OBERLIN'S ULNAR NERVE TRANSFER TO THE BICEPS MOTOR NERVE IN OBSTETRIC BRACHIAL PLEXUS PALSY: INDICATIONS, AND GOOD AND BAD RESULTS

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We present 7 children with obstetric brachial plexus palsy treated by transferring two motor fascicles out of the ulnar nerve to the biceps nerve. Three were male, and 4 were female. The left-side brachial plexus was affected in 4 patients, and the right side in 3 patients. All children had vaginal delivery; two of them presented with shoulder dystocia. The average birth weight was 4,300 g (range, 3,620–5,500 g). Average age at time of operation was 16 months (range, 11–24 months). The indication for the operation was absent active elbow flexion with active shoulder abduction against gravity in 4 cases, and no biceps function and bad shoulder function in 3 cases. Oberlin's ulnar nerve transfer was done in 4 cases without brachial plexus exploration in those children with good shoulder function, and exploration of the brachial plexus was performed in the other 3 cases with bad shoulder function. The average follow-up was 19 months (range, 13–30 months). Five children had biceps muscle $\geq M_3$ with active elbow flexion against gravity, and 2 children had biceps muscle $<M_3$. We recommend Oberlin's ulnar nerve transfer for upper-type obstetric brachial plexus palsy in 1) breech delivery with avulsion of C5 and C6 nerve roots,) late presentation with good recovery of shoulder function, and 3) neuroma-in-continuity of the upper trunk with intraoperative good nerve conduction for the shoulder muscles, the same as preoperative good shoulder function but with no biceps action. © 2004 Wiley-Liss, Inc.

The primary aim of surgery in total obstetric brachial plexus injury is to restore hand function. This aim is different in cases of upper lesions, in which the main goal is to attain elbow flexion by the biceps muscle. In complete lesions, nerve reconstruction consists of connecting ruptured roots of the brachial plexus with suitable target nerves by nerve grafting (intraplexal neurotization) or nerve transfers from outside the brachial plexus (extraplexal neurotization). The concept of nerve transfers has existed since the beginning of the twentieth century. Tuttle[1] proposed the use of branches of the deep cervical plexus in 1922, whereas Chiasserini[2] described the transfer of intercostal nerves for paraplegic patients in 1934. Modern nerve transfers in brachial plexus palsy consist of intercostal nerves,[3–5] the spinal accessory nerve,[6] the phrenic nerve,[7] and the hypoglossal nerve.[8] Each of these involves disconnection of the transferred nerve from its original target muscle with a resultant loss of function, even though this secondary palsy does not produce any additional morbidity (as with the use of intercostal nerves ICNs).

In cases of upper brachial plexus birth palsy with avulsion of C5 and C6 nerve roots, nerve grafting is impossible. In such cases, the transfer of some fascicles from the intact ulnar nerve to the nerve to the biceps is one solution.[9] As the spontaneous recovery in cases of brachial plexus birth palsy is high (80–90%), this procedure presents another solution for cases with late presentation who have active shoulder abduction and absence of elbow function.

Clinical experience has shown that transfer of fascicles from the ulnar nerve does not produce any measurable morbidity.[9] The selection of motor fascicles for transfer by intraneural dissection and stimulation appears to be a new technique, although Sunderland[10] mentioned this possibility, while Hall and Buncke[11] described the selective use of sensory fascicles.

MATERIALS AND METHODS

Patients

Case 1 was a male child, his date of birth was December 1, 2000, his birth weight was 3,620 g, his first presentation was July 25, 2001, with a left-side brachial plexus injury of upper type, he had active shoulder abduction against gravity (deltoid muscle > M3) with no biceps function, and the date of his operation was February 4, 2002.

Case 2 was a male child. Date of birth was January 6, 2000. His birth weight was 3,950 g, and his first presentation was on May 25, 2000, with right-side brachial plexus injury of upper type. He had active shoulder abduction against gravity (deltoid muscle > M3) with no biceps function; the date of his operation was February 12, 2001.

