic patellar tilt. No further malalignment of the patella. Concomitant mild synovitis and mild effusion.

2. ***No loosening of the THA R and TKA R, no misload to THA and TKA itself, no periprosthetic fracture, no particle disease, and no signs of infection***

3. Completely fused knee arthrodesis L w/o irritation. No non union. No misload. No malalignment. No implant break. Fatty degeneration of medial and lateral Vastus L leads to chronic overload to lower extremity R.

4. Slightly activated facets L5/S1 w/o instability. No root compression.

Orthopedic surgeon more than happy with this whole bunch of informations

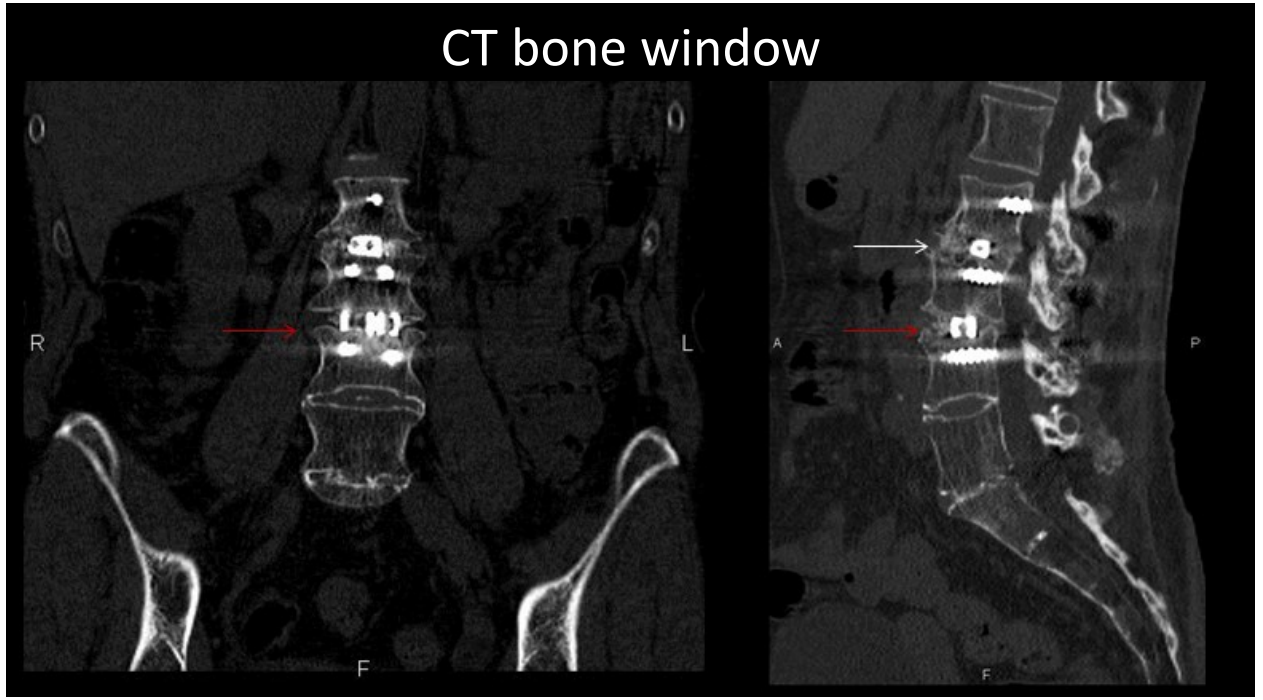
THA R, TKA R and arthrodesis L: job well done
Lateral patella overload R, minor intervention: lateral release

Lumbar transpedicular implant failure
Short visit

- **Cause of failure: poor alignment of the fusion**, causing subsequent stress on the implant and bone, leading to pain (osseous stress) and eventually implant failure (body instability, activated facets)
- **Screw breakage** and **screw loosening** represents 50% of all failures
- Poor bone healing

