The unusual clinical presentation and controversial pathogenesis of peroneal intraneural ganglia have intrigued surgeons for more than a century. The purpose of this multicenter study is to characterize the clinical, electrophysiological, imaging, operative, and histopathological findings, as well as the surgical outcomes, in a group of patients with this rare entity in the hopes of improving our understanding and, ultimately, clinical outcomes in these patients.

Clinical Material and Methods

Part I

We present our recent combined experience with peroneal intraneural ganglia after having become aware of the importance of the articular branch. Part II offers a description of three more patients who were seen after earlier operations in which the ganglion was excised, but the articular branch was not identified (all reportedly gross-total resections). Twenty-six of the 27 patients presented with clinical, electrophysiological, and imaging evidence of a common peroneal nerve (CPN) lesion, predominantly affecting the deep peroneal nerve (DPN) division, and one patient presented with a painful mass of the CPN that was not accompanied by a neurological deficit.

In all 24 patients in Part I there was magnetic resonance (MR) imaging evidence of a connection between the cyst and the superior tibiofibular joint, including one patient in whom high-resolution (3-tesla) MR neurography demonstrated the pathological articular branch itself. At the operation, the communication proved to extend through the articular branch of the CPN in all cases. The operation consisted of drainage of the cyst and ligation of the articular branch. At a minimum follow-up period of 1 year, these patients experienced significant improvements in their neuropathic pain, but only mild improvements in their functional deficits. In none of the 24 patients was there evidence of an intraneural recurrence. In three patients, however, extraneural ganglia developed: two patients with symptoms subsequently underwent resection of the superior tibiofibular joint without further recurrence and one patient with no symptoms was followed clinically after the recurrence was detected incidentally on 1-year postoperative imaging. As predicted, in Part II all three patients in whom the articular branch had not been ligated experienced early intraneuronal recurrence; both postoperative MR images and original studies, which were retrospectively examined, demonstrated a connection with the superior tibiofibular joint.

Conclusions. The clinical presentation, electrical studies, imaging characteristics, and operative observations regarding peroneal intraneuronal ganglia are predictable. Treatment must address the underlying pathoanatomy and should include decompression of the cyst and ligation of the articular branch of the nerve. To avoid extraneural recurrence, resection of the superior tibiofibular joint may also be necessary, but indications for this additional procedure need to be defined. These recommendations are based on the authors’ belief that intraneuronal peroneal ganglia arise from the superior tibiofibular joint and are connected to it by the articular branch.

KEY WORDS • peroneal nerve • intraneural ganglion • cyst • tumor

THE unusual clinical presentation and controversial pathogenesis of peroneal intraneuronal ganglia have intrigued surgeons for more than a century. The purpose of this multicenter study is to characterize the clinical, electrophysiological, imaging, operative, and histopathological findings, as well as the surgical outcomes, in a group of patients with this rare entity in the hopes of improving our understanding and, ultimately, clinical outcomes in these patients.

Abbreviations used in this paper: CPN = common peroneal nerve; DPN = deep peroneal nerve; EMA = epithelial membrane antigen; FSE = fast–spin echo; FSEIR = FSE inversion-recovery; LFB–PAS = Luxol fast blue–PAS; MR = magnetic resonance; MRC = Medical Research Council; NEX = number of excitations; SPN = superficial peroneal nerve.
of eight consecutive patients was performed at a single institution (Mayo Clinic, Rochester, MN). Then a retrospective review of 16 consecutive cases was conducted at the same institution and at two other centers at which there is a special interest in peripheral nerve tumors (Royal National Orthopaedic Hospital, Stanmore, United Kingdom; and Louisiana State University Health Sciences Center, New Orleans, LA).

