Bone SPECT/CT in orthopaedics

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Overview

- The story of SPECT/CT
- Clinical applications in the pre- and post-operative setting
 - Spine
 - Hip
 - Foot/ankle
- Pitfalls and artefacts



The story of SPECT/CT





Story of SPECT/CT



SPECT/CT combines strengths with non-overlapping limitations

The story of SPECT/CT



The story of SPECT/CT



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Van den Wyngaert T, et al. J Nucl Med 2020 [in press]

Spine





Clinical approach to chronic LBP



The issue – Where is Wally?

Degenerative facet joint disease

Importance

 Source of pain in 15-45% of patients with chronic low back pain > 6 weeks^[1]

Causes

- Normal ageing
- Accelerated degeneration and increased stress in the motion segments adjacent to fusion after spinal surgery

Consequences

- Pain
- May lead to spondylolysis and spondylolisthesis (postoperative incidence between 11 - 14%^[2])

1. Manchikanti L, et al. BMC Musculoskelet Disord 2004: 5; 15. 2. Hambly MF, et al. Spine. 1998;23(16):1785-92.

Degenerative facet joint disease

Primary degenerative facet joint disease

Treating SPECT-positive joints

Can SPECT select patients who will benefit from therapy?

- Randomized prospective study (n=47)^[1]
- Scheduled for facet joint injections, no signs of radiculopathy

Treating SPECT-positive joints

Can SPECT select patients who will benefit from therapy?

- Significant improvement in pain scores in SPECT + treated patients
- No benefit in SPECT group
- Emphasizes importance of patient selection
- 50% reduction in treated levels in SPECT group
- SPECT predicts short-term benefit of facet infiltration

Spondylolysis

- Fracture of the pars interarticularis
- Most commonly L5 (85-95%)
- Uni- or bilateral
- Most common cause of lower back pain in pediatric
- Causes:
 - Genetic predispositon
 - Injury
 - Repeated microtrauma by hyperextension (in gymnastic or football)
 - Degenerative arthritis
- Value of bone SPECT/CT
 - High sensitivity
 - More precise localization of sites of abnormal uptake in bone
 - Abnormalities of the pars interarticularis cover a spectrum
 - Stress without spondylolysis
 - Spondylolysis
 - Nonunion
 - Predict healing
- Treatment:

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- Conservative measures (brace, activity restriction, pain control, physicial therapy)
- Surgery for refractory cases (pain > 6-12 mo)

Trout AT, et al. Radiographics. 2015;35(3):819-34

Degenerative end-plate disease

Value of bone SPECT/CT

- Most value in pre-existing multilevel degenerative disease
- Difficulties in determining the active pain generator on anatomic imaging alone

Limitations of bone SPECT/CT

27-year-old truck driver with irradiating low back pain >6w

Limitations of bone SPECT/CT

MRI preferred!

Post-operative spine

Essential biomechanics (spine)

Changes after spine fusion surgery

- Residual motion transferred through fewer segments ⇒ increases stress
- Rods and screws support segment until fusion has occurred replacement of bony structures
- Intervertebral cage restores segment height, lordosis, and ligament tension
- Low lumbar spine fusion (L5-S1) increases stress on sacro-iliac joints

Selected evidence (spine)

Author, year	N	Finding
Rager, 2012	10	Bone SPECT/CT increases sensitivity and specificity over CT alone after fusion surgery.
Sumer, 2013	37	Bone SPECT/CT changes diagnosis in 45% of patients after spine fusion surgery compared to conventional imaging.
Hudyana, 2016	48	Bone SPECT/CT has high sensitivity and specificity to detect screw loosening and may guide decision for resurgery.
Al-Riyami, 2019	187	Bone SPECT/CT is a sensitive tool for identifying possible pain generators especially when conventional imaging is inconclusive

1. Rager O, et al. Clin Nucl Med 2012; 37: 339-43. 2. Sumer J, et al. Nucl Med Commun 2013; 34: 964-70.

3. Hudyana H, et al. Eur J Nucl Med Mol Imaging 2016; 43: 349-354. 4. Al-Riyami K, et al. Eur J Nucl Med Mol Imaging. 2019;46(4):989-998.

