Lower extremity free flaps: a review

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OBJECTIVE: To identify factors related to free-flap coverage of lower extremity fractures that are linked to a negative outcome.

DESIGN: A chart review.

SETTING: A large microsurgical referral centre.

PATIENTS: From 1981 to 1989, the records of all patients who underwent free-tissue transfer to the lower extremity with more than 1 year of follow-up were selected. From this was drawn a subgroup of 49 patients (mean age, 36 years) who had tibial fractures (55% were motor vehicle injuries) and in almost all cases established soft-tissue or bony defects. They formed the study group.

INTERVENTION: Free-flap transfer.

OUTCOME MEASURES: Factors that might be associated with free-flap failure: mechanism of injury, grade of tibial fracture, history of smoking, diabetes, peripheral vascular disease, ischemic heart disease, vascular compromise in the leg preoperatively, recipient artery used, type of anastomosis, and hypertension or hypotension intraoperatively.

RESULTS: Type IIIB tibial fractures were the most frequent (67%) and carried a significantly ($p = 0.02$) higher risk of free-flap failure than other types of fracture. Patients underwent a mean of four procedures before referral for free-tissue transfer. The mean time from injury to flap coverage was 1006 days. Stable, long-term coverage of the free flaps was achieved in 78% of patients. Wound breakdown was most often caused by recurrent osteomyelitis (65%). Seventy-four percent of the fractures healed. The amputation rate was 10%. Four patients required repeat free-flap transfer for limb salvage.

CONCLUSION: Only the grade of tibial fracture could be significantly related to postoperative free-flap failure.

OBJECTIF : Définir les facteurs liés à la couverture par lambeau libre des fractures des extrémités inférieures liées à un résultat négatif.

CONCEPTION : Examen des dossiers.

CONTEXTE : Important centre de référence en microchirurgie.

PATIENTS : De 1981 à 1989, on a choisi les dossiers de tous les patients qui ont subi un transfert de tissus libres à l'extrémité inférieure et qui ont été suivis pendant plus d'un an. On en a tiré un sous-groupe de 49 patients (âge moyen, 36 ans) qui avaient subi une fracture du tibia (55 % dans des accidents de la circulation) et avaient eu, dans la plupart des cas, des défauts des tissus mous ou des os. Ces patients ont constitué le groupe d'étude.

INTERVENTION : Transfert de lambeau libre.

MESURES DES RÉSULTATS : Facteurs qu'on pourrait associer à l'échec du lambeau libre : mécanisme de la blessure, catégorie de fracture du tibia, antécédents de tabagisme, diabète, acrosyndrome, cardiopathie ischémique, atteinte vasculaire à la jambe avant l'intervention, artère utilisée, type d'anastomose et hypertension ou hypotension pendant l'intervention.

RÉSULTATS : Les fractures du tibia de type IIIB étaient les plus fréquentes (67 %) et comportaient un risque

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beaucoup plus élevé (p = 0,02) d'échec du lambeau libre que les autres types de fracture. Les patients ont subi en moyenne quatre interventions avant de se présenter pour un transfert de tissu libre. Il s'est écoulé en moyenne 1006 jours entre la blessure et la greffe du lambeau. La couverture à long terme stable des lambeaux libres a réussi chez 78 % des patients. La détérioration de la plaie a été causée le plus souvent par une ostéomyélite répétitive (65 %). Soixante-quatorze pour cent des fractures ont guéri. Le taux d'amputation s'est établi à 10 %. Il a fallu procéder à un transfert répété de lambeau libre chez quatre patients pour sauver leur membre.

CONCLUSION : La catégorie de fracture du tibia était le seul facteur que l'on a pu relier de façon significative à l'échec du lambeau libre après une intervention.