Nineteen male and five female patients with peroneal intraneural ganglia were evaluated and underwent surgery. The mean age of these patients was 43 years (range 12–68 years). Twenty-three patients shared a common presentation, including clinically and electromyographically confirmed loss of predominantly DPN function as well as characteristic imaging findings. One patient experienced mechanical knee pain associated with a mass near the neck of the fibula that was not accompanied by any neurological symptom or sign. Symptoms were present for a mean of 15 months (range 3 months–10 years). Knee or proximal lateral leg pain generally preceded the neurological symptoms of motor weakness and/or sensory disturbance. Of the 23 patients with neurological symptoms, foot dorsiflexion was initially affected in 20 and toe extension in three. These patients with motor complaints subsequently experienced some degree of weakness involving all muscles innervated by the DPN and 14 noted sensory abnormalities in the foot and/or leg. Nine patients experienced problematic neuropathic pain.

Symptoms arose acutely after trauma in six patients. Three patients had suffered direct blows to the fibular neck region (one of which resulted in a fibular neck fracture): two had been injured during athletic activities and one during a fall. Three patients had antecedent ankle injuries: one had suffered a fracture and two had suffered sprains. An additional eight individuals had unusual histories of micro- or macrotrauma to the knee region related to their occupations or leisure pursuits. Another patient (Case 2) noted exacerbation of symptoms immediately following a documented knee effusion. Several patients noted intermittent symptoms or episodic neurological dysfunction, and attributed these to their position or activity level.

Two patients had undergone preoperative percutaneous aspiration of the cyst; both began to experience new neuropathic pain immediately afterward. Six others had undergone previous surgery(ies) (range one–three procedures) performed at other hospitals: a decompression procedure in three patients and an open biopsy, two decompression procedures, and an open biopsy followed by two decompression procedures in one patient each. In two of these patients the operative notes stated that gross-total removal had been performed. No pedicle was identified by the previous surgeons. In all instances, recurrence of symptoms and the mass prompted repeated MR imaging within months after the initial surgery. Both patients who underwent more than one operation noted worsening of pain and/or neurological function that persisted postoperatively, prior to our evaluation.

Physical examination demonstrated neurological deficits in 23 patients. In them, motor testing revealed a mean MRC grade of 2.5 (range 0 to 5) in muscles of the DPN. Fourteen patients (four had undergone previous operations) were found to have weakness during eversion (mean MRC Grade 3.5; range 0 to 5). In the one patient with a Grade 0 weakness in the peroneus muscles, normal muscle strength had been documented before the operation. A sensory loss in the distribution of the DPN (18 patients) and the SPN (nine patients) was also apparent. A Tinel sign was evident in 20 patients, and 16 had a detectable mass.

Electrodiagnostic studies were performed in the 23 patients with neurological deficits. Abnormalities were detected in the DPN in all 23 cases and in the SPN in 10 cases with the aid of electromyography and/or nerve conduction studies. These electrical abnormalities were always more marked in the DPN. In none of these patients were electrical abnormalities found in the tibial or sural nerve.

Magnetic resonance imaging was performed in all patients preoperatively. Magnetic resonance neurography was performed in one patient in the prospectively followed group by using a 3-tesla clinical imaging system (General Electric Medical Systems, Milwaukee, WI). Three-millimeter contiguous axial spin-echo T1-weighted images (TR 916 msec, TE 10 msec, matrix size 512 × 384, NEX 2), FSE IR T2-weighted images with fat saturation (TR 4600 msec, TE 96 msec, matrix size 512 × 512, NEX 2), FSEIR images (TR 5150 msec, TE 23 msec, matrix size 512 × 256, NEX 2), and sagittal FSEIR images of the distal CPN and the proximal segments of its three branches were obtained.

The operation was prompted primarily by the presence of a neurological deficit, pain, or mass, or a combination of these. The presence of a connection to the superior tibiofibular joint was assessed in all cases. Intraoperatively, nerve action potentials were recorded or direct nerve stimulation was performed in all patients. In four cases, contrast medium was injected into the articular branch first proximally and then distally.

