Oberlin transfer compared with nerve grafting for improving early supination in neonatal brachial plexus palsy

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OBJECTIVE The use of nerve transfers versus nerve grafting for neonatal brachial plexus palsy (NBPP) remains controversial. In adult brachial plexus injury, transfer of an ulnar fascicle to the biceps branch of the musculocutaneous nerve (Oberlin transfer) is reportedly superior to nerve grafting for restoration of elbow flexion. In pediatric patients with NBPP, recovery of elbow flexion and forearm supination is an indicator of resolved NBPP. Currently, limited evidence exists of outcomes for flexion and supination when comparing nerve transfer and nerve grafting for NBPP. Therefore, the authors compared 1-year postoperative outcomes for infants with NBPP who underwent Oberlin transfer versus nerve grafting.

METHODS This retrospective cohort study reviewed patients with NBPP who underwent Oberlin transfer (n = 19) and nerve grafting (n = 31) at a single institution between 2005 and 2015. A single surgeon conducted intraoperative exploration of the brachial plexus and determined the surgical nerve reconstruction strategy undertaken. Active range of motion was evaluated preoperatively and postoperatively at 1 year.

RESULTS No significant difference between treatment groups was observed with respect to the mean change (pre- to postoperatively) in elbow flexion in adduction and abduction and biceps strength. The Oberlin transfer group gained significantly more supination (100° vs 19°; p < 0.0001). Forearm pronation was maintained at 90° in the Oberlin transfer group whereas it was slightly improved in the grafting group (0° vs 32°; p = 0.02). Shoulder, wrist, and hand functions were comparable between treatment groups.

CONCLUSIONS The preliminary data from this study demonstrate that the Oberlin transfer confers an advantageous early recovery of forearm supination over grafting, with equivalent elbow flexion recovery. Further studies that monitor real-world arm usage will provide more insight into the most appropriate surgical strategy for NBPP.

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KEY WORDS neonatal brachial plexus palsy; Oberlin transfer; nerve grafting; peripheral nerve

EACH year, neonatal brachial plexus palsy (NBPP) affects approximately 1.5 per 1000 live births in the United States.^{43,45} Stretching of the nerves comprising the brachial plexus during the perinatal period results in weakness or paralysis of the shoulder, elbow, wrist, and/or hand. Approximately 10%–40% of infants with NBPP will have persistent NBPP at 1 year of age.^{11,43,56} Depending on the site and severity of the injury, timely diagnosis, early referral, and surgical intervention can potentially benefit infants with persistent NBPP to maximize recovery.

Decision-making regarding management incorporates physical examination, electrodiagnostic testing (EDX), and imaging studies.^{6,10,49} Although indications for reconstruction timing and surgical approaches vary from center to center, the approach is largely determined by the site and severity of the injury. Infants with a flail arm, Horner's syndrome, or lack of recovery in hand or biceps functions at 3–6 months are considered by most to be candidates for surgical intervention.^{3,4,20,23,42,55}

Nerve grafting has been the mainstay for nerve recon-

ABBREVIATIONS AROM = active range of motion; EDX = electrodiagnostic testing; ICF = International Classification of Functioning; MRC = Medical Research Council; NBPP = neonatal brachial plexus palsy.

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struction in restoring elbow/biceps function in the NBPP population, with the Oberlin transfer more recently becoming a viable, safe alternative. Due to the complexity of the injury, the consensus regarding nerve grafting versus Oberlin transfer has not been established. Early case series of patients with NBPP undergoing Oberlin transfer have suggested favorable outcomes in cases with upper brachial plexus lesions (Erb's palsy) and delayed referral.^{2,16,46} However, partial or inconsistent recovery of elbow flexion and concern for donor site morbidity have limited the use of the Oberlin transfer in infants with NBPP.^{33,39}

Recent publications have established the safety of the Oberlin transfer and presented results comparable to those for nerve grafting to improve elbow flexion function. However, disparities in the outcome measures used to evaluate NBPP postoperatively have made it challenging for readers to draw conclusions.^{15,18,26,29,48} Furthermore, data on quality of movement and real-world arm use are limited in the literature. Most treatment algorithms target restoration of elbow flexion; however, recovery of forearm supination could also influence the quality of movement. Currently, there is no study that compares the Oberlin transfer with nerve grafting as a primary nerve reconstruction strategy in infants with NBPP. The goal of this study was to compare 1-year postoperative outcomes in elbow flexion, forearm supination, and forearm pronation in infants with NBPP who underwent Oberlin transfer versus nerve grafting.

