IFSSH Scientific Committee on Neonatal Brachial Plexus Palsy

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The Role of Nerve Transfers in the Treatment of Neonatal Brachial Plexus Palsy

Abstract

Nerve transfers have gained popularity in the treatment of adult brachial plexus palsies, however, their role in the treatment of neonatal brachial plexus palsies remains unclear. The purpose of this article is to critically review the current literature surrounding the use of nerve transfers for neonatal brachial plexus palsy.

The relative merit of nerve transfers as a primary strategy for nerve reconstruction for Erb palsy is still unclear. In the cases of extended Erb palsy and more severe palsies, the current complement of nerve transfers is inadequate to satisfy all target muscles. Given implications of denervation on limb function, growth, and the possibilities for secondary musculoskeletal reconstruction, maximal re-innervation should remain the primary goal of reconstruction.

Without direct comparative studies and given the lack of consensus in methods of reporting results, future studies should consider using a well established outcome measure and should clearly define how outcomes are assessed.

Introduction

Neonatal brachial plexus palsy (NBPP) occurs in 1 in 1000 newborn infants[1,2]. Although most infants recover satisfactory function spontaneously, 10-30% benefit from surgery[3-6].

Interposition nerve grafting has been the mainstay of surgical treatment [4,5,7-9]. In the case of nerve root avulsion(s), distal targets are prioritized in the following order: hand (if affected), elbow flexion, and shoulder [3].

Nerve transfers take functioning donor nerves/branches/fascicles to innervate non-functioning distal targets. The donor may be part of the brachial plexus on the affected side (intraplexus) or may originate outside of the affected brachial plexus (extraplexus); it may be motor, sensory, or mixed motor and sensory.

Nerve transfers have gained popularity in the treatment of adult brachial plexus palsy[10] and many have been applied to NBPP (Table 1). For example, the combination of median and/or ulnar to biceps and/or brachialis (M/U-Bi/Br), radial triceps branch to axillary anterior deltoid branch (Tri-Del), and spinal accessory to suprascapular nerve (SAN-SSN) can be used to treat upper trunk palsy[11-14]. Although a recent systematic review suggests that nerve transfer may produce superior outcomes to nerve grafting in adults[15], treatment of NBPP differs greatly: the mechanisms, patterns, severity, extent of injury, and scar tissue formation are disparate; infants have a much greater potential for recovery; and the influences of a shorter limb (with shorter distances for axons to reach targets), growth, and development (with potential for central nervous system adaptation) must be considered. The purpose of this report is to review the current literature and evidence surrounding the use of nerve transfers for the treatment of NBPP. This review will focus primarily on re-innervation of distal motor targets.

We performed a Medline Search for literature documenting results of nerve grafting, nerve transfer, or both in the treatment of NBPP.

Table 1: Commonly described nerve transfers for NBPP

Donor nerve	Nerve type		Abbreviation
Intraplexus	Motor	Median and/or ulnar to biceps and/or brachialis	M/U-Bi/Br
	Motor	Radial triceps branch to axillary anterior deltoid branch	Tri-Del
	Motor	Medial pectoral nerve to musculocutaneous	MPN-MSC
	Mixed Motor and Sensory	Ipsilateral C7	iC7
Extraplexus	Motor	Spinal accessory to suprascapular nerve	SAN-SSN
	Mixed Motor and Sensory	Intercostals to musculocutaneous	ICN-MSC
	Mixed Motor and Sensory	Contralateral C7	cC7

Outcome measures

Given the variations in reporting motor function, we tabulated outcomes according to common validated systems including MRC scale, Active Movement Scale (AMS) [16], and Mallet score[17].. Some authors have simplified reporting their results by using the percentage of patients achieving "useful function" defined as an AMS score of 6 or more[18-20]. When a modified MRC scale was used, we examined whether it allowed a similar definition to be assumed.

The available literature

Only 2 studies directly compare the results of nerve transfer to nerve grafting for NBPP in a robust side-by side manner[21,22]. All other studies are case series and reports that vary greatly in patient age, palsy type, surgical indications, adjunctive/concomitant procedures, and follow-up duration (Table 2). In addition, we found variations in surgical technique that may have significant implications: results of M/U-Bi/Br may be better when performed as a double fascicular transfer compared to single fascicular transfer[19]; posterior approach for SAN-SSN decompresses the nerve through the suprascapular notch whereas the anterior approach does not[23]; the donor for Tri-Del may be the nerve branch to any of the 3 muscular heads and potential denervation of the donor was not universally investigated[24,25]. Given the inconsistencies in clinical circumstances, findings from one study are difficult to compare to another.

