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ARTICLE

Treatment of painful median nerve neuroma using pedicled vascularized lateral antebrachial cutaneous nerve with adipofascial flap: a cadaveric study and exploration of clinical application

Kenji Kawamura[a], Shohei Omokawa[b], Naoki Maegawa[a], Yasuaki Nakanishi[a], Takamasa Shimizu[a], Mitsuyuki Nagashima[a], Hideo Hasegawa[a], Hiroshi Okada[a], Kanit Sananpanich[c], Pasuk Mahakkanukrauh[d] and Yasuhito Tanaka[a]

[a]Department of Orthopaedic Surgery, Nara Medical University, Kashihara, Japan; [b]Department of Hand Surgery, Nara Medical University, Kashihara, Japan; [c]Department of Orthopedics, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand; [d]Department of Anatomy, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand

ABSTRACT

The most common procedure for the treatment of painful median nerve neuroma is coverage with vascularized soft tissue following external neurolysis. However, the ideal treatment should include reconnecting the proximal and distal stumps of the damaged nerve to allow the growth of regenerating axons to their proper targets for a functional recovery. We developed a useful technique employing radial artery perforator adipofascial flap including the lateral antebrachial cutaneous nerve (LABCN) to repair the median nerve by vascularized nerve grafting and to achieve coverage of the nerve with vascularized soft tissue. In an anatomical study of 10 fresh-frozen cadaver upper extremities, LABCN was constantly bifurcated into two branches at the proximal forearm (mean: 8.2 cm distal to the elbow) and two branches that run in a parallel manner toward the wrist. The mean length of the LABCN branches between the bifurcating point and the wrist was 18.2 cm, which enabled inclusion of adequate length of the LABCN branches into the radial artery perforator adipofascial flap. The diameters of the LABCN branches (mean: 1.7 mm) were considered suitable to bridge the funiculus of the median nerve defect after microsurgical internal neurolysis. In all cadaver upper extremities, the 3-cm median nerve defect at the wrist level could be repaired using the LABCN branches and covered with the radial artery perforator adipofascial flap. On the basis of this anatomical study, the median nerve neuroma was successfully treated with radial artery perforator adipofascial flap including vascularized LABCN branches.

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Introduction

Median nerve injuries at the wrist are common and result from lacerations, motor vehicle accidents, and iatrogenic mishap during carpal tunnel release procedures [1,2]. Painful neuromas can develop even after microsurgical repair of a median nerve injury or when the lesion is underestimated and therefore not adequately repaired [3]. The treatment of painful neuromas aims to both minimize pain and restore the function of the median nerve. Different techniques have been introduced to treat painful median nerve neuromas, and there has been no one way that is completely effective in the treatment [4]. One of the newer methods for treatment of median neve neuromas is coverage of the neuromas with vascularized soft tissue following external neurolysis [5–7]. This procedure can improve nutrition delivery to the nerve, restrict the degree of scar adhesion, and prevent the nerve lesion from resting in a vulnerable position close to the skin surface [8,9].

The ideal treatment of neuromas should include reconnecting the proximal and distal stumps of the damaged nerve to allow the growth of regenerating axons to their proper targets for functional recovery. When repair of the damaged median nerve is attempted, nerve grafting is typically necessary after microsurgical internal neurolysis of the neuroma [10]. However, nerve grafting can lead to recurrent neuroma formation as a result of failure of entry of the regenerating axons into the nerve graft in a scarred bed [11], which complicates nerve repair in the treatment of neuromas of the median nerve. Conversely, vascularized nerve grafting has the potential for healing intractable neuromas because it diminishes endoneural scarring by maintaining the Schwann cell population and decreasing fibroblast infiltration, thereby providing an optimal nutritional environment that facilitates an increased rate of axonal regeneration [12,13].

To accomplish successful repair of the median nerve neuromas with vascularized nerve grafting as well as coverage with vascularized soft tissue, we developed a useful technique employing radial artery perforator adipofascial flap including a lateral antebrachial cutaneous nerve (LABCN). On the basis of a cadaveric anatomical study, a patient with median nerve neuroma was successfully treated using this new technique.

