Surgical Techniques

Morton Neuroma: Primary and Secondary Neurectomy

orton neuroma, or interdigital Lneuritis, is a compression neuropathy with associated perineural fibrosis that is caused by entrapment of the interdigital nerve near the distal edge of the transverse intermetatarsal ligament. The second and third interdigital nerves in the forefoot are most commonly involved. In one series, Morton neuroma was found to occur at an average age of 55 years (range, 29 to 81 years), predominantly in women.¹ Most patients can be treated nonsurgically with shoe wear modification, plantar pad placement, nonsteroidal antiinflammatory drugs, Achilles stretching, and, on a limited basis, cortisone injection. Surgical treatment should be reserved for select patients with a clear diagnosis. Surgery is done to decompress the entrapped interdigital nerve by transecting the intermetatarsal ligament, releasing or resecting the interdigital nerve itself, and/or releasing any nerve branches causing tethering, thereby allowing the nerve to move more proximally away from the weight-bearing portion of the forefoot.

Patient history and physical examination are required to confirm the exact location of the neuroma (Figure 1). Careful palpation along the interdigital nerves is helpful in determining the location of compression and whether additional nerves are symptomatic. Confirmatory, but not necessarily pathognomonic, signs include reproducible pain and paresthesias with plantar pressure directed between the metatarsal heads (Figure 2), reproducible painful click upon simultaneously squeezing the forefoot while pushing upward with the thumb in the involved interspace (ie, Mulder sign), and symptomatic relief following a selective lidocaine injec-

tion beneath the intermetatarsal ligament approximately 2 cm proximal to the metatarsal head. Magnetic resonance imaging or ultrasound can be used to support the diagnosis and may have prognostic value, but clinical evaluation is critical for diagnosis.

Indications and Contraindications

Careful patient screening prior to surgical intervention is important. Although surgery to manage Morton neuroma has been reported to be successful in 51% to 85% of patients, 2-7 it is associated with a host of potential complications. The primary indications for surgical treatment of a Morton neuroma are failure of prior nonsurgical measures (eg, metatarsal pads) and a successful response, even if temporary, following injection with local anesthetic.

For accurate diagnosis, it is important to confirm that the local anesthetic was well placed. Numbness of the toes innervated by that nerve should be evident when the injection is administered. For example, if there is a second-web-space neuroma and a proper injection is done, there should be numbness in the lateral surface of the second toe and in the medial surface of the third toe. This is indicative of common digital nerve block. With this finding of numbness and patient-reported pain relief, a diagnosis can be more firmly established. Numbness with pain is indicative of another disorder (eg, metatarsophalangeal synovitis, stress fracture, arthritis). Another injection is required if the patient has no numbness and no pain relief following the initial injection.

Contraindications to surgical intervention include poor response



Craig I. Title, MD

Lew C. Schon, MD

The video that accompanies this article is "Morton's Neuroma," available on the Orthopaedic Knowledge Online Website, at

http://www5.aaos.org/oko/jaaos/surgical. cfm

Dr. Title is Orthopaedic Surgeon, New York, NY. Dr. Schon is Director, Foot and Ankle Services, Union Memorial Orthopaedics, Baltimore, MD, and Assistant Professor, Department of Orthopaedic Surgery, The Johns Hopkins University School of Medicine, Baltimore.

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Reprint requests: Dr. Schon, Union Memorial Orthopaedics, The Johnston Professional Building, #400, 3333 North Calvert Street, Baltimore, MD 21218.

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<figure>

Mapping of the plantar digital nerves of the sole of the foot and the medial heel. **A**, Plantar view of the foot demonstrating mapping of the distal branches of the tibial nerve. **B**, Oblique view of the sole of the foot and medial heel. MM = medial malleolus, ST = sustenaculum tali. (Reproduced from Title CI, Schon LC: Morton's neuroma. *Orthopaedic Knowledge Online*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2005.)

from a well-placed diagnostic lidocaine injection about the common digital nerve, inadequate wound healing potential (eg, poor circulatory system), and distal neuropathy with nonfocal nerve tenderness. A patient with a history of complex regional pain syndrome (CRPS) that is nonneurogenic and cannot be attributed either to initial trauma or surgery to the common digital nerve is a poor candidate for surgical treatment. Multiple previous steroid injections put the patient at increased risk for skin complications⁸ (eg, infection, wound healing problems). However, this alone is not a contraindication for surgery.

