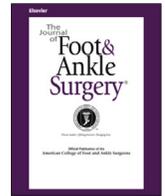




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## A Preliminary Study of Ankle Single Photon Emission Computed Tomography/Computed Tomography in Patients With Bony Impingement Syndrome: Association With the Visual Analogue Scale Pain Score

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## ABSTRACT

Both osteoarthritis and impingement syndrome are the disorders commonly observed in sports medicine. However, failure in pain alleviation by surgical intervention introduces challenges in the diagnosis and decision-making for orthopedists. Hybrid single photon emission computed tomography/computed tomography (SPECT/CT) provides both functional and structural information of ankle pathology. The purpose of this retrospective study was to evaluate whether bone tracer uptake by ankle SPECT/CT is related to the lesion type and visual analog scale (VAS) pain score for patients with osteoarthritis and bony impingement. Fifty individuals with chronic ankle pain who underwent pretreatment ankle SPECT/CT were included in the current study. The median follow-up period was 2.5 (range 1.8 to 3.2) years. The lesion types were categorized by the positions of anatomical changes and bone tracer uptake. The VAS pain score was recorded 2 weeks before and 1.5 year after surgical intervention. Twenty-nine (58%) of 50 patients had osseous impingement. Among them, 16 (55.2%), 4 (13.8%), and 9 (31%) patients had anterior, posterior, and both types of ankle impingement, respectively. The uptake grade of bone tracer was significantly related to the lesion type of ankle impingement ( $p < .001$ ). The VAS pain score was significantly correlated with bone tracer uptake before treatment ( $p < .001$ ). Bone tracer uptake was related to the lesion type of impingement detected by SPECT/CT and was confirmed by surgical findings. The VAS pain score was significantly correlated with the bone tracer uptake. Preoperative ankle SPECT/CT may be helpful to clinically correlate the VAS pain score in the pre- and postsurgical periods for patients with osteoarthritis and bony impingement syndrome.

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Osteoarthritis (OA) and impingement syndrome are commonly observed in sports medicine, are characterized by chronic ankle pain and limited dorsiflexion, and usually occur among football players and ballet dancers (1–4). Abnormal repetitive micromotion, malunion of fracture, synovitis after injuries, formation of scarring tissues, and other osseous and soft-tissue lesions are the reported etiologies of ankle

impingement syndrome and OA (5). Without the correct diagnosis and appropriate treatment, the symptoms and signs of these patients may eventually cause deformity (6). The diagnosis of OA with or without bony impingement syndrome is generally based on clinical symptoms, physical examination, and surgical findings of arthroscopy or open debridement (7). Treatment options include conservative therapy such as rest, physical therapy, and surgeries. Surgeries are recommended for those who fail to obtain effective pain relief after receiving conservative treatment (4,8,9).

Radiographs and magnetic resonance imaging (MRI) have been reported to be useful in providing additional anatomical information for potential lesions (2,3,10). In addition, bone scintigraphy is sensitive in the diagnosis of sports injuries, considering that the volume of regional blood flow and osteoblast activity can directly influence bone tracer uptake (BTU) (11). However, compared with the high space

X.Y.Z. and Z.K.S. contributed equally to this work.

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resolution and significant contrast in the signal intensity of MRI, the lack of high image resolution has limited the diagnostic accuracy of bone scans for ankle impingement syndromes in the past decades (7). Thus, both nuclear medicine physicians and orthopedists may have insufficient recognition of the diagnostic performance of bone scintigraphy in impingement syndromes (7).

Bone single photon emission computed tomography/computed tomography (SPECT/CT) is reported to be a promising imaging technique for the evaluation of knee OA (12). However, only two relevant reports have been published concerning the potential role of bone SPECT/CT in osseous and soft tissue impingement syndrome of the foot and ankle (13,14). The first report concerned a clinical study comprising 43 patients diagnosed with ankle impingement syndrome or soft tissue pathology, and bone SPECT/CT was proven to be useful in localizing and characterizing ankle impingement in patients with foot and ankle pain (13). The other was a case report concerning the complementary role of ankle SPECT/CT in localizing the uptake to the posterior subtalar joint and around the os trigonum, indicating the diagnosis of os trigonum syndrome (14). To the best of our knowledge, the relationship between ankle SPECT/CT and the visual analog scale (VAS) pain score in patients with bony impingement syndrome of the foot and ankle has not yet been reported.

