Neurolysis alone as the treatment for neuroma-in-continuity with more than 50% conduction in infants with upper trunk brachial plexus birth palsy

Clinical article

EMILY ANDRISEVIC, M.D.,1 MARSHALL TANIGUCHI, M.D.,2 MICHAEL D. PARTINGTON, M.D.,2 JULIE AGEL, M.A.,1 AND ANN E. VAN HEEST, M.D.1,2

1Department of Orthopaedic Surgery, University of Minnesota, Minneapolis; and 2Gillette Children’s Specialty Healthcare, St. Paul, Minnesota

Object. The debate addressed in this article is that of surgical treatment methods for a neuroma-in-continuity. The authors of this study chose to test the hypothesis that more severe nerve injuries, as distinguished by < 50% conduction across a neuroma-in-continuity, could be treated with neuroma resection and grafting, whereas less severe nerve injuries, with > 50% conduction across the neuroma, could be treated with neurolysis alone.

Methods. The goal of this study was to compare preoperative and postoperative Active Movement Scale (AMS) scores in children with upper trunk brachial plexus birth injuries treated with neurolysis alone if the neuroma’s conductivity was > 50% on intraoperative nerve testing. Seventeen patients (7 male, 10 female) met the criteria for inclusion in this study. Surgery was done when the patients were an average of 10 months old (range 6–19 months). The authors analyzed AMS scores from the preoperative assessment, 1-year postoperative follow-up visit, and subsequent follow-up assessment as close to 3 years after surgery as possible (referred to in this paper as > 2-year postoperative scores).

Results. Comparison of preoperative and 1-year follow-up data showed significant improvement in shoulder abduction, flexion, external rotation, and internal rotation; elbow flexion and supination; and wrist extension. Comparison of preoperative findings and results of assessment at > 2-year follow-up showed significant improvement in shoulder abduction, flexion, external rotation; and elbow flexion and supination. At final follow-up, useful function (AMS score of 6 or 7) was achieved for elbow flexion in 14 of 16 patients, shoulder flexion in 11 of 15 patients, shoulder abduction in 11 of 16 patients, and shoulder external rotation in 5 of 15 patients.

Conclusions. This report indicates that there is a subgroup of patients who can benefit clinically, with functional improvement of shoulder and elbow function, from treatment with neurolysis alone for upper trunk lesions demonstrating more than 50% conduction across the neuroma on intraoperative nerve testing. Patients with less than 50% conduction, indicating more severe disease, are treated with nerve resection and grafting in the authors’ treatment algorithm.

Key Words • neurolysis • brachial plexus birth injury • upper trunk • trauma

Abbreviations used in this paper: AMS = Active Movement Scale; BPBI = brachial plexus birth injury; CMAP = compound motor action potential; EMG = electromyography; NCV = nerve conduction velocity.
Seventeen favored resection of the neuroma with interposition grafting and 14 favored neurolysis alone. The remaining 18 would not have brought the patient to the operating room in the described case.3

Use of the Active Movement Scale (AMS) has provided a functional measure of upper-extremity function specifically for infants, who are not amenable to manual muscle testing.6,8,17 Clarke et al.6 reported on 9 patients with upper trunk palsy treated by neurolysis alone and found significant improvements in shoulder movements, elbow flexion, supination, and wrist extension at a mean of 17 months’ follow-up. There were no significant improvements in patients with total plexus palsy treated with neurolysis alone.6 Lin et al. then directly compared neurolysis alone with neuroma resection and grafting with a follow-up of 4 years. Their treatment protocol before 1993 had been to use intraoperative conduction and neurolysis if distal muscle contraction was noted on stimulation. Since 1993, they have performed neuroma resection regardless of evidence of electrophysiological conduction unless distinct fascicular architecture was noted. Only 8 of 56 patients in this study with upper trunk palsy were treated with neurolysis alone, while the remaining 48 were treated with neuroma resection. The authors found significant improvement in only supination in the neurolysis group, whereas the resection group showed improvement in 7 movements. Early improvements in function produced by neurolysis in upper trunk palsy were not sustained over time.17 The authors recommended that neurolysis alone not be used for treatment of BPBIs.

