Introduction

Electrical injury due to high-voltage contact (>1000 V) is one of the most challenging problems in emergency medicine and plastic surgery. High voltage electrical injury (HVEI) is one of the most important etiologic factors in the disruption of vascular systems and/or extremity amputations. Conversion of high voltage electrical energy into heat causes irreversible damage to different tissue types. Muscle necrosis, vessel and nerve injury is frequently encountered in this type of injury. As nerve and artery tissue has the lowest resistance to electrical injury, high current and susceptibility to heat makes arteries more vulnerable to thrombosis and hemorrhages. Brachial artery rupture or thrombosis and distal vascular collapse of the extremities have been reported in HVEI. Early vascular grafting with free or pedicled flaps and flow-through free flaps were applied to salvage the upper extremity. As harvesting the flap from the affected extremity has a high complication rate, a distant regional flap or free flap is the first choice for reconstruction. In complicated cases, protection of the exposed brachial artery is an important part of burn management to prevent early and late amputations. Our aim is to present the result of using an alternative flap creation model for arterial protection with a novel flap usage. We hypothesize that wrapping the arterial system in the case of a high voltage electrical injury decreases vascular-based hemorrhagic complications and prevents amputations. Wrapping muscle around the femoral artery in infected vascular grafts and gunshot wounds has been presented by the authors. This preliminary study is the first presentation of an exposed brachial artery segment completely wrapped with pedicled latissimus dorsi muscle to protect the main extremity vessel in HVEI.

Case report

A twenty-year-old male patient was admitted to our burn
unit two hours after injury. Total burned body surface area was 18%. On admittance, physical examination revealed a 3rd degree burn and compartment syndrome in the right upper extremity, therefore an urgent fasciotomy was performed. The open wound was protected with silver-coated wound dressing. After the fasciotomy and serial debridement, the patient returned to the operating room seven days after trauma for reconstruction with latissimus dorsi (LD) muscle. Ten cm of brachial artery was exposed before final flap creation (Fig. 1a). The patient was positioned in a lateral decubitus position. The thoracodorsal arterial system was checked with a hand-held Doppler. Standard pedicled LD flap was harvested from the ipsilateral back based on the thoracodorsal vascular system. The pedicle and humeral proximal insertion point was protected by tedious dissection. The necrotic central part of the biceps brachia muscle was totally excised and 10cm of brachial artery was skeletonized. The distal part of the LD was wrapped around the exposed brachial artery segment (Figs. 1b and c). The bicipital aponeurosis was protected for reinsertion of latissimus dorsi for functional transfer (Fig. 1d). The medial part of the LD was used to cover the remaining arm defect. At the end of the procedure, the LD not only protected the skeletonized brachial artery by wrapping it but also acted as biceps brachia muscle by reinsertion to bicipital aponeurosis. The latissimus dorsi was covered with split thickness skin graft. Simultaneously the superficial circumflex iliac artery pedicled groin flap was used for the wrist defect. Flap and graft adaptation was excellent 21 days after surgery. The patient healed uneventfully in the follow-up period. The patient’s shoulder and elbow range of motion (ROM) measurements were calculated. Fifty-degree forearm flexion was achieved at the beginning of the physiotherapy program. Magnetic resonance imaging (MRI) was used to assess the LD wrapped around the exposed brachial artery segment in the third month after surgery. In addition, there was no aneurism/pseudo aneurysm of luminal narrowing throughout the brachial artery length in the 3D magnetic resonance angiography (MRA) (Figs. 2e and f). Shoulder, elbow and wrist range of motion were compared with the opposite extremity using a universal goniometer 6 months after surgery. There was no limitation in the shoulder joint. Ten-degree extension and 40-degree flexion limitation in the elbow joint was noted after the LD transfers (Figs. 2g and h). Total wrist extension and 10-degree flexion was assessed due to loss of flexor muscle groups. Pain, function, emotional...
acceptance, hand positioning, manual dexterity and lifting ability were determined for a functional evaluation of limb salvage, as was previously proposed for a musculoskeletal tumor society scoring system by Enneking et al. The 20/30 numerical score was found by gathering numerical values (0-5 points) for each of the six categories (pain: 5, function: 2, emotion: 5, hand positioning: 2, manual dexterity: 2, lifting ability: 4).

