Preservation of the First Ray in Patients with Diabetes

Surgical approaches are often necessary to off-load excessive pressure.

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Introduction

In approaching diabetic neuropathic ulcers, the aim is to heal these wounds as quickly and effectively as possible. When these wounds become chronic or have bony involvement, attention is then directed beyond conservative options. A chronic, diabetic, neuropathic ulcer almost always involves an imbalance of pressure on the load-bearing areas of the foot, and, as with any wound, there is always the risk of soft tissue infection and osteomyelitis.

It is concerning when an amputation is required, particularly when it involves the first ray. The importance of the first ray during biomechanics of the gait cycle and mechanical stability of the medial column is well documented. Even with advances in conservative off-loading devices, there still remains a high risk of re-ulceration and a more proximal amputation due to loss of stability and mechanics. This article will describe surgical approaches for salvaging the first ray in the setting of diabetes, neuropathy, and chronic ulcers of the first ray.

Figure 1: Chronic hallux ulcer in patient with diabetes

Things to Consider

Repeated stress cycles resulting in excess pressures on the plantar foot result in unhealthy buildup of hyperkeratotic tissue. This becomes especially significant in a diabetic population as stiffening of tissue also occurs due to repeated glycosylation. Fernando, et al. found that in diabetic patients with active ulceration, plantar pressures were found to be greater despite a longer stance phase.[1] In the setting of peripheral neuropathy, the combination of increased pressures and stiffening of tissues and hyperkeratotic build-up risks the formation of a wound. There is literature to support the notion of exploring options of salvage prior to considering a definitive amputation. Lavery, et al. found that following a great toe amputation, there was subsequent increase in plantar pressure onto the lesser metatarsals as compared to the contralateral non-amputated foot.[2] Quebedeaux, et al. reinforced this finding by demonstrating that not only are plantar pressure distributions altered, but there is increased risk in developing deformities to the lesser toes as well as to the metatarsal-phalangeal joints (MTPJ).[3]

When more proximal wounds along the first ray are present, a larger portion of the ray is at risk for chronic ulcerations or osteomyelitis. Bowker, et al. found that if any portion of the first ray is lost, function of the medial column can then become compromised during propulsion and in stance phases.[4] Murdoch, et al. found a correlation between having a great toe or partial first ray amputation and needing a further amputation within an average of 10 months of the initial procedure.[5] A more recent study in 2013 by Borkosky, et al. found 70 percent of patients had ulcer recurrence after partial first ray amputations. Additionally, more than 40 percent of cases needed a more proximal amputation within two years.[6]

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Similarly, Kadukammakal, et al. found comparably high rates of a more proximal procedure being needed after partial first ray amputation, as 12 of 24 of patients progressed to trans-metatarsal amputation (TMA).[7] Dalla Paola, et al. found a large reduction with only a 17 percent re-ulceration rate following a partial amputation. As part of this study, all patients were enrolled into an intensive offloading program.[8]

There is significant evidence that shows a high risk for re-ulceration and the need for additional procedures following an amputation of the first ray. It is thus important to consider surgical approaches in dealing with this common pathology and further limit the need for additional intervention.

Figure 2: Patient healed wound after arthroplasty of the hallux interphalangeal joint.

Surgical Approach of the Great Toe

Chronic great toe (hallux) ulcerations commonly also have some degree of limited motion, contributing excess pressures and subsequent wound formation.[9,10] When considering a surgical intervention for these wounds, relieving some of this limited motion, at least in theory, should relieve some of the excess pressures. This can ideally be accomplished without losing the great toe completely. This leads to faster-healing wounds, a lower risk for future transfer lesions, and a lower risk for any possible gait abnormalities.

Rosenblum, et al. found that interphalangeal (IPJ) arthroplasty successfully prevented great toe amputation of chronic hallux ulcerations, completely healing the wound in 91 percent of cases. They concluded that "interphalangeal arthroplasty is a valuable procedure that allows the hallux ulcer to heal, avoiding amputation by maintaining function and structure to the area."[11] Twenty-two years later, Lew et al. found quicker healing times (three and a half weeks vs. nine weeks), less recurrence of ulceration (7.7% vs 53.9%) and no amputations required (0% vs. 38.5%) compared to a non-surgical group after an IPJ arthroplasty. They concluded that the hallux IPJ arthroplasty is a "viable option in preventing hallux ulcer recurrence and amputations in the setting of diabetic peripheral neuropathy." (Figures 1 and 2)[12]

