RECENT ADVANCES IN THE RECONSTRUCTION OF COMPLEX ACHILLES TENDON DEFECTS

DANIEL N. RONEL, M.D., F.A.A.P.,* MARTIN I. NEWMAN, M.D., LLOYD B. GAYLE, M.D., F.A.C.S., and LLOYD A. HOFFMAN, M.D., F.A.C.S.

Large, complex lower-extremity defects in the region of the Achilles tendon occur when tendon loss or disruption is complicated by damage to surrounding structures, including soft tissue, vessels, or bone. The surgical approach to these complex defects has evolved from simple amputation to the recognition that satisfactory reconstruction has three components: functional reconstruction of the tendon, importation of vascularized soft tissue, and skin coverage. Many techniques have been developed to address these difficult reconstructive goals, which often require multiple procedures or complicated single-stage operations. Microsurgical advances have begun to reduce the complexity of Achilles tendon region reconstruction, and excellent results can be obtained which restore function, form, and cosmesis with minimal morbidity. © 2003 Wiley-Liss, Inc.

The incidence of Achilles tendon rupture has increased over the past several decades in the Western world, coinciding with the increasing percentage of active middle-aged and elderly members of the population.[1] Surgical or nonsurgical therapy is selected by considering factors such as the anatomical and functional extent of the Achilles defect, whether surrounding tissues are affected, the patient's level of activity, and comorbid conditions.

In 1575, Ambroise Pare at the Hotel-Dieu in Paris described a nonsurgical treatment for Achilles tendon rupture that consisted of strapping bandages dipped in wine and spices to the lower leg. Surgery was first advocated as the treatment of choice for Achilles tendon ruptures 350 years later, also by surgeons at the Hotel-Dieu.[2] Early surgical procedures simply repaired the tendon primarily and did not address the problem of deficiency in length. Over the past several decades, techniques were developed to improve the quality of Achilles tendon repair, including the V-Y advancement flap, autotransplantation of fascia lata strips, transplantation of cadaver ligament, transfer of regional tendons, and implantation of Marlex mesh or carbon fiber prosthetics.[1,3–6]

COMPLEX ACHILLES TENDON REGION DEFECTS

An Achilles tendon defect in the setting of large tissue loss is a more difficult problem than simple repair of a ruptured or lacerated tendon. Successful reconstruction must include tendon repair sufficient to provide strength, durability, and tension, a soft-tissue cushion thick enough to protect the area but thin enough to permit normal footwear, and a skin cover strong enough to withstand the repetitive friction and shearing forces of ambulation.[3] The defects are often contaminated with bacteria and require the importation of vascularized tissue to supply components of the immune system, as well as antibiotics. In some cases, limited surgical treatment simply with skin-flap coverage and scar formation can achieve acceptable functional results.[7]

The availability of local muscle, skin, or fascia to cover tissue defects in the lower leg is limited. The early surgical treatment of complex injuries to the Achilles area involved multiple-stage procedures, long hospital courses, and a relatively high incidence of postoperative complications, especially the formation of fibrous adhesions impairing gliding of the reconstructed tendon. It is widely accepted that the arcs of rotation and vascular supply of the gastrocnemius and soleus muscles preclude their use in the distal third of the foreleg. Intrinsic foot muscles are too small. Plantar flaps of adequate size would hinder ambulation. Dermal turnover flaps are unreliable, and a dorsalis pedis flap would leave an unacceptable donor-site defect. Flaps that require the sacrifice of either the dorsalis pedis or posterior tibialis artery circulation would place at great risk the remaining blood flow to the foot.[8]

Despite these limitations, procedures have been developed that combine functional tendon repair and skin coverage. They are particularly suitable for hospitals where the infrastructure for microsurgery is not available. One option combines the thick skin of the medial plantar flap with a tensor fascia lata tendon graft, and can reduce friction from shoes on the repaired area, especially in distal lesions.[9] Another combination procedure replaces the Achilles tendon with a free fascia lata graft, covers it with a gastrocnemius flap turned down from above, and provides skin coverage with a local

Division of Plastic Surgery, New York-Presbyterian Hospital, New York, NY
*Correspondence to: Daniel N. Ronel, M.D., Division of Plastic Surgery, New York-Presbyterian Hospital; 525 East 68th St. Room P-719, Box 115, New York, NY 10021. E-mail: dronelmd@yahoo.com
Received 10 March 2003; Accepted 24 March 2003
Published online 30 December 2003 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/micr.10191

anteromedial fasciocutaneous flap.[10] Whereas in both of these procedures the fascial grafts are not vascularized, a pedicled medial plantar flap with vascularized plantar aponeurosis was described for the reconstruction of a relatively small defect.[11] A recently reported composite graft seemingly as complex as its name is the venoneuroadipofascial pedicled distally based sural island myofasciocutaneous flap. It is a modified neurocutaneous flap based on the vascular axis around the sural nerve, the short saphenous vein, and the lowest two septocutaneous perforators of the peroneal artery. Three cases have been reported, one of which included reconstruction of the Achilles tendon with the lateral belly of the gastrocnemius muscle.[12]