This statement was based on 8 patients with upper trunk lesions treated with neurolysis compared with 48 patients treated with resection and grafting. In their article, however, Lin and colleagues state that “direct comparison of the 2 groups was not possible due to the large difference in sample size.”17 As this study had such a small sample size, and did not allow for statistically valid comparison between treatment groups, revisiting the results of neurolysis was felt to be warranted. Additionally, in the study by Lin et al. if proximal stimulation of the nerve produced distal motor activity, a neurolysis was performed.17 Because more stringent and exact testing of nerve conduction is available, we wanted to revisit the results of neurolysis using intraoperative electromyography (EMG) that can measure compound motor action potential (CMAP) produced with stimulation above and below a neuroma. Additionally, neurolysis offers significant advantages such as no donor site morbidity, no loss of function waiting for reinnervation, and less operative time. We chose to test the hypothesis that more severe nerve injuries, as distinguished by <50% conduction across a neuroma-in-continuity, could be treated with neurosurgical resection and grafting, whereas less severe nerve injuries, with >50% conduction across the neuroma, could be treated with neurolysis alone. The goal of this study was to compare the preoperative, 1-year postoperative, and >2-year postoperative AMS scores in cases involving children with upper trunk BPBIs in whom intraoperative nerve testing demonstrated conduction >50% through the neuroma and the lesions were treated with neurolysis alone.

Methods

All cases involving BPBIs treated at Gillette Children’s Specialty Healthcare between 1999 and 2008 were reviewed. After institutional review board approval, charts were reviewed for all patients who had undergone primary brachial plexus surgery. Inclusion criteria for our study were as follows. 1) The indication for surgery was that the patient did not have antigravity flexion of the elbow (AMS score of 4 or less) by 6 months of age or was unable to bring his or her hand to his or her mouth due to combined elbow and shoulder weakness. 2) The patient had undergone surgical treatment with neurolysis alone of the upper trunk in the setting of a conducting neuroma-in-continuity for a Narakas I or II lesion14 (C5–6 or C5–7). 3) AMS scores were available for more than 2 years’ follow-up.

Data Collection

All data, including AMS scores, were prospectively collected for all children as standard of care. At each clinic visit, each child was evaluated by an occupational therapist trained and experienced in the use of the AMS (Table 1).28 Observations of shoulder, elbow, forearm, wrist, finger, and thumb movements were graded from 0 to 7 by an independent occupational therapist trained in this assessment technique. The validated AMS assessments were collected and compared for 3 time points: just prior to the surgery, as close to 1 year after the date of surgery as possible, and as close to 3 years after the date of surgery as possible (scores from this time point are described in this article as >2-year postoperative scores). Nerve lesion severity was classified as described by Narakas16 using findings of the immediate preoperative examination.

Patient Population

During the time period of 1999–2008, 441 children were evaluated and treated in the BPBI clinic of Gillette.

### TABLE 1: Active Movement Scale*

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<td>no contraction</td>
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</tr>
<tr>
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<tr>
<td>motion &gt;1/2 range</td>
<td>7</td>
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</tbody>
</table>

* Hospital for Sick Children Muscle Grading System. Full active range of motion with gravity eliminated (Muscle Grade 4) must be achieved before active range against gravity is scored (Muscle Grades 5 to 7). This table was previously published in Hand Clin 11. Clarke HM, Curtis CG: An approach to obstetrical brachial plexus injuries. 563–580, copyright W.B. Saunders Company (1995). Reprinted with permission from Elsevier.
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Children's Specialty Healthcare. During this same time period, 44 of these 441 children were treated with primary nerve surgery. Of the children treated with primary nerve surgery, 30 underwent neurolysis of the upper trunk as part of their primary nerve surgery. Eleven children underwent resection of the upper trunk neuroma as part of their primary nerve surgery when intraoperative assessment demonstrated < 50% conduction through the neuroma. In 3 of the procedures performed early in the study period, the patients were treated with resection and primary anastomosis. Of the 30 patients treated with neurolysis, 13 patients did not meet inclusion criteria (7 had incomplete AMS at follow-up, 2 had clinical indications other than elbow flexion deficiency, 3 had Narakas III or IV [pan-plexus] lesions, and 1 was not treated with upper trunk neurolysis alone.) As shown in Fig. 1, of 441 children seen during the study period in the BPBI clinic, 90% had satisfactory spontaneous nerve recovery such that primary nerve surgery was not indicated, and 10% of children did not have satisfactory spontaneous nerve recovery and therefore underwent primary nerve surgery. Of the 397 children not treated with primary nerve surgery, 20 (5%) were subsequently surgically treated for shoulder internal rotation contracture. Of the 44 children treated with primary nerve surgery, 6 (14%) were surgically treated for secondary shoulder internal rotation contractures.