Reconstruction of compound fractures of the lower extremity continues to challenge surgeons.[1–5] In spite of modern microsurgical treatment techniques, patients with these fractures suffer complications of nonunion and chronic osteomyelitis that may lead to amputation.[6–8] Results of treatment have varied greatly, and several components have been linked to an unsuccessful outcome.[3,9–11] They include: crush fracture, high-grade segmental tibial fracture, injuries to the vascular system with secondary bone and soft-tissue ischemia, and the time between injury and definitive tissue coverage. In this review of free-flap coverage of lower extremity fractures in a large microsurgical referral centre, we sought to determine whether any factors related to the patient, the injury and its treatment could be significantly linked to a negative outcome.

METHODS

We reviewed hospital and inpatient records for the period 1981 to 1989 to identify all patients who underwent free-tissue transfer to the lower extremity. All patients with less than 1 year follow-up were excluded. One hundred individual data points were recorded for each patient and transferred to a computerized database (File Force; Arcuis, Cupertino, Calif.) for analysis. Statistical evaluation was carried out on a personal computer with a commercially available software package (Statsview II; Abacus Concept, Berkeley, Calif.); significance was defined at a probability level of 0.05 by χ^2 analysis.

Classification of the bony injury

Fractures were classified by anatomic region within the lower extremity, and Gustilo's classification[12] was used to grade the severity of the tibial fractures. Type I — skin wounds less than 1 cm long; type II — skin wounds longer than 1 cm; type IIIA — adequate soft-tissue coverage of the bone despite extensive soft-tissue injury or flaps; type IIIB — extensive soft-tissue injury with stripping of the periosteum and exposure of bone; and type IIIC — open fractures associated with vascular injury. The presence or absence of associated vascular and neural injuries was confirmed by clinical examination at the time of injury and by subsequent angiography. Delayed union was defined as failure of tibial fractures to heal after 3 months and nonunion as failure of tibial fractures to unite after 6 months.

Wound classification

Soft-tissue wounds were classified as clean, contaminated or showing evidence of soft-tissue sepsis. Bone infections were defined as having either acute or chronic osteomyelitis. The criteria for chronic osteomyelitis[12] included the presence of exposed bone and drainage for more than 6 weeks, a positive bone culture, and radiographs or bone scans consistent with a diagnosis of osteomyelitis (i.e., hot bone scan [technetium and gallium], lytic lesion or sclerosis on an x-ray film). Acute or subacute bone infection was defined as a condition in which the wounds were open, with drainage and exposed bone, for less than 6 weeks.

FINDINGS

We identified 61 patients who underwent free-tissue transfer to the lower extremity in the study period and who had been followed up for at least 1 year. As tibial fractures made up the largest number (49 [80%]) of these patients, they were selected to form the study group.

Patients

The mean age of the 49 patients was 36 years (range from 14 to 77 years); 23 were younger than 29 years. The mean follow-up was 2.1 years (range from 1 to 7.3 years). Motor vehicle accidents accounted for 27 injuries. Almost all patients received initial treatment at other hospitals and had established soft-tissue or bony defects at the time of referral.

Fracture pattern

Most of the tibial fractures were type IIIB (33) or type IIIA (9) (Fig. 1). There were no type IIIC fractures. Although 11 patients showed some element of vascular compromise when first assessed, all showed improvement when the fracture was reduced. Sensory testing revealed a lower extremity neurologic deficit in the posterior tibial distribution in 16 patients. Initial stabilization of the fractures was achieved by plates and screws in 30 patients, by external fixation in 14 and by cast immobilization in 5. No intramedullary nails were used in the series.

Procedures performed before free-flap transfer

Before free-tissue transfer, patients underwent a mean (and standard deviation) of 4 (4.5) procedures (range from 0 to 31) (Fig. 2, Table I). Angiography was performed preoperatively on 45 patients: in 22 three leg vessels were injured, in 17 two vessels were injured, in 5 one vessel was injured, and in only 1 were no vessels injured. The anterior tibial artery was most frequently injured (20 patients), followed by the peroneal (9 patients) and posterior tibial (5 patients) arteries.

