Original article

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Quantitative bone single photon emission computed tomography/computed tomography in symptomatic and asymptomatic foot and ankle osteoarthritis

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Purpose: The purpose of this study was to evaluate and quantify the prevalence of increased uptake in SPECT/CT in symptomatic and asymptomatic foot and ankle joints in patients with osteoarthritis.

Methods: In 63 patients with osteoarthritis (OA), the painful symptomatic foot (SF) and asymptomatic contralateral foot (AF) were imaged with bone SPECT/CT. Presence, localization, and maximum standardized uptake value (SUV_{max}) of the active joints were assessed for SF and AF. CT OA grade (grade 1: mild, grade 2: moderate, grade 3: severe) and presence of five morphological features of OA (joint space narrowing, subchondral sclerosis, subchondral cysts, irregular joint margins, and osteophytes) were evaluated.

Results: In total 32 (51%) patients showed additional uptake in the AF, whereas 31 (49%) patients showed it only in the SF. SF showed more active joints than AF (106 vs. 43). CT OA grades positively correlated with SUV_{max} (Kendall's tau b=0.62, $P<0.001$). SUV_{max} values (per foot) in SF were higher in patients with uptake in bilateral feet (SF+, AF+) [median (IQR): 17.9 (10.7–23.3)] as compared with patients with active sites only in the SF (SF+, AF–) [10.4 (6.4–19.1); $P<0.001$]. Number of active OA joints in SF was higher in patients with bilateral uptake ($P=0.017$).

Conclusion: In conclusion, half of the patients exhibited increased uptake in the contralateral asymptomatic foot. SUV_{max} showed a significant correlation to CT osteoarthritis grade, in the symptomatic and asymptomatic foot. Future follow-up studies will provide further insights into the prognostic and therapeutic value of these findings. *Nucl Med Commun* XXX: XXXX–XXXX Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.

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Keywords: ankle, asymptomatic foot, bone scintigraphy, bone SPECT/CT, foot, osteoarthritis, quantitative bone SPECT/CT, quantitative SPECT, SPECT/CT, SUV, SUV_{max}

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Introduction

Osteoarthritis (OA) is a common posttraumatic or degenerative disorder of the joints with loss of cartilage and bone reaction. OA is a leading cause of pain and disability among adults, with increasing incidence and impact on the healthcare system [1,2]. Precise localization of OA and correlation of symptoms and clinical investigation is crucial for adequate management. Multimodality hybrid single photon emission computed tomography/computed tomography (SPECT/CT), with complementary metabolic and morphologic cross-sectional views, is an important advanced imaging modality to precisely localize bone and associated pathologies, especially in anatomically complex regions such as wrist and foot [3–5]. SPECT/CT leads to improved diagnosis in 40–79% of patients with painful foot and ankle in a literature review and is recommended as a second-line imaging modality if conventional imaging is inconclusive and bone pathology is suspected [3]. Ha *et al.* [6] reported an MRI-comparable diagnostic performance of SPECT/CT in foot and ankle pain patients.

In symptomatic patients, increased radiotracer uptake in SPECT/CT often represents the pain-generating lesion. However, incidental uptake on a bone scan in asymptomatic foot (AF) joints and bones is also regularly observed in daily routine work. Allgayer *et al.* [7] found low to intermediate uptake in asymptomatic wrist and hand joints in one-third of patients. The majority of uptake in the contralateral asymptomatic wrist remained clinically silent in the short time clinical follow-up. Prevalence of incidentally detected uptake in AF and ankle joints has not been investigated yet.

Recent advances in the software and hardware technologies in the field of SPECT/CT along with new reconstruction techniques have led to the development of quantitative estimation of radiotracer uptake, with the calculation of standardized uptake values (SUV), similar to the way it has been traditionally done in the field of PET/CT [8–12]. Experience with the implementation of quantitative bone SPECT/CT in the clinical setting is still very limited [13,14].

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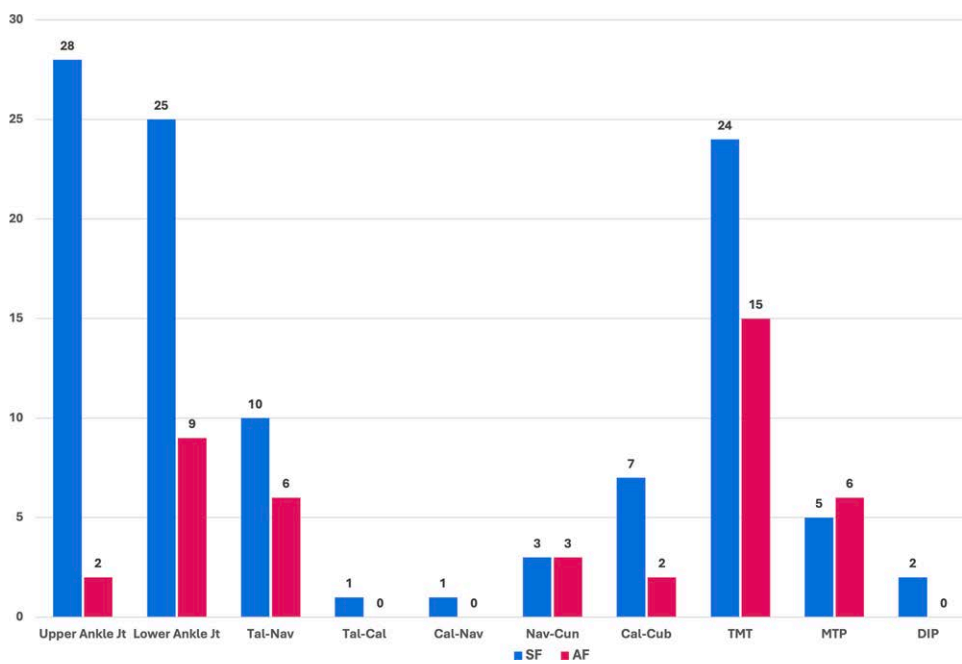
Table 1 **Distribution of maximum standardized uptake value in a sample of 149 osteoarthritis joints in 63 patients**

