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REVIEW ARTICLE

Pearls and pitfalls of fluoroscopic-guided foot and ankle injections: what the radiologist needs to know

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Abstract

Objective This article provides a comprehensive, joint-by-joint review of fluoroscopic-guided foot and ankle injections and emphasizes pre-procedural planning, relevant anatomy, appropriate technique, troubleshooting the difficult procedure, and the importance of communicating unexpected findings with the referring clinician. The interrogation of pain generators including variant ossicles, fractures, and post-surgical/traumatic findings is also described.

Conclusions Even the most challenging foot and ankle injections may be successfully completed with a solid anatomical understanding and thoughtful approach.

Keywords Ankle · Ankle joint · Foot · Injections · Pain

Introduction

Foot and ankle pain is an increasingly common affliction, occurring in up to 63% of adult patients [1]. This number is expected to increase as the "baby boomer" generation ages. Not surprisingly, there have been a concomitant increase in the number and types of surgical procedures aimed at correcting foot and ankle pathology [1–7]. Given the small joint size and complex foot and ankle anatomy, injections and interventions can be difficult to master. Fluoroscopy has long been used to guide both therapeutic and diagnostic injections with a great deal of efficacy and accuracy [8, 9]. While there is increasing utilization of ultrasound in guiding foot and ankle injections, fluoroscopy remains the most commonly used modality for confirming skin entry site, appropriate needle positioning, and confirmation of intra-articular injection [2]. Given the increasing numbers of foot and ankle fluoroscopically guided procedures and subsequent surgical interventions, it is prudent for radiologists to understand the pertinent anatomy and achieve baseline comfort in safely and expediently injecting these myriad articulations. This article reviews normal and variant anatomy of foot and ankle joints, common joint-specific fluoroscopic approaches, pearls for troubleshooting the difficult injection, including symptomatic ossicles and post-surgical/post-traumatic changes, as well as the radiologist's role as a pain interrogator.

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Indications

Fluoroscopically guided foot and ankle injections are performed for therapeutic and/or diagnostic indications. Therapeutic injections are most commonly performed with a corticosteroid and anesthetic. These injections may stave off or provide a lengthy bridge to more definitive, but invasive surgical procedures [10–13]. Therapeutic injections may also be the only option for patients who are poor operative candidates. Diagnostic injections are critical for identifying painful articulations and may guide surgery, as a positive response to a diagnostic injection may correlate with post-operative outcomes [11, 13]. Diagnostic injections are not limited to joints and may be used to interrogate additional pain generators about the foot and ankle including variant ossicles, post-traumatic and post-surgical changes [14–18].

General foot and ankle injection technique

The key to a technically successful fluoroscopically guided foot and ankle injection is thoughtful planning, which begins with a pre-procedural review of the indication and available pre-procedural imaging. We prefer to have comparison radiographs prior to injection. Prior imaging is invaluable for planning needle trajectory, particularly in cases of severe osteoarthrosis where an intra-articular window may only measure several millimeters. We do not routinely require pre-injection cross sectional imaging, but CT or MRI provide a more detailed roadmap to intra-articular access and should be reviewed if available.

After review of the salient imaging, great care must be taken to appropriately position the patient. Either the patient or fluoroscopy C-arm should be adjusted to optimize joint visualization prior to starting the procedure. Good patient positioning, the key to a successful intervention, should take into consideration both the safest and most efficient route as well as patient comfort. In our experience, appropriate patient positioning can make difficult injections fairly routine, while hasty patient positioning may cause even the most straightforward injection to become unnecessarily laborious (Fig. 1). The objective is to make subtle adjustments with the fluoroscopy C-arm so that the joint space is "opened up" or profiled "en face" as much as possible, resulting in increased lucency. It is important to remember that these articulations are very small and adjustments are often made on the measure of millimeters.

For fluoroscopy, a radio-dense object is used to mark the appropriate skin entry site. After marking the skin, standard sterile technique is employed with anesthesia provided via local injection of 1% Lidocaine buffered with sodium bicarbonate through a 1.5 in., 25-gauge needle. Ethyl chloride spray may be used instead of or in addition to lidocaine to provide local anesthesia. Frequently, the same needle and puncture site can be used for both local anesthesia and the actual injection.

Our preferred fluoroscopic approach is the "bull's-eye technique" in which needle trajectory is aligned as closely as possible with the fluoroscopic beam so that the needle appears as a small dot [2, 19]. When it comes to subtle adjustments, it is often easier to adjust the C-arm than reposition the patient. The fluoroscopic beam should be centered over the skin entry location to minimize parallax. We often target the edge of an articulation, particularly in severe arthritis, as there is usually a joint recess that may be more easily accessed. For ball-and-socket joints, such as the talonavicular or metatarsophalangeal articulations, we prefer to target the curved surfaces. The needle is advanced into the joint under intermittent fluoroscopic imaging. As compared to larger joints, it is important to have a heightened tactile sense of the needle traversing different tissue planes before entering the joint. With ideal positioning, the needle may enter the joint without much resistance and frequently without a bony "backstop" as is often present in larger joints. Given the small size of even non-arthritic foot and ankle joints, if resistance is initially encountered despite appropriate appearing needle position, the operator may need to gently "walk" the needle along the superficial osseous surface anticipating a slight "give" when the needle slips into the joint. Once the needle is intra-articular, the location is confirmed with anesthetic (we prefer 0.2% ropivacaine), followed by a small volume of iodinated contrast [20, 21]. Radiolucent local anesthetic is preferred for the initial test injection. If iodinated contrast is used, then an extra-articular needle tip position may result in contrast pooling and obscuration of the joint space, making subsequent adjustments difficult.

The capacity of the smallest foot articulations is only 1.0 to 1.5 ml (i.e., metatarsophalangeal joints) and sometimes less in the severely arthritic joint [22, 23]. The small size of these articulations requires injection of the smallest possible volume, sometimes less than 1.0 ml. The operator must have a heightened tactile sense of free flow of anesthetic away from the needle tip. Intra-articular access should be confirmed with a single spot fluoroscopic image to minimize radiation dose. Real-time fluoroscopy is typically not necessary to detect unexpected findings since the volume of injected anesthetic and steroid will "push" the iodinated contrast away from the needle tip dispersing the iodinated contrast throughout the articulation to opacify joint recesses [24]. Careful attention must be paid to the distribution of iodinated contrast to recognize unexpected findings such as extracapsular extension of contrast, which may indicate capsular injury or variant degenerative/post-traumatic joint communications (i.e., communication of the second/third tarsometatarsal joints with the fourth/fifth tarsometatarsal joints), which may have implications for surgical arthrodesis planning. If unexpected findings are present at intermittent fluoroscopy, a full exposure may be considered for documentation as warranted [25]. In the setting of contrast allergy, a small amount of air or Gadavist may be used as a contrast agent (Fig. 2) [26]. Intra-articular purchase is often tenuous for these superficial joints and great care must be exercised when exchanging syringes so as not to dislodge the needle from the joint. We have found that using a shorter a needle, less than 1.5 in., and thin tubing (holds 0.4 ml) helps maintain intra-articular position. Additionally, mixing the corticosteroid and anesthetic in the same syringe reduces the amount of needle handling during the instillation of medications. After tactile and visual confirmation of intra-articular

