

Soft tissue reconstruction in open ankle fractures

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Soft tissue envelope in the ankle area is thin and vulnerable. Prognosis of the open ankle fractures depends most of all on the severity of the soft tissue injury but also on the fracture pattern and patient related issues, like vascular status of the extremity and overall morbidity of the patient.

In open fractures soft tissue reconstruction is critical in order to minimize later complications like wound infection and osteomyelitis. Anatomical reconstruction and fixation of the fracture is mandatory. Reliable soft tissue coverage is a prerequisite for successful internal fixation of the fracture.

Assesment and planning

Fracture related immediate open wound may progress to larger soft tissue necrosis depending on the trauma severity and amount of the fracture dislocation. This zone of injury must be taken in account when planning reconstructive procedures. In high-energy injuries it may take several days until the final soft tissue damage is clinically visible.

According to the classification of Gustilo and Andersens the risk of a clinical infection depends on the severity of the injury and ranges from 0% to 2% for type-I open fractures, 2% to 10% for type-II, and 10% to 50% for type-III. (1,2).

Assesment of the soft tissue injury, peripheral vasculature of the extremity and overall status of the patient are the primary tasks immediately after the injury. It is very advisable that the treatment plan is made in close co-operation between plastic surgical and ortho-traumatological teams.

Debridement and fixation

Prerequisites for reliable reconstruction are adequate wound bed debridement prior to surgery, adequate

peripheral circulation and reasonably good quality of the soft tissues in the extremity.

It has been generally recommended that primary wound debridement and operative stabilisation of open fractures should be performed as early as possible, preferably within six hours. It might be a recommended intention although there is not any strong evidence supporting this rigid 6 hours rule (3,4).

Debridement means sharp surgical removal of all devitalised tissues and foreign bodies. The excision margins of skin should show signs of bleeding and capillary refilling. In heavy contaminated wounds a pulsatile lavage irrigation may be helpful. Damaged subcutaneous fat should be excised and fasciotomies should be performed liberally if there are any signs of compartment syndrome. The rule of four "Cs" can be used during muscle debridement: colour, consistence, capillary bleeding and contractility. A second look procedure should be done after 48-72 hours if there is any doubt about adequacy of the primary debridement (3).

Primary fixation of the fracture may be temporary external or definitive internal. Treatment protocol of the fracture must be planned individually and it depends on the severity and contamination of the injury, fracture pattern and patient related issues. When dealing with polytraumatized patient, according to damage control principles, immediate operative procedures after trauma should be fast, effective and mini-invasive.

Local wound treatment

After surgical debridement the primary task in wound management is to create a healthy and granulating wound bed in order to get optimal circumstances for definitive reconstruction of the wound and the fracture. Moist wound treatment is the basic principle (5).

Modern materials allow dressing changes in 1-3 days interval. During every dressing change wound bed should be cleaned mechanically and irrigated. There are also many antibacterial dressings in the market but scientific evidence of their effectiveness is still scarce.

Negative pressure wound treatment (NPWT) has become a first line method in local wound treatment of traumatic lower extremity wounds. The treatment is based on evenly distributed negative pressure applied to the wound surface by a special sponge and suction device. Its favourable effects on wounds have been attributed to increase of local blood flow, decrease of tissue edema, reduction of bacterial count, as well as stimulation of angiogenesis and granulation tissue formation (6,7).

Timing of the definitive soft tissue reconstruction

There has been controversy regarding the timing of definitive soft tissue reconstruction. Since 1980s microvascular free tissue transfer has become a routine method for reconstructing severe open fractures of the lower extremity. From late 1980s to 1990s, following the pioneering work of Godina (8) many authors have recommended immediate soft tissue coverage after aggressive debridement and fracture stabilization, ideally within the first 72 hours (9,10). This strategy aims at preventing the drawbacks of prolonged open wound therapy, above all tissue fibrosis, infection and tissue edema which might complicate both the flap surgery and healing of the definitive osteosynthesis performed beyond a period of 72 h.

During the last decade advances in wound care technology and better understanding of local flap design have changed the practice. There is a trend down the reconstructive ladder, currently using fewer free flaps, more local flaps and more delayed closures. NPWT provides not only safe temporary wound coverage but also soft-tissue conditioning, allowing for a more flexible schedule until definitive soft tissue coverage. Several clinical reports have shown that final reconstruction can be delayed safely beyond 72h, even over 7 days (11–14).

Methods of soft tissue reconstruction

Most of the low energy and smaller soft tissue defects in the distal leg or ankle area can be closed directly or by small skin grafts. In medium sized low energy

defects a local fasciocutaneous or muscle flap may be a reliable option, provided that flap donor site is not in the zone of injury. High-energy grade III injuries with large soft tissue defects require often microvascular flap reconstruction.

