

Magnetic Resonance Imaging of a Deep Peroneal Intranural Ganglion Cyst Originating from the Second Metatarsophalangeal Joint: A Pattern of Propagation Supporting the Unified Articular (Synovial) Theory for the Formation of Intranural Ganglia

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A deep peroneal intraneural cyst of the first web space of the foot is presented. Analysis of the magnetic resonance image scans revealed not only a connection with the medial aspect of the second metatarsophalangeal joint, but also the presence of an interconnected cyst within the lateral digital branch of the hallux. These characteristic magnetic resonance image findings are consistent with those previously described for a peroneal intraneural ganglion cyst that arose from the superior tibiofibular joint, and include (1) origin (ascent) from the second metatarsophalangeal joint with propagation along the articular branch and into the dorsal digital branch of the second toe, (2) cross-over within the shared epineurial sheath of the deep peroneal nerve, and (3) further propagation (descent) within the dorsal digital branch of the hallux. The analogous features between intraneural ganglion cysts affecting small and large-caliber nerves support the fundamental principles of the unified articular (synovial) theory for the formation of intraneural ganglia, including (1) a connection to a synovial joint, (2) dissection of joint fluid through a capsular rent along the articular branch into the parent nerve, and (3) intra-epineurial, pressure-dependent propagation of cyst fluid along paths of least resistance. Level of Clinical Evidence: 4 (The Journal of Foot & Ankle Surgery 48(1):80–84, 2009)

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Intranural ganglion cysts are mucinous, non-neoplastic lesions that can be identified within the epineurium of peripheral nerves. They have been described in the foot and ankle region within tibial, medial plantar, superficial peroneal, and sural nerves (1–5). Origins from adjacent joints have rarely been demonstrated in cases in these locations (4,

6–9), encouraging many authors to support the theory that intraneural ganglion cysts arise de novo. Recent literature dealing with intraneural ganglion cysts affecting larger diameter nerves has reliably described an articular origin in association with primary and recurrent cases of intraneural ganglia, particularly those involving the peroneal nerve arising from the superior tibiofibular joint (10, 11). Regardless of the size of the nerve, we believe that a joint connection is universally present in association with the formation of an intraneural ganglion cyst, and we have demonstrated evidence to support this theory even in cases where authors have suggested otherwise (6, 8, 9, 11, 12). An appreciation of this articular connection, we feel, is crucial to proper treatment of intraneural ganglion cysts, since identification and disconnection of the nerve's articular branch connection to the joint is necessary in order to prevent recurrent intraneural cyst formation (10, 11).

In this article, we describe the case of a patient who displayed an intraneural ganglion occurring in an unusual

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location, namely the deep peroneal nerve within the first intermetatarsal space, which, based on magnetic resonance image (MRI) findings, arose from the second metatarsophalangeal (MTP) joint. The clinical and MRI findings in this case further allow us to generalize the previously described MRI features of intraneural ganglion cysts that are known to be associated with large-caliber nerves, like the peroneal nerve, to smaller nerves, like a terminal branch of the deep peroneal nerve in the foot.

Case Report

A 55-year-old woman presented to the primary author (NMB) with a painful right forefoot with swelling that had been persistent for many months after an insidious onset. She localized the pain to the first intermetatarsal space and second metatarsal shaft, and she related having had no previous treatment. Upon physical examination, she displayed slight swelling in the first intermetatarsal space, and she was also tender to palpation along the second metatarsal shaft. Plantarflexion of the hallux resulted in diminished sensation localized to lateral side of the right hallux.

Plain radiographs of the right foot did not reveal any fracture or dislocation, and MRIs revealed a tubular intraneural ganglion cyst localized to the medial, dorsal digital branch to the second toe (Figure 1). Close inspection of the MRI also revealed a subtle joint connection, referred to as the “tail” sign, linking the cyst to the second MTP joint (Figure 1, A). The cyst extended proximally 5.8 cm within the deep peroneal (common digital) nerve, and its maximum width was 9.5 mm. The cyst was eccentrically located, thereby displacing nerve fascicles and creating the magnetic resonance “signet ring” sign (12) (Figure 1, F). Moreover, the more proximal enlargement was consistent with a “balloon” sign (8) (Figure 1 A, B, and C), which is indicative of cystic expansion within the confines of the nerve sheath. Furthermore, a “wedding ring” sign was also evident, wherein cyst fluid was located within the outer epineurium of the deep peroneal nerve (Figures 1, D and E, and 2, B). Importantly, a fluid-filled cystic expansion connected the smaller diameter lateral digital branch of the hallux to the medial digital branch of the second toe, and there was a small amount of cyst within the digital nerve to the second toe distal to the articular branch.

