THE SURGICAL MANAGEMENT OF INFECTIONS

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The successful management of any infection depends upon a number of various factors. The mainstay of treatment for any major infection is surgical debridement. Successful surgical management will depend upon a careful and thorough preoperative assessment. This may require special testing including radionuclide scans (technetium, gallium, indium or combinations), MRI or CT scans. Conventional x-rays are also routinely performed. Clinical laboratory studies will provide a baseline at the start of treatment and may provide information regarding the severity of the infection. The purpose of this paper is to emphasize the surgical management of foot and ankle infections.

SURGICAL TECHNIQUES

In most cases, the primary goal of infection surgery is to incise and drain the infected area and promote continued drainage. The extent of the incision will depend on a number of factors. Surgical incisions, however, should be executed with careful planning in anticipation of a delayed primary closure and preservation of maximum function. Incisions on the plantar aspect of the foot should be planned to avoid major weight-bearing areas.

The extent of the incision will be guided by intraoperative findings. It is important to extend an incision to the point where normal tissue layers are readily visualized. When the skin, subcutaneous tissues, deep fascia, and deep fascial layers are readily discernible, one can generally be assured that normal tissues have been reached. A careful inspection of the surrounding tissues should reveal an absence of the suppurative processes. Failure to do so is likely to result in a return to the operating room for additional debridement.

All nonviable or necrotic tissue and debris should be excised. Curettage of the tissues is a commonly performed technique. In addition, any hematoma accumulation is also removed. Mechanical debridement with a pressure irrigation system is extremely beneficial. Large volumes of normal sterile saline under high pressure provide an extremely effective means of mechanically debriding the tissue along with the curettage technique. Several studies have shown that mechanical systems provide the most effective debridement of bacteria, debris, dead cells, and nonviable tissue. Failure to accomplish an adequate debridement is likely to result in impedance of the healing process. Rather than normal sterile saline, some surgeons prefer to use dilute antibiotic solutions or dilute povidone iodine (Betadine) solutions. In any event, it is not as much the solution as it is the volume of the solution and the pressure that result in effective mechanical debridement.

Postoperative infections pose a particular challenge with regard to retained foreign bodies. At the very least, all suture materials should be completely removed. Removal of internal fixation devices is a subject of continued debate and controversy. Our practice is to carefully assess the advantages and disadvantages of leaving or removing internal fixation devices. In most cases where the internal fixation device is providing significant stability or rigid internal compression fixation of an osteotomy or fusion site, the devices are left in place. This is particularly true when the postoperative infection has been identified in the very early days and operative intervention is immediate. In these situations, the infec-

tion is generally confined to the soft tissues rather than the osseous structures. Removal of the devices greatly increases the chance of an infected nonunion or pseudoarthrosis.

In situations where the internal fixation device is clearly a contributing factor, the device is removed and temporary stabilization can be achieved by use of an external fixator with the fixation pins placed proximal and distal to the site of infection. Cases involving prosthetic implants are likely to require removal of the implant for successfully resolve the infection. In these situations, re-implantation can be performed after several months.

Successful surgical debridement may require partial or complete amputation of a part or segment of the foot. Common levels of amputation include partial digital resection, total digital resection, partial ray resection or complete ray resection. In more serious cases, especially infections in the immunocompromised patient, forefoot, midfoot or below the knee amputations may be necessary.

Infections in the immunocompromised patient present particular challenges. These infections, in addition to not uncommonly being polymicrobial, often involve one or more of the plantar spaces of the foot. Such infections are common in the diabetic patient. A thorough working knowledge of the various compartments of the plantar aspect of the foot is critical to successful management.

In the case of osteomyelitis, all infected bone is resected. Unless the bone is being resected in its entirety, the use of power instrumentation is encouraged. This technique will create clean cuts and facilitate monitoring of the infectious process by serial radiographs. All too frequently, inadequate resection of infected bone is performed. While long-term function is critical, it must be remembered that once a major portion of the weightbearing component of a bone such as the metatarsals is resected, the remaining portion of bone will be non-weightbearing and, therefore of minimal value.