All histological specimens were reviewed. Two representative lesions (Cases 1 and 2) are illustrated. Five-micron sections of formalin-fixed, routinely processed, and paraffin-embedded nerve were subjected to histological and immunohistochemical investigations. Histological stains included H & E, Masson trichrome, LFB–PAS, Meyer mucicarmine, and Alcian blue. Immunostaining procedures were performed using the avidin–biotin peroxidase complex method with antisera directed against vimentin (Dako Corp., Carpinteria, CA; clone 3B4, dilution 1:500), EMA (Dako Corp.; clone E29, dilution 1:400), S100 protein (Da-
ko Corp.; polyclonal antibody, dilution 1:800), neurofilament protein (Dako Corp.; monoclonal antibody, dilution 1:75), smooth muscle actin (Dako Corp.; monoclonal antibody, dilution 1:50), CD34 (Beckton–Dickinson, San Jose, CA; clone HPCA1, dilution 1:20), and CD68 (Dako Corp.; clone KP-1, dilution 1:200). Minced, fresh tissue samples obtained from the patient in Case 1 were primarily fixed in Trump fixative (4% formalin and 1% glutaraldehyde) and were used for electron microscopy.

All patients were evaluated postoperatively. Magnetic resonance imaging was performed in the eight patients studied prospectively. This was done 1 year postoperatively in one patient who experienced recurrent pain and in the other seven for routine surveillance. In addition, the patient in the retrospective group with the longest follow up underwent imaging 10 years postoperatively.

**Part II**

We compared our group of patients in whom the articular branch had been ligated with three separate patients who had been treated nearly a decade earlier, before the surgeons’ awareness of the importance of the articular branch. Despite the fact that, in these cases, the operative notes recorded gross-total resections, we predicted recurrence in these cases based on the fact that the articular branch had

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**Fig. 2.** Case 2. Magnetic resonance images. A: Axial T₁-weighted image obtained at the level of the trifurcation of the CPN, demonstrating the enlarged cystic articular branch (curved white arrow) arising from the DPN (straight black arrow), which exhibits a slight enlargement. Contrast this with the normal uninvolved superficial branch (straight white arrow). B: An FSEIR image obtained at a similar level, demonstrating an increased signal in the articular and DPN branches. The typical pattern of muscle denervation (abnormal hyperintensity) is localized to the anterior compartment musculature (asterisk), which is innervated by the DPN branch. Compare this to the normal lateral compartment musculature (plus sign), which is innervated by the SPN branch. Arrows indicate the same structures listed in A. C: Slightly caudal axial T₁-weighted image obtained at the level of the trifurcation of the CPN demonstrating that the intraneural cyst involves the enlarged, most anterior articular branch (curved white arrow). Note the normal-sized DPN (black arrow) and SPN (white arrow) branches. D: Axial FSEIR image obtained at the same level as the image in C demonstrating abnormal hyperintensity within the proximal DPN, as well as abnormal hyperintensity in the anterior compartment musculature. This image also shows abnormal hyperintensity in interosseous soft tissues below the superior tibiofibular joint. This represents joint fluid that has extended inferiorly from the joint (black arrowhead). Arrows indicate the same structures listed in C.
not been addressed at the operation. The initial presentations of the three patients were similar to those of patients in Part I of our study. Dysfunction of the DPN had been detected clinically and was confirmed electrically as well as by imaging studies. A retrospective reinterpretation of the preoperative MR images obtained in these patients was performed.

Results

Part I

Imaging Findings. In all patients the cysts were found to have a connection to the superior tibiofibular joint capsule, as confirmed by imaging studies and at the operation. In all cases, MR imaging demonstrated a cystic-appearing homogeneous mass in the region of the peroneal nerve (Fig. 1). The lesion was isointense or slightly hypointense on $T_1$-weighted images and hyperintense on $T_2$-weighted ones. There was no internal enhancement within cystic spaces following administration of Gd. Atrophy and a high-intensity signal was also apparent on $T_2$-weighted images within the anterior compartment muscles of the leg, suggesting selective denervation predominantly (Fig. 2). This was correctly identified preoperatively as an intraneural ganglion cyst in all cases in the prospectively followed group. In patients reviewed retrospectively, the differential diagnosis included cystic nerve sheath tumors, intraneural and extra- neural ganglion cysts, and, in one case, a recurrent sarcoma. A retrospective review of all MR images, including the initial images obtained in patients who had recurrences after operations performed elsewhere, demonstrated a connection between the cyst and the joint capsule. This connection was not always noted on the initial imaging report. The “tail” sign, or evidence of the connection between the ganglion cyst and the superior tibiofibular joint capsule, could be best seen in axial slices at the level of the joint or on sagittal images (Fig. 3).