Aspiration with an 18-gauge needle was undertaken approximately 2 months after ascertainment of the cystic nature of the lesion via MRI scanning, and 0.5 mL of clear, viscous, jelly-like material was evacuated. This resulted in reduction in the size of the lesion within the first intermetatarsal space, which was appreciated clinically, as well as decreased symptomatology, and she improved considerably. Approximately 1 month later, additional MRI scans were obtained, and these revealed slight enlargement of the in-

traneural cyst, indicative of persistence of the articular connection and refilling of the cyst with synovial fluid (Figure 2). After further consideration of the treatment options, the patient was eventually offered surgical intervention that would consist of decompression of the intraneural cyst of the second toe and first intermetatarsal space, along with disconnection of the articular branch connecting the medial digital nerve trunk to the second MTP joint. After considering of this specific option, however, the patient chose to decline surgical intervention despite ongoing symptomatology.

Discussion

We are unaware of a previous case describing the clinical and MRI findings, as well as an explanation of the probable mechanism of development, of a joint-connected intraneural ganglion along with interconnected digital intraneural cysts in either the foot or the hand. The imaging features in this patient, when carefully scrutinized, may provide insight into the etiology of intraneural ganglion cyst formation and propagation that may be comparable to ganglion cyst formation and propagation in other areas of the body. In the case described in this article (Figure 3), it appears that the first phase of development of the lesion entailed the exit of synovial fluid from a capsular rent in the second MTP joint that ascended (proximal migration) into, and then along, the articular branch of the proper digital nerve to the medial aspect of the second toe and, eventually, into the deep peroneal nerve. The second phase of development of the observed lesion was probably migration of the fluid into the shared epineurial sheath of the deep peroneal nerve, where cross-over occurred as the cyst dissected along one neural pathway (the medial digital nerve of the second toe) which could then interconnect with a second neural pathway, namely the lateral digital nerve of the hallux. Phase three of the development, thereafter, entailed descent (distal migration) of the fluid within the proper digital branch of the hallux. This proposed pattern of fluid propagation in the first intermetatarsal space and associated toes, makes sense clinically and pathophysiologically and, as such, lends credence to the fundamental principles of the unified articular (synovial) theory of formation of intraneural ganglion cysts, including (1) the presence of a neural connection to a degenerative synovial joint, (2) dissection of joint fluid through a capsular rent along the articular branch into the parent nerve, and (3) propagation of cyst fluid depending on pressure fluxes along paths of least resistance. Understanding the joint-related nature of these cysts makes clear the need to surgically address the articular branch in an effort to predictably minimize the risk of recurrence of the intraneural ganglion. In the case described in this report, we actually recommended surgical inspection and treatment of the in-

