Serial Casting and Splinting of Elbow Contractures in Children With Obstetric Brachial Plexus Palsy

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Purpose Elbow flexion contractures are a common sequela in obstetric brachial plexus palsy. The etiology and best management of these contractures is unclear. Nonsurgical treatment involving serial casting and splinting is supported in the literature. The purpose of this study is to evaluate the effectiveness of serial casting and splinting of elbow flexion contractures in children with obstetric brachial plexus palsy.

Methods A retrospective review of children with obstetric brachial plexus palsy who participated in serial casting and splinting for an elbow flexion contracture was conducted. Elbow extension passive range of motion measurements at initial, best-achieved, and final outcome were compared.

Results Nineteen patients, aged 2 to 16 years, were studied. Elbow passive range of motion improved from initial to best-achieved and final outcome measurements. Fifty-three percent of patients were noncompliant between the time of best-achieved and final outcome. Loss of passive range of motion during the noncompliant period was statistically significant. Compliant patients had better treatment results. A clinical decision tree for elbow contractures in obstetric brachial plexus palsy was formulated.

Conclusions Serial casting and splinting of elbow contractures in children with obstetric brachial plexus palsy is effective. Successful maintenance of treatment effects is dependent on patient age and compliance. *(J Hand Surg 2010;35A:84–91. Copyright © 2010 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Elbow, obstetric brachial plexus palsy, orthotics, rehabilitation.

Children with obstetric brachial plexus palsy may experience elbow flexion contractures, typically lacking between 10° and 20° of extension.[1] However, contractures between 40° and 60° or greater can occur[2,3] (Fig. 1).

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The etiology of these contractures is still questioned.[1,4] Waters[5] describes the rare clinical presentation of the child with C8-T1 neuropathy and recovery of C5-6 function. The muscle imbalance between the recovered elbow flexors and forearm supinators with weakened or absent elbow extensors and forearm pronators may result in an elbow flexion contracture and supination deformity. However, flexion contractures also occur in upper plexus patients where triceps function may appear adequate to oppose biceps and brachialis function. Ballinger and Hoffer[1] evaluated the elbow flexion contractures of a cohort of 38 children with upper plexus palsy (C5-6). In their study, the elbow extension and flexion strength was graded using manual muscle testing. Twenty-nine of 34 children who had a flexion contracture of the elbow demonstrated elbow extension strength of at least 1 grade greater than their elbow flexion strength. The authors discuss that one

FIGURE 1: Child with obstetric brachial plexus palsy with elbow flexion contracture. **A** Elbow flexion contracture of 30°. **B** Anterior view: limb length discrepancy.

possible explanation for these results is that innervation to the elbow flexors return prior to the extensors resulting in flexor dominance over extension function for a period of time. This may result in an imbalance in flexor and extensor function.[1]

Contractures of the elbow joint are typically evaluated according to intrinsic and extrinsic factors that impede joint movement.[6] The clinical findings in elbow contractures in obstetric brachial plexus palsy appear to be limited to extrinsic causes such as adhesions, joint capsule, ligament, and muscle shortening. An imbalance in elbow flexor and extensor muscle power is observed, with typically greater flexor strength. Hypertrophic changes and shortening of the biceps tendon are also palpated.

The literature recommends both nonsurgical and surgical treatment of elbow flexion contractures in children with obstetric brachial plexus palsy.[2,4] Surgical treatments include releasing soft tissues of the elbow joint in conjunction with lengthening 1 or more muscles groups. Lengthening of the biceps, brachialis, and flexor-pronator mass has been documented.[2,4,7] Surgically increasing extension may result in loss of elbow flexion range of motion.[2] Loss of elbow flexion range of motion has greater consequences as most daily living activities are accomplished in the range of 30° to 130° of elbow flexion.[8] Evaluative studies of the surgical treatment of elbow flexion contractures in children with obstetric brachial plexus palsy have not been published to our knowledge.

