Plastic Surgery and Modern Techniques

Armin K, et al. Plastic Surgery Mod Tech 2017: PSMT-106.

Research Article

Radial and Peroneal Nerve Grafting: Functional Results

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Citation: Kraus A, Werdin F, Schaller HE, Sinis N (2017) Radial and Peroneal Nerve Grafting: Functional Results. Plastic Surgery Mod Tech 2017: PSMT-106.

Received Date: 13 December, 2016; Accepted Date: 18 March, 2017; Published Date: 27 March, 2017

Abstract

Background: Lesions of the Peroneal nerve are considered to have a poorer prognosis than those of the radial nerve. We suppose that the quality of the graft bed is one reason for this observation.

Materials and Methods: Results after grafting of radial and Peroneal nerves were investigated in cases without additional tendon transfer. Clinical follow-up and chart review was performed.

Results: 6 sural nerve graftings of the radial and 5 graftings of the Peroneal nerve were included. 4 of 6 radial grafts were placed extra-anatomically. 5 patients with complete wrist drop eventually achieved wrist extension, 4 of them after extra-anatomical graft placement. 1 of 5 Peroneal grafts was placed extra-anatomically. Weakness in foot elevation could significantly be improved in 2 of 5 patients.

Conclusions: Good functional recovery can be achieved by extra-anatomic positioning of radial nerve grafts. Results for Peroneal nerve grafts are inferior, possibly, among other factors, because improvement of graft bed vascularization by extra-anatomic graft positioning is less feasible here.

Keywords: Nerve Grafting ; Peroneal; Peripheral Nerve; Radial nerve grafting; Vascularization

Introduction

Results after grafting of peripheral nerves are often far below optimal. Recovery time is long and results are hard to predict. This is particularly true for lesions of the radial and even more for those of the peroneal nerve [1-3], Tendon transfers yield the problem of higher morbidity so that there is a need to improve results after nerve grafting. Furthermore, tendon transfers not always perfectly restore coordinated muscle movement such as for foot elevation, as nerve function theoretically could do Recovery potential of the radial nerve is known to be considerably better than that of the peroneal nerve [4]. Several reasons for this are known: Nerve anatomy [5], the need for more coordinated muscle contraction in the ankle region [6], and vascularization of the nerve [7]. Length of the graft influences outcome, and longer grafts are often associated with more severe trauma [8]. It is well known that good vascularization of the graft bed is essential for a successful procedure [9-13]. Even microsurgical restoration of nerve vascularization cannot compensate for this [9]. By extra anatomical positioning, graft bed vascularization may be improved [11]. It is still unclear how to achieve best soft tissue embedding of a nerve graft. Anatomic or extra-anatomic graft positioning can be conceived for this purpose. We therefore compared results of radial nerve grafting (easy extra-anatomic positioning) and peroneal nerve grafting (difficult extra-anatomic positioning) with each type of graft placement in both nerves. Our aim was to show that extra-anatomic graft placement could be a factor that helps to improve clinical outcome when it is possible to prepare a graft bed with better vascularization in an extra-anatomical area

Patients and Methods

Outcome measurements

The results after radial and peroneal nerve grafting for neurologically proven lesions were analyzed in our institution. Observation period was eight years. Patients were scheduled for a standardized history taking, clinical examination, and patient records were reviewed. We particularly asked for existing discomforts and impairments, tested strength and sensation and photo-documented our findings. Strength was measured according to the British Medical Research Council on a scale from M0 to M5 (M0=no contraction, M1=visible muscle contraction, M2=movement of limb if examiner eliminates gravity, M3=active motion against gravity, M4=movement against moderate resistance, M5=full strength). For wrist and finger extension, the degrees of extension were measured for the respective joint. For foot elevation, the range of motion in the ankle joint was measured with a 90 degree position to the tibia regarded as neutral. Sensation was tested compared to the contra lateral side and rated as "normal", "reduced" or "absent".

The examination time point was 34 (14-73) months after surgery on average. Patients undergoing additional tendon transfers were excluded. The patients with unfavorable post grafting results we included were those who refused further tendon transfer surgery.

Patient characteristics

Patient characteristics are shown in (Table 1 and 2).

Radial nerve	**Age**	**Sex**	**Cause**	**Location of injury**	**Surgery after trauma**	**Graft length**
Patient 1	56y	m	incision injury	forearm	252 days	2 cm
Patient 2	42y	m	incision injury	forearm	200 days	17 cm
Patient 3	21y	m	humeral fracture	upper arm	357 days	18 cm
Patient 4	43y	f	radial fracture	forearm	249 days	10 cm
Patient 5	24y	m	humeral fracture	upper arm	180 days	20 cm
Patient 6	46y	f	humeral fracture	upper arm	95 days	18 cm

Table 1: Preoperative characteristics of the patients with lesions of the radial nerve.

