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SCIENTIFIC ARTICLE

Tarsometatarsal joint communication during fluoroscopy-guided therapeutic joint injections and relationship with patient age and degree of osteoarthritis

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Abstract

Objective Although the tarsometatarsal joints are separated into three distinct synovial compartments, communications between adjacent compartments are often noted during image-guided injections. This study aims to determine whether abnormal inter-compartment tarsometatarsal joint communication is associated with patient age or degree of tarsometatarsal osteoarthritis.

Materials and methods One hundred forty tarsometatarsal injections were retrospectively reviewed by two radiologists. Extent of inter-compartment communication and degree of osteoarthritis were independently scored. Univariate and multivariable analyses were performed to assess whether the presence of and number of abnormal joint communications were related to age and degree of osteoarthritis.

Results Forty out of 140 tarsometatarsal joints showed abnormal communication with a separate synovial compartment, and 3 of the 40 showed abnormal communication with two separate compartments. On univariate analysis, higher grade osteoarthritis ($p < 0.001$) and older age ($p = 0.014$) were associated with an increased likelihood of abnormal inter-compartment tarsometatarsal communication and a greater number of these abnormal communications. On multivariate analysis, the degree of osteoarthritis remained a significant predictor of the presence of ($p < 0.001$) and number of ($p < 0.001$) abnormal communications, while the association of age was not statistically significant. There was significant correlation between age and degree of osteoarthritis ($p < 0.001$).

Conclusion Higher grade osteoarthritis increases the likelihood of abnormal inter-compartment tarsometatarsal joint communication and is associated with a greater number of abnormal communications. Diagnostic injection to localize a symptomatic tarsometatarsal joint may be less reliable in the setting of advanced osteoarthritis.

Keywords Tarsometatarsal joints · Osteoarthritis · Arthrography · Cortisone injection

Introduction

Anatomic studies have noted the tarsometatarsal joints to be separated into three individual synovial compartments that are anatomically distinct from each other [1, 2]. The medial column is made up of the first tarsometatarsal joint, the central column is made up of the second and third tarsometatarsal joints, and the lateral column is made up of the fourth and fifth tarsometatarsal joints (Fig. 1). As part of the midfoot, the tarsometatarsal joints transmit forward propulsion motion from the hindfoot to the forefoot [3]. The alignment of these tarsometatarsal compartments is intimately associated with joint stability, and disruption of the normal intra-articular communication patterns may indicate pathology.

During injection, intra-compartment tarsometatarsal joint communication is expected between joints in the same synovial compartment. That is, the second and third tarsometatarsal joints are expected to communicate with each

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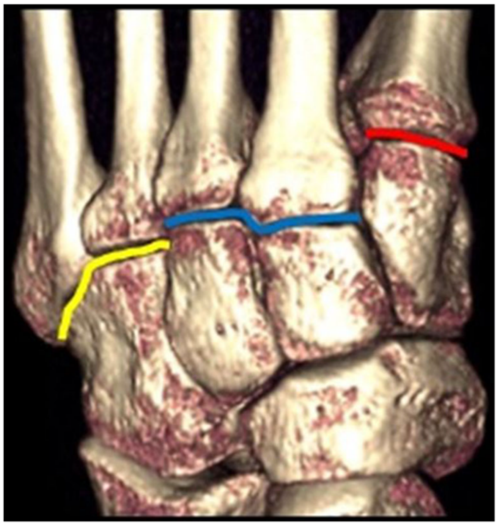

Fig. 1 Three-dimensional volume-rendered computed tomography (CT) image showing the three synovial compartments of the tarsometatarsal joints that historically have been described as separate anatomic compartments: medial (red), central (blue), and lateral (yellow)

other, as are the fourth and fifth tarsometatarsal joints. However, some studies evaluating foot arthrograms have shown that abnormal communications can occur between adjacent compartments [4, 5], and in our own institution, we have noted these abnormal communications on fluoroscopy-guided or ultrasound-guided tarsometatarsal joint cortisone injections. The reasons for these abnormal inter-compartment communications are unclear, but the fact that they exist is of clinical importance. For example, monitoring clinical response after anesthetic and cortisone injection into a particular joint can help determine whether that joint is the source of the patient's symptoms [6, 7]; however, flow of the injectate into other joints would decrease the diagnostic usefulness of the injection. Second, the presence of abnormal joint communication may result in easier spread of pathologic processes of the joint, such as septic arthritis.

