Outcome After Tendon Transfers to Restore Wrist Extension in Children With Brachial Plexus Birth Injuries

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Abstract: Children with brachial plexus birth injuries often require tendon transfer to restore active wrist extension and maximize hand function. The purpose of this study is to assess the clinical results in children with brachial plexus birth injuries after tendon transfer to reconstruct active wrist extension. Over a 10-year period, 21 children (11 male, 10 female) underwent tendon transfer to reconstruct active wrist extension by a single surgeon. Eight patients had C5/C6/C7 injury and 13 patients had global palsy (C5-T1). The average age at surgery was 5.5 years (range, 3 to 8 y). Restoration of wrist extension was measured according to the functional scale of Duclos and Gilbert. The mean duration of follow-up was 36 months (minimum follow-up of 1 y). At latest follow-up, 14 (66%) children (C5/C6/C7, n = 8; global, n = 6) demonstrated active wrist extension $\geq$30 degrees. Within the global injury subcohort, 3 patients demonstrated static extension of the wrist. Four failures occurred in the global palsy group. Children with absent active wrist extension after a brachial plexus birth injury can benefit from a tendon transfer. The more severe global palsy cases have a worse outcome.

Key Words: tendon transfer, brachial plexus, extensor paralysis

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Persistent loss of active wrist extension is seen in infants with both upper/middle (C5/C6/C7) brachial plexus birth injuries and in those with global (C5-T1) injuries. The wrist drop creates functional limitations and bothersome aesthetic issues. Although the hand surgery literature is replete with reports of various tendon transfers for wrist extension in patients with post-traumatic high radial nerve palsy, tetraplegia, cerebral palsy, and adult traumatic brachial plexus injuries, only 2 authors have presented outcomes after tendon transfers for reconstruction of wrist extension in children with brachial plexus birth injuries.[1,2] The potential presence of multiple denervated muscle groups and the inherent difficulty associated with assessment of clinical and functional losses in young children make them a challenging patient population. The purpose of this study is to assess the clinical and functional results in a series of children with brachial plexus birth injury after tendon transfer to reconstruct active wrist extension.

METHODS

Over a 10-year period, 21 children (11 male, 10 female) underwent tendon transfer to restore active wrist extension. All tendon transfer surgeries were performed by a single surgeon. Eight patients had a C5/C6/C7 injury and 13 patients had global palsy (C5-T1). The average age at the time of tendon transfer surgery was 5.5 years (range, 3 to 8 y). Five of 8 patients with C5/C6/C7 injury and all 13 patients in the global group had previously undergone primary microneurosurgical reconstruction of the plexus.

Our indication to perform tendon transfer for wrist extension included a persistent clinical wrist-drop in a child with a supple radiocarpal joint. All children had a completewrist-drop preoperatively. All children with global palsy (N = 13) and 2 children with C5/C6 injury lacked extrinsic digital extensor function. Donor tendons included the flexor carpi ulnaris (FCU) (n = 14), brachioradialis (n = 4), and pronator teres (n = 3). Within the C5/C6/C7 group, the FCU was utilized in 7 cases and the pronator teres transfer was utilized in a single case. In the global group, the FCU was utilized in 7 cases, the brachioradialis in 4 cases, and the pronator teres in 2 cases. The recipient was the extensor carpi radialis brevis in all cases. Final selection of the donor tendon was made based on serial examinations of the motor strength of available donors and the anticipated need to perform additional simultaneous or staged transfers to maximize hand function. The FCU was always selected in cases in which there was ulnar deviation of the wrist to balance the wrist. Concomitant upper extremity procedures were performed in 8 children (Table 1).

In the patients undergoing a transfer of the pronator teres or brachioradialis, the procedure was performed through a single incision. Volar and dorsal incisions were

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TABLE 1. Additional Surgical Procedures Performed Simultaneously With the Tendon Transfer

Procedure	No. Patients
Extensor digitorum communis tenodesis	1
Abductor pollicis longus tenodesis	1
Pronator teres fractional lengthening	1
Extensor digitorum communis side-to-side transfer (ring and middle fingers)	1
Release of interosseous membrane	2
First web space contracture release	1
Lateral antebrachial cutaneous nerve transfer to ulnar nerve	1

used for the FCU transfers. The tendon juncture was performed using a Pulvertaft weave and the tension set at 30 degrees of wrist dorsiflexion with care taken to maintain passive wrist and digital flexion. After 6 weeks of cast immobilization, an aggressive program of occupational therapy including direct muscle stimulation was used. In many cases donor selection was subjective.

At the latest follow-up, outcomes were evaluated using the Duclos and Gilbert functional scale (Table 2).[1] The mean duration of follow-up was 32 months (range, 4 mo to 10 y). The effect of the severity of the initial plexus injury pattern on ultimate wrist extension outcome was analyzed.