Nonsurgical treatment involving use of a long-term elbow extension orthotics has been described in the literature.[2,4] Elbow flexion contractures are typically managed with static progressive hinged elbow extension splints.[6] This has been found to be effective in children and adults with posttraumatic elbow flexion stiffness with soft tissue contracture.[9] Static serial extension splints are also recommended for flexion contractures less than 30°.[6] Serial casting has also been found to be effective in increasing the range of motion of posttraumatic elbow flexion contractures in adults.[10] The effectiveness of serial casting or splinting in children with obstetric brachial plexus palsy has not been evaluated to our knowledge. The purpose of this study is to evaluate the effectiveness of serial casting and splinting in children with obstetric brachial plexus palsy.

MATERIALS AND METHODS

The study was approved by the research ethics board at the authors' institution. A retrospective review of the brachial plexus occupational therapy charts and brachial plexus database at the authors' institution was conducted. The criteria for inclusion to the study were a diagnosis of obstetric brachial plexus palsy and a referral for nonsurgical management of an elbow flexion contracture during the 5-year period from 2004 to 2008. It is during this time that a consistent treatment protocol for serial casting and splinting was implemented. Prior to this date, multiple treatment approaches were used, and patients were not seen routinely for elbow contractures. Patients were also required to attend a minimum of 2 sessions of nonsurgical treatment at the authors' institution.

Treatment protocol for nonsurgical treatment for elbow contractures in obstetric brachial plexus palsy at the authors' institution is recommended for patients who have a functional deficit related to the elbow flexion contracture. These are patients with elbow contractures greater than 30°. However, not all patients with an elbow contracture greater than 30° are treated if they do not express a functional or cosmetic concern. For very mild contractures (<20°), the child and family are advised that the contracture does not have important negative functional implications. They are advised that nonsurgical treatment consists of long-term commitment to night splinting and stretching and that treatment gains would primarily be improvement in cosmetic appearance. Passive stretching within the child's daily activities, such as hanging from monkey bars, is highly recommended over splinting. If the patient and family still wish to pursue treatment, night splinting is provided in accordance with child and family-centered care.

The treatment protocol first consists of therapeutic heat, passive range of motion stretches, and either serial casting or splinting. Therapeutic heat is applied to the elbow joint by means of paraffin wax. This increases muscle relaxation and tissue extensibility and decreases pain and muscle spasm.[6] Heat is maintained on the joint as the occupational therapist begins passive range of motion stretches. A gentle prolonged stretch is applied to the elbow joint, moving the elbow into extension. Care is taken to provide a sustained stretch well within the patient's pain tolerance. Forceful stretching of the joint may cause joint or soft tissue injury. After stretching is completed, range of motion of the elbow in extension is measured with a goniometer on the lateral aspect of the upper arm and forearm. Evaluation of active elbow flexion range of motion and elbow joint integrity is also conducted. The maximum extension achieved after stretching is held in either a cast or a custom-made thermoplastic orthotic. In more severe cases (>40° of elbow flexion contracture), long-arm cylindrical plaster or fiberglass casts are used to completely immobilize the joint (Fig. 2). The cast is removed after 1 week. Stretching and casting is repeated until the gain in elbow extension plateaus or the contracture is reduced to 30°.

When the contracture is reduced to 30° or initially presents at 20° to 40°, serial splinting is initiated (Fig. 3). Therapeutic heat, passive range of motion stretches, and goniometer measurement are conducted as previously described. A custom-made, low-temperature thermoplastic elbow extension orthosis is fabricated to hold the elbow in maximum extension. The orthosis is secured anteriorly on the upper extremity with Velcro fasteners. It is prescribed for night use only. The patient is initially followed up every 2 weeks to continue therapeutic heat, stretches, measurement, and remolding of the orthosis to the maximum elbow extension passive range of motion. Stretching and serial splinting is repeated until the gain in elbow extension passive range of motion plateaus. A plateau in passive range of motion is defined as lack of change in passive range of motion after 2 follow-up sessions. At this time, the patient is instructed to wear the orthosis nightly to maintain the maximum elbow extension passive range of motion achieved. Follow-up is scheduled for every 6 months or sooner if change in elbow passive range of motion occurs or orthotic modifications are required.

