Timing of Management of Severe Injuries of the Lower Extremity by Free Flap Transfer

Ulf Dornseifer, Milomir Ninković*

Department of Plastic, Reconstructive, and Hand Surgery, Burn Centre, Academic Hospital Munich-Bogenhausen, Technical University Munich, Englschalkinger Straße 77, 81925 Munich, Germany

* Corresponding author

Abstract

Covering defects by free-tissue transfers enable surgeons to reconstruct or salvage the lower extremity injured or amputated in high-energy traumas which result in extensive damage to soft tissue, bone, tendons, vessels and nerve. The timing of the reconstruction using flap techniques is extremely important. It can be divided into three categories: "primary free flap closure" (12 to 24 hours), "delayed primary free flap closure" (2 to 7 days), and "secondary free flap closure" (after 7 days). Our treatment of choice in an isolated complex injury of a lower extremity with a soft tissue defect is "primary free flap closure" providing improved funcional and aesthetic results, and psychologically benefit through lowered morbidity of the patient.

KEY WORDS: management, injuries, lower extremity, free flap transfer

Introduction

Reconstruction of complex extremitiy trauma continues to be a challanging task for plastic surgeon. Characteristics of such injuries include severe destruction of functional structures, often due to high-energy trauma that causes significant invalidity. Prior to the use of microsurgical techniques, pedicled fasciocutaneous and muscle flaps were the workhorses for extremity reconstruction, although the vast majority of severe extremity traumas were treated by amputation (1). The management of complex injuries of the lower extremities has changed with the development of reconstructive microsurgery. Microsurgical techniques, including free tissue transfer, have enabled surgeons to reconstruct or salvage injured or amputated limbs. The timing of soft-tissue reconstruction using flap techniques

is extremely important, but still controversial (2-14) . Yaremchuk et al. found that delaying wound cover had no ill effects on clinical outcome (15). They suggested serial debridement at two to three day intervals and delayed wound closure between seven to 14 days after injury (15). Conversely, it has been reported that patients whose wounds are not closed in the first five days experience a much higher complication rate, resulting in soft-tissue and bone infection, non-union, and consecutive amputation (5, 6) . Since the mid-1980`s, there has been increasing entthusiasm for early flap coverage of severe extremity injury. Byrd et al. pointed out the importance of early aggressive wound management and soft tissue cover with a flap in severe injuries of the lower extremity with soft tissue defects within five days (5, 6). Godina (11) emphasized the importance of early coverage within the first 72 hours and the advantages of free-flap reconstruction vs. local flap technique. Lister and Scheker (12) first defined the emergency free-flap as "a flap transfer performed either at the end of primary debridement or within 24 hours after the injury". To standardize nomenclature in free flap wound closure Ninkovic et al. (16) presented three categories: "primary free flap closure" (12 to 24 hours), "delayed primary free flap closure" (2 to 7 days), and "secondary free flap closure" (after 7 days). This system is analogous to the standard terms "primary," "delayed primary," and "secondary wound closure." It is consistent with known biologic and microbiologic principles of wound closure in general and provides a simple basis for classifying free flap wound closure. The purpose of this paper is to review our surgical technique, concerning the timing of management of severe injuries of the lower extremity by free flap transfer.

Patients and Methods

PRIMARY FREE FLAP CLOSURE

"Primary free flap closure" suggests closure with a free flap at the end of initial radical debridement or within 24 hours of injury. The radical debridement was done under tourniquet control. All dead and devitalised tissue was removed, including small devascularised bone fragments. Debridement was performed through healthy tissue to insure that non-viable tissue was removed. Important neurovascular structures and tendons were preserved and debrided if they were damaged but structurally intact. If they were divided, they were repaired primarily, regardless of their apparent viability. Fractures were initially stabilized with external fixators. Small bone fragments were removed, and larger bone segments, even if not attached to soft tissue, were cleaned, prepared (removing the cortical bone), and used as a bone graft. If it is necessary additional débridement was done to create a flat wound surface and to avoid dead space. After release of the tourniquet (90-120 minutes) any extra compromised tissue was resected. *With primary repair*. "Primary free flap closure with primary repair" signifies that repair of longitudinal structures such as nerves, tendons, vascular structures, bone, etc., was performed at the time of primary free flap closure. *With primary reconstruction*. "Primary free flap closure with primary reconstruction" signifies flap coverage along with definitive reconstruction of missing segments of longitudinal structures with primary grafting, vascularized or otherwise, immediately after the initial radical debridement. This technique includes tendon grafting, bone grafting, vascular grafting, nerve grafting, etc. *With late reconstruction*. "Primary free flap closure with delayed reconstruction" refers to primary closure with reconstruction at a later time, usually three months or more.