Fig. 1 Preferred patient positioning for fluoroscopic-guided foot and ankle injections. For patients with difficulty holding positions, medical tape may be used for additional support. **a**, **b** AP approach for talonavicular, naviculocuneiform, metatarsophalangeal, and interphalangeal joint injections: patient supine, knee bent, with foot to be injected flat on table. Towels may be propped under knee for support as necessary. **c**, **d** Lateral approach for tibiotalar joint injection with mobile C-arm: patient supine, posterior aspect of heel of foot to be injected flat against the table, toes pointed cranially with foot in mild plantar flexion. **e**, **f** Lateral approach for posterior subtalar, calcaneocuboid, and fourth and fifth tarsometatarsal joint injections: patient positioned lateral decubitus with foot to be injected internally rotated and supported by towels. Towels may be removed to facilitate a straight lateral approach

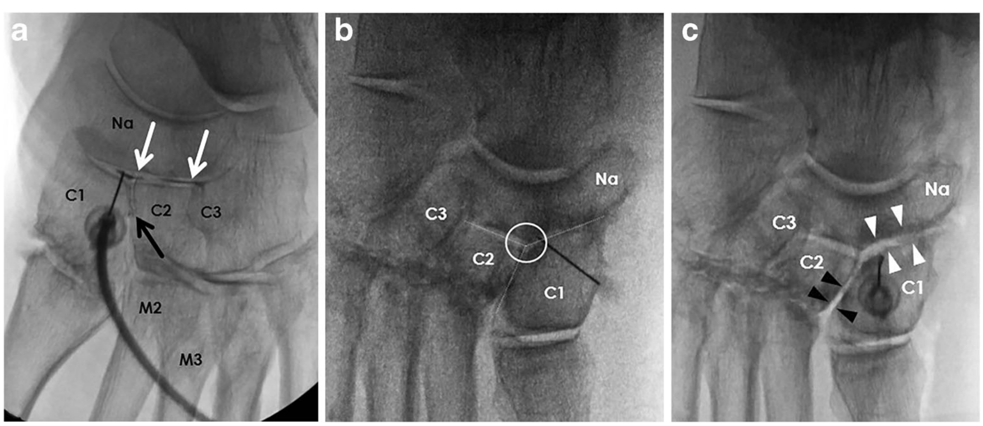

Fig. 2 A 51-year-old female referred for fluoroscopically guided naviculocuneiform (NC) joint injection. **a** AP fluoroscopic image after injection of iodinated contrast material shows appropriate needle placement targeting the Y-shaped portion of the NC joint between the navicular (Na), medial cuneiform (C1), and intermediate cuneiform (C2). Contrast outlines the NC joint (*white arrows*) as well as a portion of the intercuneiform joint between C1 and C2 (*black arrow*) which allows for NC joint communication with the second/third tarsometatarsal (TMT) joint. Lateral cuneiform (C3), second metatarsal (M2) and third metatarsal (M3). A 77-year-old female referred for fluoroscopically guided naviculocuneiform (NC) injection with iodinated contrast allergy and air contrast confirmation of needle placement. **b** AP fluoroscopic image prior to air contrast injection shows appropriate needle placement approximating the Y-shaped portion (*circle*) of the NC joint (*thin white dotted lines*). **c** AP fluoroscopic image after the injection of air shows increased lucency and widening at the NC (*white arrowheads*) and intercuneiform joints (*black arrowheads*). This appearance of the joints "breathing" with intermittent fluoroscopy is compatible with intra-articular needle placement

Table 1 General joint-specific corticosteroid dosage considerations

Articulations	Kenalog/Triamcinolone acetate or Depo-Medrol / Methylprednisolone acetate Dosage (mg)	Decadron/Dexamethasone sodium phosphate Dosage (mg)	CELESTONE, SOLUSPAN, betamethasone sodium phosphate Dosage (mg)
Tibiotalar	40 mg	2 mg	1 mg
Posterior subtalar	40 mg	2 mg	1 mg
Talocalcaneonavicular			
-Talonavicular	20 mg	1 mg	0.5 mg
-Anterior subtalar	20 mg	1 mg	0.5 mg
-Middle subtalar	20 mg	1 mg	0.5 mg
Calcaneocuboid	20 mg	1 mg	0.5 mg
Naviculocuneiform	20 mg	1 mg	0.5 mg
Tarsometatarsal (TMT)	20 mg		
-First TMT		1 mg	0.25 mg
-Second and third TMT		1 mg	0.25 mg
-Fourth and fifth TMT		1 mg	0.25 mg
Metarsophalangeal	10 mg	0.8 mg	0.25 mg
Interphalangeal	10 mg	0.8 mg	0.25 mg

*Please refer to package insert for steroid specific recommendations

needle position, corticosteroid and anesthetic are instilled. Upon needle retraction, the tract should be lysed with local anesthetic in an effort to avoid steroid related skin depigmentation and soft tissue atrophy [27, 28].

Medications

It is outside the scope of this paper to provide a detailed review of the medications used for intra-articular injection [29]. Most therapeutic joint injections combine an anesthetic and corticosteroid. Multiple studies have shown that corticosteroids are typically safe and generally effective for temporary pain relief [29–31]. There is no definitive data to guide steroid selection. However, given the superficial nature of most foot and ankle injections, dexamethasone and the sodium phosphate form of betamethasone, are preferred by some providers because they are non-particulate, or water soluble, and theoretically less likely to result in skin depigmentation or atrophy of subcutaneous fat [27–29]. Dexamethasone and betamethasone also

Table 2 Joint-specific recommended injectate volumes and normal communications

Articulations	Injectate volume (ml)	Normal communications
Tibiotalar	3.0–5.0 ml	Flexor hallucis longus tendon sheath, posterior subtalar joint 10–22%
Posterior subtalar	2.0–3.0 ml	Tibiotalar joint 10–22%
Talocalcaneonavicular		Talonavicular, anterior, and middle subtalar joints all communicate as one complex, spring ligament recess, calcaneocuboid joint variable
-Talonavicular	1.5–3.0 ml	
-Anterior subtalar	1.5–3.0 ml	
-Middle subtalar	1.5–3.0 ml	
Calcaneocuboid	1.0–2.5 ml	Talocalcaneonavicular joint variable
Naviculocuneiform	1.0–2.5 ml	Medial/intermediate intercuneiform and second/third tarsometatarsal joints
Tarsometatarsal (TMT)	1.0–2.0 ml	
-First TMT		None
-Second and third TMT		Medial/intermediate intercuneiform and naviculocuneiform joints
-Fourth and fifth TMT		None
Metarsophalangeal	1.0–1.5 ml	None
Interphalangeal	0.5–1.0 ml	None