To our knowledge, no study has attempted to determine potential causative factors for abnormal inter-compartment tarsometatarsal joint communication. The purpose of this study was to assess whether abnormal communication among the three tarsometatarsal compartments as documented on fluoroscopy-guided contrast injection is associated with certain patient factors. Specifically, we sought to determine whether patient age or degree of tarsometatarsal joint osteoarthritis on radiographs increases the likelihood of abnormal communication.

Materials and methods

Study approval was obtained from our hospital's Institutional Review Board before the initiation of the study. Although the vast majority of therapeutic intra-articular injections in the foot are now performed under ultrasound guidance at our institution [8], many were still performed under fluoroscopy guidance until recently. When done under fluoroscopy guidance, a small volume of iodinated contrast (iohexol 300 mgI/ml) was first injected into the joint of interest to confirm intra-articular needle positioning before injection of cortisone. For the current study, all patients who had undergone fluoroscopy-guided tarsometatarsal joint cortisone injections at our institution between January of 2002 and April of 2013 were identified via the hospital's picture-archiving communication system (PACS) and those with images demonstrating intra-articular contrast were included in the study. Those with a time interval between radiographs and fluoroscopy of longer than 12 months were excluded. In addition, those with prior surgery of the foot were excluded.

Two board-certified musculoskeletal radiologists with 6 (YE) and 2 (OKN) years of experience independently assessed the fluoroscopic images from each midfoot injection and documented which joint(s), if any, the injected contrast opacified in addition to the injected joint, blinded to the patient's age and degree of osteoarthritis visible on conventional radiographs. On conventional radiographs, the same radiologists also separately graded the overall degree of osteoarthritis of the tarsometatarsal joints of each foot from 0 (normal) to 3 (severe) based on a combination of joint space narrowing, marginal osteophytes, and subchondral sclerosis, looking at the most severely affected tarsometatarsal joint for each foot, regardless of which joint was injected (Table 1). Most radiographs consisted of three views (anteroposterior, oblique, and lateral), with the minority consisting of two views (anteroposterior and lateral) as dictated by the ordering physician. Any discrepancies between the two readers in the extent of contrast spread or degree of osteoarthritis were resolved by consensus.

As per prior literature [1, 2], communications between the second and third tarsometatarsal joints or between the fourth and fifth tarsometatarsal joints (Fig. 2) were considered normal intra-compartment communications, while those between the first and second or between the third and fourth were considered abnormal inter-compartment communications.

Table 1 Grading of tarsometatarsal joint osteoarthritis (based on the most affected of the tarsometatarsal joints)

0 (Normal)	No joint space narrowing, osteophytes, or subchondral sclerosis
1 (Mild)	Mild joint space narrowing, and/or small osteophytes, and/or mild subchondral sclerosis
2 (Moderate)	Focal bone-on-bone apposition, and/or prominent osteophytes, and/or marked subchondral sclerosis
3 (Severe)	Diffuse bone-on-bone apposition

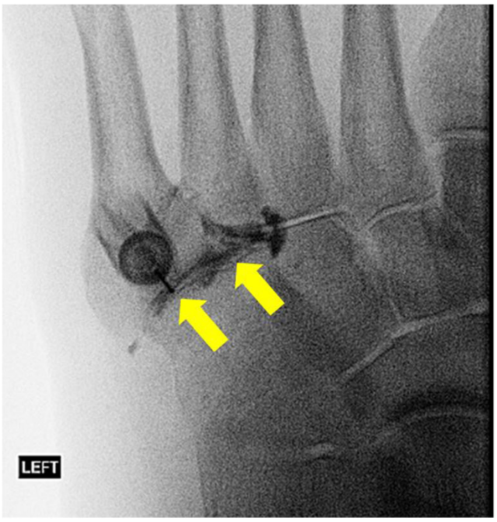

Fig. 2 A 52-year-old female with radiographically normal tarsometatarsal joints. Contrast injection of the fifth tarsometatarsal joint shows expected opacification of the lateral (4th and 5th tarsometatarsal, yellow arrows) compartment without communication with the central or medial compartments

