The Efficacy of Perforator Flaps in the Treatment of Chronic Osteomyelitis

Joon Pio (Jp) Hong, M.D.,
Ph.D., M.M.M.
Terence L. H. Goh, M.D.
Dong Hoon Choi, M.D.
Jung Jae Kim, M.D., Ph.D.
Hyun Suk Suh, M.D., Ph.D.

Seoul, Republic of Korea

Background: Treatment of chronic osteomyelitis involves aggressive débridement followed by soft-tissue coverage. The dictum of muscle coverage being superior has been challenged by successful reports of coverage with skin flaps. The objective of this article is to evaluate the efficacy of perforator flaps for reconstruction of chronic osteomyelitis defects.

Methods: A retrospective review of 120 patients with chronic osteomyelitis who underwent débridement and reconstruction using perforator flaps from April of 2000 to November of 2015 was conducted. Inclusion criteria were cases with chronic osteomyelitis for a minimum of 6 weeks and with a follow-up of at least 2 years after surgery. Correlation between recurrence and the following factors was analyzed: comorbidities, frequency of débridement, duration of chronic osteomyelitis, limb vascular status, and method of dead space obliteration. The outcomes analyzed were flap loss, recurrence rate, primary remission rate, secondary remission rate, and amputation rate.

Results: The flap loss rate was 4.2 percent flap, the recurrence rate was 8.3 percent, the primary remission rate was 91.6 percent, the secondary remission rate was 98.3 percent, and the amputation rate was 1 percent. Significant predictors of recurrence were peripheral vascular disease and major vessel compromise, which had 5.1 times higher odds of recurrence ($p < 0.05$).

Conclusions: Used with adequate débridement, bone reconstruction, and obliteration of dead space, a primary remission rate of 91.6 percent and a secondary remission rate of 98.3 percent were achieved using perforator flap. The predictors of chronic osteomyelitis recurrence were peripheral vascular disease and major vascular compromise.   (*Plast. Reconstr. Surg.* 140: 179, 2017.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

The treatment of chronic osteomyelitis regardless of cause remains challenging. Open fracture of the tibia is the most common cause of adult osteomyelitis. Without antibiotics, open fractures have a 24 percent incidence of infection, and Gustilo grade IIIB fractures have a 15 to 40 percent reported risk of infection.[1,2] Although acute osteomyelitis is amenable to antibiotic chemotherapy, chronic osteomyelitis is characterized by sessile bacteria lodged within an infective nidus and is impermeable to antibiotics. Thus, a multidisciplinary approach with surgical treatment is mandatory, and antibiotics play an adjunctive role.[3] The treatment requires aggressive surgical débridement, removing all fibrotic and ischemic bone and soft tissue surrounding the wound that impede antibiotic delivery as suggested by Attinger and Bulan, followed by definitive reconstruction with the objective of restoring ambulatory function.[4]

Reconstruction of an osteomyelitic limb comprises three major components: restoration of the bony framework, obliteration of dead space, and restoration of soft-tissue coverage.[5] Over the past three decades, major surgical advancements to provide vascularized coverage to infected bone have brought recurrence rates in chronic osteomyelitis down from 30 percent to 10 to 15 percent.[6,7] Muscle flaps have been shown to have higher blood flow, translating to increased antibiotic delivery, increased phagocytic activity, enhanced bacterial clearance, and a more effective immune

Disclosure: *The authors have no financial interest to declare in relation to the content of this article.*

response.[8–10] It has even been shown to expedite bone healing in the early phases of repair.[10,11] Although longstanding surgical dogma substantiated by clinical evidence and experimental data has shown the value of muscle flaps in the treatment of chronic osteomyelitis, the muscle flap was found to be difficult to elevate and to use for defect coverage during secondary orthopedic procedures. Numerous reports substantiate the use of skin flaps to cover the soft-tissue defect caused by chronic osteomyelitis.[7,12–16] These studies, however, were of limited sample size and heterogeneous in severity of infection.[17–21] Although it is now accepted as a treatment option for covering defects with chronic osteomyelitis, there is still debate regarding its efficacy. The purpose of this article is to validate the efficacy of using perforator flaps in treating chronic osteomyelitis based on a retrospective review of 120 patients with a minimum follow-up period of 2 years.