Peroneal nerve	Age	Sex	Cause	Location of injury	Surgery after trauma	Graft length
Patient 7	16y	m	fracture of tibial plateau	fibular head	334 days	10cm
Patient 8	33y	m	incision injury	fibular head	205 days	9cm
Patient 9	41y	m	incision injury	fibular head	369 days	5cm
Patient 10	41y	m	Knee hypertension trauma fibular head fracture	knee level	317 days	10cm
Patient 11	26y	m	fracture of tibial plateau	fibular head	278 days	10cm

Table 2: Preoperative characteristics of the patients with lesions of the Peroneal nerve.

Six graftings of the radial nerve (3 on the upper arm, 3 on the forearm) were performed on 4 male and 2 female patients. Mean age of the patients with radial nerve lesions was 43 years (21-56 years), surgery was performed 220 days after injury on average. Mean length of the graft was 17 cm. The sural nerve was taken as donor in all cases. Radial nerve injuries were caused by humeral fractures in 3 cases, lacerations in 2 cases, and radial fracture in 1 case. Radial nerve lesions were located on the upper arm in 3 cases and on the forearm in 3 cases. 5 of 6 patients with radial nerve lesions had complete deficiency of wrist extension before surgery (Table 3).

Radial nerve	Type of deficiency	Motor grade	Sensory deficiency
Patient 1	Wrist and finger extension	M0	forearm, dorsal hand
Patient 2	Wrist and finger extension	M0	forearm,dorsal hand
Patient 3	Wrist and finger extension	M0	Distal upper arm, forearm
Patient 4	finger extension	fingers Mo wrist M5	sensation preserved
Patient 5	Wrist and finger extension	M0	Distal upper arm, forearm
Patient 6	Wrist and finger extension	M0	forearm, dorsal hand

Table 3: Pre-operative deficit of motor and sensory function in the patients with radial nerve lesions

Five grafting of the peroneal nerve were performed on male patients. Mean age of the patients with peroneal nerve lesions was 33 years (16-41 years), mean length of the graft was 9 cm. grafting of the peroneal nerve was performed 317 days after injury on average. 4 of 5 lesions of the peroneal nerve were located on the level of the fibular head, 1 lesion was located on the level of the knee. All 5 patients had a total deficiency in foot elevation before surgery (M0) and atrophy of the lower leg (Table 4).

Peroneal Nerve	Motor deficiency	Motor grade	Sensory deficiency
Patient 7	foot elevation atrophy of lower leg	M0	dorsal foot, lateral lower leg
Patient 8	foot elevation atrophy of lower leg	M0	dorsal foot, lateral lower leg
Patient 9	foot elevation atrophy of lower leg	M0	dorsal foot, lateral lower leg
Patient 10	foot elevation atrophy of lower leg	M0	dorsal foot, lateral lower leg
Patient 11	foot elevation atrophy of lower leg	M0	dorsal foot, lateral lower leg

Table 4: Pre-operative deficits of motor and sensory function in the patients with peroneal nerve lesions.

Peroneal nerve injuries were caused by tibial plateau fractures in 2 cases, cutting injuries in 2 cases and knee hyperextension trauma with additional fibular fracture in 1 case.

Surgical procedure

The operative procedure included preparation and neurolysis of the nerve first under the operation microscope. The scarred section of the nerve was identified under magnification and resected. Sural grafts were harvested over an incision at the lateral ankle by using a nerve stripper. Both nerve ends were then inspected to identify the correct fascicular alignment and grafts were connected by 10-0 non-absorbable interfascicular sutures.

In all radial nerve patients who received extra-anatomic grafts, the proximal graft connection lay before the entrance of the nerve under the lateral triceps head. All grafts were placed over the triceps, under its fascia in patient 3 and in subcutaneous fatty tissue in patients 5 and 6. Distal graft connection was at the entrance of the inter muscular septum for patient 3 and 6 and under the origin of the brachioradial muscle for patient 2 and 5. Patient 1 received an anatomically placed graft at the forearm under the brachioradial muscle proximal to the entrance into the supinator tunnel. In patient 4 the graft was proximally connected before the supinator muscle, distal to the branches of ECRL and ECRB and connected distally after the exit from the supinator muscle.