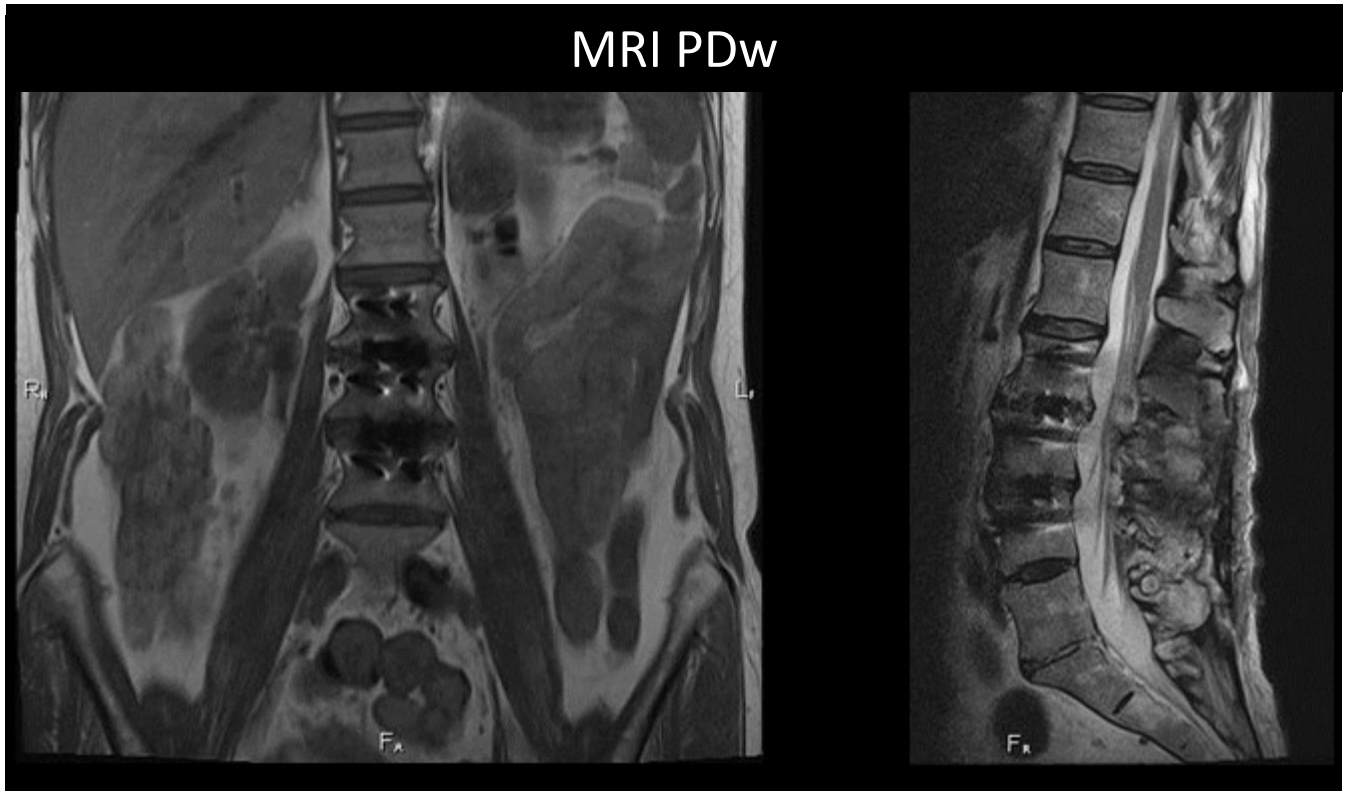
Mohi Eldin MM, Ali AM. Lumbar Transpedicular Implant Failure: A Clinical and Surgical Challenge and Its Radiological Assessment.
Asian Spine J, 2014 Jun; 8(3): 281–297

