

Preservation of lower extremity spare parts using the University of Wisconsin solution

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Abstract

The management of a mangled limb is a challenging endeavor. With the advancement in microsurgery, spare parts surgery (fillet flaps) has gained recent interest. In the context of lower extremity amputation secondary to trauma, viable spare parts can provide stump soft tissue coverage, potentially preserving critical length and obviating above-knee amputations. Commonly, spare parts surgery is performed in the acute setting but tissue preservation is sometimes necessary. The authors report their experience preserving a fillet flap of a mangled lower extremity for 48h using the University of Wisconsin solution. A sole fillet flap and a split-thickness skin graft were harvested and preserved from the amputated lower extremity (based on the posterior tibial artery and vein). Stump coverage was achieved by anastomosing the fillet flap to the proximal posterior tibial artery and vein. This solution has not been previously described for preservation of fillet flaps.

Keywords

Spare parts, fillet flap, University of Wisconsin solution, lower extremity injury

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Introduction

The management of a mangled limb is a challenging endeavor. Physicians and patients are faced with the decision of limb salvage or amputation. Amputation is often the best course of action in severely mangled limbs. Knowledge of amputation rehabilitation is paramount in the management of mangled lower extremities.^{1,2} Stump length has been shown to correlate directly with energy expenditure.^{3,4} Moreover, durable soft tissue coverage is necessary to prevent chronic wounds and optimize prosthetic rehabilitation.

With the advancement in microsurgery, spare parts surgery has gained recent interest. Numerous articles have been published in the last decade outlining the management approach for severe limb injury with spare parts.^{5–10} In the context of lower extremity amputation secondary to trauma, viable spare parts can provide stump soft tissue coverage, potentially preserving critical length and obviating above-knee amputations. Spare parts surgery is commonly performed in the acute setting but tissue preservation is necessary if simultaneous microsurgical transfer cannot be performed at the same time as harvest. Various preservation solutions have been described for microvascular replantation in animal models.¹¹ We present a case of a mangled lower limb managed with spare parts preserved in the University of Wisconsin (UW) solution, a

common preservation medium used in organ transplantation. To our knowledge, this has not been previously described in the clinical setting.

Case presentation

A 22-year-old female was brought to the emergency department 4h after being struck by a freight train on a cold winter night. On arrival to the emergency department, her core temperature was found to be less than 27°C. She had an above-knee amputation on the right side and a below-knee amputation on the left side. The crushed severed limbs were transported to the emergency department. She presented in hypovolemic shock and required intubation (Glasgow Coma Score of 8). The patient was immediately taken to the operating room (OR) for damage control by the orthopedic team and required invasive rewarming by cardiopulmonary bypass

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through cannulation of the femoral artery/vein. Plastic surgery was consulted to manage the extensive soft tissue wounds. There was insufficient local soft tissue for coverage of the left below-knee amputation stump, preventing tension-free closure (Figure 1). Soft tissue reconstruction was necessary to preserve stump length and provide stable and durable padding for prosthesis.

The amputated parts were examined for potential spare parts harvesting. The left amputated lower limb was severely crushed and did not contain viable soft tissue. The right amputated lower limb (above-knee amputation) was crushed at the proximal portion but the distal soft tissue was spared (Figure 2). A sole fillet flap (Figure 3) and a split-thickness skin grafts were therefore harvested from the right amputated lower extremity. However, as the patient was hemodynamically unstable, microsurgery was delayed and the spare parts were preserved for later use. The flap was flushed with UW solution for approximately 20 min until all the blood



Figure 1. Left below-knee amputation stump. Insufficient local soft tissue for coverage can be appreciated, preventing tension-free closure.

was removed. The flap was subsequently wrapped in sterile saline gauze and placed in a sterile plastic bag at 4°C for later use. In addition, the posterior tibial artery (pedicle of the sole fillet flap) was cannulated and flushed with heparinized saline and UW solution every 12 h. The skin graft was also preserved in a UW solution at 4°C.

