Gillette Children's Specialty Healthcare

A PEDIATRIC Perspective

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Birth Brachial Plexus Injuries:

An Update on Evaluation and Treatment

by Marshall Taniguchi, M.D., Ann Van Heest, M.D., and Michael Partington, M.D.

Injuries of the brachial plexus take place during the birth process in one to four of every 1,000 births. The injuries are associated with:

- Large birth weight
- Shoulder dystocia (the shoulders become impacted while passing through the birth canal, injuring the brachial plexus nerves)
- A difficult delivery
- Fetal distress

Birth order and gender have not been shown to affect the incidence of brachial plexus injuries.

The most common injuries occur in the upper portion of the brachial plexus (that is, in the upper trunk which is supplied from the C5 and C6 roots of the spinal cord).

Assessing an Injury

Because a weak arm is a symptom of many conditions, a physician should be familiar with brachial plexus conditions when evaluating the newborn with a weak arm. The assessment will include a history (looking for birth trauma), a physical examination of the newborn, and possibly an X-ray to look for fractures.

If a physician determines that an injury to the brachial plexus (without any bone fractures) has occurred, a referral to initiate therapy is usually made. The therapist will commonly instruct parents in how to safely protect the arm and how to safely move the arm to maintain range of motion. The child should then be monitored through physical examinations to assess whether nerve function has returned.

At Gillette Children's Specialty Healthcare, occupational therapists use the Active Movement Scale (AMS) to measure nerve function each time patients visit the organization's Brachial Plexus Clinic. The AMS measures active movement of the baby's shoulder, elbow, forearm, wrist and fingers. Gillette staff measure 14 types of movements, with gravity both present and eliminated. The results help physicians and therapists understand which muscle groups are working properly and what types of treatment a patient might need.

Table 1: Treatments for Nerve Injuries

TYPE OF NERVE INJURY	TREATMENT
Root avulsion	Surgery not possible
Peripheral disruption	Surgical repair
Fascicle disruption	Surgical repair
Fascicle continuity	Possible surgical neurolysis
No disruption	Heals adequately without surgery

Natural History of Brachial Plexus Injuries

In a study (Waters, 1999), 80 to 90 percent of 66 patients with brachial plexus injuries (evaluated for the first time at 3 months or younger) experienced a spontaneous return of function. The children had a physical exam and functional assessment every month for six months. The researchers measured nerve recovery by noting when the patients achieved full ability to flex the elbow and bring the hand to the mouth while sitting up. The study found that:

- Infants who recover full elbow flexion before 1 month of age achieve normal ability and complete neurological return.
- Infants who recover full elbow flexion between 2 and 6 months of age have progressively more long-term neurological sequelae.
- Infants who do not achieve **full** elbow flexion by 6 months of age have permanent neurological impairment.

Because of this finding, if a child does not have full elbow function by 6 months, primary nerve surgery is recommended to try to improve nerve function.

Treatment: Infants

Throughout the first six months of life for an infant with a brachial plexus injury, therapy is the mainstay of treatment. Exercises are intended to:

- Maintain joint mobility
- Prevent contractures
- Provide sensory input for sensory stimulation

Continued on Page 2

All newborns with brachial plexus injuries should begin therapy as soon as possible. Babies can develop contractures — particularly in the shoulder — even at a very young age.

Therapy alone is usually sufficient for mild brachial plexus injuries. (See Table 1, Page 1.) Therapy also is a prerequisite for successful surgery, if surgery is necessary. That will help children maintain their joint mobility, so they can use their arm when nerve recovery occurs.

Patients who have experienced birth brachial plexus injuries should be seen once a month or once every six weeks during their first six months of life. Physicians and therapists need opportunities to provide close follow–up care, monitor nerve recovery and determine whether primary nerve surgery will be necessary.

Primary Nerve Surgery

If babies reach 6 months of age without experiencing return of the ability to fully flex the elbow (bringing the hand to the mouth while sitting), they might be candidates for primary nerve surgery.

The brachial plexus sits between the anterior and the middle scalene muscles. In primary nerve surgery, surgeons perform a brachial plexus exploration through a V-shaped incision with the infant under general anesthesia. Once the brachial plexus is identified, an EMG test is performed on the nerves to measure how well the nerves are functioning throughout the sections and branches of the brachial plexus.

Depending on the results of the brachial plexus exploration and intraoperative EMG testing, several surgical options exist: neurolysis, nerve repair, nerve graft or nerve transfer.

Neurolysis is performed when the nerve is in continuity but its flow is disrupted by excess scar tissue. During the procedure, surgeons release the scar tissue that is compressing the injured segment of the nerve. That allows improved conduction of the existing neural elements and a wider conduit for improved regeneration. The main advantage of neurolysis is that patients have minimal risk of losing any nerve function that they have already regained. If the nerve injury is more severe, surgical options might include a primary repair of the nerve using either a nerve graft or a nerve tube. Nerve transfers also might be an option, depending on a patient's injury pattern. If the injury is an avulsion at the spinal cord level, however, that portion of the nerve cannot be repaired.

Outcomes of Nerve Surgery

Gillette is conducting an ongoing study of children who had a complete disruption of the nerve or a significant block in their ability to conduct messages across the nerve. Children were treated with nerve repair using a nerve conduit tube.

The results showed an increase in AMS scores (scale 0-7) following surgery using NeuroGen tubes. (See Table 2, below.) The patients averaged 7.8 months of age at time of surgery and 24.7 months at their final follow-up appointments.

The major gains occurred in external shoulder rotation, elbow flexion and supination. Patients with a C7 nerve injury also experienced significant improvements in wrist extension. Such promising results are similar to the findings of other centers.