Methods

Study Design

This retrospective cohort study reviewed infants with NBPP who underwent Oberlin transfer ($n = 19$) and nerve grafting ($n = 31$) for restoration of elbow flexion/forearm supination at a single institution between 2005 and 2015. Data were retrieved from an institutional review board–approved institutional data repository. We collected patient demographic data and NBPP-related factors at the initial clinic visit. An interdisciplinary brachial plexus team including neurosurgeons, physiatrists, and occupational therapists evaluated and diagnosed infants with NBPP via physical examination, EDX, and/or imaging evaluation. None of the patients had previous surgical intervention prior to initial assessment.

Outcomes of Interest

A certified occupational therapist assessed active range of motion (AROM) as well as biceps power using the Medical Research Council (MRC) grading scale preoperatively and 1 year postoperatively. The physical evaluation was standardized regardless of the surgical procedures. Primary outcomes of the current study included AROM of elbow flexion in adduction, elbow flexion in abduction, forearm supination, and forearm pronation, because these joints were relevant to the targeted movement after Oberlin transfer; secondary supportive outcomes reflecting the potential effects of contiguous joints included AROM of shoulder forward flexion, external rotation, internal rotation, abduction, extension, wrist extension, and finger flexion.

Patient demographic data included age at operation, sex, race, NBPP-involved side (left vs right), Narakas grade (numbers of nerve roots injured), and injury type (preganglionic, postganglionic, or mixed). The Narakas grade was not applied uniformly at 2–3 weeks of age as originally described by Narakas and subsequently suggested by Birch.^{7,37} Rather, the Narakas grade was determined by a single surgeon via either: 1) physical examination and neurological assessment at approximately 1 week of age or at initial clinical appointment, or 2) mother's or obstetrician's report of child's arm/hand movements at birth. The Narakas grade was dichotomized into Grade I/II versus III/IV in the current study. Injury type was determined by intraoperative assessment of the nerve roots in all cases. Patient demographic data; biceps MRC grade; and AROM of elbow flexion in adduction, elbow flexion in abduction, forearm supination, forearm pronation, shoulder forward flexion, external rotation, internal rotation, abduction, extension, wrist extension, and finger flexion were compared between the group undergoing Oberlin transfer and the group undergoing nerve grafting.

Surgical Decision-Making

Preoperative imaging and EDX were used as an extension of clinical examination and as a supportive indication for surgery. However, the surgical decision-making regarding nerve reconstruction strategy was primarily based on findings during intraoperative exploration of the brachial plexus. If the C-5 and C-6 nerve roots were available for grafting, then nerve grafting was performed for reconstruction; if only a single nerve root (C-5 or C-6) was available, it was directed to the anterior division of the upper trunk via grafting. Oberlin transfer was performed in cases of upper root avulsions or late presentation; a single surgeon performed all nerve transfers using the standard techniques of microsuture and tissue glue. EDX, rationale for surgery, and additional transfer procedures are included in the Appendix.

Statistical Analysis

We applied descriptive statistics for patient demographic data and NBPP-related factors. AROM for each movement at the initial preoperative visit, 1-year postoperative visit, and the mean AROM changes from the preoperative to the postoperative visit were summarized. Student's *t*-test for continuous variables, the Mann-Whitney *U*-test for ordinal variables, and the chi-square test or Fisher's exact test for categorical variables were applied to investigate differences between the Oberlin transfer and nerve grafting groups. A $p < 0.05$ was considered statistically significant. Commercially available software was used for all analyses (IBM SPSS version 22; IBM Corp.).

Results

Patient Demographic Data

The Oberlin transfer and nerve grafting groups were similar with respect to patient demographic data, with the exception of lesion type (Table 1). On average, both groups were seen before 3 months of age; there was a trend toward the nerve grafting group undergoing operation ear-

TABLE 1. Patient demographic data

Variable	Surgery Group (%)		p Value
	Oberlin Transfer	Graft	
No. of patients	19	31	
Mean age $\pm$ SD, mos			
At initial appointment	2.8 $\pm$ 2.5	2.5 $\pm$ 2.3	0.60
At op	7.1 $\pm$ 1.8	6.0 $\pm$ 1.9	0.06
Sex			0.64
Male	8 (42)	11 (35)	
Female	11 (58)	20 (65)	
Race			0.78
White	13 (68)	20 (65)	
Other	6 (32)	11 (35)	
NBPP-involved side			0.67
Lt	11 (58)	16 (52)	
Rt	8 (42)	15 (48)	
Narakas grade			0.11
I/II	13 (68)	14 (45)	
III/IV	6 (32)	17 (55)	
Lesion type			<0.001
Preganglionic only	13 (68)	0 (0)	
Postganglionic only	6 (32)	20 (65)	
Mixed*	0 (0)	11 (35)	

Values expressed as the number (%) of patients unless indicated otherwise.