Category	No. of patients	No. of joints	SUV_{max} Median	IQR	mean ± SD	Minimum	Maximum
All OA joints	63	149	10.5	7.5–17.8	12.8 ± 7.4	2.3	40.7
OA joints in SF	63	106	12.7	8.0–19.1	14.0 ± 7.7	2.7	40.7
OA joints in AF	32[a]	43	8.9	6.3–11.0	10.0 ± 5.5	2.3	25.1
OA joints in SF (Patients with activity in AF) (SF+, AF+)	32	61	13.9	9.6–19.5	15.4 ± 8.0	3.0	40.7
OA joints in SF (Patients without activity in AF) (SF+, AF–)	31	45	9.3	6.7–17.8	12.2 ± 7.1	2.7	32.0

AF, asymptomatic foot; OA, osteoarthritis; SF, symptomatic foot; SUV_{max}, maximum standardized uptake value.
[a]Out of 63 patients with OA joints in SF, 32 patients had radiotracer activity (active sites) in bilateral feet, SF and AF (SF+, AF+).

Fig. 1



Distribution of active 149 joints in bilateral feet and ankles with increased radiotracer activity. Cal-Nav, calcaneo-navicular joint; Cal-Cub, calcaneocuboidal joint; DIP, distal interphalangeal joint; MTP, metatarsophalangeal Joint; Nav-Cun, naviculo-cuneiform joint; Tal-Cal, talocalcaneal Joint; Tal-Nav, Talonavicular Joint; TMT, tarsometatarsal joint.

Therefore, this study aimed to investigate the clinical prevalence of increased radiotracer uptake in bone SPECT/CT in symptomatic foot (SF) and AF and ankle joints in patients with OA, quantify the SPECT radiotracer activity, compare the uptake grade with morphologic OA grade assessed with CT, and in turn explore its clinical significance and relevance.

Materials and methods

Study design and patients

However, 63 consecutive patients (27 women, 36 men, median age: 52 years, range: 23–84 years) with suspected foot and ankle OA were referred for bone scintigraphy with SPECT/CT by dedicated foot and ankle surgeons following a detailed clinical and physical examination of both feet. The main clinical indication for bone SPECT/CT imaging was chronic pain with suspected OA after trauma or due to nontraumatic degeneration. Only patients with one SF and contralateral AF were included. Approval of the ethics committee was obtained for this study (EKNZ Nr: 2021-02424) and the requirement for informed consent was waived by the ethics committee in view of the retrospective design of the study.

Bone scintigraphy and SPECT/CT imaging

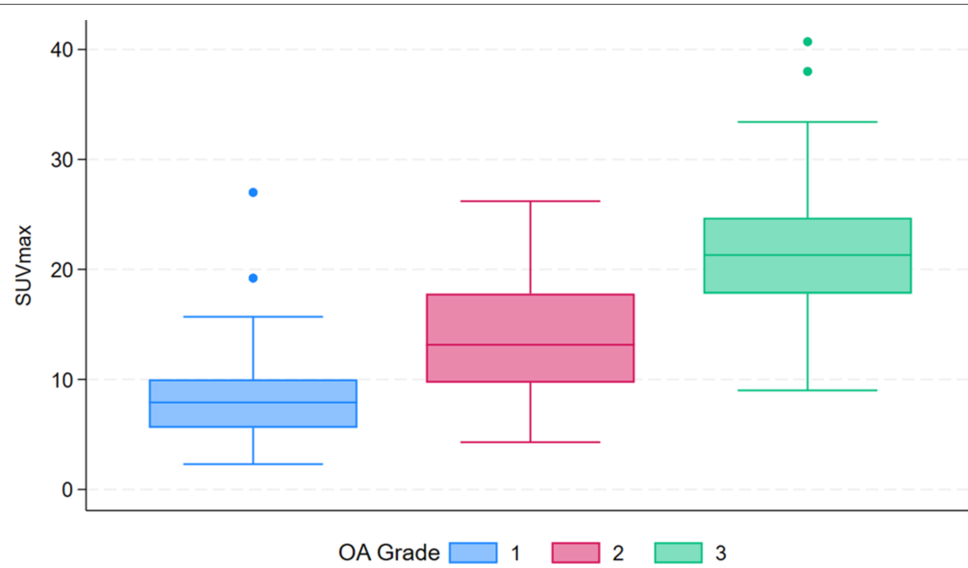
Dual-phase planar and SPECT/CT images of the symptomatic and asymptomatic feet and ankles of 63 consecutive patients, who fitted the inclusion/exclusion criteria,

Table 2 Maximum standardized uptake values across osteoarthritis grades and five morphological features of osteoarthritis (149 joints)

Category		No. of joints	SUV_{max} Median	IQR	Mean ± SD	Minimum	Maximum	Kendall's tau-b, *P* value
OA grade	1	73	7.9	5.6–10.0	8.1 ± 3.9	2.3	27.0	0.62,
	2	42	13.1	9.7–17.8	13.6 ± 5.0	4.3	26.2	*P* < 0.001
	3	34	21.3	17.8–24.7	22.0 ± 6.6	9.0	40.7	
Morphological Features								Wilcoxon rank-sum test
JSN	1	81	16.0	10.0–20.5	16.2 ± 7.6	2.7	40.7	*P* < 0.001
	0	68	8.1	5.7–10.5	8.8 ± 4.6	2.3	27.0	
SCS	1	134	10.6	7.9–18.4	13.2 ± 7.5	2.3	40.7	*P* = 0.040
	0	15	7.9	5.7–11.6	9.5 ± 5.9	2.7	27.0	
SCC	1	74	16.7	10.5–21.6	16.7 ± 7.9	4.1	40.7	*P* < 0.001
	0	75	8.6	6.3–10.6	9.1 ± 4.3	2.3	24.8	
IJM	1	79	16.2	10.5–21.8	16.9 ± 7.2	4.3	40.7	*P* < 0.001
	0	70	7.8	5.6–10.5	8.3 ± 4.3	2.3	27.0	
Osteophytes	1	100	13.3	8.7–19.3	14.4 ± 7.8	2.3	40.7	*P* < 0.001
	0	49	8.5	6.5–11.0	9.6 ± 5.2	2.7	27.0	

1: present; 0: absent; IJM, irregular joint margins; IQR: interquartile range; JSN, joint space narrowing; OA, osteoarthritis (OA grades 1, 2, 3); SCC, subchondral cysts; SCS, subchondral sclerosis; SUV_{max}, maximum standardized uptake value.