Microbiologic findings

Preoperative tissue cultures were obtained for 47 patients. The commonest isolates were *Pseudomonas* sp. (19 patients), followed by coagulase-negative staphylococci (15 patients), *Staphylococcus aureus* (11 patients), *Klebsiella* sp. (5 patients) and *Escherichia coli* (1 patient). In 9 patients, the bacteria were localized to the soft tissues only. Chronic osteomyelitis was diagnosed in 32 patients; in 5 of these, the infectious process was diagnosed as secondary to acute osteomyelitis. Four patients showed evidence of delayed union at the time of flap coverage; 11 had nonunion and 8 of these had nonunion associated with chronic osteomyelitis. Forty-seven patients received antibiotics preoperatively, but the agents used matched the sensitivities to preoperative isolates in only 76% of cases.

Bone débridement was carried out before flap coverage in 29 patients (Fig. 3). The mean (and SD) time between the last débridement and flap coverage was 11 (14) days (range of 62 days) (Fig. 4). Bone débridement was done intraoperatively on 37 patients.

Free-tissue transfer

The mean time between injury and flap coverage was 1006 days, but the SD was quite large (1684, range

Table I

Procedures Performed in 49 Patients Before Free-Tissue Transfer

Procedure	Patients, no. (%)
Débridement	41 (84)
Removal of hardware	25 (51)
Insertion of hardware	11 (22)
Split-thickness skin grafting	16 (33)
Bone grafting	15 (31)
Local-flap placement	12 (24)
Free-flap placement	2 (4)
Other	10 (20)

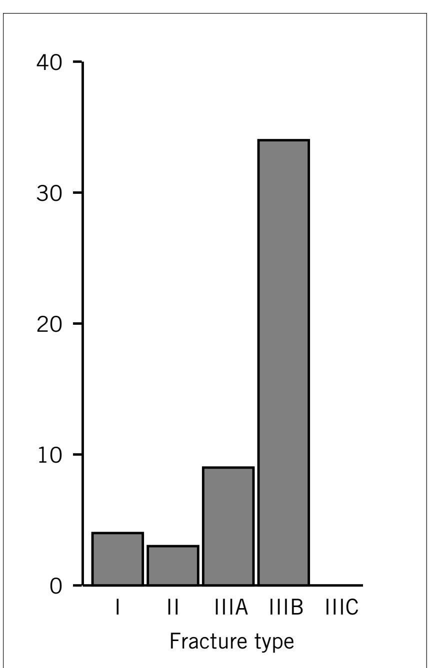

FIG. 1. Distribution of tibial injuries in 49 patients.

