

Traumatic Lower Extremity Reconstruction in a Patient with Significant Vascular Comorbidities

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How to cite this paper: Da Fonte, N. and Winters, R. (2024) Traumatic Lower Extremity Reconstruction in a Patient with Significant Vascular Comorbidities. *Modern Plastic Surgery*, 14, 113-121.

<https://doi.org/10.4236/mps.2024.144012>

Received: September 21, 2024

Accepted: October 27, 2024

Published: October 30, 2024

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Abstract

Limb salvage after devastating traumatic injuries, cancer extirpation, and intrinsic disease is a complex decision-making process. Although several scoring and evaluation tools have been created to attempt to apply algorithmic decision-making to the process, thoughtful clinical decision-making remains the most important standard. When limb salvage is deemed appropriate, selection of a tissue flap for limb reconstruction is dependent on the size and location of the defect, patient comorbidities, nicotine dependence, mechanism of injury to the limb, patient lifestyle, occupation, and ambulatory status. This case involves a male trauma patient with significant comorbidities and a large lower extremity wound requiring multiple operations to attempt limb reconstruction with a rectus abdominis free flap. This patient's complex injury and comorbidities made the risk of flap failure high, illustrating that the importance of patient- and case-specific factors cannot be overstated when planning for a limb reconstruction. This extreme resort of limb reconstruction, where limb loss is the only other option and a likely consequence of even heroic efforts, is aptly called "limb salvage".

Keywords

Free Flap, Limb Reconstruction, Limb Salvage

1. Introduction

Extremity injuries involving skin, soft tissue, bone, nerves, and major vessels are challenging to manage. This typically requires a multidisciplinary team involving plastic and reconstructive surgery, orthopedic surgery, and vascular surgery. These injuries may require multiple operations for wound debridement, orthopedic reduction of fractures, soft tissue reconstruction, and skin grafting. Tissue flaps are

frequently used in plastic and reconstructive surgery to repair tissue damage due to trauma, cancer, radiation, and poor wound healing [1]. Muscle flaps are often a key element of limb reconstruction in traumatic extremity injuries. These flaps are in several forms, the most basic distinction being pedicled or free flaps. These procedures are often long and require extensive recovery time, and positive outcomes are dependent on far more than surgical technique. Recovery and rehabilitation are paramount to the success of limb salvage, though restored mobility and/or sensation are not guaranteed. The treatment team should establish reasonable conviction that restored function is obtainable before presenting limb salvage as a treatment option. In addition, one must determine whether the orthopedic injuries are even fixable, as some multilevel injuries with a significant amount of missing bone are not. A detailed history taking and physical examination of the patient with consideration of the mechanism of injury is critical to determining the likelihood of success in an extremity reconstruction.

In contrast to a limb salvage, other treatment options for limb threatening conditions include primary amputation or delayed amputation [2]. In cases of a borderline salvageable tibial injury, some studies have shown that early amputation led to better clinical outcomes compared to limb salvage. This was assessed in terms of length of time to full weight-bearing status, functional scores, number of operations, and return to activities within 6 months [3]. However, the Lower Extremity Assessment Project (LEAP), a multicenter trial, found no difference in functional outcomes between patients who underwent limb salvage versus early amputation at 2-year and 7-year follow-up. Although limb salvage may require multiple operations, each with no guarantee of success, amputation was shown to be significantly more expensive when the cost of prosthesis maintenance and replacement is considered [4]. While treatment choice is dependent on the injury itself and the patient's comorbidities, a substantial consideration, specific to each patient, is their social, economic, and psychological status. A patient's ability to properly rehabilitate will largely determine the success of their operative management. Cases of severe limb injuries can have a significant psychological impact on the patient, and their ability to cope with limb loss or the lengthy recovery should be discussed preoperatively. Their social support systems should also be addressed, as the recovery requires substantial assistance from others. The multidisciplinary team should consider the quality of life that each treatment option will provide, and this should be discussed with the patient [5]. This case presents a patient with a significant lower extremity trauma, significant risk factors for flap failure, but with retained sensory and motor function distal to the zone of injury, and strong desire for limb salvage.