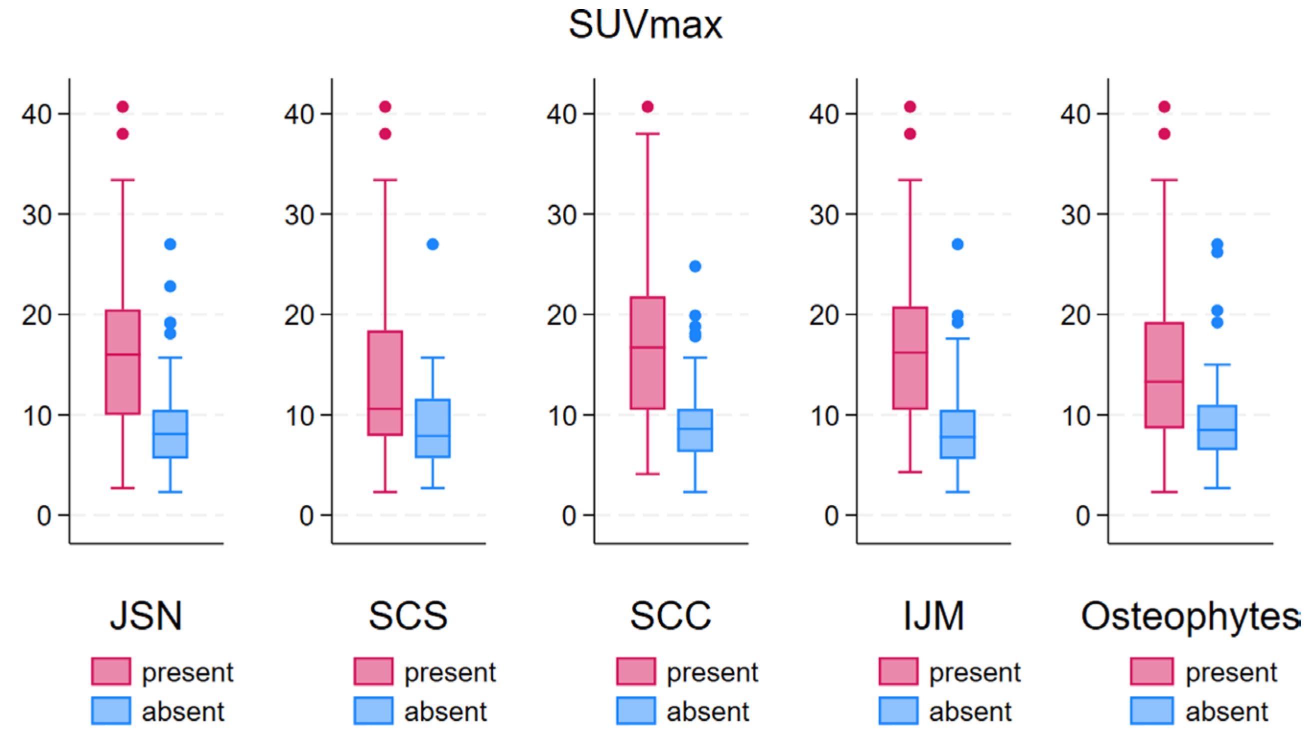
Fig. 2



Distribution of SUV_{max} in relation to osteoarthritis grade on CT in 149 OA joints. OA, osteoarthritis.

were acquired. It is the standard SPECT/CT protocol in our institution to image always both feet. ^{99m}Tc-3,3-diphosphono-1,2-propanedicarboxylic acid (^{99m}Tc-DPD) (Teceos, Behringwerke AG, Marburg, Germany) was injected intravenously (mean activity 689 MBq, range 610–736 MBq). Early phase planar images of the feet were obtained 5 min after injection of the radiotracer with a hybrid SPECT/CT system with an integrated dual-head SPECT and 16-slice helical CT scanner (Symbia Intevo Bold, Siemens Healthineers, Erlangen, Germany). Planar late-phase images of the feet were obtained 3 hours after radiotracer injection. Subsequently, SPECT/CT of the feet was acquired. SPECT was performed with a low-energy high-resolution (LEHR) parallel-hole collimator in step-and-shoot mode with 60 projections and a frame time of 15 s per frame with 180 degrees of rotation (SPECT frame matrix: 256 × 256). CT images were acquired in high-resolution mode (CT slice thickness 2 mm, matrix 512 × 512 mm) with 25 mA, 130 kV, pitch of 0.9, and combined applications to reduce exposure dose. SPECT images were reconstructed using an ordered subset conjugate gradient maximization (SPECT Bone) algorithm allowing SUV quantification, with CT-based zone information (1 subset, 24 iterations, Gaussian filter of 15.0), along with sinogram affirmed iterative reconstruction and interleaved volume reconstruction) (Siemens Healthineers) [10,15]. SPECT and CT images were fused with a dedicated software (Syngo.via,

Fig. 3



SUV_{max} for five different OA parameters in 149 OA joints. IJM, irregular joint margins; JSN, joint space narrowing; OA, osteoarthritis; SCC, subchondral cysts; SCS, subchondral sclerosis; SUV_{max}, maximum standardized uptake value.

Siemens Healthineers, Erlangen, Germany), and reformatted in axial, coronal, and sagittal planes.