PATIENTS AND METHODS

Patient Data

This is a retrospective clinical study approved by the Institutional Review Board of Asan Medical Center (number S2014-0206-0001). From January of 2000 to June of 2014, patients diagnosed with chronic osteomyelitis based on history, physical examination, radiologic imaging, confirmed histologic studies, and bacterial cultures were reviewed. The wounds were graded according to the Cierny-Mader grading for chronic osteomyelitis.[22] All patients had an open wound for a minimum of 6 weeks. The average follow-up period was 46 months (range, 24 to 122 months).

The following outcomes were analyzed: flap loss, chronic osteomyelitis recurrence rate, primary and secondary remission rates, and amputation rate. The correlation between recurrence and the following factors was analyzed: comorbidities, frequency of débridement, duration of chronic osteomyelitis, limb vascular status, method of dead space obliteration, and method of bone fixation. All of the data were summarized with frequency and percentage for categorical variables and mean and standard deviation for continuous variables. Fisher's exact test was used for univariate statistical analysis of recurrence of chronic osteomyelitis. Statistical analysis was also performed with a logistic regression model by calculating the odds ratio between recurrence of osteomyelitis and risk factors. The odds ratio was deemed significant for values of $p < 0.05$.

Preoperative Diagnostics and Surgical Débridement

Workup was performed for all cases, with preoperative blood investigations, limb radiographs, and computed tomographic angiograms. Magnetic resonance imaging scans were supplemented if the radiograph was equivocal, or to determine the extent of infection. Femoral arteriography was supplemented if the computed tomographic scan was equivocal. The patency of the lower limb vessels was documented for each patient.

Single-stage reconstruction was based on the adequacy after débridement; otherwise, serial débridement was performed followed by reconstruction. Bone cultures were taken to confirm the diagnosis and sent for bacteriologic culture. Broad-spectrum antibiotics were used before culture results, and specific antibiotics were used after confirmation of bone culture. The postoperative antibiotic regimen consisted of 4 to 6 weeks of antibiotics.

Reconstruction

Reconstruction begins with proper débridement and then isolation of recipient vessels, which allows determination of the pedicle length of the flap. The recipient artery was chosen based on pulsation, regardless of location, even within the zone of injury.[23] Small vessels such as branches from the major vessels or perforators were used as recipients if the reconstruction required only skin flaps of moderate size.[23] If a major artery was used, it was always approached in end-to-side manner unless it was a stump, in which case end-to-end anastomosis was performed. The accompanying veins were used primarily, but superficial veins were used if applicable, and all veins were anastomosed in end-to-end fashion. Various perforator flaps were selected based on the size of the defect, composite of tissues, pedicle length required, and position of the patient during surgery. The flaps performed included the anterolateral thigh perforator flap, superior circumflex artery perforator flap, gluteal artery perforator flap, upper medial thigh perforator flap, and thoracodorsal artery perforator flap.[18,24–27] The anterolateral thigh perforator flap can be harvested either as a perforator flap that includes only the skin or as a chimera flap with an independent branch supplying the vastus lateralis without the deep fascia. Reconstruction of bony structure was not performed in the patients who had minimal or no bony defects (Cierny-Mader type II). In patients with localized bony defects (Cierny-Mader type III), obliteration of the bony dead space was performed either with a small muscle flap combined with the

180

perforator flap or deepithelialized flap segment or with antibiotic beads. The same method of obliteration was applied for soft-tissue dead spaces as well. In patients with Cierny-Mader type IV chronic osteomyelitis, external fixation was performed for bone stability. Two patients required a single-stage vascularized fibula flap in addition to the soft-tissue reconstruction.

Secondary bone grafting with cancellous iliac crest bone (if required) was performed within 2 months (range, 3 to 8 weeks) after the initial reconstruction. The erythrocyte sedimentary rate and C-reactive protein levels were checked before iliac bone chip grafting to ensure that the infection had resolved.

Discharge and Follow-Up

The average length of stay in the plastic surgery department was 10 days. All patients were followed up in the outpatient clinic by both plastic and orthopedic teams. The assessment of chronic osteomyelitis remission was made after a minimum of 12 months, based on the absence of clinical symptoms, pain-free ambulation, and when all inflammatory markers (erythrocyte sedimentation rate, C-reactive protein, and white blood cell count) had normalized. The term "remission" was used instead of "cure," as suggested by Rao et al.[3] Primary remission was defined as the eradication of osteomyelitis after the first reconstruction, and final remission was defined as eradication of infection after the final procedure. Patients who defaulted were recalled for follow-up.