Materials and methods

Ten fresh-frozen cadaver upper extremities (five right and five left) from five cadavers were investigated. All five cadavers were men, with a mean age of 72 years (range, 51–78 years). The

CONTACT Kenji Kawamura kkenji@naramed-u.ac.jp Department of Orthopaedic Surgery, Nara Medical University, 840 Shijyo-cho, Kashihara, 634-8522, Nara, Japan.

cadaver's height ranged from 160 to 186 cm (mean: 168 cm). A 14-gauge catheter was placed in the brachial artery, and 20 ml of silicone rubber compound (Microfil®; Flow Tech Inc., Carver, MA, USA) was injected with the cadaveric upper extremity under manual pressure. Anatomical dissection of the forearm was performed under 2.5 × loupe magnification an hour after the injection.

First, the LABCN was identified from the elbow to the wrist. The LABCN was always bifurcated into two branches at the proximal forearm. The distances from the elbow to the bifurcating point of the LABCN and from the bifurcating point of the LABCN to the wrist were measured in each cadaver arm; the diameter of each LABCN branch was also individually measured. Next, the distally based radial artery perforator adipofascial flap including the LABCN branches was harvested. The pivot point of the adipofascial flap was 3 cm proximal to the radial styloid because the perforators from the radial artery were observed to be arising at a point located approximately 1.5–3 cm proximal to the radial styloid [14]. The two LABCN branches were cut to create four vascularized nerve grafts, with each nerve graft measuring 3 cm in length. Next, the adipofascial flap was turned 180° and the 3-cm median nerve defect at the wrist level was bridged using the four vascularized LABCN branches. The median nerve was covered with the adipofascial flap after nerve repair. We investigated whether this technique could be successfully applied in all 10 cadaver upper extremities.

Results

In one of ten cadaver upper extremities, the LABCN was bifurcated into three branches. There was the first bifurcating point at 1.0 cm distal to the elbow joint. The lateral branch of the first bifurcation was small (diameter: 1.6 mm) and ran toward the posterior forearm, whereas the medial branch was large (diameter 2.2 mm) and bifurcated again into two branches at 8.0 cm distal to the elbow joint. In this upper extremity, the lateral branch of the first bifurcation was not included in the examination.

The distance from the elbow joint to the bifurcating point of the LABCN ($n = 10$) ranged from 6.0 to 9.5 cm (mean: 8.2 cm). Notably, after bifurcation, the two LABCN branches ran in a parallel manner toward the wrist and the distance from the bifurcating point of the LABCN to the wrist ranged from 14 to 22.5 cm (mean: 18.2 cm). The diameters of the LABCN before bifurcation ($n = 10$) ranged from 2.0 to 2.6 mm (mean: 2.3 mm), whereas the diameters of the individual LABCN branches after bifurcation ($n = 20$) ranged from 1.4 to 2.2 mm (mean: 1.7 mm) (Table 1). The diameters of smaller LABCN branches ($n = 10$) ranged from 1.4 to 1.8 mm (mean: 1.5 mm) and larger LABCN branches ranged from 1.7 to 2.2 mm (mean: 1.9). For example, in the right forearm of a cadaver (height: 167 cm), the distance from the elbow joint to the bifurcating point of the LABCN was 9.0 cm and the distance from the bifurcating point of the LABCN to the wrist was 17.5 cm. The diameter of the LABCN before bifurcation was 2.5 mm and the diameters of the LABCN branches after bifurcation were 1.9 and 1.6 mm (Figure 1). In all 10 cadaver upper extremities, the 3-cm median nerve defect at the wrist level could be adequately repaired using the LABCN branches and covered with the radial artery perforator adipofascial flap.

Table 1. Summary of anatomical study findings, average (range).

Distance from elbow to bifurcating point of LABCN ($n = 10$)	8.2 cm (6.0 – 9.5)
Distance from bifurcating point of LABCN to wrist ($n = 10$)	18.2 cm (14 – 22.5)
Diameter of LABCN after bifurcation ($n = 20$)	1.7 mm (1.4 – 2.2)

Abbreviation: LABCN: lateral antebrachial cutaneous nerve.

