Acta Biomed 2021; Vol. 92, Supplement 1: e2021163 DOI: 10.23750/abm.v92iS1.9202

Original article

Muscle in vein conduits: our experience

A. Minini, A. Megaro
Clinica Ortopedica Università degli Studi di Brescia, Spedali civili di Brescia, Italy

Abstract. Muscle in vein (MIV) conduits have gradually been employed in the last 20 years as a valuable technique in bridging peripheral nerve gaps after nerve lesions who cannot undergo a direct tension-free coaptation. The advantages of this procedure comparing to the actual benchmark (autograft) is the sparing of the donor site, and the huge availability of both components (i.e. muscle and veins). Here we present a case serie of four MIV performed at our hospital from 2018 to 2019. The results we obtained in our experience confirmed its effectiveness both in nerve regeneration (as sensibility recovery) and in neuropathic pain eradication. Our positive outcomes encourage its use in selected cases of residual nerve gaps up to 30 mm.

Key words: Muscle in vein, nerve lesions, nerve conduits, digital nerve, nerve gaps.

Introduction

Digital nerve lesions are very common within hand injuries, with percentages reaching about 10% of all hand traumas[1] , frequently occurring associated to extended soft tissue loss. Primary nerve coaptation, whenever a tension-free suture is achievable, leads to better results [2, 3].In cases of wide nerve substance loss, when a direct end-to-end suture would demand an excessive tensile stress, the gold standard is still represented by autologous nerve grafting [4, 5], commonly the sural nerve.

Nevertheless, this procedure carries the disadvantages of sacrificing a healthy nerve, such as sensory loss at the harvesting site and neuroma formation [5]. To avoid these limitations, several alternative options have been proposed. Non-nervous material conduits have been widely used with positive results in nerve gap bridging [6-9]; these conduits create some sort of a track for sprouting axons from the proximal to the distal stump, limiting their dispersion troughout the surrounding tissues [10], and contribute to increase the concentration of neurotrophic factors within the tube [11, 12]; their main benefit is the preservation of healthy nerves with no co-morbidity at any donor site whatsoever. In order to find affordable alternatives, reconstructions with homologous hollow vein grafts have been used, although this technique carries the risk of scar formation around the graft with subsequent vein collapse, impairing nerve regrowth[13].

To overcome this complication, Brunelli et al.[14] described in 1993 the technique of fulfilling the vein graft with an autologous strip of muscle. Further studies have demonstrated that skeletal muscle, with its basal lamina, creates a suitable 3D structure acting as a scaffold for regerenating axons[12]; moreover, in vitro studies have shown that skeletal muscle cells produce supporting factors for regrowing nerve, such as brain-derived neurotrophic factor, glial cell-derived growth factor, bone morphogenetic protein 6, cardiotrophin 1, heparan sulfate, insulin-like growth factor, neurothophin 3 and 4, vascular endothelial growth factor [15] and Neuregulin 1, crucial for Schwann cell survival, proliferation and migration [16, 17]. These factors alltogether promote axonal regeneration within the vein graft that therefore acts as a "growing chamber".

Encouraging results of this technique on post-injury sensory recovery, as reported by Marcoccio and Vigasio

[18], helped muscle-in-vein (MIV) to regain popularity among reconstructive solutions, mostly thanks to its advantages comparing to hollow neurotubes (e.g. no adjunctive costs, histocompatibility) and autologous nerve graft (e.g. great availability of donor tissues, no comorbidity to the donor site). Here we present a case-serie of 4 MIV grafts performed between 2018 and 2019.

Clinical cases

Case 1

A 58 y.o. patient reported a sharp injury with a glass to the ulnar side of the 5th finger of his right hand. No neurovascular lesions were diagnosed at the first assessment in the E.R., so skin suture alone was performed.

With the onset of neuropathic pain, Tinel sign nearby the scar and hypo-anaesthesia at the ulnar tip of the finger, surgical revision was endorsed after 2 months.

Intraoperatively, an ulnar collateral nerve lesion with a port-trumatic neuroma was reported.