Surgical Technique

Surgical options for managing primary Morton neuroma include the following, either alone or in combination: neurectomy (dorsal or plantar approach), neurectomy with nerve burial (ie, intermuscular transposition), transverse intermetatarsal ligament release with or without neurolysis, and endoscopic decompression of the transverse metatarsal ligament. A dorsal, plantar longitudinal, or plantar transverse approach may be used. For revision surgery, an alternative approach to the primary incision may be indicated.

Most neuromas occur within the second or third interspace. Simultaneous neuromas in two adjacent interspaces are rare, occurring in 2% to 3% of patients.^{13,9,10} Further diagnoses (eg, inflammatory arthritis) should be considered in the patient with multiple Morton neuroma.²

As with most distal lower extremity surgery, an ankle block anesthetic is used in combination with sedation. The patient is positioned supine for a primary or revision procedure and prone for revision via a plantar approach. An Esmarch tourniquet is usually recommended to aid in visualization. However, some



Technique for focal palpation of nerve tenderness without applying dorsal compression. Careful palpation of the plantar nerves is performed, taking care to avoid inadvertent dorsal compression (**(()**). Dorsal palpation may induce pain associated with a stress fracture, metatarsophalangeal synovitis, or dorsal neuralgia. The arrow indicates the pressure point and the yellow lines, the course of the nerves. The large oval indicates the area where the thumb presses on the plantar neuroma in the common digital nerve as it bifurcates. O indicates that care should be taken not to apply dorsal counterpressure. Use of dorsal pressure with Morton neuroma makes the test less specific and less sensitive. The pressure direction should be plantar to dorsal only. (Reproduced from Title CI, Schon LC: Morton's neuroma. Orthopaedic Knowledge Online. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2005.)

surgeons find it easier to identify the location of the interdigital artery and nerve during exposure when the foot is not exsanguinated. Loupe magnification, a Freer elevator, Stevens tenotomy scissors, a Weitlaner retractor, a small lamina spreader, and small vessel loops may be useful during the surgical procedure.

Primary Neurectomy

A dorsal incision 3 to 4 cm in length is begun just proximal to the involved web space (W video). This incision will provide an adequate

Figure 3



A, A lamina spreader is used to expose an intact taut intermetatarsal ligament (arrow). **B**, Following ligament release, the nerve can be delivered into the wound. A vessel loop has been placed around the nerve. **C**, Resected digital nerve. (Reproduced from Title CI, Schon LC: Morton's neuroma. *Orthopaedic Knowledge Online*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2005.)

view of the proximal plantar nerve branches that must be later identified and transected. Deeper dissection is performed bluntly, with care taken to avoid the branches of the superficial peroneal nerve. To aid in visualization, a Weitlaner retractor is placed in the superficial wound.

Once the level of the metatarsals has been reached, a small lamina spreader is positioned just proximal to the metatarsal head (Figure 3, A). Use of a hemostat to provide distraction between the metatarsals will often aid in the placement of the lamina spreader. Careful opening of the lamina spreader generates tension on and assists in the identification of the transverse metatarsal ligament. A Freer elevator is slipped under the ligament and is used to gently push the neurovascular bundle more plantarly, shielding it as the ligament is transected from distal to proximal.

It is critical to carefully isolate the nerve from the more dorsal artery and the lumbrical tendon. Identification of the interdigital nerve is facilitated by not exsanguinating the foot. This allows better location of the digital artery and vein that surround the digital nerve. The surgeon's thumb may be used to apply a dorsally directed force from the plantar intermetatarsal space to help push the nerve into view. Initially it may be helpful to identify the nerve by tracing it from the distal nerve bifurcation more proximally to the common digital nerve. A vessel loop may be placed around the nerve to apply traction while freeing the nerve and its branches from the adjacent structures (Figure 3, B).

Both proper nerve branches are pulled proximally into view, grasped, and resected just distal to the bifurcation. The distal cut end is then delivered out of the wound and is pulled distally to apply tension. This aids in identifying the more proximal plantar nerve branches, which all are subsequently resected. The interdigital nerve is then transected as far proximally as possible using Stevens tenotomy scissors (Figure 3, C).

Instability between the metatarsal heads has not been reported. Thus, it is not necessary to reapproximate the intermetatarsal ligament at the end of the procedure. If a tourniquet was used, it should be deflated prior to skin closure to enable coagulation in any bleeding vessels that may otherwise predispose the patient to adhesion formation or hematoma. The wound is irrigated, and the skin edges are carefully reapproximated using interrupted or running subcuticular 4-0 sutures.

