CASE REPORT

Meaningful power grip recovery after salvage reconstruction of a median nerve avulsion injury with a pedicled vascularized ulnar nerve

Aaron C Van Slyke MD MSc, Leigh A Jansen MD MSc, Sally Hynes MD, Jane Hicks BSR PT CHR, Sean Bristol MD, Nicholas Carr MD

AC Van Slyke, LA Jansen, S Hynes, J Hicks, S Bristol, N Carr. Meaningful power grip recovery after salvage reconstruction of a median nerve avulsion injury with a pedicled vascularized ulnar nerve. Plast Surg 2015;23(4):265-268.

In cases of median nerve injury alongside an unsalvageable ulnar nerve, a vascularized ulnar nerve graft to reconstruct the median nerve is a viable option. While restoration of median nerve sensation is consistently reported, recovery of significant motor function is less frequently observed. The authors report a case involving a previously healthy man who sustained upper arm segmental median and ulnar nerve injuries and, after failure of sural nerve grafts, was treated with a pedicled vascularized ulnar nerve graft to restore median nerve function. Long-term follow-up showed near full fist, with 12 kg of grip strength, key pinch with 1.5 kg of strength and protective sensation in the median nerve distribution. The present case demonstrates that pedicled ulnar vascularized nerve grafts can provide significant improvements to median nerve sensory and motor function in a heavily scarred environment.

Key Words: *Nerve grafts; Peripheral nerve; Reconstruction; St Clair Strange; Upper extremity; Vascularized*

Une importante récupération de la prise de force après une reconstruction de rattrapage d'une avulsion du nerf médian par le nerf cubital pédiculé vascularisé

Une greffe du nerf cubital vascularisé pour reconduire le nerf médian est une solution viable lorsque le nerf cubital ne peut pas être récupéré. La sensation du nerf médian est presque toujours rétablie, mais la fonction motrice significative l'est moins. Les auteurs présentent le cas d'un homme auparavant en santé qui a subi des traumatismes des nerfs médian et cubital du bras et, après le rejet des greffes du nerf saphène externe, a subi une greffe du nerf cubital pédiculé vascularisé pour rétablir la fonction du nerf médian. Au suivi à long terme, le poing était presque complet, la prise de force atteignait 12 kg, la pince sub-termino-latérale s'associait à une force de 1,5 kg et la distribution du nerf médian était liée à une sensation protectrice. Le présent cas démontre que des greffes du nerf cubital pédiculé vascularisé peuvent améliorer considérablement la fonction sensorielle et motrice du nerf médian très cicatrisé.

Peripheral nerve injuries of the upper extremity are devastating injuries that can be effectively addressed with conventional nerve grafts, nerve transfers or vascularized nerve grafts (VNGs). While randomized controlled studies comparing VNGs and non-VNGs are lacking, most evidence suggests that VNGs produce superior results clinically and experimentally (1). Factors that warrant the use of VNGs over conventional nerve grafts are long graft length, poor vascular supply of the recipient bed, large-calibre nerve reconstruction, and prolonged denervation time from injury to presentation (1).

Strange (2) described the first pedicled nerve graft where an ulnar VNG was used to repair a median nerve defect (2). The vascular anatomy of the ulnar nerve is complex (Figure 1). It is supplied by regional arteries that provide multiple dominant pedicles that give off ascending and descending branches, which coalesce to form a continuous artery travelling along the exterior surface of the nerve (3). There are four dominant pedicles (3). In the arm, the ulnar nerve is supplied by the superior ulnar collateral artery arising from the brachial artery approximately 14 cm to 22 cm above the medial epicondyle (3). At the medial epicondyle, it is nourished by the supratrochlear and posterior ulnar recurrent artery (3). The supratrochlear artery, also arising from the brachial artery, has ascending and descending branches that anastomose with the superior ulnar collateral and posterior ulnar recurrent arteries, respectively (3). The ulnar nerve is accompanied by the ulnar artery below the elbow (3).