After wthe resection of the nerve stumps, a residual gap of 12 mm impaired an end-to-end tensionless suture (Fig.1a).

We therefore decided to perform a MIV graft harvesting a strip of muscle and a vein segment throughout a 2 cm incision on the anterior aspect of the homolateral forearm.

We sutured both the graft ends with four 9-0 Ethilon stitches at each side of suture (Fig.1b).

Postoperative dorsal splinting in a resting position (as in the Kleinert-fashion splint) was mantained for 3 weeks.

At the follow-up performed at 10 months, Tinel sign disappeared, VAS score decreased from 7/10 to 2/10, the static two point discrimination (2PD) at the ulnar tip of the finger was 3mm (stratified as reported in the Modified guidelines of the American Society for Surgery of the Hand (ASSH) [19] as "excellent" (excellent, < 6 mm; good, 6–10 mm; fair, 11–15 mm; poor, > 15 mm; failure, anesthetic).The Semmes-Weinstein monofilament test (SWmt) showed a "diminished light touch" at the ulnar side (monofilament size 3,61), comparing to a normal touch to the radial side. Preoperative vs postoperative DASH score were 53,7 and 5,14 respectively.

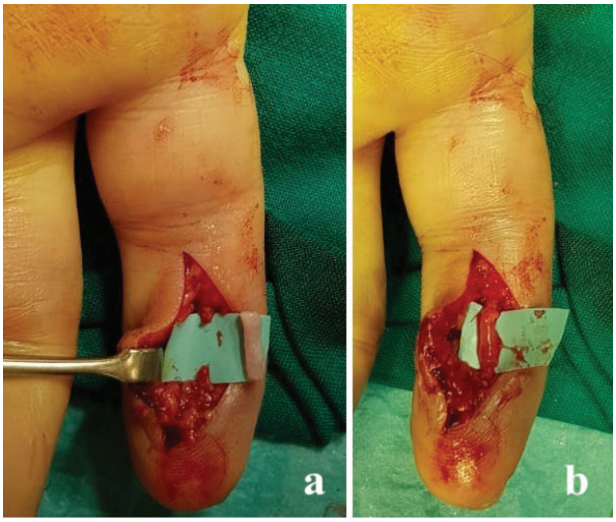

Figure. 1 a) Residual gap after stumps resection. b) After interposition on MIV graft

Case 2

A 38 y.o. patient reported a circular saw injury to the dorsum of the 1st finger (proximal phalanx) and to the volo-radial aspect of the 2nd finger (proximal phalanx).

Initially treated in another hospital, he presented to our attention 3 months later for painful Tinel on the scar and complete anesthesia on the entire radial half of the index finger.

We intraoperatively reported a complete radial collateral nerve lesion with a post-traumatic neuroma (Fig.2a). After its resection, the remaining gap was approximately 18 mm. A MIV graft was then performed with the previously reported technique (Fig.2b). Post-op immobilization with dorsal splinting was carried on for 3 weeks.

At the 8 months follow up assessment, anesthesia was still present to the 2PD and Semmes-Weinstein test. VAS diminished from 7/10 to 3/10, with a preoperative DASH score of 59,5 (postoperative score 14,49). Tinel disappeared together with neuropathic pain.

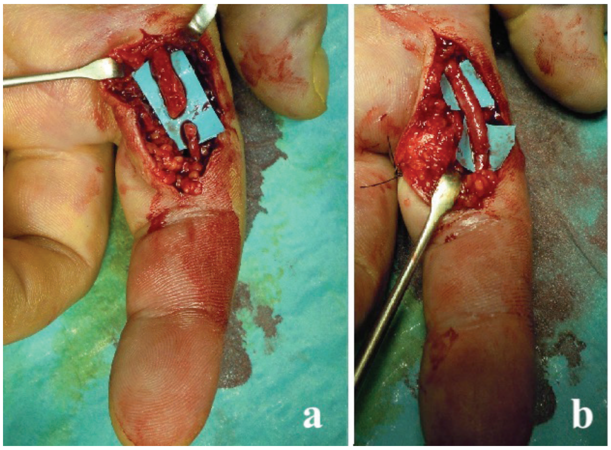

Figure. 2 a) Traumatic neuroma to the proximal stump of the nerve. b) Neuroma resection and bridging with MIV.