Inter-rater reliability between the two readers in scoring the degree of osteoarthritis was assessed by calculating a weighted kappa statistic and 95% confidence interval. Concordance between the two readers in the interpretation of the fluoroscopic images was also measured. Univariate associations between the presence of abnormal joint communication and the degree of osteoarthritis, patient gender, or foot laterality (left versus right) were assessed with chi-squared and Fisher's exact tests. Relationships with the number of abnormal communications were also assessed with chi-squared and Fisher's exact tests. The relationship between the presence of abnormal joint communication and patient age was assessed with an independent samples t-test, while the relationship between the number of abnormal communications and age was assessed with a single-factor ANOVA. Multivariable binary logistic regression was used to assess whether the presence of abnormal joint communications was associated with both age and degree of osteoarthritis when considered together, while a generalized estimating equation (GEE) was used to evaluate whether the number of abnormal communications was associated with these variables when considered together. The relationship between age and degree of osteoarthritis was assessed using Spearman's correlation. Statistical analyses were performed using SAS v. 9.3 (Cary, NC, USA), with a level of significance of $\alpha < 0.05$.

Results

A total of 140 tarsometatarsal joint injections performed on 113 feet in 105 patients fulfilled the study inclusion criteria (Table 2). In the majority of the cohort (except 11 feet in 10 patients), the radiographs had been obtained before the fluoroscopy-guided injections. Eight patients had bilateral feet injected, and in 26 feet, more than one tarsometatarsal joint was injected. The second tarsometatarsal joint was the most common joint to be injected with 64 injections, followed by the first (38 injections) and third (26 injections) tarsometatarsal joints. Forty out of 140 showed abnormal communication of the injected tarsometatarsal joint with at least one other tarsometatarsal joint in a different

Table 2 Demographic data of the injections

Patient number	105 (82 females/23 males)	
Mean age (range) (years)	65 (17–86)	
Number of feet (right, left)	113 (53, 60)	
Mean number of days between radiographs and fluoroscopy (range)	48.5 (0–338)	
Number of tarsometatarsal joints injected	140	
Injected tarsometatarsal joint:		**Abnormal communication**
1st	38	4 (10.5%)
2nd	64	19 (29.7.%)
3rd	26	14 (53.8%)
4th	8	3 (37.5%)
5th		0 (0%)
Injected compartment:		
Medial (1st tarsometatarsal joint)	38	4 (3 with central compartment, 1 with both central and lateral compartments)
Central (2nd and 3rd tarsometatarsal joints)	90	33 (29 with lateral compartment only, 2 with medial compartment only, and 2 with both medial and lateral compartments)
Lateral (4th and 5th tarsometatarsal joints)	12	3 (all with central compartment only)

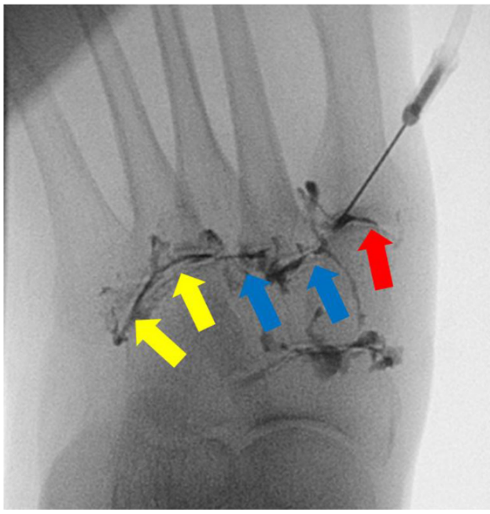

Fig. 3 A 75-year-old female with moderate tarsometatarsal joint osteoarthritis on radiographs. Contrast injection of the first tarsometatarsal joint demonstrates expected opacification of the medial compartment (red arrow) but also abnormal communication with the central (2nd and 3rd tarsometatarsal, blue arrows) and lateral (4th and 5th tarsometatarsal, yellow arrows) compartments. Communication with the medial intercuneiform and naviculocuneiform joints is also noted

compartment. Three of the 40 showed abnormal communication with two different compartments. Injection into the medial compartment communicated with the central compartment in 7.9% of cases and with both the central and lateral compartments (Fig. 3) in 2.6% of cases. Injection into the central compartment communicated with the lateral compartment (Fig. 4) in 32.2% of cases and with the medial compartment (Fig. 5) and both the medial and lateral compartments in