CASE I

A 14-year old girl sustained a crush injury of her left lower leg and foot with fracture of the tibia and fibula. Fractures were initially stabilized with external fixateur externe. After radical debridement and primary repair of injured tendons a scapular free flap was used to achieve coverage of the soft-tissue defect.

DELAYED PRIMARY FREE FLAP CLOSURE

"Delayed primary free flap closure" signifies closure alone with a free flap at two to seven days after creation of the defect. *With primary repair*. "Delayed primary free flap closure with primary repair" signifies flap closure at two to seven days along with repair of longitudinal structures. *With primary reconstruction*. "Delayed primary free flap closure with primary reconstruction" signifies flap closure at two to seven days with primary reconstruction of segmental defects of longitudinal structures. We have included this category for the sake of completion. It has been the author's experience that primary reconstruction in this time frame is seldom achieved, especially toward the latter portion of the two to seven day time period. In other words, the longer that closure is delayed, the less the opportunity for primary reconstruction. Vascularized reconstruction should be considered if reconstruction is contemplated during this period. *With late reconstruction*. "Delayed primary free flap closure with late reconstruction" signifies flap closure at two to seven days with later reconstruction, usually at three to six months after injury.

FIGURE 1. Traumatic defect of the lower leg with fracture of the tibia and fibula, large soft-tissue defect with destruction of tendons after debridement and bone stabilization.

FIGURE 2. Stabilization of fractures with fixateur externe. Reconstruction with a free scapular free flap.

FIGURE 3. Follow-up six months later.

FIGURE 4. Minimal donor site morbidity after scapula free flap

CASE II

A 40-year-old man sustained a fracture of his right ankle joint with soft-tissue defect. The leg was reconstructed with a gracilis free flap after five days, following rigid bone fixation.

SECONDARY FREE FLAP CLOSURE

"Secondary free flap closure" signifies closure with a free flap beyond one week. In this group of patients, temporary bone fixation may be achieved, but repair and reconstruction of other structures is usually postponed until a later time. *With late reconstruction.* "Secondary free flap closure with late reconstruction" signifies flap coverage beyond one week, with reconstruction at a later time, usually three months or more.

FIGURE 5. Fracture of the ankle joint with soft tissue defect after bone stabilization.

FIGURE 6. Intraoperative view after radical debridement.

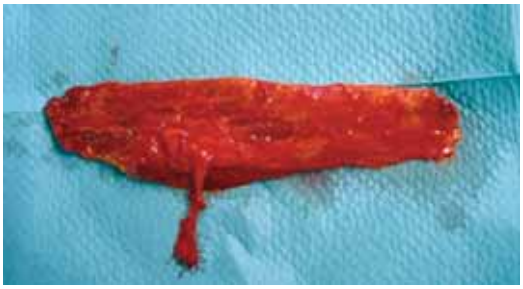

FIGURE 7. Gracilis free flap for reconstruction of the soft tissue defect.

CASE III

A 45-year-old man sustained a closed fracture of his left tibia. Wound healing problems and infection after osteosynthesis with a bone plate, resulted in a soft tissue defect. The defect was closed by a latissimus dorsi free flap after two months.

FIGURE 8. Final result six months post-operative

FIGURE 9. Soft tissue defect caused by wound healing problems after osteosynthesis in case of a closed tibial fracture.

FIGURE 10. Operative view after radical debridement.

FIGURE 11. Final result four months after coverage with a latissimus dorsi free flap.

