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Does nerve repair or transfer really help in birth associated brachial plexus injury (obstetric palsy)? Current evidence

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ABSTRACT

Brachial plexus birth palsy occurs in 0.1–0.4% of live births, with most showing signs of recovery in the first 2 mo of life. In infants who do not recover in the first 3 mo of life have a considerable risk of long-term disability. If recovery extends beyond 6 mo, surgery may be indicated, based on the type of nerve injury. Avulsion injuries are mainly treated with nerve transfers. Ruptures have varying degrees of recovery, and their treatment remains controversial concerning indications and timing of surgery. This article reviews nerve repair, timing of surgery, technique, and results.

Key Words
Nerve repair, brachial plexus injury, birth, microsurgical

INTRODUCTION

Brachial plexus birth palsy occurs in 0.1–0.4% of live births. Most infants with brachial plexus birth palsy who show signs of recovery in the first 2 mo of life will subsequently have normal function. However, infants who do not recover in the first 3 mo of life have a considerable risk for long-term disability. As the delay in recovery extends from 3–6 mo or beyond, this risk increases, and microsurgery may be indicated and is based on the type of nerve injury. Avulsion injuries will not recover spontaneously and therefore microsurgery is recommended before 3 mo of age. As the avulsed roots cannot be directly repaired to the spinal cord, they are treated mainly with nerve transfers. Ruptures have varying degrees of recovery and are the source of controversy regarding indications and timing of surgery.

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BASIS OF NERVE REPAIR

The first comparison of conservative and surgical treatment for infants with brachial plexus birth palsy was published by Gilbert and Tassin in 1984.[1] Patient groups with equal clinical pictures of neurological deficit were compared. In the surgical group, a Mallet grade IV shoulder was reached in 14 of 22 patients (63%), while delayed spontaneous recovery showed a maximum recovery of grade III. In 27% of the conservatively managed population who showed complete spontaneous recovery, the biceps muscle had gained strength to Medical Research Council (MRC) grade 3 by 2 mo of age. In children with biceps recovery after 3 mo, the end stage was incomplete. This paper concluded that surgical treatment is warranted if the biceps muscle has not recovered by 3 mo of age.

Clarke *et al.*[2] reported the outcomes of graft repair of conducting neuromas in 26 patients, and a comparison was made with 16 infants who underwent neurolysis of the lesion. This study concluded that the end results were better in the nerve repair group.

In patients with global injury, achieving hand function is crucial. This reconstruction needs to be done early before the demise of motor end plates. Pondaag and Malessy[3] demonstrated improved hand function after lower trunk reconstruction in about 70% of patients. These promising results have led to surgical strategies of nerve reconstruction, with achievement of hand function as a priority. Gilbert and Tassin[1] suggested that unlike adults, infants with brachial plexopathy may have the potential to regain hand function after nerve reconstruction.

DECISIONS ABOUT NERVE REPAIR AND TIMING

Gilbert and Tassin,[1] as well as other surgeons,[4•] adopted the absence of return of biceps function by 3 mo as an indication for microsurgical intervention. They cited poorer shoulder outcomes at 5 yr and increased likelihood for secondary procedures in patients who regained biceps function after 3 mo. Other authors have adopted more conservative management, suggesting that absent elbow flexion alone at 3 mo may incorrectly predict a poor recovery and may lead to unnecessary microsurgical intervention.[5,6] They reported that patients who regained biceps function between 4 and 6 mo of age were able to achieve global shoulder function with secondary tendon transfers[7] comparable to the function of those who underwent microsurgical procedures at 3 mo of age.

Clarke and Curtis[8] routinely used return of biceps function at 9 mo of age as an indication for microsurgical intervention. The child's ability to bring a cookie (the "cookie test") to his or her mouth without bending the torso forward to more than 45° was a defining factor guiding treatment. Chuang *et al*.[9] retrospectively reviewed 78 infants with 4 yr of follow-up and determined that improvement in shoulder and elbow function was similar for patients treated with microsurgery during infancy or later. Hand function, however, was poorer when surgery was performed after infancy.

