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MANAGEMENT OF GUNSHOT WOUNDS TO THE TIBIA

Earl W. Brien, MD, William T. Long, MD, and John H. Serocki, MD

The treatment of gunshot wounds to the tibia has not been frequently discussed in the literature[36]; however, several studies have evaluated the management of civilian gunshot wounds.[8,10,15,27,40] The principles in managing open fractures resulting from either penetrating or nonpenetrating mechanisms are similar and include determining the amount of energy expelled into the bone and soft tissues and assessing wound contamination. For nonpenetrating injuries, the mechanism usually provides adequate information to assess these two important variables,[2] which is often not the case for penetrating injuries. Gunshot wounds vary in the amount of energy dissipated through the tissues, the amount of contamination, and the frequency of associated neurovascular injuries.

Handguns vary in muzzle velocity, yaw, and bullet caliber, which are important in determining the energy dissipated through the bone and soft tissues. They deliver varying ranges of low-velocity injuries. Low-velocity gunshot wounds result from bullets traveling less than 2000 ft/sec. When a projectile transverses soft tissue, the bullet path, shock waves (>500 ft/sec), and temporary cavitation (>1000 ft/sec) determine the extent of injury. Several bullets traveling at low velocities can cause high-energy trauma, which is most commonly seen with 0.40-caliber, 10-mm, 0.45-caliber, and 0.357-caliber magnum bullet types. Low-energy injuries are often seen with 0.38-, 0.25-, and 0.22-caliber bullets. The reason for the varying amount of energy dissipated is primarily related to the bullet velocity. Yaw is the next most important variable in determining soft-tissue damage. Yaw occurs when a bullet deviates from its axis, causing more of the bullet's surface area to be exposed to the soft tissues and resulting in more rapid liberation of energy to a smaller area of tissue. In addition to velocity and yaw, the amount of gun powder in the casing and the bullet caliber can affect the extent of soft-tissue injury. New advances in bullet design also play an important role in dissipating different amounts of energy through the bone and soft tissues.

During the past 5 years, we have seen increasing numbers of penetrating injuries from assault weapons. Gunshot wounds from these weapons (AK-47 and Uzi) are nearly always devastating injuries, with severe internal destruction and massive exit wounds. These high-energy injuries commonly correspond with open grade IIIB and IIIC[23] injuries, which may result in early or late amputation. Rifle injuries are equally devastating to internal structures when bullet velocities exceed 2000 ft/sec.

From the Orthopaedic Oncology Service, Orthopaedic Hospital (EWB), Los Angeles, and the Division of Orthopaedic Surgery, Department of Surgery, Martin Luther King, Jr/Charles R. Drew Medical Center, Los Angeles, California

Close-range shotgun injuries have large cavitating entrance wounds, often with significant contamination. These injuries behave similarly to the high-energy and high-velocity injuries and are frequently contaminated with wadding and numerous pellets. All close-range penetrating injuries have some degree of blast effect (gases ejected from the muzzle that exceed the bullet velocity), which can lead to significant burns and superficial necrosis; we have seen the most devastating injuries with shotguns.

The location of the fracture is also important in assessing tissue damage. Gunshot wounds to the metaphysis cause more bone necrosis than to the diaphyseal or cortical areas. Moreover, the amount of contamination varies with the location of the wound and type of weapon used. For medial tibia wounds, often no soft tissue covers the bone. This exposure results in bone being directly aired to the environment, similar to high-velocity and shotgun injuries. Also, airborne microorganisms and clothing and skin contaminated with bacteria can be implanted in the deep tissues and lead to infection. Bullets do not achieve temperature levels high enough to kill bacteria brought into the wound, and necrotic tissue is an ideal medium to propagate bacteria. Varying infection rates occur for the following reasons: bullet velocity (amount of necrosis), location (bone exposure), and bullet surface contaminants.[54] Treatment is determined only after these variables are considered. Location and stability of the fracture will also impact on treatment for these difficult problems.

This article discusses pertinent aspects of wound care relative to the preoperative assessment, management, and postoperative care of patients who have sustained gunshot wounds to the tibia. The physician must answer three important questions prior to the treatment of open fractures.

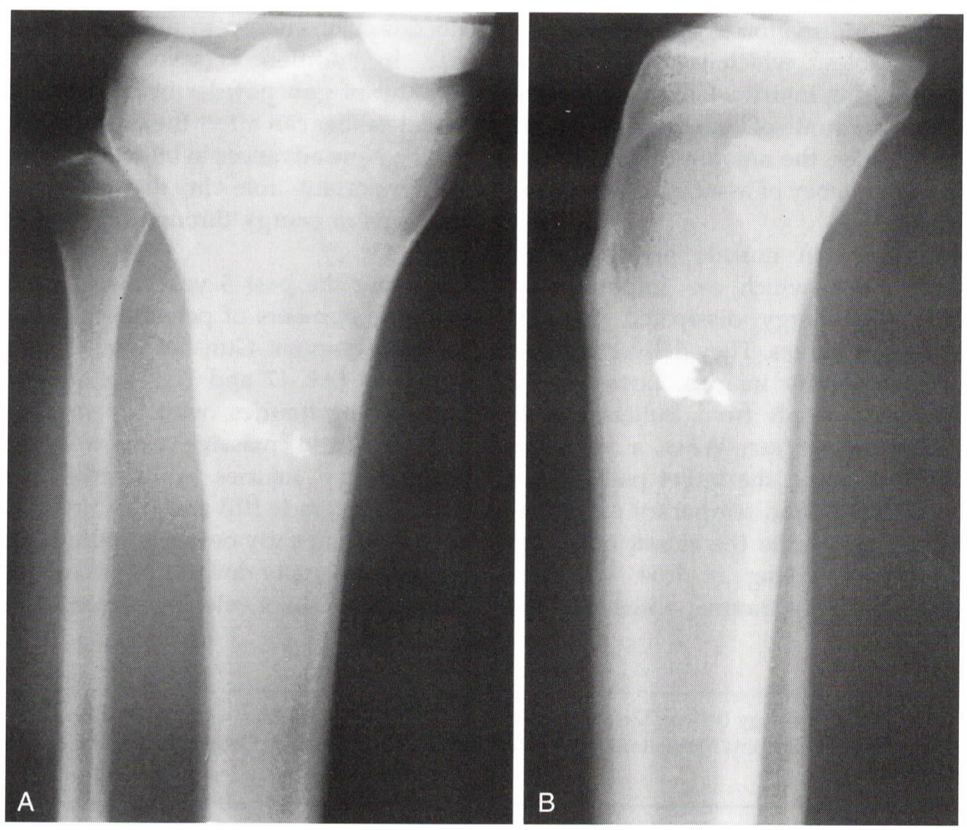

Figure 1. Anteroposterior (*A*) and lateral (*B*) views, of a unicortical gunshot wound to the tibia that was treated with intravenous antibiotics and immobilized in a long leg cast.

