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Timing of nerve transfer for elbow flexion in neonatal brachial plexus palsy

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ABSTRACT

Infants with neonatal brachial plexus palsies (NBPPs) of the upper trunk can suffer permanent loss of elbow flexion. To restore elbow flexion, nerve transfer from an ulnar nerve fascicle to the musculocutaneous nerve branch to biceps, also known as the Oberlin procedure, has reported encouraging outcomes, but the timing of surgical intervention from the time of injury remains controversial. This study is the first to focus on ulnar to musculocutaneous nerve transfer timing in NBPP, and we demonstrate a positive trend in outcomes of elbow flexion and supination in patients intervened on earlier rather than later.

1. Introduction

Neonatal brachial plexus palsy (NBPP) occurs in 1–4/1000 live births (Squitieri, Steggerda, Yang, Kim, & Chung, 2011). Infants with brachial plexus palsies of the upper trunk can suffer permanent loss of elbow flexion (Ali et al., 2015; Chang, Ankumah, Wilson, Yang, & Chauhan, 2016; Estrella, 2011; Garg, Merrell, Hillstrom, & Wolfe, 2011; Sheffler, Lattanza, Hagar, Bagley, & James, 2012; Wilson, Chang, Chauhan, & Yang, 2016). To restore elbow flexion, nerve transfer from an ulnar nerve fascicle to the musculocutaneous nerve branch to biceps, also known as the Oberlin procedure, has been reported (Loy, Bhatia, Asfazadourian, & Oberlin, 1997; Oberlin et al., 1994). Although outcomes are encouraging, the timing of surgical intervention from the time of injury continues to be controversial. Much of the data regarding the timing of brachial plexus reconstruction includes graft repair and nerve transfers other than the Oberlin procedure, so extrapolating these data to the Oberlin transfer in NBPP is problematic. This study looks to specifically examine the effects of timing of the Oberlin transfer in the management of NBPP.

2. Material and methods

2.1. Study design

We conducted a retrospective review of infants with NBPP who underwent Oberlin transfer procedure (N = 19) by a single surgeon at a single institute from 2005 to 2015. Infants with NBPP underwent preoperative physical evaluation, electrodiagnosis, and/or imaging testing by an inter-disciplinary brachial plexus team (neurosurgeons, physiatrists, nurse practitioners, and occupational therapists). Patient characteristics and NBPP-related factors were collected at the first clinic visit and at each subsequent follow-up visit. No patients had prior surgical intervention. The study protocol was approved by the Institutional Review Board.

2.2. Outcomes of interest

Main outcomes of interest were active range of motion (AROM) of elbow flexion in adduction, elbow flexion in abduction, biceps power on the Medical Research Council (MRC) grading scale, forearm supination, forearm pronation, wrist extension, and finger flexion. A certified occupational therapist evaluated the infant's AROM and MRC preoperatively and at postoperative follow-up periods of 3–5 months (period A), 6–9 months (period B), and 10–12 months (period C).

Patient characteristics and NBPP-related factors consisted of operation age, sex, race, NBPP-involved side, Narakas grade (numbers of nerve roots involved) and lesion type (pre-ganglionic or post-ganglionic). For the purpose of the study, we categorized Narakas grade into grade I–II versus III–IV. Intra-operative exploration of brachial plexus defined the lesion type.

2.3. Statistical analysis

We reported descriptive statistics for patient characteristics, NBPP-related factors, and AROM summaries at the preoperative and postoperative periods. Student's *t*-test (for continuous variables), Mann-Whitney test (for ordinal variables), and Chi-square test (for categorical variables) were used to assess AROM differences between preoperative visit versus postoperative visits at A, B, and C periods. To investigate the trends of operation age and functional recovery, we applied Pearson

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Table 1
Patients Demographics.

	All N (%) N = 19
Mean age ± SD	
At initial appointment (months)	2.8 ± 2.5
At operation (months)	7.1 ± 1.8
Sex	
Male	8 (42%)
Female	11 (58%)
Race	
Caucasian	13 (68%)
Other	6 (32%)
Involved side	
Left	11 (58%)
Right	8 (42%)
Narakas	
I–II	12 (63%)
III–IV	7 (37%)
Lesion Type	
Pre-ganglionic	13 (68%)
Post-ganglionic	6 (32%)
Lesion Site	
C5-C6	4 (21%)
C5-C7	10 (53%)
C5-T1	5 (26%)
Follow-up period	
A. 3–5 months	19 (100%)
B. 6–9 months	17 (89%)
C. 9–12 months	19 (100%)

Table 2
Electrodiagnostics, Rational for Surgery, and Additional Transfers.