2. Case Presentation

This patient is a 43-year-old male with past medical history of coronary artery disease, diabetes mellitus, hypertension, hyperlipidemia, obesity class III, one pack-per-day cigarette smoking, and obstructive sleep apnea who presented to the

Emergency Department with multiple traumatic injuries following a motorcycle collision with a car. The patient recalls colliding with the posterior of a car in front of him, resulting in ejection from the motorcycle and subsequent body contact with three parked vehicles. He was wearing a helmet and did not lose consciousness. The patient presented with a gross deformity of the left lower extremity with bones and tendons exposed and tourniquet applied by emergency medical services (EMS). He had significant abrasions to the right lower extremity, left hand, and chest and was hypotensive in the field, requiring blood transfusion. Upon arrival to the Emergency Department, the patient was alert and oriented to person, place, and time with Glasgow Coma Scale (GCS) 15, temperature 36.6°C, pulse 106 beats per minute (bpm), blood pressure 130/95 mmHg, respiratory rate 22, SpO₂ 94% on O₂ via nasal cannula at 4 liters per minute (lpm), and BMI 54.7 kg/m². On physical examination, the patient was in acute distress, with labored breathing, bilateral breath sounds present, weak left popliteal pulse, palpable left posterior tibial pulse, and absent left dorsalis pedis pulse. Bilateral radial pulses, and right popliteal, posterior tibial, and dorsalis pedis pulses were palpable. Sensory and motor function was intact.

Initial laboratory testing included complete blood count (CBC) with differential, coagulation studies, comprehensive metabolic panel (CMP), point-of-care (POC) glucose, blood type and screen, total creatine kinase, and lactic acid. Notable findings include elevated white blood cell (WBC) count at 20.9 (10⁶/μL), elevated blood glucose at 180 mg/dL, elevated creatine kinase at 306 [iU]/L, and elevated lactic acid at 3.9 mmol/L. X-ray revealed a left clavicular fracture, left distal femur fracture, and comminuted fractures of left tibia and fibula. Angiography revealed left posterior tibial artery patent to the ankle, left anterior tibial artery patent to the distal calf, and the left dorsalis pedis artery was not identified. Imaging findings also included a significant soft tissue defect of the anterior aspect of lower extremity with soft tissue edema and emphysema extending from calf to foot and ankle. Patient underwent emergent external fixation of the left femur and left tibial shaft, left tibial irrigation and debridement, and wound vacuum-assisted closure (VAC) placement over left medial lower leg. On postoperative day one, he was extubated and had a weakly palpable left dorsalis pedis pulse with warm and well-perfused toes. Plantar sensation was intact, and the remaining sensorimotor evaluation of his left lower leg was limited by external fixator pin and wound VAC placement. Three days after initial presentation, plastic and reconstructive surgery was consulted to return to the operating room to further irrigate and debride the left lower leg skin, subcutaneous tissue, muscle, and bone and to discuss options for reconstructive salvage of the left lower extremity.

The patient was thoroughly evaluated by plastic and reconstructive surgery in the operating room alongside orthopedic surgery. The patient had an extensive open wound starting from the left proximal tibia and extending to the medial ankle joint. From the medial ankle joint, the wound curved posteriorly to a partially degloved heel pad. The medial ankle tendons, the posterior tibial artery and vein,

and the tibial nerve were all exposed along the medial ankle. The anterior tibial artery was intact and pulsatile. The posterior tibial artery was clotted off at the level of the ankle and the tibial nerve was intact. Devitalized tissues, including skin, subcutaneous tissues, and muscle were debrided. Portions of the medial gastrocnemius, medial soleus, tibialis anterior, and other anterior compartment muscles were excised due to necrosis. Wounds were irrigated and a large wound VAC was applied to the open wound. The patient was extubated in the immediate postoperative period. On postoperative day one from this second operation, he had multiple episodes of oxygen desaturation to 86% while sleeping, which improved when awake. Patient returned to the operating room on postoperative day three for irrigation and debridement of the left lower extremity open wounds and wound VAC change with orthopedic surgery and plastic and reconstructive surgery, his third operation since admission. The patient was extubated in the immediate postoperative period.