Discussion

The goal in the treatment of severe injuries of the lower extremities is early and optimal functional recovery. Adequate soft tissue coverage is essential for appropriate and fast bone healing. Reconstructive surgery, including free flap transfer, may be requiered and decisions and selection of the the best available tissue are controversial. A wide variety of flaps now exist for reconstruction of the lower leg, although not all will cover open tibial fractures successfully and reliably (17). Adequate selection of the flap is most important for the outcome of reconstruction. Potentially suitable local flaps are often damaged and will therefore be unusable. The practice of compromising a severely injured leg further by sacrificing a local muscle or segment of intact skin should also be avoides. We are increasingly of the opinion that free tissue transfer provides the most appropiate repair for the most severe injuries of the lower extremities. There are three principal indications for using free flaps to cover the lower extremities: soft tissue defects in the lower third, an extensive defect at any level, and salvage free flaps in cases of a non-replantable amputation. Well-vascularized, free flaps provide adequate healthy tissue and facilitate vascular ingrowth from new surrounding soft tissue. This increased blood flow has the advantage of improving bone healing and providing greater local local resistance to infection (18-20) . Generally, for lower-extemity reconstruction we prefer to use musculocutaneous or muscle flaps, as well as fasciocutaneous flaps, for resurfacing the dorsal side of the foot. In weight-bearing areas, our preference is a muscle flap with skin graft to obtain rigid and firm binding and to provide protection against re-ulceration. Our favorite muscle free flap for primary repair is the latissimus dorsi muscle (LDM) for huge defects as well as gracilis muscle flap for mild and small size defects. These muscles provide enough tissue for coverage and can be divided along its longitudinal fibers into strands, which can be placed into irregular defects to obliterate the dead space (3). Furthermore, the very long pedicle of LDM can be used as a conduit to revascularize an injured extremity or for interposing an arterial graft from the pedicle to repair segmental defects in vessels as a through flow free flap. Following proximal below-the –knee crush amputation, when replantation is not possible, function in the lower limb depends on preservation of the knee joint, and on the length and quality of soft-tissue coverage of the stump. Limb-salvage procedures utilizing free "fillet of foot" flaps are absolutely indicated as emergency transfers. This composite flap from the amputated part is large enough to fashion a stump of sufficient length, to provide durable, thick, sensitive, glabrous skin cover, and to avoid donor-site morbidity. What time after severe injury to the leg is optimal for definitive wound closure? The timing of wound closure is of fundamental impor-

tance in correct wound care, regardless of the size of the wound (13, 14). Historically, the concept of treatment of complex extremity injuries has significantly changed since the Spanish Civil War (1935-1938), when Trueta (1) began performing true surgical debridement of open fractures prior to immobilization with plaster casts. He emphasized the importance of debridement, confirming "the removal of a tissue medium favorable to bacterial growth is the fundamental principle upon which the whole treatment is based". The fundamental principle of wound care gradually changed, and further scientific bases of debridement, systemic antibiosis, and delayed wound closure were established. As a reminder of war surgery and regardless of the introductions of microsurgery and the resulting availability of practically unlimited amounts of tissue for reconstruction, the principles of repeated debridement and delayed wound closure are still being chosen as the primary method for treating complex extremity traumas. There is a general reluctance among reconstructive surgeons to perform early coverage of complex extremity injuries because of a belief in the concept of progressive tissue necrosis after high-energy trauma and subsequent infection, classically requiring multiple debridements prior to wound coverage. In attemps to salvage tissue, these debridements are desingned to be quite conservative, when tissue viability is questionable. However, it is much more difficult to evaluate compromised tissue at a later stage, because of oedema, granulation tissue, and superficial infection. These changes mask the appearance of normal tissue. In the end, delay in definitive reconstruction also may cause additional loss of tissue and necessitate repeated anaesthesia. Infection of traumatic wounds may arise from contamination at the time of injury or secondary infection of the compromised tissue. Early radical debridement is therefore the most important aspect of wound management, as the bacterial count doubles every six to eight hours, and produces clinical infection when greater than 105 organisms/g tissue. The use of well vascularised muscle free flaps, as primary free flap, provide adequate healthy tissue to allow generous radical débridement of traumatic wounds. Moreover, emergency soft tissue cover preserves bone fragments, obviates bone resection, permits primary nerve repair or nerve grafting, and tendon repair as well as transposition of tendon and muscle. Type III open fractures are associtated with disruption of both periostal and endostal bone circulation. Vascular ingrowth from surrounding soft tissues contributes to bone healing. We believe that the greater blood flow from a free muscle flap may help to restore bone circualtion and improve local resistance to infection.

Conclusion

Our treatment of choice in an isolated complex injury of a lower extremity with a soft tissue defect is primary free flap cover (18, 21-23). Subsequent inspection and débridement can be made if required, but definitive soft tissue cover should be provide withhin the first 24 hours after injury. This approach avoids mistakes by an inexperienced surgical team at night and enables a fresh operating team to undertake definitive reconstruction in the morning. On only rare occasions (associated injury, poor general condition, or when treatment was started in another hospital and the patient transferred a few days later) should emergency cover be delayed.

References

(1) Trueta J. Treatment of war wounds and fractures. London: Harmish Hamilton, 1939.

