Treatment of Infected Tibial Nonunions with Debridement, Antibiotic Beads, and the Ilizarov Method

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This study of 10 patients presents the early results of a protocol of debridement, antibiotic bead placement, and use of the Ilizarov method with a circular external fixator for treatment of infected nonunions of the tibia in a military population. The nonunions resulted from high-energy fractures in nine cases and an osteotomy in one. The Ilizarov techniques used were transport (five cases), shortening and secondary lengthening (two cases), minimal resection with compression (one case), and resection with bone grafting (two cases). Flap coverage was required for five patients. There were two recurrences of infection (20%) among patients with the most compromised soft tissue. Only 50% of patients were able to perform limited duties while wearing the external fixator. Only four patients returned to active duty; however, three patients from special operations units were able to return to jump status. Six patients underwent medical retirement because of insufficient function, resulting from decreased ankle or knee range of motion and arthrosis or muscle weakness.

Introduction

Severe high-energy injuries to the leg can result in open fractures of the tibia and fibula and considerable soft tissue damage over very superficial bones. Despite modern techniques, infected nonunions occur, and amputation remains an option for treatment. The impact of such a complication on an active duty service member is far-reaching. Loss of duty time and the costs of treatment are institutional outlays; the possible loss of a career and personal suffering are the individual expenses. A careful algorithmic approach, although time-consuming, can guide treatment and permit salvage even in the most difficult situations. This report presents the early results of a system involving a series of debridements and antibiotic bead placements and use of the Ilizarov method with a circular frame for treatment of infected nonunion of the tibia.

Methods

Patients

Ten patients (eight male patients and two female patients; age range, 21–38 years; mean age, 31 years) presented to Walter Reed Army Medical Center with infected nonunions of the tibia. Nine of the patients were on active duty; one firefighting student was a dependent spouse at the time of treatment of her nonunion. Eight of the tibia nonunions were secondary to open fractures. One was attributable to a postoperative infection in a rotational osteotomy of the tibia performed via a closed osteotomy with an intramedullary saw and placement of a nail. One nonunion resulted from an originally closed fracture that underwent intramedullary nailing, with opening of the fracture site. The nonunion sites in the tibia were the junction of the middle and distal thirds (five cases), distal from a pilon fracture with extension (two cases), the junction of the proximal and middle thirds (one case), and the transverse diaphysis (two cases). Although all patients had been fully fit before their fractures, three patients could be considered Cierny B hosts because of their extreme tobacco abuse. One of these two had the initially closed fracture and was found to exhibit disruption of the flow of the posterior tibial artery on an arteriogram.

Of the eight open fractures, six occurred during motor vehicle accidents (two motorcycles), one was sustained during an aircraft crash, and two were the result of failures during parachute landings. Of the eight open fractures, four were Gustilo type IIIA and four were type IIIB. Previous treatment of these open fractures at other treatment facilities included irrigation and debridement, antibiotic therapy, and a variety of bone fixation procedures, including external fixation (five cases), intramedullary fixation (one case), and open reduction with internal fixation (two cases).

All patients except one presented with pain at the fracture site. Four patients had drainage from the fracture sites that were located at the junction of the middle and distal thirds of the tibia (two cases), in the subchondral area of the tibial plafond (one case), and at the junction of the proximal and middle thirds of the tibia (one case). Radiographs revealed a lucent line at the site of the fracture, with surrounding exuberant callus. Infection was confirmed with blood studies (erythrocyte sedimentation rates and C-reactive protein levels) and magnetic resonance imaging in seven cases. Indium-labeled white blood cell scans were performed in three cases with intramedullary nails.

Technique

Debridement

All patients underwent debridement and removal of hardware (if present). Debridement of at least 3 cm of dead bone was necessary to reach visibly bleeding bone edges in most cases; a 9-cm section was resected in the infected rotational osteotomy case, and one case required only local debridement. Cultures of the wound and of the resected bone were performed. The leg was stabilized in a circular Ilizarov frame.

