Operative treatment with nerve repair can restore function in patients with traction injuries in the brachial plexus

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ABSTRACT

INTRODUCTION: Brachial plexus injuries are usually a result of road traffic accidents and a cause of severe disability that typically affects young adult males. In 2010, a national centre was established for referral of these cases from Danish trauma centres. In this paper, we report on our surgical activity and reflect on the role for this new national centre.

METHODS: Records from all our operated patients were reviewed retrospectively. For outcome analysis, we focused on patients who had sustained traction injuries with a surgical follow-up exceeding one year. We used either nerve grafting or transfers for nerve repairs based on the pattern of nerve injury seen intraoperatively.

RESULTS: Overall, 24 patients were operated, and 12 patients were included in the outcome analysis. The six patients with upper brachial plexus palsies all regained shoulder function and useful elbow flexion. Of the six patients with complete brachial plexus palsies, four regained shoulder function, while only one regained useful elbow function, and this was after nerve transfers.

CONCLUSION: Operative treatment provides satisfactory results in patients with upper brachial plexus palsies, while improvement is warranted in patients with complete brachial plexus palsies. Our data suggest that nerve transfers may result in a better functional outcome than nerve grafting. We believe that there is a role for a Danish centre for the treatment of these injuries.

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Adult brachial plexus injuries usually result from road traffic accidents and the majority of those affected are young males [1]. Forceful separation of the head and shoulder causes stretching or tearing of the nerves constituting the plexus. Root avulsion from the spinal cord or rupture of the root itself are the most common sites of torn nerves, but lesions can occur throughout the full length of the plexus – supraclavicularly as well as infraclavicularly. Clinically, in upper plexus lesions the arm hangs at the side, internally rotated and extended at the elbow, while movements of the hand and forearm are unaffected. In lower plexus lesions there is weakness and, with time, wasting of the small hand muscles and a clawhand deformity. A complete brachial plexus palsy leaves the patient with a painful, frail arm. Several reconstructive strategies have been devised to restore function and relieve pain: nerve grafting within the plexus [2, 3], long nerve grafting from roots to target nerves [4] and nerve transfers from healthy nerves to target nerves [5]. Repair of root avulsions has been pioneered by Carlstedt et al [6], but this treatment is only offered in a few centres. In 2010, a national centre for brachial plexus injuries was established at Odense University Hospital, Denmark. In this paper, we report on our first four years of experience.

METHODS

We have reviewed charts of 24 patients operated for traumatic brachial plexus injury between March 2010 and April 2014. For the outcome analysis, we focused on patients who underwent primary nerve repair for traction injuries. We excluded patients with a surgical follow-up of less than one year, the reason being that one year is approximately the time it takes an axonal growth cone to travel the distance from the brachial plexus and reinnervate the biceps brachii muscle. That left a study group consisting of 11 men and one woman with a mean age of 33 years (range: 17-53 years). There were six cases of upper and six cases of complete brachial plexus palsies. A total of 11 patients sustained the brachial plexus injury in road traffic accidents. One patient suffered a blunt trauma to the neck and shoulder. Patient characteristics are summarised in **Table 1**.

Timing of surgery

All life-threatening injuries and stabilisation of major fractures were performed before surgery on the brachial plexus. We intended to operate subacutely on patients with complete brachial plexus lesions. Patients with upper brachial plexus palsies were preferably operated within 3-4 months if no spontaneous improvement was seen.

Surgical approach and exploration of the brachial plexus

Patients were operated in the supine position under

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TABLE 1

Patient characteristics.

Case no.	Sex	Age, yrs	Cause of injury	Clinical presentation	Pattern of injury
1	M	44	Motorbike accident	Upper BP palsy	C5 + C6 + C7 root rupture
2	M	18	Motorbike accident	Complete BP palsy	C5, C6, C7, C8, Th1 avulsions
3	M	26	Motorbike accident	Complete BP palsy	Rupture of superior trunk, rupture of medial fascicle, C8+Th1 root avulsions
4	M	49	Bike accident	Complete BP palsy	C5 + C6 rupture, avulsion C7 + C8 root avulsion, Th1 root rupture
5	M	19	Car accident	Upper BP palsy	C5 + C6 root rupture
6	M	29	Motorbike accident	Upper BP palsy	C5 + C6 root avulsions
7	F	49	Motorbike accident	Upper BP palsy	C5 + C6 + C7 root rupture
8	M	22	Motorbike accident	Upper BP palsy	Rupture of musculocutaneous nerve, neuropraxia of lateral fascicle
9	M	25	Bike accident	Complete BP palsy	C5 + C6 + C7 rupture, C8 + Th1 root avulsions
10	M	53	Blunt injury to the neck/shoulder	Upper BP palsy	C5 + C6 rupture
11	M	48	Motorbike accident	Complete BP palsy	C5 + C6 root avulsions, C7 + C8 + Th1 root rupture
12	M	17	Bike accident	Complete BP palsy	Truncus superior rupture avulsion C7-Th1