A high-resolution preoperative MR neurogram (obtained using a 3-tesla imaging system) in one patient depicted an enlarged, cystic articular branch (Fig. 2). At the level of

![Fig. 3. Case 2. Sagittal FSEIR MR images obtained in a lateral-to-medial direction, demonstrating the entire course of an intraneural cyst involving the distal CPN, proximal DPN, and its articular branch, which extends anteriorly and medially toward the superior tibiofibular joint.](image)

![Fig. 4. Case 2. Associated bone abnormality found in a patient with a peroneal intraneural ganglion. Axial FSE T$_2$-weighted images with fat suppression revealing a significant lateral subluxation of the patellofemoral joint, chondromalacia, and degenerative joint disease.](image)

![Fig. 5. Case 2. Intraoperative photographs showing a peroneal intraneural ganglion. In this case the high-resolution preoperative MR neurogram (obtained using a 3-tesla imaging system) correlated well with the intraoperative findings of an intraneural ganglion of the articular branch. A: The diseased articular branch (surrounded by a red loop) can be seen passing toward the superior tibiofibular joint. The cyst involves the proximal portion of the DPN and the CPN. A small branch to the tibialis anterior muscle (white arrowhead) arises from the articular branch. Note the normal-appearing DPN and the SPN branches. B: Close-up view showing that the normal SPN branch can be dissected away from the cyst proximally within the CPN. In contrast, the DPN cannot be dissected away easily because it has merged with the cyst.](image)
branching of the CPN, the DPN and SPN branches were seen separately from the inferior segment of this cyst, which clearly appeared to involve the anteriorly positioned, articular branch. Extension of the cyst to the superior tibiofibular joint and to the DPN branch was also demonstrated (Fig. 3). Axial imaging of the CPN revealed eccentric displacement of fascicles by the cyst, the result being a “signet ring” appearance (Fig. 1B).

In four patients, three of whom had undergone previous surgery, there was also imaging evidence of coexisting extraneural ganglia related to the superior tibiofibular joint. In addition, in five patients an abnormal signal was observed on images of the superior tibiofibular joint (this was similar in signal characteristics to the cyst fluid) (Fig. 2D), in four significant arthritic changes were seen in the superior tibiofibular joint, in one an intraosseous cyst of the fibular head was observed, and in 10 patients significant intraarticular pathological conditions (for example, meniscal tears) or advanced arthritic changes involving the knee joint were identified (Fig. 4).

Operative Findings. The intraneural ganglia ranged in length from 4 to 17 cm (mean 10 cm) and often had a characteristic beaded, blisterlike appearance. In two patients the intraneural ganglia were localized to the DPN and the articular branches; in all other patients, the cysts extended proximally to involve the medial portion of the distal CPN (Fig. 5A). The cystic expansion affected the DPN, whereas the SPN could usually be separated away (Fig. 5B). The cystic expansion enlarged where the CPN was relatively uncovered (that is, proximal to the point at which the nerve and its branches passed beneath the peroneus longus muscle), and also involved the lateral portion of the CPN. No cyst extended proximal to the bifurcation of the sciatic nerve.

**Fig. 6.** Case 2. Photograph showing that the articular branch is markedly enlarged. When transected, the branch appears hollow and dark following injection of contrast material. *Inset:* A cross-section of the transected articular branch. The fascicles have been displaced to the periphery.