Before flap surgery, assessment of peripheral circulation is mandatory. Handheld Doppler device is a useful tool in screening the distribution of the perfusion and detecting perforating vessels.

Direct closure, skin grafting, random skin flaps

Primary or delayed closure of the wound may be an option in small vital wounds in the absence of edema. Skin grafting is possible only on vascular wound bed, not on exposed tendon, bone or metallic hardware. Random-type skin flaps may be useful only in very small defects in the area of distal leg if the surrounding skin is well perfused and pliable.

Pedicled muscle flaps

In distal leg and ankle area a local muscle flap may be an option for small to medium sized defects. For that indication perhaps the most common local flap is distally based peroneus brevis muscle. Its arc of rotation allows coverage of lateral malleolus, small anteromedial and posterior defects in the distal leg and ankle. It is simple to harvest and reliable. Pivot point should be at least three finger-breadths proximal from the distal tip of the lateral malleolus. As long as the peroneus longus is preserved, ankle instability is not expected. (15,16). Also distally based medial hemisoleus flap has been used to cover small to medium sized defects on the medial side of the distal leg and ankle (17).

Abductor hallucis muscle flap can cover small defects on the area of medial malleolus.

Fasciocutaneous and perforator flaps

In the leg there are three constant lines of perforating vessels from the deep main arterial trunks following the line of the sensory nerves: sural nerve (peroneal artery), superficial peroneal nerve (terminating proximal branch of peroneal artery) and saphenous nerve (posterior tibial artery). Distally based neurocutaneous flaps may be harvested in the line of those perforating vessels in order to reconstruct soft tissue defects in the distal lower extremity. They are relatively fast and sim-

ple to harvest, do not sacrifice major source vessels and bring similar local tissues into a defect (18).

Distally based sural neuro-fasciocutaneous flap is a versatile tool for small to medium sized defects in distal leg, ankle and hindfoot. Its pedicle includes sural nerve and lesser saphenous vein and concomitant arterial network. The distal pivot point of the flap is designed at the lowest septocutaneous perforator from the peroneal artery of the posterolateral septum, about 5 cm above the lateral malleolus (19,20).

Lateral supramalleolar flap is based on the ascending branch of the perforating branch of the peroneal artery. Its arc of rotation allows coverage of the anterior ankle and even distal dorsum of the foot (21,22).

Propeller flaps are based on a single perforator vessel, which becomes the pivot point for the skin island. The shape of the flap is planned, then it is turned like a propeller up to 180 degrees to fill the wound. Flap rotation helps in donor site closure and reduces the need for skin grafting there (23).

Microvascular flaps

Large defects after high energy Gustilo gr III ankle fractures are best covered by microvascular distant flaps. Vascular anastomosis should be done outside of the damaged tissue area.

Muscular, musculo-cutaneous and fascio-cutaneous flaps may be used. Flaps may include bone and sensory nerves. In flap selection the size and localization of the defect must be considered, also donor site morbidity. Antero-lateral thigh flap, if not too fatty, is very suitable for covering defects in foot and ankle area.

Musculocutaneous flaps are often bulky and swollen immediately after reconstruction. During following months decreasing edema and muscle atrophy reduce flap volume. Still later operative shaping may be necessary in order to get better aesthetic and functional long term result (3,8–11).

Discussion

Open ankle fractures are challenging to treat. Meticulous debridement and appropriate orthopedic fixation according to damage control principles are the cornerstones of the primary treatment. Reliable soft tissue coverage minimizes later infectious complications in soft tissue and bone.

Advancements in wound care and better under-

standing of local flaps in lower extremity are main reasons for recent trend to step down in reconstructive ladder: to do more local flaps and less microvascular flaps. Also timing of the final reconstruction has changed: There is seldom need for an emergent flap in 72 hours after injury. Final reconstruction can be made safely even after 7 days after injury provided that local wound treatment and fracture treatment have been managed properly.