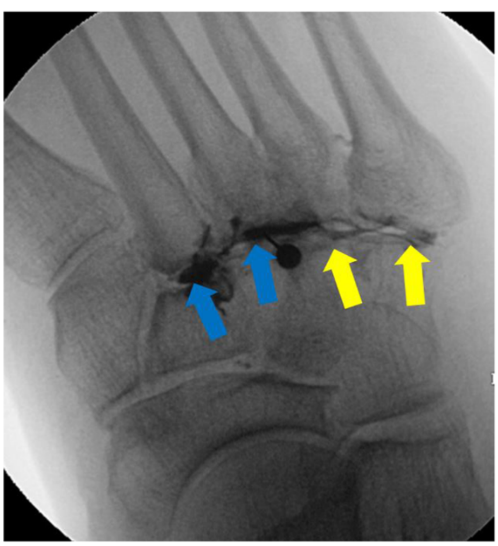

Fig. 4 A 71-year-old female with severe tarsometatarsal joint osteoarthritis on radiographs. Contrast injection of the third tarsometatarsal joint shows expected opacification of the central (2nd and 3rd tarsometatarsal, blue arrows) compartment and abnormal communication with the lateral (4th and 5th tarsometatarsal, yellow arrows) compartment but not the medial compartment

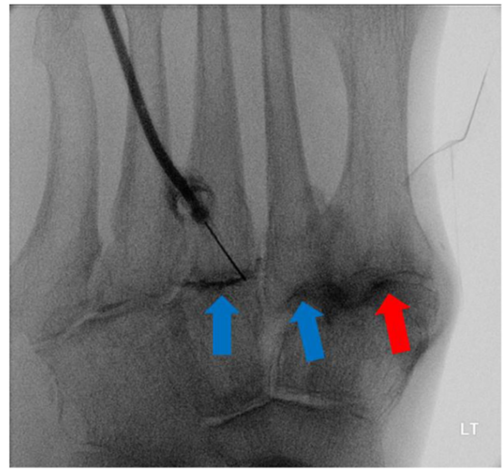

Fig. 5 A 73-year-old female with severe tarsometatarsal joint osteoarthritis on radiographs. Contrast injection of the third tarsometatarsal joint shows expected opacification of the central (2nd and 3rd tarsometatarsal, blue arrows) compartment and abnormal communication with the medial (1st tarsometatarsal, red arrow) compartment but not the lateral compartment

2.2% of cases each. Injection into the lateral compartment communicated with the central compartment in 25% of cases but none with the medial compartment. The degree of osteoarthritis scoring performed by the two readers demonstrated excellent reliability with a weighted kappa coefficient of 0.97. There was 90.3% concordance between the two readers for assessing the fluoroscopic contrast injections.

In univariate analysis, both the degree of osteoarthritis ($p < 0.001$) and age ($p = 0.014$) were associated with the presence of abnormal joint communication (Table 3), with higher grade osteoarthritis and older age increasing the likelihood of a tarsometatarsal joint having abnormal communication with a tarsometatarsal joint of a different compartment. Higher grade osteoarthritis ($p < 0.001$) and older age ($p = 0.039$) were also associated with a greater number of abnormal communications.

In multivariable analyses, the degree of osteoarthritis ($p < 0.001$) but not age ($p = 0.380$) was associated with abnormal joint communication; feet with an osteoarthritis score of 3 were 26 times more likely to have abnormal joint communication compared to feet with an osteoarthritis score of 0 (Table 4). The degree of osteoarthritis ($p < 0.001$) but not age ($p = 0.347$) was also associated with the number of compartments with which a joint abnormally communicated, with higher degrees of osteoarthritis having more abnormal communications. There was a positive correlation between age and degree of osteoarthritis based on Spearman's correlation ($r_s = 0.35$, $p < 0.001$).