**Fig. 7.** Case 1. Photomicrographs. **A:** Cross-section of the articular branch of the peroneal nerve showing the ganglion cyst within the epineurium. Fascicles (one indicated by an arrow) are seen to be displaced and are not contiguous with the cyst lumen. **B–D:** Higher-power views of the same portion of the cyst (lumen in upper part of each panel) showing a surface remnant of the cyst’s mucinous content. A collagen stain shows a mild increase in collagen in both the endoneurium and perineurial membrane (C). Mucin is evident, not only in the lumen, but to some extent in the cyst wall (D). Masson trichrome (A and C); H & E (B); and Alcian blue (D).
In all cases, a communication between the intraneural ganglion cyst and the superior tibiofibular joint capsule was demonstrated through the articular branch. In the prospectively studied group, the articular branch was markedly enlarged in five patients. In several instances, the external appearance of the articular branch did not seem cystic until it was transected or aspirated. On cross-section, the articular branch was hollow and filled with fluid in all cases (Fig. 6). The tip of a surgical probe could be passed easily both proximally and distally.

The articular branch was traced to the superior tibiofibular joint in all instances and was transected, ligated, and oversewn near the joint capsule. In all cases, the cyst was decompressed of gelatinous material. In one patient in whom the onset of symptoms was abrupt and posttraumatic, the material was hemorrhagic (similar to that described in a previous report6). In 22 patients, the cyst was drained with only limited internal neurolysis. In one patient with a profound neurological deficit and neuropathic pain, a split repair of DPN fascicles was performed when no nerve action potential was recorded over a damaged nerve segment; two sural nerve cable grafts averaged 5.5 in. In one case, a large, coexisting extraneural intramuscular ganglion cyst was also resected, its pedicle oversewn, and an interpositional muscle graft placed over the capsular defect.

Contrast dye (indigo carmine) injected distally into the articular branch did not pass into the superior tibiofibular joint unless the joint capsule was penetrated by a needle. Only then did the dye pass into the joint, its presence confirmed by intraoperative radiographs. When the dye was injected proximally through the articular branch, the margins of the cyst were well delineated within the DPN component of the CPN.

**Histopathological Findings.** Histopathological examination confirmed the diagnosis of an intraneural ganglion cyst in all cases.

**Two Representative Lesions**

**Macroscopic and Histological Features.** Grossly, the two specimens (Cases 1 and 2) differed. The first specimen (Case 1) measured 2.5 × 0.6 cm and was tubular; its somewhat eccentric lumen had a 0.5-cm diameter. The second specimen (Case 2) measured 4 × 0.6 cm, and was centrally soft and somewhat mucoid in consistency. Introduction of a 2-mm-diameter probe met with ready passage through the lumen in the first specimen (Case 1), but only partial passage in the second specimen (Case 2). Sections stained by H & E displayed nerve fascicles that were well preserved in both cases (Figs. 7 and 8). These fascicles remained somewhat separated by collagenous tissue, being eccentrically displaced by a single epineurial cyst lumen (Case 1; Fig. 7) or by multiple epineurial cysts that were smaller than 1 mm in diameter and had textured walls (Case 2; Fig. 8). In no instance was the perineurium seen to contact the cyst walls directly. The perineurium and endoneurium were uniformly intact, but mild-to-moderate interstitial collagen deposition was seen in both. The smallest cysts, best seen represented by Case 2, consisted of mucin-containing, loosely textured, fibrous connective tissue, in which a thin-walled but collagenous layer surrounded the lumen (Fig. 8). In both cases the larger, well-formed, and apparently older cyst featured a sharply defined lumen lined by a thicker layer of compact, hypocellular, collagen-containing fibroblastic cells (Figs. 7 and 8). No well-formed, uniform lining was seen, but compact and somewhat spindle-like cells were focally evident (Fig. 8). Ultrastructurally, these spindle cells consisted of myofibroblasts (see later description). The cyst content stained weakly basophilic on an H & E–stained section, strongly for Alcian blue (Fig. 7), but only weakly in LFB–PAS– and mucicarmine-stained reactions. No inflammation was noted. No mucinous degeneration of perineurium or endoneurium was noted. The epineurial vasculature was normal. Finally, in Case 1, tissue from the interface of cyst and joint space was available for study. This showed changes similar to those seen in more proximal portions of the cyst, that is, mucus extrusion in the fibrous tissue.