Surgical treatment of chronic hallux ulcers is not limited to the hallux; intervention can also be directed to the MTPJ. MTPJ arthroplasty can also relieve pressures created by hallux rigidus. Armstrong, et al. performed resection of the base of the first proximal phalanx (Keller osteotomy) for patients with chronic hallux ulcerations and compared healing times to a non-surgical group. They found that chronic hallux ulcerations healed significantly faster (24.2 days vs. 67.1 days) with fewer recurrence rates (4.8% vs. 35%) within the six-month follow-up following the arthroplasty.[13] Tamir, et al. supported this finding as they retrospectively reviewed results of recalcitrant hallux ulcers after a first MTPJ resection. They found the wounds healed in an average of 3.1 weeks after the procedure. Further, they found 78 percent of cases did not have a recurrence of ulceration in their 26 month follow-up.[14]

Understanding the etiology of these particular wounds becomes crucial and will aid in determining how they can be addressed. In the setting of chronic hallux ulcerations, there are reproducible surgical off-loading procedures, which can be addressed at multiple anatomical levels. These procedures have shown to heal wounds faster, decrease the rate of recurrent ulcerations and decrease risk for future great toe amputations.

Figure 3: Chronic sub-first metatarsal head ulcer in patient with diabetes.

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Surgical Approach of the First Metatarsal

The plantar first metatarsal head is also a common place where ulceration is encountered along the first ray. It is especially important to preserve the first metatarsal as it is a major structure for propulsion during the normal gait cycle. The first metatarsal can be altered in multiple planes as commonly seen in procedures for hallux valgus or hallux limitus. These same concepts can be applied to plantar first metatarsal head ulcerations. Fleischli, et al. described treating plantar first metatarsal head ulcers with a first metatarsal base dorsiflexion osteoto-

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my through a dorsal incision. They found approximately 95 percent of wounds healed in an average of forty days. Although they had a high incidence of complications, they concluded that this was a "reliable salvage procedure of the first ray in the setting of recalcitrant neuropathic ulcers."(Figures 3 and 4).[15]

Johnson, et al. performed a retrospective review of treating first metatarsal head wounds with a one stage resection of the first metatarsal phalangeal joint with pin stabilization. The temporary fixation allowed formation of a stiff fibrous union, which they argue recaptured some of the stability that is lost by the resection of the joint. 95 percent of the ulcers healed, with only 17 percent of ulcer recurrence under the first metatarsal head.[16]

Figure 4: Status post-first metatarsal dorsiflexory osteotomy.

Dalla Paola, et al. described treating these wounds with excision of the ulcer, resection of the base of the proximal phalanx and metatarsal head, followed by placement of antibiotic cement, stabilizing the area with a pin, and external fixation. Results showed 24 of 28 cases healed without ulcer recurrence or transfer lesions. They concluded that this as an "effective one-stage salvage approach with chronic ulceration/osteomyelitis of the first ray."[17]

Roukis and Landsman described a case study involving a two-staged procedure. The first procedure involved resection of the infected bone, antibiotic bead placement and stabilization by an external fixator. The second procedure consisted of a first MTPJ fusion with iliac crest bone graft. The patient successfully fused within three months and was complication-free during the 12 months follow-up period.[18]

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Plantar first metatarsal head ulcerations in the setting of diabetic peripheral neuropathy places the entire first ray at risk for amputation. Due to the significant role of the first ray in the gait cycle and overall stability of the foot, preservation of as much of the ray, is imperative. There are multiple options in addressing these plantar wounds without initially jumping to definitive amputation.

Surgically altering the first metatarsal with a dorsiflexory osteotomy can aid in off-loading some of the excess pressure at the metatarsal head. Resecting first MTPJ effectively eliminates the excess pressure caused by the first metatarsal head and any limited motion that may have been present at the joint (Figures 5 and 6). There also appears to be a role for temporary fixation following the resection, which allows some stability to be recuperated. This should allow for a more normal gait cycle. These procedures should be considered a viable alternative to definitive amputation.

Role of Soft Tissue Balancing

Evaluation of equinus is commonly assessed for numerous pathologies involving the foot and is often addressed while performing a TMA in this diabetic population. The same techniques can be applied to neuropathic ulcerations along the first ray. Considering a tendo-Achilles lengthening (TAL) alone may not be enough to completely address a first ray ulceration, but can adjunctively improve function of these corrective procedures by further decreasing plantar pressures. Mueller et al. compared Achilles tendon lengthening versus total contact casting (TCC) for plantar neuropathic ulcers. They found similar rates of healing: 88 percent for the TCC group and 100 percent for the Achilles lengthening group. However, at the two-year follow-up, they found the Achilles lengthening group had significantly lower rates of ulcer recurrence compared to the TCC group (81% vs. 38%). It was concluded that Achilles lengthening can help reduce the recurrence of plantar neuropathic ulceration.[19]

Figure 5: Non-healing neuropathic ulcer beneath first metatarsal head.