The patient's condition gradually improved during the following 48 h and she was taken back to the OR for further debridement of devitalized muscle and definitive soft tissue coverage. She eventually became hemodynamically stable and rewarming by cardiopulmonary bypass was discontinued. It was only after hypovolemic shock resolution and extubation that reconstruction was considered. The flap was irrigated with a heparinized saline solution and anastomosed to the posterior tibial artery and posterior tibial vein. The donor tibial nerve was anastomosed to the recipient tibial nerve for sensory innervation. The flap was well vascularized intra-operatively with good arterial flow and venous return (Figure 4). The time between thawing and reperfusion was approximately 2 h. Doppler revealed triphasic arterial signal and capillary refill was less than 2 s. The flap was inset to cover the stump and the remaining non-weight bearing raw areas were skin grafted using the preserved split-thickness skin grafts. The flap remained viable post-operatively with no concerns for 5 days. However, on the fifth post-operative day, the patient became febrile with a rising white blood cell count. Purulent fluid was noted beneath the flap and the patient was taken back to the OR. Exploration demonstrated a viable flap and necrotic hamstring muscles. Further debridement and drainage was performed. Antibiotics were also administered. On the seventh post-operative day, a hemorrhagic blister was noted over a pale and cool flap, a finding suspicious of flap ischemia. Operative re-exploration revealed a thrombosis of the arterial anastomosis. The venous anastomosis was not



Figure 2. The right amputated lower limb (above-knee amputation), used for fillet flap harvest. The spared distal soft tissue can be appreciated.

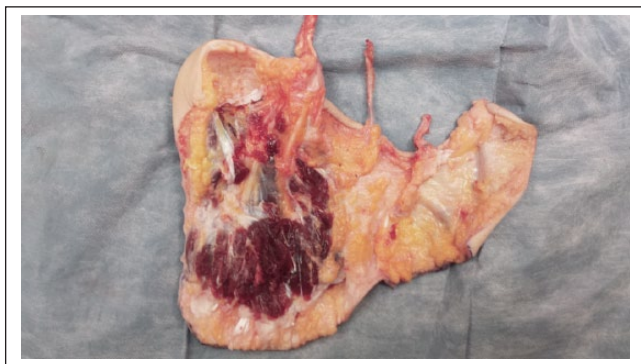


Figure 3. Sole fillet flap after harvest.



Figure 4. Flap after inset. Adequate perfusion can be appreciated.

thrombosed. Salvage attempts were futile. Discussions with the patient's family members resulted in their desire to defer any addition free flap options and expedite coverage with a skin graft. The family's wishes were respected and the debrided flap was replaced with a skin graft.

Discussion

Goals in lower extremity amputation secondary to trauma include maintaining a functional joint and preserving length.³

Table 1. Contents of the University of Wisconsin solution.

Contents
Potassium lactobionate
KH_2PO_4
MgSO_4
Raffinose
Glutathione
Adenosine
Allopurinol
Pentafraction (HES)
Penicillin
Insulin
Dexamethasone
Potassium
Sodium

KH_2PO_4 : potassium phosphate; MgSO_4 : magnesium sulfate; HES: hydroxyethyl starch.

Ambulatory energy expenditure post amputation is directly correlated with residual stump length and the maintenance of a functional stable joint.^{4,5} The concern to preserve length should be balanced with adequate soft tissue coverage. Suboptimal soft tissue coverage in an effort to preserve length may lead to complications delaying rehabilitation and subjecting the patient to additional procedures. The use of skin grafts for stump coverage may sometimes lead to suboptimal results with significant wound complications. The recent forgiving nature of modern prostheses has resulted in acceptable outcomes with skin grafts.⁶ However, when possible, coverage with vascularized tissue is favored. Spare parts offer the advantage of utilizing vascularized tissue, avoiding additional morbidity from the donor site.