MICROSURGICAL FREE FLAPS

The development of microsurgical techniques made free-tissue transfer possible into the Achilles region. Free-tissue transfer supplies vascularized tissue to enhance wound-healing and to protect against infection. Skin, fascia, muscle, bone, and nerve can be transferred in various combinations to replace the function of lost tissues. The first microvascular free flaps were reported in 1971 and 1973: an abdominal dermis-fat graft was first transferred to a facial defect by anastomosing the superficial epigastric artery and a cuff of the femoral artery to the external carotid.[13] Two years later, a defect in the skin and soft tissue of the ankle was covered with a skin island supplied by the superficial inferior epigastric and superficial circumflex arteries that were anastomosed to the long saphenous vein, posterior tibial artery, and a vena comitans.[14] The first musculocutaneous free flap, a de-epithelialized gluteus maximus transfer in a patient with aplasia of the breast, was reported in 1975.[15] Free flap coverage of posterior lower-leg soft-tissue defects with muscle or fascia quickly became popular, with donor tissue taken from many parts of the body.[16–22] Several groups enthusiastically reported operative success rates of 92–96%.[8,23–26] In addition to the benefits provided by the importation of vascularized tissue, early free-flap design often included a cutaneous paddle or gliding surface for the Achilles tendon.[27]

LOWER-EXTREMITY COMPOSITE FREE FLAPS

The simple coverage of soft-tissue defects by free-tissue transfer evolved into the reconstruction of complex defects with composite grafts made from different tissue types. Most composite grafts for reconstruction of Achilles region defects were developed from leg and arm donor sites. Early reports of composite grafts included a free groin flap with an external oblique aponeurosis sheet and a free groin flap with iliac bone and abdominal fascia.[28,29] Advantages of these groin flaps included the ability to transfer iliac bone with the graft for a calcaneal defect, and the location of the donor scar, which was usually hidden by underclothing. Disadvantages included a short and thin superficial circumflex iliac artery pedicle, the need for repair of the external oblique in the donor site with foreign material, and the frequent need for further debulking procedures of a flap that was too thick for the posterior ankle region.

Many constructs from thigh donor sites have been developed for Achilles region reconstruction. One of the first reported was a fascial composite flap that transfers the lateral femoral cutaneous nerve with the tensor fascia lata to create a neurovascular, sensate free flap.[30] A disadvantage of the flap is its bulk, which may be too excessive for normal shoes in the narrow distal posterior leg region. Other procedures involve a free lateral thigh or anterolateral thigh flap with a fascia lata sheet.[3,31] The fascia lata in these flaps is rolled into a cylinder to replace the missing tendon segment. Advantages include a long and relatively large vascular pedicle (the descending branch of the lateral femoral circumflex artery), a large skin paddle of up to 800 cm^2, ample subcutaneous fat to permit tendon gliding, and the possibility of including rectus femoris or vastus lateralis muscle. Inclusion of these muscles may be difficult, however: splitting the vastus lateralis longitudinally may jeopardize the blood supply to part of the muscle, and in the case of the rectus femoris, the takeoff of its pedicle is very close to the site of anastomosis on the lateral femoral circumflex. Other disadvantages of thigh flaps are the anatomic variation and small size of many of the perforators from the lateral femoral circumflex and the profunda femoris, as well as the need for skin-grafting the donor site.[32]

A tensor fascia lata fasciocutaneous perforator flap was reported in 5 patients.[33] The lateral femoral cutaneous nerve can be included to provide sensation to the skin of the flap, and the donor site can often be closed primarily. Several patients underwent further debulking procedures at the ankle, and the consistency of this flap's anatomical basis was questioned.[34] A tensor fascia lata myocutaneous flap was also described in a patient who required little soft-tissue replacement other than the Achilles: the entire iliotibial tract was used to replace the tendon, and skin coverage was cosmetically acceptable.[35] The only composite flap reported from the medial thigh is a gracilis free flap that that was used in one case to reconstruct the Achilles tendon and provide vascularized soft tissue.[36] The flap was fitted to the tendon defect by folding the gracilis tendon on itself and suturing it to the muscle belly. A skin graft covered the muscle. There was excellent functional restoration of the tendon and an acceptable soft-tissue contour.