In general, the author recommends an aggressive resection of all potentially infected bone at the time of initial debridement. After the initial bone has been debrided, a secondary portion of bone is resected and sent separately to both the microbiology laboratory and for histological sectioning. The author routinely divides all resected bone into halves. One half is sent to the microbiology laboratory for Gram's stain and culture and sensitivity, and the other portion of bone to the pathology laboratory for histopathological study. The information retrieved from the various portions of bone is helpful in guiding the postoperative care and ensuring that all infected bone has been adequately excised.

Finally, patients with compromised vascularity to the extremity often pose a major dilemma. In these situations, revascularization may necessarily be delayed several days. Successful management of the infection, however, requires at minimum an incision and drainage to allow rapid decompression and drainage of any abscess. This minimal surgical intervention is necessary to minimize further necrosis of underlying tissues as the pressure of purulent fluids accumulate. In these cases, the debridement is minimal. Definitive debridement will be performed at the time of revascularization or shortly thereafter.

In summary, operative intervention is of the utmost importance in the successful management of an infection. The primary principles include: 1. Adequate incision and drainage of the infected area. 2. Debridement of all necrotic and nonviable tissue and bone. 3. Removal of all retained foreign bodies including suture materials, internal fixation devices, and prosthetic implants except those whose removal is likely to result in a more devastating outcome.

The extent to which these principles apply will vary and must be individualized on a patient-to-patient basis. Factors which will influence the aggressiveness of surgical debridement include the infecting organisms, type of infectious process (localized abscess vs. soft tissue vs. bone), overall health status of the patient (e.g., presence or absence of any immunocompromised or debilitating diseases), and the presence or absence of vascular compromise.

WOUND MANAGEMENT

Immediately following the surgical debridement in the operating room, final culture and sensitivity specimens are obtained. These will, hopefully, show minimal or scant growth in comparison to the initial Gram's stain and culture specimens obtained at the start of surgery. There are several

options for management of the wound at this point. These include local wound packing, ingress/egress drainage systems, antibiotic impregnated beads or primary wound closure.

Primary closure of the wound is seldom performed and is generally limited to those situations in which a partial amputation has been performed and the surgeon is extremely confident that all infected tissue has been removed. Such an example would include the disarticulation of a digit at the level of the metatarsophalangeal joint for an infectious process involving the middle and distal phalanges and perhaps the distal portion of the proximal phalanx. Whenever there is any question as to whether a primary closure can be performed, it is preferable to defer the closure for several days pending final cultures and further wound assessment.

One of the most common wound care techniques consists of packing the wound with either iodoform impregnated gauze or plain gauze. Iodoform impregnated gauze is used in situations where there is significant purulence and/or drainage. This type of packing material will encourage "drying" of the wound. More commonly, plain NuGauze is packed in the wound deficit. In some cases, the author prefers to saturate the NuGauze with an antibiotic solution prior to packing. Large wound deficits can be packed with saline or antibiotic soaked Kerlix or even gauze sponges.

Periodic and regular sterile dressing changes and wound inspections are then performed, usually beginning the second day postoperatively. Depending on the severity of the infection and the clinical progress, dressing changes are performed one, two or even three times per day. Wound packing material is removed and the wound is mechanically debrided utilizing 1-3 L of normal sterile saline. In some cases the irrigation solution may be supplemented with a small amount of povidone iodine solution or detergent such as Dreft. The presence of a surfactant in the Dreft detergent facilitates debridement and removal of the mucous layer which tends to form on the granulating tissue. Under sterile conditions, the wound is then repacked with the material of choice. In some situations, wet to dry dressings are applied to encourage granulation and promote mechanical debridement of the wound. A moist wound environment is usually desirable and will promote granulation and healing while minimizing desiccation of vital structures.

