Coverage of the Infected Wound

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Fifty-four consecutive patients with chronic wounds were identified by the following criteria: (1) established infection for 6 months, (2) exposure of bone, mediastinum, or other vital structure, (3) mechanical and/or vascular limitations to delayed closure techniques, (4) no response to wound debridement in prolonged antibiotic therapy. These wounds were divided into four groups: osteomyelitis (21), pressure sore (17), soft tissue wound (10), and osteoradionecrosis (6). Wound treatment in all patients included debridement, muscle flap closure, and culture specific antibiotic therapy. These consecutively treated patients over a 4-year period presented with an average duration of chronic infection of 2.9 years. Ninety-three per cent of these patients after treatment have demonstrated stable wound coverage without recurrent infection with a minimum of 1 year and a maximum of 4.6 years follow-up. The results demonstrate safe, effective coverage (93% of patients) of chronic infected wounds associated with long bone and pelvic osteomyelitis as well as chronic perineal sinuses following proctocolectomy and osteoradionecrosis. Debridement with short-term (average 12 days) antibiotic therapy has been effective when muscle flap coverage is provided.

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THE ABILITY to transplant tissue with excellent blood flow appears to have expanded surgical horizons in dealing with chronic infection.[1-4] Specifically, muscle is advocated for closure of open and infected wounds when standard techniques of wound debridement, antibiotic therapy, and delayed closure or skin grafting have failed to achieve wound closure. This review of such problem wounds identifies specific wound criteria in which use of the muscle flap in coverage of the infected wound represents the most effective method for wound management.

Patient Groups

Fifty-four consecutive patients presenting over a 4-year period (1978–82) with chronic limb or life threatening wounds fit specific criteria for study of the use of the muscle flap for coverage of the infected wound. Established infection of bone and/or soft tissue was present for a minimum of 6 months. The infected wound contained exposed bone, mediastinum, or other vital structures. Prior wound debridement and prolonged antibiotic therapy had not achieved wound closure. Mechanical and/or vascular limitations prevented delayed closure or skin grafting techniques. These 54 infected wounds were divided into four diagnostic groups: (I) chronic osteomyelitis (21), (II) pressure sores (17), (III) chronic soft tissues wounds (10), (IV) osteoradionecrosis (5). Analysis of the following variables are presented: wound etiology, location and bacteriology, muscle flap type, antibiotic therapy and duration, and postoperative results after a minimum of 1 year and a maximum of 4.6 years follow-up.

Results

Group I: Chronic Osteomyelitis

Wound evaluation. The diagnosis of chronic osteomyelitis is based on demonstration of bone abnormality by radiograph and histologic evaluation and presence of viable bacteria within bone.[5] This diagnosis was established in 21 patients with an average duration of symptoms of 5.3 years. An average of 5.6 procedures had been attempted prior to management of these patients.

The locations of bone infections were as follows: tibia and tarsal bones (80%), distal humerus (5%), sternum and costal cartilages (10%), sacrum and coccyx (5%). In the 17 patients with long and tarsal bone wounds, chronic osteomyelitis developed subsequent to prior direct trauma and associated fractures. Chronic bone infections involving the sternum, costal cartilages, and sacrum developed following surgical procedures which included bone and cartilage manipulation.

Wound bacteriology. In these 21 patients, bone cultures demonstrated a single organism in 48% of the wounds. Sixty per cent of these pure cultures consisted

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of staph aureus with the remaining demonstrating gram negative organisms including *Pseudomonas aeruginosa, Serratia marcescens,* and enterococcus sp. The remaining bone infections demonstrated mixed cultures. *Staphylococcus aureus* was present in 65% of these bone infections. The second most common organism, *p.* aeruginosa, was noted in 50% of the wounds. *Candida albicans* was present in two chronic bone infections.

Wound management. All patients underwent wound debridement including radical excision of infected bone and cartilage. Muscle flap coverage was immediately utilized in every patient. In lower extremity defects, the soleus muscle transposition flap was utilized in two patients for coverage of mid-tibial defects. In two patients in which the ostemyelitis involved greater than half of the length of the tibial shaft, the latissimus dorsi muscle was transplanted by microvascular techniques to the leg vasculature for coverage of the bone debridement site. The gracilis muscle was transplanted in the 13 patients with osteomyelitis of the distal tibia and tarsal bones and in the patient with distal humerus infection.

In the two patients with chronic infection of the sternum and costal cartilages, the pectoralis major muscle was transposed directly into the mediastinal defect following resection of infected bone and cartilage. One half of a gluteus maximus muscle was transposed into the sacral-coccygeal defect after excision of involved bone.

Duration of postoperative intravenous antibiotics was 12.5 ± 5.9 days. Antibiotic selection was initially based on preoperative sinus tract cultures and altered as required with bone culture reports. Aminoglycocide (71%) and cephalosporin (64%) were the most frequently used antibiotics.

Case 1. *Osteomyelitis (Fig. 1).* This 19-year-old patient received open tibial fractures of her left leg in 1980. She achieved bone union but has developed chronic osteomyelitis in the tibia unresponsive to antibiotic therapy and bone debridement. Due to infection involving the entire upper half of her tibia, the latissimus dorsi muscle was selected for transplantation for wound coverage after bone debridement. Local muscle flaps were not utilizied since these muscles are preserved for locomotor function. The transplanted latissimus dorsi muscle has provided stable wound coverage. This patient is now 1.8 years postoperative without evidence of recurrent infection.

All patients have been followed for an average of 1.6 years. Nineteen patients are ambulatory with stable wound coverage and no evidence of recurrent infection. One patient underwent a below knee amputation at 7 months postoperative after unsuccessful ankle fusion. Operative bone cultures obtained at the time of the second procedure were negative.