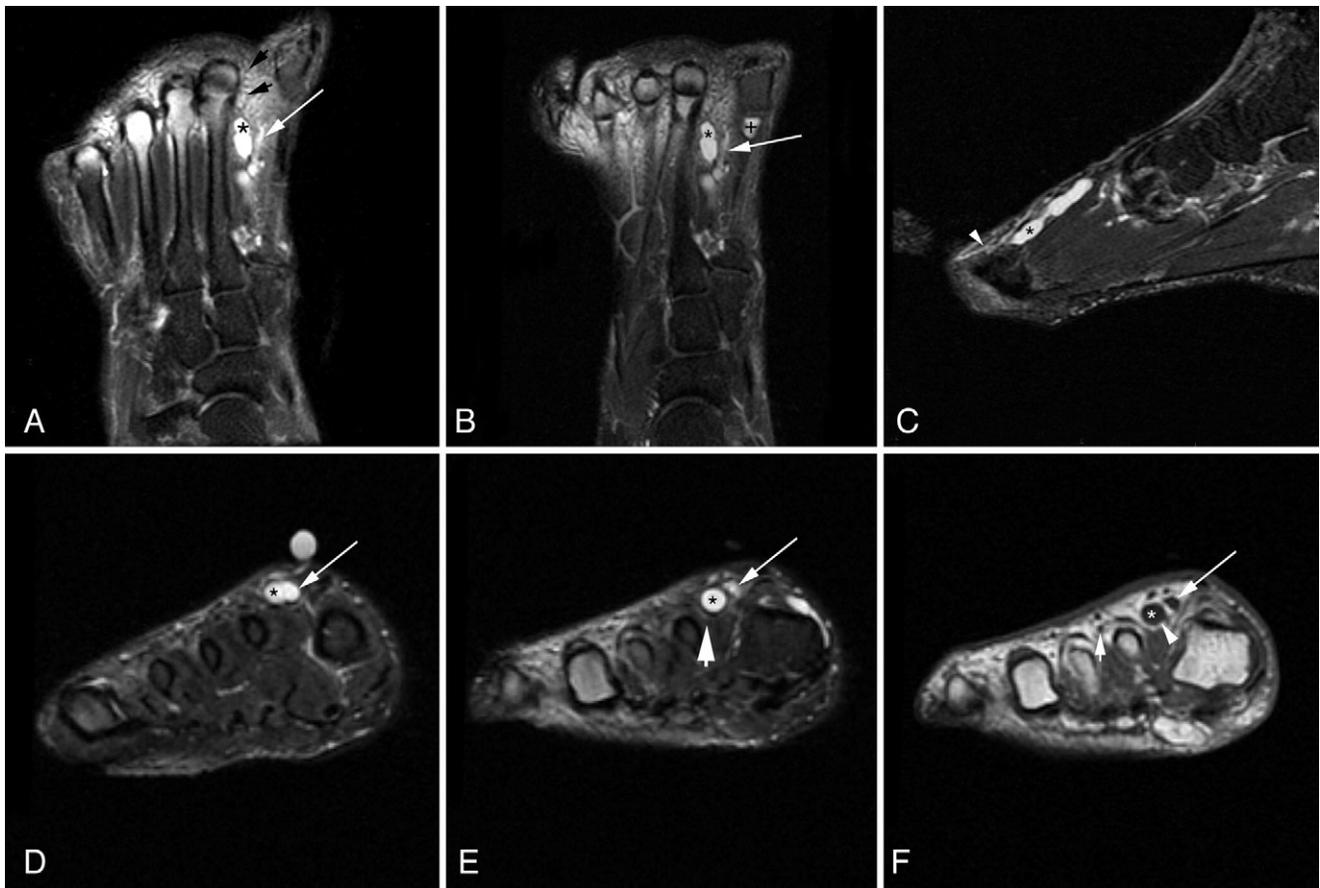


FIGURE 1 Magnetic resonance imaging of intraneural ganglion cyst. (A) Coronal maximum intensity projection (MIP) from a T2-weighted fast recovery fast spin-echo (FR-FSE) image set with fat suppression showing intraneural cyst within the medial digital branch of the deep peroneal nerve to the second toe (*asterisk*). Note cyst within the lateral digital branch of the hallux (*long white arrow*). The connection to the second metatarsophalangeal joint (“tail” sign) is also seen on this image (*short black arrows*). (B) Coronal maximum intensity projection (MIP) slightly superficial to [Figure 1, A](#), shows the intraneural cyst within the medial digital branch of the second toe (*asterisk*), and lateral digital branch of the hallux (*white arrow*). Also seen on this image is fluid within the first metatarsophalangeal joint indicative of degenerative change (*plus sign*). (C) Sagittal T2-weighted fast spin-echo (FSE) image with fat suppression shows the proximal extension of the intraneural cyst (*asterisk*) into the deep peroneal (common digital nerve) of the first intermetatarsal space. Incidentally noted is flow-related enhancement in a small digital artery (*arrowhead*). (D) Axial T2-weighted FR-FSE image with fat suppression at the level of the bifurcation of the common digital nerve showing intraneural cyst within the medial digital branch of the second toe (*asterisk*) and lateral digital branch of the hallux (*white arrow*). There is a faint ring of cyst surrounding both branches, the “wedding ring” sign. (E) Axial T2-weighted FR-FSE image with fat suppression distal to [Figure 1, D](#), showing cyst within both of the proper digital nerves (*asterisk*, medial digital branch of the second toe; *long arrow*, lateral digital branch of the hallux) distal to the bifurcation. Note fluid in the first metatarsophalangeal joint related to degenerative disease. The wedding ring sign can be seen (*short arrow*). (F) Axial T1-weighted image at the same location as [Figure 1, E](#), showing the intraneural cysts (*asterisk*, medial digital branch of the second toe; *long arrow*, lateral digital branch of the hallux). The displaced nerve fascicles around the intraneural cyst are best seen in association with the medial digital branch of the second toe (*arrowhead*). The lateral digital branch of the second toe is visible and normal on this image (*short arrow*). Blood vessels are superficial to the nerves.

traneural ganglion cysts, in an effort to diminish the risk of persistence or recurrence of pain. Aspiration or decompression without disconnecting the articular branch resulted in transient relief, but could not be expected to be a reliable or lasting treatment (10).