The use of ulnar VNGs to repair avulsion injuries to the median nerve are favoured in heavily scarred environments and when the ulnar nerve is not salvageable (1). While the restoration of protective sensation in the median nerve distribution has been consistently documented (1,2,4-7), the return of well-documented significant measurable improvements in median nerve motor function is variable (1,2,4-10). Here, we report a case of segmental median and ulnar nerve loss, failed sural nerve graft reconstruction, and subsequently successful restoration of median nerve function using a pedicled ulnar VNG.

CASE PRESENTATION

An 18-year-old right-hand dominant healthy man sustained avulsion injuries in his left upper arm to the brachial artery, musculocutaneous, median and ulnar nerves, and muscle disruption to the brachialis and biceps muscles at the mid-humeral level, including avulsion of the musculocutaneous nerve from the neuromuscular junction of the biceps, from a rollover motor vehicle accident in August of 2010. He presented with distal sensory deficits and a pulseless left limb that was initially treated with a saphenous vein graft to the brachial artery. The biceps was repaired and the avulsed musculocutaneous nerve was neurotized by direct replantation into the muscle. Nonvascularized bilateral sural nerve grafts of 9 cm and 7.5 cm in length were placed to repair the median and ulnar nerves, respectively. His postoperative course was complicated by multiple surgeries for recurrent thrombosis of his vascular graft and surrounding infection. Three weeks after his injury, the sural nerve grafts were disrupted by hematoma and infection with resulting debridement. He was left with 14 cm and 16 cm gaps between the transected ends of the ulnar and median nerves, respectively (Figure 2), and no available sural nerves for conventional nerve grafting.

It was decided to sacrifice the ulnar nerve as a pedicled VNG to reconstruct the median nerve. Normal vascular anatomy of the radial

Division of Plastic Surgery, Department of Surgery, University of British Columbia, Vancouver, British Columbia
Correspondence: Dr Aaron Van Slyke, Division of Plastic Surgery & Burn Unit, University of British Columbia & Vancouver General Hospital, 2nd Floor, JPP, 855 West 12th Avenue, Vancouver, British Columbia V5Z 1M9. Telephone 604-837-8770, e-mail vanslykeaaron@gmail.com

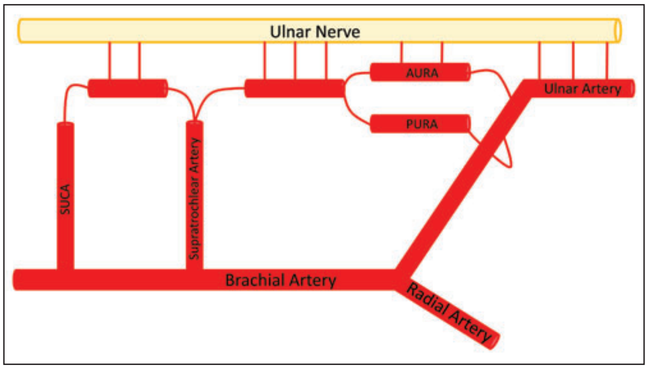

Figure 1) *Vascular anatomy of the ulnar nerve. At the level of the elbow, there is a network of vessels, with contribution from the superior ulnar collateral artery (SUCA), supratrochlear artery, anterior ulnar recurrent artery (AURA), posterior ulnar recurrent artery (PURA) and ulnar artery that parallel the ulnar nerve and comprise a continuous arterial supply via segmental perforators*