Seventeen patients (7 male and 10 female) met the criteria for inclusion in this study. Surgery was performed at an average age of 10 months (range 6–19 months). Birth weight ranged from 570 g (in an extremely low birth weight infant born prematurely due to premature membrane rupture) to 5102 g. The average birth weight of the patients in the study was 3835 g; published data report 3462 g as the average weight of full-term unaffected neonates.20 If the 1 extremely low-birth-weight neonate was excluded, the average birth weight of the remaining 16 patients in our study group was 4053 g. According to parents’ reports or available outside records, 8 deliveries involved documented shoulder dystocia, 7 deliveries required vacuum or forceps assistance. Five fractures of the clavicle or humerus were diagnosed in these 17 children.

Indications for Surgery

Although there was some variability with respect to patients’ age at presentation, the most common age was 1–2 months. A baseline AMS score was obtained. At 3 months of age, if the patient did not have full active range of motion of the elbow with gravity eliminated (that is, had an AMS score < 4), baseline EMG/nerve conduction velocity (NCV) testing was performed for diagnosis and prognosis. At 5 months of age, if the patient had less than 50% active range of motion against gravity (AMS score < 5), the EMG/NCV was repeated for comparison. On the basis of a combination of AMS score profile, physician examination, and EMG/NCV testing changes, surgery was discussed with the parents. The indication for surgical intervention

![Fig. 1. Treatment algorithm used in this study.](image-url)
was that the child could not bring his or her hand to his or her mouth by at least 6 months of age—the “cookie test.” In this study cohort, 14 of the 17 patients did not have antigravity flexion of the elbow (AMS score ≤ 3); these patients were unable to bring their hand to their mouth due to combined elbow and shoulder weakness and thus met criteria for surgical intervention.

Surgical Technique

The operative protocol involved using a V-shaped incision down to the posterior border of the sternocleidomastoid and across the clavicle. The brachial plexus was identified and surgically released from surrounding tissue to allow intraoperative nerve conduction testing. Nerve conduction recordings were acquired using a Nicolet Endeavor CR (CareFusion) The recordings were amplified and displayed (time base 100 msec; band pass 10 Hz–2 kHz). Peak to peak amplitudes were recorded. A bipolar stimulator (rhizotomy hooks) was held in place with the cathode directed toward the recording electrodes. Stimulation duration was set at 0.1 msec with a maximum intensity set at 5 mA. Compound motor action potentials were recorded using disposable subdermal needle electrodes with the active electrode placed over the muscle belly with the reference electrode on the muscle tendon. A disposable surface ground electrode was used. The following muscles were evaluated in all subjects (infra-‐spinatus, deltoit, triceps, biceps, extensor carpi radialis), with additional muscles included based upon the clinical and preoperative electromyogram. Stimulation was directed both distal and proximal to the lesion with recording of CMAPs. The stimulation rate was 1.1 Hz. Current was slowly increased to obtain a supramaximal CMAP, with care given to avoid overflow of current. A proximal CMAP of more than 50% of the distal CMAP amplitude (> 50% conduction), with a nerve in continuity, was used to determine that neurolysis alone would be the surgical treatment. Neurolysis was performed with a No. 11 blade, making multiple longitudinal incisions into the thickened epineurium of the neuroma, until axonal tissue could be visualized. For lesions not in continuity, or with less than 50% conduction, neuroma resection and grafting was performed.

All patients in this study were found to have a neuroma-in-continuity and had more than 50% conduction across the neuroma, as evaluated by the physician performing the nerve conduction testing, as well as the 2 operative surgeons. All 17 patients in this study underwent neurolysis of C-5 and C-6. Additionally, 5 patients had neurolysis of C-7. Two patients underwent spinal accessory to suprascapular nerve transfer at the time of neurolysis; these 2 patients were not included in data analysis for shoulder external rotation. Avulsions of the C-5 root were seen in 2 of the 17 patients, so the C-6 and upper trunk were neurolysed.