Although not specifically studied, contrast injected into the tarsometatarsal joints was also noted to communicate with other joints in many feet, including the medial and lateral intercuneiform joints, cuboid-lateral cuneiform joint, naviculocuneiform joint, talonavicular joint, and

Table 3 Assessment of univariate association between various factors and presence or absence of abnormal inter-compartment joint communication and number of abnormal inter-compartment joint communications. *$p < 0.05$

	Abnormal Communications			Number of abnormal communications			
	No	Yes	*p*-value	0	1	2	*p*-value
Patient gender [n (%)]			0.474				0.428
Female	77 (77.0)	33 (82.5)		77 (77.0)	31 (83.8)	2 (66.7)	
Male	23 (23.0)	7 (17.5)		23 (23.0)	6 (16.2)	1 (33.3)	
Foot [n (%)]			0.363				0.582
Left	49 (49.0)	23 (57.5)		49 (49.0)	21 (56.8)	2 (66.7)	
Right	51 (51.0)	17 (42.5)		51 (51.0)	16 (43.2)	1 (33.3)	
Degree of osteoarthritis [n (%)]			< 0.001*				< 0.001*
0	25 (25.0)	1 (2.5)		25 (25.0)	1 (2.7)	0	
1	35 (35.0)	8 (20.0)		35 (35.0)	8 (21.6)	0	
2	23 (23.0)	8 (20.0)		23 (23.0)	7 (18.9)	1 (33.3)	
3	17 (17.0)	23 (57.5)		17 (17.0)	21 (56.8)	2 (66.7)	
Age (mean ± standard deviation)	64 ± 14	71 ± 12	0.014*	64 ± 14	70 ± 12	76 ± 1	0.039*

calcaneocuboid joint. In a few patients, contrast injected into the first tarsometatarsal joint was noted to spread into the tendon sheath of the tibialis anterior tendon.

Discussion

Even though previous reports have described compartmentalization of the tarsometatarsal joints into anatomically separate medial, central, and lateral columns [1–3], the current study shows that injected contrast may not conform to these compartments during fluoroscopy-guided injection. In addition, our study suggests that the more severe the degree of tarsometatarsal osteoarthritis is, the higher the likelihood of abnormal inter-compartment tarsometatarsal joint communication and number of inter-compartment joint communications. Age is associated with the degree of osteoarthritis but was itself not a predictor of abnormal inter-compartment communication on multivariable analysis.

Others have also noted spread of contrast beyond the injected joint in the foot and ankle. Khosla et al. noted extension of injected contrast from the second tarsometatarsal joint to the third through fifth tarsometatarsal joints in 3 of 14 cadaveric feet [4]. Carmont et al. reviewed the incidence of various joint communications in 389 arthrograms of the foot and ankle, which showed that unexpected communication between two joints can occur in up to 42.3% of cases depending on which joint is injected [5]. Lucus et al. encountered five cases of abnormal communication between two joints, including the tarsometatarsal joints, among 47 patients with

Table 4 Results from multivariable analyses to assess whether age and degree of osteoarthritis are independently associated with the presence of abnormal inter-compartment communication and the number of abnormal communications. *$p < 0.05$

	Presence of abnormal communication	
Variable	Odds ratio (95% confidence interval)	*p*-value
Age (+10 years)	1.2 (0.8–1.7)	0.380
Degree of osteoarthritis		<0.001*
1 vs 0	4.8 (0.5–42.2)	0.493
2 vs 0	6.8 (0.7–62.0)	0.327
3 vs 0	26.3 (3.1–226.8)	0.016*
	Number of abnormal communications	
Variable	Parameter estimate (95% confidence interval)	*p*-value
Age (+10 years)	0.0 (0.0–0.1)	0.347
Degree of osteoarthritis		< 0.001*
1 vs 0	0.1 (−0.2–0.4)	0.329
2 vs 0	0.2 (−0.1–0.5)	0.121
3 vs 0	0.5 (0.2–0.9)	< 0.001*

fluoroscopy-guided foot injections [9]. These reports are in keeping with the findings in the current study. However, to the best of our knowledge, no study has specifically evaluated for an association with patient age or the degree of tarsometatarsal osteoarthritis.