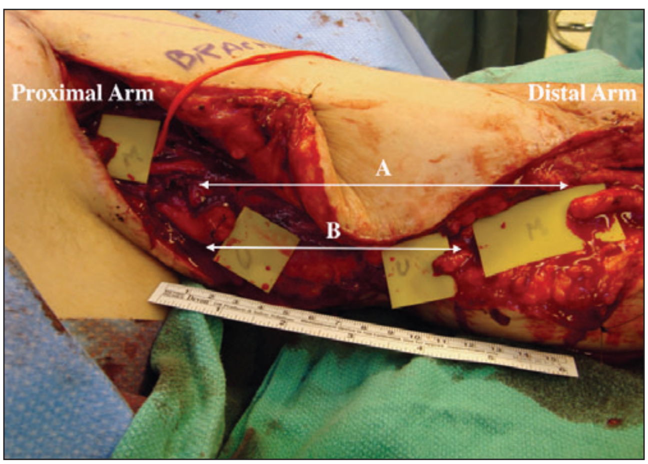

Figure 2) *Intraoperative view of remaining defects. After sural nerve graft failure, the patient was left with a 14 cm and 16 cm defect in the ulnar and median nerves, respectively, with no available sural nerves for conventional nerve grafting. Vessel loop around saphenous vein graft to brachial artery.* **A** *Median nerve gap of 16 cm.* **B** *Ulnar nerve gap of 14 cm*

and ulnar arteries and palmar arch was confirmed by angiography. Three months postinjury, a pedicled ulnar VNG to repair the median nerve defect was performed (Figure 3).

The ulnar nerve was pedicled based off the superior ulnar collateral artery. The ulnar nerve segment spanned from the medial epicondyle to the bifurcation of the superficial and deep motor branches, yielding a segment sufficient to reconstruct the 16 cm defect in the median nerve that spanned from where the median nerve arises from the medial and lateral cords of the brachial plexus to mid-humerus. The ulnar nerve was reversed on its pedicle and rotated 180° (Figure 3). The ends of the VNG and the median nerve defect were dissected back to visually normal nerve as seen with the operating room microscope. Coaptation was perfomed by microscopic neurorraphy reinforced with Tisseel (Baxter Canada).

Two months after the transposition of the ulnar VNG and five months from the initial injury, examination of his left arm revealed: biceps, 4 of 5 strength against significant resistance (likely due to successful neurotization of the musculocutaneous nerve and also due to recovery of brachialis); flexor carpi radialis (FCR), 4 of 5 strength; flexor pollicis longus (FPL), 1 of 5 strength; and positive Tinel's sign 2 cm proximal to the antecubital crease. At 17 months postoperatively, protective sensation was present in all digits supplied by the median nerve; however, thenar function had not recovered and a mild

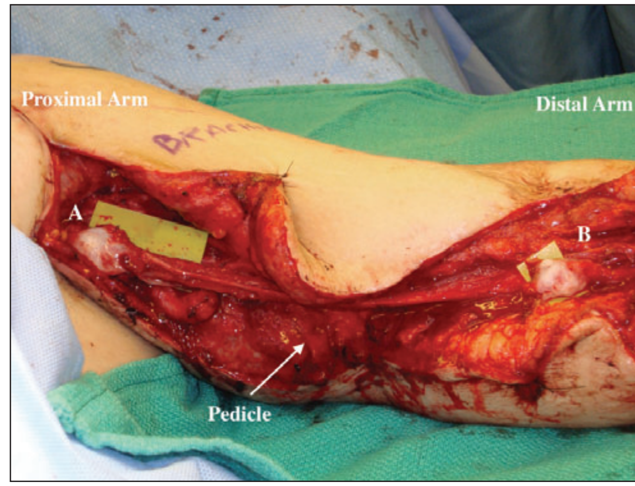

Figure 3) *Ulnar vascularized nerve graft in place and reinforced with Tisseel (Baxter Canada). At three months' post-injury, the patient received a pedicled ulnar vascularized nerve graft (VNG) to reconstruct the median nerve. Labels* (**A**) *and* (**B**) *denote distal and proximal ends of ulnar VNG, respectively*

claw deformity was present in all digits. The patient subsequently underwent a Zancolli lasso anti-clawing procedure and Burkhalter opponensplasty in May 2013. Four weeks later, he had near complete correction of his claw deformity and, after an additional three weeks, he could oppose his thumb to the base of the small finger.

In addition to his operative management, the patient attended a six-week course of hand therapy starting one month after receiving the Burkhalter opponensplasty, approximately 2.5 years following the ulnar nerve graft transposition, at a frequency of two treatment sessions per week. Therapy focused on active mobilization and progression of light prehension and hand strengthening exercises. He then returned to part-time construction work and a rigorous self-designed workout schedule in the gym. He returned to hand therapy six months later and was fitted with a serial static night extension splint for the long finger proximal interphalangeal joint.