Image evaluation/interpretation

All images were analyzed using the local picture archiving and communication system (PACS) (Merlin PACS, Phönix-PACS, Freiburg, Germany) and Syngovia software (Siemens Healthineers). The images were evaluated in consensus by two nuclear medicine physicians, one dual board-certified nuclear medicine physician and radiologist with more than 20 years of experience in musculoskeletal SPECT/CT reading and one board-certified nuclear medicine physician with more than 20 years of experience, along with a dedicated foot and ankle orthopedic surgeon. Presence, localization, and maximum standardized uptake value (SUV_{max}) of osteoarthritic joints in the foot and ankle were assessed in SF and AF on the late-phase SPECT/CT images. Joint or bone uptake caused by other diseases such as insertion tendinopathy or osteochondral lesion were excluded from the analysis. On CT, OA was graded on a three-point scale of severity (grade 1: mild, grade 2: moderate, and grade 3: severe), and the presence or absence of five morphological features of OA (joint space narrowing, subchondral sclerosis, subchondral cysts, irregular joint margins, and osteophytes].

Statistical analysis

The statistical analysis was performed using the software package Stata (version 18.0, StataCorp, College Station, Texas, USA). Categorical variables were summarized by frequency tables. Quantitative variables were presented using descriptive statistics including median, interquartile range (IQR), mean, SD, and range.

The association between the CT OA grades and SPECT radiotracer uptake (SUV_{max}) was assessed using Kendall's tau-b, a rank correlation coefficient that is also appropriate in the presence of ties.

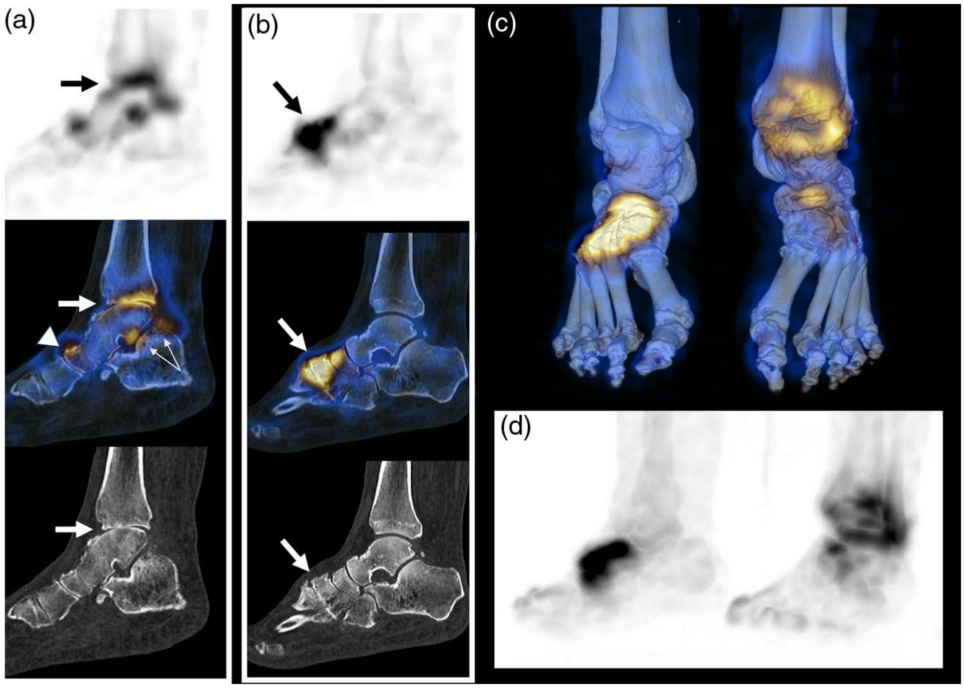
Comparisons of SUV_{max} (per OA joint) or maximum SUV_{max} (per foot) values between groups were performed utilizing the Wilcoxon rank-sum test. Intra-individual comparisons of maximum SUV_{max} between symptomatic and asymptomatic feet within patients were done using the Wilcoxon signed-rank test.

Results

Distribution of osteoarthritic joints

Out of 63 patients, 31 (49%) had increased uptake only in the SF with no uptake in the contralateral AF (SF+, AF−), whereas 32 patients (51%) showed uptake in bilateral feet (SF+, AF+) (Table 1). Overall, 149 osteoarthritic active joints were observed on the SPECT/CT, out of which 106 joints (71%) were in SF and 43 joints

Fig. 4



A 78-year-old man with pain in the left upper and lower ankle joints since 2 years, underwent bone SPECT/CT. Increased uptake is seen in the upper (SUV_{max}: 16.3) (arrow) and lower (SUV_{max}: 13.9) (thin arrows) ankle joints and in the naviculo-cuneiform joint (SUV_{max}: 14.4) (arrowhead) with moderate to severe OA on the left side (a). On the contralateral asymptomatic right side (b), increased radiotracer uptake is seen in TMT-2 (SUV_{max}: 22.0) and NC (SUV_{max}: 22.0) joints with evidence of OA on corresponding CT images. [c: anterior VRT (volume rendering technique) projection; d: SPECT MIP (maximum intensity projection)]. Arthrodesis of the left upper and lower ankle joints was performed. Right foot was managed conservatively. Clinical follow-up showed improvement in his symptoms and mobility. NC, naviculo-cuneiform joint; OA, osteoarthritis; SPECT/CT, single photon emission computed tomography/computed tomography; SUV_{max}, maximum standardized uptake value; TMT, tarsometatarsal.

(29%) in AF; 75 (50.3%) on the left side and 74 (49.7%) on the right side. In a subset of those 32 patients who showed uptake in bilateral feet (SF+, AF+), there were a total of 104 osteoarthritic active joints, 61 in SF and 43 in AF.

Upper ankle ($n = 28$), lower ankle (25), tarsometatarsal (24), and talonavicular (10) joints were most often involved in the symptomatic feet. In the asymptomatic feet, tarsometatarsal joint (15) was followed by lower ankle (9), talonavicular (6), and metatarsophalangeal (6) joints. The distribution of various joint involvement is shown in detail in Figure 1.

