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Osteomyelitis Debridement Techniques

Kevin Tetsworth, MD; and George Cierny, III, MD*

Debridement of chronic osteomyelitis can be technically demanding and difficult. The surgical principles that govern treatment of osteomyelitis involve an atraumatic approach and complete removal of all devitalized tissue and foreign material. Despite recent advances in medical science, the quality of surgical debridement remains the most critical factor in the successful management of chronic orthopaedic infections. Important areas discussed include thorough preoperative evaluation, the surgical philosophy, soft tissue aspects, bone considerations, and dead space management.

Debridement is an all encompassing term used to describe surgical techniques that are under appreciated and inadequately reimbursed. The simplest form of debridement is incision and drainage of acute infections. Release of accumulated pus, often under pressure, decreases the bacterial load sufficiently to allow host defenses and antibiotics to battle infection effectively. In the acute setting, local tissue viability is intact, and this simple procedure is usually adequate to address subcutaneous abscesses or even septic joints. However, in the presence of established infection, local and systemic compromise often result in treatment failure and recurrent infection.[4,5] Surgeons with an interest in the management of this difficult problem recognize that attention to detail, gentle soft tissue handling, and a systematic approach are all critical to achieve successful results.

The pioneers of orthopaedic surgery delineated the important surgical principles in the management of infection more than 50 years ago. Trueta[30] emphasized the need for adequate debridement in the management of orthopaedic infections and battle injuries. The original principles that governed osteomyelitis surgery included an atraumatic approach and removal of all necrotic or nonviable material. These initial principles of debridement were applied with some success for many years, but still resulted in 30% failure and recurrent sepsis.[2,8,9,15,17,28,31–33,37]

The advent of microvascular free tissue transfer more than 25 years ago allowed for improved soft tissue coverage and created the potential for more extensive and complete resection.[11,16,22,36] During the past 15 years improvements in external fixation devices and the implants available for stabilization have extended the limits for sepsis surgery further. The use of antibiotic beads[18,19,25] and other methods of dead space management have allowed development of a staged reconstruction protocol[4,5] that has become the accepted standard of care. The methods of Ilizarov[13,14] and the use of exter-

From the *Maryland Center for Limb Lengthening and Reconstruction, Kernan Hospital, Baltimore, MD.

Reprint requests to Kevin Tetsworth, MD, Maryland Center for Limb Lengthening and Reconstruction, Kernan Hospital, 2200 Kernan Drive, Baltimore, MD 21207.

nal fixation for controlled gradual mechanical distraction have been additional means of skeletal and soft tissue reconstruction.[6,24,35] Application of these current techniques has yielded dramatic improvement in results with more than 90% success showing clinical arrest of infection.[4,5,25] Despite the technical advances that have made these results possible, the quality of surgical debridement remains absolutely the most critical factor in the successful management of chronic orthopaedic infections.

The principles of management and the treatment protocol are general, and can be applied to problems as diverse as infected nonunions or failed septic joint arthroplasty. The techniques used for debridement were developed during the course of many years and reflect a broad experience with problem wounds, often reluctant to heal. The important issues to discuss include thorough preoperative evaluation, the surgical philosophy, soft tissue aspects, bone considerations, and dead space management.

PREOPERATIVE EVALUATION

Preoperative evaluation plays a critical role in the management of chronic osteomyelitis, and often determines the most appropriate treatment. Thorough physical examination and a complete medical history are mandatory. It is critical to evaluate the entire patient and not focus only on the involved limb. Comorbid conditions are extremely common in this patient population, and contribute significantly to treatment failure. Host compromise can be either local, systemic, or both, and can be used to predict the risk of wound complications or recurrent infection.[4,5] The most important product of preoperative evaluation is to identify the treatment alternatives most appropriate for a specific clinical presentation. The outcome will be a function of the number of different treatment alternatives within the capabilities of a given surgeon at a particular institution. The preliminary goal is to delineate those options and then to match these with the patient under consideration. It is paramount to identify the desired outcome and, after reviewing with the patient the considerable risks, potential benefits, and morbidity of the treatment itself, together clearly define the goals of treatment. These initial considerations are crucial, and cannot be overemphasized.