At slightly more than 3.5 years post-ulnar VNG transposition, the patient exhibited dramatic results (Figure 4 and Supplementary videos). Residual clawing was absent at rest, but present with extension, and he could almost make a complete fist with all four digits making skin contact with the palm (see Table 1 for complete active and passive range of motion measurements); additionally, he was able to actively oppose his thumb to the tip of the ring finger. Using Strauch's Ten Test, where 10 was normal compared with the uninjured contralateral arm, sensation was as follows: medial brachial cutaneous nerve, 1 of 10; medial antebrachial cutaneous nerve, 1 of 10; lateral antebrachial cutaneous nerve, 8 of 10; dorsal sensory branch of the radial nerve, 10 of 10; dorsal sensory branch of the ulnar nerve, 0 of 10; ulnar surface of the small finger, 0 of 10; radial surface of the index finger, 6 of 10; radial surface of the long finger, 5 of 10; and palmar branch of the median nerve, 8 of 10. Dynamic two-point discrimination at the tip of the index, long and small fingers were 6 mm, 12 mm and insensate, respectively. His grip strength was 12 kg in the left hand and 54 kg in the right, key pinch was 1.5 kg on the left and 14 kg on the right, and there was no measureable tip or chuck pinch strength. Biceps, pronator, FCR, flexor digitorum superficialis (FDS) of index, middle and ring fingers, and flexor digitorum profundus (FDP) of the index were graded as 4 of 5 but with significant resistance achieved. FDS of the small finger was 3 of 5, FDP of the long finger was 4 of 5, FDP of the ring finger was 3 of 5, FDP of the small finger was 3 of 5, FPL was 4 of 5 (Supplementary video) and the first dorsal interosseous muscle was 0 of 5. Despite having his ulnar nerve transected, the patient did not experience pain in the ulnar nerve

TABLE 1
Active and passive range of motion

	Flexion		Extension	
Digit	**Active**	**Passive**	**Active**	**Passive**
Small finger	MCP: 90°	MCP: 130°	MCP: 225°	
	PIP: 60°	PIP: 90°	PIP: 140°	PIP: 160°
	DIP: 30°	DIP: 90°	DIP: 135°	DIP: 180°
Ring finger	MCP: 90°	MCP: 90°	MCP: 205°	
	PIP: 90°	PIP: 90°	PIP: 170°	PIP: 180°
	DIP: 20°	DIP: 85°	DIP: 175°	DIP: 180°
Long finger	No deficit	No deficit	MCP: 210°	
			PIP: 130°	PIP: 160°
			DIP: 170°	DIP: 180°
Index finger	No deficit	No deficit	MCP: 220°	
			PIP: 130°	PIP: 175°
			DIP: 170°	DIP: 180°

Active and passive flexion and extension at each joint of each digit of the left hand, measured with a goniometer at three and a half years post ulnar vascularized nerve graft transposition. DIP Distal interphalangeal joint; MCP Metacarpophalangeal joint ; PIP Proximal interphalangeal joint

distribution or at the proximal ulnar nerve stump. He did, however, report paresthesias on palpation of the proximal coadaptation site within the axilla with radiation into the index and long fingers. In addition, he also experiences hypersensitivity to temperature over the thenar eminence. There were no complications following VNG transposition, and the patient did not experience ongoing neuropathic pain nor require any pain medications or referrals to pain clinics.