Correlation of uptake and osteoarthritis grade/ morphologic osteoarthritis features

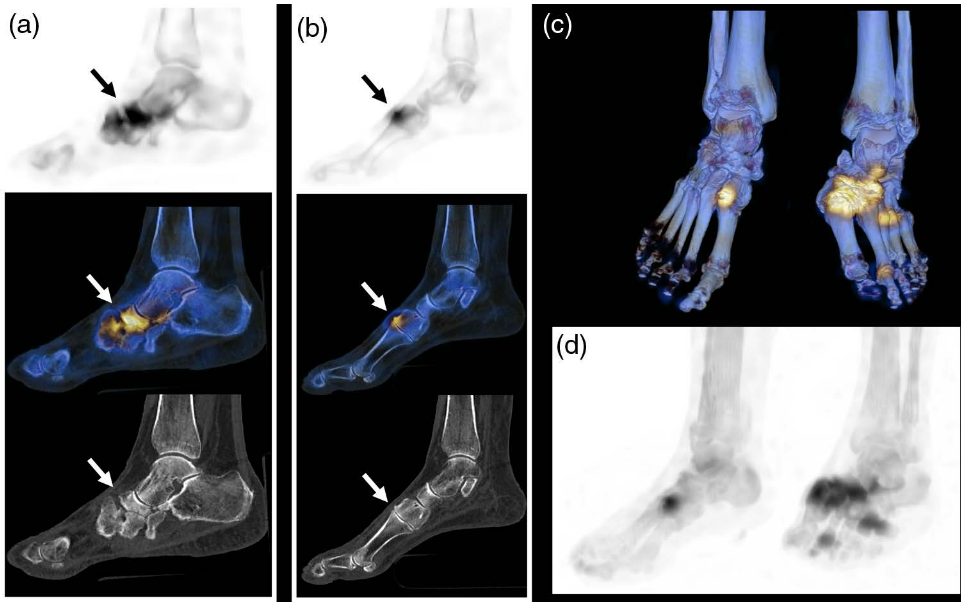
Grade 1 OA joints showed a median SUV_{max} value of 7.9 (IQR: 5.6–10.0), whereas grade 2 OA had median SUV_{max} value of 13.1 (IQR: 9.7–17.8), and grade 3 OA had median SUV_{max} of 21.3 (IQR: 17.8–24.7) (Table 2 and Fig. 2). There was a positive correlation between grade of OA and SUV_{max} values in the involved joints of the feet (Kendall's tau-b = 0.62, $P < 0.001$, Kendall's tau) (Fig. 2). Out of the five morphologic signs for OA, subchondral sclerosis was present in 134 (90%) out of 149 joints, osteophytes in 100 (67%), joint space narrowing in 81 (54%), irregular joint margins in 79 (53%), and subchondral cysts in 74 (50%) (Table 2 and Fig. 3). There were robust associations between SUV values and five OA parameters (Table 2). The SPECT/CT fusion images (Figs. 4–6) illustrate with clarity the distribution of radiotracer uptake in foot and ankle joints and the corresponding morphologic changes. The prototype of SUV quantification is depicted in Figure 7.

Uptake in symptomatic foot (SF) for patients with active sites in bilateral feet (SF+, AF+) versus patients with activity only in the SF (SF+, AF–)

In patients with bilateral feet uptake (SF+, AF+), the median SUV_{max} of active joints in SF was 13.9 (IQR: 9.6–19.5) and it was, in general, higher compared with symptomatic joints in patients with negative (asymptomatic) contralateral foot (SF+, AF–) (9.3, IQR: 6.7–17.8) (Table 2).

For a fair, equally weighted statistical comparison, we used only one SUV_{max} value from each patient, including those with several OA joints. For this purpose, we selected an OA joint in the SF with the highest uptake, that is, the maximum SUV_{max}. Considering the

Fig. 5



A 67-year-old diabetic woman with Charcot foot with pain in the left foot since few years along with polyneuropathy, metabolic syndrome, and obesity. Increased uptake is seen in the SPECT/CT in symptomatic left foot (a) in TMT-1 (SUV_{max}: 20.5), TMT-5 (SUV_{max}: 15.9), MTP-2 (SUV_{max}: 13.4), and Talocalcaneal (SUV_{max}: 15.0) joints with moderate to severe OA on the corresponding CT images. The contralateral asymptomatic right foot (b) showed increased uptake in TMT-1 (SUV_{max}: 20.3) joint with OA on corresponding CT images. (c: anterior VRT projection; D: SPECT MIP). Lisfranc (TMT) arthrodesis of the left foot was performed. MIP, maximum intensity projection; OA, osteoarthritis; SPECT/CT, single photon emission computed tomography/computed tomography; SUV_{max}, maximum standardized uptake value; VRT, volume rendering technique; TMT, tarsometatarsal.

maximum SUV_{max}, the uptake in the SF was higher in patients with bilateral feet uptake (SF+, AF+) (median: 17.9, IQR: 10.7–23.3) compared with patients with activity only in the SF (SF+, AF−) (10.4, 6.4–19.1; $P < 0.001$; Table 3).

In patients with contralateral inactive joints (SF+, AF−), predominantly only one joint (68%) was active on the symptomatic side, followed by two (19%) and three (13%) joints (Table 3). In patients with bilateral active joints (SF+, AF+), only one joint was active in the symptomatic side in 34%, two in 44%, three in 19%, and 4 in 3%, indicating a higher number of OA joints per SF in patients with bilateral feet activity ($P = 0.017$; Table 3).