Postoperative Care and Assessment

The limb was not immobilized following the surgery, and physiotherapy was reinstated as soon as the patient was comfortable, usually within 2 weeks. No postoperative complications were noted.

All patients included in this study were seen at regular follow-up visits with reassessment by the occupational therapist for repeat AMS. For this study, data from 3 time points were collected: presurgery (n = 17); 1 year after surgery (n = 17; average 15 months postoperatively, range 11–27 months); and more than 2 years after surgery (> 2-year follow-up, n = 16, average 41 months postoperatively, range 29–52 months). The > 2-year follow-up AMS score was the AMS assessment closest to 3 years after the surgery.

Secondary surgeries were performed in 6 (35%) of the 17 cases. Five patients had secondary shoulder procedures. One patient had pectoralis major and subscapularis lengthening 2 years after neurolysis; 3 patients had pectoralis lengthening with latissimus dorsi and teres major tendon transfers—one at 21 months, 1 at 3 years, and 1 at 4 years after neurolysis; and 1 had lengthening and tendon transfer with open reduction 18 months after neurolysis. Lastly, 1 patient was treated with a derotational osteotomy of the radius for a supination contracture after the 3-year follow-up examination.

Statistical Methods

Statistical analysis was performed using descriptive statistics for demographics. A group t-test was used for comparison of preoperative assessment to the 2 subsequent follow-up assessments. Statistical significance was set to be less than 0.02 (corrected for multiple comparisons).

Further analysis was performed by grouping of patients into subgroups with AMS score of 5 or less and AMS score of 6 or 7 at final follow-up. This grouping was chosen based on Clarke's description of a more demanding test of functional results, where only active movement against gravity of greater than 50% arc of motion was considered an improvement in useful function, as simple improvement in movement of the joint is not necessarily equated with useful function. For the present study, useful function of joint movement was defined as an AMS score of 6 or 7. For each joint movement in each group, the number of children who, at final follow-up, had obtained an AMS score of 6 or 7 (useful function) was compared with the number of children with an AMS score of 5 or less. Categorical data were analyzed using the Wilcoxon signed-rank test with significance set at p < 0.025 for multiple comparisons.

Results

As shown in Fig. 2, between the baseline level and 1-year follow-up, significant improvement was seen in shoulder abduction, shoulder flexion, shoulder external rotation, shoulder internal rotation, elbow flexion, forearm supination, and wrist extension. Between baseline and > 2-year follow-up, there was significant improvement in shoulder abduction, shoulder flexion, shoulder external rotation, elbow flexion and supination.
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Table 2 presents the mean, standard deviation, and p values of preoperative, 1-year follow-up, and > 2-year AMS scores. More than 2 levels of improvement on the AMS at more than 2 years’ follow-up were noted in shoulder abduction, shoulder flexion, shoulder external rotation, elbow flexion, and supination.

Figure 3 shows the percentage of children that achieved a > 2-year AMS score of 6 or 7, indicating useful function for each of the measured movements. At final follow-up, useful function (AMS score of 6 or 7) was achieved for shoulder flexion in 14 of 16 patients, for shoulder flexion in 11 of 15 patients, for shoulder abduction in 11 of 16 patients, and for shoulder external rotation in 5 of 15 patients. Only those patients with complete prospective data points for > 2-year follow-up were included in this evaluation.

**Discussion**

The goal of this study was to compare the preoperative, 1-year postoperative, and > 2-year postoperative AMS scores of children with upper trunk brachial plexus birth injuries (BPBIs) after treatment with neurolysis alone if the neuroma conducted > 50% on intraoperative nerve testing. Of the 441 patients treated for BPBI at Gillette Children’s Specialty Healthcare between 1999 and 2008, 44 (10%) were treated with primary nerve surgery. In these primary nerve surgeries, various combinations of nerve grafting, neurolysis, or nerve transfer were used. Only 17 of these surgeries met the specific inclusion criteria of this study and are the subject of this report describing neurolysis alone in treatment of upper trunk (C-5 and C-6) injuries. Thus, this is a specific, yet important, treatment option only for a small subgroup of patients with BPBI.

