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Nerve vascularity in free vascularized nerve flaps

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Abstract: The blood supply of peripheral nerves consists of a complex internal vessels' network, feeding external vessels and the interlinking vasa nervorum. Patients with nerve damage may require nerve substitution. While the commonly performed avascular nerve grafts obtain vascularization only from random and slow inosculation into the vasa nervorum, their insufficient revascularization causes loss of the graft's potential due to central necrosis. This gets more relevant with the larger diameter of nerves injured. Examples for neurovascular flaps are the lateral femoral cutaneous nerve vascularized *via* the superficial circumflex iliac artery perforator (LFCN-SCIP) flap or the iliohypogastric nerve graft vascularized *via* the superficial inferior epigastric artery (SIEA). LFCN-SCIP shows a well concealed donor scar site with a maintained vascularization and a minor donor site morbidity. Therefore, the guaranteed axial nerve vascularity in LFCN-SCIP makes it a preferred autologous vascularized nerve therapy for peripheral nerve defects. A further option example is the anterior lateral thigh (ALT) flap with the LFCN.

***Keywords*:** perforator, supermicrosurgery, SCIP, nerve reconstruction, microsurgery, flap, vascularized nerve

Soft tissue defects may often require nerve reconstruction. This can occur after cancer resection, after trauma or iatrogenically. Based on the reconstructive ladder, short defects of nerves can first be repaired *via* primary coaptation or avascular nerve grafts (*e.g.* sural nerve graft).

Nerve grafting provides the necessary extracellular matrix along with viable Schwann-cells for the proximal axons to grow along, until the distal target is reached. These nerve grafts (*e.g.* sural nerve graft) are vascularized only *via* inosculation from the surrounding tissue, which limits viability of their core, and thus their potential (*1*). For short distances (up to 3 cm), nerve allografts (Axogen®) are commercially offered, yielding no superiority to autologous material except preventing donor site morbidities. Additionally, they offer no additional benefit regarding vascularization. Scarring, long or thick nerve defects require preferably vascularized nerve reconstruction (*2*), where the vascular structure (external and internal vessels) are intact, which provides the optimal condition for the proximal nerves to grow (*3*). This vascularized nerve reconstruction can be in the form of vascularized nerve grafts (*e.g.* anterior interosseous nerve graft or ulnar nerve graft), neurovascular flaps (*e.g.* lateral arm flap), and neurocutaneous flaps (where the nerve is a guide for skin vascularization).

The vessels of a peripheral nerve are commonly categorized into the intrinsic and the extrinsic vascular systems (*4*). The intrinsic system is the dense mesh, which nourishes the nerve. It consists of the longitudinal microvessels within the endoneurium. It is very rich and allows a nerve to be supplied for up to 40 cm. Yet, the intrinsic system receives its supply from extrinsic segmental nutritive vessels, each of them not vital, because there is a huge redundancy among them for the vital nervous system. Taylor *et al*. categorize them morphologically based on parallel vessels with multiple perforators into the nerve, or scattered perforators from nonparallel vessel sources (*5*). Preserving any type of extrinsic vessels from the surrounding feeder tissue sustains the intrinsic nerve vascularity for relatively long distance.

We usually harvest vascularized nerves as a free neurovascular flap, which is axially based, for example lateral femoral cutaneous nerve (LFCN). The superficial circumflex iliac artery perforator (SCIP) accompanies the LFCN (*6,7*). It can also be harvested based on the deep circumflex iliac artery, which lies deeper and harvesting is more invasive (*5*). LFCN nourished by the SCIP (LFCN-SCIP) flap can be harvested as a long nerve flap with a guaranteed axial continuous vascularization avoiding central nerve necrosis. It is possible, from our experience, to harvest an over 15 cm long nerve graft. Intraoperatively it is assessed for viability by bright colored bleeding at the nerve endings. The superficial circumflex iliac artery originates from the femoral artery and this flap does not require main artery sacrifice. Compared to common nerve flaps, LFCN-SCIP flap shows a well concealed donor scar site and less invasiveness.

In the inferolateral abdominal region, there are two workhorse neurovascular flaps, which are capable of providing a vascularized nerve graft with or without composite tissue coverage. These are the LFCN-SCIP flap or the superficial inferior epigastric artery (SIEA) flap with the subcostal nerve (T12) respectively the iliohypogastric nerve (IHN).

IHN-SIEA was applied for a volar nerve defect of a 55-year-old patient with posttraumatic composite tissue defect of the palm, including a 3.6 cm nerve defect of the 3rd common digital, ulnar and radial digital nerves. The IHN was vascularized through the anastomosis of the SIEA (diameter = 0.5 mm) to the 3rd common digital artery stump. After 6 months, the 2-point discrimination inside the flap was restored up to 4.17 mm distally, as compared to 2 mm in the control (*8*).

LFCN based on SCIP flap can be applied to any kind of nerve reconstruction. The advantage of SCIP flap is that it can be harvested as vascularized composite graft less invasively. It is especially suitable for hand complex injuries. Of course, it is also available for simple nerve reconstruction as in facial palsy. However, one major further benefit is the possibility of chimeric flap design including muscle, bone and skin for further compound defect reconstruction (*9*).

Another example is the LFCN-anterior lateral thigh (LFCN-ALT) flap, which is larger in the reconstructed nerve diameter. A 70-year-old female with recurrent, extremely painful CTS neuroma in continuity was treated with a 2 cm LFCN-ALT neurovascular flap, especially due to recurrent scarring. The severe pain disappeared completely and the motor impairment of median nerve improved after 5 months (*10*).

In conclusion, nerve vascularity must be considered, when treating peripheral nerve defects. Neurovascular SCIP flap is preferable for vascularized nerve flap transfer due to its axial pattern, versatility and hidden donor site. Another option is the ALT flap with the larger LFCN sensory nerve.

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