In this osteomyelitis group, two patients (10%) developed recurrent infection postoperatively. Failure of wound closure occurred in the patient with osteomyelitis in the distal humerus (gracilis transplantation) at five months and distal tibia (latissimus dorsi transplantation) at one month after surgery. In each instance, subsequent debridement and repositioning of the flap has been performed with resultant stable closure.

Group II: Pressure Sores

Wound evaluation. Seventeen patients presented with infected pressure sore wounds. The wounds were characterized by exposed underlying bone with infection involving the outer cortex but without deep bone invasion. The wounds were located as follows: trochanter (12%), ischium (47%), and sacrum (41%). The majority of these patients (71%) developed the initial wound from pressure necrosis from lack of protective sensation related to prior spinal cord injury. The remainder (29%) developed pressure sores during acute illness (*i.e.,* Guillian-Barré syndrome, rheumatoid arthritis, etc.) with subsequent unsuccessful attempts at local wound closure or skin grafting.

Wound bacteriology. The predominate bacteriology of these wounds were as follows: *S. aureus* (24%), proteus sp. (18%), *Escherichia coli* (18%), bacteroides (12%), and mixed flora (28%). Sixty-five percent of intraoperative cultures involved more than one organism.

Wound management. All patients underwent wound excision including removal of outer cortex of exposed bone. Immediate wound coverage was accomplished with use of a muscle or musculocutaneous transposition flap in 15 patients (88%). In two patients (12%), a skin-fascial extension of the inferior half of the gluteus maximus (gluteal thigh flap) was used for wound coverage of trochanteric and ischial sores, respectively. A tensor fascia lata flap was used for the other pressure sore involving the trochanter.

The gluteus maximus musculocutaneous flap was the most frequently utilized muscle transposition flap (53%) and was used for three ischial and six sacral pressure sores. The gracilis musculocutaneous transposition flap (18%) was used for three ischial pressure sores. The tensor fascia lata was used for two patients with ischial pressure sores.

Intravenous antibiotics were used for 4.7 ± 4.8 days. Specific antibiotic therapy included cephalosporin (77%), aminoglycocide (18%), clindamycin (6%), and penicillin (6%). Long-term follow-up of 2.2 years ± 1 year was achieved in this group of patients. There was one postoperative death from pulmonary embolism. One patient suffered a wound dehisence following use of the gluteus maximus musculocutaneous flap with subsequent recurrent infection. Two patients required secondary skin grafting before complete healing was achieved but did not develop recurrent infection. Ninety–four per cent of patients have stable wound coverage without evidence of recurrent infection.