Our study shows significant clinical improvement in shoulder and elbow movement for children with BPBI treated with neurolysis alone of the upper trunk. Between baseline and > 2-year follow-up, there was significant improvement in shoulder abduction, flexion, and external rotation, and elbow flexion and supination. Clarke and colleagues have questioned whether the improvements in active movement are sufficient for activities of daily living. He suggested using a more demanding test of “functional results,” where only active movement against gravity with greater than 50% arc of motion (AMS score 6 or 7) was the criterion for an improvement in “useful function.” Using this more stringent criterion, clinically useful improvements were demonstrated for shoulder abduction and flexion and elbow flexion and supination. Active Movement Scale scores of 6 or 7 were achieved in 70% of children for shoulder abduction, 73% of children for shoulder flexion, and 90% of children for elbow flexion.
A comparison study of neurolysis versus the natural history of untreated BBPI is necessary to address the question of whether neurolysis alone is better than no surgery. Current practice standards preclude us from initiating a trial with a nontreatment arm, so we are left making comparisons to historically presented data. Waters in his landmark study on the natural history of untreated BBPI provides 2 groups for comparison. His study cohort is similar to our study cohort in that both groups were followed over 3 years (5- and 6-month return of function averaged 44 months’ follow-up compared with 41 months in our neurolysis group). Our cohort of patients did not have return of biceps activation until 6 months of age and were unable to bring the hand to the mouth against gravity. Thus, our neurolysis group could be compared with his natural history group that did not have the ability to bring the hand to the mouth by 6 months of age.

Waters’ natural history study group was evaluated using the Mallet classification, and ours was evaluated using Active Movement Scale (AMS). To provide a direct comparison, the Mallet ability to bring the hand to the mouth (ranked 1–5) would be analogous to the AMS of elbow flexion (ranked 0–7). Similarly, the Mallet class of global abduction (ranked 1–5) would be analogous to the AMS of shoulder abduction (ranked 0–7).

For shoulder abduction, a Mallet score of 1–3 is defined as less than 90° of shoulder abduction. In the AMS, a score of 0–5 represents a less than 50% arc of shoulder abduction against gravity. These 2 groups would be directly comparable. A Mallet score of 4–5 would be comparable to an AMS of 6–7, as both would indicate greater than 90° of movement. Similarly, a Mallet score of 1–3 would indicate a partial trumpet sign when bringing a hand to the mouth as maximum function, which would correlate with an AMS score between 0 and 5, which would be less than 50° of active elbow flexion against gravity. A Mallet score of less than 4 or 5 would indicate less than 40° of trumpeting when bringing the hand to the mouth, or normal function, which would correlate to an AMS of 6 or 7 with greater than 50% elbow flexion against gravity.

As shown in Table 3, and in Waters’ natural history study, none of the patients in Waters’ 6-month-return group achieved shoulder abduction of greater than 90°, whereas in the neurolysis group presented in this study, 11 of 16 patients achieved active ability to abduct greater than 90° at final follow-up (> 2 years after surgery). This difference was analyzed using a Fisher exact test, which shows that the neurolysis group had significantly greater return of shoulder abduction when compared with the natural history group (p < 0.0001).

In Waters’ natural history study, none of the pa-

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* Statistical significance level: 0.025. NS = not significant.
† For comparison of baseline versus 1-year data
‡ For comparison of baseline data versus data obtained at assessment closest to 3 years after surgery (> 2 years).
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Patients in his 6-month-return group achieved the ability to bring the hand to the mouth with less than 40° of abduction, whereas in our neurolysis group, 14 out of 16 achieved more than 90° of elbow flexion against gravity. This difference was analyzed using a Fisher exact test, which showed that the neurolysis group had significantly greater return of elbow flexion than the natural history group ($p < 0.0046$).

Thus the improvements achieved by neurolysis alone are significantly greater than those that would be expected based on the natural history of BPBIs for children who could not reach their hand to their mouth by 6 months of age, according to the natural history study of Waters.