RESULTS

Patient characteristics are listed in Table 1. A total of 120 patients were evaluated, and their ages ranged from 13 to 77 years (mean, 47.2 years), with 98 male patients and 22 female patients. The majority of the patients (89.0 percent) developed chronic osteomyelitis secondary to trauma. The other causes were soft-tissue infection, burn, and iatrogenic cause. Forty-one patients (34.0 percent) did not have any comorbidity, whereas the other patients had diabetes, were older than 60 years, and/or were smokers. Twenty-three patients (19.0 percent) had obstruction of vascular flow to the affected limb. The majority of the defects were located in the tibia (86.0 percent), followed by the calcaneum (13.0 percent). Forty-one patients (34 percent) had chronic osteomyelitis for more than 12 months, and of these, 15 patients had chronic osteomyelitis for more than 5 years. A total of 89 patients had chronic osteomyelitis resulting in a bone defect of Cierny-Mader grade III or IV.

Table 1. Characteristics of 120 Patients Who Underwent Reconstruction with a Perforator Flap to Treat Chronic Osteomyelitis of the Lower Extremity

Patient Characteristics*	No. (%)
No.	120
Demographics	
Male	98 (82.0)
Female	22 (18.0)
Cause	
Trauma	107 (89.0)
DM	6 (5.0)
Burn	3 (2.5)
Iatrogenic	1 (1.0)
Soft-tissue infections	3 (2.5)
Comorbidity	
None	41/120 (34.0)
Age >60 yr	28/120 (23.0)
Type 2 diabetes	23/120 (19.0)
Smoker	43/120 (36.0)
Peripheral vascular disease†	23/120 (19.0)
Location of defects	
Tibia	103 (86.0)
Calcaneum	16 (13.0)
Fibula	1 (1.0)
Duration of COM	
<6 mo	56 (47.0)
6–12 mo	23 (19.0)
>12 mo	41 (34.0)
Cierny-Mader grading	
Anatomical type	
I, medullary osteomyelitis	0 (0.0)
II, superficial osteomyelitis	31 (26.0)
III, localized osteomyelitis	35 (29.0)
IV, diffuse osteomyelitis	54 (45.0)
Physiologic class	
A host, normal	11 (9.0)
B host, local or systemic	
Bs, systemic compromise	23 (19.0)
Bl, local compromise	41 (34.0)
Bls, systemic and local compromise	45 (38.0)

DM, diabetes mellitus; COM, chronic osteomyelitis
*Mean age at first presentation was 47.2 years (range, 13–77 years).
†Diagnosed either on computed tomographic angiography or arteriography.

Orthopedic Procedures, Flap Choice, and Outcomes

Flaps and orthopedic procedures performed and outcomes of the 120 patients who underwent reconstruction are listed in Table 2. A total of 77 patients underwent perforator flap–only reconstruction, and 43 patients had an anterolateral thigh perforator flap combined with an independently pedicled vastus lateralis muscle without including the deep fascia. Once admitted at our center, patients underwent an average of 1.74 débridements (range, one to eight) before definitive reconstruction. Sixty-nine patients were approached with single-stage débridement and simultaneous reconstruction, whereas 51 patients underwent multiple débridements before definitive reconstruction. Fifty-two patients required an external fixator for stabilization, and 25 patients

Table 2. Flaps Performed, Orthopedic Procedures, and Outcomes of the 120 Patients Who Underwent Reconstruction for Chronic Osteomyelitis of the Lower Extremity

	No. (%)
Perforator flaps	
ALT combined with vastus lateralis	43 (36.0)
ALT	41 (34.0)
SCIP	30 (25.0)
UMT	3 (2.5)
SGAP	2 (1.5)
TDAP	1 (1.0)
Orthopedic procedures	
External fixator	52 (43.0)
Antibiotic beads	25 (21.0)
Bone graft	22 (18.0)
Outcomes	
Complications	23 (19.2)
Total flap loss	5 (4.2)
Partial flap loss	10 (8.3)
Recurrence	10 (8.3)
Nonunion	5 (4.2)
Amputation	1 (1.0)
Primary remission	110 (91.6)
Secondary remission	118 (98.3)

ALT, anterolateral thigh flap; SCIP, superficial circumflex iliac artery perforator; UMT, upper medial thigh; SGAP, superior gluteal artery perforator; TDAP, thoracodorsal artery perforator.

had antibiotic beads inserted into the bone cavity later requiring secondary orthopedic reconstruction. Twenty-two patients required secondary bone grafting within 2 months after reconstructive surgery.