Table 3 Joint-specific structures to avoid and approaches

Articulations	Structures to avoid	Conventional fluoroscopy approach
Tibiotalar	Anterior tibial lip, dorsalis pedis artery, deep peroneal nerve	Lateral decubitus, anterior approach 1-2 cm distal to joint, medial or lateral talar dome, angle needle tip 30–45 degrees cranial Lateral mortise approach same positioning as above targeting lateral mortise
Posterior subtalar	Peroneal tendons	Lateral decubitus with foot rotated internally, lateral approach just posterior to angle of Gissane Posterolateral approach same positional as above targeting posterior aspect of joint
Talocalcaneonavicular		
-Talonavicular	Dorsalis pedis artery	Supine, knee bent with foot flat on table, AP approach
-Anterior subtalar	Peroneal tendons	Lateral decubitus, lateral approach
-Middle subtalar	Peroneal tendons	Lateral decubitus, lateral approach
Calcaneocuboid	Peroneal tendons	Lateral decubitus with foot rotated internally, lateral approach, target mid to cranial joint space
Naviculocuneiform	Dorsalis pedis artery	Supine, knee bent with foot flat on table, AP approach, Y-shaped articulation between medial/intermediate cuneiforms and navicular
Tarsometatarsal (TMT)		
-First TMT	Dorsalis pedis artery	Supine, knee bent with foot flat on table, AP approach
-Second and third TMT	Dorsalis pedis artery	Same as first TMT, mild internal rotation of foot
-Fourth and fifth TMT	None	Lateral decubitus with foot internally rotated, lateral approach, T-shaped articulation between fourth/fifth metatarsal and cuboid
Metarsophalangeal	Dorsal lip of proximal phalanx, extensor tendon	Supine, knee bent with foot flat on table, target metatarsal head
Interphalangeal	Extensor tendon	Supine, knee bent with foot flat on table, target phalangeal head

have the advantage of increased potency, which allows for smaller volumes of injectate to achieve desired therapeutic effects.

On the other hand, some clinicians prefer triamcinolone for joint injections, despite the increased risk for skin atrophy and depigmentation, because triamcinolone is less water soluble and dissolves more slowly in the joint (depot effect) than dexamethasone. Therefore, triamcinolone's intra-articular effects are thought to be longer-lasting. At our institution, we typically use triamcinolone due to referring orthopedic surgeon preference (Table 1).

While nearly universally performed, the intra-articular injection of local anesthetics is not Food and Drug Administration (FDA) approved and is instead considered off-label use. The chondrolytic effects of any local anesthetic are time- and more importantly dose-dependent [32, 33]. While many operators use ropivacaine 0.2% or 0.5% some prefer bupivacaine 0.25% based on the literature [32, 33]. In larger joints, using a lower concentration of local anesthetic has been shown to be clinically similar in efficacy to a higher concentration of local anesthetic [34]. We prefer to inject 0.2% ropivacaine following the corticosteroid to reduce post-procedural discomfort and to obtain immediate diagnostic information about the efficacy of the injection [20, 21]. Joint-specific injection volumes and communication are provided in Table 2.

Complications

There is a very low rate of complications for intra-articular foot and ankle injections [30]. Foot and ankle joints are superficial and small gauge needles are used for access. Thus, even the most commonly reported complication of bleeding is rare and can be easily managed [31]. Serious complications such as septic arthritis are extremely rare. One case series reported a septic joint occurring in fewer than 1 in 10,000 cases [30]. Cellulitis and bacteremia are contraindications to elective injections. The most common adverse reaction related to corticosteroid injection is a post-injection "flare" resulting from locally increased inflammation that develops within hours and may last for several days. Rates of post-injection flare vary from 2 to 25% and do not portend a poor response [29, 35]. The clinical presentation of a flare may mimic a septic joint. Symptoms persisting for greater than 24 h may warrant joint aspiration to definitively exclude infection [35].

Research has shown an increase in blood glucose levels in diabetic patients after receiving corticosteroid injections [36]. This steroid induced hyperglycemia may occur 2–5 days post-injection and diabetic patients should be warned to expect a transient increase in blood glucose level. Given the relatively small dose of corticosteroid in isolated foot and ankle injections, the transient rise of blood glucose level following an injection may be less of a concern than in large joints. Prior to injection, we routinely review medical records and ask patients about recent corticosteroid injections in an effort to limit the total amount of steroid injected within a fixed time period [29]. In our practice, we prefer to not inject greater than 80 mg of corticosteroid during a 6-week period. We recommend following all package inserts for specific dosing guidelines.

Skin depigmentation and subcutaneous fat atrophy are a complication of steroid injection, and occur more frequently with superficial injections. Although these risks are thought to be mitigated by using non-particulate, water-soluble injectable steroids (such as dexamethasone or betamethasone), we have seen these complications occur even with the non-particulate steroid formulations. Skin depigmentation is more conspicuous in darker-skinned patients and patients should be counseled about this risk during informed consent. It may take up to 2 months for depigmentation to occur and it typically normalizes over the course of a year [27, 28]. Corticosteroid-related subcutaneous fat atrophy presents clinically as dimpling or "thumbprinting" of skin with possible alopecia. Although these findings typically normalize within 1–2 years, long-lasting effects have been reported [27, 28].

Joint-specific approach to injection

All injections are performed with a 25-gauge needle unless otherwise specified. Short needles are helpful for maintaining intra-articular access in superficial articulations. Joint-specific approaches and structures to avoid are summarized in Table 3.

Tibiotalar joint

The tibiotalar joint is the largest articulation in the foot and ankle with an average joint volume ranging from 8 to 20 ml [37]. It is a pure hinge joint with the talar dome held in the mortise by the tibia and fibula. The joint capsule attaches to the tibia just above the joint line and to the dorsal aspect of the talar neck at the talar ridge with anterior, posterior, medial, and lateral recesses. The tibiotalar joint communicates with the flexor hallucis longus tendon sheath and the posterior subtalar joint in 10–22% of patients [38–41]. With conventional fluoroscopy, the patient is positioned lateral decubitus, opposite the side of injection. With a C-arm, the patient can alternatively be positioned supine with the beam oriented medial-lateral. It is important to palpate, mark, and avoid the dorsalis pedis (DP) artery, which typically courses between the extensor hallucis longus and extensor digitorum longus tendons. The skin entry site may be between the anterior tibialis and extensor hallucis longus tendons, or along the far lateral or medial aspects of the talar dome, with a planned needle course completely lateral or medial to the tendons [2, 4, 19, 42]. Entering the skin 1–2 cm distal to the tibiotalar joint and angling the needle tip 30–45 degrees caudal to cranial will aid in avoiding the anterior tibial lip (Fig. 3). The lateral mortise approach uses approximately half the fluoroscopic time of the more traditional medial approach and has become the preferred method at many institutions [43]. The lateral mortise approach is also efficacious in accessing severely arthritic joints since the lateral mortise usually remains visible even in the presence of large osteophytes [43, 44]. Some authors have advocated for a posterolateral approach with severe anterior predominant osteoarthrosis [45].