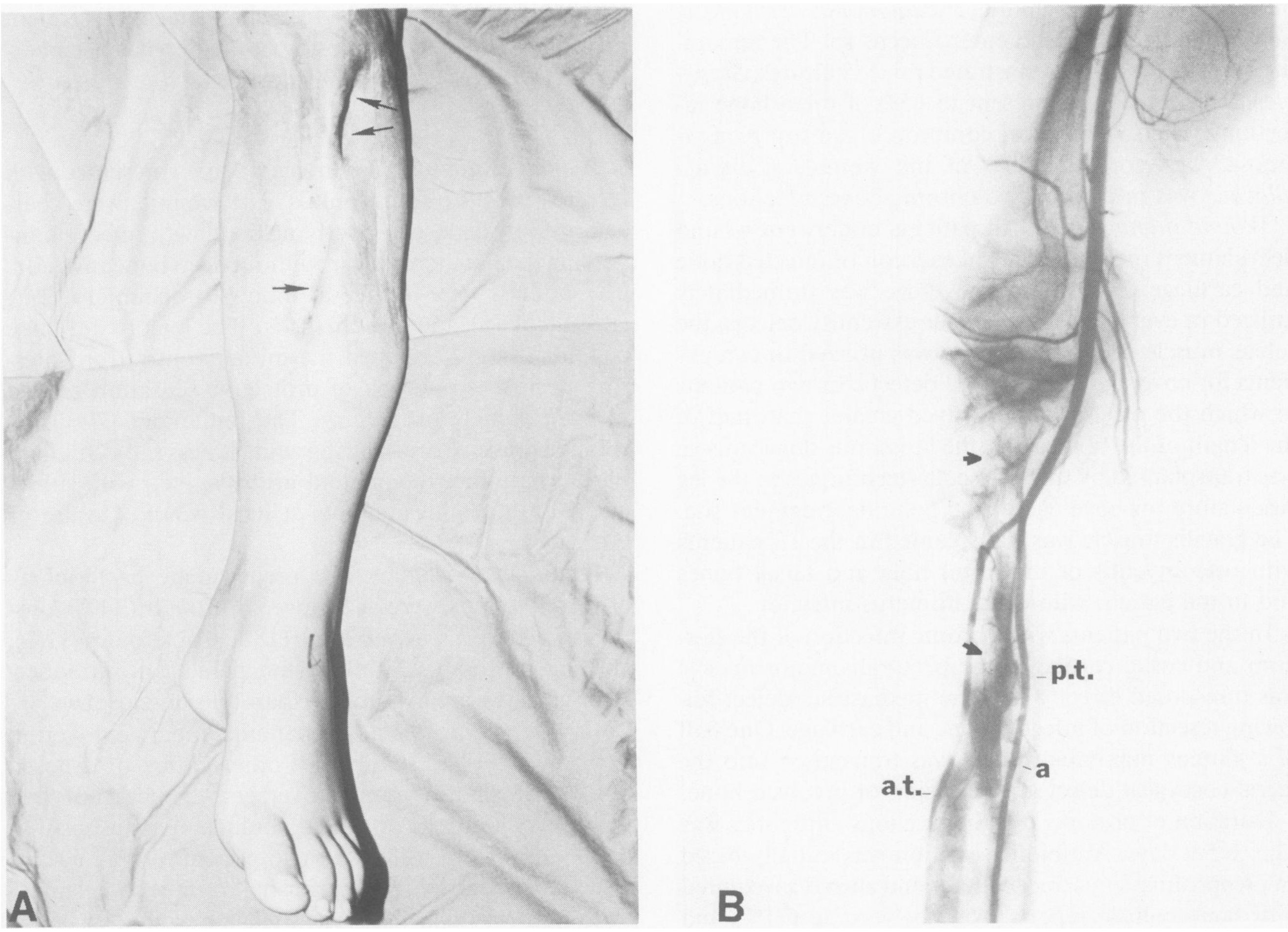

FIG. 1. Chronic osteomyelitis. A, Nineteen year-old patient with chronic osteomyelitis right tibia (arrows designate chronic sinus tracts into bone). B, Preoperative arteriagram is required to locate suitable receptor vessels: p.t.—posterior tibial artery, a.t.—anterior tibial artery; a—site of arterial end to side anastomosis to vascular pedicle of latissimus dorsi muscle; arrows designate site of chronic osteomyelitis of proximal tibia. C, Bone debridement of proximal tibia has been performed: (arrows designate debridement site); L—latissimus dorsi muscle, p.—thoracodorsal artery and associated veins; t.—posterior tibial artery (recipient site for microvascular anastomosis to establish circulation to transplanted muscle). D, End-to-side anastomosis were performed in 82% of patients between muscle artery and associated veins to recipient vessels. In single leg vessels, this technique is essential to preserve distal extremity circulation: p.t.—posterior tibial artery, t.d.—thoracodorsal artery. E, Anterior view of lower extremity 1.8 years following surgery demonstrates stable wound coverage. No evidence of recurrent infection noted. F, Donor site for latissimus dorsi muscle flap is concealed beneath axilla and upper arm. Patient notes no donor site disability following use of latissimus dorsi muscle for lower extremity reconstruction.

Group III: Chronic Soft Tissue Wounds

Wound evaluation. Ten patients presented with chronic soft tissue wounds with exposed bone or vital structures. Five of these patients had chronic perineal sinuses from previous abdominal perineal resections for an average duration of 2.2 years. The remaining five patients had infected wounds involving the abdominal wall, knee, tibia, achilles tendon, and open thoracic wound, respectively, for an average duration of 2.8 years. These ten patients had undergone an average of 2.3 prior procedures for wound management.

Wound bacteriology. The wound cultures in the chronic perineal infection group demonstrated a single organism in one patient (*staphylococcus faecalis*) and mixed cultures in the remaining five patients consisting of *Staphylococcus faecalis* (40%), *E. coli* (20%) and *Staphylococcus epidermis* (40%). In the remaining four patients with infected soft tissue wounds, the abdominal wall wound contained mixed flora, the lower extremity and chest wound *S. aureus,* and the knee wound, *S. marcescens.*

Wound management. All patients underwent wound excision and immediate flap coverage. A curette was used to debride the proximal wound in the proctocolectomy infections to avoid injury to small bowel adherent to the peritoneal reflection. All perineal wounds were then closed using gracilis muscle transposition flap.

Case. 2. *Soft tissue wound (Fig. 2).* This 26-year-old patient has undergone multiple procedures for Crohn's disease. In 1981, he underwent abdomino-perineal resection of a sigmoid colon and rectum for recurrent

