Comparison of Pediatric Outcomes Data Collection Instrument Scores and Range of Motion Before and After Shoulder Tendon Transfers for Children With Brachial Plexus Birth Palsy

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Background: Children with brachial plexus birth palsy (BPBP) may undergo shoulder external rotation tendon transfers (ERTT) to improve function. In terms of outcome measurements, and according to the World Health Organization International Classification of Functioning, Disability, and Health model, ERTT reduces impairment as measured by range of motion (ROM), but has not been shown to improve activity and participation. Furthermore, correlation between these outcome measures has not been established. The Pediatric Outcomes Data Collection Instrument (PODCI) is a well-validated musculoskeletal health questionnaire that addresses activity and participation components of function. The aim of this study is to determine whether PODCI scores improve after ERTT, and whether this improvement correlates with improvement in ROM.

Methods: A total of 23 children with a mean age of 6.3 years (range, 4.4–12.8 years) with BPBP and standard indications for ERTT underwent preoperative and 1-year postoperative shoulder ROM measurements, and parental completion of the PODCI. Change in ROM was compared with change in PODCI scores to determine if these were correlated.

Results: Average range of active shoulder abduction improved 35 degrees ($P < 0.001$), and average range of active external rotation improved 41 degrees ($P < 0.001$). The PODCI scores for Upper Extremity Function, Sports Function, and Global Function improved (12 points [$P < 0.001$], 4 points [$P = 0.04$], and 6 points [$P = 0.001$], respectively). Improvement in ROM did not correlate with improvement in PODCI scores. However, postoperative peak active abduction correlated strongly with postoperative PODCI scores for Upper Extremity Function, and Global Function ($r_s = 0.712$ [$P < 0.001$], $r_s = 0.735$ [$P < 0.001$], respectively), and moderately with Transfers and Basic Mobility and Sports Function scores ($r_s = 0.496$ [$P = 0.016$], $r_s = 0.449$ [$P = 0.032$], respectively).

Conclusions: For children with BPBP, ERTT is associated with reduced impairment and improved activity and participation. Maximum postoperative abduction is positively associated with PODCI scores, but change in ROM is not. Further study is needed to determine if ceiling effects or other factors account for the lack of correlation between these outcome measures.

Level of Evidence: Level of evidence IV, case series.

Key Words: external rotation tendon transfer, brachial plexus birth palsy, Pediatric Outcomes Data Collection Instrument, PODCI, functional outcomes

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The incidence of brachial plexus birth palsy (BPBP) ranges from 0.38 to 4.6 per 1000 live births.[1–4] The BPBP causes variable weakness of shoulder abduction and external rotation depending on the extent of neural injury.[5]

Shoulder external rotation weakness makes performance of activities that require reach above the shoulder difficult or impossible, including hand-to-mouth and hand-to-head motions.[6] Moreover, imbalance between intact shoulder internal rotators and adductors and weak or paralyzed external rotators causes adduction and internal rotation contractures, glenohumeral joint deformity and subluxation, and worsening functional deficits.[7,8]

Surgical treatment of the sequelae of BPBP includes muscle releases, tendon transfers, and rotational osteotomy of the humerus. The Hoffer method of pectoralis major muscle release and latissimus dorsi and teres major tendon transfer to the infraspinatus and supraspinatus tendons (shoulder external rotation tendon transfer [ERTT]) improves active external rotation, strength of abduction, and above-horizontal functioning as assessed by goniometric measurements and the Mallet classification.[6,9,10] In accordance with the World Health Organization International Classification of Functioning, Disability and Health, measurement of change in activity and participation after an intervention such as surgery may be a more valuable measure of function than range of motion (ROM).[11] An instrument that is able to evaluate how well a child interacts with his environment would enhance the assessment of ERTT outcomes.[12]

The Pediatric Outcomes Data Collection Instrument (PODCI) is a well-validated musculoskeletal health questionnaire that addresses activity and participation components of function.[13–15] The PODCI records patient and parent-reported measures across 5 domains: Transfers and Basic Mobility, Upper Extremity and Physical Function (UE Function), Sports and Physical Function (Sports Function), Pain/Comfort, and Happiness; a sixth measure, Global Function, is

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TABLE 1. The ROM Scores Preoperative and 1 Year Post-ERTT Surgery