Posterior subtalar joint

The posterior facet is the largest of the three articulations at the subtalar joint. The facet extends in a diagonal fashion from posterosuperior to anteroinferior, extending anteriorly into the sinus tarsi. The posterior subtalar joint may communicate with the tibiotalar joint. However, it does not communicate with the anterior or middle subtalar facets [38–41, 46]. Anterior oblique positioning, opposite the affected foot, with mild forefoot inversion will clearly demonstrate the lateral process of the talus and angle of Gissane. The foot can be stabilized with pads or towels for patient comfort. The skin should be entered just posterior to the lateral process of the talus and the angle of Gissane, anterior to the peroneal tendons. During subtalar access, there is no osseous backstop, thus requiring tactile perception as the needle traverses the different tissue layers. Placing the needle too deeply is a common pitfall. When resistance is encountered upon injecting, even though the needle appears appropriately positioned, the operator should slowly retract the needle, on the measure of a mm at a time, while continuously gently injecting anesthetic. Once a subtle "give" is felt with anesthetic flowing freely, the needle is likely intra-articular (Fig. 4). An alternative posterolateral approach has been posited as technically more straightforward, as there is always a joint recess if the operator is unable to access the joint [47, 48].

Talocalcaneonavicular joint

The talar head articulates with the concave posterior portion of the navicular, the anterior process of the calcaneus medially, and upper surface of the spring ligament. The talonavicular, anterior, and middle subtalar joints communicate through a single synovial cavity. The talocalcaneonavicular joint communicates with the spring ligament recess, which extends between the medioplantar oblique and inferoplantar longitudinal components of the spring ligament complex [38–41, 49].

For intra-articular access, the patient is positioned supine with knee bent and plantar aspect of the foot on the table. The standard approach is dorsal and, in our experience, the far medial aspect of the talonavicular articulation, targeting the curved part of the talus at the medial articular surface, is most patent/least arthritic. When injecting dorsally, contrast may flow deep to the talonavicular articulation into the anterior and middle subtalar joints rather than outlining the talonavicular joint proper. Although this is a potentially disorienting finding, it is normal and indicative of successful intra-articular needle placement (Fig. 5).

Calcaneocuboid joint

The anterior process of the calcaneus articulates with posterior portion of the cuboid. The calcaneocuboid has a relatively prominent inferior joint recess with the typical volume of injectate between 1.0–2.5 ml [38–41]. The standard approach is lateral with the patient in lateral decubitus position, with the lateral aspect of the affected ankle facing up [4]. The foot should be internally rotated until the joint space is identified in profile. The overlying peroneal tendons should be palpated and avoided. Targeting the craniocaudal mid-portion of the calcaneocuboid joint allows for avoidance of the peroneal tendons (Fig. 6).

Naviculocuneiform joint

The distal aspect of the navicular has three facets, one for each cuneiform. There is one joint capsule for all three articulations. The naviculocuneiform (NC) joint also communicates with the second and third tarsometatarsal (TMT) joint via the medial and intermediate cuneiform intercuneiform joint [38–41, 50, 51]. A dorsal approach is utilized. The patient is placed supine with the knee of the affected foot bent and the plantar aspect of the foot on the table. The DP artery should be palpated, marked, and avoided. The skin may be entered between the navicular and the cuneiforms. In our experience, the Y-shaped articulation between the medial and intermediate cuneiforms is least arthritic (Fig. 2).

Tarsometatarsal joints

The mid foot is divided into three separate synovial spaces with three separate TMT joint capsules: First (medial cuneiform and first metatarsal base), second (intermediate and lateral cuneiforms and second and third metatarsal bases) and third (cuboid and fourth and fifth metatarsal bases). The TMT joints may communicate with the intercuneiform joints [38–41, 52, 53]. The second and third TMT joint communicates with the NC joint as previously described. A dorsal approach is used for access to the first, second, and third TMT articulations. The patient is positioned supine with affected knee bent and plantar aspect of the foot on the table. The DP artery should be palpated, marked, and avoided.

For the fourth and fifth TMT joint, the patient should be positioned lateral decubitus, opposite the affected side, to facilitate an oblique approach (Fig. 7). We have found it easiest to target the center of the first TMT joint, the least arthritic ray of the second/third TMT joint and the T-shaped space between the fourth/fifth TMT joints. It is possible to pass the needle through the plantar aspect of the foot so care must be taken to stabilize the needle while exchanging syringes.

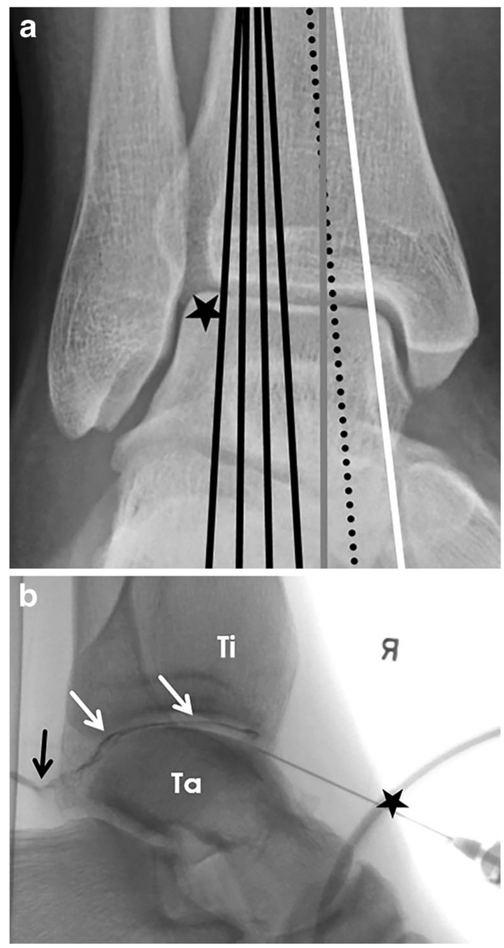

Fig. 3 A 52-year-old female referred for fluoroscopically guided tibiotalar joint injection using the lateral mortise approach. **a** Normal mortise view ankle radiograph shows anterior ankle structures that should be considered when planning a tibiotalar joint injection including: lateral talar dome target for injection (*star*), anterior tibialis tendon (*white line*), extensor hallucis longus tendon (*dotted line*), dorsalis pedis artery (*gray line*), and extensor digitorum longus tendons (*black lines*). **b** Lateral fluoroscopic image after injection of iodinated contrast shows appropriate anterior skin entry site (*star*) with caudal to cranial orientation of the needle in order to avoid anterior lip of the tibial plafond. Intra-articular contrast flows over the talar dome (*white arrows*), outlining the joint, and into the posterior joint recess (*black arrow*). Tibia (Ti) and talus (Ta)

Metatarsophalangeal joints

All the metatarsophalangeal (MTP) joints have a ball-and-socket-type articulation between the metatarsal head and proximal phalangeal base. The first MTP joint has distinct anatomy including paired sesamoids with their own articulations at the crista or plantar aspect of the metatarsal head. The first MTP joint communicates with the sesamoid articulations and has small dorsal and plantar recesses. The second through fifth, or lesser MTP joints, have small dorsal and larger plantar recesses, which extend from the metatarsal necks to the bases of the proximal phalanges [38–41]. The extensor tendons are located in the midline and the neurovascular bundles along the medial and lateral aspects of the MTP joints. For MTP intra-articular access, the patient should be positioned supine, with affected knee bent and plantar aspect of the foot on the table. The skin is entered dorsally, just off midline and proximal to the joint line. We typically aim for the medial edge of the joint along the curved surface of the metatarsal head to avoid dorsal osteophytes. It is also important to target the metatarsal head in an attempt to avoid the dorsal lip of the proximal phalanx (Fig. 8). The MTP joints are small, with injectate volumes of 0.5–1.5 ml [22, 23].