Antibiotics

Aminoglycoside antibiotic-containing polymethylmethacrylate (PMMA) beads were prepared in the operating room; 2 g of...
tobramycin were mixed with one bag of PMMA, and the beads (approximately 7–10 mm) were threaded onto 0 Prolene suture material. Enough beads were placed to fill the resection gap. The wounds were closed as much as possible with retention sutures, and an Opsite dressing (Smith and Nephew, Largo, FL) was placed over the wound. If the wound could be closed, then the beads were left in place for 3 weeks before further intervention. If the wound could not be closed, then debridement and bead exchange were performed until the wound could be closed. Five cases eventually required a free muscle flap for wound closure. Patients were treated with at least 6 weeks of organism-specific, intravenously administered antibiotics.

Ilizarov Method

Five patients underwent bone transport. Two patients underwent gradual shortening at the defect with lengthening at another site. Two patients were kept at length in the frame and underwent bone grafting. One patient underwent resection, minimal shortening, and compression.

Results

There was a 14- to 64-month follow-up period (average, 3 years) from the time of the start of the reconstruction. There were at least four anesthetic events per patient. Most bone and wound cultures grew mixed organisms; two patients also demonstrated growth of methicillin-resistant Staphylococcus aureus. All patients eventually experienced healing of the fracture. The time in the frame and the time to healing were 6 to 24 months (average, 9 months). The loss of duty days was considerable in all cases because of the frequency and length of hospitalization for surgery and antibiotic therapy. Five patients were not able to fulfill their job requirements because of the obstacles caused by the frame; five patients returned to limited duty while wearing the frame. Only three patients returned to active duty after reconstruction and rehabilitation (Table I).

Knee and ankle stiffness was a problem during the reconstruction, particularly among patients who were reluctant to bear weight on the affected extremity. After frame removal and vigorous physical therapy, all patients regained a functional knee range of motion of 0 to 120 degrees. The ankle range of motion remained limited for all patients in both dorsiflexion and plantar flexion, with average dorsiflexion of 5 degrees.

One patient required placement of a second frame for additional reconstruction because of translation and rotation at the original fracture site. Two patients (20%) experienced a recurrence of infection, one at 10 months after frame removal and the other at 18 months. Both of these patients had fractures at the junction of the middle and distal thirds of the tibia, both originally presented with drainage from an anteromedial tibia skin opening, and both required muscle flap coverage for closure. One of these recurrences occurred in the patient whose closed fracture was opened during surgery and who had the additional compromising factors of a disrupted posterior tibial artery and chronic tobacco abuse. This patient has undergone a resection, acute shortening, and secondary lengthening with an Ilizarov frame. The other patient with recurrence had sustained a Gustilo type IIIB fracture in an airplane crash, had a closed head injury, and developed methicillin-resistant S. aureus. This patient elected to be placed on suppressive antibiotic therapy and is considering another reconstruction.

Case Reports

Patient 5, a 36-year-old airman, underwent an elective closed rotational osteotomy at another institution for treatment of an idiopathic external rotation deformity. He was transfused to our institution with pain and fluctuance at the site of the osteotomy 4 months after surgery (Fig. 1). The patient smoked four packs of cigarettes per day and consumed large amounts of pain medication. Indium scans confirmed the presence of a septic nonunion with extensive osteomyelitis. The rod was removed and a total of 12 cm of infected bone was resected in two operations. A circular thin-pin fixator was placed at the time of rod removal. Antibiotic beads were placed in the segmental defect and were changed during multiple consecutive debridement and irrigation events. Multiple organisms grew from the original cultures. Approximately 1 month after nail removal, a proximal corticotomy was performed and a bone transport was accomplished. At the end of the transport, because of the poor appearance of the regenerate bone, a fibular osteotomy was performed; the fibula was fixed to the tibia with a wire and compression was placed across the regenerate bone. The docking site united despite the patient’s continued smoking. A local cutaneous flap was necessary to close an ulcerated area in the midshaft region. The patient was medically discharged from the military and is unemployed 6 years after his reconstruction.