There were five patients with total flap loss, and all were treated with a second free flap. Ten patients developed partial flap loss; three were treated with a second free flap, one had a local transposition flap, and six were treated with minor procedures (healing by secondary intention or split-skin grafting).

In total, 10 patients developed recurrence, developing in two patients after partial flap loss; eight patients developed recurrence despite complete flap healing. Three of these 10 patients required a second free flap; one patient required a local flap; and the other six cases of recurrence were treated with antibiotics, débridement, and secondary closure using sutures. Among the recurrences, 90 percent occurred within 12 months of reconstruction (range, 3 to 18 months). The primary remission rate after the first reconstruction

Table 3. Logistic Regression Model Analysis of Risk Factors*

Factor	No.	Recurrence (%)	p	OR	OR 95% CL Lower	OR 95% CL Upper
Comorbidities						
Nil						
Yes	41	3 (7.32)	0.772	0.812	0.199	3.321
No	79	7 (8.86)		Ref		
Age > 60 yr						
Yes	28	2 (7.14)	0.795	0.808	0.161	4.044
No	92	8 (8.70)		Ref		
Type 2 diabetes						
Yes	23	1 (4.35)	0.453	0.444	0.053	3.696
No	97	9 (9.28)		Ref		
Smoker						
Yes	43	2 (4.65)	0.288	0.421	0.085	2.078
No	77	8 (10.39)		Ref		
PVD						
Yes	23	5 (21.74)	0.017	5.111	1.340	19.492
No	97	5 (5.15)		Ref		
Duration of COM			0.231			
<6 mo	56	4 (7.10)		Ref		
6–12 mo	23	4 (17.40)	0.183	2.737	0.622	12.049
>12 mo	41	2 (4.90)	0.649	0.667	0.116	3.827
Vascular injury			0.017			
None	97	5 (5.15)		Ref		
Vessel injury	23	5 (21.74)		5.111	1.340	19.492
External fixator			0.658			
No EF required	68	5 (7.40)		Ref		
EF required	52	5 (9.60)		1.340	0.367	4.898
Débridements preoperatively			0.251			
Single stage	69	4 (5.80)		Ref		
Multiple stages	51	6 (12.70)		2.167	0.578	8.119
Flap composition			0.774			
Perforator skin flap	77	6 (7.80)		Ref		
ALT combined VL flap	43	4 (9.30)		1.214	0.323	4.562

Ref, reference; PVD, peripheral vascular disease; COM, chronic osteomyelitis; EF, external fixator; ALT, anterolateral thigh; VL, vastus lateralis.
*The odds ratio was deemed significant for values of $p < 0.05$.

182

was 91.6 percent, and the final remission rate at 2-year follow-up was 98.3 percent.

Predictors of Recurrent Osteomyelitis

Among the factors analyzed, clinical significance was shown only in patients with major vessel compromise; these patients had higher chronic osteomyelitis recurrence rates (21.7 percent) than those without (5.2 percent) ($p < 0.05$). Among the five cases that recurred, the involved arteries were anterior tibial (two cases), posterior tibial (one case), and tibioperoneal trunk (two cases). Although not significant, chronic osteomyelitis recurrence is most common in patients with the disease for 6 to 12 months compared with all other groups (Table 3).

CASE REPORTS

Case 1

A patient was referred for Cierny-Mader grade III chronic osteomyelitis after previous healed fracture from 10 years previously. He underwent single-stage surgical débridement, obliteration of dead space using antibiotic beads, and reconstruction with a superior circumflex artery perforator flap. Secondary bone grafting was performed 6 weeks after reconstruction. He is currently ambulating well and was in remission for 2 years during his last follow-up (Fig. 1).

Case 2

A 54-year-old male diabetic smoker had undergone previous intramedullary nailing for right tibia and fibula fracture 15 years previously. He presented with a chronic discharging wound over the right tibia. He was diagnosed with Cierny-Mader grade IV chronic osteomyelitis supported by radiographs and computed tomographic scans. He underwent external fixation and débridement of infected soft tissue and bone. The dead space was obliterated by antibiotic beads, and he underwent reconstruction with a superior circumflex artery perforator flap. The anastomosis was performed in end-to-side fashion to the posterior tibial artery and vein. Secondary bone grafting was performed with removal of the external fixator. A radiograph obtained at 18 months shows complete healing of the tibia and the patient is ambulatory without assistance (Figs. 2 and 3).