**Immunohistochemical Findings.** The nerve fascicles dis-
played uniform perineurial staining for EMA (Fig. 9A). Endoneurial nerve fibers exhibited normal staining patterns for S100 protein (Schwann cells) and neurofilament protein (axons) (Fig. 9B and C, respectively). The hypocellular cyst walls contained occasional spindle cells or somewhat stellate, vimentin-positive fibroblasts that displayed variable CD34 reactivity. Also present were myofibroblasts showing smooth-muscle immunoreactivity for actin (Fig. 10A). No EMA or S100 protein staining was noted in cells comprising the cyst walls (Fig. 9A and B).

**Ultrastructural Findings.** Study of the cyst wall in Case 1 demonstrated bipolar and, occasionally, multipolar fibroblasts with oval-to-elongated and, often irregularly, indented nuclei as well as moderate quantities of cytoplasm rich in dilated rough endoplasmic reticulum. Golgi and lamellar mitochondria were also present (Fig. 10B). The myofibroblastic nature of some of the cells was evidenced by the additional finding of subplasmalemmal intermediate filaments and dense bodies, as well as occasional pinocytotic vesicles or strips of basal lamina (Fig. 10B). The intercellular matrix was electron lucent and contained normal-appearing collagen fibers. No long-spacing collagen was noted.

**Operative Results.** With a minimum follow-up period of 1 year (mean 3.5 years, range 1–10 years) information on clinical outcomes was available. Significant pain relief was achieved in all patients: complete relief in 17 and moderate relief in seven. Overall neurological function was only mildly improved, more so for sensation than for motor function. The latter improved to an average MRC Grade 3.3 (range 0–5) for muscles innervated by the DPN and Grade 4.2 (range 3–5) for the peroneus longus and brevis muscles in the SPN distribution. In no case did postoperative neurological function deteriorate after our operations. A split repair, which was performed in one patient, did not produce any demonstrable motor function, despite some electrical evidence of reinnervation. Only one patient elected to un-
dergo a posterior tibialis tendon transfer; this tendon transfer augmented the Grade 3 MRC outcome and the patient functioned well in conjunction with an ankle foot orthosis.

In this group of patients, there was no clinical evidence of intraneural recurrence. This was confirmed in all eight postoperative MR images in the prospectively studied group and in the patient with the longest (10-year) follow-up review in the retrospectively studied group. The one patient who underwent concomitant resection of an extraneural ganglion did not experience further extraneural recurrence.

Magnetic resonance imaging in the patient (a 59-year-old man) with the longest follow-up review revealed advanced arthritic changes in the superior tibiofibular joint, which had developed since the operation. Another patient (Case 1) subsequently underwent staged, total knee replacement procedures for bilateral tricompartmental degenerative arthritis.

Complications. Three patients experienced new extraneural ganglia. In one patient who did not experience any symptoms this recurrence was detected on an MR imaging study obtained 1 year postoperatively and was followed clinically. In two patients surgery was performed for recurrent symptoms.

A 70-year-old man (Case 1) had a stable, mild foot drop, but noted improvement in his neuropathic pain postoperatively. Magnetic resonance imaging performed 1 year after the operation revealed several small extraneural cysts within and adjacent to the arthritic superior tibiofibular joint, both anteriorly and posteriorly; the appearance of the cysts on MR imaging remained stable for the next 6 months. After that period, the patient began to experience a combination of neuropathic and mechanical pain following a period of increased loading on the affected limb; on the advice of his physician he had refrained from bearing weight on the contralateral limb following total knee arthroplasty for degenerative joint disease. At that time, MR imaging revealed an increase in the size of the multilocular cyst involving the superior tibiofibular joint, a portion of which was extrinsically compressing the CPN.

A 65-year-old woman (Case 2) with rheumatoid arthritis experienced proximal leg and knee pain soon after a knee effusion 1 year following her operation. Magnetic resonance imaging (Fig. 11) demonstrated two extraneural cysts, both of which were derived from the inferior aspect of the superior tibiofibular joint: one 1 × 1 × 3–cm cyst was located in the posterior tibialis muscle and a smaller one was in the flexor hallucis muscle. This patient experienced a transient episode of new tibial nerve irritation. In each of these patients with symptomatic extraneural recurrences, the superior tibiofibular joint was resected and the extraneural cysts were decompressed but not resected. No further recurrence was noted on follow-up MR imaging at 1 year postoperatively (Fig. 12). Outcomes in these two patients remain quite good for pain and functional improvement compared with these patients’ initial status.