It is known that increased severity of osteoarthritis results in changes in the bony architecture of the joint, including the formation of marginal osteophytes and subchondral cysts. It is also known that synovitis occurs in osteoarthritic joints, although the degree of synovial expansion is less than that of rheumatoid arthritis [10], and many believe that subchondral cysts are due to intrusion of synovial fluid into the bone secondary to elevated intra-articular pressure [11, 12]. It is conceivable that these structural changes in osteoarthritis play a part in abnormal joint communication. Alteration to the architecture of the bony margins as well as the synovial lining of the joints due to chronic inflammation may result in abnormal communication between joints that were once separate. In fact, we did note communication of the tarsometatarsal joints with several other joints in the midfoot, including the intercuneiform and naviculocuneiform joints, although we did not specifically study their incidence or any association with the degree of osteoarthritis and age.

The findings of the current study have clinical implications. In our practice, we are often asked to inject anesthetic with or without cortisone into specific joints under imaging guidance to identify the source of the patient's pain. The concept of this technique is that symptom relief from the anesthetic immediately after the injection is a sign that the injected joint is the source of the patient's symptoms, while persistence of symptoms after the injection is a sign that the injected joint is not the symptom generator. Pain relief after injection has been shown to be a good predictor of success after surgical arthrodesis of the joint [6, 7]. However, the results of the current study show that a positive response after a particular tarsometatarsal joint is injected may not be a reliable sign that the injected joint is the cause of symptoms, especially in feet with severe osteoarthritis, as the injectate can unexpectedly spread to other joints. In addition, the presence of extra communications among various joints in the midfoot may facilitate the spread of pathologic processes of the joints, such as septic arthritis.

The results of the current study also underscore the value of performing a test injection during therapeutic cortisone injections into the joints of the midfoot under imaging guidance, be it under fluoroscopy or ultrasound. One can avoid having to subject the patient to multiple needle punctures if the injectate from the first puncture is noted to spread to the other tarsometatarsal joints. Although the degree of spread of injectate may be more easily demonstrated on fluoroscopy rather than ultrasound, we are not suggesting that intra-articular injections of the foot should be performed using fluoroscopy rather than ultrasound. On the contrary, we strongly advocate the use of ultrasound guidance because of the ease of needle placement, less patient discomfort, the ability to identify concomitant soft tissue abnormalities such as tenosynovitis or soft tissue ganglia, and lack of ionizing radiation. The degree of spread of the injectate is also appreciable on ultrasound if the radiologist monitors the adjacent joints during test injection.

Our study has several limitations. The retrospective nature of the study prevented us from controlling certain factors. Specifically, because the contrast injections were performed for the sole purpose of confirming intra-articular needle placement before administration of cortisone, the volume of contrast and the amount of pressure applied during the manual injection varied from injection to injection. It is conceivable that insufficient volume of contrast could have resulted in under-reporting of contrast spread into adjacent joints; however, excess volume of contrast would likely have resulted in extra-articular contrast extravasation rather than false-positive spread into adjacent joints. In addition, only limited fluoroscopic images were taken during contrast injection, compromising the ability to confidently assess all of the tarsometatarsal joints in some cases. However, the high inter-reader concordance for the evaluation of the fluoroscopy images confirms that the readers' interpretations were reproducible. Lastly, even though an effort was made to score the extent of contrast spread on fluoroscopy independent of the degree of osteoarthritis, complete blinding may not have been possible as the fluoroscopic images were not digital subtraction images. Most of the images acquired during contrast injection were fluoroscopy images, and thus the degree of anatomic detail obtained from them were much less than from conventional radiographs.

In conclusion, our study indicates that there is variability in how the tarsometatarsal joints communicate with each other based on spread of contrast under fluoroscopy, and more severe osteoarthritis is associated with both the presence of abnormal inter-compartment tarsometatarsal communications and increased number of abnormal communications. Clinicians should be aware that diagnostic injection of anesthetic and/or cortisone into a particular tarsometatarsal joint to assess whether it is the symptomatic joint may be less reliable in the setting of advanced osteoarthritis.

Compliance with ethical standards

Ethical approval 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.

Conflict of interest All authors state that they have no conflict of interest.

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