Surgeons from both orthopedic and plastic surgery had multiple extensive conversations with the patient and his mother about the options for his left lower limb—salvage versus amputation. Emphasis was given to the difficulty of a successful limb salvage given the extensive wound, the degree of soft tissue loss, and the challenge of distant blood supply targets. Limb salvage and below knee amputation would both require multiple surgeries. Although he would have plenty of length for an adequate below knee amputation, the femur fracture above complicated this treatment option. Limb salvage would involve much longer procedures, a longer hospitalization, and a longer recovery to walking when compared with prosthesis. The anticipated surgical plan for limb salvage was outlined to the patient as follows: free flap muscle transfer from latissimus dorsi and serratus anterior of the right back to the left lower extremity, and vein grafting from the right leg with connection to the superficial femoral artery of the left leg. During this operation, the patient would also undergo open reduction and intramedullary nail fixation of left tibia and closed reduction of left fibula with orthopedic surgery. The patient was made aware of the risks associated with this plan, including flap failure, donor site weakness, infection, scarring, malunion, nonunion, hardware failure, loss of limb, and need for further procedures. The patient chose to proceed with an attempt at limb salvage.

On postoperative day four from his third operation, the patient returned to the operating room for removal of left femur external fixator, intramedullary nail fixation to left femur, irrigation and debridement, and wound VAC change, his fourth operation since admission. Three days later, he returned to the operating room with plastic and reconstructive surgery and orthopedic surgery for limb salvage. The external fixator was removed, and the open reduction and intramedullary nail fixation to the left tibia was completed without complications. The greater saphenous vein was harvested from the right lower extremity, from ankle to proximal thigh, for a length of approximately 70 centimeters. Given the patient's high BMI (54.7 kg/m²) and obstructive sleep apnea, anesthesiology was not

comfortable with positioning the patient prone for the right latissimus dorsi and serratus anterior dissection. An attempt was made to position the patient in the left lateral decubitus position for the back dissection, but it was deemed too difficult to proceed in this position due to the left femoral artery being inaccessible and patient instability on the table. At this point, it was decided that the only safe position to proceed with for this patient was supine. The surgical plan was then changed to a left rectus abdominis free flap for the distal left lower leg, and two pedicled muscle flaps for the proximal left lower leg using the medial gastrocnemius and the medial hemisoleus. The left greater saphenous vein was dissected in the subcutaneous tissue, which was thrombosed in the zone of injury but patent and uninjured proximally. The left rectus abdominis flap was harvested while the left superficial femoral artery and vein were exposed in the distal thigh. The left abdominal defect was reinforced with Phasix mesh. The left posterior tibial artery and vena comitans were dissected out and were patent with outflow. There were three viable options for venous outflow from the flap—the left greater saphenous vein and the two posterior tibial vena comitans. The rectus flap was positioned over the posterior medial ankle to the lateral tibia, covering the ankle joint and the exposed peroneal tendons. The inferior epigastric artery of the rectus flap was first anastomosed to the reverse saphenous vein graft using a long segment of the donor vein graft, using microvascular technique. There were no leaks in antegrade flow and heparinized saline flushed out through the inferior epigastric vein of the flap. The superficial femoral artery was controlled proximally and distally, and an end-to-side anastomosis was performed between the reverse saphenous vein graft and the superficial femoral artery. Proximal and distal control of the superficial femoral artery was released, and blood flow was established through the rectus flap with substantial venous outflow and no leaks in antegrade flow. Venous outflow from the rectus flap was then established, with the decision to use the left greater saphenous vein rather than the vena comitans. After measurement, the vein graft was cut, and an end-to-end anastomosis was performed between the donor saphenous vein graft and the left greater saphenous vein outside of the zone of injury. The inferior epigastric vein of the rectus flap was anastomosed to the donor saphenous vein graft, and flow was sustained in and out of the flap with adequate flap perfusion and no leaks. The rectus flap was inset distally, and the medial hemisoleus and medial gastrocnemius were inset proximally within the left lower extremity open wound. The patient remained intubated postoperatively as decided by anesthesiology because the total surgery length was 12 hours. Postoperative management involved hourly flap checks and bair hugger therapy for the first 48 hours after surgery, heparin infusion at 800 U/hr, continued antibiotic therapy, and no turning or repositioning of the patient. The patient remained sedated and intubated. On postoperative day 2, he had a fever of 39.8°C with oxygen desaturation to 80%, resulting in increased ventilator requirements. Antibiotic therapy was broadened to vancomycin and piperacillin-tazobactam, and a chest x-ray was consistent with pneumonia. Starting at the 48 hours postoperative