In addition there was one seroma that resolved spontaneously during several months and one postoperative hema-

![Fig. 11. Case 2. An example of extraneural recurrence.](image)
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![Fig. 12. Case 2. Postoperative contrast-enhanced T2-weighted MR images with fat saturation demonstrating the resected superior tibiofibular joint and no recurrence of ganglia. Mild denervation can be seen in the anterior compartment musculature in (A) and mild enhancement in (B) representing a postoperative change.](image)

...toma that produced a painful swelling but no new neurological deficit, which was evacuated successfully on the 4th postoperative day.

**Part II**

Neither the initial interpretation of preoperative MR images nor the operative findings demonstrated a connection to the superior tibiofibular joint in any of the three patients (Fig. 13) included in Part II of this study. As predicted, in all these patients there was retrospective imaging evidence of a connection to the superior tibiofibular joint preoperatively (Fig. 14). A connection between the ganglion cyst and the superior tibiofibular joint capsule via a cystic articular branch was still present (positive tail sign), although it apparently had been unrecognized at the operation. In addition, all three patients experienced early recurrence of their intraneural cysts (within 6 months), as documented by postoperative MR images that still demonstrated a connection between the cyst and the superior tibiofibular joint (Fig. 15). At this short-term follow up, one patient noted a moderate improvement in his pain and a mild improvement in function, one had stable symptoms and a static neurological deficit, and one patient who had moderate immediate neurological improvement after the operation, experienced recrudescence of the original DPN paresis 6 weeks postoperatively. None of these patients requested additional surgery and long-term follow up was unavailable.

**Discussion**

In this series, we have demonstrated a predictable clinical, electrical, and imaging pattern and stereotypical operative findings in patients with peroneal intraneural ganglia. Five additional patients who recently underwent operation and were not included in this study due to short follow up had identical findings to the patients described in this report. The patients typically presented with features consistent with a predominant DPN lesion. Although nearly all our patients had neurological complaints in addition to mechanical and neuropathic pain, one patient presented with vague proximal leg pain and a mass lesion, but no neurological symptoms. Other patients described in the literature occasionally had a painless swelling or pain alone without neurological complaints. Early detection of patients with knee pain may reveal isolated superior tibiofibular joint cystic abnormalities or articular branch involvement before cyst enlargement and proximal dissection have occurred, perhaps even before a long-standing or irreversible neurological deficit develops. The presence of knee pain and the clinical diagnosis of a DPN lesion, especially with a cystic mass, are pathognomonic of this entity. Although rare (~140 reported cases), we believe that intraneural peroneal ganglia1–3,5,7–12 will become increasingly recognized in the future, especially in those patients presenting with knee pain and/or foot drop who undergo MR imaging. A connection to the superior tibiofibular joint could be seen consistently on imaging studies and at operation. A pathological articular branch could be demonstrated, although it was not always obvious. Characteristically, the cyst occupied the medial portion of the distal CPN, the DPN, and the articular branch. Because of the nature of this multicenter study, the purpose of this review is not to establish definitive treatment recommendations for this challenging medical condition. We believe that an operation for intraneural ganglia should...
be directed at decompressing the cyst as well as eradicating the articular branch, without resection of the cyst wall.\textsuperscript{10,11} This approach simplifies the operation by avoiding intraneural dissection, and minimizes the associated risks of further neurological deficit or neuropathic pain.

Currently we are performing joint procedures under the following circumstances: 1) when the joint produces clinical symptoms; 2) in cases of revision or recurrent diseases; 3) when MR images demonstrate that the superior tibiofibular joint is degenerative or has excess fluid; and 4) when there is evidence of coexisting extraneural and intraneural cysts. In these situations, together with articular branch ligation and cyst decompression, we perform a resection arthroplasty of the superior tibiofibular joint; this disconnects the articular branch from the joint capsule and eliminates the synovium.