				Active Shoulder Abduction (degrees)		Active Shoulder External Rotation (degrees)	
ID	Sex	Side	Age	Preoperative	1 Y Postoperative	Preoperative	1 Y Postoperative
1	F	L	4 y 5 mo	135	WNL	0	70
2	M	L	4 y 6 mo	60	100	0	55
3	F	L	5 y 1 mo	80	155	0	60
4	M	R	8 y 3 mo	120	No follow-up	0	No follow-up
5	F	L	4 y 7 mo	125	170	20	40
6	M	L	4 y 10 mo	90	115	40	80
7	F	L	8 y 3 mo	145	WNL	35	70
8	F	R	8 y 10 mo	130	160	50	65
9	M	R	7 y 10 mo	160	Not recorded	40	Not recorded
10	F	L	5 y 0 mo	70	140	25	75
11	M	R	6 y 2 mo	110	120	0	45
12	M	R	6 y 10 mo	170	160	0	55
13	F	R	8 y 3 mo	140	145	0	30
14	F	L	5 y 11 mo	65	135	15	0
15	F	L	5 y 10 mo	Not recorded	Not recorded	Not recorded	Not recorded
16	F	R	4 y 7 mo	Not recorded	Not recorded	Not recorded	Not recorded
17	F	L	4 y 5 mo	90	130	0	30
18	F	R	5 y 3 mo	85	80	0	90
19	F	R	8 y 8 mo	120	170	10	60
20	F	L	5 y 0 mo	120	No follow-up	0	80
21	F	R	4 y 6 mo	135	No follow-up	20	No follow-up
22	F	L	12 y 9 mo	130	WNL	20	55
23	M	R	6 y 0 mo	150	165	-15	25

WNL indicates within normal limits.

the average of the scores for the first 4 domains. Although Huffman et al[16] demonstrated that the PODCI can distinguish children with BPBP who are candidates for ERTT from normal controls, it remains to be seen whether the PODCI can discern and measure functional gains in children with BPBP after surgery. The aim of this study is to determine whether PODCI scores improve after ERTT, and whether this improvement correlates with improvement in shoulder active ROM.

METHODS

A total of 23 children with BPBP aged 4.4 to 12.8 years (mean, 6.3 years) underwent ERTT by the same surgeon (M.A.J.) between May 2000 and May 2002 (Table 1). Inclusion criteria included standard indications for ERTT: upper trunk BPBP with external rotation weakness, parent or patient-perceived functional deficits, and passive external rotation to at least neutral with the shoulder adducted. In addition, candidates demonstrated strength against resistance in shoulder adduction, with palpable contraction of the latissimus dorsi and teres major, adequate deltoid strength to abduct the shoulder greater than 60 degrees, and hand/wrist function sufficient to be useful once hand-to-head range was surgically established.[17] The ERTT was performed as described by Hoffer,[9] except that a transverse axillary incision was used.[17] All 23 subjects underwent a standardized postoperative therapy protocol as previously described,[17] and preoperative and 1-year postoperative evaluations including shoulder active ROM measurements by an occupational therapist in a standardized fashion, and parental completion of the PODCI (Tables 2).

Statistical Analysis

Preoperative and postoperative shoulder abduction and external rotation measures, and PODCI domain scores were compared using *t* tests for dependent measures. Change in PODCI scores with standardized mean difference (mean postoperative score minus mean preoperative score divided by the SD of the preoperative score) greater than 0.5 was judged to be clinically significant.[18] Spearman rank correlation coefficients were computed to assess the correlation between PODCI scores and both active abduction and external rotation ROM before and 1 year after surgery. Spearman rank correlation coefficients were also calculated to assess the correlation between post-ERTT PODCI scores and change after surgery in both active abduction and external rotation. Correlations of 0.25 to 0.50 were considered fair, and correlations of 0.50 to 0.75 were considered moderate to good.[19]

A $P < 0.05$ was selected as the criterion for statistical significance. To test for a ceiling effect in PODCI measures, skewness scores were generated for presurgical and postsurgical PODCI scores. Negative skewness scores greater than 2 SEs of skewness, or -1.022, indicated nonnormal score distributions, where SE of skewness was calculated as the square root of (6/n).[20]

RESULTS

Range of active shoulder abduction improved 35 degrees ($P < 0.001$) from a preoperative mean of 115 degrees (SD, 33 degrees) and range of active external rotation improved 41 degrees ($P < 0.001$) from a preoperative mean of 14 degrees (SD, 18 degrees) (Table 3).