Case 3 was a female child. Date of birth was September 12, 1999. Her birth weight was 5,500 g. Her first presentation was on June 6, 2000, with left-side brachial plexus injury of upper type. She had active shoulder abduction against gravity (deltoid muscle > M3) with

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Received 19 July 2003; Accepted 27 January 2004
Published online 6 May 2004 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/micr.20037

no biceps function; the date of her operation was April 30, 2001.

Case 4 was a female child. Date of birth was June 29, 2000. Her birth weight was 4,230 g. The delivery was vaginal with shoulder dystocia and perinatal asphyxia. Her first presentation was December 27, 2000, with left-side brachial plexus injury of upper type. She had active shoulder abduction against gravity (deltoid muscle > M3) with no biceps function. The date of her operation was May 28, 2001.

Case 5 was a female child; date of birth was September 9, 2000; birth weight was 3,850 g. Her first presentation was on December 27, 2000, with right-side brachial plexus injury of upper type. She had active shoulder abduction against gravity (deltoid muscle > M3) with no biceps function. The date of her operation was June 18, 2001.

Case 6 was a female child; date of birth was December 4, 1999; birth weight was 4,600 g. Her first presentation was on March 6, 2001, with right-side brachial plexus injury of upper type. She had active shoulder abduction against gravity (deltoid muscle > M3) with no biceps function. The date of her operation was April 30, 2001.

Case 7 was a male child; date of birth was August 20, 1998; birth weight was 5,230 g. The delivery was vaginal with shoulder dystocia. His first presentation was on April 6, 2000, with left-side brachial plexus injury of upper type. She had active shoulder abduction against gravity (deltoid muscle > M3) with no biceps function. The date of his operation was August 21, 2000.

Technique

A longitudinal incision 5 cm in length is made along the medial aspect of the upper arm. This is done separately either with or without brachial plexus exploration. The fascia covering the biceps is incised, and the muscle is retracted laterally. The musculocutaneous nerve is approached between the biceps and the coraco-brachialis muscles. The motor nerve to the biceps is identified.

The ulnar nerve is approached at the same level. Its identification is formally assessed by means of electrical stimulation. Further dissection is performed under microscopic magnification. The branches destined for the biceps are identified. Usually, the vascular pedicle to the biceps has a more transverse orientation and does not interfere with the nerve dissection. The branches to the biceps muscle are split proximally from the musculocutaneous nerve for approximately 2 cm and transected. The distal part is then rotated medially toward the previously dissected ulnar nerve.

The epineurium of the ulnar nerve is incised. One (or two) fascicle(s) with an adequate size is (are) selected. They are subjected to low-intensity electrical stimulation.

Table 1. Gilbert-Raimondi Score for Hand Function

Hand stage	Description
0	Complete paralysis or slight finger flexion of no use, useless thumb, no pinch, some or no sensation
I	Limited active flexion of fingers, no extension of wrist or fingers, possibility of thumb lateral pinch
II	Active extension of wrist with passive flexion of fingers (tenodesis), passive lateral pinch of thumb (pronation)
III	Active complete flexion of wrist and fingers, mobile thumb with partial abduction-opposition, intrinsic balance, no active supination, good possibilities for secondary surgery
IV	Active complete flexion of wrist and fingers, active wrist extension, weak or absent finger extension, good thumb opposition with active ulnar intrinsics, partial pro/supination
V	Hand IV with finger extension and almost complete pro/supination

It is possible to distinguish precisely between sensory and motor fascicles. Occasionally, one is able to locate fascicles with a response in the extrinsic flexors and those corresponding to the intrinsic muscles of the hand. In these cases, the fascicles innervating the extrinsic flexors are selected for transfer.

These fascicles are often located anteriorly and medially within the ulnar nerve. The chosen fascicle is separated from the rest of the ulnar nerve over 2 cm and divided distally. The fascicle is turned laterally and sutured to the motor nerve and biceps, with 10 nylon without any tension at the repair site. The nerve repair is performed in front of the brachial vascular bundle, and fibrin glue may be added.

The nerve to the brachialis muscle is not reinervated in those cases.

