Split Thickness Skin Grafting in the Diabetic Foot

This is one of the most effective techniques for wound closure.

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The incidence of the diabetic foot has increased steadily over the past half century. According to the International Diabetes Foundation, there are more than 300 million people living with diabetes worldwide. The World Health Organization estimates that by 2030, more than 350 million people will be suffering from diabetes around the globe, ten times the amount inflicted with HIV/AIDS.[22] The United States, with an estimated 25-35 million people with confirmed diabetes, has the third largest number of confirmed cases in the world.[22] With these statistics, heightened consideration and effort need to be shown towards this growing global issue.

Limb preservation among patients with diabetes presents an ongoing challenge for the foot and ankle surgeon. Compromised health status and consistent non-compliance are contributory factors to overall pedal conditions. With a large number of people affected by diabetes, lower extremity surgeons often perform a wide variety of pedal amputations. Up to 83% of all non-traumatic lower-extremity amputations are associated with diabetes mellitus in the United States.[3] Among these, transmetatarsal amputations have shown success regarding long-term limb salvage.[1-3] Described by McKittrick and colleagues, the transmetatarsal amputation (TMA) is considered a lower extremity salvage procedure for diabetics with infection and/or gangrene.[3] In comparison to a more proximal amputation, this procedure demonstrates a viable option with respect to patient satisfaction, healing, and long-term results.[1]

One of the major benefits of a distal amputation involves the decreased oxygen consumption required for ambulation. Literature has shown that oxygen consumption increases with a more proximal amputation.[5-6] Subsequently, partial pedal amputations offer a better option to the high energy expenditure and the 65-70 percent oxygen increase with ambulation in patients with more proximal lower extremity amputations.[11-13]

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The Angiosome Concept

Due to the fact that transmetatarsal amputations correlate with fewer failures in amputation of the diabetic foot with or without underlying vascular disease, improving its management and surgical technique is paramount for the surgeon. The angiosome concept introduced by Taylor and Palmer in 1987 is one theory that has proven beneficial regarding its clinical implications for limb salvage and a predictor of post-operative healing. Taylor went on to describe the concept, which divided the body into three-dimensional vascular territories supplied by several specific source arteries with subsequent venous drainage.[23]

He demonstrated that the primary vascular supply to the skin is through direct cutaneous arteries which vary in length and density in various anatomical regions. This primary supply is reinforced by numerous indirect vessels which are considered terminal branches of arteries supplying deep tissues.[23] Taylor went on to define five distinct angiosomes of the lower extremity supplied by the medial sural artery, lateral sural artery posterior tibial artery, anterior tibial artery, and peroneal artery. The foot and ankle has six distinct angiosomes arising from the three main pedal arteries: posterior tibial artery (PTA), anterior tibial artery (ATA), and peroneal artery (PA). Subsequently, the PTA supplies the medial ankle and plantar foot. The ATA supplies the dorsum of the foot with the two branches of the PA supplying the anterolateral portion of the ankle and rearfoot.[24]

The angiosome model can be applied to surgical incision planning

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and soft tissue exposures that preserve vascular supply to allow surgical wounds to heal. This concept can also assist the surgeon in predicting which pedicle flap can be successfully harvested or whether a certain amputation site will have a positive outcome.[24] Regarding revascularization principles, this may also facilitate selecting whether an endovascular procedure or bypass gives the best method of healing a pre-existing ischemic ulceration. Nagata and colleagues concluded that acquiring direct flow by way of the angiosome concept is vital for limb salvage.[25] Juvonen in 2014 described how direct arterial-arterial connections exist between angiosomes and compensate for ischemic events that may occur in an adjacent angiosome.

He demonstrated that direct revascularization of the pedal angiosomes may improve wound healing and limb salvage rates compared with indirect revascularization.[26] Concerning patients who undergo transmetatarsal amputations, achieving pulsatile arterial flow directly to the intended site is of significant importance. This will facilitate treatment of the wound, promote the healing cascade, and ultimately attempt preservation of the limb. Although the angiosome concept has been documented in the literature, it does pose some limitations. Anatomical angiosomes may vary among patients. Also, lesion severity and location do play a significant role and may pose a challenge during treatment.[26]

Angiosomes of the Foot and Ankle

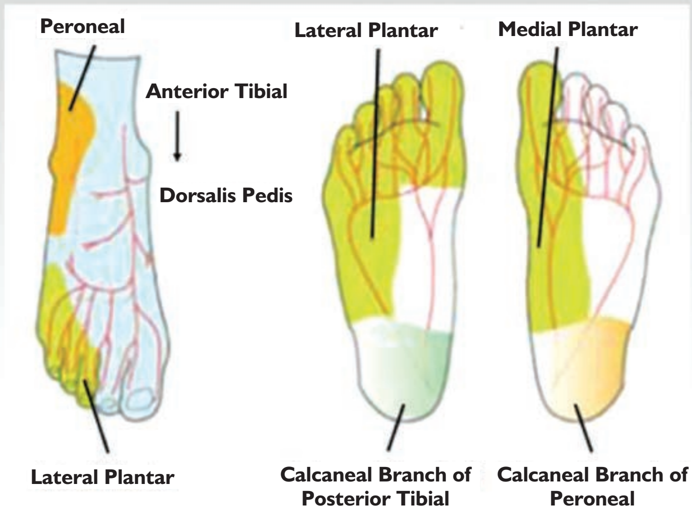

Figure 1: Angiosomes of the foot and ankle

Any level of amputation can be viewed involving three main areas: loss of sensation, loss of function, and loss of body image.[18] Having an appropriate economic and psychosocial support structure is vital to long-term amputation rehabilitation. An important consideration in discussion of any amputation with patients and family are the psychological issues that may result from the procedure. Once the disease process has progressed to the point that an amputation is necessary, any patient is likely to have significant and complex issues to resolve.