* Mixed included postganglionic at C-5 and preganglionic at C-6 or C6-T1.

lier (6 months) compared with the Oberlin transfer group (7 months), but this did not reach statistical significance ($p = 0.06$). The majority of patients in both groups were white (68% in Oberlin transfer; 65% in nerve graft repair) and female (58% in Oberlin transfer; 65% in nerve graft repair). Fifty-five percent were Narakas Grade III/IV in the nerve grafting group and 32% in the Oberlin transfer group, with no statistical significance. The only difference between the groups was observed for lesion type; all lesions were postganglionic for C-5 in the nerve grafting group, whereas only 32% were postganglionic in the Oberlin transfer group.

Comparison of Outcomes

Preoperative AROM of elbow flexion in adduction and

abduction, biceps MRC grade, and forearm pronation were significantly better in the group of patients who underwent Oberlin transfer (Table 2). At 1 year postoperatively, the difference in AROM of elbow flexion in adduction and abduction and biceps MRC grade persisted, with the Oberlin transfer group exceeding the AROM of the nerve grafting group. The difference in forearm pronation was lost, while the Oberlin transfer group significantly exceeded the nerve grafting group in forearm supination.

The mean AROM changes from the preoperative visit to the 1-year postoperative visit were compared (Table 2). Similar gains were observed for elbow flexion in abduction and adduction for both treatment groups, with no statistical significance. However, the Oberlin transfer group showed a larger gain in supination compared with the nerve grafting group (100° vs 19° ; $p < 0.0001$). Full forearm pronation was maintained in the Oberlin transfer group, while the nerve grafting group improved 32° postoperatively (0° vs 32° ; $p = 0.02$).

Regarding the secondary outcomes of arm continuity, our results showed that the Oberlin transfer group had advantageous shoulder, wrist, and finger AROM outcomes compared with the nerve grafting group at 1 year postoperatively, although the AROM changes from preoperative to postoperative visits were equivalent between the groups (Table 3).

Discussion

Surgical treatment for infants with NBPP has evolved over the last decade; however, the results for Oberlin transfer and nerve grafting are still under debate. To our knowledge, the current study presents the first series comparing Oberlin transfer and nerve grafting as primary nerve reconstruction strategies for infants with NBPP. At the 1-year follow-up, both techniques restored similar mean AROM in elbow flexion, whereas Oberlin transfer achieved advantageous forearm supination compared with nerve grafting.³¹

Although surgical decision-making varies from center to center, surgical intervention is typically indicated if biceps function has not recovered sufficiently to allow the infant to get hand to mouth by 6 months of age.^{20,23,55} Our specific decision algorithm has been published.⁴⁹ Nerve transfer and nerve grafting are the primary surgical techniques for treating infants with NBPP. The specific treat-

TABLE 2. Elbow and forearm AROM at 1-year follow-up

Measure	Preop AROM ($^\circ$)			1-Yr Postop AROM ($^\circ$)			Preop vs Postop AROM Improvement ($^\circ$)		
	Oberlin (n = 19)	Graft (n = 31)	p Value	Oberlin (n = 12)	Graft (n = 28)	p Value	Oberlin (n = 12)	Graft (n = 28)	p Value
Elbow flexion in adduction	28 $\pm$ 35	5 $\pm$ 39	0.04	82 $\pm$ 37	47 $\pm$ 40	0.01	54 $\pm$ 40	37 $\pm$ 47	0.27
Elbow flexion in abduction	51 $\pm$ 45	3 $\pm$ 40	<0.0001	108 $\pm$ 39	61 $\pm$ 44	0.004	58 $\pm$ 40	62 $\pm$ 43	0.74
Median MRC strength of biceps (range)	2 (0–3)	0 (0–2)	0.022	3 (0–4)	2 (0–4)	0.025	1 (0–4)	1 (0–4)	0.77
Forearm supination	-67 $\pm$ 38	-61 $\pm$ 42	0.60	31 $\pm$ 39	-39 $\pm$ 55	<0.0001	100 $\pm$ 54	19 $\pm$ 56	<0.0001
Forearm pronation	90 $\pm$ 0	52 $\pm$ 69	0.005	90 $\pm$ 0	87 $\pm$ 17	0.52	0 $\pm$ 0	32 $\pm$ 66	0.02

Values expressed as the mean $\pm$ SD unless otherwise indicated.