The entire limb must be examined carefully in a systematic fashion. Motion of adjacent joints, limb length discrepancy, angular or rotational deformities, the neurologic status, and the vascular supply must be documented completely. These injured limbs most often have distorted anatomy, have already undergone multiple procedures, and treating orthopaedic surgeons may be at risk for litigation. It behooves the treating surgeon to establish the current status before considering additional intervention.

Physical examination is multisensory, not only visual but also tactile. The character and quality of the surrounding soft tissue must be examined critically as to its healing potential. The presence of scars and the probable prior surgical approaches must be kept in mind. The choice of optimal approach often is dictated by complex soft tissue considerations. The neurovascular examination and the presence or absence of pulses can determine when additional vascular studies are beneficial. Transcutaneous O_2 potentials generally are available and may be useful when assessing wound healing potential. Local soft tissue compliance is best assessed clinically by palpation. When microvascular free tissue transfer already is present, the location of the anastomosis also must be identified. A mature free flap generally is atrophied and fibrotic with diminished compliance and limited potential for transposition.

Plain radiographs often reveal much of the information the experienced surgeon needs to make informed decisions regarding the anatomic extent of involvement. The presence or absence of a dense intramedullary cortical sequestrum, endosteal scalloping, or an involucrum generally are visible on good quality standard radiographs. If routine radiographs fail to provide adequate information for determining the extent of involvement and potential resection margins, more sophisticated studies are indicated.

Nuclear scans occasionally can be useful in making the diagnosis, but are nonspecific and do not provide adequate detail to determine resection margins. Technetium scans sometimes are beneficial for assessment of local bone viability. Radionuclide scans are used to document the presence of infection when the presentation is atypical. They also can be beneficial in determining the extent of infection when metallic implants are present, which precludes the use of computed tomography (CT) or magnetic resonance (MR) imaging.

Computed tomography scans are useful for the evaluation of chronic infected united fractures when determining the optimal location and approach to use to create an oval cortical window. Magnetic resonance imaging is occasionally the best means of establishing the diagnosis, particularly when infection is restricted to the medullary canal. Magnetic resonance imaging also is useful when making the distinction between osteomyelitis restricted to the cortex with an overlying soft tissue defect, and cases with extension of infection that involve the medullary canal. Magnetic resonance imaging can reveal extremely fine details of the extent of anatomic involvement and may be beneficial for the less experienced surgeon when estimating resection margins preoperatively. The extent of involvement is estimated based on preoperative imaging studies, but with adequate experience the surgeon will rely on intraoperative findings to determine the limits of debridement.

SURGICAL PHILOSOPHY

An atraumatic approach and gentle soft tissue handling are most important, while following the prior planes of surgical dissection. Successful debridement is negated by failure to obtain and maintain viable soft tissue coverage. Preoperative evaluation identifies most wounds at risk for ischemic necrosis and this requires some knowledge regarding local vascular supply.[23] As a general rule, in septic cases the surgeon is obligated to follow previous incisions and approaches. In the wound that has been operated on multiple times and has several scars, this can be particularly difficult and must be considered carefully. If one chooses to cross a prior surgical plane or scar in an attempt to minimize the risk of immediate postoperative wound failure, a new incision should cross prior scars at right angles to maximize inflow to the corners at the junction with the scar, thereby minimizing the risk of edge necrosis (Fig 1).

All dense and adherent overlying or surrounding scar should be excised. If tissue is of insufficient vascularity and cannot contribute to wound healing, it must be considered an impediment to success and should be removed during the course of debridement. This includes all tissue, hard and soft; the wound begins at the surface and extends down to and includes bone. The surgeon should estimate the magnitude of bone and soft tissue debridement defects preoperatively and prepare for them accordingly.

Rather than use an extensile approach, debridement is performed through an expansile exposure. Unfortunately, landmarks often are obscured by overlying scar and it can be difficult preoperatively to determine the exact location of the focus of infection. It is not unusual for the procedure to evolve gradually based on intraoperative findings. The initial exposure is centered over the most likely area of involvement, and extended in either direction as necessary. Additional dissection and devascularization are limited to what is absolutely required. Cortical viability is preserved by minimizing the area of soft tissue stripped from the bone in the region of interest. The standard orthopaedic