Adjacent segment degeneration (ASD)

Facet joint and disk

- Increased uptake? Evidence of lysis of interarticular part?
- ASD in the motion segments above/below fusion (source of pain in 15-45%^[1])
- May lead to spondylolysis and spondylolisthesis^[2]

1. Manchikanti L, et al. BMC Musculoskelet Disord 2004: 5; 15. 2. Hambly MF, et al. Spine. 1998;23(16):1785-92.

Subsidence, clefts, lucencies and bone resorption

- Sign of movement at the operated level and loosening
- Linear defects intradiscal bone or disc-cage interface

1. Rager O, et al. Clin Nucl Med 2012; 37: 339-43. 2. Fogel GR, et al. Spine J 2008; 8: 570-577. 3. Selby MD, et al. J Am Acad Orthop Surg 2012; 20: 694-703. 4. Williams AL, et al. AJNR 2005; 26: 2057-2006.

Screw loosening 8 months after PLIF

Fracture of pedicle screw

Change in device position

Spondylolisthesis

Pseudo-arthrosis

CT assessment of bony bridging

Pseudo-arthrosis

- CT may overestimate the significance of lucencies^[1]
- SPECT has a high false positive rate (42%)^[2, 3]
- Taken together (at >1 year post-surgery)
- Negative SPECT = no pseudo-arthrosis, think of ASD
- Low/moderate (central) SPECT uptake and signs of fusion on CT
 = no pseudo-arthrosis but micro-motion (significance?)
- High uptake and no CT fusion = pseudo-arthrosis likely

SPECT/CT information can be very helpful to carefully select patients who can benefit from reoperation^[1]

Sacroiliac joint degeneration

Causes

 Fusions from L4 to S1 place considerable rotatory stress on the sacroiliac joints during sitting^[1]

Significance

- Pain source in up to 30% of chronic LBP below L5-S1^[2]
- Therapeutic options^[3]
- Sacroiliac joint block or neurotomy

1.Lazennec JY, et al. Eur Spine J 2000;9:47-55. 2. Schwarzer AC, et al. Spine. 1995;20(1):31-7. 3. Manchikanti L, et al. Pain Physician 2013; 16:S49-S283.

Bone SPECT/CT imaging algorithm

Gnanasegaran G, at el. Semin Nucl Med. 2018;48(5):410-424.

Total Hip Arthroplasty

Causes of recurrent pain after THA

Percentage of reasons for revision surgery. Various sources.

Selected evidence (THA)

Author, year	N	Finding
Arican, 2015	20	Bone SPECT/CT more sensitive to detect loosening/infection compared with SPECT. Changes diagnosis in 16% of patients.
Dobrindt, 2015	23	Bone SPECT/CT identifies cause of pain in 65% of patients after negative conventional imaging.
Berber, 2015	15	Bone SPECT/CT changes management in 68% of patients with unexplained painful THA. Non-hip pathology in 32%.
Schweizer, 2017	58	Bone SPECT/CT identifies cause of pain in 61% of studied THAs.
Barthassat, 2017	37	Semi-quantitative assessment of bone turnover using SPECT/CT.

Arican P, et al. Nucl Med Commun. 2015 Sep;36(9):931-40. Dobrindt O, et al. BMC Med Imaging. 2015 Jun 2;15:18. Berber R, et al. J Arthroplasty. 2015 Apr;30(4):687-94. Barthassat E, et al. BMC Med Imaging. 2017 May 8;17(1):31. Schweizer T, et al. Eur J Nucl Med Mol Imaging. 2018 Feb;45(2):283-291

Spectrum of diagnoses (THA)

Bone SPECT/CT

- Loosening
- Periprosthetic fracture
- Heterotopic ossification
- Infection
- Avascular necrosis
- Tendinopathies
- Histiocytic reaction
- Polyethylene wear
- Referred pain (spine)

Evolution in hip arthroplasties

Van den Wyngaert T, et al. Semin Nucl Med. 2018;48(5):425-438.

Evolution in hip arthroplasties

Van den Wyngaert T, et al. Semin Nucl Med. 2018;48(5):425-438.