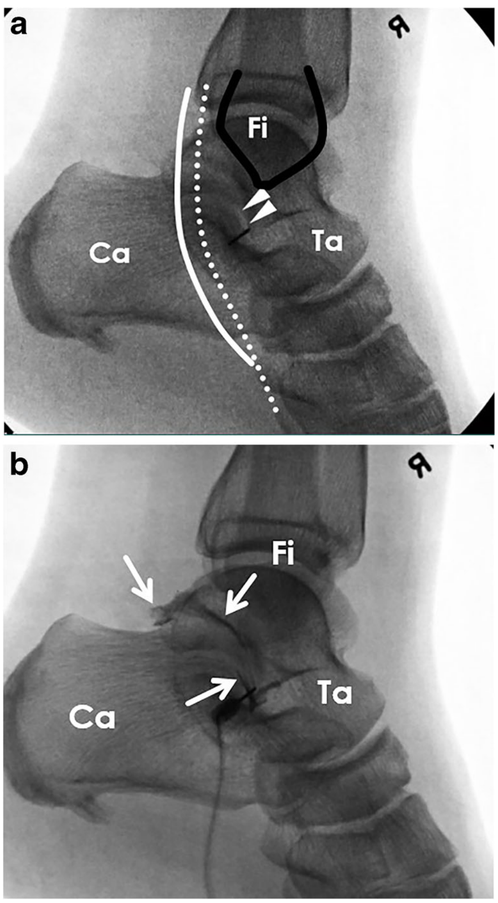

Fig. 4 A 41-year-old female referred for fluoroscopically guided posterior subtalar joint injection. **a** Lateral fluoroscopic image pre-contrast injection demonstrates appropriate needle positioning within the posterior subtalar joint targeting the "en face" clear space just posterior to the angle of Gissane (*arrowheads*). The foot has also been inverted to clear the fibula (Fi) superiorly (*black outline*). The peroneus brevis (*white dotted line*) and peroneus longus (*solid white line*) should be palpated and avoided. **b** Fluoroscopic image after injection of iodinated contrast shows contrast outlining the posterior subtalar joint and extending into the posterior subtalar joint recess (*arrows*). Calcaneus (Ca) and talus (Ta)

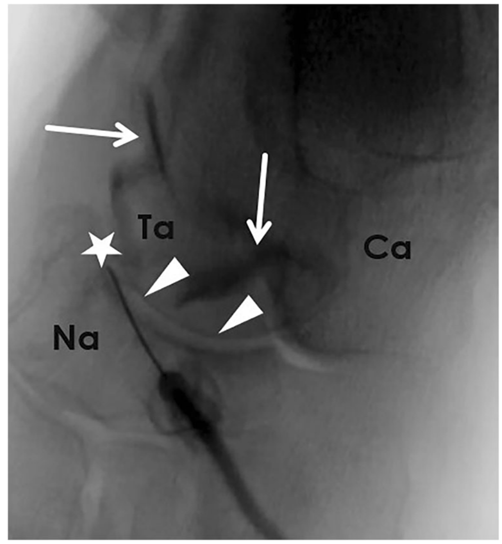

Fig. 5 A 62-year-old male referred for fluoroscopically guided talonavicular joint injection. AP fluoroscopic image after injection of iodinated contrast shows intra-articular placement of a 25-gauge needle at the medial aspect of the talonavicular joint (*star*). No contrast outlines the talonavicular joint (*arrowheads*). Contrast instead tracks beneath the talus outlining the anterior and middle subtalar joints (*arrows*), which can be disorienting if the operator is not familiar with this normal communication. Navicular (Na), calcaneus (Ca), cuboid (Cu), and talus (Ta)

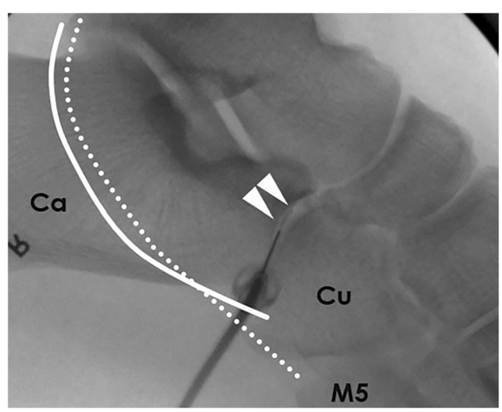

Fig. 6 A 43-year-old female referred for fluoroscopically guided calcaneocuboid joint injection. Lateral fluoroscopic image after injection of iodinated contrast shows needle placement along the mid portion of the joint to avoid the peroneal tendons with contrast outlining the cranial aspect of the calcaneocuboid joint (*arrowheads*). Peroneus brevis (*white dotted line*), peroneus longus transiting through cuboid tunnel (*solid white line*), calcaneus (Ca), cuboid (Cu), base of fifth metatarsal (M5)

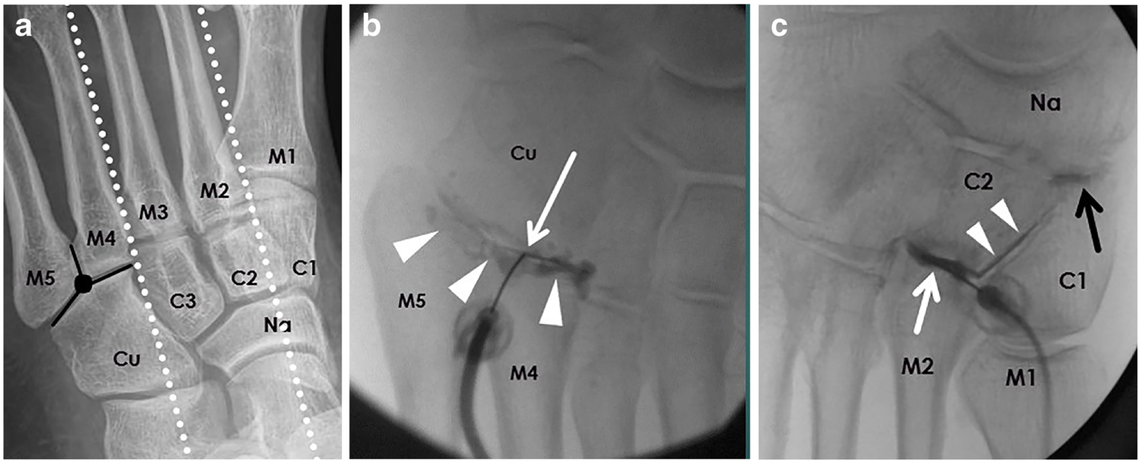

Fig. 7 A 26-year-old male normal oblique foot radiograph. **a** Pertinent normal tarsometatarsal (TMT) and naviculocuneiform (NC) joint anatomy. M1-first metatarsal (MT), M2-second MT, M3- third MT, M4- fourth MT, M5- fifth MT, Cu- cuboid, C1- medial cuneiform, C2- intermediate cuneiform, C3- lateral cuneiform, Na- navicular. *White dotted lines* divide the foot into medial, middle, and lateral columns. *Black lines* show fourth and fifth TMT joint, which intersect at the preferred site "T-shaped" site of injection (*black dot*). A 59-year-old female referred for fluoroscopically guided fourth/fifth tarsometatarsal joint injection. **b** Oblique fluoroscopic image after injection of iodinated contrast shows appropriate needle tip position (*arrow*) with contrast outlining the fourth/fifth TMT joint (*arrowheads*). A 65-year-old male referred for fluoroscopically guided second/third TMT joint injection. **c** AP fluoroscopic image after injection of iodinated contrast shows contrast outlining the second TMT joint (*white arrow*) as well as the normal communication with the NC joint (*black arrow*) via the intercuneiform joint between C1 and C2 (*arrowheads*)