Patient 8, a 21-year-old U.S. Military Academy cadet, sustained a Gustilo type IIIB open fracture of the right tibia, with massive degloving, in a motor vehicle accident. He was treated initially, in a local hospital, with debridement, irrigation, and placement of an intramedullary nail. He was then transferred to our institution. At presentation, he was in severe pain, with odoriferous drainage from his open wounds. Immediate surgical debridement resulted in removal of all of the deep posterior and most of the medial superficial posterior compartment muscles. Vascularity was assessed with an arteriogram. Although the arterial supply was intact, the location of the wound made complete flap coverage difficult. In subsequent months, the tibia showed no signs of healing. Indium scans confirmed osteomyelitis at the fracture site. The rod was removed, and a circular thin-pin fixator was placed. An extensive section of infected bone was resected, and antibiotic beads were placed. Gradual shortening was performed. In a second operation, a proximal corticotomy was made for lengthening. The patient regained equal limb lengths with a pain-free but cosmetically peculiar-looking extremity. He was discharged from the military and successfully completed a civilian university degree program (Fig. 2).

Patient 9, a 22-year-old active duty male enlisted Marine was thrown through the windshield during a motor vehicle accident. He sustained a closed tibia fracture and a contralateral Lisfranc fracture-dislocation. He was taken to a local hospital where the tibia fracture was treated with an intramedullary nail. During that procedure, the fracture site was opened and the tibia became comminuted. The patient was transferred to this institution with malunion of the tibia. The patient was a two-pack per day smoker and he continued to smoke throughout his treatment. The fracture was reduced with a circular thin-pin fixator.
### TABLE I

#### PATIENT DATA

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (years)</th>
<th>Gender</th>
<th>Rank</th>
<th>Cause of Injury</th>
<th>Initial Injury</th>
<th>Initial Management</th>
<th>Cultured Organism</th>
<th>Time in Frame (months)</th>
<th>Technique</th>
<th>Worked in Frame</th>
<th>Duty Status</th>
<th>Additional Surgery or Complications</th>
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<tr>
<td>1</td>
<td>29</td>
<td>M</td>
<td>SSG</td>
<td>Parachute landing</td>
<td>Grade IIIA tibia fx</td>
<td>External fixator</td>
<td>None</td>
<td>4</td>
<td>Resection; bone graft</td>
<td>No</td>
<td>Return to full duty</td>
<td>No</td>
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<tr>
<td>2</td>
<td>38</td>
<td>M</td>
<td>MAJ</td>
<td>MVA (motorcycle)</td>
<td>Grade IIIA tibia and fibula fx</td>
<td>External fixator tibia; Rush rod fibula</td>
<td>MRSA</td>
<td>6</td>
<td>Resection; transport; flap</td>
<td>Yes</td>
<td>Return to full duty</td>
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<td>25</td>
<td>F</td>
<td>SPC</td>
<td>MVA (automobile)</td>
<td>Grade IIIA pilon fx</td>
<td>ORIF; flap</td>
<td>Multiple</td>
<td>12</td>
<td>Resection; transport</td>
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<td>MEB</td>
<td>Ankle fusion</td>
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<td>CPT</td>
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<td>Bacillus subtilis, MRSA</td>
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<td>Medical hold</td>
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<td>6</td>
<td>38</td>
<td>M</td>
<td>SFC</td>
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<td>ORIF</td>
<td>S. aureus</td>
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<td>Closed tibia &amp; fibula fx</td>
<td>IM nail</td>
<td>Multiple</td>
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<td>Osteomyelitis; second resection with shortening and lengthening</td>
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<tr>
<td>8</td>
<td>21</td>
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<td>CDT</td>
<td>MVA (automobile)</td>
<td>Grade IIIB tibia fx</td>
<td>IM nail</td>
<td>S. aureus, Clostridium perfringens</td>
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<td>Resection; shortening; lengthening</td>
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<td>Discharge</td>
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<tr>
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<td>Grade IIIB tibia &amp; fibula fx</td>
<td>External fixator</td>
<td>S. aureus</td>
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<td>No</td>
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<tr>
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<td>External fixator</td>
<td>S. aureus</td>
<td>6</td>
<td>Resection; bone graft</td>
<td>No</td>
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</table>

*MVA, Motor vehicle accident; fx, fracture; MRSA, methicillin-resistant *S. aureus*; IM, intramedullary; MEB, Medical Evaluation Board; ORIF, open reduction and internal fixation.*
In subsequent months, there was no evidence of fracture healing; eventually, the wound over the tibia broke down. An arteriogram showed obliteration of the posterior tibial artery at the site of the fracture, with distal collateral circulation. Resection of the infected fracture site was performed with fibulotomy, and the tibia was compressed. Because of persistent wound breakdown, a second arteriogram was performed and showed recannulation of the posterior tibial artery. A free flap was used to provide wound coverage but, unfortunately, a portion failed and wound drainage continued. Finally, the patient was convinced to stop smoking. He has undergone a second extensive resection, with gradual shortening and delayed lengthening (Fig. 3).