All peroneal grafts were connected proximally at a position dorsal to the biceps femoris muscle and lateral to the fibular head. With one exception (patient 10), all grafts were positioned subcutaneously, on the surface of the lateral gastrocnemius head, and connected distally before division into superficial and deep branch. In patient 10, the graft was placed into a tunnel dissected under the lateral gastrocnemius head.

Results

Post surgery results are outlined in table 5 and 6 (Figure 1a)

Figure 1: Typical pre-operative view of high radial nerve palsy- no finger and wrist extension is possible

Shows a typical preoperative view of a high radial nerve palsy with deficiency in wrist and finger extension, (Figure 1b)

Figure 1b: Typical pre-operative view of a low radial nerve palsy-wrist extension, but no finger extension is possible.

Shows a typical preoperative view of a low radial nerve palsy with deficiency in finger extension only. Shows a typical preoperative view of a peroneal palsy with deficiency in foot elevation (Figure 2)

Figure 2: Peroneal palsy at the level of the fibular head- no toe and ankle extension is possible.

Radial nerve grafting

All radial nerve patients with pre-operative deficiency in wrist extension achieved extension between 20 and 60 degrees. 3 of 4 patients after extra-anatomic nerve grafting showed favorable results hereby (Figure 1 and Table 5).

Radial nerve	Location of grafting	Examination after surgery	Result	Motor grade	Sensory function
Patient 1	proximal forearm	73 months	wrist extension 55 degrees complete finger extension	M4	improved on forearm
Patient 2	proximal upper and forearm extraanatomic-subcutane-ously	26 months	wrist extension 20 degrees complete finger extension	M3	improved on forearm
Patient 3	Lateral upper arm extraana-tomic-subfascially	62 months	wrist extension 60 degrees complete finger extension	M5	improved on forearm and dorsal hand
Patient 4	forearm	31 months	unchanged: no finger exten-sion full wrist extension	Fingers: 40 Wrist: M4	no improvement
Patient 5	upper arm and forearm, ex-traanatomic-subcutaneously	60 months	wrist extension 25 degrees no finger extension	Wrist: M4	improved on upper arm and elbow
Patient 6	upper arm extraanatomic-subcutaneously	22 months	wrist extension 25 degrees partial finger extension	Wrist: M4 Fingers:M3	improved on forearm

Table 5: Results after radial nerve grafting- good wrist and finger extension has been achieved. Radial nerve location of grafting examination after surgery result motor grade sensory function.

Patient no.1 (Figure 3)

Figure 3: Result 73 months after extranatomic-subcutaneous grafting of the radial nerve in the area of the upper arm (patient no. 1, best result in our series).

could achieve complete independent thumb extension. Independent index finger extension was not possible to him. Patient no. 4 achieved no improvement in her deficiency of finger extension. She underwent Merle-D' Aubigné´s tendon transfer two years later. Finger and thumb extension was significantly improved by this procedure. Patient no.5 had additional spiral fractures of the third and fourth metacarpal bones with subsequent stiffness of all metacarpal joints. A tendon transfer was therefore not recommended to him.

1 patient undergoing extra-anatomic nerve grafting had an additional wrist fracture with motion impairment. He improved triceps strength from M0 to M5 as well as sensitivity of the dorsal forearm. 1 patient with the lesion located on the forearm and deficiency in finger extension could not improve function after surgery (M0 before and after surgery).

Peroneal nerve grafting

In the patients receiving peroneal nerve grafts, foot elevation deficiency could significantly be improved in 2 out of 5 (M3 and M4, Figure 4). 1 patient had positive Hoffmann´s sign 10 cm distally to the grafting site but no foot elevation. 2 patients did not improve function, including the case of extra-anatomic grafting. To patient no. 8, tendon transfer was recommended 1 year after nerve grafting, but the patient refused further surgery. As there were explicit neuro graphic signs of regeneration in patients no. 9 and no. 10 at the time point of examination, it was decided to put the option of tendon transfer still on hold. These patients are in regular follow-up and tendon transfer will be the next step in case of no further clinical improvement.

Peroneal nerve	Location of grafting	Examina-tion after surgery	Motor grade	Sensory func-tion
Patient 7	fibular head	39 months	M2	no improve-ment
Patient 8	fibular head	41 months	M0	improvement
Patient 9	proximal lower leg	34 months	M1	no improve-ment
Patient 10	extraanatomical under lateral gastrocnemius head	14 months	M1	no improve-ment
Patient 11	fibular head	28 months	M4	lower leg improved

Table 6: Results after peroneal nerve grafting- results are inferior to those achieved after radial nerve

Figure 4: Successful regeneration 39 months after anatomical grafting of the peroneal nerve in the region of the fibular head (patient no. 11 best result in our series).

