WOUND HEALING, SURGICAL DECOMPRESSION AND SOFT TISSUE COVERAGE IN THE INFECTED FOOT

The basic rules for treating most foot infections are: 1) appropriate clinical recognition, 2) correct laboratory and radiographic analysis, 3) accurate cultural data, and 4) judicious surgical debridement, drainage and wound closure. This section will review the surgical drainage, debridement and wound closure techniques that are useful in treatment of pedal wounds and the infected foot.

Initial Acute Phase

In the initial acute phase of any well perfused foot infection, especially with a known or suspected abscess formation, the simplest approach to surgical treatment is debridement. With the proper incision and drainage of abscesses or infected spaces, all other adjuncts to care may be to no avail. Decompression may involve the removal of sutures, or the release of purulence from the wound.

It also may entail the deep removal of any implant device, fixation hardware, or other possible foreign body or focus of infection. This later type of prosthetic implant infection is classified into three types:

- An "early acute infection" (occurring within the first 4-6 weeks of surgery), presents with the cardinal signs of inflammation. Radiographs are normal, but the ESR or CRP may be elevated. A differential diagnosis is hematoma, but conformational diagnosis is through aspiration and cultural data.
- A "delayed acute onset" infection (signs occur after a year or normalcy), presents with an acute attack of first metatarsophalangeal pain, with normal radiographs but an elevated WBC count. Again, joint aspiration confirms the diagnosis.
- Finally, a "chronic infection" (present greater than 4-6 weeks without acute signs and symptoms) presents with a history of inflammatory changes for many weeks. ESR and WBC changes may be seen, along with an open or draining sinus tract. Radiographs may or may not be normal and bone scans may be positive in many cases. Generally, the suspicious fixation or implant device is left intact if deemed clinically stable, and removed if unstable.

This is performed in order to allow unhindered drainage of infected exudates in the foot and reduce the likelihood of occult infection.
It cannot be over stressed that adequate and extensive drainage and debridement of necrotic tissue is essential. This usually means a trip to the operating room to have the procedure performed under sterile conditions.

General or local anesthesia (generally without epinephrine) is mostly used, with the infiltrative block administered well away from the site of active infection. Tourniquets are not typically used. The incision should be linear and sloped to form a trough for ease of postural drainage. The often ill-conceived notion of foot elevation counters this concept and may involve the patient resting in a prone position to encourage gravity drainage. It makes no sense to elevate a foot to allow infected exudates to travel through tissue planes proximally, and possibly infect uncontaminated rear-foot, ankle or lower leg tissue planes.

Normal post inflammatory edema will subside naturally with proper decompression, antibiosis and debridement. Typical incision placement sites following routine foot surgical procedures may extend from the first or lesser metatarso-phalangeal joints, inter-digital toe web spaces, over the dorsum of the foot to the arch area or around the heel, anterior ankle or posterior leg. Segments of necrotic extensor or flexor tendons, as well as plantar fascia or muscles, may even have to be removed to expose the depths of the infection or to permit adequate drainage of tendon sheaths or tissue planes.

Soft tissue, fascial and tendon-debridement is the prime prerequisite to eventual wound healing and recovery after the infection process has occurred. These tissues are not vital because of their poor vascular status and can usually be removed without serious adverse effects. A pulsatile irrigation system enhances debridement of infected tissues. The criteria for infected muscle debridement, is based on four parameters: consistency, contractility, perfusion and color. Osseous structures are dependent on intact blood supply and both the macrocirculation and the microcirculation. Therefore, bone as well as any other tissue that does not bleed when incised is necrotic, and should be removed.

Saucerization or exteriorization is performed to bevel bone edge surfaces, to promote tissue coverage at a later date. Stabilization of osseous fragments is done with external fixation devices, placed proximal and distal to the affected bone margins, well away from the site of infection. Rigid fixation provides favorable conditions for infected fractures, because of the potential for primary bone healing, minimal sequestration and less bone resorption. Osteosynthesis (AO/ASIF) material is used with caution.

Avascular bone, cartilage and joints tolerate infection poorly and ultimately the infected bone in the digits or feet may have to be resected. Until the ultimate decision is made as to salvage or amputation, the aim and first priority is to provide proper dependent drainage to the affected part(s).

At times, a necrotic toe or ray may be associated with an abscess around its metatarsophalangeal joint and be the cause of cellulitis or lymphangitis as it streaks up the leg. This usually occurs on the medial aspect of the foot or ankle and involves the medial saphenous vascular and lymphatic tree. However, when cellulitis exists at some site proximal to the focus of infection, one must resist the urge to incise and drain the area.
Injudicious surgery in the face of cellulitis is contraindicated and can do more harm than good by spreading the infection and prolonging recovery from iatrogenically induced open wounds. In the event of cellulitis without abscess formation, it is acceptable to infiltrate a small amount of sterile saline subcutaneously, and then evacuate the specimen for cultural examination. Of course, prior to complete localization and "pointing" of an abscess, warm Turkish towels, dependency and bed rest are ideal aids to hasten the localization process. At other times, when a gangrenous digit is associated with a mummified dry black toe or a weeping cyanotic wet toe, the patient is best served by resecting the digit itself with its associated bones and joints.