Neurolysis is not as effective at improving shoulder external rotation. Only 5 of 15 patients gained clinically useful shoulder external rotation (AMS score of 6 or 7). For this reason, 6 secondary surgeries were performed in our study, with 5 of these being performed to treat internal rotation contractures.

The movement improvements seen in this study are in contrast to the findings of the study by Lin et al., in which 8 patients with Erb’s palsy underwent neurolysis, and at final follow-up of 4 years, a significant increase in AMS scores was seen only in supination, with a corresponding decrease in pronation. It cannot be determined how many of the 8 patients treated with neurolysis in that study would have passed our > 50% conduction criteria for a neuroma-in-continuity. Lin and colleagues used a less stringent test of intraoperative stimulation in which the production of distal gross movement was considered evidence of a neuroma-in-continuity, and these patients were treated with neurolysis. Their patients may have been more severely affected. They also reported a higher greater return of elbow flexion than the natural history group ($p < 0.0046$).

### TABLE 3: Comparison between > 2-year results of present study and 6-month-return group of Waters (natural history of BPBI)*

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</tbody>
</table>

* The table shows a comparison of the function in the 6-month-return group in the study by Waters and the final results (> 2-year follow-up data) in the present study. The neurolysis group (present study) had significantly greater return of shoulder abduction and elbow flexion than the natural history group (Fisher exact test, $p < 0.0001$ and $p < 0.0046$, respectively).

† Seven patients had no return of biceps function at 6 months.

Significantly different at $p < 0.025$ by Wilcoxon signed rank test: • Baseline vs. 1 Year, ◆ Baseline vs. > 2 Years

**Fig. 3.** Percentage of patients with AMS scores of 6 or 7 at preoperative assessment (baseline), at 1-year follow-up (1 year), and at the follow-up assessment closest to 3 years after surgery (> 2 years).
need for secondary procedures in the group treated with neurolysis alone (56.3%) than in the group treated with neuroma resection and grafting (29.4%). Similar to Lin and colleagues, we also found a greater need for secondary procedures in our patients treated with neurolysis alone (3%) as compared with those treated with neuroma resection and grafting (7%).

Indications for exploration in our study were lack of useful biceps function by age 6 months (AMS score ≤ 4) or a combined elbow flexion and shoulder function score that would not allow hand to mouth function (failing the “cookie test”). Our patients’ average age at the time of neurolysis was 10 months (range 6–18 months). Most authors would agree that surgery would be indicated for patients without hand to mouth function by 6–9 months of age, as patients without return of biceps function by this age would have poor outcomes without surgical intervention.²,³,⁶,¹²,²³

Paramount to our treatment protocol in this study was the use of intraoperative nerve conduction studies as a guide to determining whether to treat patients with neurolysis alone or with neuroma resection and interposition grafting. Historically, intraoperative nerve testing has been incorporated in the treatment algorithms and also reported in the surgical methods. Gilbert wrote “only those roots that are apparently in continuity and respond well to stimulation are neurolysed” but also noted “its utility when there is no neuroma present but a soft, pale root that does not respond to stimulation.”¹⁰,¹¹ Boome and Kaye⁴ performed a visual inspection only, whereas others⁵,⁶,²¹ performed neurolysis alone if electrical stimulation of nerve trunks elicited gross distal motor functions. In addition to nerve stimulation testing, some have used EMG and sensory evoked potentials more than others. Alanen et al. wrote that “intraoperative EMG and SEP [sensory evoked potential] measurements guided the management.”¹¹ Another stated, “Intraoperative studies of root sensory evoked potential, nerve action potential, and evoked muscle response facilitate the decision-making process and are imperative in these cases.”²² Kawabata considered the nerve to be in continuity when the nerve action potential from at least 1 peripheral nerve could be recorded with proximal stimulation.¹⁴

Although these articles published prior to 1995 favor the use of intraoperative nerve testing for decision making regarding possible neurolysis, more recently neurolysis has been viewed as producing unfavorable results. In a 2010 current-concepts review, Hale et al. reported, “neurolysis alone is no longer indicated in BPBI.”¹³ Similarly, Lin et al.¹⁷ wrote in their 2009 publication, “neurolysis as a complete surgical treatment for obstetrical brachial plexus palsy should be abandoned in favor of neuroma resection and nerve grafting.” This statement was based on their 8 patients with upper trunk lesions treated with neurolysis compared with 48 patients treated with resection and grafting. However, direct comparison of the 2 groups was not possible due to the large difference in sample size. Our results at more than 2 years’ follow-up show significant improvement to functional levels (AMS score 6–7) for shoulder abduction, shoulder flexion, and elbow flexion and supination, which is in contrast to the findings of Lin et al.