Where are the entrance wound, exit wound, and fracture located (proximal, middle, or distal)?
What is the grade of injury and amount of contamination?
Is the fracture stable or unstable?

The answers to these questions are discussed relative to the various clinical presentations of penetrating injuries. An algorithm has been developed that can assist the physician in managing gunshot wounds to the tibia. Postoperative care is also discussed based on these findings.

HISTORY AND PHYSICAL EXAMINATION

A thorough history, physical examination, and laboratory and imaging studies are essential to properly characterize the extent of bone and soft-tissue injury. The history should include information about other organ systems, motor and sensory changes, and bleeding disorders. Determination of the time of injury, range of the weapon, and type of weapon used will begin the process to assess wound severity and degree of contamination.

As with all gunshot wounds, it is important to examine the patient for additional injuries. After removing all clothing, the entire body, with emphasis on poorly seen areas such as the scalp, axillae, groin, and between the buttocks, must be examined and findings documented. In addition to the history, information on the bullet path (entrance, and if present, exit wound) may help in assessing the risk of neurovascular injury. Careful motor, sensory, and vascular examinations should also be performed, remembering the possibility of compartment syndrome developing. Details concerning the size of the wound(s), color and amount of blood loss, soft-tissue assessment for devascularized tissue, and skin changes should be recorded.

LABORATORY AND IMAGING STUDIES

Routine laboratory studies, with emphasis on the hemoglobin and hematocrit levels to assess blood loss, should be performed. The hematocrit value can be misleading at initial presentation. Therefore, vital signs, clinical examination, and urinary output should initially be recorded to assess blood volume. In patients with multiple gunshot wounds and significant volume loss, the platelet count and bleeding time should also be closely monitored. Plain radiographs can provide information about the type of fracture (unicortical, transverse, or comminuted), degree of comminution as described by Winquist (types I–V), and fracture stability. Bullets seen on admitting radiographs may help in determining the bullet caliber. This differentiation has only been successful between small-caliber bullets (e.g., 0.22 mm and 0.25 mm) and larger-caliber bullets (e.g., 0.45 caliber). Intermediate bullet sizes, such as 9 mm, 0.38 caliber and 0.357 magnum, are only 1 mm smaller than the 0.40-caliber and 10-mm bullets. Because magnification varies in each radiograph and bullets deform after hitting bone, the size of the bullet seen on standard radiographs is unreliable. In most cases, treatment cannot be determined by this method. In proximal and distal gunshot wounds juxtaposed to the joint, CT scan may help in further assessing the presence of intra-articular bone and metal fragments and articular displacement. Angiography should be performed in cases when vascular injury is suspected on clinical examination or the location of vessel damage cannot be determined clinically or with a Doppler study.

STANDARD TREATMENT FOR OPEN TIBIA FRACTURES

Low-Velocity, Low-Energy, Stable Fractures

Once an open tibial fracture resulting from a gunshot wound has been determined, immediate intravenous antibiotic therapy and tetanus (as indicated) should be given in the emergency department. In one study of 1104 open fracture cases, the time from injury to administration of intravenous antibiotic agents was the most important factor in reducing the infection rate of patients with open fractures.[42] An antibiotic agent with particularly good gram-positive coverage for *Staphylococcus aureus* is needed in most cases; however, if significant contamination is noted, gram-negative and anaerobic agents should be promptly administered. Stabilization with a posterior-molded splint and CT scan in cases involving the plafond or plateau follow. For unicortical (Fig. 1)