The UW solution has become the most used preservation solution for livers, kidneys, and pancreases with exceptional experimental and clinical data.¹²⁻¹⁴ The UW solution has recently been considered the current golden standard solution. To the best of our knowledge, the UW solution has not been previously described for preservation of spare parts in lower extremity trauma. This solution is responsible for the longest period of safe preservation of isolated cells, particularly in pancreatic islets and hepatocytes.^{15,16} Animal studies have confirmed the efficacy of using UW solution for preservation of fasciocutaneous flaps.^{17,18} Some authors have hypothesized that lactobionate is the key component of the UW solution.¹³ Lactobionate has been reported to suppress hypothermally induced cell swelling in all tissues tested. Lactobionate is also a relatively strong chelator of calcium and iron, resulting in reduced oxidative injury in cold-stored tissues.¹⁹ The contents of the UW solution are displayed in Table 1.

Other solutions have been successfully used for preservation of spare parts in lower extremity trauma (Table 2). Heparinized Hartmann's solution has been successfully used for preservation of a fillet sole of foot flap.²⁰ Successful reconstruction was

Table 2. Review of the literature.

Patient	Preservation time	Temperature stored	Solution	Storage Method	Type of flap	Recipient Site	Vascular anastomosis	Nerve anastomosis	Complications
Shah et al. ²⁰ 39-year-old male	57 (of which 48 h were stored at 4°C)	4°C	Heparinized Hartmann's solution	Wrapped in a saline gauze. Placed in a sterile plastic bag	Sole of foot	Right lower extremity below-knee amputation with residual tibial stump (length 8 cm)	Posterior tibial to medial geniculate (end to end)	Tibial nerve to proximal stump of the tibial nerve	Evacuation of hematoma, debridement of blistered keratin layer, and 2 cm area of necrosis (POD 2)
Anderl ²¹ 20-year-old male	30 h	4°C	Heparin-saline	Wrapped in a saline gauze and antibiotic solution (neomycin, bacitracin, polymyxin B)	Groin flap	Complete degloving of the left heel and loss of a plantar piece of the calcaneum. Vessel spasm and patient hypothermia prevented immediate reconstruction	Superficial circumflex iliac artery and vein to posterior tibial artery and vein (end to end)	None	None
Current case 22-year-old female	48 h	4°C	University of Wisconsin solution	Pedicle flushed with heparin and the UW solution every 12 h	Sole of foot	Right below-knee traumatic amputation stump coverage	Posterior tibial artery and vein to posterior tibial artery and vein	Tibial nerve to proximal stump of the tibial nerve	Evacuation of infected hematoma (POD5). Flap failure due to infection (POD7)

UW: University of Wisconsin; POD: post-operative day.
 Studies reporting results of fillet flap preservation in lower extremity trauma.

performed after 57h of preservation. To the best of our knowledge, this is the longest preservation period for a fillet flap. A saline solution with antibiotics has also been described to successfully store a free groin flap for 30h.²¹ Cold ischemia time remains an independent risk factor for organ function and should be minimized when possible. The authors of the current case report decided to use UW solution given the numerous studies that have demonstrated its superiority for organ preservation. Despite flap loss due to infection, we believe that the UW solution expands the armamentarium of the reconstruction surgeon in spare parts surgery, especially in unstable patients and/or contaminated wounds. The complications leading to flap loss were likely unrelated to the preservation method because there were no signs of failure until the fifth post-operative day. Multiple factors including severe tissue crush, frostbite, wound contamination, and trauma-induced immunosuppression (compensatory anti-inflammatory response syndrome) were likely the major culprits leading to loco-regional muscle necrosis of the amputated leg, resulting in peri-anastomotic abscess formation with subsequent arterial thrombosis and flap loss. A more radical debridement of the wound may have avoided the complication.

Conclusion

The authors present their experience using the UW solution for fillet flap preservation in lower extremity trauma. More research is needed to identify the optimal solution for preservation of fillet flaps. Research specific to fasciocutaneous flaps is required as preservation and metabolic demands may differ from those of other organs.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

Our institution does not require ethical approval for reporting individual cases or case series (exempt).

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Informed consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief.

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