DISCUSSION

There have been numerous reports showing the reliability of using skin-only perforator or fasciocutaneous flaps for treating chronic osteomyelitis.[17–21] In addition, Salgado et al. have confirmed in an animal study that skin flaps are similar to muscle flaps for this purpose.[28] However, a comprehensive clinical review has yet to be reported. Since our first report, we have further refined the concept of using perforator skin flaps and expanded it to various perforator flaps.[18]

Fig. 1. A patient referred for chronic osteomyelitis after previous healed fracture more than 10 years previously. He presented with ulceration and discharge over the pretibial area (*left*). Magnetic resonance imaging confirmed the presence of Cierny-Mader grade III chronic osteomyelitis with involucrum and overlying cellulitis (*second from left*). After débridement, the dead space was filled with antibiotic beads and then reconstructed with a superficial circumflex iliac perforator flap (*second from right and right*). He subsequently underwent removal of beads and delayed secondary bone grafting 6 weeks after reconstruction. He is currently ambulating well and was in remission for 2 years during his last follow-up (*right*).

Fig. 2. A 54-year-old male diabetic smoker who had undergone previous intramedullary nailing for right tibia and fibula fracture 15 years previously.

Fig. 3. A radiograph obtained at 18 months shows complete healing of the tibia, and the patient is ambulatory without assistance.

After débridement and proper antibiotic use, reconstruction consists of three major components: reconstructing the bone, obliterating the dead space, and covering the defect. For the scope of this article, the first component of reconstructing the bone is not described in detail. It usually can be reconstructed by a single-stage bone flap along with soft-tissue reconstruction or performed by distraction or secondary grafting. In our series, external fixation was required in 43 percent, antibiotics beads were used in 21 percent, secondary bone grafting was performed in 18 percent, and a single-stage bone flap reconstruction was performed in two patients. The second component of reconstruction is obliterating the dead space for bone and soft tissues. The goal of dead space management is to replace dead bone and scar tissue with durable vascularized tissues.[29–31] One of

Fig. 2. (*Continued*). He presented with a chronic discharging wound over the right tibia (*above*, *left*). Radiographs and computed tomographic scans confirmed and delineated the extent of Cierny-Mader grade IV chronic osteomyelitis (*above*, *right*). He underwent external fixation and débridement of infected soft tissue and bone (*second row*, *left*). The bony defect was obliterated by antibiotic beads and he underwent reconstruction with a superficial circumflex iliac perforator flap (*second row*, *right* and *third row*, *left*). The anastomosis was performed in end-to-side fashion to the posterior tibial artery and venae comitantes. He underwent removal of antibiotic beads and bone grafting at 5 weeks after initial flap coverage.

the major advantages of using muscle is the conformability of the muscles to obliterate the dead spaces of the soft-tissue and bone defect while providing coverage. Using an anterolateral thigh perforator flap combined with an independently pedicled vastus lateralis can provide obliteration of the dead space like a muscle flap while resurfacing with a skin flap. This flap efficiently accommodates the three-component reconstruction approach, whereas a musculocutaneous flap will be bulky and has less versatility for addressing the dead space and resurfacing components. Thus, the use of a combined anterolateral and vastus lateralis flap will provide an external resurfacing separately, whereas the muscle flap addresses the dead space as shown in this study for 43 cases. Another alternative to manage bone defects is to use antibiotic beads to temporarily control infection and dead space followed by secondary replacement of bone.[31,32] In our series, 25 cases (21 percent) were approached in this manner with a successful outcome. We then further evolved and started to use the deepithelialized segment of the perforator flap either in combined form or just by partially deepithelializing the flap. When evaluating the different methods to obliterate the dead space of the bone, there was no significant difference in recurrence between using muscle, antibiotic beads, or deepithelialized flaps, which all had perforator flap coverage over the skin defect. Although we will need a larger series to reach a definite conclusion, from this experience

we can assume that muscle, antibiotic beads, and deepithelialized skin flaps are all effective in obliterating the dead space to serve its purpose. Our current protocol is to use antibiotic beads for all bone defects, use muscle for functional muscle reconstruction and to obliterate large soft-tissue dead spaces, and use deepithelialized skin flaps to obliterate small soft-tissue dead spaces.