FIGURE 2: Long-arm cylindrical plaster cast.

FIGURE 3: Low-temperature thermoplastic elbow extension orthotic.

Data were collected for each patient who participated in serial casting or splinting in a password-protected and encrypted spreadsheet. Age of patient and type of treatment intervention (ie, cast or splint) at initial treatment was collected. The degree of elbow flexion contracture recorded by the occupational therapist at each therapy session was compiled. The retrospective review of the charts indicated consistent documentation of elbow passive range of motion, but data were missing for active range of motion measurements across all visits and patients. Therefore, only elbow passive range of motion at initial treatment, best-achieved passive range of motion, and final treatment was extracted. The best-achieved passive range of motion was defined as the lowest degree of elbow contracture that was achieved by each patient. This was typically at the termination of serial casting or splinting, prior to initiating the night splint to maintain passive range of motion. The patient's loss or gain in elbow passive range of motion per sequential therapy session was calculated. Documentation of the type of treatment, casting, splinting, or noncompliance was recorded for each session. Visits were defined as noncompliant when the patient or family reported that they did not wear the splint or cast as prescribed by the occupational therapist. Any complications experienced during treatment were noted.

RESULTS

Twenty-seven patients were referred for nonsurgical management of an elbow flexion contracture. The average age at the time of referral was 11 years (range, 2 to 16 y). Flexion contractures at the time of referral ranged between 15° and 85°. Sixteen patients had a contracture greater than 40°, 10 patients had a contracture between 20° and 40°, and 1 patient had a contracture of less than 20°. The average initial degree of elbow flexion contracture of patients who started treatment with casting (n = 16) was 60°, and that of patients who started treatment with splinting (n = 11) was 35°. Of the 27 patients referred, 7 patients were referred to a community health care facility for active ongoing nonsurgical treatment and were therefore excluded from the study. One patient was involved in a different nonsurgical treatment program prior to 2004 and was excluded from this study.

Nineteen patients received nonsurgical treatment for an elbow flexion contracture at the authors' institution. At the time of data collection, 13 patients were still receiving ongoing active treatment, and 6 patients discontinued treatment. Patients received treatment from a range of 2 weeks to 4 years and 2 months. Nine patients were followed up less than 1 year and 11 patients between 1 and 4 years. The patients were between 2 and 15 years of age, with 5 patients 8 years or younger and 14 patients older than 8 years.

The mean initial, best-achieved, and final degree of elbow contracture passive range of motion was 48° ± 18, 17° ± 9, and 26° ± 14, respectively.

TABLE 1. Effectiveness of Nonsurgical Treatment

	T Value	*P* Value	α Value
Initial vs best-achieved passive range of motion	8.14	<.0001	.05
Initial vs final passive range of motion	5.81	<.0001	.05
Best-achieved vs final passive range of motion	–2.33	.03	.05

TABLE 2. Demographics of Compliant versus Noncompliant Patients

	Compliant (n = 9)	Noncompliant (n = 10)
Percentage of patients (%)	47	53
Mean age (y)	12	9
Age range (y)	9–13	2–14
Number of patients ≤8 y	0	5
Number of patients >8 y	9	5

Multivariate ANOVA was conducted using the SAS program (SAS Institute, Cary, NC) to evaluate the effectiveness of splinting and casting intervention at the time intervals of initial, best-achieved, and final passive range of motion (Table 1). The differences in passive range of motion from initial to best-achieved and final time intervals were statistically significant ($p < .0001$, $\alpha = .05$). Further, all patients (100%) demonstrated an improvement in their elbow flexion contracture with nonsurgical treatment.