BP = brachial plexus.

general anaesthetics without muscle relaxants. A single dose of 2 g dicloxacillin was given prior to surgery and a solution of adrenaline 1:200,000 was injected into the skin. A transverse skin incision was made approximately 1 cm above the clavicle. For exploration of the infraclavicular part of the plexus, the incision was extended into the deltopectoral groove with osteotomy of the clavicle when indicated. The pattern of nerve injury was assessed intraoperatively. Roots were dissected if necessary to the level of the lateral border of the transverse processes of the cervical vertebrae and trimming of the roots was performed inside a healthy zone. A root stump was considered viable if the nerve fascicles were seen bulging on the cross section (bulging phenomenon). In all cases, roots were checked using electrical stimulation (Stimuplex HNS 11, Braun, Melsungen, Germany). The final decision on type of nerve repair was made intraoperatively.

Nerve grafting

To bridge defects within the plexus, donor nerves were harvested from the sural nerve and approximated to the corresponding nerve fascicles (*cable grafting*) with 1-2 stitches (Ethilon 9-0) and a fibrin sealant (Tisseel).

Nerve transfers

To regain shoulder function, transfer of accessory nerve to the suprascapularis nerve was done, and in some cases combined with a radial nerve branch to axillary nerve transfer. Either an ulnar nerve to musculocutaneous nerve transfer (Oberlin's procedure [5], see **Figure 1**C) or intercostal to musculocutaneous nerve transfer was done to re-establish elbow flexion. For Oberlin's procedure, we selected fascicles to the flexor carpi ulnaris muscle for transfer by using nerve stimulation. See **Table 2** for details on the nerve repairs.

Post-operative care

Patients had local analgesics delivered via a pump to the wound for 24 hours. The affected arm was immobilised in a sling for three weeks post-operatively. Patients were then referred for physiotherapy.

Follow-up

Patients were reviewed in the outpatient clinic every three months. The time from surgery to first signs of clinical nerve recovery – if any – was recorded. At the time of final evaluation, we assessed the range of active motion in the shoulder for abduction, flexion and external rotation as well as the strength of elbow flexion using the Medical Research Council (MRC) muscle strength grading system, which rates from 0 (no contraction) to 5 (normal strength) through a full range of motion. Any complication that could be attributed to surgery was also recorded.

Trial registration: not relevant.

RESULTS

Overall operative activity

We operated 24 patients between March 2010 and April 2014. A total of 20 patients had sustained traction injuries to the plexus, three patients had penetrating injuries, while in one patient the brachial plexus injury was secondary to a shoulder dislocation. Eight of the 20 patients with traction injuries were excluded from further analysis for the following reasons: Only surgical exploration (two cases), neurolysis at surgery (two cases) or surgical follow-up in less than one year (four cases).

Operations for traction injuries

The mean time interval from injury to surgery was three months (range: 0.5-8 months) for the six patients who sustained complete brachial plexus injuries. For the six patients with upper brachial plexus palsies, surgery was carried out at a mean five months (range: 0.5-9) after injury. Two patients underwent surgery twice. In both cases, the brachial plexus was explored and an accessory to suprascapularis nerve transfer was carried out at the first operation. No further reconstruction was done as the biceps muscle contracted to proximal electric stimu-

lation. As no recovery of elbow flexion occurred post-operatively, an Oberlin procedure [5] as well as a radial-to-axillary nerve transfer was done at the second procedure. Thus a total of 14 procedures were done in our 12 patients. Patients were followed-up for a mean of 28 months (range: 16-49 months) after surgery.

Patterns of nerve injury

In seven patients, nerve roots were avulsed from the spinal cord as part of the injuries. Root ruptures alone or in combination with other lesions occurred in eight cases and were located mainly within the upper part of the plexus. One patient had only infraclavicular injuries, i.e. rupture of the musculocutaneous nerve and neuropraxia of the lateral fascicle. The patterns of nerve injury are summarised in Table 1.

Recovery of shoulder function

The first signs of recovery of function were observed after a mean of six months (range: 3-13 months), earlier after nerve transfers than after nerve grafting (mean, five versus seven months). In two of the 11 patients with impaired shoulder function, no improvement was achieved. These two cases were complete brachial plexus lesions repaired with nerve grafting.