We were interested in knowing whether BTU by ankle SPECT/CT was associated with the pre- and post-treatment VAS pain score or whether it was correlated with different impingement sites in patients with osseous impingement syndrome. Therefore, we wanted to further evaluate the potential role of ankle SPECT/CT in evaluating patients with bony impingement syndrome. We hypothesized that the BTU type and the lesion type on hybrid SPECT/CT were correlated with the pre- and postoperative VAS pain scores. The purpose of this study was to evaluate the relationship between: (1) different BTU types on ankle SPECT/CT and the clinical VAS pain score before and after surgical intervention; (2) different lesion types of bony impingement syndrome and the VAS pain score; and (3) different patient groups (with or without osseous impingement) and the VAS pain score.

## Patients and Methods

In total, 76 patients with chronic ankle pain visited our department from November 2015 to June 2018. Informed consent was obtained from all individual participants involved in the study. All procedures involving human participants performed in this study 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. Among the 76 participants, 26 individuals were excluded for several different reasons such as the following: (1) Eleven patients were examined by other imaging modalities rather than ankle SPECT/CT (3 participants underwent <sup>18</sup>F-fluorodeoxyglucose positron emission tomography/computed tomography, whereas 8 individuals received technetium-99m methylene diphosphonate [<sup>99m</sup>Tc-MDP] whole-body scan). (2) Fifteen individuals had a final diagnosis other than arthritis with or without impingement syndrome, for example, infection, bone fracture, and previous surgeries. Finally, 50 patients were included in the study. The inclusion criteria for this retrospective study were as follows: (1) The patients complained of clinical symptoms such as chronic ankle pain and limited foot and ankle movements. (2) The patients underwent preoperative ankle SPECT/CT and arthroscopy or open debridement surgeries at our institution. (3) Preoperative and postoperative clinical history, physical examination, and the VAS pain scores were recorded in the present study. (4) There was a confirmed diagnosis of arthritis and osseous impingement.

### Evaluation of the VAS Pain Score and Clinical Follow-Up

To evaluate the improvement in the painful symptoms before and after arthroscopy or open debridement among participants diagnosed with arthritis with or without impingement syndrome, the VAS pain score of each patient was recorded independently pre- and post-treatment. Meanwhile, the clinical history results of the physical examination and surgical records were also recorded for each patient (Z.M.S and Z.L.Q). All patients were followed up using the VAS pain score and a self-developed item for demographic data. The median follow-up period was 2.5 (range 1.8 to 3.2) years. Pain was rated using the VAS pain score, ranging from 0 (no pain) to 10 (maximum pain) and was classified into four groups: 0 (no pain), 1 to 3 (mild pain), 4 to 6 (moderate pain), and 7 to 10 (severe pain).

### Data Acquisition and Image Reconstruction

Bone SPECT was acquired 3 to 3.5 hours after the intravenous administration of the radiotracer <sup>99m</sup>Tc-MDP (7.4 MBq/kg). All hybrid SPECT/CT examinations were obtained using a GE Discovery NM/CT 670 (GE Healthcare; GE Medical Systems, Tirat HaCarmel, Israel) scanner. The hybrid SPECT/CT images can integrate the functional images of SPECT with precise anatomical detail of multislice high-resolution CT. Imaging data were reconstructed by incorporating 2 powerful software packages: Volumetrix 3D and Volumetrix IR (GE Healthcare, Madison, WI). The participants were in the supine position, with relaxed feet and pointed toes.

### Image Interpretation and Analysis

All primary image files of ankle SPECT/CT were transferred to our local picture archiving and communication system on medical diagnostic display monitors and were reviewed by a board-certified radiologist with 20 years of musculoskeletal experience (Z.K.S) who was blinded to the findings of ankle SPECT/CT images. Ankle SPECT/CT examinations were performed in the axial, sagittal, and coronal planes on the hybrid imaging analysis workstation (Xeleris 3.0; GE Healthcare, WI). Ankle SPECT/CT images were interpreted and classified by the BTU type according to the consensus of three board-certified nuclear medicine physicians (Z.K.S, Z.L.Q, and H.J.S) with more than 2 years of experience in clinical practice who were blinded to the ankle SPECT and hybrid SPECT/CT findings. The lesion types of patients with bony impingement by the ankle were classified according to different types of BTU by <sup>99m</sup>Tc-MDP whole-body scans and ankle SPECT/CT scans, anatomical changes in ankle CT, and hybrid SPECT/CT scans. Abnormal increases in the BTU types compared with the background were considered as a lesion. The locations of each lesion were determined according to the coregistered CT images. The BTU patterns were categorized into 4 types as follows (15): type 1, none; type 2, local uptake in the unilateral ankle; type 3, diffuse uptake in a single ankle; and type 4, multiple uptake lesions in both ankles.