Lumbago after lumbar spine fusion and stabilization L2-L4



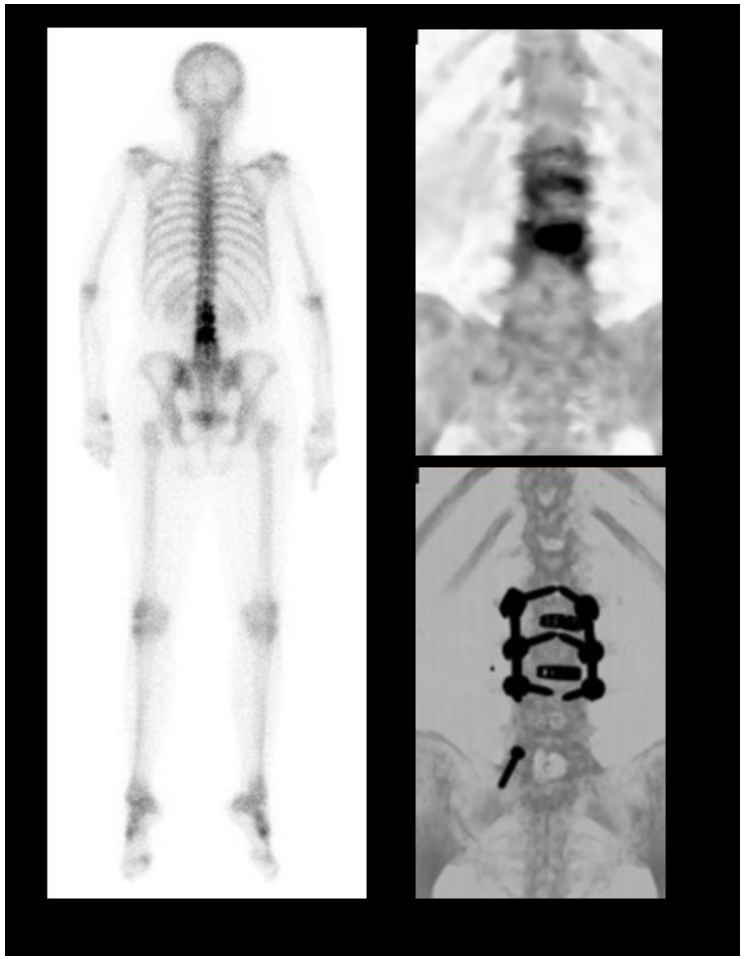
Instability?

Lumbago after lumbar spine fusion and stabilization L2-L4



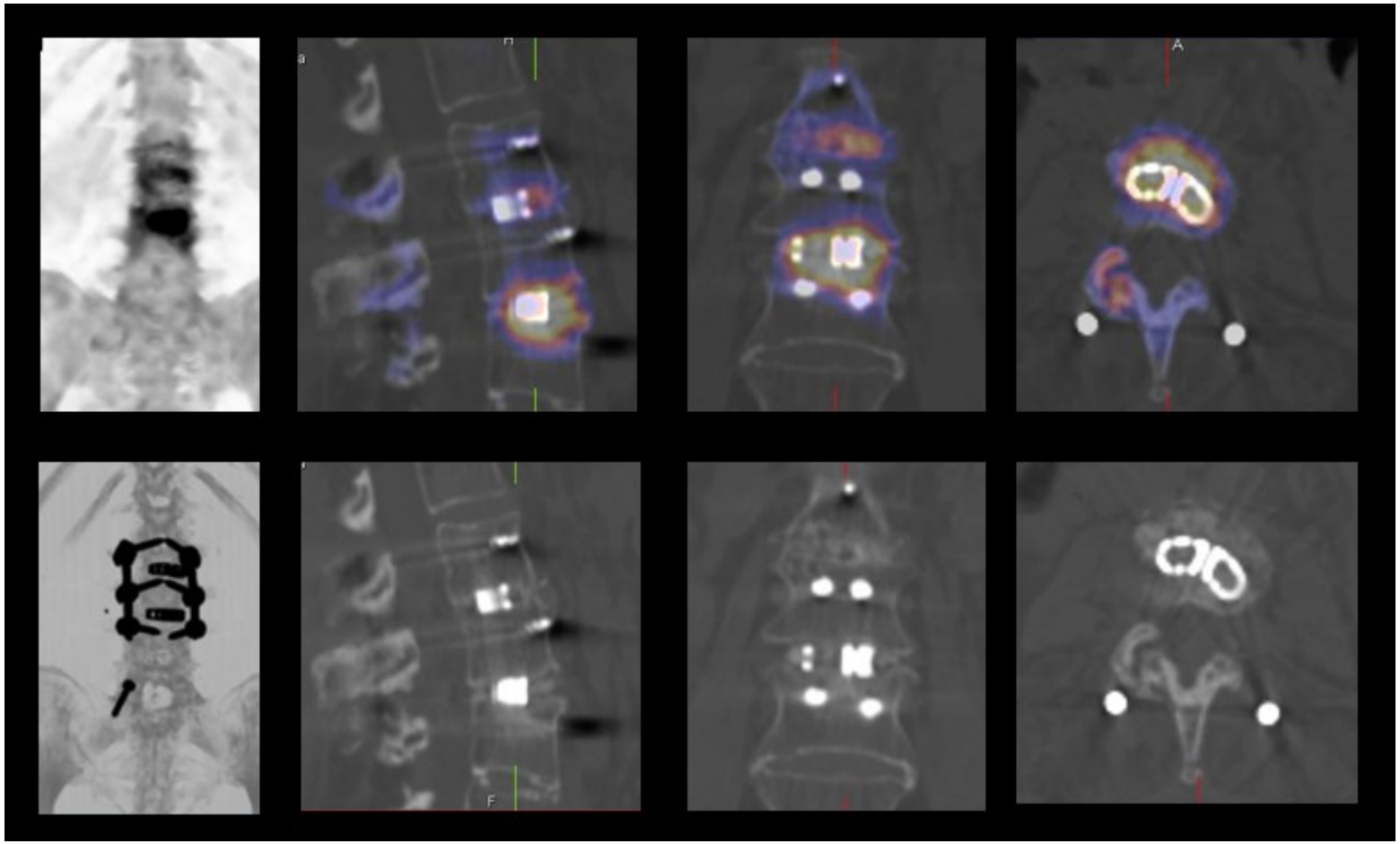
Instability?