Additional Gram's stain and culture and sensitivity specimens are obtained periodically at the dressing change. This information is correlated with the clinical appearance of the wound. Unfavorable changes in the wound accompanied by persistent organism growth or identification of new organisms would suggest the need for additional surgical debridement. It should be emphasized that the clinical appearance of the wound is by far the most important factor in determining the future course of management. While obtaining two or three serial negative cultures is generally preferred by members of the Institute, there is no scientific documentation that this, in fact, is necessary. Clinical experience has shown that infected wounds will progress without further complication, even in face of scant or light growth, as long as excellent clinical progress and improvement is being made. In short, the reliability of cultures alone should be questioned. While culture reports should certainly be given careful consideration, the clinical appearance of the wound, based on a daily inspection, is of greater importance. Persistent drainage, increased distention and swelling about the wound, increasing erythema, and pain are but a few of the clinical signs suggesting unfavorable wound healing.

Ingress/egress drain systems also represent a viable option. Although once popular, their use has become primarily of historical interest. The initial concept involved mechanical debridement of the wound by irrigation and the simultaneous delivery of an appropriate antibiotic. Fabrication of ingress/egress drain systems is extremely cumbersome. Over the last ten years, there has been no significant scientific data to support their routine use. This technique is not a preferred method of wound management by members of the Institute. Other methods have proven equally or more successful.

Another option in local wound management employs the use of antibiotic impregnated polymethylmethacrylate beads. The most common antibiotic solutions used include gentamicin and tobramycin. The use of antibiotic impregnated beads has been extensively reported in the medical literature, both in the United States and Europe. They are commonly used in major cavi-

ties within the long bones as well as defects left after removal of infected prostheses.

Antibiotic impregnated beads are particularly valuable in the patient with compromised vascularity (i.e., diabetic infections). The beads are capable of providing extremely high concentrations of the antibiotic over a protracted period of time in a specific tissue site. The use of antibiotic impregnated beads is considered to be relatively safe with no known systemic toxicity from the antibiotic agent employed.

The author has found the use of antibiotic impregnated beads to be a very valuable adjunctive measure in the management of an infected wound.

The downside of the bead technique is the requirement that the wound must be closed primarily or covered by an impervious adherent material. Sealing of the wound is necessary to allow build-up and sustained levels of antibiotic within the tissue fluids. In addition, the antibiotic impregnated beads are not available commercially, and must be fabricated in the operating room at the time of surgery, or prior to surgery and re-sterilized. Fabrication of the beads is a relatively time-consuming process and it is helpful to have more than one individual assisting in the actual process.

Other contraindications to the use of antibiotic beads include anaerobic and streptococcal infections. Antibiotic beads should not be used as a substitute for surgical debridement, however, when judiciously used, they may prove very beneficial. In comparison to other packing materials, the beads do not require daily wound inspection. They do, however, require removal at a later date, most commonly 10-14 days after their insertion. This may be performed either at bedside or in the operating room under appropriate anesthesia if necessary.

Current research centers around the use of body fluids which have been transformed into a gel (fibrin clots or blood clots) and are then impregnated with an antibiotic solution of choice. This process is being studied at many major medical centers throughout the country. It is believed that within the next several years, this technique will be an important component of local wound management in infected wounds.

SUBSEQUENT WOUND MANAGEMENT

As previously discussed, primary closure at the time of the incision and drainage is rarely indicated or performed. Following the initial incision and drainage, the wound is monitored carefully for several days. Clinical progress will determine the definitive subsequent management of the infected wound. Several options are available:

1. Delayed primary closure.
2. Secondary intention healing.
3. Skin grafting or rotational flap.

The preferred method of management by members of the Institute is a return to the operating room and the performance of a delayed primary closure as soon as possible. This delayed closure is usually done following a series of two or three negative cultures, clinical resolution of the infection, and a marked improvement or return of preoperative laboratory studies to near normal values. In addition, systemic response to the infection should also show marked improvement, indicated by return of normal vital signs.