(2) Arnez Z.M. Immediate reconstruction of the lower extremity--an update. Clin. Plast. Surg. 1991; 18(3):449-457.

(3) Banic A., Wulff K. Latissimus dorsi free flaps for total repair of extensive lower leg injuries in children. Plast Reconstr Surg 1987; 79(5):769-775.

(4) Breidenbach WC, 3rd. Emergency free tissue transfer for reconstruction of acute upper extremity wounds. Clin. Plast. Surg. 1989; 16(3):505-514.

(5) Byrd H.S., Cierny G., 3rd, Tebbetts J.B. The management of open tibial fractures with associated soft-tissue loss: external pin fixation with early flap coverage. Plast. Reconstr. Surg. 1981; 68(1):73-82.

(6) Byrd H.S., Spicer T.E., Cierney G., 3rd. Management of open tibial fractures. Plast. Reconstr. Surg. 1985; 76(5):719-730.

(7) Chen S., Tsai Y.C., Wei F.C., Gau Y.L. Emergency free flaps to the type IIIC tibial fracture. Ann. Plast. Surg. 1990; 25(3):223-229.

(8) Chen S.H., Wei F.C., Chen H.C., et al. Emergency free-flap transfer for reconstruction of acute complex extremity wounds. Plast. Reconstr. Surg. 1992; 89(5):882-888; discussion 889-890.

(9) Chick L.R., Lister G.D., Sowder L. Early free-flap coverage of electrical and thermal burns. Plast. Reconstr. Surg. 1992; 89(6):1013-1019; discussion 1020-1021.

(10) Francel T.J., Vander Kolk C.A., Hoopes J.E., et al. Microvascular soft-tissue transplantation for reconstruction of acute open tibial fractures: timing of coverage and long-term functional results. Plast. Reconstr. Surg. 1992; 89(3):478-487; discussion 488-489.

(11) Godina M. Early microsurgical reconstruction of complex trauma of the extremities. Plast. Reconstr. Surg. 1986; 78(3):285-292.

(12) Lister G., Scheker L. Emergency free flaps to the upper extremity. J. Hand. Surg .(Am) 1988; 13(1):22-28.

(13) Ninkovic M., Deetjen H., Ohler K., Anderl H. Emergency free tissue transfer for severe upper extremity injuries. J. Hand. Surg. (Br) 1995; 20(1):53-58.

(14) Ninkovic M, Deetjen H, Öhler K, Anderl H. Zeitpunkt der Versorgung schwerer Verletzungen der oberen Extremität durch freie Lappen. Handchir. Mikrochir. Plast. Chir. 1995; 27:297.

(15) Yaremchuk M.J., Brumback R.J., Manson P.N., et al. Acute and definitive management of traumatic osteocutaneous defects of the lower extremity. Plast. Reconstr. Surg. 1987; 80(1):1-14

(16) Ninkovic M., Mooney E.K., Kleistil T., Anderl H. A new classification for the standardization of nomenclature in free flap wound closure. Plast. Reconstr. Surg. 1999; 103(3):903-914; discussion 915-917.

(17) Rainer C., Meirer R., Gardetto M., et al. Perforator-pedicled skin island flaps for coverage of microvascular anastomoses in myocutaneous flaps in the lower extremity. Plast. Reconstr. Surg. 2003; 112(5):1362-1367.

(18) Ninkovic M., Schoeller T., Wechselberger G. et al. (Infection prophylaxis in complex limb trauma through immediate definitive reconstruction via a free tissue transfer). Chirurg. 1997; 68(11):1163-1169.

(19) Nylen S., Carlsson B. Time factor, infection frequency and quantitative microbiology in hand injuries: a prospective study. Scand J Plast Reconstr Surg 1980; 14(2):185-189.

(20) Richards R.R., Orsini E.C., Mahoney J.L., 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(6):946-958.

(21) Ninkovic M., Schoeller T., Benedetto K.P., Anderl H. Emergency free flap cover in complex injuries of the lower extremities. Scand. J. Plast. Reconstr. Surg. Hand Surg. 1996; 30(1):37-47.

(22) Ninkovic M., Schöller T., Wechselberger G., et al. Primary flap closure in complex limb injuries. J. Reconstr. Microsurg. 1997; 13(8):575-583.

(23) Rhomberg M., Frischhut B., Ninkovic M., et al. A single-stage operation in the treatment of chronic osteomyelitis of the lower extremity including reconstruction with free vascularized iliac bone graft and free-tissue transfer. Plast. Reconstr. Surg. 2003; 111(7):2353-2361.