Lysis/aseptic loosening: distal locking

Signs of loosening

- Increased uptake/radiolucency at the bone-prosthesis interface in fixation zones (2,3,5,6)
- Combination of uptake at the tip and other zones indicates movement
- Proximal radiolucency (1,7)

= stress-shielding

Crucial fixation zones = Pathological uptake

Lysis/aseptic loosening

Acetabular cups

- Crucial fixation zones at outer circumference (zones I and III)
- Frequently increased uptake in surrounding bone (≠ bone-prosthesis interface)
- Osteolysis zone II may not be clinically relevant
- Loosening suspected if increased uptake at prosthesis-bone interface
 - >1 compartment OR
 - Corresponding CT radiolucency

Lysis/aseptic loosening

Acetabular cups

Septic loosening

Bone scintigraphy

- Negative bone SPECT/CT makes infection highly unlikely
- But specificity of increased tracer uptake is low

Multimodality assessment preferred

Bone marrow scintigraphy, WBC scintigraphy, FDG-PET/CT

	Bone scan ^[2]	Antigranulocyte scan ^[1]	WBC scan ^[2]	FDG-PET ^[2]
N° studies	10	13	5	8
N° THA	745	317	299	485
Sensitivity	78%	83%	76%	85%
Specificity	84%	80%	96%	90%

Septic loosening

Importance of correlation SPECT with CT findings

• Osteolysis, periosteal new bone formation, fistula tract, and collections

Heterotopic ossification

Value of bone SPECT/CT

- Early and accurately localization of immature HO
- Identifying developing pseudoarthrosis with the native bone
- Activity on delayed bone scans usually peaks a few months after surgery and returns to baseline within 1 year ("mature")
- Timing of intervention

Periprosthetic fractures

Value of bone SPECT/CT

- Equivocal X-rays
- Persistence of a linear lucency across fracture suggestive of delayed or nonunion
- Absent or reduced tracer activity at the fracture site indicates non-union

Periprosthetic fractures

Stable fracture, but can be symptomatic because of pseudo-arthrosis

Tendinopathies

Common findings

- Greater trochanter (GTPS), gluteus, and iliopsoas tendinitis
- However, ultrasound and MRI preferred with bone SPECT/CT in case of equivocal or non-diagnostic findings

Referred hip pain

Spine and sacro-iliac joint frequent sources of referred pain

- Continuation of the degenerative disease spectrum
- Bone SPECT/CT offers comprehensive survey of potential pain generators

Bone SPECT/CT imaging algorithm

* Followed by dedicated radionuclide infection imaging if required

Foot/Ankle

Selected evidence (foot/ankle)

Data still very scarce!

Author, year	N	Finding
Pagenstert, 2009	20	Bone SPECT/CT is useful in localising active arthritis
Mason, 2015	14	High incidence of medial sided talar prosthesis activity consistent with loosening. This was not apparent on plain radiographs.
Ellis, 2015		"caution when interpreting the results of the SPECT-CT in patients with a painful total ankle until we have more clinical data or a better gold standard"

1. Mason LW, et al. Foot & Ankle International 2015; 36:635-640. 2. Pagenstert GI, et al. J Bone Joint (Br) 2009; 91-B:1191-1196. 3. Ellis SJ. Foot Ankle Int. 2015;36(10):1251

Occult stress fracture

Stressfracture of the os cuneiforme laterale

Coalition

Determine activity

- Talo-calcaneal coalition
- Confirmation of anatomic finding as pain generator
 - Focal increased uptake
 - No other hotspots in subtalar joint
- Fibrous coalition with symptomatic pseudo-arthrosis

Os trigonum syndrome

Posterior impingement

Osseous causes

Os trigonum

Fracture of lateral talar process (Shepherd's fracture)

Prominent posterior talar process (Stieda's process)

Processus lateralis tuberis calcanei

Other accessory bones posterior ankle

Osteochondral lesions

SPECT/CT can provide additional information on activity in case of multiple lesions

Arthrodesis

Potentially important rol in recurrent pain after arthrodesis

- Evaluation of arthrodesis (n=40)
 - 25% delayed or non-union, with 75% impact on management
 - 88% concordance with operative findings

Nathan M, et al. J Nucl Med 2011; 454 (suppl 1).

Arthrodesis

SPECT/CT as "problem solver" subtalar fusion

Bone SPECT/CT imaging algorithm

- Depending on clinical context SPECT/CT is recommended in 2nd or 3rd line
- Mostly used as problem solving tool

Delayed osteob L

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Truncation

- In some scanning angles, not all the object is within the FOV
- Streaking at transitions with high contrast, for example, bone or metal
- Hyperdense areas seen adjacent to the section outside the FOV

Table 4 Causes of Artifacts on SPECT/CT44-53

Thick CT slices

Limitations of the equipment
 Incorrect reconstruction parameters

- Potential loss of visibility of smaller details
- Stair step slices in the craniocaudal direction

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Thank you!