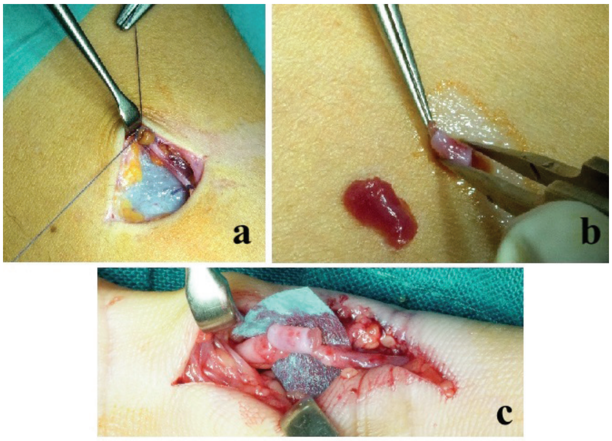

Figure. 3 a) Vein harvesting from the anterior aspect of the forearm. b) Preparation of the muscle strip for its insertion into the vein. c) Graft positioned between the two stumps.

Case 3

A 18 y.o. male, manual worker, reported a sharp lesion to the proximal phalanx of his middle finger with a broken glass. He came to our assessment after 2 months for grip discomfort and numbness to the ulnar side of the third finger with initial neuropathic pain and Tinel sign.

In the operatory room we reported a retained glass splint with a complete lesion of the ulnar collateral nerve. After the resection of the stumps, the residual gap was about 6 mm; we chose the MIV graft to bridge the defect (Fig.3). Postoperative immobilization was with the usual dorsal splint for 3 weeks. At 16 months after the operation, the 2PD stratification according to ASSH was excellent, with a Semmes-Weinstein monofilament test of "diminished light touch" at the ulnar side. DASH score decreased from 58,4 to 7, with a postop VAS of 1/10 (preop 6/10).

Case 4

A 29 y.o. male reported a sharp injury with the cutting edge of a can to the radial side of the index finger. The patient underestimated the injury, presenting to our attention only after 5 months of complete anaesthesia to the radial side of the finger, pinch impairment and grip pain as in presence of a painful neuroma.

Intraoperatively, a complete radial collateral nerve lesion was observed; after the resection of the stumps the residual gap was 13 mm; we therefore decided to perform a MIV graft (Fig.4a-b). Same immobilization protocol as the previous cases with dorsal splint was adopted. At 13 months follow up, 2PD was "good", the SWmt showed a "diminished light touch" on the radial aspect of the finger, DASH decreased from 53,2 to 9.4, with a post-op VAS score of 2/10 (preop 7/10).

Discussion

About 10% of all hand traumas requiring surgery involves a nerve injury. Among these, common and proper digital nerves are the most frequently involved [1, 20], with well known negative outcomes such as sensory loss or numbness and painful neuroma formation [11, 21]. Socioeconomic repercussions such as sick leave or even permanent employment disability have been widely described[22, 23].

The effect of suture tension on nerve regeneration is of utmost importance: direct end-to-end with no to a minimum tension yelds the best results[5, 24]; it is demonstrated that even just an 8% elongation of the nerve leads to a 50% blood flow loss, and suture failure occurs with a 17% stretch [25].

Similarily, axonal regeneration too is influenced by mechanical tension. A progressive increase from "no tension" to "minor tension", up to "moderate tension" promotes an impairment of axonal growth from 30 to 50%[26].