Hand function is assessed both pre- and postoperatively by Gilbert-Raimondi score (Table 1). The hand function of the first 5 cases was grade V according to the Gilbert-Raimondi score, and the last 2 cases were grade IV. There was no loss of hand function postoperatively.

Oberlin's procedure with neurolysis of C5, C6, and the superior trunk was done in the first case (Fig. 1).

Oberlin's procedure was the only procedure done in the nonexplored cases (cases 2–5).

Neurolysis of the middle and inferior trunk, Oberlin's procedure, and neurotization of the spinal accessory nerve to the suprascapular nerve and the pectoral nerve to the axillary nerve were done in case 6.

Figure 1. Neuroma in continuity of C5, C6, and superior trunk.

Neurolysis of the inferior trunk, Oberlin's procedure, and neurotization of the spinal accessory nerve to the suprascapular nerve were done in case 7.

RESULTS

The average follow-up was 19 months (range, 13–30 months). We used the Medical Research Council Scale for evaluation of the biceps muscle (Table 2), and the Gilbert-Raimondi score for evaluation of elbow function (Table 3). Table 4 summarizes our results and shows excellent to good biceps muscle recovery and elbow function in the first 5 cases (Fig. 2), and poor results in the last 2 cases.

DISCUSSION

Neurosurgical reconstruction of the brachial plexus in patients suffering from birth palsy was first reported by Kennedy in 1903.[12] However, Sever[13] reported a larger series in 1925, and concluded that there was no definitive advantage in direct repair of the brachial plexus. Therefore, reports of the procedure in the literature disappeared for a long time.

In the 1980s, advances in microsurgical technologies enabled surgeons to repair damaged nerves more precisely, and brachial plexus surgery was again performed in patients suffering from birth palsy.[14]

There are two alternative methods of microsurgical nerve repair: intraplexal nerve repair, and neurotization of peripheral nerves by using other intact nerves.[14]

The former is applied to postganglionic lesions, and most frequently a bundle of sural nerves is interposed as free-cable nerve grafts. The latter is applied in more

Table 2. Medical Research Council Grading System

Observation	Muscle grade
No contraction	0
Flicker or trace of contraction	1
Active movement with gravity eliminated	2
Active movement against gravity	3
Active movement against gravity and resistance	4
Normal power	5

Table 3. Gilbert-Raimondi Score for Elbow Function

Observation	Muscle grade
Flexion	1
Nil or some contraction	1
Incomplete flexion	2
Complete flexion	3
Extension	
No extension	0
Weak extension	1
Good extension	2
Extension defect	
0–30°	0
30–50°	−1
More than 50°	−2

severe cases, in which the cervical nerve roots have been avulsed from the spinal cord, and the proximal nerve stumps are not available for transplantation.[14]

Plexoplexal nerve grafting is the most common procedure for traction injury of the brachial plexus, whereas Intercostal nerves (ICNs),[5] the accessory nerve,[6] the cervical plexus,[15] the phrenic nerve,[7] and the C7 root on the contralateral side[16] have also been used in combination procedures.

In 1994, Oberlin et al.[17] described a new technique of nerve transfer for restoration of elbow flexion in traumatic C5–C6 avulsion of the brachial plexus in adults: they cut 10–15% of the fascicles of the intact ulnar nerve in the upper arm, and sutured these fascicles to the biceps nerve. Subsequent authors also used Oberlin's nerve transfer in adults, but we are not aware of any report describing this transfer in Erb's birth palsy. Al-Qattan[18] is the only one who described two cases of Erb's birth palsy of the C5–C6 type. Both patients presented late (16–18 months after birth) and had a stable shoulder (active shoulder abduction against gravity was present in both patients). The main functional deficit was the absence of elbow flexion, and Oberlin's nerve transfer was performed within 2 weeks of presentation without exploration of the brachial plexus. Initial biceps motor recovery was noted at 12 weeks in the first patient and at 14 weeks in the second patient. At 5 months after surgery, elbow flexion was graded as normal (M5 of the Medical Research Council; MRC). This is the first report of Oberlin's nerve transfer in Erb's birth palsy. Authors