The mean range of active motion in the shoulder was 38 degrees (range: 0-110 degrees), 30 degrees (range: 0-140 degrees) and 13 degrees (range: 0-50 degrees) for flexion, abduction and external rotation respectively.

Recovery of elbow function

The first signs of recovery occurred after a mean of six months (range: 3-14 months) and 13 months (range: 8-20 months) after surgery for upper and complete brachial plexus palsies, respectively - again earlier after nerve transfers than after nerve grafting. In all cases of upper palsies, patients recovered elbow flexion strength of grade M3 or more. Four patients in this group achieved strength of grade M4. Only one of the five patients with complete brachial plexus palsies obtained useful elbow flexion. This patient had nerve transfers done. The results are summarised in **Table 3**.

Complications

No cases of infection occurred. We had no injuries to the subclavian vessels. There were no cases of pneumo- or chylothorax. We have not been able to detect any muscle weakness as the result of the Oberlin procedure.

DISCUSSION

All six patients with upper brachial plexus injuries (C5 + C6 or C5 + C6 + C7) recovered shoulder function as well as elbow strength of M3 or more after surgery (M3 denotes the ability to resist gravity which is considered a cut-off point for useful function). This translates into the injured arm not being in the way and of use in activities of daily living. Four had nerve transfers and two had nerve grafting. The outcome is comparable to results from a meta analysis [7].

Six patients were operated for complete brachial plexus palsies. Four were treated with nerve grafting and two with nerve transfers. Four patients regained shoulder function, while only one regained useful elbow function, the latter after nerve transfers. For some patients only minor improvement was seen; however, we agree with Sterling Bunnell (the father of hand surgery) in that "to someone who has nothing, a little is a lot".

This study was not designed to compare the outcome after nerve grafting to nerve transfers. It was,

FIGURE 1

A and **B**. Nerve grafting bridging a gap between the upper roots and the superior trunk of the brachial plexus. **C**. Transfer of a fascicle of the ulnar nerve to a biceps muscle nerve branch (Oberlin's procedure).

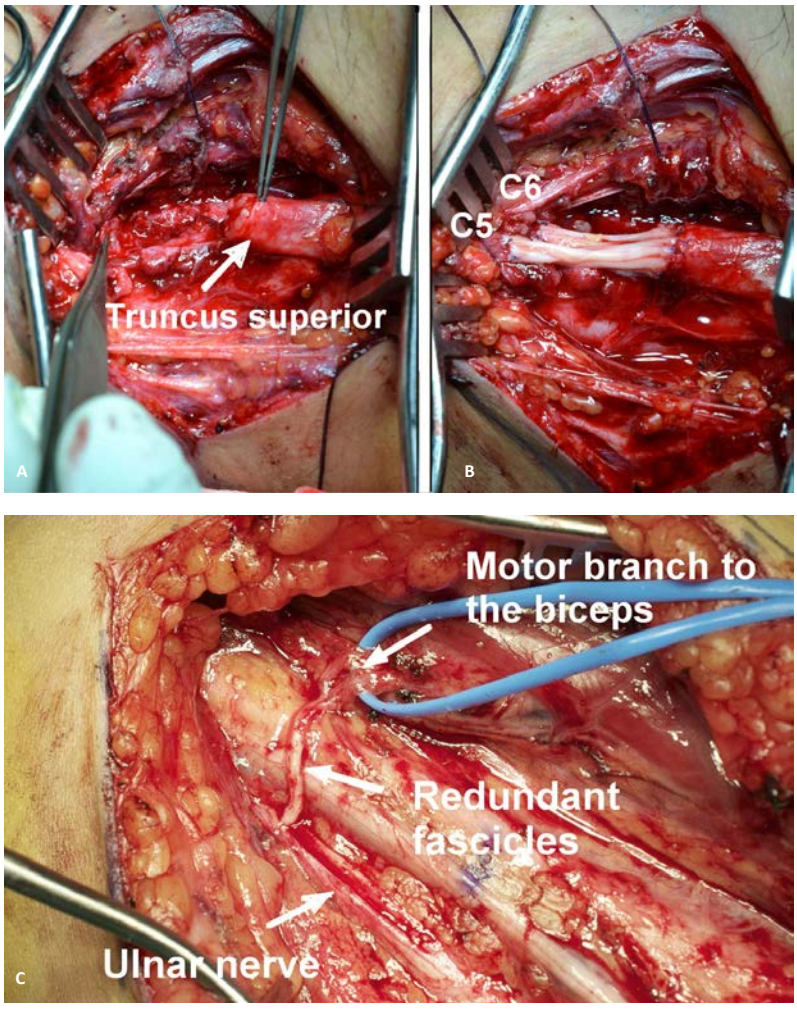

TABLE 2

Summary of surgical reconstructions.