Case report

A 74-year-old left-handed woman sustained an iatrogenic left median nerve injury during carpal tunnel release surgery performed 3 years previously. Although she underwent microsurgical repair of the median nerve immediately, left wrist pain and sensory disturbance persisted. One year after her left median nerve injury, she visited our clinic for further treatment. She complained of burning pain in the left median nerve distribution area. Tinel's sign was positive over the median nerve at the wrist level. The key pinch strength of the left thumb was 1.8 kg (5 kg in the right thumb). The score of the Semmes–Weinstein (S-W) monofilament test was 5.12 (loss of protective sensation) and the static 2-point discrimination (s2PD) test was 15 mm in the left thumb. Moreover, the Disabilities of the Arm, Shoulder and Hand (DASH) score was 54 points. Magnetic resonance imaging showed median nerve neuroma formation at the wrist level. Additionally, surgical exploration revealed the same (Figure 2). Further, a 4-cm partial defect of the median nerve was identified after microsurgical internal neurolysis (Figure 3). A distally based radial artery perforator adipofascial flap including the LABCN branches was harvested and a tourniquet was subsequently released to visualize the blood supply of the flap (Figure 4). The patient's median nerve defect was

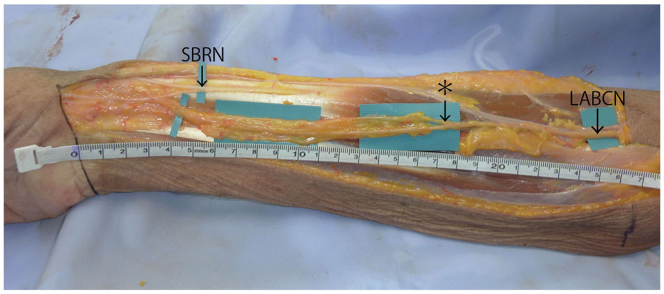

Figure 1. Photograph showing dissection of the cadaver forearm. The asterisk (*) showed the bifurcating point of the lateral antebrachial cutaneous nerve. Abbreviation: LABCN: lateral antebrachial cutaneous nerve; SBRN: superficial branch of the radial nerve.

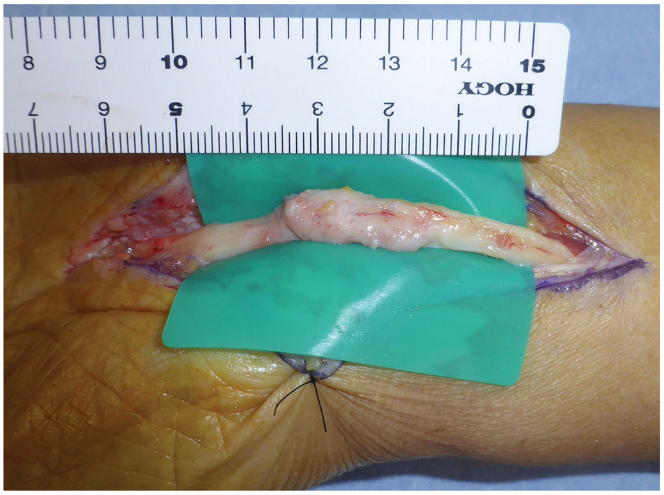

Figure 2. Intraoperative photograph of the presented case (1). Surgical exploration revealed a left median nerve neuroma at the wrist.

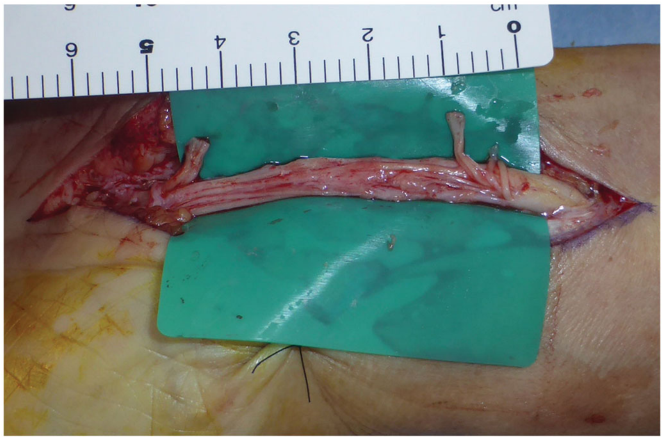

Figure 3. Intraoperative photograph of the presented case (2). There was a 4-cm partial defect in the median nerve noted after microsurgical internal neurolysis.