A forefoot compression wrap is used for the first 2 to 5 weeks to minimize metatarsal head splaying, permit healing of the intermetatarsal ligament, reduce swelling, and provide better comfort. The patient is initially permitted heel weightbearing as tolerated in a postoperative sole. Early range-of-motion exercises of the toes and ankle are encouraged. Sutures are removed at 10 days postoperatively, and activity is gradually progressed. Typically, patients are permitted a gradual increase in activities as tolerated at 1 month postoperatively. It is not uncommon for patients to experience forefoot discomfort, neuritic pain, and swelling during the recovery period. Patients are advised that they will be 75% healed by 3 months postoperatively and 90% healed by 6 months.

Revision Neurectomy

Recurrent painful neuroma is often a result of inadequate proximal nerve resection or incomplete resection of tethering plantar nerve branches.^{6,11,12} It may also occur from incorrect identification of the involved nerve. Patients with diffuse neuropathy or proximal nerve sensitivity from tarsal tunnel syndrome or a herniated disk may not respond to surgery; such patients usually are poor candidates for revision surgery. Poor response to prior surgery also may be related to the existence of other local pathologies, such as metatarsophalangeal joint disorders (eg, subluxation, dislocation, deviation, synovitis, arthritis), fat pad atrophy or insufficiency, unrecognized stress fracture, and Achilles contracture. Unsuccessful results occur in 15% to 40% of patients.²⁻⁷ Either a dorsal or a plantar approach may be used for revision neurectomy. A plantar approach provides a more direct exposure to the nerve in an area with less secondary adhesion formation caused by the primary dissection.

Dorsal Approach

When using the dorsal approach, the surgeon must be sure to extend the original incision proximally, carefully identify and resect all tethering plantar nerve branches, and transect the nerve well proximal to the level of the metatarsal heads (Figure 4). The surgeon should use a long enough proximal exposure and skin incision, including the previous scar. Injury to the superficial peroneal nerve branches must be avoided. The lamina spreader is inserted, taking care to avoid causing metatarsal fracture or disruption of neighboring joint capsules, as well as instability of either the metatarsophalangeal joint or the metatarsal cuneiform joint. Care must be taken to avoid

injury to the vessels and the lumbrical tendon, which lie just underneath the transverse metatarsal ligament and dorsally over the nerve. Inadvertent laceration of the lumbrical tendon may lead to splaying of the toes. The tendon should be repaired if it is divided.

Whenever possible, the surgeon should avoid resecting two intermetatarsal nerves from adjacent spaces as this will result in dense sensory loss of the central toe.⁹ Occasionally, inadvertent transection of the accompanying vein and artery results in vascular compromise to the central toe. When two adjacent neuromas are diagnosed, one option is to resect the more symptomatic nerve or the larger-appearing one during surgery, followed by ligamentous release of the less involved intermetatarsal space.

It is important to identify and resect all multiple plantar branches of the interdigital nerve just proximal to the level of the metatarsal heads. Otherwise, these branches will tether the interdigital nerve, preventing its proximal retraction off the weight-bearing portion of the forefoot.^{1,2,6,11} An uncut retained branch that originates proximally may be a conduit for persistent neuritic syndromes. The surgeon must be careful to avoid injury to the superficial peroneal nerve branches upon exposure.

Plantar Approaches

Two variations exist for approaching the nerve plantarly: transverse and longitudinal. A transverse incision permits greater exposure for multiple nerve dissections, while a longitudinal incision allows for more proximal resection and burial of the nerve endings. Both plantar approaches have the advantage of more readily avoiding the plantar digital artery and vein, with less traumatic exposure and decreased residual sensory loss.^{13,14} Dorsal scar tissue, which can make exposure difficult, is circumvented with a plantar approach. The challenges of these



The dorsal approach for surgical management of Morton neuroma. The second, third, and fourth metatarsal heads are labeled. The dorsal incision (arrow) is placed between the metatarsals, avoiding the dorsal branches of the superficial peroneal nerve (SPN). DPN = deep peroneal nerve

approaches are identifying the nerve from this less commonly used exposure and avoiding a painful scar on a weight-bearing surface.

Plantar Transverse Approach The plantar transverse incision should be made 1 cm proximal to the weightbearing area of the metatarsal heads to enable exposure of the adjacent interdigital nerve (Figure 5). With this approach, it is easier to avoid injury to the artery, vein, and tendon because the dissection is proximal to the place at which these structures are more intermingled. The incision is located within the skin fold lines, making it cosmetic and well tolerated. Because the exposure is proximal to the pathology, the surgeon must be confident that nothing in the web space requires resection. Some expe-

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The plantar transverse approach for surgical treatment of a Morton neuroma, demonstrating the course of the asymptomatic nerves. (Reproduced from Title CI, Schon LC: Morton's neuroma. Orthopaedic Knowledge Online. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2005.)

rience is necessary to be comfortable with this approach and with the orientation.