Such removal of a toe or ray must properly be considered radical debridement, for such is not an amputation in the true sense that the wound is expected to heal by primary intention. Of course, such stumps and rays will heal in time, but the prime objective of the surgery is to remove necrotic tissue and bone as well as drain infection fluids.

It is obvious that most foot infections do not require the extensive salvage surgery described here. However, the basic principles must always be remembered. Once the foot has been surgically decompressed, and if delayed primary or tertiary healing is not anticipated, the next step in recovery involves daily debridement in the office or hospital setting. If pain is a deterrent to this therapy, then proximal wound blocks, nitrous oxide sedation, ketamine or intravenous agents such as diazepam may be used. Periodically, the patient may even be returned to the operating room for additional debridement, for as many times as needed. Chemicals, enzymatic agents and whirlpool baths also aid in the cultivation of granulation tissue. Care must be taken when using whirlpools to prevent additional waterborne contaminants such as Gram-negative infections. Liberal wound irrigation is also a helpful but often neglected portion of the daily debridement regime.

Various solutions may be used, such as normal sterile saline, hydrogen peroxide, or provodine-iodine in a concentration of one percent. When Pseudomonas is involved, weak acetic acid (vinegar) solution will inhibit the growth of organisms via changes in Ph. If the wound cavity is significant in size with a large "dead space", open wound packing with sterile gauze impregnated with iodophor or some other antiseptic that is not irritating to delicate granulation tissue, is indicated. The encouragement of fluid removal through the use of various wicks, drains or gauze strips is also beneficial. Of course, daily wound debridement is done by the attending surgeon, rather than the nursing staff and strict sterile conditions must be maintained. The wound must never be exposed to the contaminated air for more than a brief period and desiccation must be avoided at all costs. This can be accomplished through the use of wet to dry dressings, performed two or three times daily. Once granulation tissue begins to flourish, periodic gram stains and cultures are needed to evaluate wound progress in anticipation of healing by secondary intention, delayed primary closure or skin grafting techniques.

Finally, philosophical considerations of the foot specialist inherently seem to favor the above limb salvage techniques rather than amputation. Although more risky, painful, time and cost intensive, most specialists and patients, opt at an attempt to save the limb rather than remove it. Whether such heroic measures of limb salvage are appropriate in all cases, is a societal question.
Terminal Chronic Phase

Once wound cultures prove less serious, temperature and laboratory parameters normalize, granulation tissue growth commences, and the patient clinically improves, the final stage of local wound management may begin. Essentially, this involves three healing possibilities: 1) secondary intention, 2) delayed primary closure, and 3) skin grafting techniques.

Healing by Secondary Intention:

Healing by secondary intention is the most predictable method in the terminal phase of wound healing. It is also the most damaging, frustrating, time consuming, economically devastating, and traditional method of post-infection wound repair. As we have seen, in this method, the wound is simply allowed to granulate in until closed, providing adequate blood supply is available. It produces fibrous adhesions to involved, as well as indirectly involved, vital other structures. In many cases, dense scarified tissues may laminate or glue together vital structures, rendering the body part functionless, or disfigured. Unfortunately, however, it still seems to be the most medico-legally sound course of action to pursue following infected cases, since it is known that the risk of acute infection is decreased with a packed wound; although chronicity is another matter. On the other hand, a primarily closed wound does gain resistance to infection, from subsequent colonization, faster than one that is left open. It is especially feasible in the case of a small wound, such as those that follow digital or lesser metatarsal surgery. Frequently, follow-up care can be nicely rendered in the outpatient, office or home setting.

Delayed Primary Wound Closure:

Again, delayed primary closure refers to the suturing of a previously infected wound. Usually this means a wound, rendered clean but not necessarily sterile, with no overt bone contamination. It may involve several weeks of hospitalization and parenteral antibiotics in preparation for the closure. It may also involve the "freshening" and undermining of wound margins in order to mobilize adjacent soft tissue structures. Negative serial cultures are not required prior to closure, since such a wound might rightly be considered culturally contaminated but not clinically infected.

The wound is usually closed "per primum" with non-braided and non-absorbable suture materials, preferably with simple or horizontal mattress sutures and with absolutely no wound tension on fragile edges. Infectious disease consultation is highly desirable when one is contemplating the delayed primary closure of a wound, since timing is of critical importance.