The loss of passive range of motion between best-achieved and final time interval was also statistically significant (Table 1) ($p = .03$, $\alpha = .05$). Noncompliance was experienced in 53% of patients (n = 10). Nine of these patients were noncompliant during the time interval between best-achieved passive range of motion to final passive range of motion. The comparison between the demographics of compliant and noncompliant patients is presented in Table 2. The interaction effects between compliant and noncompliant patients at the 3 time intervals of initial, best-achieved, and final passive range of motion were evaluated using multivariate ANOVA (Table 3). No interaction effects were found between the 2 groups nor between time intervals. However, a statistically significant main effect was found between the 2 groups ($p < .001$, $\alpha = .05$). Compliant patients had better treatment results than those of patients who were noncompliant.

TABLE 3. Comparison Between Compliant and Noncompliant Patients

Patients	Time Interval	Mean (°)	SD
Compliant (n = 9)	Initial passive range of motion	44	13
	Best-achieved passive range of motion	14	9
	Final passive range of motion	18	10
Noncompliant (n = 10)	Initial passive range of motion	52	21
	Best-achieved passive range of motion	19	9
	Final passive range of motion	33	14

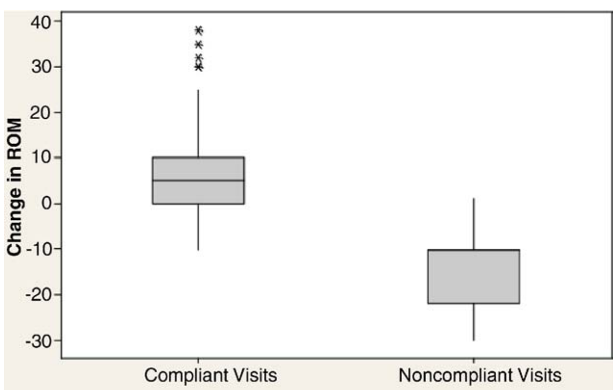

FIGURE 4: Compliant versus noncompliant visits.

The total number of occupational therapy treatment visits for elbow contractures attended by the 19 patients in this study was 124. These visits were divided between compliant and noncompliant visits. The boxplot in Figure 4 illustrates the comparison between the change in elbow contracture passive range of motion between compliant (n = 16) and noncompliant (n = 108) visits. All noncompliant visits resulted in no change or loss in treatment effects.

During nonsurgical treatment, 2 patients were documented to have minor complications: 1 developed signs of radial head instability, and 1 temporarily lost active elbow flexion range of motion.

The results of this study have led us to formulate a clinical decision tree to manage elbow flexion contractures in children with obstetric brachial plexus palsy (Figure 5). Education of the child and family regarding treatment commitment and evaluation of compliance is central to this algorithm.

The first step is *Assessment* of whether the child and family have functional or cosmetic concerns regarding the elbow flexion contracture. Step 2 is to provide *Education* to the child and family regarding the commitment required to participate in conservative treatment and maintain treatment results. Step 3 is the *Evaluation of Motivation* for treatment. It is important to determine if motivation to improve the elbow flexion contracture is driven by the parent or child. Step 4 is participation in the *Treatment Protocol*. As previously discussed in the "Materials and Methods" section, treatment at the authors' institution is determined by the severity of elbow flexion contracture. Contractures greater than 40° are treated with serial casting and progress to treatment with serial splinting and night splinting when the contracture is reduced to less than 40°. Less severe contractures, 20° to 40° of elbow flexion contracture, are only treated with serial splinting. Lastly, step 5 is *Long-Term Follow-Up* of the elbow flexion contracture with night splinting. Follow-up appointments will be scheduled for 6 months or earlier when a change in range of motion occurs or if orthotic revisions are needed to accommodate growth.