period, flap checks were decreased to every two hours, heparin was continued at 800 U/hr, bair hugger therapy was discontinued, and patient repositioning and turning was initiated. Throughout the postoperative course, the left lower extremity flap remained warm and pink, with intact internal arterial and venous doppler signals, and strong handheld doppler signals on the flap surface. Serosanguinous fluid was collecting in drains as anticipated.

3. Discussion

Surgical planning for limb reconstruction is inherently complex and can be further complicated by patient-specific factors, as in this case. This patient was a poor surgical candidate. He had multiple risk factors, including coronary artery disease, diabetes mellitus, hypertension, obesity, cigarette smoking, and obstructive sleep apnea, that placed him at high risk of complications from anesthesia and surgery. However, given the extent of his injuries and critical condition on initial presentation, nonoperative management was not a viable option for him. While amputation may appear to be the less risky treatment, he would have required multiple surgeries for irrigation and debridement nevertheless to reduce the risk of postoperative infection and subsequent higher amputation [6]. His level of amputation would make ambulation difficult at best. In addition to his risk of complications from anesthesia, many of these same risk factors are highly associated with flap failure and/or vascular compromise, including smoking, hypertension, diabetes, and coronary artery disease [7]. In an ideal world, the limb reconstruction would be delayed until the patient was optimized for surgery, by ceasing smoking, controlling his diabetes, losing weight, and so on [1]. Again, this was not a viable option given his traumatic presentation. In summary, this patient's comorbidities and initial presentation placed him at high risk of complications—including respiratory compromise, poor wound healing, need for subsequent surgeries, limb loss, flap failure, infection, and mortality—regardless of his choice for operative management. After taking all of this into consideration and having multiple extensive conversations with the patient and his family, the multidisciplinary team initiated their surgical planning for a limb reconstruction of the left lower extremity.

For lower extremity traumas, flap choice is dependent on the location and size of the defect. A local flap is one raised from tissue bordering the defect, whereas a free flap is one transferred from another site on the body. Free flaps are often used when defects are too large for a local flap, or when vascular compromise renders a local flap unusable [2]. For the upper-third of the tibia, the gastrocnemius typically serves as a suitable local flap, depending on the integrity of the sural artery. A pedicled flap is one that retains its blood supply while the tissue is mobilized to the defect. In the case of our patient, the gastrocnemius was a suitable option for the most proximal region of his defect. This comfortably covered the proximal half of his tibia, without tension. The soleus muscle was dissected out and served as an option to extend local flap coverage. The soleus muscle has one dominant vascular pedicle and minor supplemental vascular pedicles, meaning that perforator