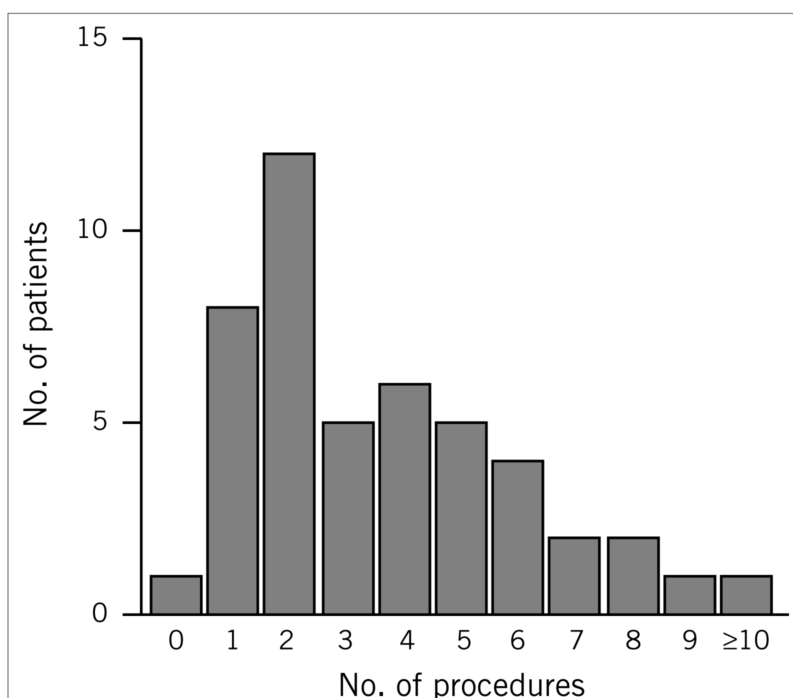

FIG. 2. Number of procedures performed before free-flap transfer.

from 7 to 7962). Of the tibial fractures, 38% were covered by free flaps within 86 days and 50% within 166 days. The types and numbers of free-tissue transfers are shown in Table II. Muscle flaps predominated. Gracilis and rectus abdominis flaps were used most frequently. The flap selected depended on the dimensions of the cutaneous defect. Small defects (up to 5 cm in transverse dimension) were usually closed with gracilis flaps; for intermediate defects (up to 10 cm in transverse dimension) we used rectus abdominis flaps and for large defects (more than 10 cm in transverse dimension) we generally used latissimus dorsi flaps. When vascularized bone was required for a large composite defect, the most commonly used flap was the iliac crest. The preferred recipient artery was the posterior tibial (54%), followed by the anterior tibial (36%), dorsalis pedis (8%) and peroneal (4%) arteries. Of the arterial anastomoses, 86% were performed end to side. One vein was repaired in 89% of transfers and two veins in the remaining 11%. All venous repairs were completed end to end.

The mean (and SD) operating room time was 9.2 (2.6) hours (range from 5 to 15 hours). Whereas the mean preoperative hemoglobin level was 131 g/L, preoperatively it was 115 g/L. The mean (and SD) number of units of blood transfused was 2.4 (2.5) (range from 0 to 13).

Intraoperative problems

Intraoperatively thrombosis occurred in five arteries and five veins. Revision was successful in all. One flap could not be salvaged. Systemic anticoagulants were not given routinely. Seven patients required heparin intra- and postoperatively because of vascular compromise of the flap. Two patients received dextran and one received acetylsalicylic acid.

Postoperative complications

Nine patients experienced partial flap loss, which was the most frequent complication postoperatively (Table III). There were three cases of soft-tissue abscess, which required drainage, and two cases of postoperative cellulitis, which responded to intravenous administration of antibiotics. There were three total flap losses perioperatively. Two were attributed to arterial thrombosis and one to venous insufficiency. Three pa-

Table II

Distribution of Lower Extremity Flaps in 49 Patients

Type of flap	Patients, no. (%)
Gracilis	18 (37)
Rectus abdominis	10 (21)
Latissimus dorsi	8 (16)
Iliac crest	8 (16)
Fibular	4 (8)
Other	1 (2)