There is also still a role for TAL if a partial first ray amputation is required. Cunha, et al. retrospective-

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ly reviewed patients who received a prophylactic percutaneous Achilles tendon lengthening with concurrent partial first ray amputation versus patients who had the amputation without the Achilles tendon lengthening. They found 8 of 12 patients who initially received a TAL along with their first ray amputation did not have new or recurrent ulcerations. All cases who did not receive a TAL with the initial amputation developed further ulcerations that required additional debridement and further amputation for some.[20]

When dealing with distal neuropathic ulcerations of the foot, one should always evaluate the role of limited dorsiflexion and determine if it is a factor contributing to the etiology of the ulceration. Achilles tendon lengthening is a reproducible and effective procedure in the setting of equinus and plantar diabetic neuropathic ulcerations.

Discussion

For first ray diabetic neuropathic ulcers, the primary contributing factor is excess pressure. When these wounds enter the realm of chronic in the setting of failed conservative treatment or progression to infection, one must consider a more aggressive approach. Whether the wound is on the hallux or more proximal along the first ray, these wounds must not obtain deeper involvement in order to decrease the risk of osteomyelitis. Dalla Paola, et al. found a much lower than historical rate of re-ulceration following a partial first ray amputation when patients were enrolled into a strict intensive off-loading program.[8] Even with enrollment into this program, almost one in five patients still had recurrence of ulceration. It also must be considered that not all facilities or providers may have the ability to provide patients with such an extensive program.

There is also a financial burden that might have an effect on patients and/or the provider. Biomechanical consequences in the form of altered distribution of pressures following a great toe amputation can present with high risk for transfer lesions or deformities at the level of the lesser digits.[2,3] When a more proximal amputation along the first ray is required, the risk for ulceration in the same or another part of the foot increases.[5-7] In the setting of chronic hallux ulcerations, IPJ arthroplasty, or MTPJ arthroplasty have been shown to be reproducible surgical options allowing the hallux wound to be surgically off-loaded, while still preserving overall structure of the first ray.[11-14] These procedures allow the hallux enough relief from focal pressures to allow the wounds to heal.

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When addressing plantar first metatarsal head ulcerations, similar principles from everyday bunion surgeries can be applied to surgically off-load the metatarsal head. Such procedures as a dorsiflexory base wedge osteotomy can successfully off-load the metatarsal head without disrupting the first ray in its entirety.[15] As with any surgical procedure, these procedures do carry risk. Regarding the first metatarsal base dorsiflexion osteotomy, there was a 65 percent complication rate. In particular, there were a significant number of patients developing Charcot. All procedures still run the risk of infection and recurrent ulcerations as well as new transfer ulcerations.

Figure 6: Foot healed after first metatarsal head resection.

Resection of the MTPJ (with or without fusion) with short-term fixation to the area has also been shown to treat recalcitrant wounds while still allowing some stability and preservation of the first ray versus outright amputation. The literature has shown success with short-term fixation such as a pin or external fixator, and can play a role in allowing overall length of the ray to be preserved while providing concurrent stability in the proper position. With any fixation that integrates both the internal and external environment, a portal for entry for infection is then created and remains open until the fixation is removed.

Also, adjunctive soft tissue balancing has a significant role preserving the first ray. In comparison with TCC, considered the gold standard of conservative offloading, TAL provided better long-term outcomes versus conservative TCC off-loading alone. This implies that soft tissue re-balancing has a crucial role in healing these neuropathic plantar ulcers. When addressing the soft tissue, careful attention must be paid to avoid over-correcting the soft tissue which, in the setting of TAL, may result in a calcaneal gait.

In addition to surgically off-loading of these diabetic neuropathic wounds, there is still a need for proper wound care and conservative off-loading. It is also crucial to evaluate for adequate vascular supply and ensuring that the area is free of infec-

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tion. With a multi-pronged approach, combining surgical and conservative principles, the patient reaches the highest probability to heal these wounds.

Conclusion

Aggressive management of diabetic wounds along the first ray is crucial. The first ray plays a significant role in gait stability and biomechanics and thus requires special attention. Loss of integrity to this area can often lead to altered pressure distribution and mechanics that can be detrimental to other areas of the foot. Excess pressure plays a significant role in the etiology of such wounds. There is significant literature showing that loss of the great toe or a partial first ray amputation increases the risk for recurrent ulceration and further risks a more proximal amputation.

In treatment of chronic hallux ulcerations, there are reliable reproducible procedures to aid in the decompression of hallux rigidus, which can be addressed at multiple anatomical levels. The same applies to a wound more proximal along the first ray, where dorsiflexion osteotomies and MTPJ resection also aid in reduction of these pressures, and still allow some function of the first ray. These procedures increase the chance of providing a functional outcome in preservation of the first ray in the setting of diabetic chronic pressure ulcerations. **PM**

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