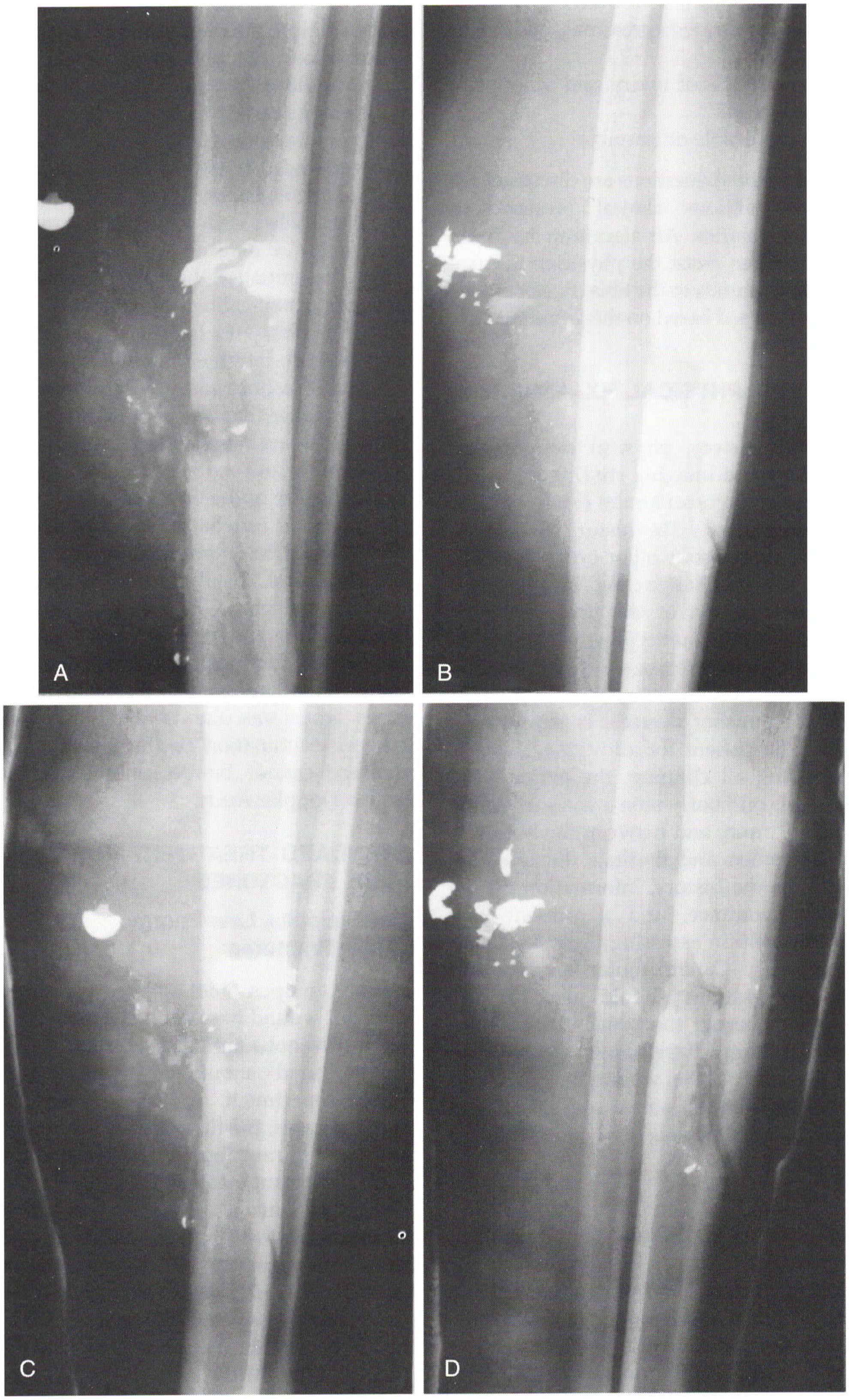

Figure 2. *See legend on opposite page*

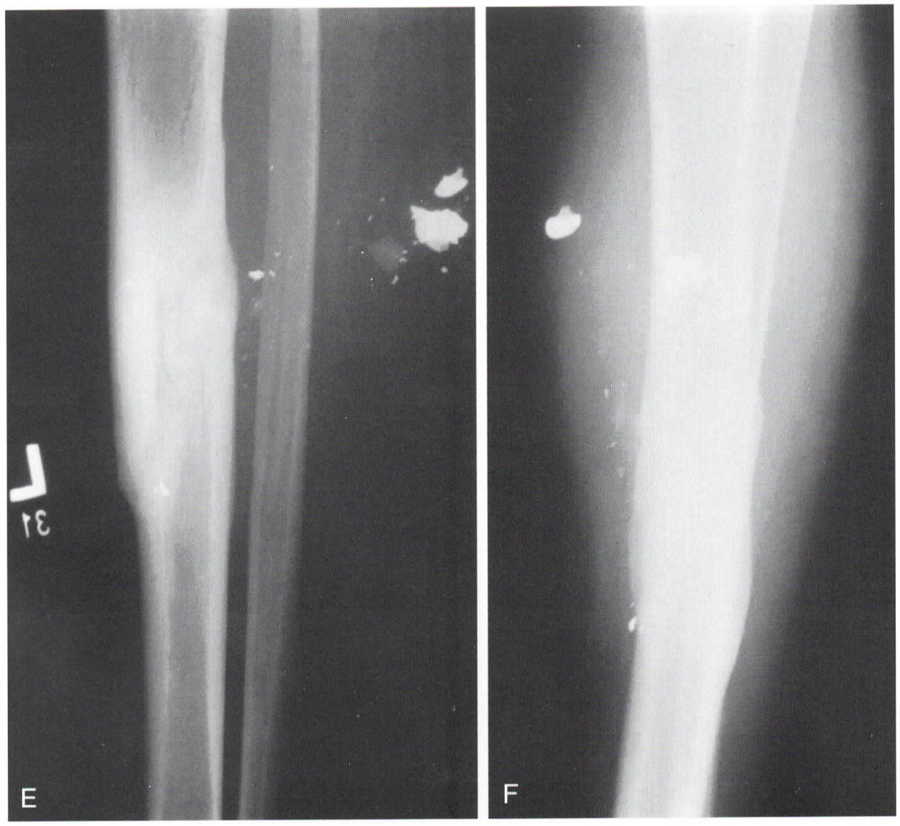

Figure 2. *A–F*, Complete, stable fracture in the middle third of the tibia with an intact fibula from a low-velocity gunshot wound treated with casting and showing subsequent union.

or stable, complete (Fig. 2) fractures in which the fibula remains intact with minimal soft-tissue necrosis, intravenous antibiotic agents given over a 48-hour period and setting with a long leg cast in which the patient cannot bear weight followed by a patellar tendon-bearing cast at 4 weeks (for a total of 3 to 6 months) can achieve adequate stability.

Low-Velocity, High-Energy, Stable Fractures

For the uncommon case in which a stable fracture is associated with significant soft-tissue damage, the need for repeat debridement and/or muscle flaps for bone coverage will be determined by the bacterial contamination, bone, and soft-tissue damage. Aggressive wound care at the bedside and repeat debridement every 48 hours will generally allow for local muscle flap in proximal and middle third injuries or free flap in distal third injuries by the desired 4th or 5th day. Split-thickness skin grafts have been performed at the time of muscle flap surgery without complications. Intravenous antibiotic agents are continued for a minimum of 72 hours after injury. Once complete healing of the soft tissues is observed, the external fixator is removed, and the patient is treated with casting.