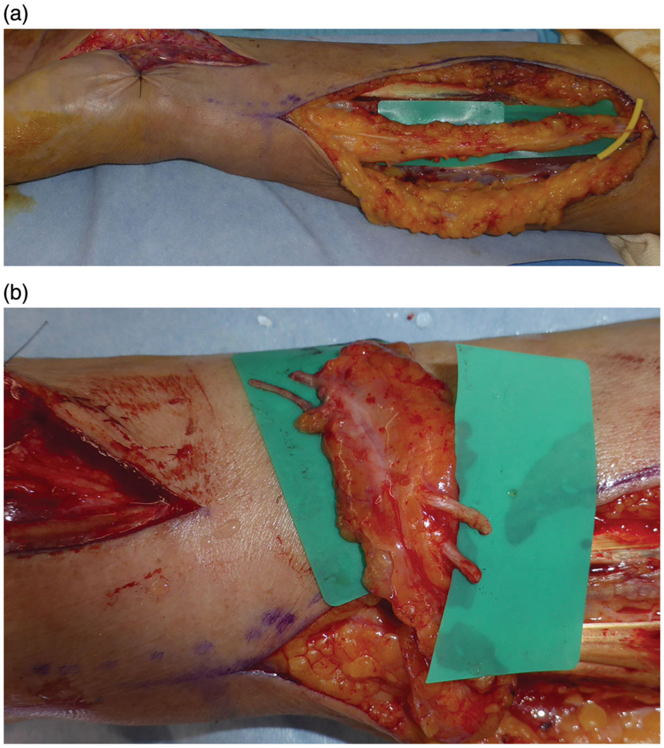

Figure 4. Intraoperative photograph of the presented case (3). (a) A distally based radial artery perforator adipofascial flap including the lateral antebrachial cutaneous nerve was harvested. (b) The tourniquet was released to visualize the blood supply in the flap.

Figure 5. Intraoperative photograph of the presented case (4). The median nerve defect was repaired using the vascularized nerve grafts (a) and covered with the adipofascial flap (b).

Figure 6. Postoperative photograph of the presented case. The patient showed strong thumb opposition, and there was no atrophy in the adipofascial flap observed at 2 years after the surgery.

repaired with two 4-cm vascularized LABCN branches and covered with a vascularized adipofascial flap (Figure 5). At 2 years after surgery, she did not experience any pain and Tinel's sign over the median nerve had disappeared. The sensitivity in the left thumb had improved to 3.61 score (diminished light touch sensation) by S-W test and 6 mm by s2PD test. The DASH score had improved to 10 points and the patient showed strong thumb opposition (3.5 kg of the key pinch strength), with no atrophy in the adipofascial flap (Figure 6).

Discussion

The surgical management of patients with painful neuromas follows three principles: (1) If appropriate distal nerve and sensory receptors are available, a nerve graft can be used to direct fibers from the proximal stump distally into the nerve; (2) if a distal nerve is not available and restoration of function is critical, innervated free tissue transfers can be used to accept the regeneration nerves from the injured nerve; and (3) if the local tissue environment is not suitable for a nerve graft, or if the patient has had multiple previous unsuccessful operations for pain control, the neuroma is resected and the proximal stump of the nerve is managed in one of the several manners such as transposition into muscle or vein, burying in bone, nerve stripping, and silicone rubber capping [4,7]. The present study was aimed to develop a useful technique in order to restore the median nerve function with painful median nerve neuromas which is not usually suitable for a nerve graft because of a scarred recipient bed.

The present anatomical study showed that the LABCN typically bifurcates into two branches at the proximal forearm (mean: 8.2 cm distal to the elbow) and both branches run parallel toward the wrist. The mean length of the LABCN branches measured between the bifurcating point and the wrist was 18.2 cm, enabling inclusion of an adequate length of each LABCN branch into the radial artery perforator adipofascial flap. The diameters of the LABCN branches (mean: 1.7 mm) were considered suitable to bridge the funiculus of the median nerve defect. This anatomical study revealed that the 3-cm median nerve defect at the wrist level could be bridged using four vascularized LABCN branches. However, the length of nerve defects and number of the damaged funiculus in the neuroma vary; thus, the length and number of vascularized LABCN branches should be considered in each clinical case. In cases with large nerve defects, nonvascularized nerve grafts may need to be combined with vascularized LABCN grafting. The best indication for this technique is a neuroma in the continuity of the median nerve, which typically results from peripheral nerve lesions with preserved continuity of the nerve trunk but loss of distal function to varying extent [5,9,15]. In this type of neuroma, some funicular bundles of the nerve remain intact and there is a possibility of successful resection and repair of the damaged portion [4].