Even without surgical or histological confirmation, we believe that the MRI features of intraneural ganglion cysts are, in and of themselves, pathognomonic (12). MRI in this case was also helpful not only in establishing the presence of the connection between the nerve and the synovial cavity

of the second MTP joint, but also in establishing the propagation pattern of the intraneural ganglion. Knowledge of the unified theory for intraneural ganglion cyst formation, and an understanding of the anatomy of the common and proper digital nerves of the foot, is also important in the evaluation and treatment of this condition and, as depicted in the case described in this article, the connection between the intraneural ganglion and the adjacent joint can be subtle and easily missed without the use of optimal imaging techniques. Such techniques include the maximum intensity

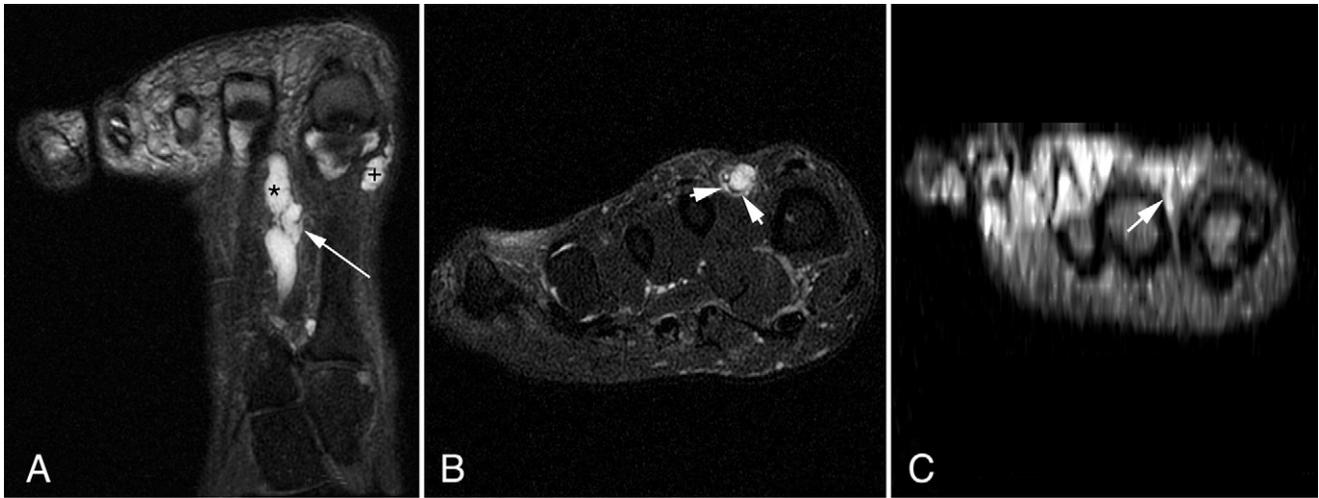


FIGURE 2 Post-aspiration MRI. (A) Coronal maximum intensity projection (MIP) image from a T2-weighted FR-FSE data set with fat suppression showing enlargement of the recurrent intraneural cyst within both proper digital nerves of deep peroneal nerve (*asterisk*, medial digital branch of the second toe; *white arrow*, lateral digital branch of the hallux), extending proximally to the common digital nerve to the base of the first metatarsal. The extraneural cyst associated with the first metatarsophalangeal joint has also increased in size (*plus sign*). (B) Axial T2-weighted FR-FSE image with fat suppression at the level of the bifurcation of the common digital nerve shows cyst in both proper digital nerves. A “wedding ring” sign (*arrows*) with cyst within the outer epineurium surrounds the medial digital branch of the second toe. (C) Axial reformation from a coronal T2-weighted FR-FSE data set with fat suppression shows the joint connection and cyst within the articular branch of the medial digital branch of the second toe (*arrow*).

projection (MIP) from a T2-weighted fast recovery fast spin-echo (FR-FSE) MRI set with fat suppression. Careful scrutiny of the images is particularly important, since the digital nerves themselves are very small and hard to visu-

alize, and establishing the relationship between the cyst and the nerve can be difficult. This difficulty may actually contribute to what we believe to be a generally incomplete recognition of the full extent of the underlying pathology

FIGURE 3 Artistic rendering (Mayo Foundation, 2008; with permission). **Left-side image (normal anatomy).** The deep peroneal nerve is located in the first interspace and bifurcates to form the dorsal digital branches of the lateral aspect of the hallux and the medial aspect of the second toe. An articular branch is highlighted innervating the second metatarsophalangeal joint. **Right-side image (intranural ganglion cyst).** Cyst fluid exiting a capsular rent in the second metatarsophalangeal joint and ascending along the articular branch and the digital nerve of the second toe and into the deep peroneal nerve (phase I). Cross-over (phase II) is necessary for subsequent descent into the digital nerve of the hallux (phase III).

related to the formation of intraneural ganglion cysts. In conclusion, in this article, we described the case of a small-caliber intraneural ganglion cyst in the first intermetatarsal space. This observation is important, since it can be explained by the unified theory of intraneural ganglion cyst formation as it pertains to a small nerve in the foot. Specifically, this case provides a direct analogy to the formation and propagation of intraneural ganglion cysts not only within the hand (13), but also throughout the body. In the future, histopathological confirmation of the lesion, in conjunction with the aforementioned MRI findings, should be possible.

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