TECHNIQUE OF NERVE REPAIR

The spectrum of nerve surgery historically includes neurolysis, neuroma resection, and nerve grafting. Nerve transfers[10] and nerve conduits have led to an expansion of procedures available for nerve reconstruction. Neurolysis alone is no longer indicated in obstetric brachial plexus palsy. After excision of the neuroma, direct repair is rarely performed because of the difficulty in repairing healthy nerve ends without tension, although some surgeons describe favorable results in younger patients.[11] Nerve grafts bridge the viable nerve tissue proximal and distal to the injury. Autologous sural nerve grafts are typically used, although other donor grafts from the affected limb also have been employed.[12] Neuroma resection and nerve grafting are the standard of microsurgical care for rupture injuries to which other techniques need to be compared.

RESULTS OF NERVE REPAIR

Lin *et al*.[13•] demonstrated that early improvements in the neurolysis group were not maintained for a long period of time. Patients who underwent nerve repair showed significant improvement in Active Movement Scale (AMS) scores at 4 yr follow-up. Patients who had grafting for Erb's palsy had improved function in seven movements, while patients who had grafting for total palsy showed improved function in 11 of 15 movements.

In the long-term study of patients who underwent nerve repair, Gilbert *et al*.[14] reported encouraging results. At 4 yr, 80% of children had good or excellent results in shoulder function for C5–C6 lesions. For C5–C7 lesions, 61% patients had good or excellent results. In complete palsy, the results after 8 yr were 77% with average, good, or excellent results. Results of elbow function were rated good or excellent in 81% patients at a follow-up of 8 yr.

After complete paralysis, the results of hand function were quite encouraging. Although at 2 yr only 35% of children had a useful hand, after 8 yr and several tendon transfers, 76% had a useful hand. This reflected that even lower-root avulsions should be repaired.

Birch and Ahad[15] published the results of nerve repair in 100 infants at mean postoperative follow-up of 85 mo (30–152 mo). They utilized the Gilbert score, Mallet score, and Raimondi score as outcome measures. Good results were obtained in 33% of repairs of C5, in 55% of C6, in 24% of C7, and in 57% in C8 and T1. They suggested the utility of preoperative electrodiagnosis and intraoperative somatosensory-evoked potentials to detect occult intradural (preganglionic) injury.

LIMITATION OF OUTCOMES STUDIES

A systematic review of the literature was performed by Pondaag and Messely[16•] to identify studies that compare nerve reconstruction with conservative treatment. Eight of nine papers had a level of evidence of IV, while the remaining had a level of evidence of V. They concluded that the quality of papers supporting the surgical treatment of obstretic brachial plexus palsy differed significantly. As the selection process for surgery differed between the studies, a definite conclusion on how to select patients for surgery could not be drawn. Thus, the key question of whether nerve repair or a late salvage procedure should be done in patients who have biceps recovery between 3 and 6 mo remains.

FUTURE OF NERVE REPAIRS

Recent approval by the Food and Drug Administration of synthetic collagen nerve conduits has led to increased interest in the use of these nerve guidance channels in microsurgery for brachial plexus palsy. Previously, synthetic tubes constructed from materials such as polyglycolic acid, polylactide-co-caprolactone, and silicone yielded poor results. There are no trials at this time to compare collagen synthetic nerve grafts with autologous nerve grafts. The advantages of synthetic grafts over conventional autologous grafts include eliminating donor site morbidity, increasing the amount of graft material available, and providing direct conduits for neural growth factors produced by the proximal segment to reach the distal segment. A preliminary series by Ashley *et al*.[17] described five children treated with collagen tubes, with the result of a good recovery for four of five patients (Motor Scale Composite [MSC] $>$ 0.6), and three attaining an excellent recovery (MSC $>$ 0.75) at the 2-year follow-up visit. Although larger studies will be needed, the data from this small study suggest that collagen matrix tubes could be a safe alternative to autologous nerves for select short segments.