### Statistical Analysis

Semiquantitative grades were analyzed between different groups by using the Mann-Whitney *U* test or Kruskal-Wallis test. *p* < .05 was considered statistically significant. Statistical analysis performed (by H.J.S and C.T.S) was calculated by commercial software packages of SPSS (version 23.0; IBM Software, Chicago, IL).

## Results

The clinical characteristics and final diagnosis of patients selected for the current study are listed in Table 1. A total of 50 patients were

**Table 1**  
Clinical characteristics and final diagnosis of all patients (N = 50 patients)

Variable	No.	%
Age (y)		
≤ 45	12	24
> 45	38	76
Gender		
M	25	50
F	25	50
Clinical diagnosis		
OA without impingement	21	42
OA with impingement syndrome	29	58
Impingement lesion types		
Anterior ankle impingement	16	55.2
Posterior ankle impingement	4	13.8
Anterior and posterior impingement	9	31
Grades of bone tracer uptake		
Grade 1	18	36
Grade 2	23	46
Grade 3	9	18
VAS pain score		
Preoperative VAS		
1 to 3	17	34
4 to 6	23	46
7 to 10	10	20
Postoperative VAS		
1 to 3	39	78
4 to 6	8	16
7 to 10	3	6

Abbreviations: F, female; M, male; No., number; OA, osteoarthritis; VAS, visual analogue scale.

**Table 2**  
Bone tracer uptake type on ankle single photon emission computed tomography/computed tomography (N = 50 patients)

	Uptake Type	P Value
Correlation with final diagnosis		.078
OA without ankle impingement	1.7 ± 0.8	
OA with ankle impingement	1.9 ± 0.7	
Lesion type of ankle impingement		< .001*
Anterior ankle impingement	2.1 ± 0.6	
Posterior ankle impingement	1.3 ± 0.5	
Anterior and posterior	2.0 ± 0.7	
VAS pain scores before treatment		.566
1 to 3	1.3 ± 0.6	
4 to 6	1.9 ± 0.3	
7 to 10	2.7 ± 0.7	

Abbreviations: OA, osteoarthritis; VAS, visual analogue scale.

\*  $p < .05$  was considered statistically significant.

included in the analysis. Among these, 29 (58%) were diagnosed with OA and ankle impingement syndrome, and 21 (42%) had OA or post-traumatic arthritis without ankle impingement syndrome. Among all the included patients, 25 (50%) were female and 25 (50%) were male. The mean age was  $53.98 \pm 13.68$  (range 19 to 80) years. Among the 29 patients with arthritis and impingement syndrome, 16 were diagnosed with anterior ankle impingement syndrome, 4 were confirmed to have posterior ankle impingement syndrome, and 9 were diagnosed with both anterior and posterior ankle impingement syndrome. The BTU type on ankle SPECT/CT is presented in Table 2. The BTU type among those who had arthritis without impingement syndrome was  $1.67 \pm 0.79$  (range 1 to 3). In addition, for 29 patients with ankle impingement syndrome, the BTU type was  $1.93 \pm 0.65$  (range 1 to 3).

For 21 patients who had arthritis without ankle impingement syndrome, the VAS pain score was  $4.4 \pm 2.4$  (range 2 to 9) before surgical intervention and  $3.5 \pm 2.3$  (range 1 to 8) after ankle surgeries by certified specialists. Otherwise, for the 29 patients diagnosed with arthritis and ankle impingement syndrome, the VAS pain score was  $5.2 \pm 2.0$  (range 2 to 9) before surgical intervention and  $1.8 \pm 1.0$  (range 1 to 5) after surgical intervention. The statistical analysis of the correlation with the VAS pain score of patients with OA before surgical intervention is presented in Table 3. Because ankle SPECT/CT was performed before surgical intervention, after surgical intervention, the BTU types were not considered for analysis with the VAS pain score in patients with arthritis (Table 4).