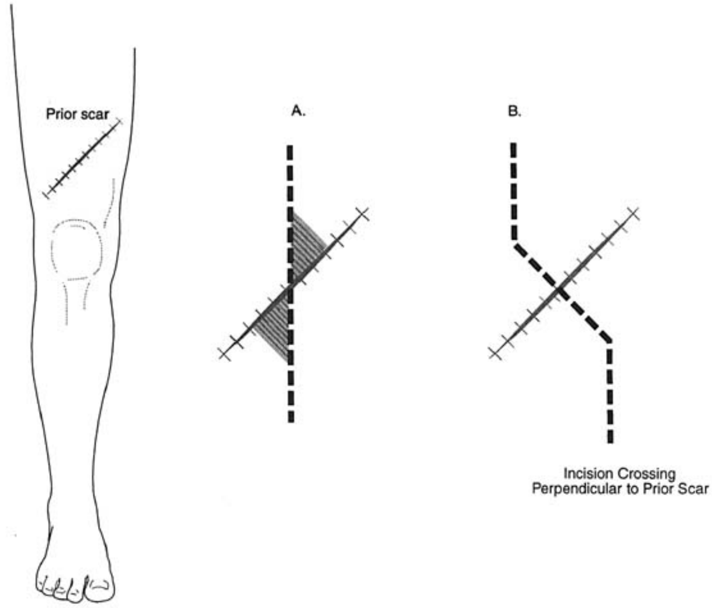

Fig 1A–B. (A) Linear longitudinal incision intersects prior scar at an acute angle. Shaded areas are potentially hypovascular and at risk for ischemic necrosis. (B) Preferred incision crosses perpendicular to prior scar. This orientation maximizes available inflow proximal and distal. This incision is safer and has less risk of breakdown postoperatively.

dictum, bone is your friend, is contrary to this approach. Resist the tendency to expose bone in a subperiosteal fashion, stripping the cortex of one source of vascularity.[38] Bone is exposed only after satisfactory exposure of the region of interest first is obtained by dissection in the extraperiosteal plane (Fig 2). Periosteum is stripped only from cortical bone intended for debridement; periosteum and vascularity are otherwise strictly preserved.

SOFT TISSUE ASPECTS

Excise all dense adherent overlying scar that will not contribute to wound healing.[5,17] Preoperative planning must include provisions for expected soft tissue defects and dead space management. Accessory sinus tracts distant from the intended course of the incision used for debridement are not routinely excised. After the source of drainage is eliminated, these generally close spontaneously.

Most incisions through prior exposures are prepared for closure by excising the original scar with a margin of several millimeters on either side. After incising the dermis the dissection can be taken tangentially for several millimeters before penetrating the fascia. This pants over vest incision creates a second layer for closure that often is beneficial when dealing with problem wounds. When possible, the incision through fascia is shaded in the direction of greater vascular supply to avoid creating a hypovascular dermal flap at risk for ischemic necrosis (Fig 3).

Tension free wound closure is mandatory after completing the procedure. Wound margins often can be mobilized additionally by judicious dissection of skin and subcutaneous fat from deep fascia. Local advancement is an extremely valuable technique that also is used routinely. Regions of dense scar may have a predilection for wound inversion that must be addressed at closure, either by excision or mobilization from below. Adequate closure requires eversion of wound margins, even after suction drains are activated. The use of braided or absorbable sutures should be avoided. The geometry of braided sutures may harbor microorganisms and become a source of recurrent sepsis. Absorbable sutures may stimulate an inflammatory response that is undesirable. Nylon and

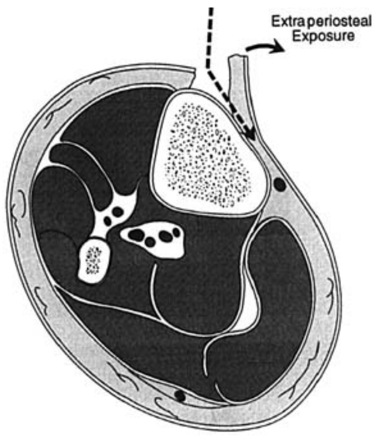

Fig 2. The region of interest is exposed in an extraperiosteal fashion to preserve potential sources of vascularity. Subperiosteal exposure and subsequent intramedullary debridement will devitalize cortical bone inadvertently.

stainless steel are the least reactive suture materials, and of these nylon is far more convenient. Most tension free wounds can be closed readily with 2-0 or 3-0 monofilament nylon suture in a vertical or horizontal mattress fashion.