NERVE TRANSFER

When a nerve root is avulsed from the spinal cord nerve, repair is not possible. In such cases, nerve transfer can be used for regaining the function. Nerve transfer connects the extrabrachial plexus or functioning intraplexus nerve to the nerve whose function is desired. Nerve transfer permits faster reinnervation of muscle than traditional nerve repair because anastomosis is closer to the neuromuscular junction. Nerve transfer is carried out as an isolated procedure or along with nerve repair.

NERVE TRANSFER FOR SHOULDER EXTERNAL ROTATION

External rotation is mainly carried out by the infraspinatus, which is innervated by the suprascapular nerve (SSN). To improve external rotation, the SSN should be neurotized. The spinal accessory nerve (SAN) is an attractive extraplexal option to restore shoulder function because it is a pure motor donor. It lies in close proximity to the SSN.

The results of this transfer have been published in a number of series. Though these papers have used different scoring systems to evaluate outcome, all studies have shown improvement in shoulder function.

Pondaag *et al.*[18] assessed active external rotation and functional outcome score after SAN to SSN transfers in 21 patients. Their data suggest that even though there is not much improvement in external rotation, there is improvement in shoulder function. Grossman *et al.*[19] reported results in 26 infants, and all children achieved a shoulder function grade of 4 or better using the modified Gilbert Scale. Van Ouwerkerk *et al.*[20] reported their results in 54 children, with 39 achieving more than 20° of active external rotation by 4 mo postoperatively. Terzis and Kostas[21] carried out SAN to SSN transfer in 25 children with improvement in abduction and external rotation components of the Mallet score. Schaakxs *et al.*[22•] studied the results of SAN to SSN in 65 patients. In 71.5% of the patients, active external rotation between 60–90° was gained. Seven patients with clinical signs of dysplasia before the operation did not show any sign of dysplasia in the postoperative follow-up. Ruchelsman *et al.*[23•] reported their results of the SAN to SSN in 25 infants. At a minimum follow-up of 24 mo, mean active external rotation was 69.6°, the mean Gilbert score was 4.1, and the mean Miami score was 7.1. These results suggest good shoulder functional outcomes. Loss of trapezius function was not reported as a complication of this transfer.

What is the effect of age on the result of this transfer? It is likely that as the denervation time increases, muscle atrophy increases. So delay may have a negative effect on the result. Three papers[20,21,23•] analyzed age at the time of operation and its effect on the results. They provided contradictory suggestions.

A prerequisite for SAN to SSN transfer is adequate passive external rotation at the shoulder. If internal rotation contracture is present, it should be corrected by surgery before or at the time of nerve transfer.

NERVE TRANSFER FOR SHOULDER ABDUCTION

SAN to SSN transfer helps to regain function of infraspinatus and supraspinatus. However the supraspinatus alone is a weak abductor. For better abduction, additional deltoid action is required. This can be achieved by neurotizing the axillary nerve. All three heads of the triceps receive their motor supply through a separate branch from the radial nerve. The nerve supplying one of the heads of triceps can be transferred to the axillary nerve.

In a small case series, McRae[24] reported the results of this procedure in two patients with obstetric brachial plexus palsy. Preoperative shoulder abduction scores were 2 and 3 by active movement scale (AMS). After transfer, the scores were 5 and 6, which indicates that patients were able to achieve antigravity shoulder abduction.

NERVE TRANSFER FOR ELBOW FLEXION

Elbow flexion is an important upper extremity function. Nerve transfers can be directed to the biceps or to the brachialis or to musculocutaneous nerve. In infants who have upper middle trunk lesions, local transfer from the ulnar, median, or medial pectoral nerve is possible as they receive contribution predominantly from the C8 and T1 roots. In global lesions, local transfers are unavailable and so intercostal transfers are preferred.