Lumbago. WB and SPECT (xSPECT).

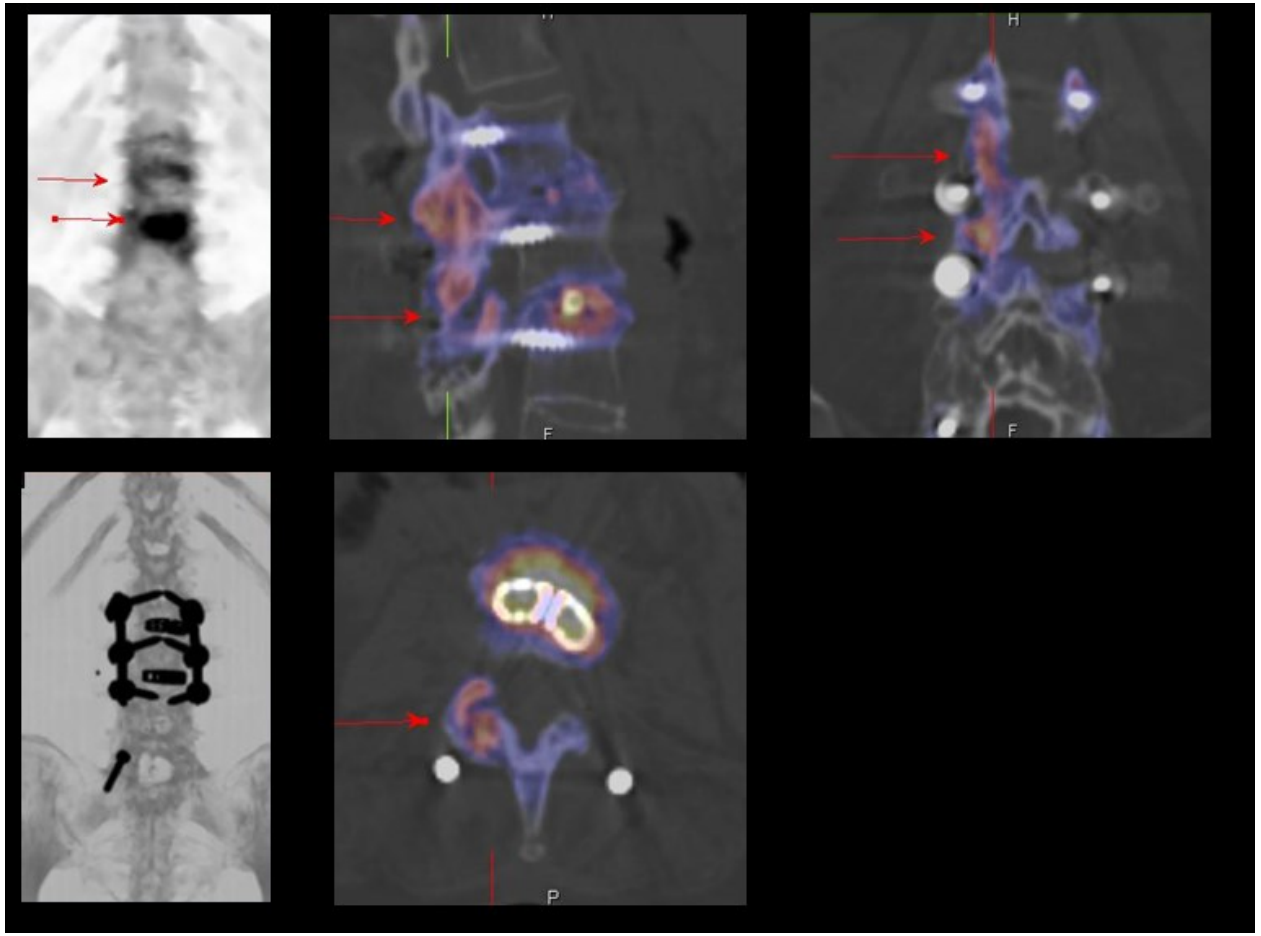


Intense BR/osseous stress reactions along fusions/ intervertebral disc spaces

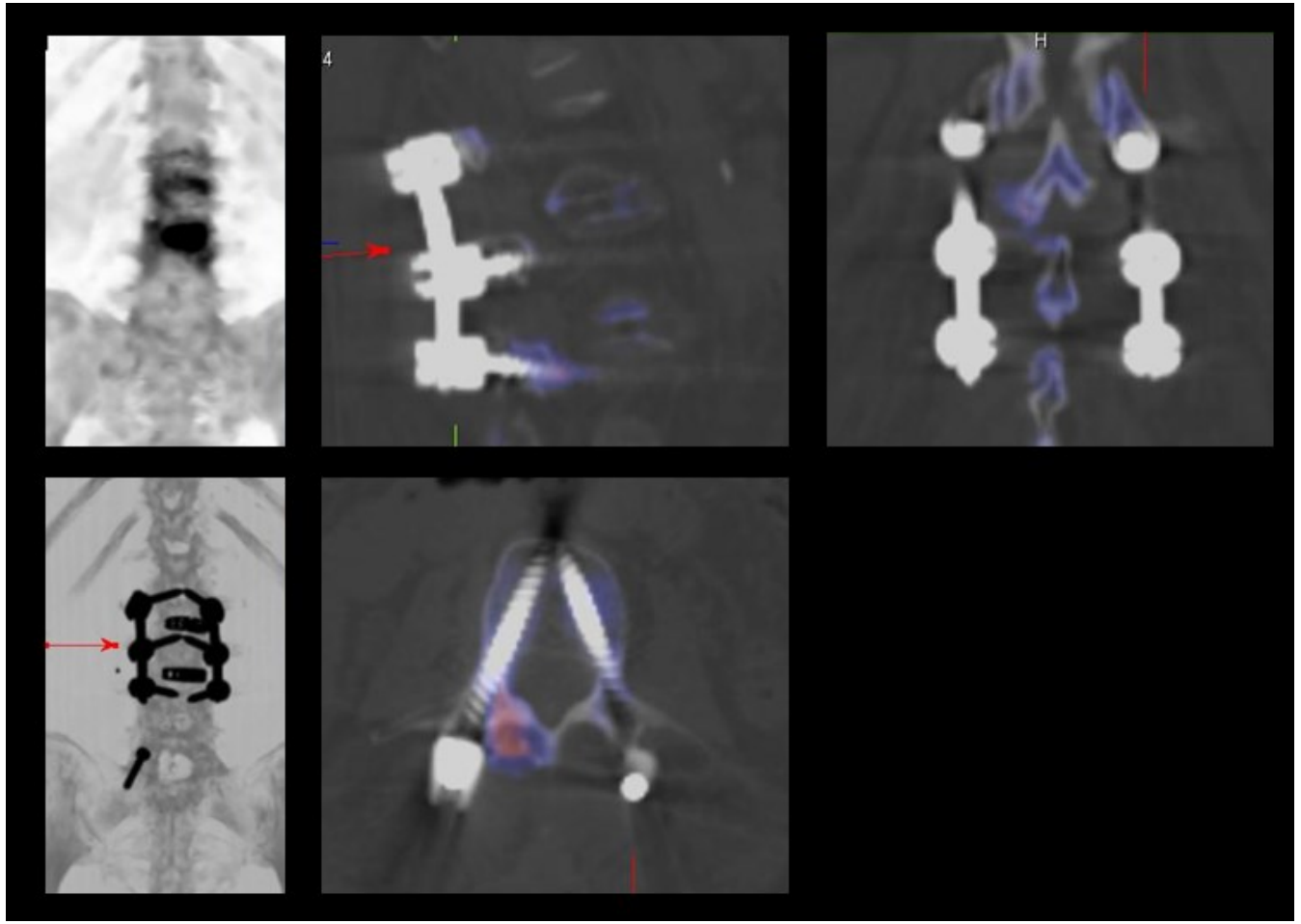
Lumbago. SPECT/CT.
Impression fracture ALIF L3/4