The protocol followed at our institution and in this study most closely mirrors that of Laurent and Lee.³,¹⁰ If neural conduction recorded by amplitude of the electromyogram of the appropriate muscle dropped by more than 50% across a neuroma, the lesion was excised and an interposition graft was placed. If less than a 50% drop across a neuroma was recorded, then neurolysis was performed. Neurolysis is believed to reduce high intraneuronal pressure, improve blood flow, and alleviate the physical barriers to regeneration.¹⁹ In our opinion, intraoperative electrophysiological testing is of paramount importance to surgical decision making during these primary explorations.

The present study has several weaknesses. Thirty patients were treated with neurolysis of the upper trunk during the study time period, and 13 of these patients were excluded from the study, with lack of follow-up in 7 cases; the results achieved in these cases are unknown. Although the literature shows it is rare to have functional neurological recovery after the age of 9 months if a child shows no antigravity biceps function, it is still possible that a number of those 17 patients who underwent neurolysis as the sole surgical treatment of the upper trunk might have gone on to similar recovery even without surgery.

Because BPBI involves a heterogeneous constellation of nerve injuries, as well as an array of nerve resection and neurolysis options, we tried to narrow the cases to look at neurolysis alone of upper trunk lesions. The resulting data would not be applicable to other BPBI lesions. The decision was made to include 2 patients with single upper root avulsions. By including these root lesions, our final outcomes may have been less positive than if we had included only less severe nerve injuries. One of the 2 patients with a C-5 avulsion underwent concurrent spinal accessory transfer, and this patient’s case was omitted from the external rotation analysis. The other patient’s case was included to assess the benefit in neurolysis alone to the lower C-6 nerve root.

Six of our 17 patients had secondary surgeries, and their AMS scores were included at final follow-up, which does confound the pure result of neurolysis alone for the 6 patients whose secondary surgeries fell within the 3-year study window. The secondary surgeries were performed an average of 2.5 years from the date of the index surgery. This did not affect 1-year follow-up data but did affect the analysis of > 2-year data analysis for 4 of the 6 patients. Additional benefits of performing a neurolysis as the sole treatment of the upper trunk are the decreased donor site morbidity from harvesting a sural nerve autograft, lack of need for postoperative immobilization of the limb, no loss of function in the early postoperative period, and shorter operating room times. These benefits were not specifically measured.

We used the Laurent and Lee treatment algorithm and a 50% conduction threshold as the cutoff for neurolysis alone versus neuroma resection.³,¹⁰ This is not a validated threshold and was arbitrarily chosen on the basis of surgeon preference. Future work could be done analyzing different EMG cutoff levels and resultant AMS score outcomes.

There are multiple strengths to this study as well. The patient population treated for BPBI during the study
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period numbered 441 patients, so the operative group for primary nerve surgery represented 10% of that total (44 patients). This rate is similar to previously published studies, making it unlikely that our neurolysis group of children would have improved spontaneously. Of our operative group, 30 patients underwent neurolysis, but only 17 met the inclusion criteria for this study. Although this group is small, it was large enough to show clinically significant improvement in shoulder abduction, shoulder flexion, elbow flexion and supination.

Conclusions

Although neurolysis alone was used historically for treatment of BPBI, many have come to believe this treatment is no longer recommended. This report indicates that there is a subgroup of patients who can obtain clinical benefit, with functional improvement of shoulder and elbow function, from treatment with neurolysis alone for upper trunk lesions with more than 50% conduction across a neurona on intraoperative nerve testing. Patients with less than 50% conduction, indicating more severe disease, are treated with nerve resection and grafting in our treatment algorithm. A direct comparison study of neurolysis alone in conducting neuromas versus neurona resection and grafting could be done in the future, now that the benefits of performing neurolysis as a sole treatment have been demonstrated.

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Disclosure

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

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