The differentiation of Erb/Type 1 from Extended Erb/Type 2 palsy is of specific interest in the setting of nerve transfers given that the triceps nerve branch may be abnormal for the Tri-Del transfer. However, only a few studies provided enough description to make this distinction possible[5,25-28]. Table 2 summarizes the available data for elbow flexion with presentation grossly divided between "Upper palsy" (C5-6 +/- C7) and "Total palsy" (C5-8 +/- T1)[29].

Table 2: Results of nerve graft and nerve transfer for elbow flexion

					Reported outcome									
					% functional (AMS≥6 or equivalent)		Mean AMS Score		MRC Score		Mallet (hand to mouth) or other			
Approach/Author	**Palsy**	**N**	**Clinical situation/Indications**	**Average age (range) (months)**	**Pre-op**	**Post-op**	**Pre-op**	**Post-op**	**Pre-op**	**Post-op**	**Post-op**	**Follow up (Years)**	**Donor morbidity**
Nerve grafting													
Lin 2009	U	48	Toronto algorithm	9.4 ± 2.1 (SD)	12.5	100	3.6	6.6	-	-	-	4	
Lin 2009	T	44	Toronto algorithm	6.1 ± 2.3 (SD)	0	86.3	0.7	6	-	-	-	4	
El-Gammal 2010	T	18	Pan plexus at 3 months	10.8 (3-60)	0	72	-	-	-	-	-	4.2 (2.5-7.3)	
Boome 1988	U	22	No C5/6 recovery at 3 months	5.3 (3-20)	-	-	-	-	N/A	78% MRC≥3	-	N/A	
Waters 1999	U, T	6	No biceps function at 6 months	N/A (N/A)	-	-	-	-	-	-	33% Mallet 2, 33% Mallet 3, 33% Mallet 4	3.8	
Nerve transfer													
Intraplexus - Pure motor transfer													
M/U-Bi/Br													
Ladak 2014	U	10	Failed "Cookie Test"	N/A (10-18)	-	-	3.7	6.3	-	-	-	2	No changes in wrist flexion
Little 2014	U	31	Late presentation, dissociative recovery, avulsions, or failed reconstruction	8.4 (3-20)	0	87	1 (0 to 3)*	6 (5-7)*	-	-	-	1.5	3% transient AIN palsy
Al-Qattan 2014	U	10	Late presentation	16 (13-19)	0	90	0.8	6.2	-	-	-	1.5	No detectable donor deficits
Siqueira 2012	U, T	17	Late presentation, avulsios, or failed reconstruction	12.9 (4-26)	N/A	65	-	-	-	-	-	2.6 (1.6-5.4)	No changes (hand x-ray or Al-Qattan hand score)
Noaman 2004	U	7	Late presentation	15.4 (9-24)	-	-	-	-	N/A	71% MRC≥3	-	1.6 (1.1 to 2.5)	Not specified
Al-Qattan 2002	U	2	Dissociateive recovery	13 (12-14)	0	100	0	7	-	-	-	0.4	Not specified
Estrella 2012	U	1	No elbow and shoulder flexion	10 (N/A)	0	100	0	7	0	MRC 5	-	5	No finger or wrist weakness
Al-Qattan 2010	U	1	Dissociateive recovery	12 (N/A)	0	100	0	7	-	-	-	1.5	None
Shigematsu 2006	U	1	No elbow flexion and shoulder abduction	8 (N/A)	0	100	-	-	0	MRC 5	-	3.3	None
MPN-MSC													
Wellons 2009	N/A	20	Not Specified	7 (5-10)	-	-	-	-	-	-	80% had ability to bring hand to mouth	1.8 (0.8-7)	None
Blaauw 2003	U	25	Not Specified	5.28 (3-10)	-	-	-	-	-	68%	8% Mallet 2, 16%	5.8 (SD 2.9)	Not specified