Uptake grade in symptomatic foot versus asymptomatic contralateral foot

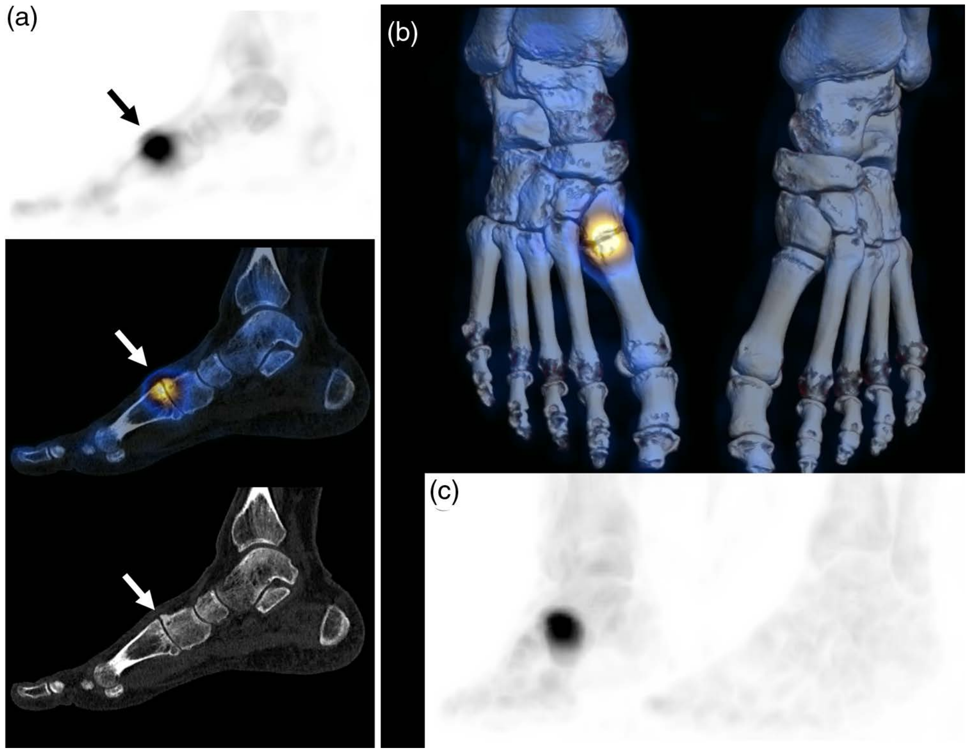
In general, there was a higher median SUV_{max} of 12.6 (IQR: 8.0–19.1) in the 106 OA joints on the symptomatic side (SF) compared with the 43 joints in the asymptomatic side (AF) (median SUV_{max}: 8.9, IQR: 6.3–11.0) (Table 1). This also includes symptomatic side data from patients without any uptake in the AF (SF+, AF−). However, within the subset of 32 patients with active sites in bilateral feet (SF+, AF+), the median SUV_{max} of 13.9 (IQR: 9.6–19.5) in SF was also quite similar (Table 1).

For an intra-individual comparison of whether the uptake was higher in the SF than in the AF (if patients had active sites in bilateral feet: SF+, AF+), we again used the maximum SUV_{max} value measured in the respective foot (Table 4). Regardless of the number of OA joints per foot, this enabled an equally weighted, intra-individual comparison of those OA joints from SF vs. AF, which are presumably most likely to be responsible for potential complaints. The maximum SUV_{max} in SF had a median of 17.9 (IQR: 10.7–23.3) compared with a median of 9.0 (IQR: 5.9–11.1) in AF ($P < 0.001$, Table 4 and Fig. 8).

Discussion

In this study, we demonstrated that half of the patients referred for evaluation of foot and ankle pain have increased uptake in the contralateral AF and ankle joints in SPECT/CT imaging, indicating potential early-stage OA, as shown by the presence of 43 OA joints (29%) in AF. This finding has substantial clinical implications. The presence of subclinical foot OA (AF), as identified in our study, emphasizes the importance of vigilance in asymptomatic joints. Likewise, the active OA joints in the symptomatic side (SF) would benefit from aggressive management and surgical intervention, as appropriate, and proactive follow-up imaging. Furthermore, our findings suggest that the altered weight distribution and loading patterns resulting from moderate to severe symptomatic OA in the affected foot may contribute to malalignment and abnormal loading in the contralateral side. This, in turn, could lead to the development of OA

Fig. 6



28-year-old man with pain in the right foot after trauma at TMT-1 joint 1 year ago. SPECT/CT shows (a) increased uptake in the TMT-1 joint (SUV_{max}: 14.2) with moderate OA in corresponding CT image. The contralateral left foot is asymptomatic without any abnormal uptake. Arthrodesis was performed successfully for the active TMT-1 joint. (b: anterior VRT projection; c: SPECT MIP). MIP, maximum intensity projection; OA, osteoarthritis; SPECT/CT, single photon emission computed tomography/computed tomography; SUV_{max}, maximum standardized uptake value; VRT, volume rendering technique; TMT, tarsometatarsal.

in weight-bearing joints on the opposite side, highlighting the intricate interplay between the symptomatic and asymptomatic joints.

We observed a significant correlation between the uptake grade measured with SUV in SPECT/CT and the presence, signs, and grade of OA assessed with the corresponding CT images. In general, the symptomatic side exhibited higher SUV_{max} of the radiotracer uptake compared with the asymptomatic side, indicating that higher uptake is more likely associated with symptomatic and therapeutically relevant stages of OA. Additionally, the radiotracer uptake in patients with bilateral active feet (SF+, AF+) tends to be higher compared with unilateral active foot (SF+, AF−), probably indicating that these patients have a generally more advanced stage of OA and uptake on the asymptomatic side indicates overload and degeneration due to severe OA on the clinically evident foot.

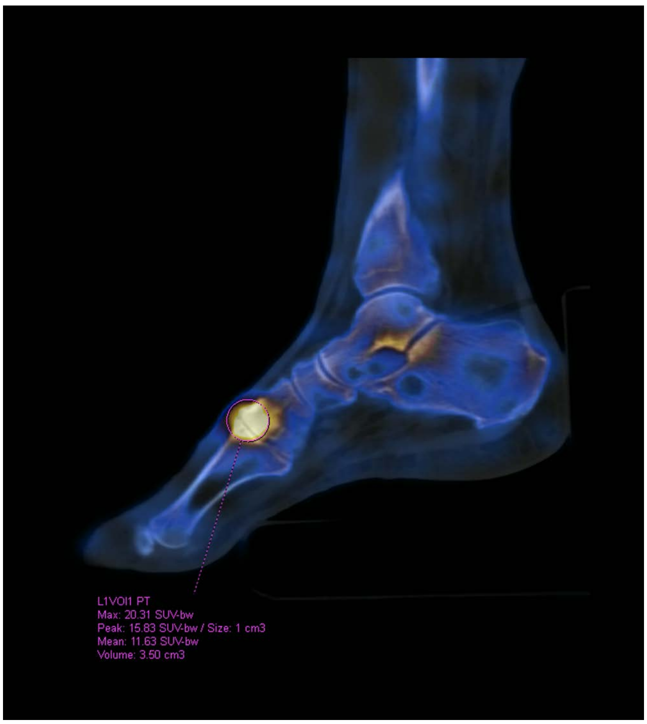
OA is a multifaceted joint pathology involving mechanical, inflammatory, and metabolic factors. It encompasses structural alterations in various joint components, ultimately leading to joint failure. It is an active dynamic disease process influenced by an interplay between tissue repair and destruction. Pain, the most debilitating symptom, significantly influences clinical decision-making and management [1,16,17].