To avoid creating abnormal softtissue planes, dissection should be performed straight down through the subcutaneous fat and then immediately through the plantar fascia (Figure 6, A). The interdigital nerve is exposed immediately deep to the plantar fascia within the adipose tissue between the flexor digitorum longus tendons (Figure 6, B). Aberrant or accessory nerve branches can be identified in this area (Figure 6, C and D). The nerve can be transected proximally (Figure 6, E). Adjacent in-

Figure 6











A, Plantar transverse approach for Morton neuroma surgery. Revision neurectomy is performed through a transverse incision proximal to the metatarsal heads, involving the second and third web-space neuromas. **B**, Close-up view demonstrating the course of the common digital nerve, perpendicular to the incision. **C**, The two adjacent nerves are identified. **D**, Close-up of panel C. **E**, The proximal aspect of the nerve has been cut. **F**, Two nerves have been cut and excised. In general, two nerves are not resected because of the potential for central toe numbness. (Reproduced from Title CI, Schon LC: Morton's neuroma. *Orthopaedic Knowledge Online*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2005.)



The plantar longitudinal approach for surgical treatment of a Morton neuroma. (Reproduced from Title CI, Schon LC: Morton's neuroma. *Orthopaedic Knowledge Online*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2005.)

terdigital neuroma can be approached by widening the incision (Figure 6, F). The wound is closed with 4-0 nylon suture. A compression dressing is applied for 10 to 14 days, at which time the sutures are removed. A circumferential wrap is recommended to support the foot and provide comfort as the patient progresses with weight bearing.

Plantar Longitudinal Approach The plantar longitudinal incision is reported to be more cosmetic than a dorsal approach because it runs parallel to the lines of the connective tissue fibers. To avoid scarring directly under the metatarsal head, the plantar longitudinal incision should

Figure 8





be centered directly over the intermetatarsal space. Typically, the incision is made approximately 1 to 2 cm proximal to the proximal end of the metatarsal head (Figure 7). It can be continued distally between the metatarsal heads or proximally into the midfoot. This exposure permits identification and resection of distal pathology as well as higher transection with or without nerve burial (ie, transposition).

To avoid creating abnormal softtissue planes, dissection should be performed straight down through the subcutaneous fat and then immediately through the plantar fascia. The interdigital nerve is exposed immediately deep to the plantar fascia within the adipose tissue between the flexor digitorum longus tendons. Aberrant or accessory nerve branches can be identified in this area (Figure 8, A and B). The nerve can be transected as proximally as possible. If desired, it can be kept slightly longer to permit transposition into



A, Vessel loops have been placed beneath three nerves that were found in the area immediately deep to the plantar fascia within the adipose tissue between the flexor digitorum longus tendons. **B**, Retraction enables excellent visualization of these structures. **C**, Resected plantar nerve from a patient with suspected recurrent and adjacent neuroma. (Reproduced from Title CI, Schon LC: Morton's neuroma. *Orthopaedic Knowledge Online*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2005.)

muscle (Figure 8, C).

When a transposition is performed, the end of the epineurium of the transected nerve can be held with a 4-0 Vicryl suture (Ethicon, Somerville, NJ) (Figure 9). The suture is fed through a straight needle (eg, Keith needle), and then the needle is passed through muscles between the metatarsals, finally penetrating the dorsum of the foot. With the nerve end within the muscle belly, the suture can be tied on the dorsal aspect of the foot to help keep the nerve in place during the first 10 to 14 days postoperatively.

The wound is closed with 4-0 nylon suture. A compression dressing is applied for 10 to 14 days, until suture removal. An elastic wrap is recommended while the patient progresses with weight bearing.

Complications

CRPS type 2 (ie, sympathetically mediated nerve pain) is one potential

Figure 9



Prone positioning of a patient treated with revision neurectomy involving the distal branches of the medial plantar nerve. This position facilitates exposure of the plantar aspect of the foot. **A**, In this patient, a more proximal exposure was necessary to reveal the pathologic nerves. The vessel loop is seen beneath the branches of the medial plantar nerve. **B**, Close-up view demonstrating the transected nerve with a Vicryl epineurial suture (Ethicon), in preparation for transposition into the medial and dorsal musculature. (Reproduced from Title CI, Schon LC: Morton's neuroma. *Orthopaedic Knowledge Online*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2005.)

complication after surgery to manage a Morton neuroma. Severe intractable neuralgia with or without sympathetic involvement (ie, CRPS type 2) is uncommon. Infection, which is rare (<1%),² may be associated with previous steroid injection, atrophic skin, or wound site contamination from previous surgery. In the experience of one author (LCS), the risk of wound dehiscence is low; the patient who has previously been treated with steroid injection is at greatest risk for this complication. The occurrence of synovial cyst or sinus is approximately 1%, resulting from trauma to the joint before or during surgery or during wound healing. Ischemic changes or cold intolerance with a tendency toward frostbite are uncommon. The patient undergoing adjacent neuroma resection is at risk of arterial damage to the common digital arteries.