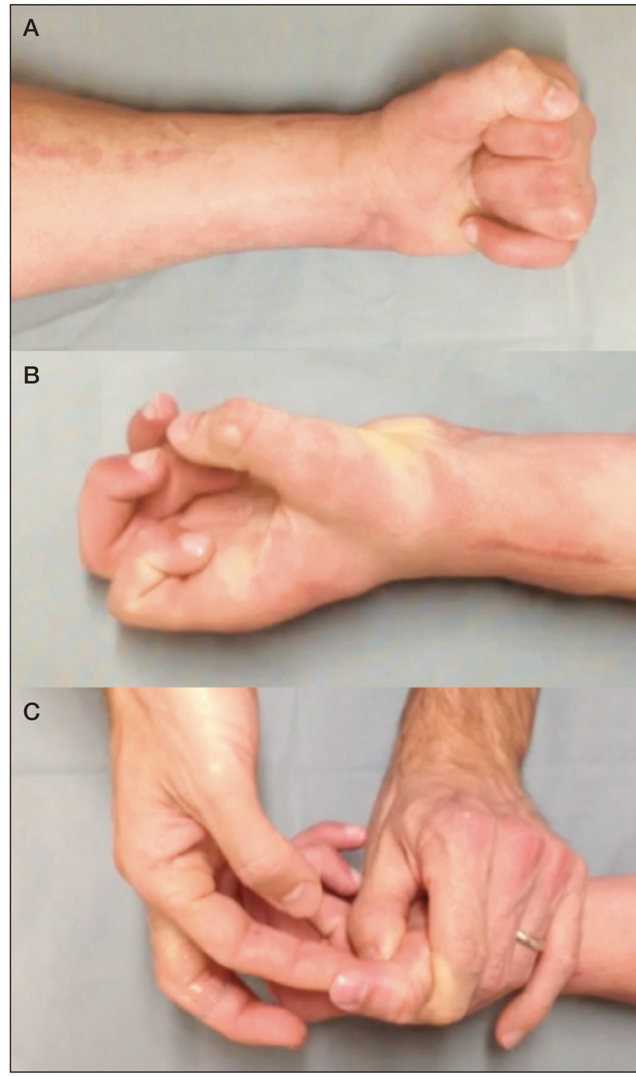

Figure 4) *Postoperative hand function. At 3.5 years post ulnar vascularized nerve graft transposition, the patient is able to make a fist (***A***) with 12 kg of grip strength, oppose his thumb to the ring finger (***B***), and exhibit full flexion of his thumb interphalangeal joint with 4 of 5 strength of his flexor pollicis longus muscle (***C***). See the supplementary material for videos demonstrating this*

DISCUSSION

The first pedicled nerve graft was a two-stage nerve grafting procedure described by Strange (2) to repair a median nerve transection by sacrificing the ulnar neurovascular bundle. During the first stage, the proximal ends of the ulnar and median nerve defects were conjoined, followed by neurotomy of the ulnar nerve above the cubital tunnel with subsequent placement of the proximal stump within the triceps muscle (2,4). The second stage was performed seven months later, in which the ulnar nerve was transferred distally from its temporary location in the triceps muscle to join the median nerve in the palm (2,4). This two-stage nerve grafting procedure was successful at restoring median nerve sensation but not motor function (2). Other authors have had similar success with the Strange procedure or variations of it (1,2,4-10), but recovery of well-documented quantitative motor findings is variable. One report described "full thenar muscle strength" in two of three patients (10), whereas another report described "some recovery of motor activity in the thenar muscles" following a two-stage ulnar VNG and opponensplasty (8). Sheldon et al (9) followed three patients after two-stage ulnar VNG transposition and observed restoration of voluntary action of the flexor pollicis brevis and opponens pollicis muscles at three months postoperatively in one patient, and a "useful degree of motion" in the thumb of a second patient. In another case series, one patient could resist gravity for the FDP and FPL muscles at three months post ulnar VNG transposition, and a second patient, who also received a subsequent opponensplasty, was able to withstand strong resistance in the wrist flexors, FPL and FDP at two years postinjury (5). Finally, five patients who received two-stage ulnar VNGs with various tendon transfers were reported to be able to assist themselves with activities of daily living using their injured extremity either directly or as an assist, but no quantifiable measurements of motor function were reported (4).

Conventional nerve grafts are effective treatment options. However, in cases with poor recipient beds, and/or where large-calibre and/or long nerve grafts are required, then non-VNGs are less effective (1). This is confirmed in a recent literature review and large retrospective case series based on one institution's 23 years of experience repairing median nerve deficits, suggesting VNGs are superior to nonvascular nerve grafts (1).