While the role of bone scintigraphy and SPECT/CT in knee joint OA has been explored, there is limited research on their application in foot and ankle OA [4]. SPECT/CT has been studied in other pathologies of foot and ankle such as arthrodesis, arthroplasty, infection, and so on [3–5]. Paul *et al.* [18] studied the correlation between radiotracer uptake in bone SPECT/CT and histologic findings in six patients with end-stage ankle OA undergoing total ankle replacement and found increased radiotracer uptake exclusively subjacent to the subchondral bone plate of tibial and talar joint compartments indicating that increased bone turnover and SPECT uptake represents reactive changes of cartilage damage.

Parthipun *et al.* [19] explored the role of bone SPECT/CT in localizing the site of pain-originating structures for joint injections in osteoarthritic joint disease of the foot and ankle in 52 patients and found bone SPECT/CT to be a very useful diagnostic tool with an impact on change in therapeutic management with changing the site of joint injection in 37% of cases [19]. The study had a high clinical success rate for SPECT/CT-guided joint injections, with 90% of patients showing improvement in their symptoms.

Traditionally, the quantitative estimation in gamma camera imaging and SPECT/CT was limited to the relative uptake of the radiotracer/radiopharmaceutical in one region compared with the background or to the opposite side, for example, sacroiliac joints relative uptake in bone scintigraphy or mandibular condylar relative uptake in bone SPECT/CT. However, semiquantitative quantification as in PET/CT imaging with SUV was lacking. This had remained a shortcoming in gamma scintigraphy and SPECT/CT imaging vis-a-vis PET/CT imaging till a few years back. However, with new-generation SPECT/CT scanners, quantification of SPECT/CT data has become feasible [8–10,12,20]. Our study demonstrates the feasibility of quantifying radiotracer uptake in foot and ankle joint OA using SPECT/CT. De Laroche *et al.* [21] studied quantitative bone SPECT/CT in the preoperative assessment of knee OA in 120 knees of 103 patients and found a good correlation between SUV_{max} and preoperative OA staging (International Cartilage Repair Society [ICRS] scale) [21]. Our study reflects their finding for the foot and ankle joints with the correlation between SUV_{max} and OA grade. The higher SUV_{max} in the SF fits well into the clinical picture of why a patient may feel symptoms, but not yet on the asymptomatic side despite measurable uptake.

Fig. 7



The prototype SPECT/CT image with quantification of the radiotracer uptake and estimation of SUV_{max} at the active sites in the foot and ankle. SPECT/CT, single photon emission computed tomography/computed tomography; SUV_{max}, maximum standardized uptake value; TMT, tarsometatarsal.

Bae *et al.* [22] carried out an objective quantitative assessment of accessory navicular bone (ANB) using bone SPECT/CT of foot and estimation of SUV_{max} to investigate its usefulness as an imaging biomarker for ANB, in a cohort of 105 patients, of which 74 had ANB and 31 were negative controls without ANB. SUV_{max} derived from quantitative bone SPECT/CT was strongly associated with symptoms, surgical treatment, and a known high-risk type of ANB, demonstrating quantitative bone SPECT/CT to be a promising technique.

Menz *et al.* [23] studied the sensitivity of radiographic variables and their relationship to foot symptoms and observed that radiographic foot OA is common in older people and is moderately associated with symptoms. In their study, the joint-specific prevalence of OA in foot joints was as follows: 1st MTP joint (42.4%), 1st tarsometatarsal (TMT) (22.6%), 2nd TMT (60.2%), N-1st C (39.1%), and TN (32.7%) [23].

Table 3 Maximum standardized uptake value and No. of osteoarthritis joints in SF for 32 patients with activity in AF (SF+, AF+) versus 31 patients without activity in AF (SF+, AF–) (Total: 63 patients):

Category		No. of patients	Maximum SUV_{max}					Wilcoxon rank-sum test
			Median	IQR	Mean ± SD	Minimum	Maximum	
Activity in AF	1	32	17.9	10.7–23.3	17.9 ± 9.2	3.2	40.7	$P = 0.025$
	0	31	10.4	6.4–19.1	13.1 ± 7.9	2.7	32.0	
Category		No. of Patients		No. of OA Joints in SF		*N*	%	Wilcoxon rank-sum test
Activity in AF	1	32		1		11	34.4%	$P = 0.017$
				2		14	43.8%	
				3		6	18.8%	
				4		1	3.1%	
	0	31		1		21	67.8%	
				2		6	19.4%	
				3		4	12.9%	
				4		0	0.0%	