Representative images of patients with different lesion types, as illustrated in Fig. 1, showed that, although axial (Fig. 1A), sagittal (Fig. 1D), and coronal (Fig. 1G) CT highlighted that the bone density of the cortical plate of the left astragalus bone thickened, axial (Fig. 1B), sagittal (Fig. 1E), and coronal (Fig. 1H) fused SPECT/CT

**Table 3**  
Visual analog scale pain score before surgical intervention (N = 50 patients)

	VAS Pain Score	p Value
Correlation with final diagnosis		.566
OA without ankle impingement	4.4 ± 2.4	
OA with ankle impingement	5.2 ± 2.0	
Lesion type of ankle impingement		.301
Anterior ankle impingement	4.8 ± 1.9	
Posterior ankle impingement	4.8 ± 1.3	
Anterior and posterior	6.1 ± 2.3	
Bone tracer uptake grade		< .001*
Grade 1	3.1 ± 1.6	
Grade 2	5.1 ± 1.1	
Grade 3	7.8 ± 1.9	

Abbreviations: OA, osteoarthritis; VAS, visual analog scale.

\*  $p < .05$  was considered statistically significant.

**Table 4**  
Visual analogue scale pain score after surgical intervention\* (N = 50 patients)

	VAS Pain Score	p Value
Correlation with final diagnosis		.135
OA without ankle impingement	3.5 ± 2.3	
OA with ankle impingement	1.8 ± 1.0	
Lesion type of ankle impingement		.821
Anterior ankle impingement	1.6 ± 0.7	
Posterior ankle impingement	1.5 ± 0.6	
Anterior and posterior	2.3 ± 1.4	

Abbreviations: OA, osteoarthritis; VAS, visual analogue scale.

\* The ankle single photon emission computed tomography/computed tomography was taken only before surgical intervention; therefore, the bone tracer uptake grades were not taken into consideration in Table 4.

images demonstrated that the thickened cortical plate coincided with abnormal osteoblast activity at the left tibiotalar joint. Regarding MRI, T2-weighted axial (Fig. 1C), sagittal (Fig. 1F), and coronal (Fig. 1I) images showed increased signal intensity and demonstrated diseased lesions on the left anterior talofibular ligament tear, without obvious surrounding soft tissue swelling. No abnormal signal changes were demonstrated in the talus.