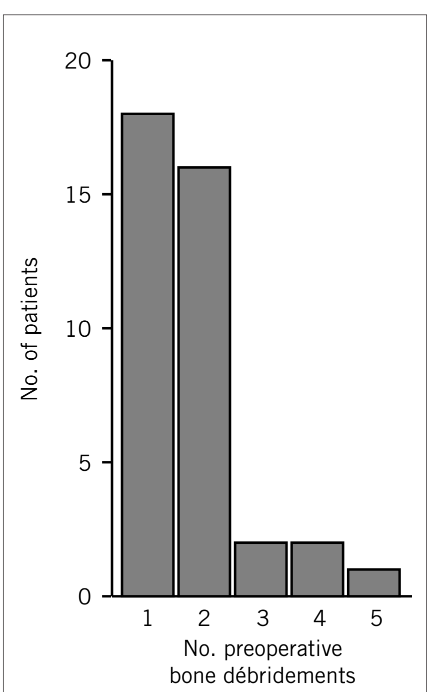

FIG. 3. Distribution of preoperative bone débridements in 29 patients

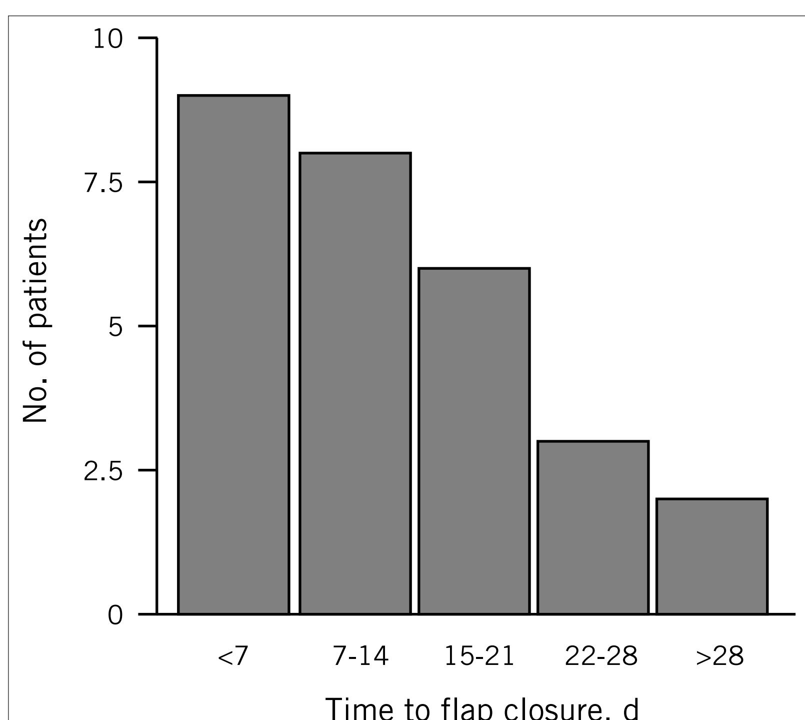

FIG. 4. Time from last preoperative bone débridement to free-flap coverage in 29 patients.

tients had pneumonia postoperatively, but there were no deaths, myocardial infarction or pulmonary embolism.

Long-term results

Of the 49 patients, 38 (78%) had stable, long-term coverage of the tibial fracture. Wound instability (11 patients) was most often caused by recurrent osteomyelitis (7 patients). Other causes of breakdown were free-flap loss (three patients), loose hardware (one patient) and soft-tissue abscess (one patient). Mean time to breakdown was 26 weeks, but the SD was quite large (87 weeks). Of the seven patients who had recurrent osteomyelitis, six were infected by the same organism present preoperatively.

Table III

Postoperative Complications of Free-Flap Coverage in 49 Patients

Complication	Patients, no. (%)
Partial flap loss	9 (18)
Total flap loss	3 (6)
Soft-tissue abscess	3 (6)
Cellulitis	2 (4)
Skin-graft loss	1 (2)

Table IV

Procedures Performed After Free-Flap Coverage in 49 Patients

Procedure	Patients, no. (%)
Débridement	12 (24)
Bone grafting	8 (16)
Split-thickness skin grafting	6 (12)
Removal of fat from flap	6 (12)
Amputation	5 (10)
Local-flap placement	4 (8)
Free-flap placement	4 (8)
Removal of hardware	3 (6)
Insertion of hardware	1 (2)

A mean (and SD) of 1.2 (1.2) procedures were performed after free-tissue transfer. Wound débridement and secondary bone grafting were the most frequently performed procedures (Table IV). There were five amputations; three were performed for recurrent osteomyelitis and nonunion, and failure of the free-tissue transfer accounted for the other two. Four patients required a repeat free-flap transfer for limb salvage.