Low-Velocity, Low-Energy, Unstable Fractures

Management of unstable tibial fractures varies with the grade of injury (low or high energy) and location of fracture. For low-energy fractures, which result from low-velocity handguns, incision and drainage are not required prior to stabilization. Clinically, the entrance wound over the tibia is without burns, and the wound is less than 1 cm in diameter. We recommend treating

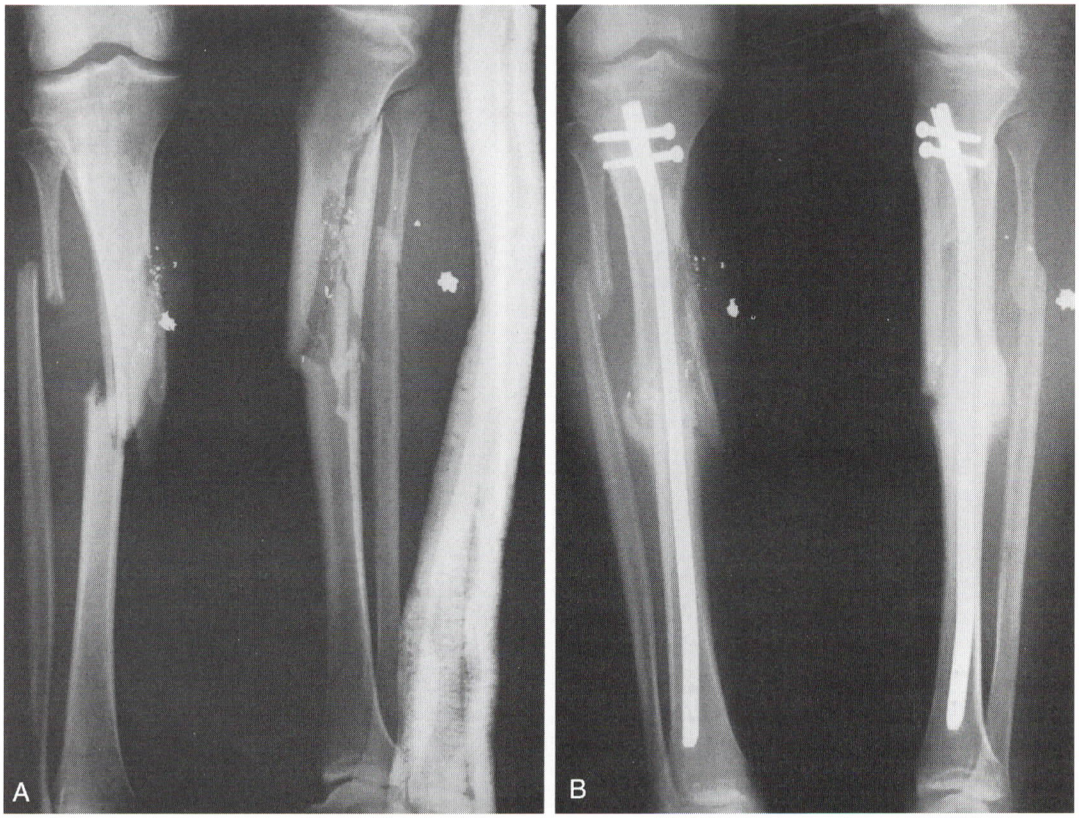

Figure 3. *A*, Unstable, low-velocity gunshot wound to the tibial diaphysis with an associated fibular fracture (*B*) treated with an unreamed, intramedullary nail shown after dynamization and healing.

unstable, diaphyseal fractures with closed, unreamed, interlocked, intramedullary nails (Fig. 3) and metaphyseal fractures with fine-wire, external fixation and screws.

Low-Velocity, High-Energy, Unstable Fractures

Patients with low-velocity, high-energy wounds involving the diaphysis or metaphysis associated with an unstable tibial fracture should be treated with early debridement and stabilization. After debridement of the wound, immediate interlocked, unreamed nailing for diaphyseal fractures and external fixation with fine wires for metaphyseal fractures can be performed safely. Infection after low-velocity, high-energy gunshot wounds is unique to the proximal and distal one third of the tibia, probably because of the minimal amount of soft tissue juxtaposed to the necrotic metaphyseal bone. These wounds include those caused by many makes of handguns, shotguns, and assault rifles (Fig. 4).

High-Velocity, High-Energy, Unstable Fractures

High-velocity, high-energy injuries often require repeat debridement, muscle flaps, and skin grafts. They are often associated with neurovascular deficits, compartment syndromes, nonunion, and infection. External fixation provides early stabilization, easy accessibility to the wound while the patient is hospitalized, and minimization of contaminants in the tibia proximally and distally. Careful attention to placement of external fixator pins in an appropriate pattern should be emphasized to access the wound and, if necessary, to allow for rotational flaps later. Unreamed, interlocked, intramedullary nailing should be used only in cases where complete debridement can be performed at the initial surgery and if delayed amputation is not expected.

TREATMENT AT KING/DREW MEDICAL CENTER

Algorithm

Our treatment algorithm (Fig. 5) is based on a review of 168 penetrating injuries to the tibia over a 5-year period at Martin Luther King, Jr/Charles B. Drew Medical Center. The majority of cases included men younger than 30 years old who were involved in gang-related activities, principally "drive-by-shootings." Gunshot wounds were classified as either high-energy or low-energy injuries. High-energy gunshot wounds were associated with soft-tissue destruction, cavitation, or bone comminution. All patients received intravenous cefazolin, which was started in the emergency room. For the high-energy gunshot wounds and shotgun injuries, penicillin and gentamicin were given in addition to cefazolin. Low-energy, stable tibia fractures were treated with antibiotics alone. Low-energy, unstable tibia fractures were fixed with an external fixator, reamed intramedullary nails, or unreamed nails with or without incision and drainage. High-energy, unstable fractures were debrided and fixed with either an external fixator or an unreamed nail.

The type of stabilization is best determined by the location of the unstable tibial fractures. For diaphyseal fractures, unreamed, interlocked, intramedullary nails provide excellent fixation with less disruption of the endosteal blood supply than reamed nails. In the majority of cases, patients were placed on a fracture table in the supine position with the knee flexed to more than 90°. Calcaneal traction made reduction easier and allowed easy access to the distal screws after rod insertion.