Anesthesia is typical in the adja-

cent aspects of the toes. If two web spaces are affected, then the entire toe may be numb. A pathologic variation of this phenomenon is anesthesia doloroso (painful numbness), which occurs in <1% of patients in our experience. Anesthesia of the toe is occasionally accompanied by severe dysesthesia or hyperesthesia. Anesthesia doloroso reflects a deafferentation phenomenon that is typical following nerve transection. The painful sensations are attributable to signals being carried by the adjacent nerves and/or the sympathetic nerve system. This condition can be observed as a typical transient phenomenon following nerve transection, but in the pathologic state it persists.

Painful hypertrophic plantar scar occurs in a small number of patients. Such scarring is particularly problematic if the incision is made between metatarsal heads or, worse, directly beneath the metatarsal heads.

Recurrent neuroma may occur as a result of an incorrect neurologic diagnosis, such as believing that an adjacent web space is causing symptoms. Alternately, it may be caused by persistent neuroma in the correct web space, radiculopathy, peripheral neuropathy, or tarsal tunnel syndrome. Recurrent neuroma may also occur following surgery for a nonneurologic diagnosis (ie, an incorrect initial impression). For example, a surgeon may misdiagnose and incorrectly treat with nerve transection a capsular, ligamentous, or synovial condition of the metatarsophalangeal joint; stress fracture or osteonecrosis of the metatarsal head; or arthritis. Stump neuroma may occur if the end of the nerve is not cut back proximally enough and remains symptomatic.

Summary

For a patient with symptomatic neuroma who has not improved with nonsurgical treatment and who has experienced even temporary improvement associated with a local nerve block (ie, lidocaine injection), we prefer to perform primary release of the transverse metatarsal ligament and neurectomy via a dorsal approach. Successful results following primary surgical treatment are expected in 51% to 85% of patients, with 70% having some limitations in shoe wear and up to 38% requiring activity restriction.²⁻⁷ Patients with residual pain may still report a satisfactory result.²

For stump neuromas, we prefer a plantar revision approach because it permits a more direct and extensile exposure of the nerve. There is less secondary scar formation with the plantar approach, and it is easier to identify neurovascular structures and branches. For patients who have had multiple prior resections, the cut nerve should be buried between the metatarsals. Successful results following revision neurectomy range from 60% to 80%.^{1,12,14}

Pearls

- To ensure an accurate diagnosis, the surgeon should perform a thorough patient history and physical examination along with a diagnostic lidocaine injection.
- The focal physical examination should include palpation of the nerve, joint, and bone as well as provocative stress maneuvers (eg, dorsal metatarsophalangeal drawer sign, dorsal metatarsophalangeal translation, squeezing together of the metatarsal heads). The examiner should be able to reproduce the neuritic symptoms. Comparison with the contralateral side may be helpful.
- A dorsal incision should be used for primary surgical treatment.
- The nerve should be transected as far proximally as possible to avoid weight-bearing zones, such as the metatarsal heads.
- A plantar approach should be used for revision neuromas, keeping the scar off the weight-bearing surface, if possible.

Pitfalls

- A "failed" response to a local anesthetic may be indicative of a poorly placed injection. Numbness in the anticipated zone and lack of pain relief indicate that the targeted nerve is the source of the pain.
- In a dorsal approach, the surgeon must take care not to incorrectly identify the lumbrical tendon as the distal nerve (or neuroma); transection of the lumbrical and not the nerve would lead to failure of the procedure and potential toe deviation.
- It is sometimes difficult to identify the nerve via the plantar approach. The nerve should be located deep to the plantar fascia in the zone of adipose tissue between the flexor tendons of the adjacent toes.
- Occasionally, a nerve will bifurcate or send out an aberrant branch just proximal to the location of the transection. In these situations, the nerve signals will continue to be carried, and pain will persist after transection. Medial, lateral, or proximal exploration in the adjacent tissues can help to identify these branches.
- A dorsal approach, when used either primarily or secondarily, is more likely than a plantar approach to result in vascular injury.

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Citation numbers printed in **bold type** indicate references published in the past 5 years.

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