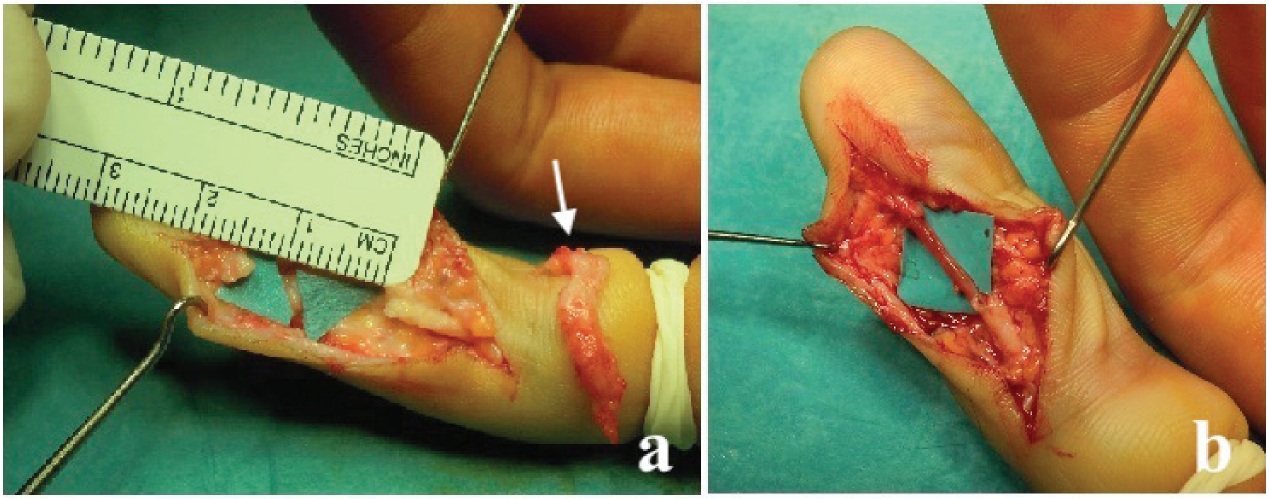

Figure. 4 a) Measurement of the gap after stumps resection. The white arrow points to the resected neuroma. b) Aspect of the MIV at the end of the procedure.

No-tension direct suture after a complete nerve transection can be performed only in about 82% of the cases[27]. That means that 18% of complete nerve lesions would imply an excessive tensile strenght, thus requiring a nerve graft or tubulization for the gap to be covered; in these patients, autologous nerve graft is still to be considered the gold standard technique[28]. Promising results are coming from nerve reconstruction using artificial conduits both in terms of sensibility recovery and neuroma formation reduction[16, 29], with a growing interest on 3D printing[30]; the main advantage of these materials is the preservation of donor nerves When deciding how to bridge the gap, the paramount factor is represented by the width of the gap that needs to be bridged: manifactured tubes are best chosen for gaps <10 mm, while autografts or processed nerve allografts can show good results up to 70 mm[29].

Concerning MIV, Marcoccio et al. demonstrated excellent clinical results even up to 30 mm[18]. In our cases the mean gap was 12 mm (min 6 – max 18).

As for sensibility recovery, we observed good to excellent sensibility in 3 out of 4 cases at the Modified guidelines of the American Society for Surgery of the Hand (ASSH).

It is true, though, that recovery may take place even beyond the 12-months time lapse, with cases with short gap lenghts who haven't regained any sensibility at one year that might expect a recovery later[31].

The main feature we observed is the disappearance of neuropathic pain due to neuroma formation after the first injury in all of the 4 cases. The efficacy of MIV technique on reducing neuropathic pain due to traumatic neuromas (as a reduction in autotomy rate) has been recently demonstrated in rats[32], endorsing our results. We chose a dorsal splint for 3 weeks as post-op immobilization to protect sutures from excessive stretching; literature disproves long lasting immobilization, showing no significative difference on nerve regeneration between early mobilization (after 3-7 days from the MIV graft) comparing to a complete immobilization for 10 days [33]; the presence of a nerve injury with a subsequent tension-free suture should not impair a tendon mobilization protocol for a concomitant tendinous lesion [34].

As for the timing, traditionally MIV is performed at least after 2-3 weeks from the initial injury; in fact, it is demonstrated that from day 1 to 21 from the trauma a progressive fibrosis and collagen deposition takes place at the injury site, so that it is preferreable to delay the procedure after this period to better delimit the damaged area [35]; nevertheless, Tos et al. observed good clinical results even in primary repair surgeries performed in emergency, endorsing this technique for a all-in-one stage [36].