TABLE 3. Shoulder and hand AROM at 1-year follow-up

Measure	Preop AROM (°)			1-Yr Postop AROM (°)			Preop vs Postop AROM Improvement (°)		
	Oberlin (n = 19)	Graft (n = 31)	p Value	Oberlin (n = 12)	Graft (n = 28)	p Value	Oberlin (n = 12)	Graft (n = 28)	p Value
Shoulder flexion	55 ± 41	28 ± 29	0.01	105 ± 41	75 ± 37	0.03	46 ± 33	48 ± 49	0.90
Shoulder abduction	41 ± 36	21 ± 30	0.03	91 ± 35	58 ± 40	0.02	50 ± 24	39 ± 51	0.37
Shoulder extension	3 ± 12	-2 ± 10	0.12	10 ± 14	1 ± 4	0.07	5 ± 23	3 ± 11	0.81
Shoulder exorotation adduction	-64 ± 49	-67 ± 46	0.84	-6 ± 53	-37 ± 49	0.09	55 ± 71	31 ± 60	0.27
Shoulder exorotation abduction	-46 ± 45	-69 ± 45	0.08	10 ± 53	-30 ± 55	0.04	60 ± 55	40 ± 65	0.36
Shoulder endorotation adduction	70 ± 0	43 ± 53	0.007	70 ± 0	65 ± 18	0.36	0 ± 0	23 ± 46	0.02
Shoulder endorotation abduction	70 ± 0	39 ± 54	0.004	70 ± 0	55 ± 35	0.03	0 ± 0	22 ± 58	0.07
Wrist extension	21 ± 52	-19 ± 57	0.02	55 ± 23	8 ± 50	0.003	30 ± 58	26 ± 61	0.84
Finger flexion	90 ± 0	61 ± 51	0.003	90 ± 0	52 ± 52	0.001	0 ± 0	-14 ± 65	0.26

Values expressed as the mean ± SD.

ment strategy implemented for a given patient depends on a variety of factors, including age, lesion type, lesion site, and timing of presentation. Nerve grafting has been performed in the NBPP population for more than 3 decades; it is recommended for patients who present with rupture (postganglionic) of the upper nerve roots of the brachial plexus (C-5 and C-6).^{9,19,36}

Oberlin nerve transfer was introduced in the early 1990s and has since been widely used in traumatic pediatric BPP and adult brachial plexus injury, particularly for avulsion (preganglionic) lesions where viable proximal nerve stumps are not available.^{13,35,40} The consensus is that nerve transfer is an indicated option in cases of late presentation, failed primary nerve reconstruction, isolated deficit, absence of proximal root for grafting, and multiple nerve root avulsions (preganglionic lesion).^{2,14,25,29,51} Although these specific indications are not highly controversial, what remains debated is whether use of the Oberlin transfer should be expanded in the NBPP population.^{14,15,25,34,51}

Inconsistent outcome reporting in the current literature makes this discussion challenging because of the difficulty in comparing outcomes for nerve transfer and nerve grafting.^{8,17,18,22,24,26,30,39,41,54} Potential advantages of nerve transfer include safer technique, shorter operative time, and less regeneration time needed for recovery compared with nerve grafting.²⁶ Currently, the International Federation of Societies for Surgery of the Hand Committee has recognized similar results for nerve grafting and nerve transfer in patients with NBPP with Erb's palsy but continue to recommend brachial plexus exploration and nerve grafting when feasible.⁵¹ Physicians should use the information from electrodiagnostic/imaging studies and physical examination to develop a preoperative surgical plan to optimize outcome.^{19,21,25,49,50,52,56}

Our results demonstrate that early forearm supination is significantly improved with Oberlin transfer compared with nerve grafting, whereas elbow flexion recovery was the same in both groups. Despite the biceps muscle being a key supinator of the forearm, previous studies have not compared forearm supination function in infants with