The PODCI scores for Transfers and Basic Mobility, UE Function, Sports Function, and Global Function all improved (1 point [$P = 0.04$], 12 points [$P < 0.001$], 4 points [$P = 0.04$], and 6 points [$P = 0.001$], respectively) (Table 4), but the 1 point improvement in Transfers and Basic Mobility was not considered clinically significant. There were no significant changes in the PODCI Pain/Comfort and Happiness domains.

There was a moderate negative correlation between change in abduction and postoperative Sports Function scores ($r_s = -0.456$, $P = 0.029$), but no correlation between change in ROM and any other postoperative PODCI score (Table 5).

TABLE 2. The PODCI Scores

	Preoperative PODCI Domain Scores					
ID	**Transfers and Basic Mobility**	**UE Function**	**Sports Function**	**Global Function**	**Pain/Comfort**	**Happiness**
1	97	88	89	94	100	100
2	97	79	92	92	100	100
3	94	54	86	77	75	95
4	100	75	72	87	100	45
5	100	83	94	94	100	100
6	100	62	81	86	100	81
7	100	92	100	98	100	95
8	100	83	97	95	100	80
9	97	71	86	86	92	No answer
10	100	83	89	93	100	95
11	100	100	100	100	100	100
12	97	58	92	80	75	90
13	94	38	83	79	100	95
14	97	75	83	84	83	90
15	100	100	97	99	100	95
16	94	58	85	84	100	100
17	94	79	78	86	92	55
18	100	83	76	90	100	No answer
19	100	96	97	96	92	100
20	100	71	85	89	100	100
21	100	100	97	89	58	100
22	97	96	94	97	100	100
23	85	71	79	69	42	85
	1 Y Postoperative PODCI Domain Scores					
1	100	100	92	98	100	100
2	94	83	92	92	100	95
3	97	79	89	89	92	95
4	100	96	94	98	100	80
5	100	96	97	98	100	100
6	97	83	94	94	100	100
7	100	100	97	99	100	95
8	100	96	100	93	75	90
9	100	96	97	98	100	90
10	100	100	89	97	100	100
11	97	88	86	93	100	100
12	100	96	97	98	100	100
13	100	58	94	80	67	100
14	100	92	79	91	92	80
15	100	100	94	98	100	80
16	97	75	87	90	100	95
17	100	96	92	97	100	100
18	100	80	88	92	100	100
19	100	100	94	98	100	100
20	100	94	86	95	100	100

TABLE 3. Pre- and Post-ERTT Active Shoulder Abduction and Active External Rotation

Motion	Pre-ERTT (range, SD)	Post-ERTT (range, SD)	Change (range)	*P*	Standardized Mean Difference
Abduction	115 degrees (60 to 170 degrees, 33 degrees)	150 degrees (80 to 180 degrees, 28 degrees)	+35 degrees (−10 to 75 degrees)	<0.001	1.06
External Rotation	14 degrees (−15 to 50 degrees, 18 degrees)	55 degrees (0 to 90 degrees, 21 degrees)	+41 degrees (−15 to 90 degrees)	<0.001	2.28

When preoperative and postoperative PODCI scores were compared with preoperative and postoperative active ROM scores, correlations were seen between peak postoperative abduction and postoperative PODCI scores for Transfers and Basic Mobility ($r_s = 0.496$, $P = 0.016$), UE Function ($r_s = 0.712$, $P < 0.0001$), Sports Function ($r_s = 0.449$, $P = 0.032$), and Global Function ($r_s = 0.735$, $P < 0.0001$) (Table 6). There was no correlation between peak post-ERTT external rotation and post-ERTT PODCI scores (Table 6).

Scores for pre-ERTT UE Function, Sports Function, and Global Function all had normal distributions. However, scores for post-ERTT PODCI UE Function and Global Function showed significant negative skewness at −1.480 and −1.804, respectively (Table 7), suggesting that nonsignificant correlations between change in ROM and PODCI UE Function and Global Function are caused by a ceiling effect.