Discussion

Clinical outcome is better after radial than after peroneal nerve grafting. This is generally accepted knowledge and is shown in various studies: In a study by Pan et al., authors performed radial nerve grafting in 37 patients with lesions on the level of the humerus spiral groove [3]. They report successful wrist extension in 89%, finger extension in 73% and thumb extension in 57% of their cases. Kim et al. analyze outcome after peripheral nerve repair in two large retrospective series [1,2], They report overall motor function grade 3 or better in 80% of 54 patients undergoing radial grafting. For procedures at the upper arm, motor function was at least grade 3 for 60% of patients with a lesion not in continuity and for 89% of patients with a lesion in continuity. At the level of the forearm and elbow, motor function was grade 3 or better for 67% of patients with a lesion not in continuity and for none of two patients with a lesion in continuity. For 138

peroneal graftings, the same authors report motor function grade 3 or better in 75% of patients with grafts shorter than 6 cm, in 38% of patients with grafts between 6 and 12 cm and in 16% of patients with grafts between 13 and 24 cm.

In another well-written study, Roganovic et al. prospectively evaluate outcome after peripheral nerve repair and focus on grafting in their work [4], They report “useful recovery” (motor grade M3 or larger) for 7 of 46 patients (15,2%). The authors mention that results significantly improve when performed on the distal part of the lower leg and not in the area of the fibular head. In this work, a list of various risk factors for bad outcome is presented. For the peroneal nerve, inadequate vascularization is identified as the main risk factor. Results in our collective, with better outcome for the radial than for the peroneal nerve and better outcome for extra-anatomical than anatomical radial grafting support the findings presented above. Extra-anatomic grafting in better

vascularized tissue is much less feasible for the peroneal nerve, particularly in the area of the fibular head. Terzis et al. recommend microsurgical vascularization of peroneal grafts and report adequate motor recovery in 11 patients with this approach [15], but this technically challenging procedure is not applied routinely.

Millesi reports significantly improved outcome with the combination of peroneal nerve grafting and peroneal tendon transfer compared to peroneal nerve grafting alone [14]. The author explains this by prevention of Achilles tendon contracture. The muscles of the anterior tibial compartment are elongated and a better balance between the strong flexor and the weakened extensor muscle group is achieved. By this combination method, regeneration of all muscles of the anterior compartment was stimulated in six out of seven cases in this series. According to the work of Prasad et al. [8], the accident mechanism in peroneal injuries is responsible for the bad outcome. It often includes shear and stretch forces with consecutive myoneural junction damage and this impairs regeneration even after skilled surgical grafting. Accordingly, this group suggests direct neurotization of the peroneal-innervated muscles and a simultaneous posterior tibialis to anterior tibialis tendon transfer in case of supposed traction injury.

Our reason to avoid immediate tendon transfer was to limit the extent of surgery at first in order to decrease associated morbidity. Generally, the peroneal grafting procedures in our collective were performed at a later time point than suggested by other groups [16]. This was due to the fact that neurographic examinations suggested a tendency towards spontaneous recovery in these cases. Time until grafting was three months longer (98 days on average) for the peroneal nerve than for the radial nerve in our collective because of this neurographically measurable improvement. It is theoretically possible that this longer time led to more muscular degeneration and inferior grafting results. However, in our opinion, this three month additional period should not have significantly spoiled regeneration, particularly as all patients received regular motion therapy before surgery.

Graft length was almost twice for the radial than for the peroneal nerve in our collective. This longer distance did not negatively influence recovery when the groups are compared. This is in accordance with a study by Lee et al, where the authors describe good functional outcome for radial nerve grafts longer than 10cm [17]. However, the authors state that recovery is generally better for shorter than for longer grafts. Giuseffi et al. report a dependence of peroneal recovery from graft length, too. According to their results, recovery rate is not higher than 44% for peroneal grafts longer than 6 cm [18]. In the upper extremity, the median to radial nerve transfer described by McKinnon et al. is a way to reduce graft length in case of a proximal injury [19].

We acknowledge that the explanatory power of our study is limited by a low case number. However, our studies support existing knowledge from studies cited above. We encourage further confirmation of our results in larger series.

Conclusion

Good functional recovery can be achieved by extra-anatomic positioning of radial nerve grafts, as this could be a way to improve graft bed vascularization. Results for peroneal nerve grafts are inferior, possibly, among other factors, because improvement of graft bed vascularization by extra anatomic graft positioning is less feasible here.

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