Risk factors for flap loss

The following risk factors for flap loss were considered: smoking, peripheral vascular disease, diabetes mellitus, ischemic heart disease, mechanism of injury, grade of tibial fracture, presence of a single leg vessel or vascular compromise preoperatively, time from injury to flap coverage, type of free flap chosen, choice of recipient artery, type of anastomosis performed, number of patent vessels in the leg and intraoperative hypertension or hypotension. Of all these factors, only the grade of tibial fracture was of significance in predicting the increased likelihood of free-flap failure. Type IIIB fractures were associated with a significantly (p = 0.02, χ^2 test) higher risk of flap loss than lower grade tibial fractures.

Risk factors for recurrent osteomyelitis

Two variables were found to be significant ($p < 0.05$) indicators of recurrent osteomyelitis postoperatively: preoperative administration of antibiotics that did not match the sensitivities of organisms isolated from the bone preoperatively and the development of a soft-tissue abscess postoperatively. Other predictors, although not statistically significant, were high-grade tibial fracture and preoperative diabetes mellitus.

Discussion

The high rate of complications seen in association with high-impact tibial injuries is well documented[12–15] As this study confirms, the severity of the original injury is a major determinant of prognosis. Gustilo's classification[12] has proved valuable in predicting rates of infection, delayed union and the need for amputation.[15]

Not all type IIIB tibial fractures are the same. They may vary in the degree of osseous disruption and trauma to the soft tissue. There were long delays in referring these difficult cases for definitive coverage. Our patients probably experienced more complex tissue injuries than those generally described because of the referral nature of our centre.

The use of local muscle flaps for coverage of tissue defects in the leg was introduced by Ger[9] in the 1970s. However, in high-impact tibial injuries, local flaps are frequently inadequate to provide the necessary soft-tissue coverage. In their series of muscle-flap transfers to the lower extremity, Neale and colleagues[16] observed that patients who had a soft-tissue defect associated associated with an underlying fracture had a 40% complication rate. This high complication rate was attributed to the use of recently traumatized muscle within the zone of injury in patients who had high-impact tibial injuries. The complication rate is lower when healthy untraumatized free muscle is transferred. For coverage of defects in the lower third of the leg, local flaps are generally not available, and free-tissue transfer is necessary to effect coverage.

The preferred method of soft-tissue coverage for our patients was the free muscle flap with skin grafting. Muscle flaps are easily contoured to a variety of defects, and their bulk allows them to be placed into irregular cavities within the wound, allowing better elimination of dead space and revascularization of the wound bed. Experimental evidence has suggested that the immediate blood supply to the fracture site originates from muscles contiguous with the wound.[17,18] Additional experimental evidence indicated that muscle flaps can tolerate higher concentrations of bacteria before exhibiting overt infection.[4] Recurrent infection will result if significant amounts of bony infection remain in the wound, regardless of the vascularity of the flap. Our cases of recurrent osteomyelitis were probably caused by inadequate bone débridement. If acute or chronic osteomyelitis was present, it was our practice to debride back to bleeding bone. "Petallage" (multiple cuts in the cortical surface of the bone made with an osteotome) of the bony bed was performed before flap transfer. This practice was thought to augment the regrowth of vessels from the flap to the bone by enhancing periosteal blood and hence host defences of the bone. Similarly, if the intramedullary canal of the tibia was blocked by callus or fibrous tissue, it was reopened to assist re-establishment of the endosteal blood supply. In cases in which there was free pus or infected sequestra, the débridement was done as a separate preliminary procedure. When there were soft-tissue defects and superficial osteomyelitis localized just to the base of the defect, débridement and soft-tissue coverage were done at the same time. Even with meticulous serial débridement, infectious complications remain high in patients with high-impact tibial injuries.[12,15]

There has been a trend to earlier definitive coverage of soft-tissue defects after lower extremity trauma. Godina[19] frequently performed free-tissue transfer to the lower extremity as an emergent procedure during the initial orthopedic intervention. Yaremchuk and colleagues[2] performed aggressive repeated operative débridement of the wound, obtaining definitive coverage within 7 to 14 days. Byrd, Spicer and Cierney[3] reported the lowest complication rate when coverage was done within 6 days of injury and the highest rate when coverage was done between 6 days and 6 weeks. This high rate was attributed to conversion of the wound from a contaminated state early after injury to a colonized wound in the later period after injury. Chronic wounds were more easily managed because "vascular ingrowth had localized the infection to a central mass of devascularized bone and surrounding scar,"[20] making demarcation of the margins of débridement clearer.