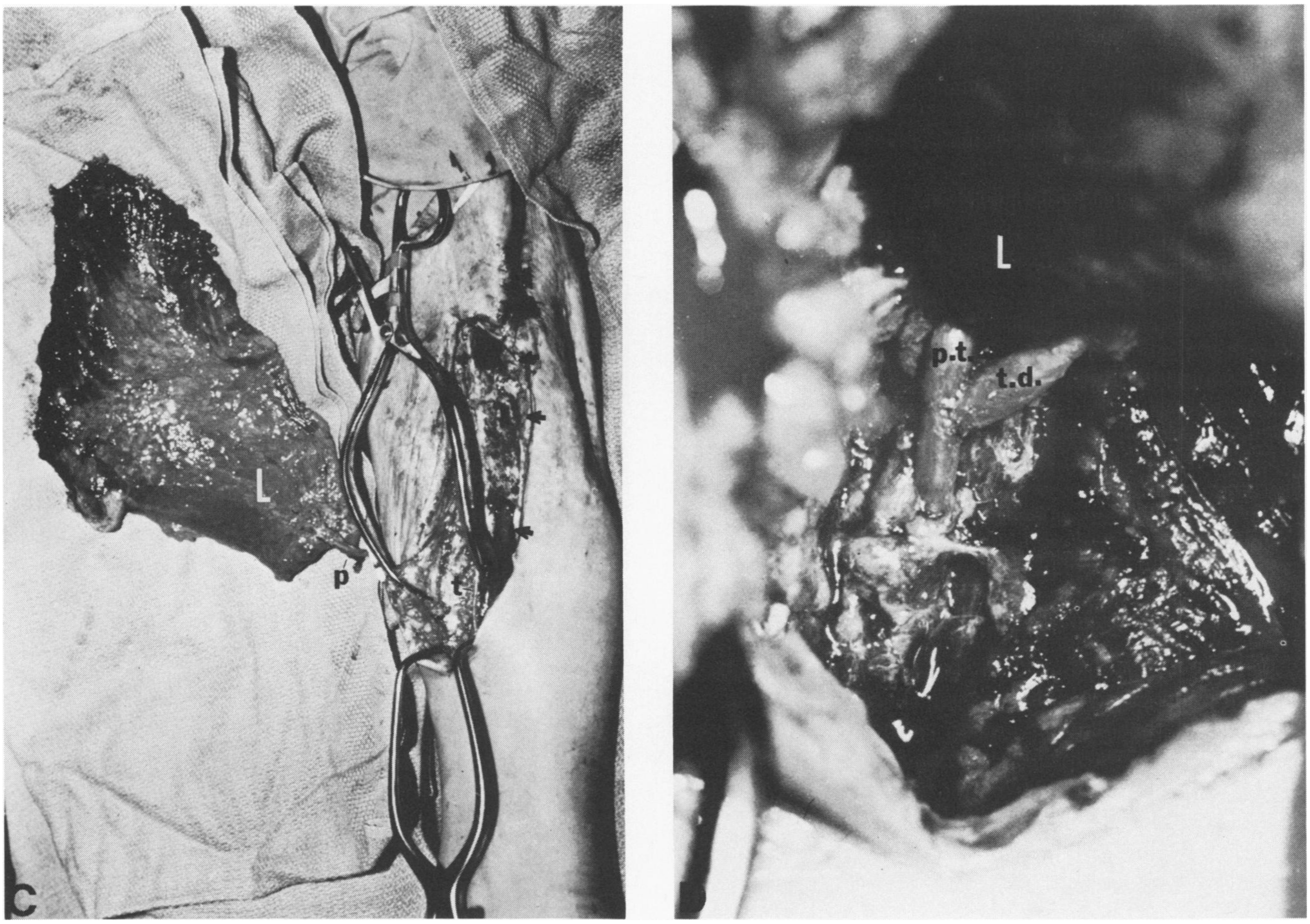

FIG. 1. (*Continued*)

perirectal fistulas tracts. Subsequently, the patient failed to heal the pelvic wound with the persistent pelvic-perineal infected wound. In 1982, the patient underwent wound debridement and gracilis muscle transposition for defect coverage. At 6 months postoperative, the patient has no recurrence of pelvic infection.

Case. 3. *Soft tissue wound (Fig. 3).* This 30-year-old patient had undergone total colectomy with abdominal perineal resection for Crohn's disease in 1976. Chronic infections persisted in the perineal pelvic wound. In 1981, she developed a small bowel-perineal fistula treated with steroids and hyperalimentation. In 1982, she underwent resection of distal ilium, wound debridement and a gracilis muscle transposition flap. A pelvic abscess was drained via the abdominal approach in the early postoperative period. No infections complicated the perineal pelvic wound closure. This patient is now 1 year postoperative without recurrent pelvic-perineal infection and stable wound coverage.

The gracilis and latissimus dorsi muscles were transplanted by microvascular techniques to cover the wounds of the distal tibia and knee, respectively. The trapezius muscle transposition flap was used to close the chest wound. The abdominal wound was covered with an axial groin flap.

Intravenous antibiotics were utilized in the perineal wounds for an average of 3.2 days and consisted of cephalosporin (80%), aminoglycocide (40%) and clindamycin (20%). Oral antibiotics were given for an additional 3.2 days.

All perineal wounds have remained healed without recurrent infection with average follow-up of 2 years.

The remaining five patients with infected soft tissue wounds were treated with cephalosporin intravenously for an average of 2.5 days and orally for an average of 4.5 days. All patients have healed wounds without evidence of recurrent infection with average follow-up of 1.9 years.

Group IV: Osteoradionecrosis

Wound evaluation. Six patients presented with osteoradionecrosis complicated with wound infection. Prior craniectomy with infected bone flaps were noted in three patients. Chronic infections following radiation therapy for tumor control resulted in the following three patients: abdominal wall wound communicating with pelvis following abdominal perineal resection, mediastinal wound following mid-sternotomy for constrictive pericarditis, and sacral wound following trauma.