Lumbago. SPECT/CT.
Impression fracture ALIF w concomitant instability/ activated facets



Lumbago. WB and SPECT/CT
Rod and screws w/o lysis and break



Interpretation/results

1. Impression fracture ALIF L3/4 with concomitant instability with bilateral activated facets L2-L4 (L3 is moving)

2. No loosening of screws (no lysis, no osseous stress reaction along the screws)

3. Screws and rods intact w/o break

Patient did fine after revision

Take-away points

3 phase SPECT/CT of painful implants + CT alignment adresses/offers us so much information

- All implant-related bone pathologies, their expansion and a grading of their stress activity (bone window, soft tissue window, fusion window, dynamic imaging)
- Evaluation of malalignment of joints and implants
- Evaluation of maltracking of patella (many MSK radiologists do not know impact)
- Evaluation of muscle quality (many not know impact)
- Evaluation of nerve root compression (many not know impact)

Whole bunch of informations lead to:

SPECT/CT is far superior to MRI and other imaging
in the assessment of implant failures
(Joint Replacements, Osteosyntheses and Spinal fusions)

Why SPECT/CT not routinely used in case of painful implants/joints?

- MSK radiologists do not know the power of SPECT/CT
  - not allowed to read/perform
  - need to know

- Orthopedic surgeons do not know the power of SPECT/CT
  - hybrid reading frequently not offered
  - need to know

- Nuclear Medicine loves cancer

  - should love MSK, much more friendly field than cancer

Acknowledgements

- Prof. Michael Hirschmann, Dr. Helmut Rasch, Kantonsspital Baselland
  - Sharing their knowledge at the beginning

- Prof. Hubert Nötzli (hip), Prof. Stefan Eggli (knee), Prof. Paul Heini (spine), Prof. Ralph Hertel (Shoulder) and teams Lindenhof Hospitals
  - First patients

- Orthopedic teams:
  - Public Hospitals Langenthal, Biel, Aarberg, Burgdorf, Münsingen, Thun, Interlaken
  - Hirslanden Hospitals: Salem, Beau Site, Permanance
  - Lindenhof Hospitals: Engeried, Lindenhof, Sonnenhof
  - Siloah Group
  - Outercantonal