RESULTS

Preoperatively, all patients demonstrated complete wrist-drop (grade 0). The average result based on the modified Duclos and Gilbert scale was 2.14. At latest follow-up, 14 (66%) children (C5/C6/C7, n = 8; global, n = 6) demonstrated active wrist extension of ≥ 30 degrees at latest follow-up. Within the global injury subcohort, 3 patients demonstrated static extension of the wrist.

Four transfer failures occurred in the global group. On retrospective review of these failures, it was observed that these children had previously demonstrated a suboptimal outcome after tendon transfer surgery at the shoulder to restore external rotation. Two failures occurred in children who underwent brachioradialis transfer and 2 occurred in children who underwent FCU transfer. During revision surgeries in 2 patients, the donor tendon was noted to be markedly attenuated at the site of transfer. Revision consisted of pronator teres transfer (n = 1) and flexor carpi radialis (n = 1) transfer. Two patients await reoperation, which no patient's family has declined.

TABLE 2. Modified Functional Scale of Duclos and Gilbert[1]

Activity	Functional Result
0	Wrist-drop
1	Static extension
2	< 30 degrees active extension
3	≥ 30 degrees active extension

DISCUSSION

In the child with inadequate spontaneous neurological recovery or residual functional deficits after microsurgical brachial plexus reconstruction that included the posterior division of the upper trunk and posterior cord, restoration of active wrist extension may be attempted with the use of tendon transfers. Several well-described donors (ie, FCU, flexor carpi radialis, brachioradialis, pronator teres, and flexor digitorum superficialis)[3–6] to the central wrist extensor have been utilized to restore active extension in various patient populations, including those with posttraumatic high radial nerve palsy, tetraplegia, cerebral palsy, and adult traumatic brachial plexus injuries.

Children with wrist extension deficits represent a unique population, and data on dynamic transfers from other patient series of tendon transfer for wrist dorsi flexion cannot be extrapolated here. Only in 2 other studies,[1,2] investigators have specifically addressed outcomes and challenges with tendon transfers for reconstruction of wrist extension in children with brachial plexus birth injuries. These children must be thoroughly evaluated by a multidisciplinary subspecialty team before undergoing tendon transfer surgery. Available donor muscle-tendon units in these children are often fewer, and may have to achieve multiple functions. In addition, motor donors have often been initially denervated then reinnervated, and thus may be weaker to begin with. The use of electrical stimulation and occupational therapy for dedicated strengthening of preoperative donors is essential. In addition, because of the paucity of usable donor motors, absent extrinsic digital and thumb extension was not addressed at the time of this procedure to restore wrist extension. A staged approach for digital extensor function reconstruction is advocated based on the evolution of function and available donors. To date, no child or parent has requested treatment for this aspect of the extensive deformity of the hand. Tenodesis effect may allow for sufficient passive digital extension for activities of daily living.

This review of our experience with these children highlights significant findings that are consistent with the 2 prior reports. All children with C5/C6/C7 injury achieved active wrist extension of ≥ 30 degrees. In contrast, all 4 failures occurred in the global palsy subcohort. Duclos and Gilbert[1] reported that none of their patients with a total plexus injury achieved > 30 degrees of active extension. In our cohort, these 4 children with a poor result had all previously demonstrated a suboptimal outcome after tendon transfer surgery at the shoulder to restore external rotation. This may suggest that prior unsuccessful soft tissue reconstruction in children with global injuries may portend additional failures with distal tendon transfers, as all or most muscles in the limb have been denervated and then reinnervated. In addition, 2 of 4 failures occurred after transfer of the brachioradialis. We have previously used the brachioradialis as a primary donor to spare other donor muscles for thumb and digital reconstruction to be

performed in a staged manner. Although the Duclos and Gilbert scale does not provide an assessment of hand function, it allows objective grading outcomes achieved relative to the 2 previously reported series in this select population.[1,2] Moreover, once grade 2 is achieved, it is obvious that the basic benefits of restoration of wrist dorsiflexion such as improved grasp strength and appearance have been achieved.

With regard to choice of donor, we prefer the pronator teres when wrist flexors are required for digital reconstruction. Otherwise, we select FCU to better balance the wrist. In contrast, Al-Qattan[2] advocates use of only the FCU or flexor carpi radialis for reconstruction of wrist extension in these children. In their analysis, Duclos and Gilbert[1] found similar clinical results after pronator, FCU, or flexor carpi radialis transfers in children with upper trunk injuries; however, they advocated use of FCU in the global palsy group. Finally, it should be appreciated that in many children with severe brachial plexus birth injury that involves the hand, the role of a tendon transfer for wrist dorsiflexion is often palliative. Achieving maximum hand function will involve additional carefully selected procedures based on ongoing recovery.

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