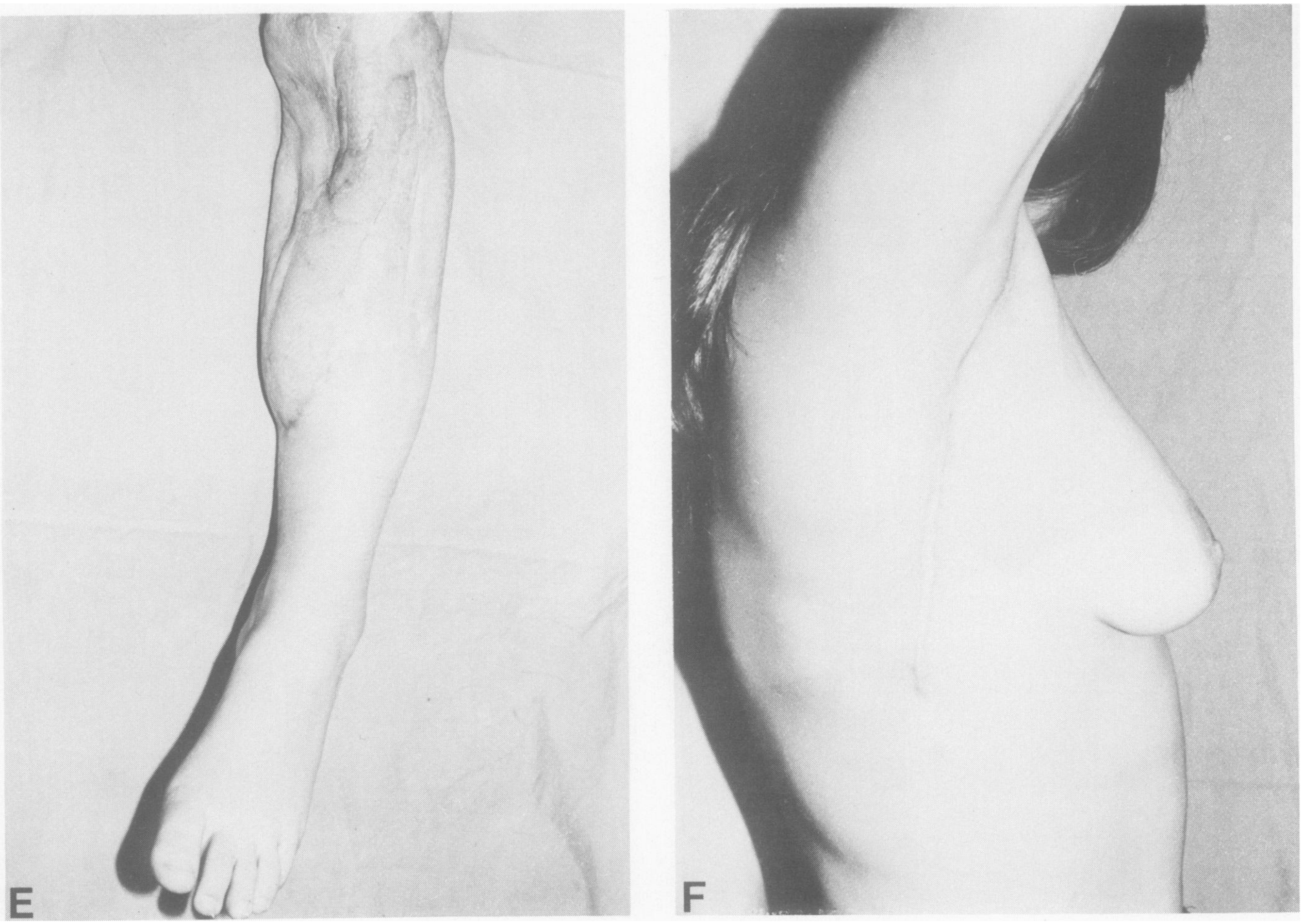

FIG. 1. (*Continued*)

Wound bacteriology Staphylococcus aureus was the predominant organism (60%). The perineal wounds were characterized by mixed flora including *P. aeruginosa.*

Wound management. All patients underwent wound excision and immediate flap coverage. Extensive perineal wounds were treated with bilateral rectus femoris muscle transposition flaps. Two skull defects were covered with axial scalp flaps and the third required transplantation of the latissimus dorsi musculocutaneous flap. The mediastinal wound was covered with bilateral pectoralis major and one rectus abdominis muscle transposition flap.

Case 4. *Osteoradionecrosis (Fig. 4).* This 54-year-old woman underwent staging laparotomy and mediastinal radiation therapy for Hodgkin's disease in 1974. In 1978, she underwent pericardiectomy for constrictive pericarditis. Her postoperative course was complicated by development of chronic infection of sternum, costal cartilages and anterior mediastinum. In 1979, the patient underwent debridement of entire sternum and upper costal cartilages and bilateral pectoralis major muscle transposition flaps. A left rectus abdominis muscle flap was also elevated and placed within the anterior mediastinum. The patient remained healed without evidence of recurrent infection until 1982 when she developed a small area of recurrent infection in retained right inferior costal cartilage. Wound debridement and a right rectus abdominis muscle transposition flap were performed. At 1 year postoperative treatment of recurrent infection, the patient is asymptomatic without evidence of recurrent infection.

Antibiotic therapy was utilized intravenously for an average of 12 days and consisted of cephalosporin (50%), nafacillin (34%), aminoglycocide (34%), and vancomycin (17%).

Although the mediastinal wound has remained asymptomatic with stable wound coverage for 4.5 years, the patient developed a recurrent area of infection in the right inferior lateral costal cartilages requiring a second wound debridement and rectus abdominis muscle transposition flap. The remaining patients (83%) have stable wound