In our case series the mean delay after the first injury has been of 3 months (min 2-max 5).

The main weaknesses of this study are the small number of patients analysed, combined with the fact that pre-op sensibility measurements (i.e. Semmes-Weinstein monofilament test, 2PD) were not performed; for these reasons, any statistic analysis would not be significative at all. Nevertheless, the only case that did not recover any sensibility after MIV grafting is the patient with the circular saw avulsion lesion. That remarks the well known notion of how the mechanism of injury is of utmost importance in the prognosis of nerve regeneration[35].

Conclusions

MIV graft is a relatively new technique; its cost-effectiveness comparing to manifactured conduits and the preservation of healthy donor nerves makes it a valuable option in bridging nerve gaps up to 3 cm, with comprable outcomes to other available techniques in terms of sensibility recovery and neuropathic pain resolution. Best results are obtained in patients with a sharp lesion as a primary injury, rather than avulsions.

Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article".

References

1. Renner, A., F. Cserkuti, and J. Hankiss, *[Late results after nerve transplantation on the upper extremities].* Handchir Mikrochir Plast Chir, 2004. **36**(1): p. 13-8.
2. Siemionow, M., M. Bozkurt, and F. Zor, *Regeneration and repair of peripheral nerves with different biomaterials: review.* Microsurgery, 2010. **30**(7): p. 574-88.
3. Dahlin, L., *Techniques of peripheral nerve repair.* Scand J Surg, 2008. **97**(4): p. 310-6.
4. Meek, M., J. Coert, and P. Robinson, *Poor results after nerve grafting in the upper extremity: quo vadis?* 2005. **25**(5): p. 396-402.
5. Paprottka, F., et al., *Sensory recovery outcome after digital nerve repair in relation to different reconstructive techniques: meta-analysis and systematic review.* Plast Surg Int, 2013.
6. Konofaos, P. and J. Ver Halen, *Nerve repair by means of tubulization: past, present, future.* J Reconstr Microsurg, 2013. **29**(3): p. 149-64.
7. Ichihara, S., Y. Inada, and T. Nakamura, *Artificial nerve tubes and their application for repair of peripheral nerve injury: an update of current concepts.* Injury, 2008. **39**: p. 29-39.
8. Houshyar, S., A. Bhattacharyya, and R. Shanks, *Peripheral Nerve Conduit: Materials and Structures.* ACS Chem Neurosci, 2019. **10**(8): p. 3349-65.
9. Bushnell, B., et al., *Early clinical experience with collagen nerve tubes in digital nerve repair.* J Hand Surg Am, 2008. **33**(7): p. 1081-7.
10. Pfister, L., et al., *Nerve conduits and growth factor delivery in peripheral nerve repair.* J Peripher Nerv Syst, 2007. **12**(2): p. 65-82.
11. Daly, W., et al., *A biomaterials approach to peripheral nerve regeneration: bridging the peripheral nerve gap and enhancing functional recovery.* J R Soc Interface, 2012. **9**(67): p. 202-21.
12. Meek, M., A. Varejão, and S. Geuna, *Use of skeletal muscle tissue in peripheral nerve repair: review of the literature.* Tissue Eng, 2004. **10**(7-8): p. 1027-36.
13. Meek, M. and J. Cohert, *Clinical use of nerve conduits in peripheral nerve repair: review of the literature.* J Reconstr Microsurg, 2002. **18**(2): p. 97-109.
14. Brunelli, G., et al., *Bridging nerve defects with combined skeletal muscle and vein conduits.* Microsurgery, 1993. **14**(4): p. 247-51.
15. Montoya, G.J., et al., *Muscle-conditioned media and cAMP promote survival and neurite outgrowth of adult spinal cord motor neurons* . Exp Neurol, 2009. **220**(2): p. 303-15.
16. Ronchi, G., et al., *Chitosan Tubes Enriched with Fresh Skeletal Muscle Fibers for Primary Nerve Repair.* Biomed Res Int, 2018. **13**.
17. Nicolino, S., et al., *Expression of alpha2a-2b neuregulin-1 is associated with early peripheral nerve repair along muscle-enriched tubes.* Neuroreport, 2003. **14**(11): p. 1541-5.
18. Marcoccio, I. and A. Vigasio, *Muscle-in-Vein Nerve Guide for Secondary Reconstruction in Digital Nerve Lesions.* J Hand Surg Am, 2010. **35**(9): p. 1418-26.
19. Bushnell, B., et al., *Early clinical experience with collagen nerve tubes in digital nerve repair.* J Hand Surg Am, 2008. **33**(7): p. 1081-7.
20. McAllister, R., et al., *The epidemiology and management of upper limb peripheral nerve injuries in modern practice.* J Hand Surg Br., 1996. **21**(1): p. 4-13.
21. Braga Silva, J., et al., *Nerve conduits for treating peripheral nerve injuries: A systematic literature review.* Hand Surg Rehabil., 2017. **36**(2): p. 71-85.
22. Rosberg, H., et al., *Injury to the human median and ulnar nerves in the forearm -- analysis of costs for treatment and rehabilitation of 69 patients in southern Sweden.* J Hand Surg Br., 2005. **30**(1): p. 35-9.
23. Jaquet, J., et al., *Median, ulnar, and combined median-ulnar nerve injuries: functional outcome and return to productivity.* J Trauma, 2001. **51**(4): p. 687-92.
24. Siemionow, M. and G. Brzezicki, *Current techniques and concepts in peripheral nerve repair.* Int Rev Neurobiol, 2009. **87**: p. 141-72.