**Discussion**

Of the steps in this treatment plan for septic nonunions, debridement is the most important. It has long been known that debridement is essential for the treatment of combat injuries. Tetsworth and Cierny²,³ have shown that the quality of surgical debridement remains the most critical factor in the successful management of chronic orthopedic infections. In most cases, debridement must be repeated to eradicate the infection. It has been shown that from a bacteriologic standpoint, a second debridement affords an opportunity for wound sterilization. In the series reported by Patzakis et al.,⁴ the percentage of positive cultures decreased from 100% to 26% at the time of the second debridement.
Antibiotic therapy for treatment of bone infections has evolved. Not long ago, open fractures were treated with weeks of antibiotic therapy and osteomyelitis and septic nonunions were treated with months of intravenous therapy. Swiontkowski et al.5 showed that when antibiotic-impregnated PMMA beads were used, outcomes were the same whether long-term or short-term intravenous antibiotic therapy was used. Antibiotic beads have been shown to have significant positive effects in decreas-
ing bony infections. Use of an antibiotic bead pouch was shown to decrease infections in open fractures with reamed nails. Henry et al.7 and Ostermann et al.8 clearly outlined the technique for use of the bead pouch and demonstrated a significant decrease in infections when the pouch was used in the initial treatment of open fractures. Bowyer9 outlined the potential benefits of using the antibiotic bead pouch for open fractures resulting from combat, and the necessary ingredients have been added to the packing kits for far-forward medical care for the Army. However, prepackaging of the beads is problematic.

The use of antibiotic-containing PMMA beads has some logistical and legal problems in the United States. Antibiotic-impregnated beads have not been approved by the U.S. Food and Drug Administration. The necessary phase 3 trials are expensive and time-consuming and have not been completed. The use of antibiotic beads is considered an “off-label” use of the approved components. Beads are manufactured intraoperatively in most instances, unless the institution has an approved protocol for prepackaging. Packaged strands of 10 gentamicin-impregnated beads are manufactured in Europe by Merck Darmstadt and are sold throughout the world ex-
The use of antibiotic beads along with bone resection, stabilization, and reconstruction is an accepted technique at this time. The results of this series are not as good as some of the most recently reported results from the United States (>90% cure). This series is quite small and it may not be valid to compare its results with those of other studies. The results are comparable to failure rates of 10% to 20% in older series. In both cases of failure, there was significant soft tissue compromise, with poor availability for reasonable coverage. In both cases, the tibia fractures were sustained during violent trauma, i.e., a plane crash in one case and being propelled through a windshield in the other. In one case, the patient was a heavy smoker. However, the real reason for the failure most likely involved insufficient bone resection.

The technique chosen for reconstruction also has an effect on the results. Nonunions have been treated with a variety of conventional techniques, such as reamed nails and compression plating, with a variety of results. Accepted techniques for reconstruction after segmental loss of the tibia include bone transport, shortening and subsequent lengthening, vascularized fibula grafting, translation of the fibula and synostosis, and retention of length in the frame and subsequent bone transport, shortening and subsequent lengthening, vascularized fibula grafting, translation of the fibula and synostosis, and retention of length in the frame and subsequent bone transport. In cases of infection, however, the reconstruction must be tailored to the patient’s situation. It is wisest to use the simplest technique that ensures the best soft tissue coverage.

The future for treatment of open fractures and prevention of infection and nonunion is bright. Significant work has been performed with local antibiotic therapy. Antibiotic-impregnated cancellous bone grafting and use of biodegradable antibiotic beads are possible. Bone morphogenic protein shows potential for filling the defect itself.