Documentation of long-term outcomes of patients undergoing amputations of the foot and ankle has demonstrated that 48% of patients were able to remain employed after amputation and 74% reported psychological problems in addition to their physical ailments.[17] The patient will not only have to deal with the pain of surgery, but also the psychological implications of body image and disease.[14] Physicians should consider discussing all psychological consequences and issues with patients and be willing to provide recuperative options and social support if an amputation is warranted.[15-16]

Financial concerns must be considered when dealing with any lower extremity amputation. These hardships not only present a burden for the patient but also to the medical community. Evidence demonstrates that the cost of a lower extremity amputation may range from $30,000 to $60,000 in initial hospital costs, with an additional $40,000 to $60,000 for follow-up care over the sub-

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Figure 2: Conversion to transmetatarsal amputation with primary wound closure

Figure 3: Dehiscence of wound site with evidence of infection

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Figure 4: Post-debridement with application of STSG

Figure 5: Healed amputation site with 100% coverage with STSG

sequent three to five years after the procedure. In addition to financial hardship that a majority of patients and families endure, amputations are also expensive for the healthcare system. For patients undergoing an initial amputation, the cost of hospitalization and post-acute care must be taken into consideration. Post-acute care varies on a patient-to-patient basis but may well involve rehabilitation, outpatient clinical visits, and physical or occupational therapy.

Also important to note is the fact that the majority of amputees will require some form of prosthesis in order to have a functional long-term outcome. Burgess and colleagues documented that prosthesis-related costs added to an initial hospitalization showed a substantial increase compared to initial hospitalizations costs alone.[18] Although the area of prosthetics and orthotics continues to make significant strides in offering patients the possibility of regaining much of the function lost through limb amputation, patients frequently exhibit psychosocial issues with them during the rehabilitation process.

Evidence shows that appropriate preparation for surgery and adequate education alleviate patients' stress and facilitate the rehabilitation process.[21] As mentioned prior, loss of body image is an important consideration when dealing with any level of amputation. A patient may have difficulty conceptualizing the loss of a limb. Narang and Jape described the psychological impact of an altered body image after an amputation as "unsettling in the extreme."[20]

Case Report

The following case presentation involves using the angiosome concept to target the appropriate vessels for intervention in order to assist the podiatric surgeon with limb salvage efforts. A 60-year-old Hispanic male with a past medical history of type II diabetes, end-stage renal disease on hemodialysis, and peripheral vascular disease presented with a chief complaint of dry gangrene and a non-healing surgical wound site from a previous 4th and 5th ray amputation with rotational skin plasty of his left foot.

A vascular evaluation was performed and the patient was found to have significant tibial disease of the affected extremity and underwent an angiogram with angioplasty of the posterior tibial, peroneal, and popliteal arteries. Following the vascular procedure, the podiatric surgical team then performed a transmetatarsal amputation with primary wound closure (Figure 2).

Six weeks post-operative, the patient returned to the clinic with signs of a non-healing transmetatarsal amputation with underlying soft tissue infection (Figure 3). A repeat vascular evaluation was performed which revealed further occlusion of his posterior tibial artery. The vascular surgical team again performed an angioplasty of the posterior tibial artery, tibial peroneal trunk, and popliteal arteries.

Due to the poor vascular status to the foot and the patient's unwillingness to undergo a higher level amputation, it was determined he would return to the operating room post-vascular intervention where the podiatric surgical team initially performed an incision and drainage with wound debridement; however, this time, wound closure was not obtained and NPWT was applied to the open amputation site. Five days post-revision, the patient was taken back to the OR for further debridement and application of a split-thickness skin graft (STSG) (Figure 4).

Having an appropriate economic and psychosocial support structure is vital to long-term amputation rehabilitation.

The amputation site with the STSG was bolstered with use of NPWT for five days, and the patient was discharged to a skilled nursing facility with regular follow-up visits in the podiatric surgical clinic. Approximately six weeks post-operative, the patient returned and demonstrated complete healing of the wound site (Figure 5).

Discussion

With treatment of severe diabetic lower extremity infections, substantial soft tissue loss is a frequent sequela of partial foot amputations. Multiple debridements may be required in the

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presence of osteomyelitis, septic arthritis, superficial/deep abscess, peripheral vascular disease, and/or gangrene. A series of staged reconstruction procedures may also be warranted based on the severity of the disease as observed with a particular patient. The literature supports a multitude of reconstructive procedures which have been described for the closure of the diabetic foot, including localized random skin flaps, pedicle and free flaps, and negative pressure wound therapy.[8] The appropriate selection of the most suitable skin graft or procedure will ultimately depend on the patient's condition, medical comorbidities, vascular status, wound location, and donor site availability.

With the plethora of skin graft substitutes available in the medical community, autogenous split thickness skin grafts (STSG) represents one of the most beneficial and effective techniques for diabetic foot wound closure.[8] The STSG provides an acceptable procedure for coverage of wound sites that otherwise do not have adequate skin to cover a deficit. STSG offers more coverage than the surgical cicatrix which results from secondary closure and provides more closure when compared to standard local wound care dressings.[9]

STSG produces the greatest results when placed on recipient tissues that are capable of producing adequate amounts of granulation tissue for adherence, the revascularization phase (5-7 days), and a maturation phase. The psychological burden that the patient may endure from any form of amputation must also be shown consideration. The physician must be willing to provide rehabilitation resources to the patient and family including post-operative management treatments, rehabilitation protocols, and adequate prosthetics if necessary. **PM**

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