UPPER-EXTREMITY COMPOSITE FREE FLAPS

Radial forearm and lateral arm constructs have also been developed to address the problem of complex Achilles region reconstruction. A radial forearm flap raised with an extensor carpi ulnaris and palmaris longus tendons was used to reconstruct an area of the posterior lower leg that did not require much tissue bulk.[18] Other radial forearm composite flaps included the tendons of the brachioradialis and palmaris longus, as well as the superficial radial nerve.[37,38] Reconstruction in these flaps sometimes required an interpositional vein and nerve graft. Advantages of the forearm flap include a moderately large area of donor skin, a long pedicle of relatively good caliber and consistent anatomy, and a thin subcutaneous layer of fat that can provide a contour similar to the normal lower leg. Disadvantages include the unappealing cosmetic result of a skin graft on the donor site and the requirement for a patent ulnar artery.

Lateral forearm flaps based on the profunda brachii vessels have been reported.[39–42] Composite combinations may include the posterior cutaneous nerve, the triceps tendon vascularized with a portion of the triceps muscle, and the brachioradialis tendon vascularized with fasciocutaneous perforators. The olecranon or a portion of the radius can be included to secure the distal triceps or brachioradialis tendon anchors, respectively.[41,42] Advantages of lateral forearm flaps include consistent vascular anatomy, a long pedicle of relatively good caliber, an area of thinness near the lateral epicondyle, and a relatively large area of donor skin. Disadvantages include the noticeable donor-site scar, occasional dysesthesia from radial nerve injury, and soft-tissue bulkiness, although the flap has been extended distally to an area of thinner subcutaneous tissue.[43]

Although bacterial inoculation studies for musculocutaneous and fasciocutaneous flaps suggest that muscle flap coverage is superior in the presence of infection, an anterior rectus sheath fasciocutaneous free flap was successfully used to reconstruct the Achilles tendon and provide skin coverage in 2 patients with infected recipient sites.[44,45]

LATISSIMUS DORSI FREE FLAP

An underutilized donor site for complex Achilles tendon region reconstruction is the latissimus dorsi. The latissimus dorsi is a large, versatile muscle (Latin *latissimus*, superlative of *latus*, wide). It can be removed completely or in part, and when necessary, it can be transferred with an overlying skin paddle.[46] Although it contributes to arm extension, adduction, internal rotation, and scapular medial downward movement, its removal produces only a minimal functional deficit.[47] The thoracodorsal pedicle is relatively large and can be skeletonized from 9–15 cm, sufficient length to allow up to a 180° arc of rotation.[48] One or two venae comitantes and the thoracodorsal nerve accompany the artery.

Iginio Tansini, a professor of surgery at the University of Padua, first described in 1906 the use of the latissimus dorsi to provide wound coverage with well-perfused skin. He noted in his patients who underwent amputation of the breast that the distal third of a skin flap from the posterior trunk, which was based on an axillary pedicle, became necrotic. When he included the latissimus muscle within his skin flap, necrosis no longer occurred. Use of the musculocutaneous latissimus flap succumbed for decades to the tremendous influence of William Halstead, who wrote, ''to attempt to close the breast wound more or less regularly by any plastic method is hazardous, and in my opinion, to be vigorously discountenanced.''[49] Halstead advocated simple closure of the chest wall, with or without a skin graft.[47] In the late 1970s, the latissimus musculocutaneous flap reemerged as a useful solution to breast reconstruction and soon became widely used to reconstruct defects throughout the body. A free axillary skin flap to the scalp based on the thoracodorsal artery was reported in 1976, and a free latissimus dorsi myocutaneous flap followed in 1978.[50,51]

The early free latissimus dorsi transfers were bulky myocutaneous flaps. Transfer of the muscle alone, followed by a split-thickness skin graft, improves the appearance of both the recipient and donor sites.[52,53] Atrophy of the muscle over 6–12 months usually leaves a thin subcutaneous layer. The latissimus dorsi was first used to reconstruct the Achilles and to provide soft-tissue coverage in 4 patients in 1999. Split-thickness skin grafts covered the flaps: in one patient, the latissimus was raised as a myocutaneous unit, but was de-epithelialized and folded over on itself to provide additional bulk for bony protection. The patients had fair to good plantar flexion and dorsiflexion, and were walking without difficulty after 36–54 months of follow-up. This is the first description of the latissimus as a force-bearing conduit in Achilles tendon repair, and capitalizes on the observation that denervated muscle becomes fibrotic like a tendon.[54]

Our experience includes free latissimus dorsi transfers for Achilles tendon reconstruction in a 25-year-old man with severe lower-leg burns (Fig. 1) and a 75-year-old man with resection of a chronically infected Achilles tendon and surrounding tissues (Fig. 2). There is no standardized method of evaluating the outcomes of Achilles tendon repairs, making it difficult to compare results among surgical techniques. One simple classification scheme groups outcomes into four categories, from excellent to poor.[55] An excellent result is full function with no residual disability; a good result has the presence of slight weakness, an adherent scar, or a