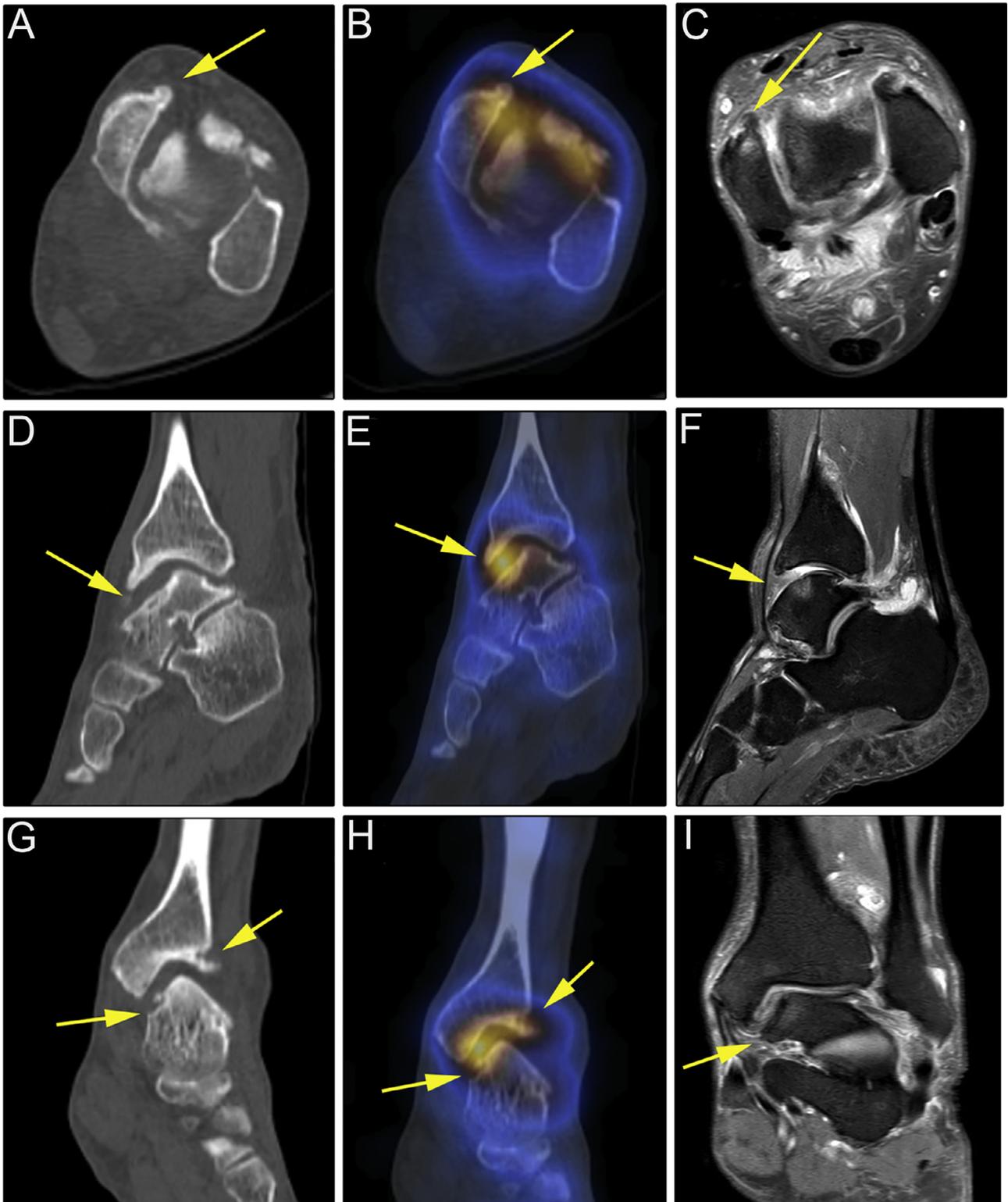
Different types of  $^{99m}\text{Tc}$ -MDP uptake and morphological changes are indicated in Fig. 2. The first patient showed no BTU in the foot and ankle (Fig. 2A). The second patient had congenital ankle deformity, as shown in sagittal, coronal, and axial CT images. Ankle SPECT/CT showed local uptake in the tibiotalar joint (Fig. 2B). The SPECT/CT images explain accurate painful lesions, and the potential cause of pain may be owing to multiple microtrauma events during movement with the deformed foot and ankle. The third patient showed diffuse uptake on ankle SPECT/CT (Fig. 2C), and the fourth patient showed diffuse radiotracer uptake in both ankle joints on ankle SPECT/CT (Fig. 2D).

A 21-year-old male with ankle arthritis and deformity in the left planovalgus complained of chronic ankle pain for many years. Preoperative plain radiographs (Fig. 3A–C), SPECT/CT (Fig. 3D, E), postoperative plain radiographs (Fig. 3F–H) showed the treatment procedure. The preoperative radiographs showed no obvious anatomical alterations; however, conservative therapy could not alleviate the pain symptoms of the patient. Owing to the uncertainty of the diagnosis, ankle SPECT/CT was presented, which showed mild BTU, indicating active arthritis. The patient described relief of ankle pain after the operation.