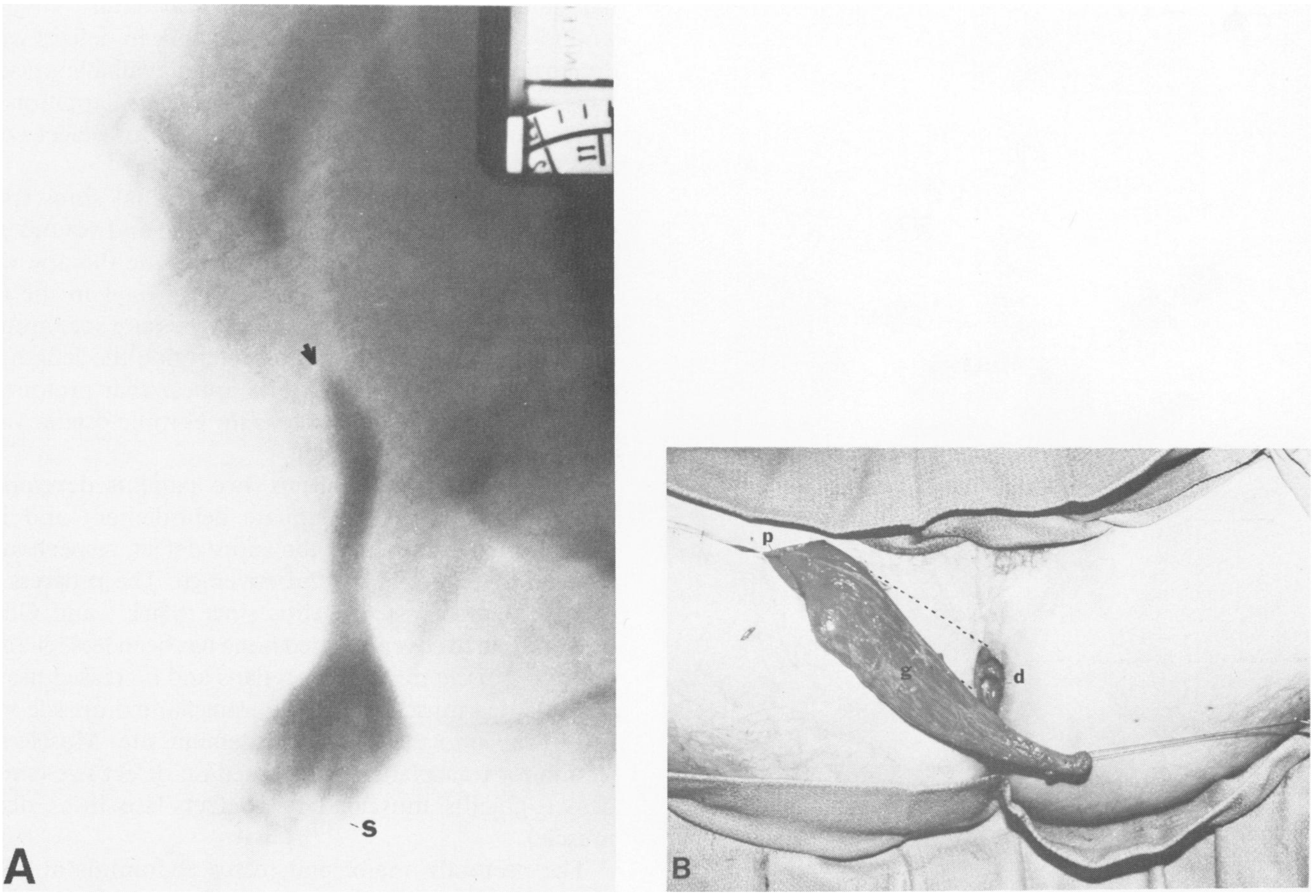

FIG. 2. Soft tissue wound. A, Twenty-six-year-old man with persistent infection of pelvic-perineal wound following abdomino-perineal resection for Crohn's disease. Sinogram denotes infected cavity extending to peritoneal reflection (arrows demonstrate limits of infected wound, s.—junction of perineal wound with anal skin). B, Gracilis muscle is transposed into perineal defect: (p.—site of dominant vascular pedicle to gracilis muscle, d.—site of debridement of pelvic-perineal wound extending to peritoneal reflection, g.—gracilis muscle; dotted lines indicate tunnel through which muscle is passed into pelvic wound). Note, with legs adducted muscle will reach peritoneal reflection.

coverage without recurrent infection with an average follow-up of 1.4 years.

Discussion

The 54 patients included in this study with chronic infected wounds had failed to respond to routine methods of treatment, including prolonged topical and systemic antibiotic therapy and repeated wound debridement. Infected cavities surrounded by bone (perineal wounds) or exposed vital structures (mediastinum) and impaired local wound circulation due to trauma (osteomyelitis) or vasculitis (osteoradionecrosis) prevented use of delayed closure techniques or skin graft coverage. The addition of vascularized tissue such as muscle within the site of wound debridement provides direct delivery of the components of the host defense mechanism (phagocytic leukocytes), oxygen, and systemic antibiotics to the wound.[6]

Unlike the traditional random pattern flap in which distal subdermal circulation is impaired with flap elevation, the muscle flap retains its circulation during elevation and transposition into an adjacent defect based on its dominant or major vascular pedicle. When the random pattern flap is compared to the musculocutaneous flap using paired flaps in the canine experimental model, the musculocutaneous flap demonstrates superior resistance to bacterial inoculation both on its deep and skin surfaces.[7]

Our current studies on tissue oxygen tension,[8] leukocyte migration activity and intradermal blood flow[9] indicate that muscle flaps have specific advantages over other techniques for closure of infected wounds, especially in ischemic tissue. Tissue oxygen drops well below 20 mmHg in the elevated random pattern flap and remains at this level in the early postoperative period; whereas the musculocutaneous flap in the paired canine

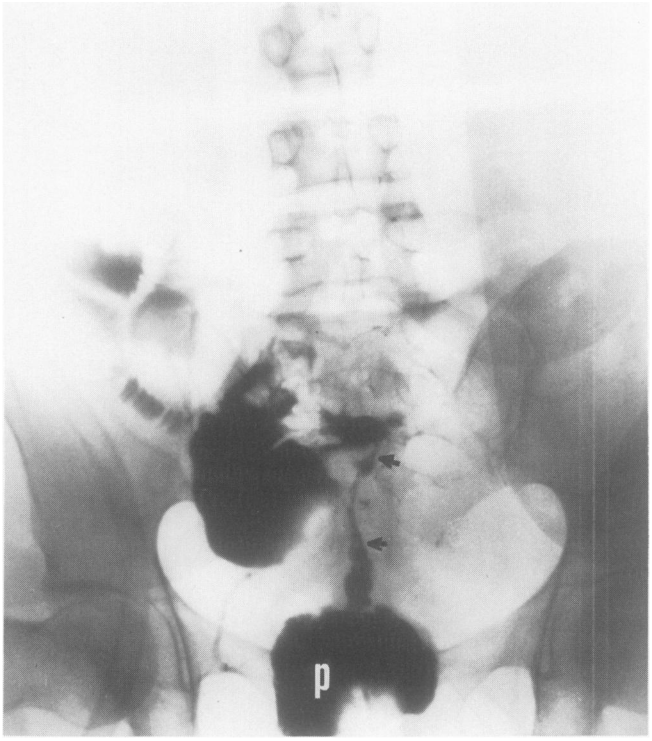

FIG. 3. Soft tissue wound. Radiograph demonstrates sinogram between chronic perineal pelvic wound into small bowel fistula in patient with Crohn's disease (arrows denote course of fistula, p.—pelvic perineal wound).

model demonstrates a minimal drop in tissue oxygen after elevation and this small decrement disappears in the early postoperative period. Unlike the random pattern flap, the tissue oxygen in muscle flap dramatically increases when inspired oxygen content is increased.[8] Leukocyte migration is efficient in the musculocutaneous flaps with the leukocytes progressing immediately to the site of bacterial inoculation. In the random pattern flap, leukocytes appear in even larger numbers than in the musculocutaneous flap, but they seem unable to control the infection. The muscle flap delivers phagocytic leukocytes and oxygen to the site of chronic infection. Correction of local wound ischemia and hypoxemia allows improved leukocyte function[10] via the oxidative bacterial mechanism and may explain the ability of the muscle to cover the infected wound.