Table 4. Results of Oberlin's Procedure*

Case	Age at operation (months)	Nerve lesion	Nerve repair	Follow-up (months)	Gilbert-Raimondi score for elbow function	Medical Research Council scale for biceps muscle
1	14	NIC of ST	Oberlin's and ST neurolysis	13	4	5
2	13	No exploration		15	5	4
3	20	No exploration		14	4	3
4	11	No exploration		19	5	4
5	9	No exploration		29	5	5
6	17	RA of C5 and C6, NIC of MT and IT	AN-SSN, Oberlin's procedure, PN-AxN, neurolysis of MT and IT	16	3	1
7	24	RA of C5 to C7, NIC of IT	Oberlin's operation, AN-SSN, neurolysis of IT	30	2	1

**NIC, neuroma-in-continuity; RA, root avulsion; ST, superior trunk; MT, middle trunk; IT, inferior trunk; C5–C7, cervical nerve roots; AN, accessory nerve; SSN, suprascapular nerve; PN, pectoral nerve; AxN, axillary nerve.*

Figure 2. Demonstration of positive Cookie test (biceps muscle G5), 13 months postoperatively.

who utilized this nerve transfer in adults obtained a functional recovery of the biceps without any functional disturbance of the ulnar nerve.[19]

Our study included 7 cases of Oberlin's ulnar nerve transfer to the biceps motor nerve. They presented late (range, 11–24 months after birth; average, 16 months). The main functional deficit was the absence of elbow function. Oberlin's nerve transfer was performed with exploration of the brachial plexus in 3 cases. The average follow-up was 19 months (range, 13–30 months). The biceps power according to the MRC scale was M5 in 2 cases, M4 in 2 cases, M3 in 1 case, and M1 in 2 cases. Five patients had gained elbow flexion out of 7 cases (71%) (Table 3). No complication had been developed in these children for the ulnar nerve function in the hand after the transfer.

One must be aware of the numerous variations of the origin and distribution of the musculocutaneous nerve. In rare cases, the musculocutaneous nerve does not pierce the coracobrachialis muscle. In approximately 10% of cases, there is a common trunk for the median and the musculocutaneous nerves. There is more than one nerve supply from the musculocutaneous nerve to the biceps (two neurovascular bundles or more). The main nerve supply to the biceps muscle from the musculocutaneous nerve is more proximal and thicker than the others (Fig. 3). Among these variations, the direct origin of the nerve to the biceps from the median nerve is not uncommon.

A high-intensity electrical stimulation of the neighboring medial cutaneous nerve of the forearm may conduct the stimulation for the ulnar nerve, and this may mislead the surgeon to suture the sensory nerve to the biceps nerve. This might have happened in cases 6 and 7, who had poor results (Table 3). Thus the poor results may be due to misconnection of the sensory fascicles to the nerve to the biceps, and also to the initial traumatic involvement of the middle and lower trunks of the brachial plexus.

Figure 3. Postmortem specimen, showing biceps muscle with two nerves supplied from musculocutaneous nerve (Noaman's preparation). Upper part is proximal side of specimen.