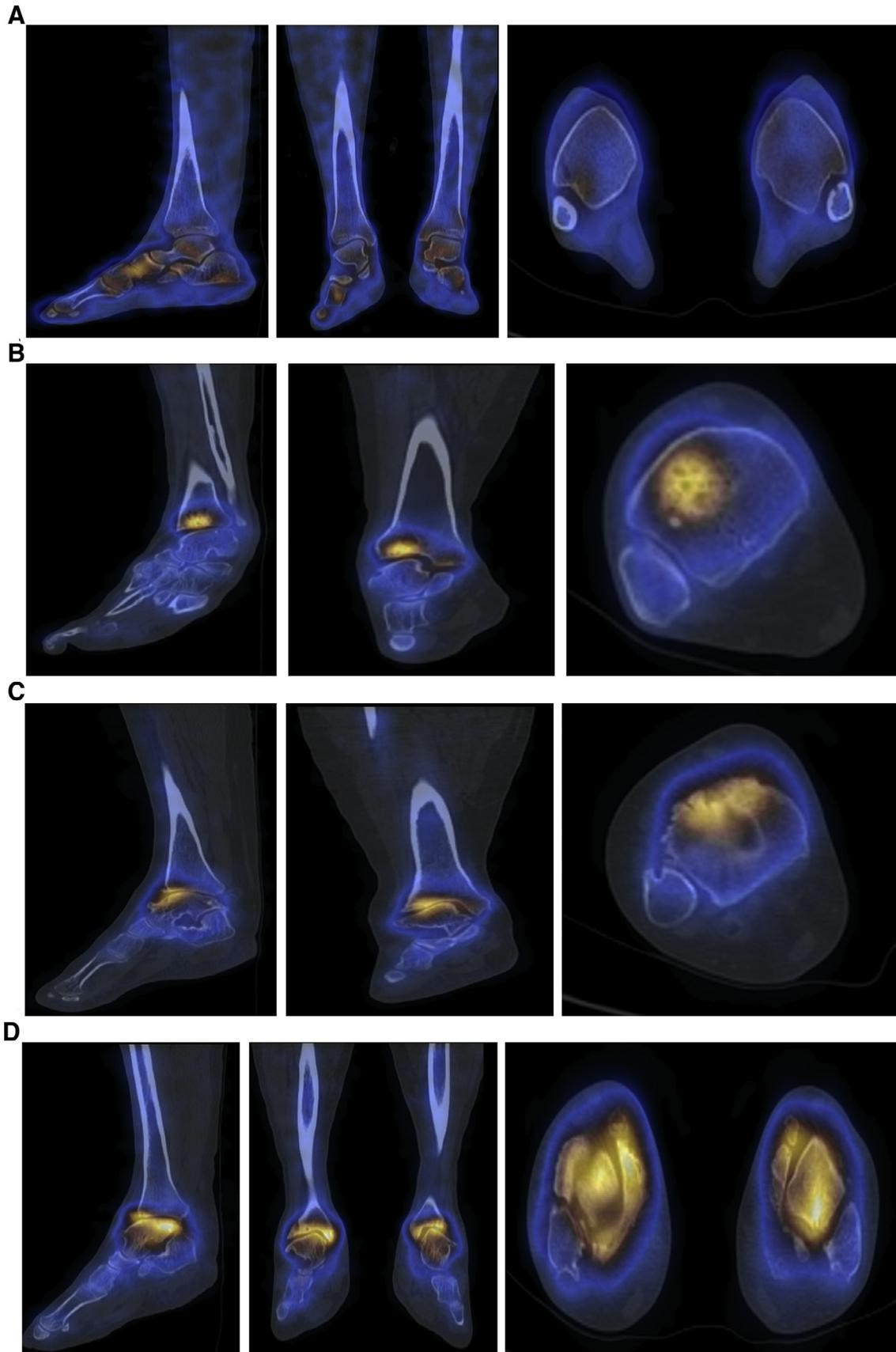
## Discussion

In the present study, we retrospectively evaluated the relationship among the lesion type, BTU grade, and the VAS pain score for patients diagnosed with OA with or without osseous impingement syndrome of the foot and ankle. Because the anatomical features of the foot and ankle are quite complex, the surgical outcomes of various patients who complained of chronic foot and ankle pain are deficient in completely alleviating the degrees of pain in these patients (16,17). Thus multiple imaging modalities are necessary to ensure an accurate diagnosis (9,11,18–20). The combination of anatomical and functional information by ankle SPECT/CT led to higher concordance in both specific and nonspecific imaging observers and made SPECT/CT an excellent tool to evaluate active arthritis and bone repair after trauma (21). Thus  $^{99m}\text{Tc}$ -MDP SPECT/CT may be helpful for those who fail to comply with conservative treatment and require further surgical intervention.