References

1. Gustilo, RB, Mendoza, RM, Williams, DN: Problems in the management of type III (severe) open fractures: A new classification of type III open fractures. *J Trauma*. 1984;24:742.
2. Patzakis MJ, Wilkins J: Factors influencing infection rate in open fracture wounds. *Clin Orthop Relat Res*. 1989;243:36–40.
3. Tu YK, Yen CY, Ma CH, Yu SW, Chou YC, Lee MS, et al: Soft-tissue injury management and flap reconstruction for mangled lower extremities. *Injury*. 2008;39 Suppl 4:75-95.
4. Charalambous CP, Siddique I, Zenios M, Roberts S, Samarji R, Paul A, et al: Early versus delayed surgical treatment of open tibial fractures: effect on the rates of infection and need of secondary surgical procedures to promote bone union. *Injury*. 2005;36(5):656-661.
5. Bryan J: Moist wound healing: a concept that changed our practice. *J Wound Care*. 2004;13(6):227-228.
6. Morykwas MJ, Argenta LC, Shelton-Brown EI, McGuirt W: Vacuum-assisted closure: a new method for wound control and treatment: animal studies and basic foundation. *Ann Plast Surg*. 1997;38(6):553–562.
7. Argenta LC, Morykwas MJ: Vacuum-assisted closure: a new method for wound control and treatment: clinical experience. *Ann Plast Surg*. 1997;38(6):563–576.
8. Godina M: Early microsurgical reconstruction of complex trauma of the extremities. *Plast Reconstr Surg*. 1986;78:285e96.
9. Ninkovic M, Schoeller T, Benedetto KP, et al: Emergency free flap cover in complex injuries of the lower extremities. *Scand J Plast Reconstr Surg Hand Surg*. 1996;30:37e47.
10. Heller LS, Levin S: Lower extremity microsurgical reconstruction. *Plast Reconstr Surg*. 2001;108:1029e41.
11. Yaremchuk MJ, Brumback RJ, Manson PN, Burgess AR, Poka A, Weiland AJ: Acute and definitive management of traumatic osteocutaneous defects of the lower extremity. *Plast Reconstr Surg*. 1987;80:1–14.
12. Parrett BM, Matros E, Pribaz JJ, Orgill DP: Lower extremity trauma: trends in the management of soft-tissue reconstruction of open tibia-fibula fractures. *Plast Reconstr Surg*. 2006;117(4):1315-1322.
13. Steiert AE, Gohritz A, Schreiber TC, Krettek C, Vogt PM: Delayed flap coverage of open extremity fractures after previous vacuum-assisted closure (VAC) therapy - worse or worth? *J Plast Reconstr Aesthet Surg*. 2009;62(5):675-683.
14. Rinker B, Amspacher JC, Wilson PC, Vasconez HC: Subat-

mospheric pressure dressing as a bridge to free tissue transfer in the treatment of open tibia fractures. *Plast Reconstr Surg.* 2008;121(5):1664-1673.

15. Eren S, Ghofrani A, Reifenrath M: The distally pedicled peroneus brevis muscle flap: a new flap for the lower leg. *Plast Reconstr Surg.* 2001;107:1443e8.

16. Lorenzetti F, Lazzeri D, Bonini L, Giannotti G, Piolanti N, Lisanti M, et al: Distally based peroneus brevis muscle flap in reconstructive surgery of the lower leg: Postoperative ankle function and stability evaluation. *J Plast Reconstr Aesthet Surg.* 2010;63(9):1523-1533.

17. Pu LL: Further experience with the medial hemisoleus muscle flap for soft-tissue coverage of a tibial wound in the distal third of the leg. *Plast Reconstr Surg.* 2008;121(6):2024-2028.

18. Sananpanich K, Tu YK, Kraissarin J, Chalidapong P: Reconstruction of limb soft-tissue defects: using pedicle perforator flaps with preservation of major vessels, a report of 45 cases. *Injury.* 2008;39 Suppl 4:55-66.

19. Akhtar S, Hameed A: Versatility of the sural fasciocutaneous flap in the coverage of lower third leg and hind foot defects. *J Plast Reconstr Aesthet Surg.* 2006;59(8):839-845.

20. Tu YK, Ueng SW, Yeh WL, Wang KC: Reconstruction of ankle and heel defects by a modified wide-base reverse sural flap. *J Trauma.* 1999;47(1):82-88.

21. Masquelet AC, Beveridge J, Romana C, Gerber C: The lateral supramalleolar flap. *Plast Reconstr Surg.* 1988;81:74.

22. Lee YH, Rah SK, Choi SJ, Chung MS, Baek GH: Distally based lateral supramalleolar adipofascial flap for reconstruction of the dorsum of the foot and ankle. *Plast Reconstr Surg.* 2004;114(6):1478-1485. Review.

23. Jakubietz RG, Jakubietz MG, Gruenert JG, Kloss DF: The 180-degree perforator-based propeller flap for soft tissue coverage of the distal, lower extremity: a new method to achieve reliable coverage of the distal lower extremity with a local, fasciocutaneous perforator flap. *Ann Plast Surg.* 2007;59(6):667-671.