										MRC≥3	Mallet 3, 72% Mallet 4		
Pondaag 2012	U	25	Pan plexus at 3 months or poor shoulder and biceps at 4-6 months	5.8 (3-11)**	-	-	-	-	-	92% MRC≥3	-	3.7 (0.9-8.2)**	None
Intraplexus - Mixed motor and sensory transfer													
iC7													
Romana 2014	U	1	Not Specified	5 (N/A)	N/A	100	N/A	7	-	-	-	8	Not specified
Extraplexus - Mixed motor and sensory transfer													
ICN-MSC													
Pondaag 2012	U, T	17	Pan plexus at 3 months or poor shoulder and biceps at 4-6 months	5.8 (3-11)**	-	-	-	-	N/A	82% MRC≥3	-	3.7 (0.9-8.2)**	No donor deformity noted
Kawabata 2001	U	30	No biceps at 3 months and avulsions on exploration	5.8 (3-14)	-	-	-	-	0	93% MRC≥3	-	5.2	No donor deformity or dysfunction
El-Gammal 2008	U, T	31	Not specified	14 (4-24)**	N/A	93.5	-	-	-	-	-	4 (1-7.2)**	100% atelectasis; 4.3% pneumonia
Luo 2011	U, T	12	Avulsions or dissociative recovery	5.7 (3-11)	N/A	100***	-	-	-	100% MRC≥3	-	4.3 (3-5.5)	
cC7													
Lin 2011	U	15	Avulsions	7.5 (3-15)	N/A	73***	-	-	-	60% MRC≥3	-	3.9 (3-5.2)	80% synchronous contralateral movement
Lin 2010	T	9	Avulsions (≥4)	4 (3-6)	N/A	78***	-	-	-	78% MRC≥3	-	4.2 (3.7-5.2)	66% synchronous contralateral movement; 11% transient loss of abduction
Chen 2007	T	4	Avulsions (≥4)	9.75 (6-14)	N/A	75***	-	-	-	75% MRC≥3	-	3.8 (3.2-4.6)	100% synchronous contralateral movement; 25% transient loss of abduction

N/A = Not Available or Not Specified, U = Upper, T = Total
* Expressed as median
**Age and follow-up are for the entire study group
*** Assumes author defined MRC 2+ (Lin 2011, Lin 2010, Chen 2007) or MRC 3 (Luo 2011, Little 2014) is equivalent to AMS 6 or greater

Outcomes

1. Primary reconstruction of Erb palsy

Although there are no studies that directly compare results of nerve transfers to nerve grafting (Table 2), two studies describe outcomes using each approach in patients with similar clinical circumstances. Lin reported results of nerve grafting in a group of 48 patients with Erb palsy who were evaluated according to the algorithm developed in Toronto[4], that includes the Cookie test administered at 9 months of age[18]. Ladak reported results of nerve transfers (M/U-Bi/Br, Tri-Del, and SAN-SSN) in a similar group of 10[25]. Although the durations of follow-up varied, mean AMS scores for shoulder abduction, shoulder external rotation, elbow flexion, and forearm supination were similar (Table 2).

Given that, in most of the other studies, the available outcomes are contained in case series and reports with widely varying circumstances, these are summarized below according to target movements.

1. a) Elbow flexion

There are no direct comparisons of nerve grafting to nerve transfers and all studies are in the form of case series or report (Table 2).

Nerve grafting

Few studies report the results of nerve grafting in isolation and in a manner that specifically assesses elbow flexion. Lin found 86% of patients with total plexus palsy and 100% of patients with upper plexus palsy attained AMS≥6[18].

Nerve transfers: Extraplexus donors

Intercostal nerve transfer (ICN) is most often used as an adjunct in the setting of nerve root avulsions[30-32]. The percentage of patients obtaining functional elbow flexion (AMS >6 or equivalent) has been reported at 82 to 100%. ICN transfers can be undertaken safely in infants if the ipsilateral phrenic nerve is functioning normally. The sacrifice of ICNs risks alterations in chest growth and breast development. In addition to potential pneumothorax, El-Gammel reported atelectasis in all patients and pneumonia in 4.3%[33].

Transfer of the contralateral C7 (cC7) via a vascularized ulnar nerve graft has been described for pan plexus palsy with 4 or more avulsions. Lin and Chen respectively report 78% (N=9) and 75% (N=4) achieving active movement against gravity (>½ range) [34,35]. Lin also reported using cC7 transfers via sural nerve grafts to the upper trunk for Erb palsy with C5-6 or C5-7 avulsions with similar outcomes for elbow flexion [36]. Voluntary control was not specifically assessed, however, transient decreases of donor limb shoulder abduction were reported[34,35] and most to all patients had some degree of synchronous contralateral movements[34-36].

Nerve transfers: Intraplexus donors

Medial pectoral nerve to musculocutaneous nerve (MPN-MSC) has been used as an adjunct for more extensive brachial plexus reconstruction[30,37] or as a sole strategy for recovery of elbow flexion[38]. Pondaag reports 92% with MRC≥3[30] while Blaauw reports that 68% had flexion against gravity[37].