Skin Grafting and Plastic Surgical Techniques

The history of skin grafting dates back to the early 1880's and is properly defined as transplanted tissue that has been detached from a donor site and moved to a recipient bed. Skin graft nomenclature includes the following types: (a) Autograft (transplanted tissue from one site to another on the same individual), (b) Isograft (transplanted tissue between genetically identical individuals), (c) Allograft or Homograft (graft between two individuals of the same species and (d) Xenograft or Heterograft (graft between two different species).
Skin for grafting purposes is available from several body sites, and includes the top of the foot, lateral malleolus, popliteal fossa and inguinal ligament region. The elasticity, color, thickness and durability of the skin varies with site, age and sex. The dermal skin layer compromises most of the actual skin thickness and contains appendages such as hair follicles, sebaceous and sweat glands.

Skin grafting a previously infected wound is performed when an extensive amount of soft tissue has been lost and the wound is not considered colonized by pathogenic bacteria. The acquisition of a uniform and regular bed of granulation tissue is of utmost importance since it is the single most important factor for graft survival or "take". Characteristics of an ideal bed include a vascularized granulation tissue and maintenance of intimate contact with the graft until mature. A skin graft cannot be applied directly to bare bone or tendinous tissue because a delicate interface is needed for vascularization. Once cultivated however, virtually any tissue type with a vascular and granulating stroma, may be an acceptable bed for a skin graft. The wound is grafted with a split or full thickness skin graft, harvested from the contralateral anterior thigh and applied dermal side down on the recipient bed. It can either be sutured in place, affixed with adhesive plastic strips or a Vaseline impregnated gauze dressing.

The processes of graft survival is divided into three phases: a) fibrin adhesion immediately after placement on the recipient bed, b) plasmatic absorption for initial graft nourishment, and c) inosculation that reestablishes new circulation within the graft, after 48-72 hours. Adverse factors to graft survival include:

- **Movement**: Disrupts vascular attachments, however a bridging phenomenon may occur over a small area less than 0.5cm. in diameter.
- **Hematoma / Seroma**: Fluid under the graft may lead to necrosis as well as movement. If identified early, "rolling" or aspiration may be performed to evacuate the contents and prevent the graft from floating away.
- **Infection**: Skin grafts are particularly prone to water loving Pseudomonas sp., and cellulitis producing Streptococcal organisms. Ironically, grafting over an open or granulating wound may reduce bacterial counts and serve to prevent an infection by acting as a biological barrier.

**Split Thickness Skin Grafts (STSG’s):**

A split thickness skin graft (STSG) consists of the epidermis and variable portions of the dermis. Depending on the amount of dermis present, the STSG can be classified as either (a) thin (0.008-0.0012 inches), medium (0.012-0.016) or thick (0.016-0.020 inches). A full thickness skin graft (FTSG) contains the epidermis and entire dermal layer. A STSG is more likely to survive than a FTSG graft, but may leave an unsightly scar and is less durable than its full thickness counterparts. STSG's are usually harvested with a pneumatic or electric dermatome from the anterior thigh, fenestrated and applied dermal side down on the wound, after perforation. Small portions of skin may be taken free-hand with a straight razor or Humby knife.

The technique used with a power dermatome first lubricates and tenses the skin with sterile mineral oil. The blade is then advances slowly, utilizing uniform pressure and speed. As the cut skin is peeled away,
an assistant grasps it to prevent folding in front of the dermatome blade and shredding the freshly harvested graft. Local anesthesia is used for donor site site acquisition and the specimen is perforated for drainage. It may also be stored for future use, under moist refrigeration at 0-5 C. The donor site is covered with a non-static dressing and typically is more painful to the patient than the recipient bed.

If a larger area must be grafted, the graft can be "pie-crusted" or "crosshatched" with a mesher to increase its surface area and allow fluid seepage. Once healed, a molded shoe can be fabricated to prevent irritation and protect the friable site. The technique is economically advantageous, psychologically palatable and fosters a more rapid period of rehabilitation. Skin graft cosmetic results are superior to healing by secondary intention but generally less pleasing than a delayed primary wound closure. Obviously, the technique is available to only the experienced foot surgeon.

**Full Thickness Skin Grafts (FTSG's)**

As noted, full thickness skin grafts (FTSG's) differ from split thickness skin grafts (STSG's), in that the latter is more likely to survive while the former is more cosmetically acceptable. Furthermore, a full thickness graft is more likely to contract but also provides a more durable surface. Typical donor sites include the dorsum of the foot, malleoli and inguinal fold. Anatomically, the graft is composed of both the dermis and epidermis, which contains the protein, elastin, which increases durability. When harvesting the graft, a surgical template is used to mark the necessary pattern, although a bit more skin is usually taken, than needed, as the elastin produces a degree of contractility to the graft and some shrinkage occurs. The specimen is denuded of its fat and placed dermal side down over the wound. As the graft is full thickness, the blood vessels available for in growth are relatively large and few in number. It is then dressed with a stent bandage, and examined within 72 hours.