DISCUSSION

Serial casting and splinting is effective in improving elbow flexion contractures in children with obstetric brachial plexus palsy. Patient compliance is a significant factor in the success of maintaining treatment gains. Noncompliance with 1 or more therapy sessions resulted in loss of treatment effects. In this study, a loss of the treatment effect was experienced with noncompliance in splinting in as early as 2 weeks. In our experience, patients who did not comply with wearing their splint reported that they either forgot or chose not to wear their device. Some patients did not comply with splinting recommendations because they found the splint uncomfortable.

This study demonstrated that all patients were able to achieve improved extension with nonsurgical treatment up until the elbow contracture was reduced to its best passive range of motion. At this time, all elbow contractures were reduced to less than 30°, thus achieving the range of optimal function in elbow movement for daily activities.[8] Compliance and effectiveness of treatment were also best during this period. This is typically when the patient is having serial casting or splinting, and visible improvement in elbow extension is experienced progressively. However, maintaining this passive range of motion with night splinting was difficult. The period between best-achieved passive range of motion

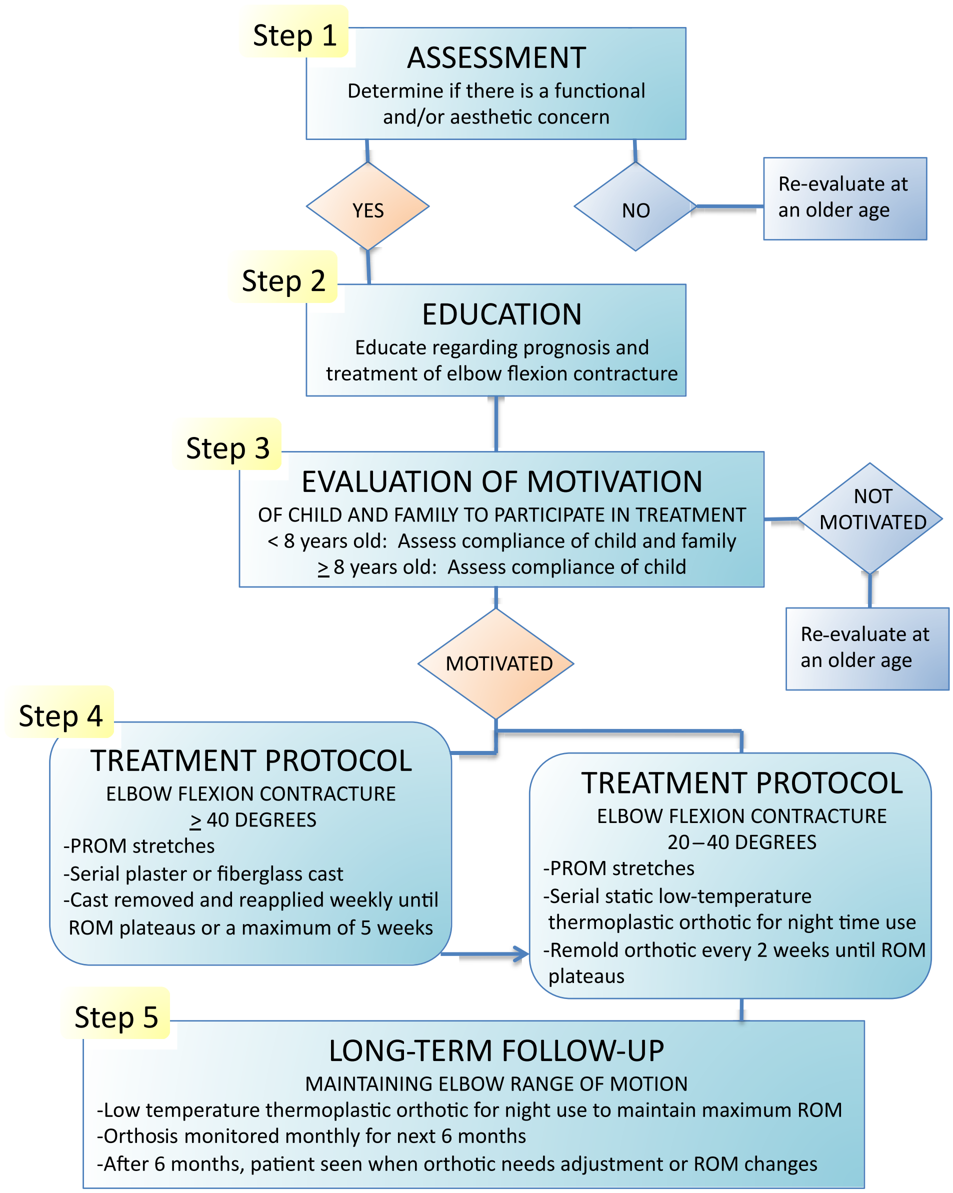

FIGURE 5: Clinical decision tree for elbow flexion contractures in obstetric brachial plexus palsy. PROM, passive range of motion.

and follow-up is when night splinting is introduced. This is where compliance waned.