Wrapping a painful median nerve neuroma with the radial artery perforator adipofascial flap after neurolysis is not a new technique. Adani et al. reported the treatment of eight cases of painful median nerve neuromas using a radial artery or ulnar artery perforator adipofascial flap [3]. They performed coverage of the median nerve neuromas with the adipofascial flaps following external neurolysis without microsurgical internal neurolysis. A satisfactory decrease in the pain level was experienced by five patients, mild pain persisted in two patients, and one patient did not report any improvement in their pain level after surgery. Tinel's sign disappeared in five cases, was reduced in two cases, and remained unchanged in one case. Recovery of sensory function was achieved after surgery in only three cases. No postoperative changes occurred in the motor function of the thenar muscles. These results support the idea that coverage of a median nerve neuroma with an adipofascial flap after only external neurolysis might be effective for achieving pain relief but not functional recovery. Regarding the safe elevation of the radial artery perforator adipofascial flap, they described that the proximal margin of the flap was located 10 cm distal to the elbow and the distal base of the flap was 2–4 cm proximal to the radial styloid. Our anatomical study showed that the mean bifurcating point of the LABCN was 8.2 cm distal to the elbow. These findings indicate that LABCN branches included in the radial artery perforator adipofascial flap achieve good vascularity from the vascular network within the adipofascial flap [16].

Ideally, reconnecting the proximal and the distal stumps of a damaged nerve in median nerve neuroma after microsurgical internal neurolysis is warranted to allow the growth of regenerating axons to their proper targets for a functional recovery. Successful transfer of a nonvascularized nerve graft requires a well-vascularized recipient bed because the revascularization of a nonvascularized nerve graft is accomplished mainly through the surrounding tissue. Even under ideal conditions, it requires 3 weeks for a nonvascularized nerve graft to revascularize [12]. The ischemia of a nonvascularized nerve graft in a scarred recipient bed is associated with intraneural fibrosis of the graft, which does not guarantee a favorable result [11]. In the median nerve neuroma at the wrist, the recipient bed is so badly scarred that it will not support a nonvascularized nerve graft. In comparison with a nonvascularized nerve graft, a vascularized nerve graft has several theoretical advantages, including increased and faster regeneration, decreased intraneural fibrosis, and better Schwann cell survival [12,13]. These advantages enable usage of a vascularized nerve graft even in cases with a scarred recipient bed, proximal nerve lesions, or large nerve gaps [17]. Furthermore, vascularized nerve grafting has the potential to heal intractable neuromas because it diminishes endoneural scarring by maintaining the Schwann cell population and decreasing fibroblast infiltration, thus providing an optimal nutritional environment that promotes an increased rate of axonal regeneration. Moreover, a vascularized nerve graft has the ability to act as a vascular carrier system for a nonvascularized nerve graft if the two grafts are applied together. Although a free vascularized sural nerve graft, which has been one of the most popular vascularized nerve grafts, can be applied in the treatment of median nerve neuromas, operative procedures, including harvesting the graft from the lower extremity and performing microvascular anastomosis in the forearm, are complicated. The presented technique using radial artery perforator adipofascial flap including LABCN branches is simple and reliable because repair of the median nerve with vascularized nerve grafting as well as coverage of the nerve with vascularized soft tissue can be simultaneously completed without microvascular anastomosis.

The presented case showed pain relief as well as restoring of the median nerve function postoperatively. Repair of the damaged funiculus with the vascularized LABCN grafting after microsurgical internal neurolysis served re-starting of nerve regeneration of the damaged median nerve. Coverage of the repaired median nerve with the adipofascial flap provided an ideal recipient bed for nerve regeneration and prevented re-formation of a neuroma. Furthermore, the adipofascial flap served pain relief by prevention of the nerve lesion from resting in a vulnerable position close to the skin surface.

In conclusion, radial artery perforator adipofascial flap including vascularized LABCN branches may be a good treatment alternative for patients with painful median nerve neuroma, particularly in those with neuroma in continuity, to both minimize pain and restore function of the median nerve.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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