Aggressive debridement of the infected wound is an essential aspect of wound closure. The surgeon is reluctant to enlarge a critical wound without confidence in obtaining reliable coverage. The safety of muscle flap transposition is now well established and is based on selection of muscle with a major vascular pedicle distant to the wound. In a recent review of 4,244 muscle transposition flaps utilized for reconstructive procedures in all body regions, recipient site complications related to flap failure were limited to 8% of patients.[11] When wound debridement requirements result in defects with dimensions exceeding the size of local available muscle flaps, microsurgical techniques allow transplantation of better suited muscles from distant sites for defect coverage.

Antibiotic therapy was based on initial sinus tract cultures and altered as dictated by bone and wound excision specimens. The length of antibiotic therapy was variable ranging from an average 12.5 days in the osteomyelitis group to 4.7 days in the pressure sore group. Future studies are required to determine the length of antibiotic requirements. It does appear that prolonged antibiotic therapy (*i.e.*, 6 weeks for chronic osteomyelitis) is not required.

In the osteomyelitis group, two patients developed recurrent infection. Inadequate debridement and inability of muscle to cover the entire defect, respectively, resulted in failure of wound coverage. The progress in management of osteomyelitis since Stark[12] and Ger[13] used muscle to cover infected bone has been less reliance on local muscle transposition flaps and increased use of transplanted muscle.[6,14,15] The transplanted muscle will fit directly into the bone debridement site. Muscle selection for transplantation is based on defect size (small defects-gracilis muscle, large defects-latissimus dorsi muscle).

The pectoralis major and rectus abdominis muscles are utilized for coverage of the mediastinal wound when infection requires excision of sternum and/or costal cartilages.[16]

The pressure sore areas (trochanter, ischium, and sacrum) are surrounded by muscles suitable as transposition flaps. Extensive wounds may require multiple flaps. Excessive tension resulted in wound dehiscence with recurrent infection in one patient.

The chronic infected perineal wound following proctocolectomy has been successfully treated by wound debridement and gracilis muscle transplantation. The rigid walls of this wound do not allow for wound contracture. With muscle flap used as a vascularized tissue to fill this area, no recurrent infections have been observed.

The single patient with infection recurrence with osteoradionecrosis illustrates the need for aggressive debridement and the potential for late recurrent infection despite muscle flap coverage in these patients. If bone and wound debridement allow muscle contact with the wound, infection is readily controlled. Late recurrence remains a potential complication in all of these patients if debridement or muscle coverage is inadequate.

The results of this study of 54 consecutive patients demonstrates safe, effective coverage (93% of patients) of chronic infected wounds associated with long bone,