BONE CONSIDERATIONS

Bone is exposed in an expansile manner, dissecting in the extraperiosteal plane to limit additional vascular compromise.[38] The surgeon must avoid devitalizing cortical bone by stripping the periosteum and then additionally disrupting vascularity by interrupting endosteal inflow. This commonly is done when treating nonunions if plates and screws are removed during the same procedure when an exchange to an intramedullary rod is performed. There is a substantial risk of creating a long sequestrum by potentially devitalizing the entire original cortex. When possible, one should stage these procedures with a 6- to 8-week interval between each to minimize this risk. Similarly, the surgeon should not strip periosteum during exposure and then debride the medullary contents within. Again, the overlying cortex will be devitalized and is at great risk of becoming an iatrogenic sequestrum.

Reactive new bone surrounding an area of chronic infection is by definition living and does not require debridement. The sequestrum must be identified and removed, but the involucrum generally should be preserved.

Sharp, precise, rapid debridement of bone is best done with high speed burrs. Always use fresh burrs to maximize cutting efficiency and limit thermal necrosis. These always are used under continuous iced saline irrigation, again to limit thermal effects.

During the process of debridement, one should monitor the bone in question constantly and look for scattered pinpoint sites of bony bleeding that indicate adequate vascular inflow. This appearance of uniform punctate haversian bleeding, often referred to as the paprika sign,[5] is characteristic of living bone and is useful for establishing the limits of debridement. Dense cortical bones, particularly the anterior tibial cortex, generally will have less punctate bleeding than other locations, and the surgeon must be able to recognize normal anatomic variations. Use of a laser Doppler probe has been advo-

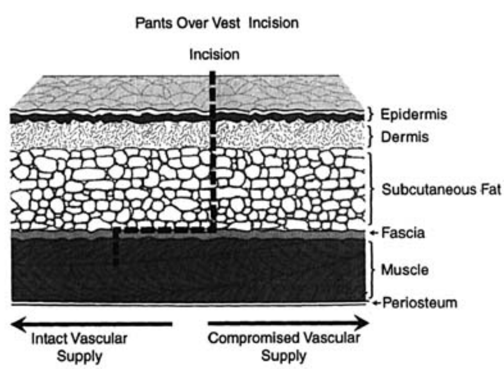

Fig 3. The pants over vest incision is a useful approach when dealing with problem wounds. The incision through fascia is shaded 4 to 5 mm toward the greater vascular supply to avoid creating a hypovascular dermal flap. This incision leaves a second layer and increases the probability of a water tight closure.

cated as a means of determining bone viability,[29] but this is cumbersome and of limited benefit to a surgeon experienced with sepsis.

Infection restricted to the medullary canal sometimes is debrided adequately by reaming.[20] To limit potential thermal effects of reaming, a saline soaked cotton gauze pad can be draped over subcutaneous bones, such as the tibia, to act as a heat sink. Irrigation directly into the canal can be performed with a standard nasogastric tube. This should be configured to lavage the canal from distal to proximal in the femur and tibia, so as to create a constant flow out of the bone. When irrigating either segment of the lower limb, the patient should be placed in slight Trendelenberg's position, again for the purpose of promoting flow of irrigator out of the bone. The same nasogastric tube also will be useful for suction directly from the canal, once more from distal to proximal. The characteristic tone of suction from a hollow tube can be useful when determining if debridement and irrigation of the medullary canal has been complete.

If the infection involves areas proximal or distal to the diaphysis proper, the internal dimensions of the canal expand and reaming alone is inadequate. Reaming also is contraindicated when preoperative radiographs show endosteal scalloping. In either instance, reaming alone is a suboptimal technique. In those cases it is necessary to debride the canal directly by creating a trough. The trough is a long thin elongated oval cortical window to provide access to the medullary canal and its contents (Fig 4). Biomechanical studies have established the oval as the ideal geometry for biopsy portals.[7] This window can be extended longitudinally a substantial distance with only a slight diminution in torsional strength provided the width is limited and the margins smooth. Extraperiosteal exposure of the region of interest is first provided and the periosteum stripped from the cortex only from the area of the intended trough. A high speed burr under continuous iced saline irrigation then is used to create a longitudinal trough that is oriented parallel with the long axis of the bone. The dimensions of the trough are generally 7 to 10 mm in width and 3 to 9 cm in length. Occasionally, longer troughs are required that may measure 30 cm or greater in length. It then is prudent to limit the width of the trough to 5 to 7 mm to diminish the risk of iatrogenic fracture.