**Skin Flaps:**

A skin flap is a segment of subcutaneous tissue that is transferred to restore a soft tissue defect, but remains permanently or temporarily attached to the donor site for blood supply. The base of the flap, which contains the blood supply, is called the "pedicle". There are 3 types of skin flaps:

- A "random" flap is vascularized from the random intradermal and subdermal plexus. Because of perfusion limitations, a random flap can supply only a fixed length of tissue regardless of its base; approximately a 1:1 length-to-width ratio. It therefore has limited use.
- An "axial" flap consists of an artery and vein that is incorporated into the pedicle. This increases perfusion and may be useful in digital or metatarsophalangeal infections. Essentially, the appropriate toe is filleted and used for wound coverage.
- An "island" flap is similar to an axial flap in which the soft tissue and vascular elements are removed to increase mobility, as it may be rotated through an arc of 180 degrees or more.

**Muscles Flaps:**

Local muscles flaps, for the secondary closure of chronic osteomyelitis, have been used since the 1920's. Most treatment areas are in the axial skeleton, and in the femur or tibia in the lower extremity. The gastrocnemius or soleus muscles are most commonly used.
Specialized Skin Flaps:

Three additional flap techniques may be used in the foot, following certain infection and wound defect types.

- The "neurovascular island" flap contains a nerve located within the vascular plexus. This flap maintains tactile sensation and is being increasingly used in foot surgery.
- The "myocutaneous" (musculocutaneous) flap is a special anatomic variation that permits the transfer of a portion of the muscle underlying the skin on a single neurovascular pedicle. The tissue may be used as an axial or island flap or it can be detached and transferred as a free flap to cover a peripheral defect in a single procedure. An example of this flap type is a "cross leg flap".
- The "tree" flap is an axial flap in which the blood supply has been severed and the flap transferred to its recipient site. Circulation is reestablished by microvascular anastomosis of its respective artery and vein. There is generally a 20% risk of flap loss this type of transfer, and many wound defects can be managed with the other types of techniques just reviewed.

Viability of Skin Flaps:

Unlike skin grafts, the usual cause of flap failure is vascular embarrassment, produced by mechanical tension, excessive edema, restrictive bandages or tight sutures. Flap viability may be evaluated through clinical appearance, Doppler ultrasound, fluorescein dye and digital plethysmography. Treatment is symptomatic but usually fails if not recognized early.

Miscellaneous Skin Graft Techniques:

Small full thickness "postage stamp" grafts are used to "pepper" a wound defect and allow epithelialization to fill in remaining spots. Larger, rotational pedicle and bi-lobed skin flaps are used for localized defects left by the infectious process. A dermal (reverse) overlay graft is used when circulation will not support a STSG. First, the STSG graft is harvested and the dermis removed. The previously removed STSG is placed over the donor site and the remaining dermal graft is reversed and placed over the recipient bed with its superficial layer facing down. Five to seven days later, another STSG is placed over it and allowed to heal. It is occasionally used in foot surgery.

Finally, the concept of soft tissue expansion, through the use of soft tissue expanders (stretchers), is increasingly being used to cover soft tissue defects. In this technique, deflated plastic silicone balloons are inserted under the subcutaneous tissue layer, but above the fascial plane. The bladders are then slowly expanded, to allow the overlying tissue to adapt and respond to the challenge. Upon removal, the redundant tissue is harvested for immediate or later use. The surgical site is then primarily closed.

Infected Surgical or Traumatic Non-unions

The case of an iatrogenic or traumatic non-union of the foot is indeed complex. Much has been published in the medical literature about various treatment regimes.
According to Gustillo, they can be distilled into the following general principles:

- Radical debridement of infected and necrotic bone and surrounding soft tissue structures.
- Achievement of fracture stability, especially with external hardware fixation devices placed proximal and distal to the break.
- Promotion of granulation tissue and abundant cancellous bone grafting to fill large skeletal defects.
- Frequent dressing changes for proper wound toilet.
- Skin and soft tissue coverage, through the techniques just described.
- Non-weightbearing until the fracture has healed.
- Appropriate antimicrobial therapy.

**Concluding Remarks**

The surgical treatment of the infected foot and pedal wounds entails many different surgical, medical, mechanical and physiologic processes. These often begin with the normal or abnormal stages of wound healing, progress to the acute and/or chronically infected phase, and usually terminate with different types of plastic or reconstructive surgical techniques. The purpose of this material was to review some of these techniques, in order to appreciate the multifaceted challenge the infected foot presents to the informed clinician. And, it may be important for board certification examinations.

**References:**

Additional References:

- Podiatry Institute Updates, 2004-2006, Tucker, Georgia.

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