Delayed primary closure is usually performed under general anesthesia. In the operating room, the wound is again irrigated with high volumes of a pressure irrigation solution. Gentle curettage of the wound itself may be performed to stimulate bleeding and remove any residual devitalized or necrotic tissue and debris. If performed within the first several days following the initial incision and drainage, the wound can be directly reapproximated. When closure has been delayed by 5-10 days, it is not uncommon to resect the skin margins and then perform primary reapproximation of the wound edges. Prudent selection of the type and amount of suture materials utilized is strongly recommended. Sutures used for closure of deep tissue layers are kept to a minimum. When necessary, the least reactive synthetic absorbable suture is preferred (Dexon or Vicryl). Not uncommonly, large vertical mattress or horizontal mattress stitches are placed along the course of the wound to serve as retention or bolster sutures and help decrease tension on the primary wound edges. The skin is then reapproximated with the least reactive synthetic monofilament nonabsorbable suture (ie., polypropylene or nylon). Closure is usually performed in a simple interrupted manner.

The insertion of a suction drainage system such as the TLS drain should be considered. This is particularly important when there is a residual dead space or anticipation of fluid accumulation. In addition, subsequent drainage from the TLS drain can be sent to the laboratory for a Gram's stain and/or culture and sensitivity if there is any question about the progress of the wound.

In some situations, delayed primary closure does not represent a viable alternative. This is particularly true when the wound edges have undergone significant contraction and/or there has been debridement of a significant amount of the skin and subcutaneous tissues in the area of infection. In these cases, delayed primary closure is likely to meet with significant wound complications, especially wound dehiscence. Under these circumstances, it is not uncommon to allow the wound to heal by secondary intention. In this process, granulation tissue will form from the base of the wound upward, filling the defect completely. Simultaneously, epithelialization will take place from the wound margins, as long as the base is clean and a moist environment is maintained. Many surgeons elect this method of wound closure in lieu of delayed primary closure hoping to decrease the chance of re-infection. The faculty of our institution have not seen an increased incidence of recurrent infection following delayed primary closure, when the previously discussed criteria have been met.

The open wound must be provided with some type of coverage. Because skin is man's greatest protection against bacterial invasion, delayed primary closure is clearly our preference. In cases where delayed primary closure may not be achieved, other wound coverage techniques may be employed. Some of these techniques include skin grafting or musculocutaneous and free flaps. Amnion, artificial skin, and xenografts provide temporary wound coverage and are helpful to promote healing and preparation of the wound for an appropriate wound coverage technique.

Prior to performing a skin graft or flap, the wound must be carefully assessed. Quantitative bacterial counts may be particularly valuable in this situation. It has been demonstrated that the presence of 105 bacteria (or greater) per gram of tissue indicates a significant level of bacterial contamination and is indicative of infection. Wound coverage techniques in these situations are likely to be met with failure. Clinical studies have supported this finding. The presence of Streptococcus pyogenes or Pseudomonas pyocyanea are two particular types of bacteria which are likely to result in failure of a skin graft or flap. These organisms must be eliminated prior to any such surgery. This may require the use of systemic antibiotics in addition to aggressive local wound care. Only once the wound is clean, free of infection and necrotic tissue and debris with a good, healthy, granulating base, should a complex wound coverage technique be employed. In addition to the previously described local wound care, topical medicaments (enzymatic debriding agents and topical antibiotics such as Bactroban) may be helpful in preparing the wound. Once the wound has been adequately prepared, a skin graft, skin flap, or muscle/myocutaneous flap may be performed. It is not uncommon to employ the expertise of a welltrained plastic surgeon who is specifically knowledgeable in the area of wound coverage techniques in the lower extremity.

SUMMARY

The surgical management of infection is a complicated and challenging area. Successful treatment depends on the prompt recognition and accurate assessment of the infectious process. Paramount to successful treatment is immediate radical and aggressive surgical debridement. The incision and drainage must include decompression of all areas of infection as well as complete debridement of all necrotic and nonviable tissues. Local wound care and daily wound inspections will determine the definitive management of the wound. Although delayed primary closure is our preferred technique, at times, secondary intention healing may be necessary, as well the use of any one of a variety of wound coverage techniques. Finally, adjunctive therapy including appropriate antibiotics and systemic supportive therapy are also important components.