Nailing

The unreamed nails that we have had most experience with include the Ace Fisher (Med tech), Alta (Howmedica), AO (Synthes), Chandler (Depuy), and Delta (Richards) nails. All of these systems have similar rod sizes, however, distinct differences are also found with each nail. The size of the unreamed nail needed is determined by the diameter of the patient's canal and location of the fracture. In most cases, 8-mm rods are sufficient; however, a 9-mm rod should be used for proximal and distal one third fractures to avoid rod breakage.

The Ace Fisher and Alta nails are titanium rods with titanium screws. These flexible nails allow easier access to the intramedullary canal than the stiffer stainless steel nail. The titanium screws are less likely to break than are the stainless steel screws; we have not observed any nail fractures in either type. Another important aspect of the titanium screws is that they allow for more proximal or distal fixation of the fracture than the stainless steel screws because the most proximal and distal screw holes are closer to the ends of the nails in the titanium rods. The Alta nail has a single screw proximally; however, a proximal attachment is also available. The Ace Fisher nail has two oblique screws proximally, which are placed in the metaphysics of the tibia. Careful attention should be taken when drilling through the thin, metaphyseal cortex into the soft tissues. Only in an unusually large tibia would screws larger than 45 mm be required. Postoperatively, patients should be prescribed not to bear weight for 6 to 8 weeks, then allowed progressive bearing of weight once callous formation is evident. If there is minimal callous at 3 to 4 months, dynamization of the rod is performed with or without posterior lateral bone grafting. Nonunion is most commonly treated by fibular osteotomy and exchange rodding using a reamed nail after infection has been ruled out.

External Fixation

For proximal and distal gunshot wounds to the tibia, a fine-wire, external fixator in the