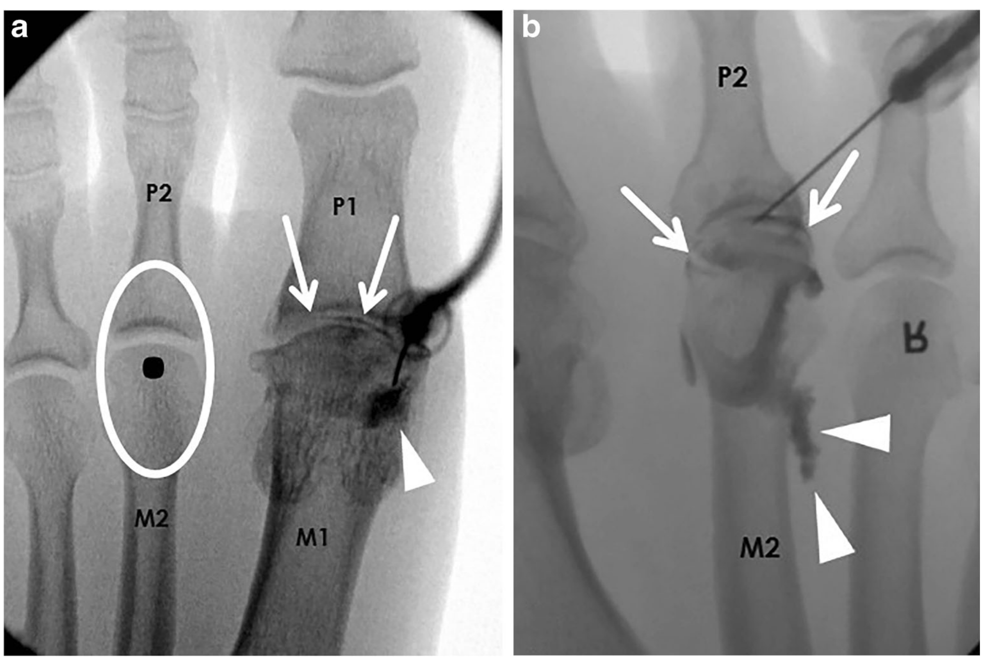

Fig. 8 A 47-year-old male referred for fluoroscopically guided injection of the first metatarsophalangeal joint. **a** AP fluoroscopic image after injection of iodinated contrast shows a medial approach targeting the first metatarsal head to avoid the proximal phalanx dorsal lip with contrast outlining the joint space (*arrows*) as well pooling along the plantar plate (*arrowhead*). Second metatarsophalangeal joint capsule (*white oval*) with *black dot* at the second metatarsal head indicating target for needle placement in order to avoid dorsal lip of proximal second phalanx. First metatarsal (M1), second metatarsal (M2), first proximal phalanx (P1), and second proximal phalanx (P2). A 35-year-old female referred for fluoroscopically guided injection of the second metatarsophalangeal joint. **b** AP fluoroscopic image after injection of iodinated contrast targeting the mid portion of the second metatarsal head to avoid the proximal phalanx dorsal lip shows contrast outlining the joint space (*arrows*) as well as extending beyond the confines of the joint capsule via a plantar plate rupture (*arrowheads*). Second metatarsal (M2) and second proximal phalanx (P2). This unexpected finding was relayed to the referring clinician and the patient subsequently underwent MRI followed by successful capsuloligamentous reconstruction