DISCUSSION

For children with BPBP, ERTT is associated with reduced impairment as measured by increased active ROM, and improved activity and participation as measured by the PODCI Transfers and Basic Mobility, UE Function, Sports Function, and Global Function domains. These findings suggest that other measures included in the PODCI related to quality of life, such as Pain/Comfort and Happiness, may not improve after ERTT; however, their preoperative and postoperative scores in these domains are within normal limits.[12] A previous study of this cohort concluded that although PODCI was able to measure clear differences between normal controls and children with BPBP who are candidates for ERTT, differences were measurable only with respect to UE Function, Sports and Physical Function, and Global Function.[16] This study is consistent with our previous findings, except with regard to Transfers and Basic Mobility.

It is possible that the changes in ROM and PODCI scores are associated with more intensive therapy postoperatively instead of surgery; this study can neither prove nor disprove this because subjects were not randomized to therapy or surgery.

Although preoperative scores in UE Function, Sports Function, and Global Function domains indicated that the subjects were not severely disabled by their condition (only 1 score, UE Function, was below the low 80s, the proposed lower limit of normal[12]), the PODCI measured statistically and clinically significant improvement in these domains after ERTT. This was expected given the significantly reduced level of impairment observed in shoulder active abduction and external rotation. Postoperative PODCI scores were not associated with change in either abduction or external rotation, with the exception of Sports Function, which was negatively associated with change in active abduction. Postoperative shoulder peak abduction and PODCI scores, especially UE Function and Global Function, were positively correlated. A similar correlation was not seen between postoperative peak external rotation and PODCI scores. These findings suggest that improvement in ROM after ERTT is less important than peak ROM attained and may reflect that children who have the most room to improve also have the most severe functional deficits after surgery.

The incomplete correlations between ROM and PODCI measures reinforce that ROM and the PODCI are measuring different things. The PODCI may not be sensitive to changes in shoulder function. However, the moderate-to-strong correlations between postoperative abduction and several PODCI domains suggest that the PODCI is sensitive to measures of abduction, if not to external rotation. It may be that the tasks included in the PODCI require upper extremity abduction more than external rotation. For instance, of the upper extremity tasks (lift heavy books, use a fork and spoon, write with a pencil, turn door knobs, open a jar that has been opened before, button buttons, pour a half gallon of milk, comb hair), only the use fork and spoon and comb hair tasks require significant external rotation. In contrast, all tasks, except write with a pencil, require shoulder abduction.

TABLE 4. Pre- and Post-ERTT PODCI Scores

PODCI Domain	Mean Pre-ERTT (range, SD)	Average Post-ERTT (range, SD)	Change (range)	*P*	Standardized Mean Difference
Transfers and Basic Mobility	98 (85–100, 4)	99 (94–100, 2)	+1 (−3 to 6)	0.04	0.25
UE Function	78 (38–100, 16)	90 (58–100, 11)	+12 (−12 to 38)	<0.001	0.75
Sports Function	88 (72–100, 8)	92 (79–100, 5)	+4 (−14 to 22)	0.04	0.50
Global Function	89 (69–100, 7)	95 (80–99, 4)	+6 (−7 to 29)	0.001	0.86
Pain/Comfort	92 (42–100, 15)	97 (67–100, 9)	+5 (−33 to 58)	0.20	0.33
Happiness	91 (45–100, 15)	95 (75–100, 8)	+4 (−25 to 45)	0.20	0.27

TABLE 5. Rank Correlations Between Change in Shoulder Active ROM and Post-ERTT PODCI Scores

PODCI Domain (Post-ERTT)	Change in Active Abduction	*P*	Change in Active External Rotation	*P*
Transfers and Basic Mobility	$r_s = -0.018$	0.935	$r_s = -0.118$	0.592
UE Function	$r_s = 0.216$	0.322	$r_s = -0.011$	0.959
Sports Function	$r_s = -0.456$	0.029	$r_s = -0.231$	0.289
Global Function	$r_s = -0.094$	0.670	$r_s = 0.064$	0.770
Pain/Comfort	$r_s = -0.093$	0.672	$r_s = 0.326$	0.129
Happiness	$r_s = -0.107$	0.626	$r_s = 0.630$	0.091

r_s indicates Spearman rank correlation coefficient.