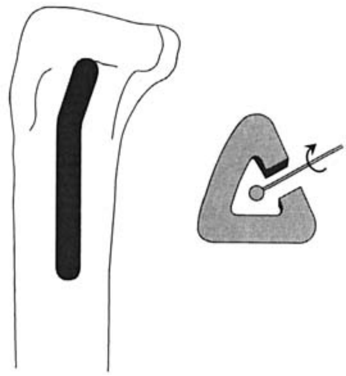

Fig 4. The trough is a useful technique to provide access to debride the medullary canal. The elongated oval is the optimal shape for a cortical defect. This window can be extended safely 7 cm or more provided the width is limited and the margins smooth. The width should be less than 10 mm in large bones, but may only measure 7 mm or less in small bones.

The need for stabilization of bone after adequate debridement is sometimes difficult to determine intraoperatively. As a general rule, when 70% or more of the original cortical volume remains intact at the level of debridement, the risk of iatrogenic fracture is low and stabilization is not necessary.[1] If the extent of debridement leaves less than 70% of the original cortical volume intact, the risk of iatrogenic fracture is great enough to make prophylactic stabilization mandatory. Prophylactic stabilization can take many forms, including internal fixation or intramedullary rodding. In the presence of established infection, external fixation is most often the preferred method of stabilizing bone at risk while preserving maximal local vascular supply. It occasionally is prudent to apply a simple external fixator to an intact limb segment after completing debridement. Assessment of residual bone volume then is determined best from a postoperative CT scan through the region of interest. The fixator can be removed easily thereafter if the remaining intact bone renders stabilization superfluous.

Segmental resection of the tibia or femur is an excellent means of dealing with an intractable infected nonunion, provided the surgeon is able to reconstruct the defect in a timely fashion and restore satisfactory function.[6,24,35] It generally is best to stabilize the limb before debridement, often using a circular multiplanar external fixator. Stabilizing the limb first minimizes blood loss by reducing the time the wound remains open. It also is prudent to take advantage of normal anatomy when present, and this can facilitate fixator application. This is particularly true when using a circular external fixation device. The region of intended debridement or expected segmental resection can be exposed in an extraperiosteal fashion with the benefit of a tourniquet immediately before stabilization. The tourniquet then can be released, hemostasis secured, and the wound closed loosely while having unencumbered access to the limb. After applying the external fixator, the provisional closure can be opened and the debridement or segmental resection completed. Properly applied fixator components, such as rings or threaded rods, may be useful as alignment aides while performing the osteotomies necessary for segmental resection.

Segmental resection requires adequate exposure to allow for placement of retractors as necessary to protect surrounding soft tissues, including neurovascular structures. The osteotomies usually are performed with an oscillating saw under continuous iced saline irrigation. It is safest to complete each osteotomy with an osteotome to limit the risk of inadvertent injury to adjacent soft tissues. After proximal and distal osteotomies, the intercalary segment can be removed in a subperiosteal fashion. The medullary canal and cortical bone of the two exposed osteotomized surfaces then are inspected carefully to ensure viability and satisfactory resection margins. If necessary, either osteotomy can be repeated until the remaining exposed osteotomized surface is satisfactory. Typically, the surrounding periosteum is thickened and fibrotic or partially ossified, and this rind also must be resected to complete satisfactory debridement.

DEAD SPACE MANAGEMENT

Successful sepsis surgery requires obliteration of the potential dead space created by debridement with excision of bone. This includes biologic and nonbiologic techniques, such as local myoplasties, free tissue transfers, and antibiotic impregnated local antibiotic depots. Polymethylmethacrylate beads are a popular form of local antibiotic depot,[4,5,18,19,25,35] but biodegradable alternatives also have a role in certain situations. Polymethylmethacrylate beads have been discussed in detail in prior publications and will be reviewed here briefly.

Antibiotic laden local depots facilitate staged management,[4,5] one of the keys to successful treatment of chronic osteomyelitis. When one elects to treat a particular case in a staged fashion, the local antibiotic depot plays a dual role. At the initial procedure the depot delivers high local concentrations of antibiotic while simultaneously obliterating dead space. Paradoxically, the same depot preserves dead space for the second procedure, the subsequent osseous reconstruction.