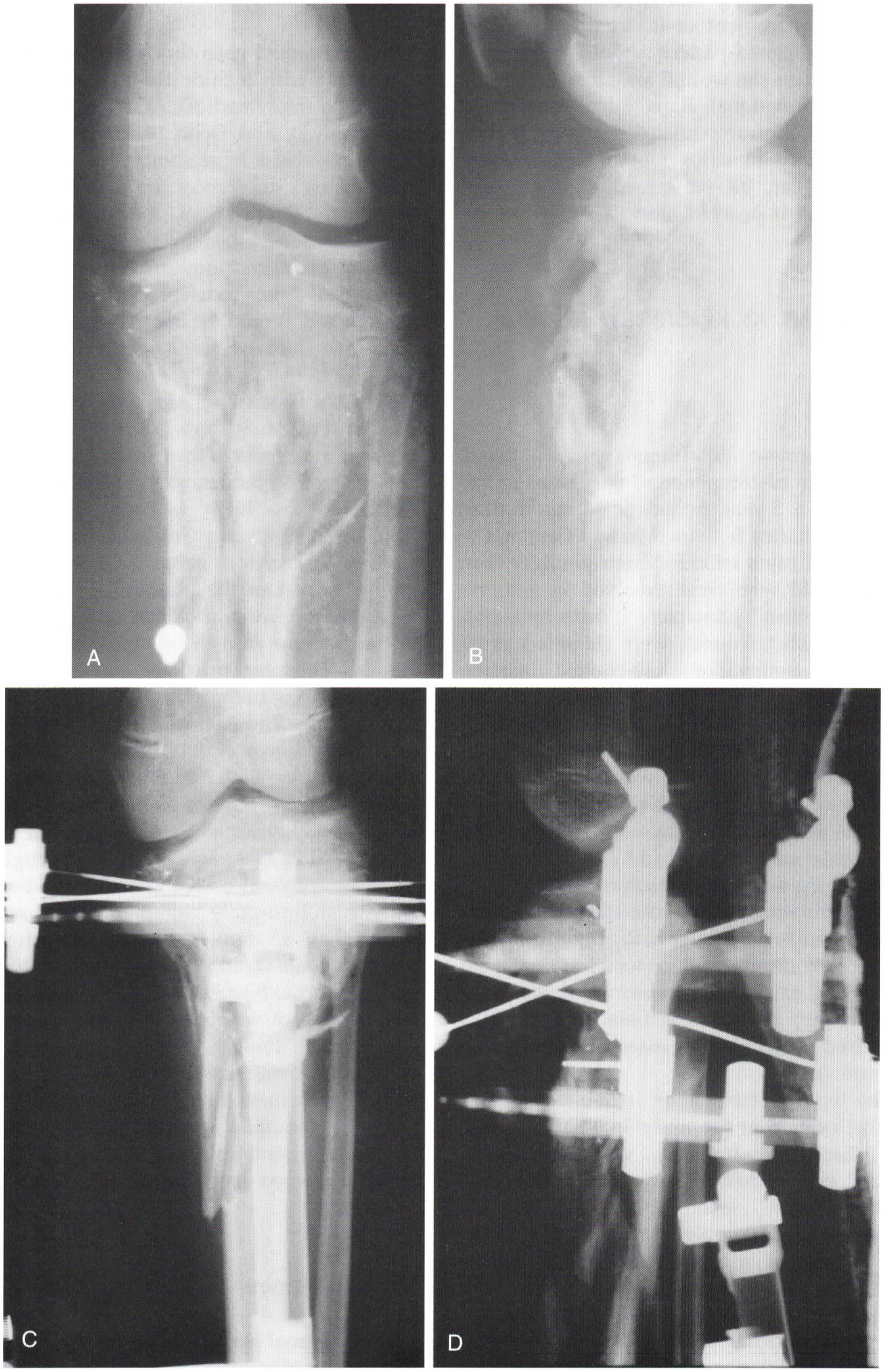

Figure 4 *See legend on opposite page*

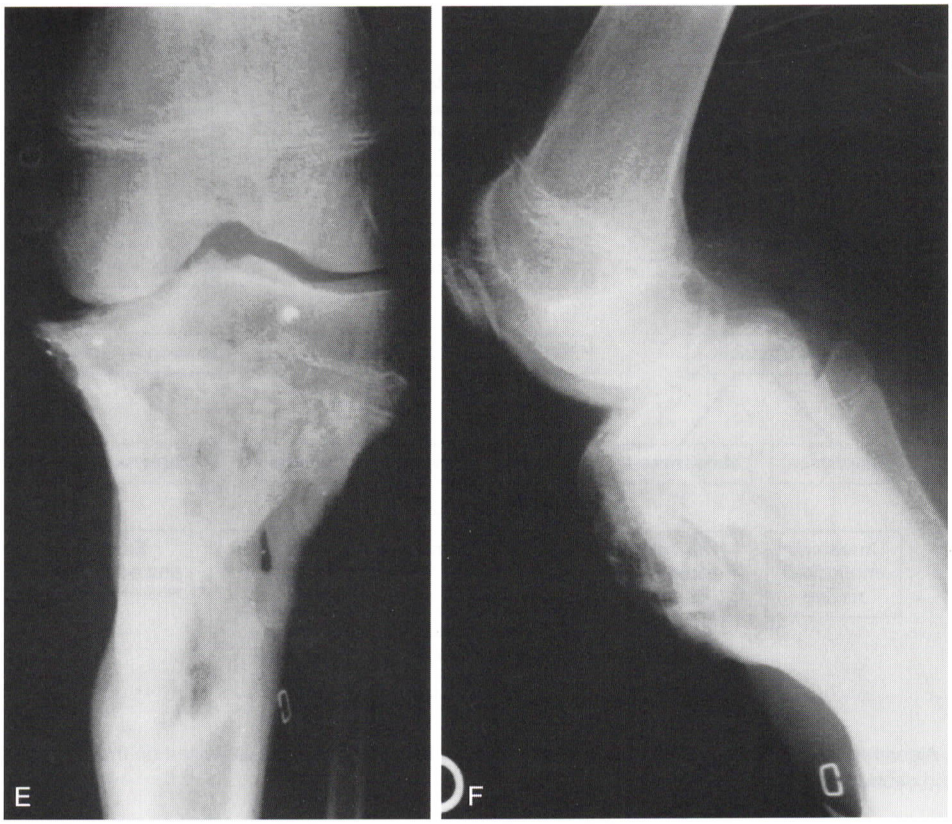

Figure 4. *A* and B, High-energy fracture by an assault weapon to the proximal tibia with an 8-cm defect medially and a 4-cm defect laterally (*C* and *D*) treated with fine-wire external fixation and percuntaneous screws proximally and half-pins distally. In addition to multiple debridements, a medial and lateral gastrocnemius muscle flap with skin grafting led to (*E* and *F*) eventual bony union and soft-tissue coverage.

metaphyseal bone with percutaneous screws can be used to stabilize intra-articular fractures. Combining this fixation with half-pins in the diaphysis provides excellent fixation while allowing ankle or knee joint range of motion. This procedure can be performed in a timely manner, requires no additional soft-tissue stripping, and is ideal for low-energy, unstable, metaphyseal fractures. After the necrotic soft tissue and bone are debrided with a fluoroscope, two cannulated screws are placed subchondrally to stabilize the intra-articular fracture. Two or three fine wires are then placed in the metaphysis. One wire is directed into the proximal tibia laterally to medially, through the fibula anteriorly, and out the anterior medial aspect of the proximal tibia. A second wire is placed anterolaterally and exits out of the posterior medial aspect of the tibia. If additional fixation is required, a third wire can be placed between these two wires; however, the recurrent articular branch of the anterior tibial artery is at risk. Depending on the location of the fracture, a half-pin placed proximally can also supplement the fine-wire fixation. Half-pins are placed in the diaphysis using the standard external fixation technique, and the rings are constructed with the fracture reduced. Intraoperative radiographs should be taken after the fracture is reduced, and adjustments can be made intraoperatively or postoperatively with this technique. The majority of cases treated in this manner used the Ace Fisher external fixator. The Ilizarov apparatus was also used, but it was a technically more difficult procedure and did not allow for postoperative adjustments.

A similar technique was used for cases involving the distal tibia; however, open reduction was performed in most of these cases because intra-articular fractures were displaced more commonly than proximal metaphyseal

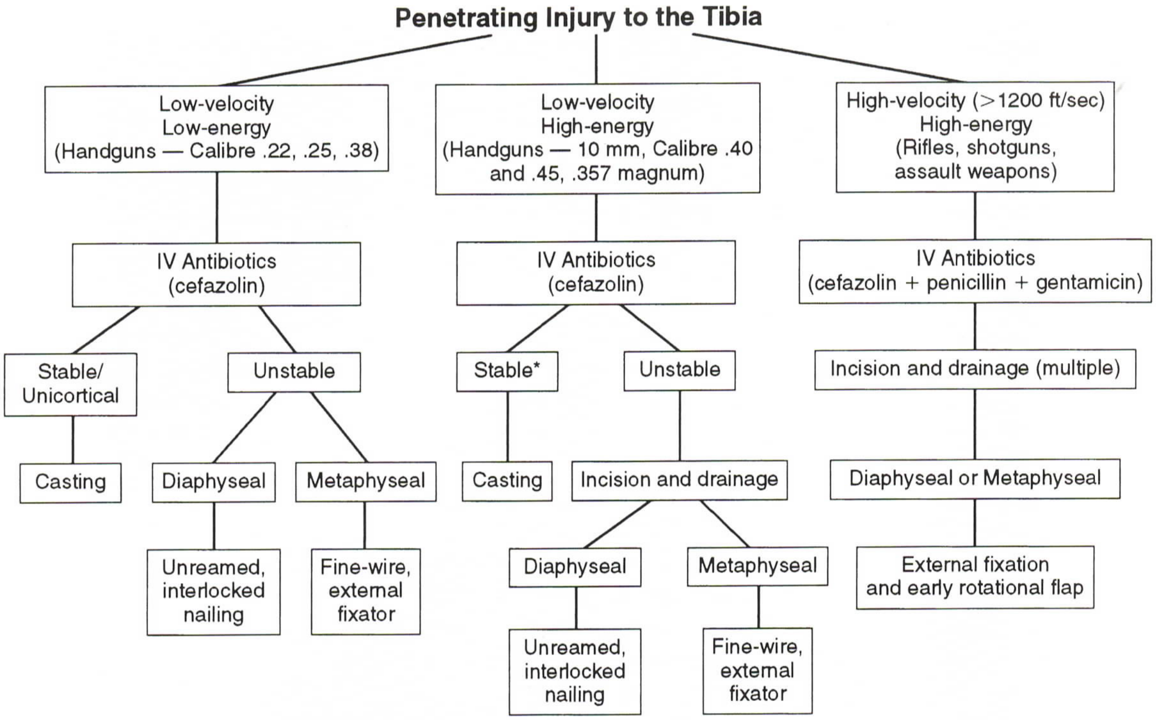

Figure 5. Algorithm for the management of gunshot wounds to the tibia. *If bone is exposed on the tibial aspect, then irrigation and debridement are recommended.