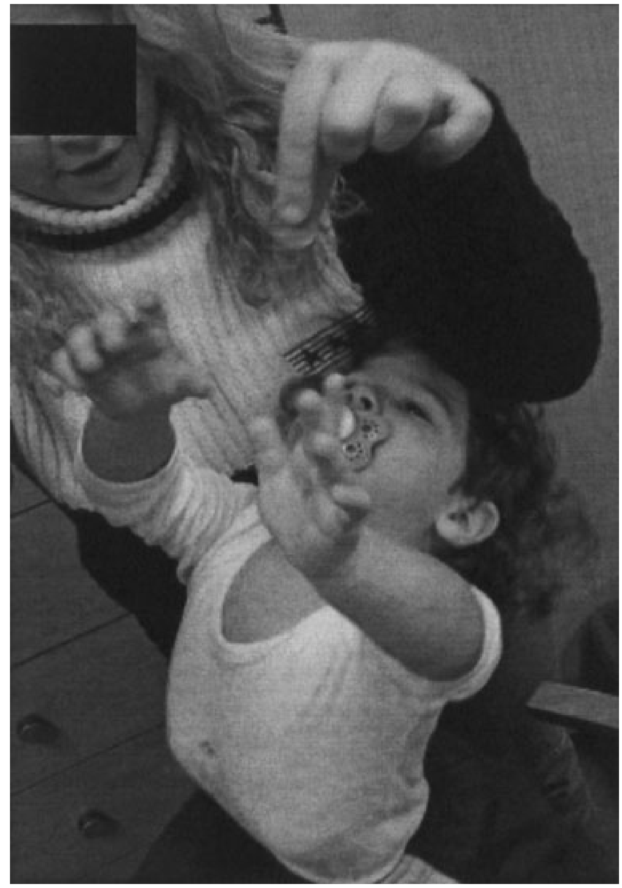

Figure 4. Demonstration of equally normal shoulder function in both sides, at 13-month follow-up.

Most authors[20–23] relied on spontaneous recovery of the biceps as the indication for surgery in Erb's birth palsy. If the recovery of the biceps had not begun at 3–4 months of age, the functional prognosis was considered poor, and primary surgical repair of the plexus was warranted. Therefore, Oberlin's nerve transfer would be indicated in upper obstetric brachial plexus palsy in four situations:

1. The first situation is when primary surgical exploration of the plexus shows isolated avulsion of the C5 and C6 roots. This is generally a rare finding in obstetric paralysis, but was described in several cases of birth palsy associated with breech delivery.[24] In these cases, shoulder stability could be obtained by accessory to suprascapular nerve transfer, and elbow flexion could be obtained by Oberlin's nerve transfer.
2. The second indication is the late presentation. In these cases, the results of reconstruction of the brachial plexus using nerve grafts or neurotization of the plexus in the neck are severely compromised by the prolonged period of denervation to the biceps muscle. On the other hand, motor reinnervation of the biceps occurs within 3 months after Oberlin's transfer, and thus elbow flexion is restored before permanent atrophy of the muscle.
3. The third indication is spontaneous recovery of the upper obstetric brachial plexus palsy without biceps function.
4. The fourth indication is good conducting neuroma in continuity of the upper trunk with nearly normal shoulder function and no biceps function (Figs. 1, 4).

The technique is different from the "end-to-side nerve repair" developed by Viterbo et al.,[25] Lundborg et al.,[26] Tham and Morrisson.[27] These authors demonstrated in the animal model that a nerve could sprout into a distal nerve stump after simple excision of the epineurium and epineural suture into the "donor" nerve.

Franciosi et al.[28] reported on 5 cases of reinnervation of the musculocutaneous nerve in adults with interesting recovery. However, these results seem inferior to those obtained with an end-to-end repair using fascicles of the ulnar nerve.

The transfer of some fascicles from intact ulnar nerve to the nerve to the biceps is a new technique[9] supported by several hypotheses:

The reinnervation of the biceps gives better results than palliative treatment. In cases of upper obstetric brachial plexus palsy, the closest normal nerve to the biceps nerve is the ulnar nerve. This close proximity allows a direct repair that results in rapid reinnervation of the biceps. The nerve of the biceps is very small, and needs only a thin fascicle for reinnervation. The selection of a suitable fascicle for transfer is facilitated by electrical stimulation of the nerve during surgery.

CONCLUSIONS

Ulnar nerve transfer to the biceps nerve in cases of upper obstetric brachial plexus injury is a good solution, especially for C5–C6 nerve root avulsion, late presentation of children with no biceps and good shoulder function, and good conducting neuroma in continuity of the upper trunk with no biceps function.

The results of this transfer could be improved by good indications for the transfer, transferring the correct motor fascicles of the ulnar nerve by low-voltage nerve stimulation, and by suturing the chosen ulnar nerve fascicles to the main biceps nerve.

If at least M3 strength of the biceps muscle is not achieved, a flexorplasty or triceps transfer (if C7 is not involved) may be added. A free muscle transfer may be done if local muscles are not available.

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