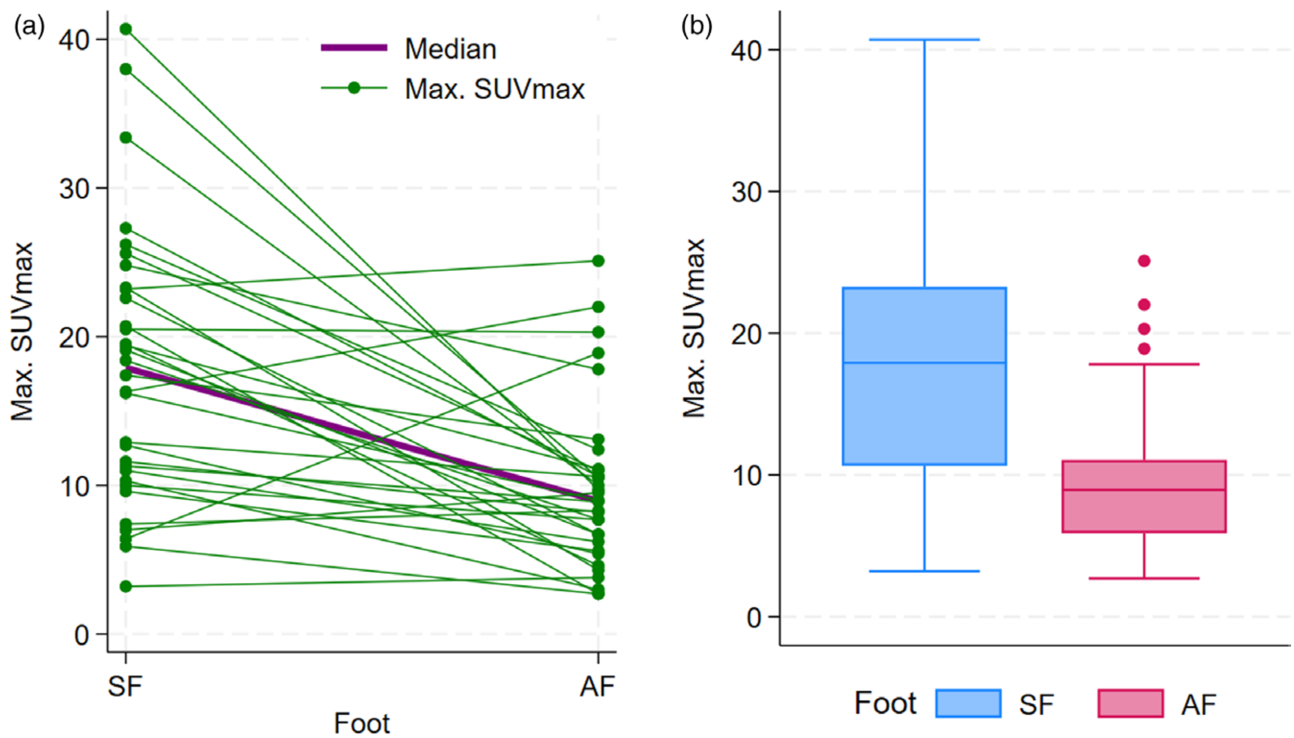
AF, asymptomatic foot; IQR, interquartile range; OA, osteoarthritis; SF, symptomatic foot; SUV_{max}: maximum standardized uptake value in SF per individual patient; 1: present; 0: absent.

Table 4 Comparison of Maximum standardized uptake value between symptomatic foot and asymptomatic foot within those patients who had activity (active sites) in bilateral feet (SF+, AF+) (32 patients)

Category		No. of patients	Maximum SUV_{max}					Wilcoxon signed-rank test
			Median	IQR	mean ± SD	Minimum	Maximum	
Foot	SF	32	17.9	10.7–23.3	17.9 ± 9.2	3.2	40.7	$P < 0.001$
	AF	32	9.0	5.9–11.1	9.8 ± 5.6	2.7	25.1	

AF, asymptomatic foot; IQR, interquartile range; SF, symptomatic foot; SUV_{max}: maximum standardized uptake value in the respective foot, SF or AF, per individual patient.

Fig. 8



Maximum SUV_{max} per individual foot compared between symptomatic and asymptomatic foot (SF vs. AF) in 32 patients with radiotracer uptake in bilateral feet (SF+, AF+). (a) Individual values of SUV_{max} plotted for each group, with clear trend for higher SUV_{max} in SF compared with AF. (b) Box plot of the maximum SUV_{max} for SF and AF depicting a clear separation between the two groups. AF, asymptomatic foot; SF, symptomatic foot; SUV_{max}, maximum standardized uptake value.

The 1st MTP joint is probably the most mobile joint, has a relatively wide range of motion, and plays an important role in enabling smooth transfer of body weight over the foot while walking; and due to all these factors, it is more likely to undergo degenerative changes.

Downes *et al.* [24] studied the symptomatic course of radiographic foot OA (three phenotypes: no or minimal foot OA, isolated 1st MTP joint OA, and polyarticular OA) in community-dwelling older adults prospectively over 18 months and observed that mild to moderate SF OA appears to remain relatively stable with usual care, and additional follow-up over a longer time period is needed to understand further the natural history of foot OA and whether different phenotypes of foot OA exhibit different course of foot symptoms [24].

Allgayer *et al.* [7] conducted a study on asymptomatic wrists in patients referred for evaluation of painful symptomatic wrists. Out of 44 patients, 70% exhibited increased radiotracer uptake on the symptomatic side and 32% in the contralateral asymptomatic wrist. Notably, the majority of the uptake in the asymptomatic wrists remained clinically silent in the short time follow-up. The lower prevalence of asymptomatic activity in the wrist compared with the foot may be attributed to the greater weight-bearing stress experienced by the foot and ankle joints.

One limitation of this study is the lack of detailed follow-up information, especially regarding the discrepancy between scintigraphically active but asymptomatic joints. It is planned to follow these patients clinically to evaluate the prognostic and therapeutic value of such findings.

Conclusion

In conclusion, half of the patients in our study exhibited increased radiotracer uptake in the contralateral asymptomatic foot, indicating various grades of OA. Awareness of the high prevalence of asymptomatic increased uptake in foot bone SPECT/CT is crucial for adequate interpretation and therapy planning. Quantification of radiotracer uptake with SUV_{max} is feasible and showed a significant correlation to CT-based OA grade, in the symptomatic as well as asymptomatic foot. Future follow-up studies will provide further insights into the prognostic and therapeutic value of these findings.

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All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethics committee approval was obtained for the study (Ethikkommission Nordwest und Zentralschweiz EKNZ Nr: 2021-02424). Informed consent was waived by the ethics committee due to the retrospective design.

The datasets can be made available from the corresponding author on reasonable request.

Conflicts of interest

There are no conflicts of interest.

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