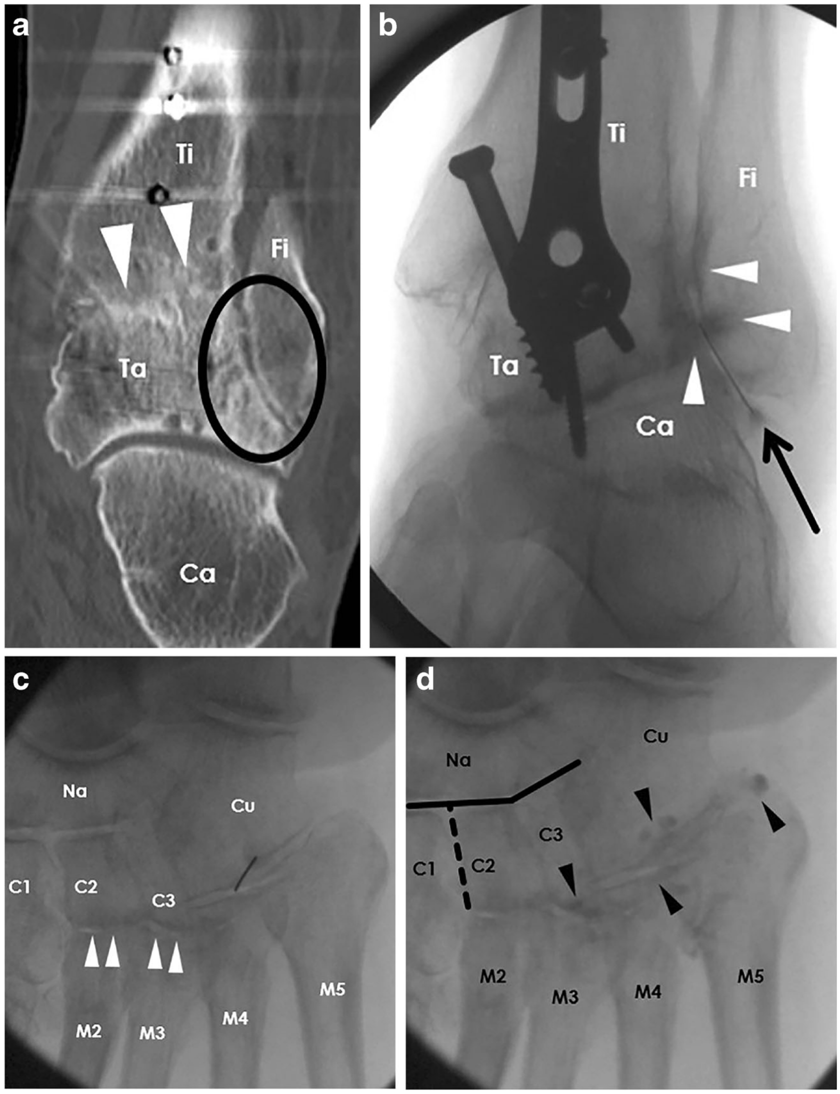

Fig. 9 Fluoroscopically guided degenerative and post-traumatic/surgical injections. A 62-year-old male with a history of tibiotalar arthrodesis and severe/partially ankylosed talofibular osteoarthrosis who was referred for talofibular injection and experienced immediate cessation of symptoms following the peri-articular injection. **a** Coronal CT reformatted image shows mature tibiotalar osseous bridging (*arrowheads*) and marked narrowing of the talofibular joint with partial osseous bridging (*oval*). Tibia (Ti), talus (Ta), fibula (Fi), and calcaneus (Ca). **b** AP fluoroscopic image after injection of iodinated contrast shows needle hub (*arrow*) with tip positioned at the mid-portion of talofibular articulation with contrast pooling (*arrowheads*) in a peri-articular fashion given absence of joint space. A 71-year-old female referred for fourth and fifth tarsometatarsal (TMT) injection in the setting of diffuse TMT osteoarthrosis who was found to have variant communication with the third TMT joint after contrast injection. **c** AP fluoroscopic image pre-contrast injection shows needle tip positioned over fourth TMT clear space and marked joint space narrowing at the second and third TMT joints (*arrowheads*). The typically targeted "T-shaped" portion of the fourth and fifth TMT joint was avoided due to osteophytosis. Navicular (Na), cuboid (Cu), medial cuneiform (C1), intermediate cuneiform (C2), lateral cuneiform (C3), second metatarsal (MT) (M2), third MT (M3), fourth MT (M4), and fifth MT (M5). **d** AP fluoroscopic image after injection of iodinated contrast and removal of needle shows contrast outlining the third through fifth TMT joints demonstrating a variant communication between the second/third and fourth/fifth TMT joints which is most likely degenerative/post-traumatic in nature. *Black lines* outline the naviculocuneiform (NC) joint and *dashed black line* shows the normal anatomic communication between the second/third TMT joint and NC joint via the intercuneiform C1-C2 articulation. This variant joint communication between the fourth/fifth TMT and NC joint via the second/third TMT joint should be reported as it may affect patient pain scores/relief at all of these articulations which ultimately could influence arthrodesis planning

Interphalangeal joints

The interphalangeal (IP) joints are hinge joints between the phalanges. Patients undergoing IP injections are positioned supine, with the affected knee bent and plantar aspect of the foot on the Table. A dorsal approach is utilized, entering the skin just off the midline to avoid extensor tendons. Similar to the MTP joints, the head of the phalanx should be targeted and the needle walked distally into the joint [38–41]. The joint access is particularly tenuous at the IP joints and extra care must be taken to stabilize the needle when exchanging syringes. The IP joints are among the smallest encountered with injectate volumes of approximately 0.5–1.0 ml. A shorter, 1-cm 25-gauge needle is preferable to a 1.5-in. needle in this case.

Injection troubleshooting

Post-traumatic, post-surgical, and/or severely arthritic joints may be particularly challenging to inject. A thorough grasp of normal anatomy, review of prior imaging, and meticulous patient positioning are pre-procedural musts. For example, if a second/third TMT or NC joint injection is requested, we routinely evaluate both and make a decision to access the least arthritic articulation, taking advantage of the previously mentioned normal anatomical communication in a "path of least resistance" approach [38–41, 50]. Once a portion of the joint is made radiolucent for targeting, the needle should be advanced using the "bulls-eye" technique. If initial attempts with the 25-gauge needle are unsuccessful despite an appropriate appearing needle tip position, the needle may be clogged with debris or minute, fluoroscopically occult osteophytes may be present. In our practice, we have had success troubleshooting in this scenario by upsizing to a 23-gauge needle and simply reproducing the trajectory of the 25-gauge needle. Rarely, the needle may become clogged by particulate corticosteroid. This is another reason to mix the local anesthetic and steroid in the same syringe.

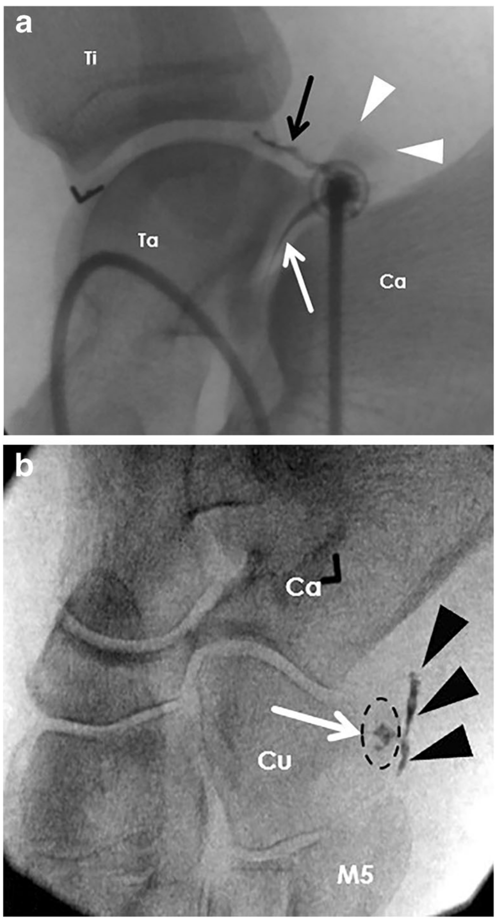

Fig. 10 Fluoroscopically guided injection of painful ossicles. A 23-year-old male referred for fluoroscopic-guided injection of a painful os trigonum who experienced immediate cessation of symptoms following the injection. **a** Lateral fluoroscopic image after injection of iodinated contrast material targeting the synchondrosis between the os trigonum (*arrowheads*) and posterior process of the talus shows contrast outlining the posterior subtalar joint (*white arrow*) and tibiotalar joint (*black arrow*). Talus (Ta), calcaneus (Ca) and tibia (Ti). **b** A 33-year-old female referred for fluoroscopic-guided injection of a painful os peroneum (*dashed oval*) who experienced immediate cessation of symptoms following the injection. Lateral fluoroscopic image after injection of contrast and removal of the needle shows contrast pooling about the os peroneum (*arrow*) as well as extending linearly within the peroneus longus tendon sheath (*arrowheads*). Cuboid (Cu) and fifth metatarsal (M5)

During the contrast test injection, it is imperative to monitor the initial location of the contrast with intermittent fluoroscopy. If contrast is extra-articular, the injection should be stopped immediately to avoid contrast pooling and resultant obscuration of the targeted joint space. Documenting the exact location of intra-articular contrast is important as post-traumatic/surgical and/or severely arthritic joints often have variant communications (Fig. 9) [3]. These observations have allowed us to forego multiple injections in the same patient on numerous occasions. If these variant/unexpected communications are subtle, the operator may take a full exposure instead of a last image hold to more definitively demonstrate the variant joint communications to referring clinicians.