vessels provide blood supply to the muscle, in addition to its main blood supply [1]. The soleus muscle has a limited arc of rotation, so there is a higher risk of excess tension when mobilizing this muscle [8]. In the case of this patient, a hemi-soleus flap was used rather than the entire muscle. This provides a greater arc of rotation in the flap, while potentially retaining some functional plantar flexion from the remaining soleus muscle [9]. The medial gastrocnemius and medial hemi-soleus local flaps provided adequate coverage for the proximal two-thirds of the left tibia, without tension. This left the distal one-third of the tibia, the medial ankle joint, and the partially degloved heel pad exposed. Some fasciocutaneous flaps serve as options for coverage of the distal one-third of the tibia, as well as the malleolus and/or the heel. A sural fasciocutaneous flap may be used for coverage of soft-tissue defects of the distal tibia, perimalleolar regions, and the heel. One study found that the largest documented sural flap was 17×16 centimeters, which is significantly smaller than the remaining area of defect in this patient [10]. Moreover, the complication rate increases with graft size. The lateral supramalleolar skin flap provides similar coverage to the sural flap, but it is a more difficult dissection, provides no advantages over the sural flap, and should not be used on the weight bearing surface of the foot [10]. In addition, these are either pedicled off small perforators or reverse flow flaps. These were not viable options for the patient in this case due to insufficient coverage, necessity for coverage of part of his weight-bearing heel pad, his body weight, his compromised perfusion, and the fact that his injury degloved all these fasciocutaneous options—which have tenuous blood supply in the best of circumstances. In our patient with no suitable options for local flap coverage of his remaining defect, he would require a free flap.

The most used free muscular flaps for coverage of the lower-third of the tibia are the latissimus dorsi, serratus, rectus abdominis, and gracilis muscles. These are preferable choices because they have a rich blood supply, can be molded to the irregular shape of a wound, and their loss is not a problem for function. While fasciocutaneous flaps may become edematous over time depending on their position, muscle flaps tend to improve in contour with time [10]. The latissimus dorsi is commonly used as a free flap because it can cover large defects of the leg, has a long vascular pedicle, offers minimal morbidity at the donor site, and can be combined with subscapular flaps if needed. The latissimus dorsi, in combination with the serratus, was initially intended to be the donor site in this patient. This was a suitable option given the irregular contour of his remaining defect. Moreover, given the substantial blood supply from the thoracodorsal artery, this is a suitable option in cases of atherosclerotic disease. This portion of the procedure was limited by patient-specific factors and required a change in surgical plan. To harvest the latissimus dorsi, the patient must be transitioned to the lateral or prone position intraoperatively [2]. This patient could not be safely positioned prone given his high risk of cardiopulmonary decompensation. He was successfully positioned in the lateral position intraoperatively, but it was determined at that time that the muscle harvest could not be performed in a timely manner given his body habitus;

thus, it was not a safe option. The most reasonable operative position for this patient was supine, so the next choice for a free flap needed to be accessible from this position; thus, the rectus abdominis was a suitable option to cover his large remaining defect. This muscle has dual blood supply, with the inferior epigastric system being the most reliable [1]. In this patient, the inferior epigastric system was successfully transferred with the rectus abdominis to the recipient site. Using microvascular techniques, the inferior epigastric artery was anastomosed with the reverse saphenous donor vein graft, followed by microvascular anastomosis of the reverse donor graft to the superficial femoral artery. Vein grafts are “reversed” so that the valves are facing antegrade to flow. The inferior epigastric vein was then anastomosed with a shorter segment of the donor vein graft, which was anastomosed with the native left greater saphenous vein. The posterior tibial vena comitans were dissected and available as other options for venous anastomosis. This case did not require use of a “backup plan” for the venous supply, but the multidisciplinary team was prepared if the microvascular anastomosis did not come together perfectly on the first attempt. Without a contingency plan, free flaps demise can occur rapidly. In plastic and reconstructive surgery, anticipating complications by creating a preoperative plan, with multiple backup plans, allows for successful limb reconstruction—even in patients with significant vascular comorbidities.

4. Conclusion

In cases of significant lower extremity injury, a multidisciplinary team is required to stabilize the patient and devise a treatment plan involving multiple surgeries and a definitive operative treatment based on patient-specific factors. It is often prudent to go straight to more complex free flaps rather than borrow local flaps from an already compromised extremity. While surgical technique constitutes a significant part of this planning, the patient’s preferences, understanding, anticipated postoperative recovery, and social support are also incredibly important in determining the best plan. An extremely complex limb salvage could be conducted in a technically perfect manner, but the limb would be unlikely to survive if the patient could not rehabilitate appropriately. This case presented a medically complicated patient who was not an ideal candidate for limb salvage, but with meticulous preoperative planning, including contingency planning, and consideration for his preferences, the patient underwent five operations with no signs of ischemia in the postoperative period.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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