Transfer of Ulnar Nerve

Oberlin *et al.*[25] described transfer of the fascicle of the ulnar nerve supplying the flexor carpi ulnaris muscle to nerve to biceps, and Noaman *et al.*[26] reported results of this transfer in seven children. Five children regained biceps function of MRC grade 3 or more, and two children had biceps function less than MRC grade 3. Siqueira *et al.*[27•] performed this transfer in 17 infants. Three children obtained MRC grade 3, and 11 children had MRC grade 4 elbow flexion power.

Transfer of Median Nerve

Alternatively, the biceps can be innervated through a fascicle of the median nerve. Al-Qattan *et al.*[28] reported their results in 10 patients with obstetric brachial plexus palsy. The preoperative AMS for elbow flexion ranged from 0–2. At final follow-up, all seven patients with C5-6 palsy obtained a score of 7. Two patients with C5-6-7 palsy had a score of 6 and 7.

Transfer of Both Ulnar and Median Nerves

Nerve transfer to innervate both the biceps and the brachialis is preferred. The reason for this preference is that the brachialis muscle is primarily an elbow flexor, and the biceps muscle is primarily a forearm supinator. Therefore, reinnervation of both the muscles provides better elbow flexion and supination strength. To innervate both muscles, one fascicle of ulnar and median nerve are taken. In a recently published paper, authors used combined transfer in five patients.[29•] Postoperatively, elbow flexion achieved an AMS of 7 and supination achieved an AMS of 5 or more, whereas single-fascicle transfer in 21 children resulted in elbow flexion of an AMS greater than 6 and supination of AMS grade 2 to 5. Thus, combined transfer achieved better supination.

Medial Pectoral Nerve Transfer

One or two terminal branches to the pectoralis major can be transferred to musculcutaneous nerve or nerve to biceps. Pondaag and Malessy[30] reported transfer of the medial pectoral nerve (MPN) to biceps in 25 children. Twenty three children achieved greater than MRC grade 3 elbow flexion power. Wellons *et al.*[31•] reported MPN to musculocutaneous nerve transfer in 20 children; 80% gained functional recovery. Blaauw and Slooff[32] reported MPN to musculocutaneous nerve transfer in 25 cases, achievinge excellent results in 17 on the Mallet scale.

Intercostal Nerves

The intercostal nerve is an extraplexus source. Intercostal nerves can be cut 1 cm distal to the mammary line and coapted directly to the musculocutaneous nerve in the axilla. Kawabata *et al*.[33] reported their results of transfer of the intercostal nerve to the musculocutaneous nerve in 31 children. Twenty six achieved MRC grade 4 strength in the elbow flexors. El-Gammal *et al*.[34] used intercostal transfer in 46 infants with satisfactory restoration of elbow flexion in 93.5% of the patients

Surgeons face a dilemma of selecting the best donor nerve for elbow flexion in cases of C5-6 or C5-7 involvement, but if possible both the biceps and brachialis should be innervated.

Transfer of Contralateral C7 Root

The contralateral C7 root is another extraplexus source. Lin *et al*.[35] reported this transfer in 15 infants having brachial plexus palsy. Motor function greater than MRC grade 2+ was gained in 11 patients. Sensory function greater than MRC grade 3 was gained in all patients.

Chen *et al*.[36] reported results of 12 patients with brachial plexus root avulsions from birth injury or other trauma. Motor function greater than MRC grade 2+ was gained in 10 of 12 patients, and sensory function greater than MRC grade 3 was gained in all.

Other Transfers

No study has shown promising results with transfer of the anterior rami of C3 and C4, phrenic nerve, or hypoglossal nerve. As the use of nerve transfers increases, more and more studies describing short-term and long-term results are being published. We continue to understand various factors affecting the results of nerve transfer. Future studies will answer how late nerve transfer can be carried out without compromising the result.

CONCLUSION

Current literature suggests that nerve repair and transfer both improve function in children having birth associated brachial plexus injury. Advancement in surgical technique will continue to improve the results.

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