**Discussion**

Limb salvage is still a challenge for the burn surgeon. HVEI can cause extremity amputations and/or disruption of major vascular systems. In the arm, the muscle insertions in the inferior humeral region, such as the brachialis, biceps brachii, triceps brachii and coracobrachialis muscles are most affected by HVEI. 90% of HVEI patients have vessel wall necrosis leading to thrombosis and local obstruction of blood flow in their upper extremities. Upper-extremity HVEIs are associated with a concomitant amputation rate of up to 40%. Most of the amputations take place in the first two weeks after HVEI. HVEI defects can be reconstructed with local, distant or free flaps. Local fasciocutaneous flaps can be applied for only small size defects. On the other hand, free flap reconstruction can fail in the acute management of an HVEI defect due to vascular problems such as hemorrhage, thrombosis or infection. The patient’s systemic conditions did not allow microsurgical operations during the first two weeks. Saint-Cyr et al. reported that the survival rate of free flaps in extremity reconstruction is about 80% with 87% limb salvage in HVEI. Reconstruction of medial upper arm defects of HVEI is usually performed by LD myo/myocutaneous flap in burn units. Since the vascular pedicle of the LD is further away from the injury, the latissimus dorsi (LD) muscle can be used for moderate to large defects in a pedicled manner to salvage the upper extremity, as previously described.

In the acute treatment period, soft tissue defects and main artery destruction may occur at the same time in HVEI. After fasciotomy or debridement of medial arm in HVEI, the brachial artery is usually exposed. Rupture of the artery due to non-visible tissue around the wound should be expected during follow up. It is difficult to predict which tissues will be affected and the extent of the involvement of electrical burn necrosis around the vascular system. Vascular complications can be observed a long time after hospital discharge. Lee et al. present a patient with delayed rupture of a brachial artery due to pseudoaneurysm, who had HVEI and underwent fasciotomy and defect coverage with LD musculocutaneous flap. They proposed that the strict adhesion of the artery under the flap is an etiologic

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**Fig. 2**: 2D and 3D Magnetic Resonance Imaging of wrapped brachial vascular system with latissimus dorsi muscle flap shows no abnormality along the length of the vascular system (e and f). Late postoperative views of shoulder and elbow joints after latissimus dorsi muscle wrapping operation (g and h).
factor. The separation of vital structures from an ongoing infectious process may be important in preventing vascular complications. The wrapping procedure in many surgeons’ personal experience is used primarily for vascular graft protection. Creating muscle with the wrap-around technique has evolved to salvage infected vascular grafts and aneurysm.\textsuperscript{13} Pedicled latissimus dorsi, pectoral muscle and rectus abdominis flaps have been used in wrap-around vascular graft protections in the literature.\textsuperscript{4} As a different usage, the serratus anterior flap was decreased wound complications, deep fascia of wrapped LD muscle flap can decrease adhesion of the artery to the affected wound bed and infection can be controlled around the vascular system.\textsuperscript{6,15}

The end result of restoring arm function, especially elbow flexion, was achieved in this study. The forearm flexor muscle and median nerve loss affected manual dexterity. There was little limitation in shoulder and elbow movement, and according to the Enneking scoring system to evaluate arm function, the procedure had advantages, especially regarding pain and emotional issues.

In our study, no hemorrhage or amputation was observed. The luminal status of the exposed brachial artery segment on MRI and MRA showed no abnormality along the length of the vascular system. On MRI, we detected a distinct plane between the artery and deep muscle fascia that indicated that there was no adhesion or vascular aneurysm. Flap and graft adaptation was excellent with 100% brachial artery patency.

In this study, we have presented a technique using LD muscle flap (wrap-around) to wrap an exposed brachial artery in a high voltage electrical injury. This method allows the surgeon to protect the main upper extremity artery and reconstruct arm defects with LD, which contributes to arm functioning.

BIBLIOGRAPHY