An analysis of patient outcomes showed that the best results were achieved in pain control.\textsuperscript{5} This probably relates more to cyst decompression accompanied by decreasing intraneural pressure than to neurolysis. Neuropathic pain was relieved, even in selected cases in which the articular branch was not specifically addressed. Pain relief is not universal, however. We evaluated several patients not included in this study who had been referred for refractory pain syndromes and neurological deficits after “simple” procedures (such as percutaneous biopsy), overzealous procedures with extensive internal neurolysis, and/or revision operations following recurrence.

Motor recovery following an operation for peroneal intraneural ganglia was less predictable. Prognostic factors related to motor recovery may include the following: 1) duration of symptoms; 2) extent of the compression; 3) duration of the mass; 4) length of the cyst; and 5) the neural

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**Fig. 14.** The case depicted in Fig. 13 was predicted to recur based on the fact that the operation did not involve distal dissection to identify and treat the articular branch. In fact, when the preoperative MR images were reviewed, the connection to the joint could be seen in this series of images. A–C: Sequential axial FSE T\textsubscript{2}-weighted images with fat saturation revealing the cyst extending proximally from above the fibular neck region to the inferior portion of the superior tibiofibular joint. D: An oblique sagittal reformatted image demonstrating the large cyst (asterisk) and the “tail” at the superior tibiofibular joint (white arrow). E: The availability of two-dimensional data from the initial stored preoperative images allowed the recreation of images of the articular branch by using oblique and curved reformattng techniques. Coronal reformatted image demonstrating continuity of the cyst (asterisk) and the tail at the superior tibiofibular joint (white arrow) via a recurrent cystic articular branch (curved arrow).

**Fig. 15.** Postoperative FSE T\textsubscript{2}-weighted MR images with fat saturation, which were obtained 3 months postoperatively, demonstrating cyst recurrence in the patient shown in Fig. 13. Despite the presence of cyst recurrence on MR images, the patient had good pain control and a mild improvement in neurological function. A: The cyst (asterisk) recurring proximally within the CPN. B: The persistent tail (arrow) from the articular branch remaining connected (curved arrow) to the cyst (asterisk).
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The anatomy of the tibialis anterior muscle, specifically whether a tibialis anterior branch is derived directly from the articular branch [Fig. 5A], or the total number of branches to this muscle). Furthermore, the peroneal nerve generally does not recover as readily as many other nerves. Last, outcomes in patients who have received an intraoperative injury, such as that caused by an injection, a hematoma, and extensive internal neurolysis, are not as favorable as those in patients with injuries due to extrinsic compression. In our experience, peroneal nerve recovery is slightly better after an operation for compressive extraneural ganglia than after one for intraneural ganglia. Still, there were several instances in which patients had marked improvement after operation on their intraneural ganglia, suggesting that cautious optimism is reasonable.

An operation on intraneural ganglia can be especially challenging because of their propensity to recur. We believe that the 10% reported recurrence rate is an underestimate, because most reported cases have short follow-up periods and no postoperative MR imaging. We have demonstrated that subclinical intraneural recurrence is possible, even in patients with fixed deficits or partial recovery. We also believe that extraneural recurrences are both common and logical, and, as we observed, occur both in clinically asymptomatic and symptomatic cases.

The treatment guidelines for intraneural ganglia are evolving and prospective studies will need to be performed to compare various approaches. With more experience and earlier intervention with these ganglia, outcomes will likely improve in the future. Clearly, these patients should participate in long-term follow-up review.

A unified theory describing the pathogenesis of peroneal intraneural ganglia and delineating a treatment rationale will be presented in the following companion article.

Conclusions

The clinical presentation, electrical studies, imaging characteristics, and operative observations regarding peroneal intraneural ganglia are predictable. The articular branch connection to the superior tibiofibular joint is a significant component of the pathogenesis and must be sought out in all cases.

Acknowledgments

We appreciate the assistance of Doris E. Wenger, M.D., Rochester, Minnesota, and Jerry Ortiz, A.R.R.T. and Denise Echelard, M.R.I.T., Seattle, Washington.

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