	Oberlin N (%) N = 19
Electrodiagnostics	
Minimal biceps MUAP	11 (58%)
Few deltoid and biceps	3 (16%)
No EMG	3 (16%)
No biceps, few MUAPS	1 (5%)
No MUAPs to all muscles	1 (5%)
Rationale for Surgery	
C5-6 avulsion	2 (11%)
C6 avulsion	5 (26%)
C5-7 avulsion	2 (11%)
C6-7 avulsion	1 (5%)
C5-6, and C8 avulsion	2 (11%)
Late referral	2 (11%)
No NAPs from C6 but some from C5 and suprascapular	1 (5%)
No NAPs from C5 posterior, none to C6 anterior	1 (5%)
No recovering biceps in isolation	1 (5%)
Unknown	2 (11%)

EMG, electromyogram; MUAP, minimal biceps motor unit action potential; NAPs, nerve action potentials

correlation between operation age and AROM of elbow flexion in adduction, elbow flexion in abduction, and forearm supination at period C. We considered $P < .05$ as statistically significant. All analyses were conducted using commercially available software (SPSS version 22; IBM Corporation, Somers, NY).

3. Results

A total of 19 patients were included in this study (Table 1). Mean age at initial appointment was 2.8 ± 2.5 months, and mean age at operation was 7.1 ± 1.8 months. Eleven (58%) patients were female, 13 (68%) were Caucasian, and 11 (58%) were left-sided lesions. The Narakas grade ranged from I–IV, with 12 (63%) being grade I–II and 7 (37%) being grade III–IV. Thirteen (68%) lesions were pre-ganglionic and 6 (32%) were post-ganglionic.

Electrodiagnostic work-up revealed 11 (58%) patients with minimal biceps motor unit action potential (MUAP), 3 (16%) with minimal deltoid and biceps EMG, 3 (16%) with no EMG signals, 1 (5%) with no biceps signal, but other minimal MUAP, and 1 (5%) patient with no MUAP in all muscles (Table 2).

Mean elbow flexion in adduction continued to improve throughout at 3–5 months, 6–9 months, and 10–12 months: 46° ± 68° (P = .201), 76° ± 41° (P < .0001), and 82° ± 40° (P = .015), respectively. Mean elbow flexion in abduction continued to improve throughout the 3–5-month, 6–9-month, and 10–12-month follow-ups: 68° ± 69° (P = 0.219), 101° ± 51° (P = .001), and 111° ± 36° (P < .0001), respectively (Table 3). Mean forearm supination continued to improve throughout the 3–5-month, 6–9-month, and 10–12-month follow-ups: −26° ± 65° (P = .041), −10° ± 66° (P = 0.027), and 17° ± 51° (P < .0001), respectively (Table 4). Mean finger flexion remained stable among the cohort at 3–5 months, 6–9 months, and 10–12 months: 86° ± 12° (P = .125), 84° ± 16° (P = .164), and 85° ± 15° (P = .163).

There appears to be a slight negative trend with increasing age at operation in both elbow flexion in adduction and elbow flexion in abduction, as evidenced by the slope noted in Figs. 1 and 2. The average age at operation was 7.1 months, 11 (58%) patients had nerve transfer before 7.1 months, and 8 (42%) had nerve transfer after 7.1 months. The mean age of the group with early intervention was 6.0 months, and the mean age of the group with late intervention was 8.7 months (P = .0001). Recovery of elbow flexion had a greater difference from pre-op to 12 months in the early intervention group when compared to the late intervention group. There also appeared to be a more dramatic rate of improvement in the early intervention group in both elbow flexion and supination (Fig. 3).

4. Discussion

Brachial plexus palsies that include the upper nerve roots result in a loss of elbow flexion, and this loss has multiple direct and indirect effects upon a developing child (Ali et al., 2015; Sheffler et al., 2012; Yang, Chang, & Chung, 2012). Although there are varying paradigms in the treatment of brachial plexus palsies, the loss of elbow flexion can be effectively treated by the utilization of the Oberlin transfer (Little, Zlotolow, Soldado, Cornwall, & Kozin, 2014; Loy et al., 1997; Oberlin et al., 1994).

The Oberlin transfer has been increasingly utilized, and the nerve transfer has produced robust results in the recovery of elbow flexion

Table 3
Elbow Active Range of Motion (degree).

	Preoperative.	Postoperative.			P-value. (Pre-op vs. time A).	P-value. (Pre-op vs. time B).	P-value. (Pre-op vs. time C).
	(*n = 19*)	A. 3–5 months (*n = 19*)	B. 6–9 months (*n = 17*)	C. 10–12 months (*n = 19*)			
Elbow flexion in adduction	28 ± 35	46 ± 68	76 ± 41	82 ± 40	0.201	**< 0.0001**	**0.015**
Elbow flexion in abduction	51 ± 45	68 ± 69	101 ± 51	111 ± 36	0.219	**0.001**	**< 0.0001**
Medical Research Council (MRC) strength of biceps	2 (0–2)	2 (0–3)	2 (0–3)	3 (0–4)	–	–	–