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 implant 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

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

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

Bone remodeling, whole body

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
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, neurocompression 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)

BMLs = source of pain?

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

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
SPECT/CT (xSPECT): Evaluation of stress reaction and bone matrix close to implant possible

- No misload
- No lysis
- No fracture

High resolution due to xSPECT reconstruction software

MRI:
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)

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

Mild to severe synovitis 2015  
Mild synovitis 2018
Imaging maltracking of patella (patella hypervascularity, alignment)

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

Improved. 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
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
No malrotation of prosthesis
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

Normal

Synovitis knee R;
Mild hypervascularization patella R
No irritation knee L, hips
Staging pain
Evaluation of implant failure
Evaluation of malalignment

Bloodpool hips, knee

Bone remodeling, whole body

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

Focal moderate bone remodeling in patella R
Mild synovitis R
Mild patella hypervascularity 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

Fusion SPECT/CT knee (xSPECT)

CT knee

No irritation of TKA R and arthrodesis L

Fatty atrophy of medial and lateral Vastus
Staging pain
Evaluation of implant failure
Evaluation of malalignment

No instability, no spinal disc herniation, no root compression
Slightly activated facets L5/S1
Interpretation/results


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

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 addresses/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
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