Dry powdered polymethylmethacrylate (40 g) is mixed completely with the dry powdered antibiotic(s) of choice. Vancomycin (3 g) and tobramycin (3.6 g) together will cover the majority of organisms typically responsible for chronic osteomyelitis, and the elution characteristics of both have been studied thoroughly.[3,10,34] The antibiotic powder, particularly vancomycin, first must be passed through a medium grade tea strainer to destroy any accretions of drug that form during storage. After initiating polymerization, the surgeon should allow the polymethylmethacrylate to become moderately viscous before forming it into spheric beads roughly 7 mm in outer diameter. These beads then are strung on 1 Prolene suture and allowed to cure completely. Braided or absorbable sutures are contraindicated. Alternatively, when placed down an intramedullary canal after reaming, the polymethylmethacrylate beads are instead strung on 18-gauge stainless steel wire. Methylmethacrylate inhibits neutrophil function,[26,27] and one must wait an additional 20 minutes to allow the excess monomer to evaporate completely before using the beads.

Polymethylmethacrylate beads almost always are intended for subsequent removal, and the surgeon should bear this in mind as the beads are placed in the defect. One should orient the beads in layers, deepest first and then more superficial. Removal is scheduled only after allowing the soft tissues to recover completely, generally a period of 3 or 4 weeks. If a free flap was used for soft tissue coverage, the overlying split thickness skin graft will not be mature enough to tolerate additional surgery for 6 to 8 weeks. Beads within the intramedullary canal must be removed within 10 to 14 days, or the formation of granulation tissue will make subsequent removal extremely difficult.

When stable soft tissue coverage is available, a tension free watertight wound closure is mandatory. After final hemostasis is secured, a large bore drain always must be placed before closure of the wound. The volume of antibiotic used creates a substantial oncotic load, and the influx of fluids postoperatively may result in wound dehiscence if drainage is inadequate. Drains are placed in an antigravity position, proximal and superior when the patient is recumbent. Drains remain in place for several days, until output is less than 30 cc per 24 hours.

When debridement leaves an overlying soft tissue defect, the bead pouch technique[12] is particularly valuable. After achieving final hemostasis, a large bore drain is placed exiting at least 5 cm from the wound edge. The wound margins should be dried thoroughly, and benzoin should be applied to the skin. An adhesive porous polethylene film (Op Site, Smith and Nephew Medical, Limited, Hull, England) then is applied with the goal of watertight edges circumferentially. A skin stapler is used to secure the plastic adherent dressing further. Staples at 1-cm intervals are placed tangential to the wound margin, 5 mm from the edge. The drain next is connected to self suction, and finally a second gas permeable plastic adherent dressing applied. Using this specific technique, the bead pouch can remain in situ for 7 to 10 days when necessary. However, if the pouch leaks there will be contamination of the wound and potential recurrent infection. When fluid accumulation threatens to leak, the surgeon should use iodine preparation and aspirate the pouch with a fine needle, then repair the puncture site with a small piece of adherent plastic dressing.

The second stage consists of bead removal, repeat irrigation and debridement, and exchange for bone graft or a bone graft substitute. Final debridement involves careful inspection to verify complete removal of all beads and any remaining nonviable tissue. Autogenous cancellous bone chips are the preferred substances for exchange, although allograft cancellous chips are sometimes useful to augment volume. The bone graft also can serve as a local antibiotic depot[21] in addition to obliterating residual dead space. Dry powdered antibiotic, selected according to previous cultures and sensitivities, can be sprinkled liberally onto the bone graft immediately before filling the defect.

Debridement of chronic osteomyelitis can be a technically demanding and difficult procedure. Local anatomy often is distorted by trauma or previous surgery. The surrounding soft tissues can be scarred and fibrotic, and the risk of subsequent wound complications is high. Adherence to the principles of surgery and techniques discussed can increase the probability of success. Thorough preoperative evaluation, attention to detail, meticulous technique, an atraumatic approach, and gentle handling of soft tissues are all critical considerations. Enumerate the goals of treatment before initiating therapy. Dead space management together with the staged reconstruction protocol has been a very successful means of dealing with this most difficult problem. Anticipate initial treatment failure and have alternative options available if necessary.

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