Age at initiation of casting or splinting may contribute to the success of treatment. In this study, all patients younger than 8 years of age were noncompliant during 1 or more sessions of treatment. For children less than 8 years of age, it is often the motivation of the parents or caregivers that drives the decision to proceed with treatment. If the child is not motivated, compliance with wearing the cast or orthotic may be compromised. The family needs to be strongly committed to splinting to increase the likelihood of successful treatment in this younger population.

Children older than 8 years may be more intrinsically motivated to straighten their elbow for functional and cosmetic reasons. Contractures greater than 30° have a negative impact on optimal daily functioning.[8] The elbow joint is important in positioning the hand in space for hand function.[6] A unilateral elbow flexion contracture causes an asymmetry of hand position for reaching activities that require full arm length. This affects the quality of upper-extremity performance in daily activities such as overhead reaching for large objects and leisure activities such as playing sports and musical instruments. An elbow flexion contracture can also exaggerate further the limb length discrepancy that al-

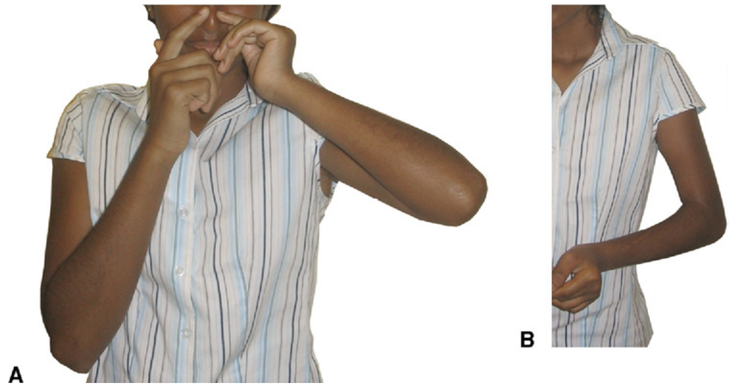

FIGURE 6: Trumpet sign. **A** Patient with left obstetric brachial plexus palsy demonstrating trumpet sign to illustrate the connection between shoulder range of motion and the position of the elbow. **B** The same patient with limb at resting position to illustrate elbow flexion contracture. This will assist with determining whether the child's discontent with the function and appearance of the limb originates at the elbow. The problem in this limb is primarily at the elbow.