More contemporary strategies of intraplexus nerve transfer have involved fascicles of ulnar nerve, median nerve, or both with either the biceps branch (single fascicular transfer) or both biceps and brachialis branches (double fascicular transfer) of the musculocutaneous nerve as recipient(s). Results of single fascicular transfer were reported by Ladak in a homogeneous group of patients failing the Cookie test at 9 months with a mean AMS improvement of 3.7 to 6.3[25]. Other reports using this transfer have been in the setting of late presentation[19,28,39,40], isolated deficit[19,28], root avulsions[19,40], or failed primary nerve graft reconstruction[19,40].

Siqueira reported the lowest percentage attaining functional elbow flexion (AMS ≥6) at 65%, however 30% of patients had a previously failed primary nerve graft reconstruction portending to a lower chance of success[40]. In contrast, Little included only 2 patients (6%) with failed primary nerve graft reconstruction and had 87% patients attain functional elbow flexion[19].

Al-Qattan reported on a group of 10 patients who presented late, without prior reconstruction, and underwent median fascicle to biceps branch transfer at 13 to 19 months of age[39]. No other procedures were noted and 90% attained functional elbow flexion (AMS ≥6). Given that age at nerve reconstruction is thought to be an important factor in treatment success, Al-Qattan's results suggest that nerve transfer is a good option for patients presenting late. Results of nerve grafting at a similar age are not available for comparison.

Patients with "isolated" deficits of elbow flexion may be at a relative functional advantage given that motor control of the rest of the extremity may be intact or mostly intact. This group of patients with "dissociative" recovery may have other motors, such as brachioradialis that contribute to elbow flexion. The merits of isolated nerve transfer in this situation are difficult to determine.

In the instance of C5 and C6 avulsions, nerve transfer is the only option. Siqueria and Little report on 5 and 10 patients respectively who underwent M/U-Bi/Br transfer for elbow flexion in the case of root avulsions[19,40]. All patients in Little's study achieved functional elbow flexion[19] suggesting that this is an ideal indication for this transfer.

1. b) Forearm supination

Few studies report outcomes of forearm supination and there are no direct comparisons of nerve grafting with nerve transfers.

The mean AMS scores reported by Ladak following M/U-Bi/Br were similar to those reported by Lin following nerve grafting for primary reconstruction of Erb palsy.

1. c) Shoulder abduction

There are no direct comparisons of nerve grafting with nerve transfers and all studies are in the form of case series or report. Given the many confounders and paucity of data, inferences on relative merit of each approach are limited.

1. d): External rotation

Comparison of suprascapular nerve reconstruction with either nerve grafting from C5 or SAN-SSN transfer has been reported[21,22]. Although each study looked at different outcome parameters, both studies found no significant difference in outcome with nerve grafting or transfer.

2. Primary reconstruction of Type 2/3/4 NBPP

Several authors have reported nerve transfers for extended Erb palsy (Type 2), however, only motor outcomes related to the specific transfers performed were described and function of the unaddressed targets was not described[19,27,39].

Nerve transfers for pan plexus palsy have been described in the setting of 4 or 5 avulsions where proximal nerve roots are limited or unavailable for nerve grafting[34,35]. A vascularized ulnar nerve was used in cases of cC7 transfer, however, sacrifice of the ulnar nerve precludes any intrinsic hand function, one of the primary goals of reconstruction in these situations.

Discussion

The role of nerve transfers as a sole strategy for primary reconstruction of brachial plexus palsy is unclear given the lack of comparative studies with nerve grafting.

Nerve transfers do have an important role to play in specific circumstances including inadequate proximal roots (ie. multiple avulsions), failed primary reconstruction, late presentation, and isolated deficits.

Surgeons who commit to care of infants with NBPP need to avoid an over-reliance on nerve transfers and should have the capability and inclination for brachial plexus exploration and nerve graft reconstruction. While multiple nerve transfers (M/U-Bi/Br, Tri-Del, and SAN-SSN) can be used to address all of the targets of isolated Erb/Type 1 palsy, in the case of more severe palsies (Type 2 or greater), they leave targets unsatisfied. This not only leaves persistent deficits, it limits motors available for secondary musculoskeletal reconstruction and may have implications on growth. Maximal re-innervation may involve both nerve grafting and nerve transfers.

In spite of the advantages of nerve transfers, the associated morbidity is not clear. Direct donor dysfunction, in an already compromised limb, has significant implications and the effect of partial denervation on musculoskeletal growth is unknown. Although few adverse outcomes have been reported (Table 2), few studies have examined morbidity rigorously and long-term effects on growth are not available.

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