If the PODCI is sensitive to measures of abduction, then it may be useful in tracking abduction gains over time. Pagnotta et al[8] found that long-term gains in abduction after ERTT were highly correlated with extent of BPBP injury and diminished over time. In a study of children with BPBP, those with C5 to C6 injury and preoperative active abduction of 45 to 90 degrees enjoyed the greatest post-ERTT gains in abduction, but these gains peaked at 15 years and deteriorated progressively thereafter.[8] Children with more severe C5 to C6 to C7 or complete plexus paralysis fared worse, with smaller gains in abduction and deterioration after 10 and 3 years, respectively.[8] To the extent that PODCI scores are associated with abduction, they may also decline over time after ERTT.

A possible limitation of these findings is that the score distributions for postoperative PODCI UE Function and Global Function domains showed significant negative skewness, with scores clustered near the maximum value reportable. This could indicate that after surgery, many of these children had normal activity and function as measured by these PODCI domains; alternatively, the negatively skewed distributions may reflect a ceiling effect of the PODCI. Tests of correlations require variability of scores. The PODCI scores for our sample clustered at the high end of the scale, which is referred to as a ceiling effect; data with a ceiling effect have restricted variability, which limits the likelihood of finding a significant correlation. Haynes and Sullivan[12] propose that PODCI scores above the mid-80s represent normal range function and that the instrument is not sensitive to change in normal functioning children. If the PODCI is less sensitive to improvement in a higher functioning cohort such as ours, it would not be surprising if improvement in ROM and improvement in PODCI scores failed to strongly correlate.

TABLE 6. Pre- and Post-ERTT Rank Correlations Between Shoulder Peak Goniometric and PODCI Scores

PODCI Domain	Peak Abduction	*P*	Peak External Rotation	*P*
Pre-ERTT				
Transfers and Basic Mobility	$r_s = -0.001$	0.996	$r_s = 0.359$	0.092
UE Function	$r_s = 0.116$	0.599	$r_s = 0.190$	0.386
Sports Function	$r_s = 0.285$	0.187	$r_s = 0.376$	0.077
Global Function	$r_s = 0.063$	0.776	$r_s = 0.317$	0.140
Pain/Comfort	$r_s = -0.221$	0.311	$r_s = 0.265$	0.221
Happiness	$r_s = -0.107$	0.646	$r_s = 0.015$	0.949
Post-ERTT				
Transfers and Basic Mobility	$r_s = 0.496$	0.016	$r_s = 0.129$	0.556
UE Function	$r_s = 0.712$	<0.001	$r_s = 0.099$	0.653
Sports Function	$r_s = 0.449$	0.032	$r_s = 0.017$	0.938
Global Function	$r_s = 0.735$	<0.001	$r_s = 0.085$	0.700
Pain/Comfort	$r_s = 0.143$	0.514	$r_s = 0.237$	0.277
Happiness	$r_s = -0.089$	0.688	$r_s = 0.053$	0.811

TABLE 7. Skewness Scores for Pre- and Post-ERTT PODCI Scores

PODCI Domain	Pre-ERTT	Post-ERTT
Transfers and Basic Mobility	−2.125	−1.735
UE Function	−0.589	−1.480
Sports Function	−0.265	−0.794
Global Function	−0.718	−1.804
Pain/Comfort	−2.178	−2.906
Happiness	−2.200	−1.389

An additional potential limitation of this study is that results cannot be adjusted for the possible confounding effect of age. Daltroy et al[13] found that the UE Function Scale, in particular, was susceptible to age bias because older children found it easier to perform the tasks addressed by the questionnaire independent of level of impairment. Because our study participants were 1 year older when they were administered the PODCI postoperatively, it is possible that some of their perceived improvement was caused by the effects of developmental maturation as opposed to surgery-related gains.

The present study has shown that PODCI scores increase after ERTT and that postoperative peak abduction and PODCI scores correlate. This correlation may reflect improved activity and participation associated with abduction, at least for PODCI upper extremity tasks. Because abduction gained from ERTT may diminish over time, long-term PODCI follow-up would be a useful way to determine if the activity and participation improvements associated with ERTT are lasting. This conclusion should be interpreted with some caution because the PODCI's usefulness may be limited by a ceiling effect for high-scoring children, by its susceptibility to age bias, and by its limited sensitivity to shoulder function.

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