ready exists from generalized hypoplasia of the limb and thereby limit function.[4,7] Irrespective of the degree of impairment, evaluation of function should consider if the elbow contracture affects the child's optimal performance in daily activities within their unique life situation. Cosmetically, the flexed position of the elbow may make the impairment in the arm more apparent (Fig. 1B). In this older age group, the child's happiness with the cosmetic appearance of their limb can be evaluated objectively using a 10-point scale or visual analog scale. In the presence of an internal rotation contracture of the shoulder, distinguishing whether the cosmetic concern originates at the shoulder or elbow is essential. This is best determined by physically asking the child to hold their unaffected elbow in the same degree of elbow flexion contracture as that of the affected arm. While looking in a mirror, the child is asked to take the unaffected limb, with the elbow held in flexion, through normal movement of their shoulder. The child and family should be asked to reflect on the function and cosmetic appearance of the limb with and without an internal rotation contracture of the shoulder with an elbow flexion contracture. Contrasting the effect of a shoulder internal rotation contracture during hand-to-mouth function should also be modeled to demonstrate the trumpet sign (Fig. 6).[11] An explanation regarding the connection between shoulder internal and external rotation range of motion and severity of trumpet sign is important to help the family understand how shoulder movement affects the position of the elbow.

The clinical decision tree (Fig. 5) was devised to improve patient selection and compliance with treatment. Education of the child and family is key to this algorithm. Care should also be taken to explain that maintaining the gains from treatment requires a lifelong commitment to wearing a night elbow extension orthotic. Families need to know that the imbalance between elbow flexor and extensor muscles will persist throughout the child's life because of the primary injury to the brachial plexus. Discontinuation of treatment will result in a recurrence of the elbow flexion contracture. Further, treatment is unlikely to result in complete resolution of the elbow flexion contracture. In this study population, the average best passive range of motion result demonstrated a residual contracture of 17°. Permanent skeletal and soft tissue changes in the elbow joint may contribute to the inability to fully straighten the contracture. Alteration in bone growth of the radius and ulna has been documented radiographically in this population.[12] Diagnostic imaging was not feasible in this study to investigate this further.

Complications can occur during nonsurgical treatment. Dislocation of the radial head may be a possible confounder. Reassessment of joint integrity is also important during stretching and splinting intervention. In this sample, radial head instability was detected early in the 1 patient. Magnetic resonance imaging of children with obstetric brachial plexus palsy with elbow flexion contractures has demonstrated pathology in the elbow joint including radial head dislocation and humeroradial joint subluxation that was not appreciated clinically.[3] The patient in our study may have had pre-existing pathology, and stretching the humeroradial joint into extension created more instability as the joint moved toward a loose-packed position. Treatment was modified for this patient to maintain passive range of motion and passive stretches, and serial modification of the orthosis was discontinued. The maximum elbow extension passive range of motion achieved through therapy prior to indications of instability was maintained with night splinting.

For children with severe contractures, elbow flexion should also be monitored closely. It has been our experience that aggressive gains in elbow extension may occasionally result in the loss of the same degree of elbow flexion range. In this situation, the intervention has only changed the arc of movement in the elbow joint. More importantly, loss of end-range of the elbow flexion will negatively impact function, such as hand-to-mouth activities. In this sample, 1 patient lost active elbow flexion after a session of casting. This patient discontinued casting and was given active elbow flexion exercises. Full active elbow range of motion and strength was recovered in 1 month. The patient continued treatment for the elbow flexion contracture using serial splinting in conjunction with active elbow flexion exercises. This was successful in improving the elbow flexion contracture and preventing reoccurrence of loss of active elbow flexion. Monitoring active elbow flexion range of motion throughout the treatment process is essential.

This study was retrospective in design and limited by the small sample size and data available for collection. The authors recognize that the findings of this study would have been enhanced if elbow extension active range of motion was evaluated, although it is our experience that clinically, gains in elbow extension passive range of motion correspond with gains in elbow extension in active range of motion in this population. The small sample size resulted in a wide range in the ages and treatment duration between patients and limited the ability to statistically analyze confounding factors. Studying patient-reported functional and cosmetic outcomes in daily activities is a recommendation for future studies.

Serial casting and splinting of elbow flexion contractures in children with obstetric brachial plexus palsy is effective in improving elbow range of motion. Compliance is the key factor in the long-term success of the treatment program. Because of the inevitability of recurrence of this impairment if splinting is discontinued, it is imperative that the child and family understand the long-term commitment needed to maintain the benefits of treatment.

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