The final component of reconstruction is coverage. As mentioned before, disadvantages of muscle flaps can be addressed by using perforator flaps.[33,34] In 2003, we stopped using muscle flaps unless the defect required a large muscle bulk or needed a functional muscle transfer. Although the perforator flap may require a learning curve and may also have a donor-site scar in large flaps, the advantages outweigh the disadvantages. The advantages of using skin-only perforator flaps are as follows:

1. The elasticity of skin flap allows elevation and resurfacing without tension during secondary orthopedic procedures. Furthermore, the impact on flap survival if the pedicle is injured during secondary procedures is less likely, as early dermal inosculation and angiogenesis allows skin flaps to be pedicle-independent during reelevation.[35] In the 24 patients requiring secondary orthopedic intervention, the flap was able to provide good circulation without breakdown of the flap.
2. Skin perforator flaps provide superior skin coverage, "replacing like with like," in contrast to skin grafted muscle flaps, which often develop eczema and dryness.
3. With respect to bone healing, the radiologic imaging has shown that patients are able to restore bony discontinuity with the use of bone grafts under the skin perforator flaps.
4. A skin paddle allows for easier flap monitoring.
5. Elevation of perforator flaps above the suprafascial plane is expedient and spares functional muscle morbidity.[36,37]
6. The supermicrosurgery concept of using perforator-to-perforator anastomosis allows a less invasive approach for recipient and donor sites and application of multiple new perforator flaps with shorter pedicle lengths.[23]

This study reviewing over 10 years shows the perforator flap's ability to achieve 91.6 percent primary remission, reflecting similar results from other studies using muscle flaps.[6,7] After complete débridement, obliterating the dead space with either independent muscle, antibiotics beads, or deepithelialized skin flap, the use of

a perforator skin flap against chronic osteomyelitis is as effective as using muscle flaps for this purpose.[7,13] Our shortest follow-up was 2 years, and this may not be long enough to exclude further recurrences, but we believe this to be an adequate period, as 90 percent of the patients usually develop recurrence within 12 months of reconstruction.[38]

When evaluating the risk factors for recurrences such as comorbidities, number of débridements, duration of chronic osteomyelitis, obliteration method of dead space, limb vascular status, and use of external fixators, the only significant factor was patients who had sustained major vascular injury or with peripheral vascular disease ($p < 0.05$). In our series, 19 percent of patients sustained vascular injury as a consequence of trauma, and five patients (21.7 percent) had recurrence of osteomyelitis, which shows a 5.1 times higher odds of having recurrence. The same was observed for patients who had peripheral vascular disease. We suspect that the vascular compromise and reduction of blood flow to the limb leads to ischemia, impedes wound healing, and increases the risk of osteomyelitis. Because of this finding, we are now attempting to reconstruct major vessel injuries with a graft or a bypass flap to see whether better results can be obtained.

The authors believe that by enforcing the basic concept of débridement and approaching the three components of reconstruction to correct the bone defect, obliterate bone or soft-tissue dead space, and provide well-vascularized coverage, the actual composition of the resurfacing flap is less critical in determining the final outcome. Among the 10 recurrences, eight actually had good initial healing with perforator flap coverage. It was most likely inadequate débridement or vascular insufficiency that played the major role in leading to recurrence. With the evolution of flaps and the variety of combined flaps that are available for reconstruction, one should determine coverage based on the merits provided by the flaps. Breaking down reconstruction into three components can help choose the flap suitable for each reconstruction. The use of antibiotics plays a major role along with surgical débridement and reconstruction. In our protocol, we used 4 to 6 weeks of antibiotics, but recent studies show that prolonged antibiotic therapy lacks strong evidence, and one should individualize duration of antibiotic therapy based on the patient's clinical response.[39,40]

The authors recognize that this study was a retrospective, nonrandomized study, which carries

with it selection and treatment biases. Nonetheless, this study shows that perforator flaps work efficiently to cover the defects with chronic osteomyelitis when approached with adequate débridement, obliteration of dead space, and proper bone reconstruction.

CONCLUSIONS

A retrospective review of 120 cases of chronic osteomyelitis treated with perforator flaps for coverage showed the following outcomes: used with adequate débridement, bone reconstruction, and obliteration of dead space, the primary remission rate was 90 percent and the secondary remission rate was 98 percent. The predictors of chronic osteomyelitis recurrence included the presence of major vascular compromise.