25. Clark, W., et al., *Nerve tension and blood flow in a rat model of immediate and delayed repairs.* J Hand Surg Am., 1992. **17**(4): p. 677-87.
26. Yi, C. and L. Dahlin, *Impaired nerve regeneration and Schwann cell activation after repair with tension.* Neuroreport, 2010. **21**(14).
27. de Medinaceli, L., M. Prayon, and M. Merle, *Percentage of nerve injuries in which primary repair can be achieved by end-to-end approximation: review of 2,181 nerve lesions.* Microsurgery, 1993. **14**(4): p. 244-6.
28. Stang, F., et al., *Posterior interosseus nerve vs. medial cutaneous nerve of the forearm: differences in digital nerve reconstruction.* Arch Orthop Trauma Surg, 2013. **133**(6): p. 875-80.
29. Safa, B. and G. Buncke, *Autograft Substitutes: Conduits and Processed Nerve Allografts.* 2016. **32**(2): p. 127-40.
30. Dixon, A., et al., *Bridging the gap in peripheral nerve repair with 3D printed and bioprinted conduits.* Biomaterials, 2018. **186**: p. 44-63.
31. Schmauss, D., et al., *Is nerve regeneration after reconstruction with collagen nerve conduits terminated after 12 months? the long-term follow-up of two prospective clinical studies.* J Reconstr Microsurg, 2014. **30**(8): p. 561-8.
32. Ramli, K., et al., *Efficacy of Human Cell-Seeded Muscle-Stuffed Vein Conduit in Rat Sciatic Nerve Repair.* Tissue Eng Part A, 2019. **25**(19-20): p. 1438-55.
33. Manoli, T., et al., *Influence of immobilization and sensory re-education on the sensory recovery after reconstruction of digital nerves with direct suture or muscle-in-vein conduits.* Neural Regen Res, 2016. **11**(2): p. 338-44.
34. Jabir, S. and F. Iwuagwu, *Postoperative mobilization regimens following digital nerve repair: a systematic review.* Eplasty, 2014. **14**: p. e5.
35. Zachary, L. and A. Dellon, *Progression of the zone of injury in experimental nerve injuries.* Microsurgery, 1987. **8**(4): p. 182-5.
36. Tos, P., et al., *Primary repair of crush nerve injuries by means of biological tubulization with muscle - vein -combined grafts.* Microsurgery, 2012. **32**(5): p. 358-63.

Received: 21 January 2020
Accepted: 10 February 2020
Correspondence:
Andrea Minini, Via M.G. Setti n 10,
Treviglio (BG) Italy
email: minini.andrea@gmail.com