Case no.	Interval from injury, months	Type of nerve repair	Donor & recipient nerve
1	3	Nerve grafting	C7 to intermediate trunk + SSC
2	4	Nerve transfers	ICC to MCN, ACC to SSC
3	5	Nerve grafting, direct suture	C5 to lateral fascicle, C6 to lateral fascicle, C7 to posterior fascicle, C8 to distal C7 stump
4	0.5	Nerve grafting	C5 to superior trunk + SSC, C6 to intermediate trunk
5	0.5	Nerve transfers	UN to MCN, ACC to SSC
6	4	Nerve transfers	UN to MCN, RN to AXL, ACC to SSC
7	8	Nerve transfers	UN to MCN, RN to AXL, ACC to SSC
8	9	Nerve grafting	MCN, neurolysis of lateral fascicle
9	0.5	Nerve grafting	C5 to superior trunk, SSC, C6 to superior trunk, C7 to intermediate trunk
10	5	Nerve transfers	ACC to SSC, RN to AXL, UN to MCN
11	8	Nerve grafting and transfers	ACC to SSC, IC to MCN, C7 to intermediate trunk
12	0.5	Nerve grafting	Superior trunk to intermediate trunk

ACC = accessory nerve; AXL = axillary nerve; IC = intercostal nerve; MCN = musculocutaneous nerve; UN = ulnar nerve; RN = radial nerve; SSC = suprascapularis nerve.

TABLE 3

Summary of results.

Case no.	1st signs of shoulder regeneration, months	1st signs of elbow flexion regeneration, months	Shoulder abduction, degrees	Shoulder flexion, degrees	Shoulder external rotation, degrees	Elbow flexion, GMC scale
1	13	14	10	20	10	3
2	6	20	15	35	0	3
3	–	–	–	–	–	–
4	6	8	30	20	10	2
5	7	8	10	60	20	4
6	4	4	50	50	20	4
7	3	4	30	40	0	4
8	4	4	140	110	50	4
9	–	10	–	–	–	2
10	3	3	25	35	10	3
11	6	14	45	50	25	2
12	5	15	10	30	10	2

GMC = General Medical Council.

however, noteworthy that none of our patients with complete brachial plexus palsies obtained useful elbow function after nerve grafting.

There are several potential reasons for the observed failures of nerve grafting. First, intraoperative assessment of the viability of neural structures suitable for grafting can be difficult [8], and the nerve stump may not have been viable in some cases. Had it been available, the use of intraoperative stimulation/recording to direct the extent of resection before nerve grafting may have resulted in a better outcome. Second, the sprouting axons have to pass two nerve anastomoses and then travel for a longer distance before reaching its target. Third, there is a risk of dispersion of axons with only a few axons reaching their target muscle. Forth, if there is a second, initially undiagnosed, more distal nerve injury involving e.g. the musculocutaneous nerve, nerve grafting within the plexus will fail to restore elbow flexion [4]. Fifth, spontaneous recovery in patients with complete brachial plexus palsies is unlikely [9] which calls for early surgery in these cases. Our patients were operated at a mean 3 months after their injury occurred. Ideally, we would like to operate on these patients within 3-4 weeks. The delay was largely attributable to referral patterns as most traumatic brachial plexus lesions were managed conservatively prior to 2010. As practice has changed, we now get prompt referrals.

There are proponents for nerve transfers as the procedure of choice for almost any brachial plexus injuries [10], for upper brachial plexus injuries [7, 11] and complete brachial plexus palsies [4]. When there is a delay in referral, our data suggest that one should certainly consider nerve transfers rather than nerve grafting allowing for earlier re-innervation of the target muscle.

For complete brachial plexus palsies, a different strategy involving the use of long grafts to connect non-avulsed roots to the musculocutaneous nerve may also have resulted in a better elbow function [4]. Our practice has changed to more often resorting to nerve transfers. We continue to explore the plexus as we agree with others [12] that this is essential to understand the exact nature of the injury.

The first year we only operated two patients, but since then we have operated 5-8 patients a year. Judged by these figures, traumatic brachial plexus lesions are a rare occurrence in Denmark. However – in our opinion – the current patient volume is sufficient to maintain a national level service.

CONCLUSION

Operative treatment provides satisfactory results in patients with upper brachial plexus palsies, while improvement is warranted in patients with complete brachial plexus palsies. Our data suggest that nerve transfers may result in a better functional outcome than nerve grafting. We believe that there is a role for a Danish centre for treatment of these injuries.

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