Joon Pio (Jp) Hong, M.D., Ph.D., M.M.M.
Department of Plastic and Reconstructive Surgery
Asan Medical Center
University of Ulsan Collage of Medicine
388-1 Pungnap-dong
Sonpa-gu, Seoul138-736, Republic of Korea
joonphong@amc.seoul.kr

REFERENCES

1. Patzakis MJ, Wilkins J, Moore TM. Use of antibiotics in open tibial fractures. *Clin Orthop Relat Res.* 1983;178:31–35.
2. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: Retrospective and prospective analyses. *J Bone Joint Surg Am.* 1976;58:453–458.
3. Rao N, Ziran BH, Lipsky BA. Treating osteomyelitis: Antibiotics and surgery. *Plast Reconstr Surg.* 2011;127(Suppl 1):177S–187S.
4. Attinger CE, Bulan EJ. Débridement: The key initial first step in wound healing. *Foot Ankle Clin.* 2001;6:627–660.
5. Ong YS, Levin LS. Lower limb salvage in trauma. *Plast Reconstr Surg.* 2010;125:582–588.
6. Shannon JG, Woolhouse FM, Eisinger PJ. The treatment of chronic osteomyelitis by saucerization and immediate skin grafting. *Clin Orthop Relat Res.* 1973;96:98–107.
7. Anthony JP, Mathes SJ, Alpert BS. The muscle flap in the treatment of chronic lower extremity osteomyelitis: Results in patients over 5 years after treatment. *Plast Reconstr Surg.* 1991;88:311–318.
8. Russell RC, Graham DR, Feller AM, Zook EG, Mathur A. Experimental evaluation of the antibiotic carrying capacity of a muscle flap into a fibrotic cavity. *Plast Reconstr Surg.* 1988;81:162–170.
9. Gosain A, Chang N, Mathes S, Hunt TK, Vasconez L. A study of the relationship between blood flow and bacterial inoculation in musculocutaneous and fasciocutaneous flaps. *Plast Reconstr Surg.* 1990;86:1152–1162; discussion 1163.
10. Richards RR, Orsini EC, Mahoney JL, Verschuren R. The influence of muscle flap coverage on the repair of devascularized tibial cortex: An experimental investigation in the dog. *Plast Reconstr Surg.* 1987;79:946–958.
11. Richards RR, McKee MD, Paitich CB, Anderson GI, Bertoia JT. A comparison of the effects of skin coverage and muscle flap coverage on the early strength of union at the site of osteotomy after devascularization of a segment of canine tibia. *J Bone Joint Surg Am.* 1991;73:1323–1330.
12. Ger R. Muscle transposition for treatment and prevention of chronic post-traumatic osteomyelitis of the tibia. *J Bone Joint Surg Am.* 1977;59:784–791.
13. Patzakis MJ, Abdollahi K, Sherman R, Holtom PD, Wilkins J. Treatment of chronic osteomyelitis with muscle flaps. *Orthop Clin North Am.* 1993;24:505–509.
14. Mathes SJ, Alpert BS, Chang N. Use of the muscle flap in chronic osteomyelitis: Experimental and clinical correlation. *Plast Reconstr Surg.* 1982;69:815–829.
15. May JW Jr, Jupiter JB, Gallico GG III, Rothkopf DM, Zingarelli P. Treatment of chronic traumatic bone wounds: Microvascular free tissue transfer. A 13-year experience in 96 patients. *Ann Surg.* 1991;214:241–250; discussion 250–252.
16. Weiland AJ, Moore JR, Daniel RK. The efficacy of free tissue transfer in the treatment of osteomyelitis. *J Bone Joint Surg Am.* 1984;66:181–193.
17. Hallock GG. The proximal pedicled anterolateral thigh flap for lower limb coverage. *Ann Plast Surg.* 2005;55:466–469.
18. Hong JP, Shin HW, Kim JJ, Wei FC, Chung YK. The use of anterolateral thigh perforator flaps in chronic osteomyelitis of the lower extremity. *Plast Reconstr Surg.* 2005;115:142–147.
19. Park G, Kim H. Treatment of chronic osteomyelitis using the medial sural perforator flap. *J Plast Reconstr Aesthet Surg.* 2010;63:153–159.
20. Zweifel-Schlatter M, Haug M, Schaefer DJ, Wolfinger E, Ochsner P, Pierer G. Free fasciocutaneous flaps in the treatment of chronic osteomyelitis of the tibia: A retrospective study. *J Reconstr Microsurg.* 2006;22:41–47.
21. Zumiotti AV, Teng HW, Ferreira MC. Treatment of post-traumatic tibial osteomyelitis using microsurgical flaps. *J Reconstr Microsurg.* 2003;19:163–171.
22. Cierny G III. Surgical treatment of osteomyelitis. *Plast Reconstr Surg.* 2011;127(Suppl 1):190S–204S.
23. Hong JP. The use of supermicrosurgery in lower extremity reconstruction: The next step in evolution. *Plast Reconstr Surg.* 2009;123:230–235.
24. Hong JP, Sun SH, Ben-Nakhi M. Modified superficial circumflex iliac artery perforator flap and supermicrosurgery technique for lower extremity reconstruction: A new approach for moderate-sized defects. *Ann Plast Surg.* 2013;71:380–383.
25. Hong JP, Yim JH, Malzone G, Lee KJ, Dashti T, Suh HS. The thin gluteal artery perforator free flap to resurface the posterior aspect of the leg and foot. *Plast Reconstr Surg.* 2014;133:1184–1191.
26. Angrigiani C, Grilli D, Siebert J. Latissimus dorsi musculocutaneous flap without muscle. *Plast Reconstr Surg.* 1995;96:1608–1614.