The majority of patients in this series were referred after multiple procedures failed to achieve coverage. The 78% rate of long-term, stable coverage together with a minimum of 1-year follow-up is comparable to that of other reports. Khouri and Shaw,[21] reporting their experience with 304 free-flap transfers to the lower extremity over 10 years, achieved long-term coverage in 66% of those who underwent coverage from 2 to 12 months after injury and in 73% of those who underwent coverage more than 1 year after injury. Because late attacks of osteomyelitis are not uncommon, caution must be used in interpreting the statistics for long-term cure. The mean time to breakdown in our series was 26 weeks, but the large SD of 87 weeks indicates the need for long-term follow-up.

Our data on the timing of wound closure contradict those reported by Byrd, Spicer and Cierney.[3] Although 78% of our patients underwent flap coverage more than 6 weeks after injury, the rate of recurrent osteomyelitis was no higher than for the 22% who underwent coverage less than 6 weeks after injury. Yaremchuk and colleagues[2] reported similar results. This finding is likely the result of aggressive bone and soft-tissue débridement perioperatively.

Pseudomonas aeruginosa was the organism most often isolated from the bone in this study. Coagulase-negative staphylococci and *S. aureus* were found less often. Other reports[22–24] found a predominance of infection by *S. aureus,* but Patzakis, Wilkins and Moore[25] noted an increased incidence of gram-negative infections and recommended that tobramycin be added to the usual gram-negative regimens to cover this. In their study the highest infection rate (24%) was noted in patients with open tibial injury receiving no antibiotics and the lowest infection rate (4.5%) in patients receiving a cephalosporin and an aminoglycoside. Although antibiotics are not a substitute for adequate surgical débridement, their beneficial effect has been well documented. In this study, when the antibiotics given were not sensitive to the organisms found in the wound preoperatively, the incidence of recurrent osteomyelitis was significantly increased. Further, when recurrent osteomyelitis was documented, the organisms isolated in 92% of the cases matched those present preoperatively.

Although five arterial thromboses and five venous thromboses occurred intraoperatively, no significant correlation could be made between the likelihood of thrombosis and any specific recipient vessel or type of anastomosis. Our preferred method of arterial anastomosis was end to side, because such an anastomosis preserved the native blood supply in a limb having an already compromised vascular supply. Godina[26] reported nine failures in 27 free flaps transferred by an end-to-end anastomosis and no failures in 41 free flaps transferred by an end-to-side anastomosis.

As noted also by Khouri and Shaw,[21] our study indicates that a type IIIB tibial fracture was the only factor that could be significantly associated with an increased likelihood of flap failure. A significant bony gap and wider zone of injury emphasize the more severe traumatic forces present in these injuries and the need to perform the vascular anastomosis outside the zone of injury.

Our 10% amputation rate is similar to that of larger series of free-flap transfers for limb salvage.[12,21] Recurrent osteomyelitis and nonunion accounted for three of these five failures; failure of the free-tissue transfer accounted for the other two. If traditional open methods of treatment had been used, the amputation rate would have been much higher.[27] Amputation as a treatment alternative in high-grade tibial injuries should not be overlooked. The salvage of a severely traumatized lower extremity requires sound judgement on the part of the surgeon, and the patient must be made aware of the length of time involved to complete the reconstruction and of the functional limitations of this method of limb salvage.

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