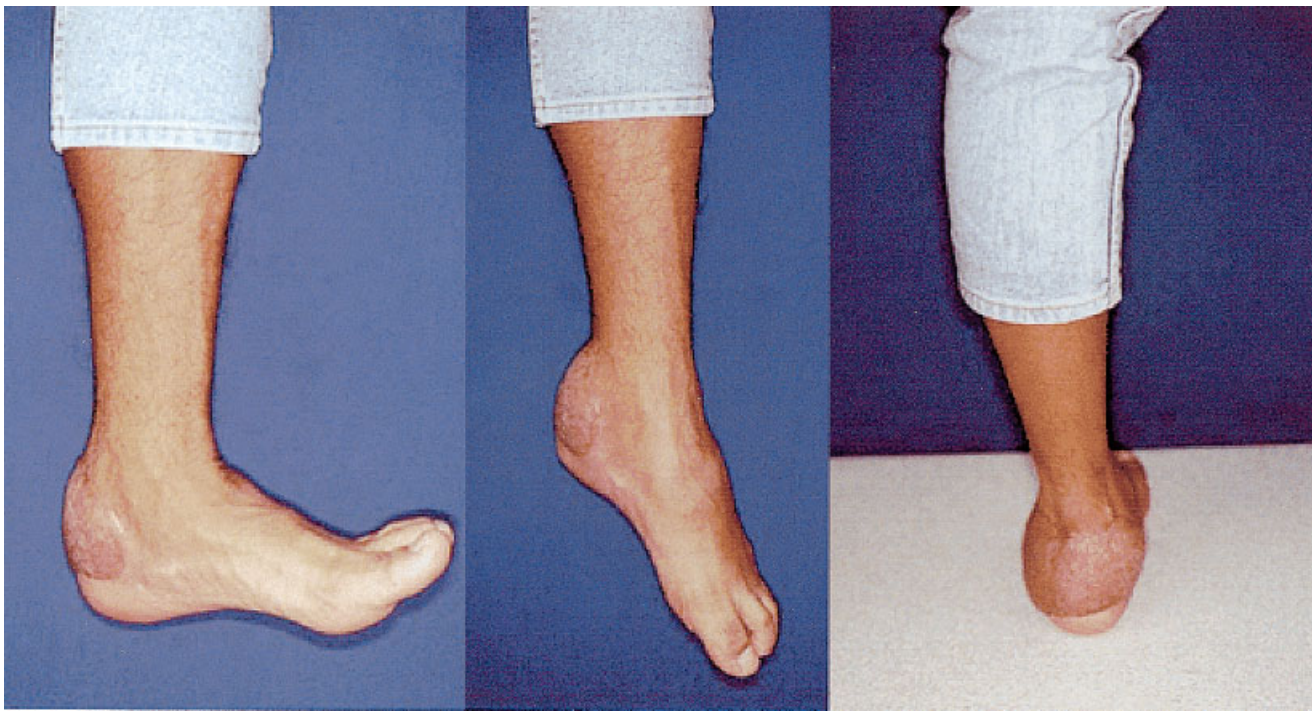

Figure 1. Twenty-five-year-old man almost 1 year after a latissimus dorsi free flap was interposed into the remaining Achilles tendon and surrounding tissue after severe burn injury.

Figure 2. Seventy-five-year-old man almost 1 year after a latissimus dorsi free flap was used to replace the Achilles tendon and surrounding tissue after chronic infection.

minor sensory deficit, but with no real limitation of activities and a full return to function as in the preinjury period; a fair result has a definite weakness, some limitation of activities, and a slight limp; a poor result has a rerupture or complete failure, with severe weakness and a marked limp. The patients in our experience have excellent results according to this classification.

CONCLUSIONS

Repair of complex injuries to the Achilles tendon and surrounding tissue, especially in the presence of infection, requires the importation of vascularized tissue to restore function and sustain healing. Microsurgical free flaps are versatile and can replace tendon-transfer procedures or the use of allografts or foreign material. Several techniques have been developed to provide adequate tendon function, an appropriate amount of soft-tissue coverage, and abundant vascularized tissue to enable rapid wound-healing and to protect against infection. Flaps with large and reliable vascular pedicles have been constructed, but may result in excessive soft-tissue bulk in the narrow region of the Achilles. Single-step procedures involving the latissimus dorsi are applicable to a wide range of defect sizes, have low donor-site morbidity, and achieve a cosmetically satisfactory contour in the posterior lower leg.

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