In preoperative patients, ankle SPECT/CT can accurately locate active lesions (11,13,14). As in this study, ankle SPECT identified almost all functional bony impingement lesions for patients with active arthritis with or without ankle impingement syndrome. Hybrid SPECT/CT images with the addition of high-resolution CT can improve the diagnostic performance (13). Moreover, ankle SPECT/CT can provide ideal visualization of bone



**Fig. 1.** Images of representative cases by lesion type. A 52-year-old male had a bone fracture at the left ankle 3 years ago, which laterally developed into traumatic arthritis. Axial (A–C), sagittal (D–F), and coronal (G–I) computed tomography, hybrid single photon emission computed tomography-computed tomography, and T2-weighted magnetic resonance imaging were performed. Axial (A), sagittal (D), and coronal (G) computed tomographic scans demonstrated that the bone density of the cortical plate of the left astragalus bone was thickened, and arrows indicated the location of osteophyte formation. Axial (B), sagittal (E), and coronal (H) technetium-99m methylene diphosphonate single photon emission computed tomography-computed tomographic scans indicated focal osteoblast activity localized at the left tibiotalar joint and arrows indicated osteophyte with abnormal bone metabolism. T2-weighted axial (C), sagittal (F), and coronal (I) magnetic resonance images showed increased signal intensity, demonstrating diseased lesions on the left anterior talofibular ligament tear, without obvious surrounding soft tissue swelling, and arrows indicated the diseased lesions.



**Fig. 2.** Representative images of different bone tracer uptake patterns. Four different patients with bone tracer uptake types (0, none; 1, local uptake with a single lesion; 2, diffuse uptake with a single ankle; and 3, multiple uptake lesions or diffuse uptake with both the left and right ankles) (A–D). The first patient showed no bone tracer uptake in the foot and ankle (A). The second patient had congenital ankle deformity shown in the sagittal, coronal, and axial computed tomographic images, and ankle single photon emission computed tomography-computed tomography showed mild uptake located in the tibiotalar joint (B). The third patient showed moderate uptake on ankle single photon emission computed tomography-computed tomography (C). The fourth patient showed severe radiotracer uptake in both ankle joints on ankle single photon emission computed tomography-computed tomography (D).



**Fig. 3.** Example of ankle single photon emission computed tomography-computed tomography altering the therapeutic decision-making for patients with osteoarthritis with ankle deformity. (A–C) represent preoperative plain radiographs. (D,E) represent single photon emission computed tomography-computed tomography. (F–H) represent postoperative plain radiographs. A 21-year-old male with ankle arthritis and left planovalgus deformity complained of chronic ankle pain for many years. The preoperative radiographs showed no obvious anatomical alterations; however, conservative therapy failed to alleviate the pain symptoms of the patient. Owing to the uncertainty of the diagnosis, ankle single photon emission computed tomography-computed tomography was presented, which showed mild bone tracer uptake, indicating active arthritis. The patient described relief of ankle pain after the operation.

metabolism, and the uptake grade of bone tracer by hybrid SPECT/CT showed high consistency with pathological bone lesions (22).

Previous literature has reported that hybrid SPECT/CT can predict functional and clinical outcomes for those with asymmetric ankle arthritis and identified which patients may have a successful supramalleolar osteotomy (23). Another previous study found that bone SPECT/CT is advantageous in patients with chronic ankle and foot pain in identifying the characterization and localization of impingement syndrome and soft tissue pathology (13). These findings were similar to our results; however, as we know, the relationship between the VAS pain score before and after surgical intervention and lesion type of ankle impingement syndrome was first analyzed in the present study. Considered to be at the end stage of impingement syndrome, OA was studied more methodically by bone SPECT/CT (23–25). However, ankle impingement syndrome may represent an earlier disease status for OA. Thus the early discovery of active lesions for patients with foot and ankle pain by bone SPECT/CT may help those who may need surgical intervention at an earlier time to avoid disability and improve their quality of life after timely aggressive therapy.

Meanwhile, this study had the following limitations. First, the patient sample included in the current study was quite small. Thus statistical analysis in our study may be influenced by selection bias. Second, this study lacked the postoperative data of patients with ankle SPECT/CT, because the surgical trauma can increase BTU and was retrospective in nature. Some of these limitations were inevitable, owing to clinical practice. However, despite our appreciation of the limitations of our investigation, we believe that the results of this study could be useful in the future development of prospective cohort studies and randomized controlled trials that focus on the additional value of ankle SPECT/CT for patients with chronic ankle pain after surgeries.

In conclusion, ankle SPECT/CT confirmed the diagnosis of ankle impingement syndrome for patients with unexplained chronic ankle pain. Preoperative ankle SPECT/CT may be helpful to clinically correlate the VAS pain score in the pre- and postsurgical period for patients with OA and bony impingement syndrome.

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