tibial fractures. When the technique of open reduction and internal fixation with screws followed by external fixation is used, it is important to place the wires through the skin while the skin edges are held approximated so that skin is not taught at closure.

For pilon fractures, three wires can be placed after open reduction and limited screw fixation under direct visualization and protection of the neurovascular bundle (anterior tibial artery and deep peroneal nerve). A marked reduction in wound dehiscence and infection has been observed with this technique because of the diminished tension on the wound edges. Postoperatively, the external fixator is not removed until union has occurred. Bone grafting would be delayed but is not commonly needed. Range of motion of the knee and ankle is critical, and equinus contracture was the most common complication with this technique. This contracture can be minimized by reinforcing range-of-motion exercises, placing pins in the foot while the foot is kept in a neutral position, or placing a lambs' wool attachment to the external fixator distally.

DISCUSSION

Management of open fractures involving the tibia continues to be controversial in the orthopedic trauma literature, and results evaluating open tibial fractures secondary to gunshot wounds are limited. The general principles in managing open tibial fractures from low- and high-energy injuries, whether from penetrating or blunt trauma, are similar; however, several unique conditions exist with penetrating injuries that need to be emphasized.

The history of the injury is important because it provides information to assess the amount of energy involved in the fracture. This history includes the type of weapon (handgun, shotgun, or rifle), the bullet caliber, and the distance traveled by the bullet. Many patients who have sustained penetrating injuries know these important details, which may influence treatment. Rifles, shotguns, high-caliber bullets (greater than 0.38 caliber), or low-caliber bullets at very short range often create significant soft-tissue and bone necrosis classified as grade III injuries.[23] These injuries require immediate debridement of the necrotic tissue and shotgun debris, stabilization of the fracture, and early soft-tissue coverage. Of interest are two patients with close range low-velocity gunshot wounds to the proximal one third of the tibia involving the metaphysis, with entrance wounds medially, who developed infections. Both patients had stable fractures and were treated with intravenous antibiotic agents and cast immobilization. This type of wound is a relative indication for incision and drainage because the amount of necrotic bone is underestimated. The literature does not provide a clear answer regarding the importance of timing of early debridement and primary nailing.

Wound characteristics can provide information regarding the path of the bullet. This information is important in determining the patient's neurovascular status, the amount of energy expelled into the injured area, and any contamination of the wound. The size of the wound has been emphasized in open fractures,[23] however, it should be stressed that with gunshot injuries, small entrance wounds may be associated with significant bone and soft-tissue damage, particularly in the metaphysis of the tibia. Soft-tissue damage cannot be overemphasized and may require microvascular expertise, particularly for the distal one third of the tibia or for massive wounds caused by high-velocity weapons.[20,25,34] Extensive serial debridements, early wound coverage (0 to 7 days), and early bone grafting (2 to 4 weeks) improve results regarding infection, healing, and rehabilitation.[14] Despite these aggressive protocols, some patients with high-energy, grade IIIB and IIIC injuries will do best with early below-the-knee amputations.[21,43] It has also been observed that patients with nonischemic arterial injury have a threefold increase in delayed union and nonunion of open fractures. Vascular examination, angiography, and possible vascular repair in these uncommon cases are important (Fig. 6).[18] In our review of gunshot wounds to the tibia, one amputation was performed for a penetrating injury in a patient who had a vascular injury requiring repair, neurologic deficits, and subsequent infection of an ischemic compartment. Treatment should be dictated by the clinical and radiographic presentation.

The initial goal of treatment is to prevent infection. Immediate administration of appropriate antibiotics,[42] adequate exposure to ensure a thorough debridement of necrotic tissue,[9,52,65] and reduction of bacterial counts with pulsatile lavage[22,45] for more severe open fractures (grade II and III) are critical. Perioperative and intraoperative cultures have not been of significant value,[33] but antibiotic therapy, depending on the severity of the bone and, soft-tissue injuries and wound contamination, are important. In cases of low-energy trauma requiring stabilization, antibiotic administration for less than 2 days is as effective as chemotherapy for 3 to 5 days.[17] The skin on all open fractures is never closed primarily. Stabilization of the bone follows debridement.

The types of stabilization include nonsurgical and surgical procedures. Nonsurgical treatment, such as skeletal traction, casting, or functional bracing, has been used successfully for stable tibial fractures.[16,47,56] Unstable, open fractures are often associated with bone loss, and if treated nonoperatively, angulation, shortening, and malrotation are common complications .[4,41] Also, poor exposure may compromise wound care when treatment includes closed reduction and casting. Because of these problems, surgical stabilization of unstable, open, tibial fractures is recommended.