Favourable prognostic factors for the use of ulnar VNGs to repair median nerve deficits are decreased delay from injury to surgery, harvest of the ulnar VNG from the ipsilateral arm, younger age, and distal rather than proximal lesions (1,11). Interestingly, there does not appear to be a significant difference in functional results when free versus pedicled ulnar VNGs are used (1).

After failing repair with nonvascularized sural nerve grafts, we decided to sacrifice the ulnar nerve as a VNG single-stage procedure to restore median nerve function. While recovery of median nerve sensation is similar to that previously described (1,2,4-10), his motor recovery is beyond expectations from other reports. Remarkably, our patient demonstrates meaningful grip and key pinch strength, with near full recovery of strength in FCR, FPL and FDP of the index and long fingers, and FDS of the index, long and ring fingers.

As with high median nerve injuries, our patient presented with sensory, proximal and distal motor deficits. The VNG was beneficial for sensation and proximal median innervated muscles (FCR, FPL, FDS, FDP) but not for distal thenar muscles. In the present case, we performed the VNG first, and then followed the patient to monitor the extent of recovery, including the distally innervated thenar muscles, before performing a secondary opponensplasty. Given that we did not observe any significant recovery of thenar muscle function, and given that recovery of thenar muscle function has not been promising in the literature (1,2,4-10), it may be reasonable to perform a secondary opponensplasty at the same time as the VNG in future similar cases.

While we are impressed with the results of this operation, it cannot be stressed enough that a large part of our success can be attributed to our highly motivated patient. His dedication to his own rehabilitation with strengthening exercises in the gym, along with the formal hand therapy he received has provided him with the outstanding results listed above.

Collectively, the present case highlights the utility of the ulnar vascularized nerve graft for restoration of sensory and proximal median nerve function when appropriate non-VNGs are not available or not appropriate for use, and distal reinnervation of the intrinsics is unlikely.

DISCLOSURES: The authors have no financial disclosures or conflicts of interest to declare.

INFORMED CONSENT: Written consent for release of the patient's historical, photographic and videographic information was obtained from the patient and included with submission of the manuscript.

REFERENCES

1. Terzis JK, Kostopoulos VK. Vascularized ulnar nerve graft: 151 reconstructions for posttraumatic brachial plexus palsy. Plast Reconstr Surg 2009;123:1276-91.
2. Strange FG. An operation for nerve pedicle grafting. Preliminary communication. Br J Surg 1947;34:423-5.
3. El-Barrany WG, Marei AG, Vallée B. Anatomic basis of vascularised nerve grafts: The blood supply of peripheral nerves. Surg Radiol Anat 1999;21:95-102.
4. Greenberg BM, Cuadros CL, Panda M, et al. St Clair Strange procedure: Indications, technique, and long-term evaluation. J Hand Surg 1988;13:928-35.
5. Hattori Y, Doi K, Ikeda K, et al. Vascularized ulnar nerve graft for reconstruction of a large defect of the median or radial nerves after severe trauma of the upper extremity. J Hand Surg 2005;30:986-9.
6. Macionis V. A pedicled vascularized ulnar nerve graft based on the epineurial vascular supply: A case report. J Reconstr Microsurg 2008;24:453-5.
7. Louis DS, Eckenrode JF. Autogenous nerve pedicle graft in the forearm. J Hand Surg 1986;11:703-6.
8. Hiles RW. Freeze dried irradiated nerve homograft: A preliminary report. Hand 1972;4:79-84.
9. Shelden CH, Pudenz RH, MacCarty CS. Two-stage autograft for repair of extensive median and ulnar nerve defects. J Neurosurg 1947;4:492-6.
10. Alpar EK, Brooks DM. Long-term results of ulnar to median nerve pedicle grafts. Hand 1978;1:61-4.
11. Ruijs AC, Jaquet JB, Kalmijn S, et al. Median and ulnar nerve injuries: A meta-analysis of predictors of motor and sensory recovery after modern microsurgical nerve repair. Plast Reconstr Surg 2005;116:484-94.