Finally, it is important to understand that anatomic alterations following surgery or trauma result in variable appearance of intra-articular contrast injection [3]. This awareness will allow the operator to forego excessive needle repositioning in a futile attempt to obtain an image of articular contrast confined to a well-outlined joint space. In our experience, similar to image-guided sacroiliac joint injections, the injection of LA and steroid about the residual "joint" in a peri-articular fashion often results in significant pain relief [54–58] (Fig. 9).

Pain generator interrogation

Besides providing pain relief, fluoroscopically guided foot and ankle injections also have significant diagnostic value. Evaluation of foot and ankle pain can be very difficult clinically and therapeutic injections are often utilized to aid in the identification of specific pain generators. Although often disappointing to patients, an intra-articular injection that does not

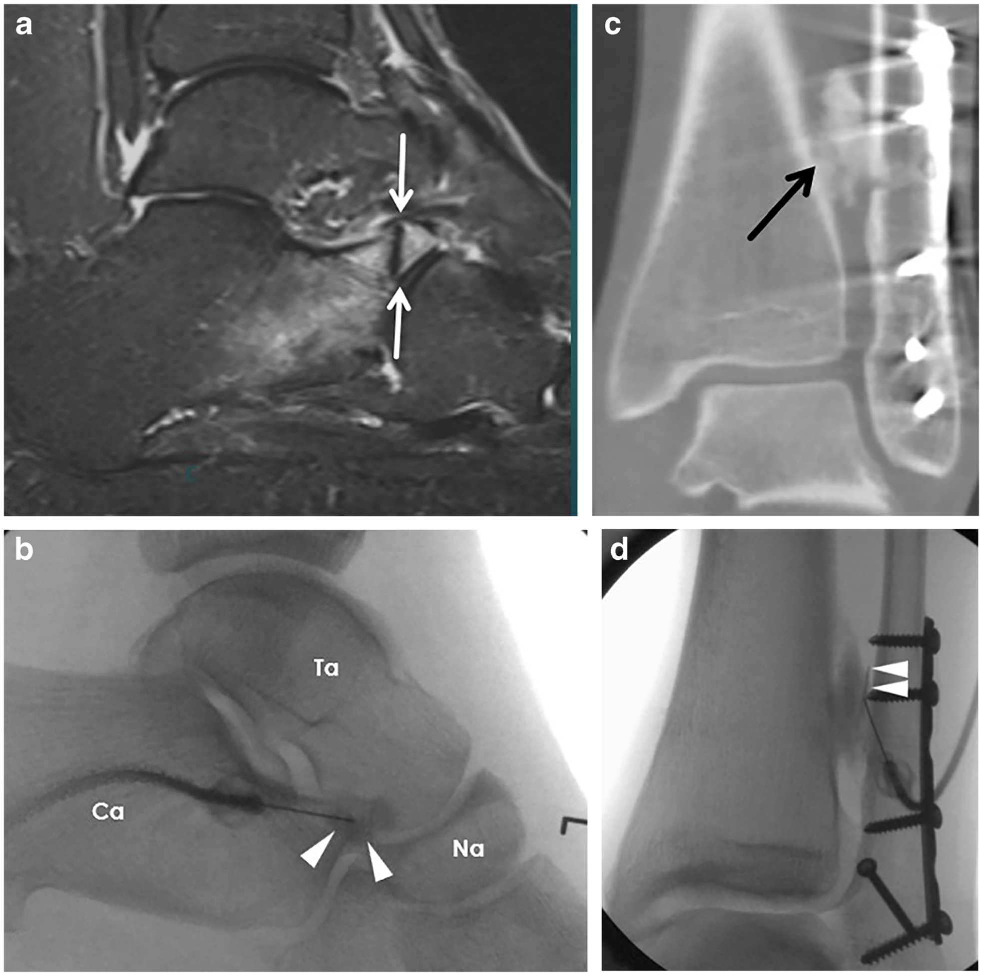

Fig. 11 Fluoroscopically guided interrogation of pain generators. A 21-year-old female referred for diagnostic injection of an anterior process calcaneal fracture who experienced immediate cessation of symptoms following the injection. **a** Sagittal STIR MRI of the ankle shows a non-displaced fracture through the anterior process of the calcaneus (*arrows*) with surrounding bone marrow edema. **b** Lateral fluoroscopic image after injection of iodinated contrast material shows needle tip at the fracture plane with pooling of contrast about fracture (*arrowheads*). Calcaneus (Ca), talus (Ta), and navicular (Na). A 24-year-old male referred for diagnostic injection of distal syndesmosis heterotopic ossification who experienced immediate cessation of symptoms following the injection. **c** Coronal CT reformatted image shows heterotopic ossification (*arrows*) at the distal syndesmosis in the setting of prior trauma and fibular fracture fixation. **d** AP fluoroscopic image after injection of iodinated contrast shows the needle tip located along lateral aspect of ossification with contrast extending cranially between heterotopic bone and fibula

provide pain relief rules out a potential source of pain. This information may be instrumental in pre-operative decision-making regarding which joint or joints to surgically fuse [11–13]. Since these injections may guide surgical planning, it is important to fully characterize and communicate to referring clinicians which articulations communicate after contrast injection. Bringing non-anatomical joint communications to the referring clinician's attention prior to any planned intervention may influence the type and extent of surgical fusion, ultimately leading to more satisfactory patient outcomes. Lastly, the extra-articular extension of contrast may have diagnostic value, particularly at the MTP joints, where a plantar plate tear may be diagnosed by identifying the extension of contrast beyond the expected confines of the joint capsule (Fig. 8) [22].

The fluoroscopically guided interrogation of pain generators about the foot and ankle extends beyond joint-based injections and may be used to evaluate variant ossicles, post-surgical changes, and even fractures. Interrogation of an os peroneum is typically performed via a direct lateral approach. During an os peroneum injection, the peroneus longus tendon sheath is often opacified [16, 17] (Fig. 10). When injecting an os trigonum, a lateral approach is undertaken targeting the synchondrosis between the os trigonum and posterior process of the talus. Contrast is often observed communicating with the tibiotalar and subtalar joints with possible extension to the flexor hallucis longus tendon sheath (Fig. 10) [14, 15]. Although infrequent, our referring orthopedic colleagues have requested the interrogation of sub-acute to chronic fractures and heterotopic ossification with anesthetic injections as the outcome may influence surgical planning with regard to fracture fixation or even fracture fragment resection (Fig. 11) [18].

Conclusions

In summary, both the frequency and indications for therapeutic and diagnostic fluoroscopically guided foot and ankle injections are increasing. While these injections are typically safe and effective, the small joint volumes and complex anatomy may cause technical difficulty. Use of a fluoroscopy C-arm is very helpful in avoiding difficult positions for the patient while facilitating use of the preferred "bulls-eye" technique. Familiarizing oneself with the relevant anatomy, reviewing prior imaging, and meticulous patient positioning increase the likelihood of a successful injection. Beyond relieving patient pain, fluoroscopically guided injections provide the radiologist an opportunity to take on a role as a value-adding consultant to the referring clinician. By performing diagnostic injections of pain interrogators and describing unexpected variant anatomical communications, radiologists may alter surgical planning and improve patient outcomes.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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