NBPP treated with nerve transfer versus nerve grafting.^{26,29} Recovery of forearm supination increases the ability for children to bring their hand to mouth, making it an important consideration. Recovery of supination could potentially improve the quality of movement during daily activities such as feedings, grooming, and lifting.³²

However, the inconsistency of outcome measures for NBPP recovery make it challenging to evaluate the quality of movement. In a 2013 systematic review, the authors elucidated disparities in NBPP outcome evaluation in the current literature, which posed difficulties when evaluating the overall impact and effectiveness of clinical treatments in a comparative fashion across the various specialties.¹² Furthermore, the majority of the outcome measures focus on the International Classification of Functioning (ICF) Body Function and Structures domain, with limited outcome measures regarding ICF Activity and Participation domains.²⁷ It is critical to incorporate physical function into patients' participation in daily activities and psychosocial status. All ICF domains should be considered when evaluating patients with NBPP in a comprehensive manner. Further studies that remotely monitor real-world arm movement using body-worn movement capture technology will provide more insight into spontaneous use of the affected arm in activities of daily living.

To our knowledge, this is the first study to compare the effect of Oberlin transfer versus nerve grafting on biceps reinnervation among an NBPP population at a single institution. Anatomically, biceps muscle function could also be affected by surrounding shoulder or hand movements.^{5,26,38,44,47,53} For infants with NBPP, impaired growth of denervated biceps muscle may lead to weakness or even contracture of the affected area. The process of muscle remodeling might reorganize the muscle structure such that infants with NBPP tend to compensate for the lack of biceps function with shoulder subscapularis or wrist muscles. For example, children could achieve elbow flexion by pronating the forearm with wrist flex while swinging the arm against gravity (Steindler effect).¹

However, our results show that shoulder, wrist, and finger improvements are comparable between the treatment

groups, which is consistent with published results.^{26,28,41} This finding eliminates shoulder or hand movement compensation as the confounder for the biceps recovery. Hence, given similar recovery of shoulder and hand AROM in both treatment groups, it is evident that the improvement of forearm supination indicates a true biceps recovery following Oberlin transfer.

Limitations exist in the current study. Due to institutional differences, surgeons' experience, small sample size, and the retrospective design of the study, the sample might not be sufficient to detect differences between treatment groups, and the results might not be generalizable to the entire NBPP population. Furthermore, lesion type and lesion site vary between the treatment groups. It is possible that an extensive lesion site may affect the postoperative outcome, especially in the Oberlin transfer group, because an extensive lesion might affect the availability of functional fascicles in the ulnar nerve. However, all of the patients who underwent Oberlin transfer had recovered hand function prior to surgery, which indicated sufficient functional fascicles in the ulnar nerve to conduct the Oberlin transfer.

In addition, it is possible that the recovery outcomes could be the result of natural recovery. During nerve grafting, C-5 and/or C-6 are cut and then grafts are inserted such that all pathways out of C-5 and C-6 are lost at the time of surgery. During the Oberlin procedure, only the biceps branch is cut and the rest of the pathways out of C-5 and C-6 are intact; recovery of elbow flexion could occur as part of spontaneous recovery through the brachialis or brachioradialis muscles, which are not disrupted by the Oberlin procedure. Future studies comparing natural recovery versus surgical outcomes in NBPP might shed light on this topic.

Finally, to reinnervate the targeted muscle, the proximal nerve stump must regenerate through the distal stump following both procedures.⁵⁷ The regenerating process could take up to 3 years before functional recovery occurs; therefore, future studies with a larger sample size and at least a 3-year postoperative follow-up could provide more evidence on this topic.

Conclusions

We have demonstrated that Oberlin transfer confers advantageous early recovery of forearm supination compared with nerve grafting in infants with NBPP. Regained elbow flexion is equivalent in both procedures. Combined elbow flexion and forearm supination recoveries might improve quality of movement in infants with NBPP. However, current outcome measures mainly focus on ICF Body Function and Structure, whereas information regarding quality of movement is lacking. Future studies that monitor real-world arm usage will provide more insight into spontaneous use of the affected arm in activities of daily living and shed light on the appropriate surgical strategy for infants with NBPP.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Yang, Popadich. Acquisition of data: Yang, Popadich. Analysis and interpretation of data: Chang, Wilson. Drafting the article: Chang. Critically revising the article: Yang, Chang, Wilson, Brown, Chung. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Yang. Statistical analysis: Chang. Administrative/technical/material support: Yang, Popadich. Study supervision: Yang, Chung.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

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