The surgical options for treating unstable, open, diaphyseal tibial fractures include external fixation, plating, and nailing (reamed or unreamed). For many years, the treatment of choice for severe, open, tibial fractures has been external fixation. The major advantages of external fixation compared with casting include easy wound access and more stability to control alignment, shortening, and rotation; however, several authors have reported a high incidence of delayed union and nonunion, which reflects the inability of the external fixation device to allow axial loading.[1,11,31,53] Improved component design combined with early dynamization decreases the incidence of such complications.[37,38] Similarly, new techniques of pin placement, the use of larger, blunted half-pins, and pin care can improve the success rate and avoid the most common complication: pin-tract infections.[6] The Ilizarov device has also been advocated, with good results, for the initial management of open tibia fractures[48,58] and for bridging bone gaps.[3] Ex-

Figure 6. *A* and *B*, Gunshot wound to the distal femur and proximal tibia resulting in a vascular injury managed with (*C*) vascular repair, fine-wire external fixation and percutaneous screws proximally and half-pins distally.

ternal fixation remains the treatment of choice for injuries that are at risk for amputation and that require multiple debridements (grade IIIA and IIIB), but the associated complications exceed the benefits that unreamed, interlocked nails provide for lower-grade, open fractures (grade I to IIIA).[30,49,51,61] Secondary intramedullary nailing, after initial or failed external fixation for open tibial fractures, has been reported to have satisfactory results,[29,62] but caution must be taken with this method because of the risk of spreading infection from pin tracks.

Open reduction and internal fixation with either a reamed, intramedullary nail or compression plating has been used in an attempt to eliminate the complications associated with external fixation while achieving anatomic alignment and fracture stability. Both of these techniques have fallen out of favor because of the high incidence of infection[5] thought to be a result of further trauma to the blood supply. To achieve stable fixation with a plate, muscle must be retracted, and the tibia must be adequately exposed to accept a 4.5-mm plate proximal and distal to the fracture. The endosteal blood supply is preserved, but further devascularization of fragments often occurs, which may lead to the increased infection rates seen when this treatment method is used.[5,12,13]

For reamed nails, Rhinelander demonstrated that reaming destroys the endosteal circulation, thereby increasing the chances of complete devascularization of fracture fragments.[44] The rationale for using unreamed nails in open tibial fractures arises from the assumption that by the avoidance of reaming, endosteal blood supply can be preserved, thus reducing the risk of infection and facilitating healing. Klein et al[32] compared the effects of reamed and unreamed nailing on cortical circulation by using canine tibias. They found that reaming impaired 70% of the cortical circulation, whereas the unreamed technique disrupted only 31%.[32] Similarly, Rhinelander[44] found that when using unreamed nails to fix canine tibial fractures, rapid regeneration of the medullary blood supply in areas where the nail did not contact the endosteum was seen. Decreased vascularization was present in areas of nail-canal contact. Clinical studies support the implications of these findings. A review of three recent series of closed, reamed nailing of open tibial fractures revealed a combined infection rate of 7% in grade I and nearly 10% in grade II fractures (Table 1).[7,33,60] In addition to an increased infection rate, compartment syndrome of the leg has been reported.[39,55] These complications have led to a resurgence in the use of unreamed nails, which resulted in decreased infection rates in two independent studies.[28,64] Both of these studies used flexible nails for open fractures. These nails are reliable for stable fracture patterns but not for unstable, open fractures with comminution or bone loss. Similarly, flexible medullary nailing was compared with external fixation. The use of flexible, unreamed nails resulted in fewer complications except in unstable fractures where significant comminution or bone loss had occurred.[63] Thus, the locked, unreamed, intramedullary nail provides excellent stability while minimizing vascular impairment.

Reports evaluating unreamed, unlocked nails for open tibial fractures showed reduced infection rates of 0% to 2% (Table 2).[25,59,64] Using unlocked nails did not result in stability of comminuted, unstable, tibia fractures, however. Consequently unreamed, interlocked, intramedullary nails were developed in an attempt to achieve adequate fixation while minimizing disruption of the endosteal blood supply.

To determine if a locked, unreamed, intramedullary nail should be used instead of an external fixator, the physician must assess if necrotic tissue or bacterial contamination remains. With grade IIIB injuries, these two factors are often underestimated. External fixation is recommended because it avoids placing an

Table 1. INFECTION RATES WITH REAMED NAILINGS

Grade of Open Fracture	Klemm	Werry	Bone	Total (%)
I	6/93	2/17	*	8/110 (7.3)
II	0/0	1/5	2/26	3/31 (9.7)
III	0/0	0/0	0/1	0/1 (2.0)
Closed	3/368	N/A	2/50	5/358 (1.4)

*A breakdown between grade I and II open fractures was not given. It was reported that the two cases resulting in infection were grade II injuries.

N/A, not available.

Table 2. INFECTION RATES WITH UNREAMED NAILINGS

Grade of Open Fracture	Velazco	Holbrook	Wiss	Total (%)
I	0/12	0/8	0/22	0/42 (0)
II	0/6	1/15	0/28	1/49 (2.0)
III	1/32	1/6	4/6	6/44 (13.6)

intramedullary rod through contaminated, necrotic tissue that would benefit from multiple debridements. Determination of the best fixation method for grade IIIA injuries remains a grey area. This should be decided based on several important factors which include the history, clinical and radiologic evaluation, timing of surgery, bacterial contamination, and necrotic tissue present at initial debridement. Patients with low-energy gunshot wounds (grade I and II) can be treated with unreamed, intramedullary rods, often more effectively than with external fixators. This is presently the treatment of choice, although the nonunion rate for unreamed, interlocked nails approaches that of external fixation. This problem can be avoided by early bone grafting, combined with dynamization of the nail, without loss of alignment or shortening.

The patients with unstable, metaphyseal, open fractures pose a more difficult challenge. Closed tibial pilon and plateau fractures are often complicated by massive soft-tissue swelling and late wound problems. Plating has been the treatment of choice for these injuries, but the procedure is often complicated by wound breakdown, leading to exposure of the plate. Wound problems are even greater with open fractures, and consequently, we have changed our approach to the management of open fractures involving the ankle or knee joint. Our protocol includes early debridement, stabilization of the joint with screw fixation, and external fixation using a hybrid of fine wires near the joint and half-pins in the shaft to stabilize the metaphysis to the diaphysis. This protocol has markedly reduced skin slough and infections without compromising the principles of stable fixation, early motion, and late bearing of weight. Preliminary results have revealed a reduction in skin slough and infection with this technique.

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Address reprint requests to
Earl W. Brien, MD
Associate Director of the Bone Tumor Service
2400 South Flower Street, #523
Los Angeles, CA 90007