27. Eom JS, Sun SH, Hong JP. Use of the upper medial thigh perforator flap (gracilis perforator flap) for lower extremity reconstruction. *Plast Reconstr Surg.* 2011;127:731–737.

28. Salgado CJ, Mardini S, Jamali AA, Ortiz J, Gonzales R, Chen HC. Muscle versus nonmuscle flaps in the reconstruction of chronic osteomyelitis defects. *Plast Reconstr Surg.* 2006;118:1401–1411.

29. Mader JT, Shirtliff ME, Bergquist S, Calhoun JH. Bone and joint infections in the elderly: Practical treatment guidelines. *Drugs Aging* 2000;16:67–80.

30. Irons GB Jr, Wood MB. Soft-tissue coverage for the treatment of osteomyelitis of the lower part of the leg. *Mayo Clin Proc.* 1986;61:382–387.

31. Lazzarini L, Mader JT, Calhoun JH. Osteomyelitis in long bones. *J Bone Joint Surg Am.* 2004;86:2305–2318.

32. Mader JT, Ortiz M, Calhoun JH. Update on the diagnosis and management of osteomyelitis. *Clin Podiatr Med Surg.* 1996;13:701–724.

33. Khouri RK, Shaw WW. Reconstruction of the lower extremity with microvascular free flaps: A 10-year experience with 304 consecutive cases. *J Trauma* 1989;29:1086–1094.

34. Yazar S, Lin CH, Lin YT, Ulusal AE, Wei FC. Outcome comparison between free muscle and free fasciocutaneous flaps for reconstruction of distal third and ankle traumatic open tibial fractures. *Plast Reconstr Surg.* 2006;117:2468–2475; discussion 2476–2477.

35. Sofiadellis F, Liu DS, Webb A, Macgill K, Rozen WM, Ashton MW. Fasciocutaneous free flaps are more reliable than muscle free flaps in lower limb trauma reconstruction: Experience in a single trauma center. *J Reconstr Microsurg.* 2012;28:333–340.

36. Hong JP, Choi DH, Suh H, et al. A new plane of elevation: The superficial fascial plane for perforator flap elevation. *J Reconstr Microsurg.* 2014;30:491–496.

37. Hong JP, Chung IW. The superficial fascia as a new plane of elevation for anterolateral thigh flaps. *Ann Plast Surg.* 2013;70:192–195.

38. Waldvogel FA, Medoff G, Swartz MN. Treatment of osteomyelitis. *N Engl J Med.* 1970;283:822.

39. Froimowitz M, Wu KM, Moussa A, et al. Slow-onset, long-duration 3-(3',4'-dichlorophenyl)-1-indanamine monoamine reuptake blockers as potential medications to treat cocaine abuse. *J Med Chem.* 2000;43:4981–4992.

40. Spellberg B, Lipsky BA. Systemic antibiotic therapy for chronic osteomyelitis in adults. *Clin Infect Dis.* 2012;54: 393–407.

188