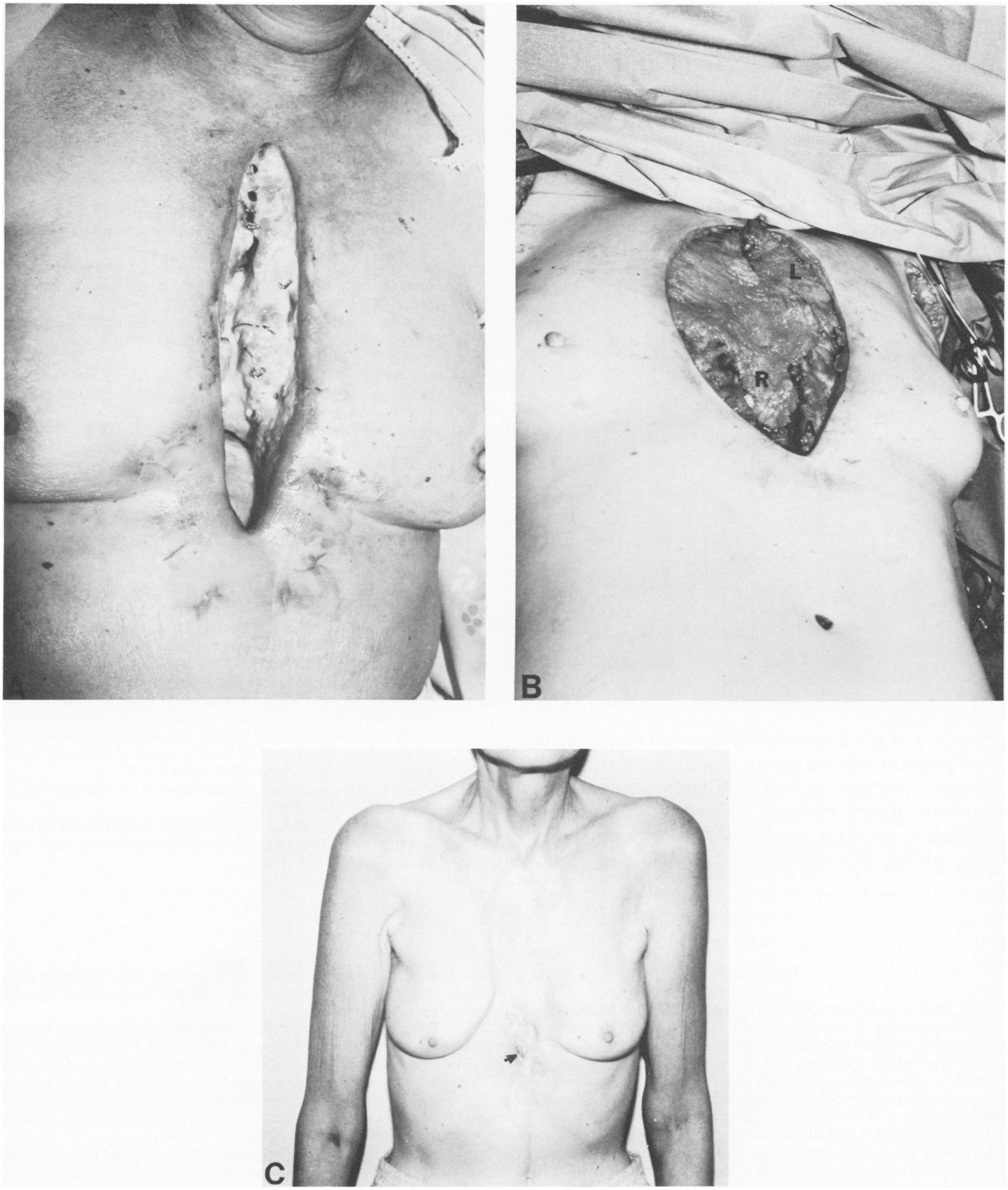

FIG. 4. Osteoradionecrosis. A, Fifty-four-year-old patient with sternal, costal cartilage and anterior mediastinal infection. B, After excision of infected bone and cartilage, anterior mediastinum is covered with bilateral pectoralis and left rectus muscle flaps (L.—left pectoralis muscle, R.—right pectoralis muscle, A.—site where rectus flap is placed in anterior mediastinum). C, 3.5 years after wound coverage, patient has no mediastinal infection but develops recurrent infection in right inferior costal cartilage (see arrow). D, Stable wound coverage noted 4.5 years after initial infection and 1 year after excision of infected cartilage and right rectus abdominis muscle flap.

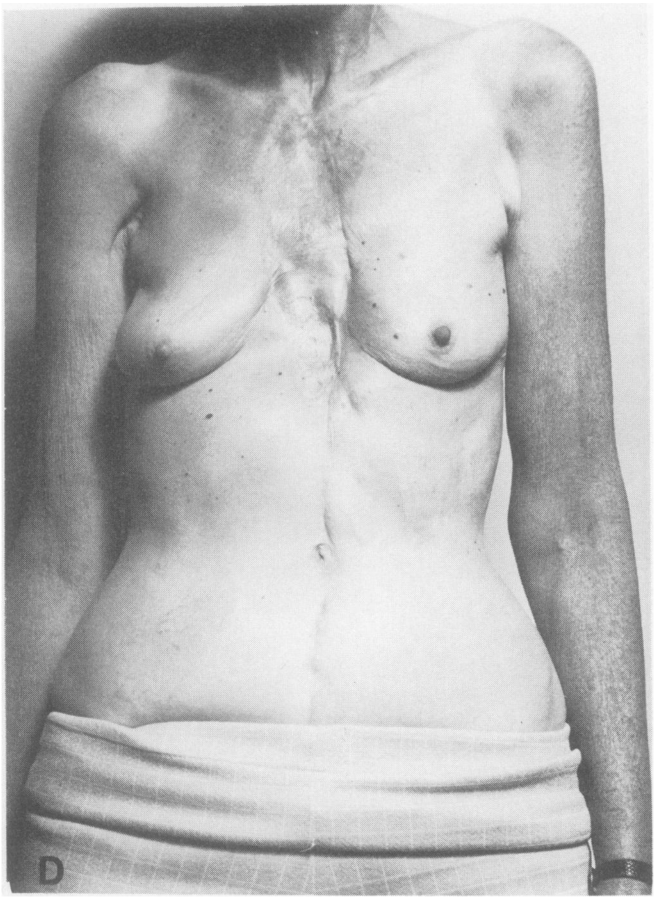

FIG. 4. (*Continued*)

thoracic and pelvic osteomyelitis as well as chronic perineal sinuses following proctocolectomy and osteoradionecrosis. Debridement with short-term (average 12 days) antibiotic therapy has been effective when muscle flap coverage is provided. As predicted by experimental results, muscle flap technology is a safe and effective means for coverage of complex infected wounds involving soft tissue and bone.

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DISCUSSION

DR. M. J. JURKIEWICZ (Atlanta, Georgia): Common to the chronic wound, regardless of the initial cause or etiology, are ischemia and fibrosis. The fibroblast becomes the fibrocyte, imprisoned in desmoplasia of its own making. This zone of fibrosis, while serving as a barrier of sorts of invasive infection, actually ensures chronicity of the wound. Angiogenesis, phagocytoses, and repair are all impeded. So, too, is the effective delivery of antibiotics to the wound.

What Dr. Mathes and his colleagues are advocating makes a great deal of sense biologically. Remove the infected fibrotic barrier by thorough debridement; bring into the wound a highly vascularized muscle flap, with a permanent pedicle—to (1) protect the wound from its environment, (2) to prevent desiccation, (3) to permit a physiologic response to injury, and (4) to permit repair to proceed unimpeded.

Is this important work? Yes. Muscle flaps have revolutionized reconstructive surgery in its broadest sense, and have had an enormous impact, not only on my own field of plastic and reconstructive surgery, but also in all surgical disciplines where there are chronic closure problems. In this era of cost-consciousness, hospital stay and cost of repair have been sharply reduced.

As President Warren said, Steve Mathes began this work while a resident on his service at Emory, and he did the first free muscle flap to be used in the treatment of chronic osteomyelitis at the tibia while a resident. We have now accumulated an additional 30 such patients of osteomyelitis of the distal third of the tibia. All of the patients fit the Mathes criteria of chronicity; in fact, they were salvage cases, some of them destined for amputation.

This subset of patients excludes those with osteomyelitis of the proximal or middle third of the tibia, where transposition flaps are possible. As such, these patients provide a provocative clinical test of the validity of the method.

In these 33 flaps, there were no vascular failures. All but two patients are apparently cured of their osteomyelitis, with a follow-up from 1 to 5 years. Of the two failures, one was technical. I do not believe that the debridement was sufficiently adequate; and in the second there was a