Table 2: Average AMS Scores

TYPE OF MOTION	BEFORE SURGERY	AFTER SURGERY
Shoulder Abduction	1.8	2.8
Shoulder Adduction	4.3	5.6
Shoulder Flexion	2.0	2.8
Shoulder External Rotation	0.3	1.1
Shoulder Internal Rotation	2.2	3.9
Elbow Flexion	0.7	2.8
Elbow Extension	6.0	5.2
Pronation	3.7	5.2
Supination	0.7	2.7
Wrist Flexion	5.6	5.9
Wrist Extension	3.0	4.4
Finger Flexion	6.2	5.9
Finger Extension	4.6	5.4
Thumb Flexion	6.0	6.4
Thumb Extension	3.9	5.4

N = 9

Treatment: 1- to 4-Year-Olds

Children who have not experienced full return of arm function need to be followed throughout their growth years. Children are usually monitored for nerve function using the AMS scale, physical examination of joints and movement, and possibly X-rays to monitor bone growth and shoulder development. During this period, several treatment options exist, depending on the extent of the birth brachial plexus injury. Nonsurgical options include rehabilitation, botulinum toxin injections, and constraint-induced movement therapy. If problems develop with shoulder movement and shoulder-joint development, secondary shoulder surgery can become necessary.

Rehabilitation Management
The goals of rehabilitation management for brachial plexus injuries are to:
- Prevent contractures, which can develop because of muscle imbalances
- Increase the child's awareness of the paretic limb
- Improve muscle strength
- Assist with normal development and function

Stretching is an important part of therapy for children with brachial plexus injuries. Because children with weakened arms caused by brachial plexus injuries can't stretch their muscles through everyday activity, passive range-of-motion stretching is often necessary.

Botulinum Toxin
To assist with stretching and to reduce contractures, injections of botulinum toxin might be recommended for the muscle groups that tend to be tight in children with brachial plexus injuries. Botulinum toxin inhibits the release of acetylcholine at the neuromuscular junction. Studies have shown reduced muscle contractures following such treatment (Basciani and Intiso, 2006).

Another study looked at botulinum toxin as an adjunct to motor learning therapy. The study followed eight children who, because of muscle imbalances, were unable to develop proper motor patterns and movement. The patients received injections of botulinum toxin to their triceps, pectoralis major and/or latissimus dorsi, in hopes that weakening stronger muscles would allow the other muscles to develop. The children in the study had all reached a plateau with their function, but they all improved their abilities following the injections. The decrease in muscle imbalance led to increased activity in reinnervated muscles (DeMatteo et al., 2006).

At Gillette, we have given botulinum toxin injections primarily to reduce contracture of the shoulder girdle. Those injections have resulted in an average of about 30 degrees of additional range in the patients. In addition to that improved range of motion and ease of stretching, families have noted that their children tolerate stretching better after the injections. About half of families reported improvements in function. Some patients have required repeated injections.

Constraint-Induced Movement Therapy
Children with brachial plexopathies usually explore using predominantly the uninvolved, or stronger, side. Constraint-induced movement therapy prevents patients from using their uninvolved side. Therapists restrain the patient's uninjured arm by casting it, encouraging use of the injured arm. While wearing the cast for four weeks, children are more likely to spontaneously use their affected side. Throughout the casting and at completion of the constraint therapy, physicians prescribe occupational and/or physical therapy so patients can continue working toward optimal use of the injured arm.

Shoulder Joint Management
Contractions in young children can lead to glenohumeral dysplasia of the shoulder joint. Treating the dysplasia might require interventions beyond range-of-motion stretching and botulinum toxin injections.

The glenoid is a shallow disc on which the humeral head rests, something like a golf ball sits on a golf tee. The shoulder muscles, ligaments and capsule are the glenoid's main stabilizers. The internal and external rotation forces across the shoulder must be equal to keep the "ball" in the center of the scapula.

The main problem in brachial plexopathy is muscle imbalance: too little external rotation and too much internal rotation. The external rotators are most susceptible to injury because injury to the suprascapular nerve branch is common in birth brachial plexus injuries. Because the suprascapular nerve has been injured with decreased reinnervation, the external rotators might be partially or fully paralyzed.

The natural sequelae of paralyzed external rotation and unbalanced rotation in the shoulder result in contracture, possible joint subluxation, and — if left untreated — possible shoulder dislocation. The humeral head can sublux or dislocate posteriorly. The glenoid becomes severely misshapen, so that the posterior edge does not develop normally, and the humeral head slides out the back. Plain radiographs, CT scans and ultrasound can help in evaluating the condition.

Secondary Tendon Transfer Surgery
If children are unable to reach their hand to their mouth, ear, or head, weak external rotation of the shoulder may be diagnosed. Furthermore, if radiographic evaluations show evidence of significant asymmetry and early glenohumeral dysplasia, patients should be evaluated with CT scans. In cases of weak external rotation, with glenohumeral dysplasia, secondary tendon transfer surgery might be necessary.

Surgery involves releasing or lengthening the tight muscles and augmenting the weak muscles. A release is done in the front of the shoulder, involving the pectoralis major and subscapularis muscles. Strengthening the weak muscles might include a latissimus dorsi and teres major tendon transfer. When the muscles that should rotate the arm outward cannot do so, it is often helpful to transfer a tendon to the shoulder to rebalance shoulder movement and improve shoulder joint development. The latissimus dorsi and the teres major muscles can be surgically transferred to

become external rotators, leaving the pectoralis major and the subscapularus as internal rotators. In this model, the idea is to promote more balanced bony secondary development by having a balanced muscular system.

CT scans have shown that the earlier the age at which the tendon transfers are done, the less the patient experiences secondary glenohumeral deformity. Without such surgery, a child's growth might hamper shoulder movement and development. At Gillette, we have shown that, if done properly, shoulder dislocations can remodel.

Glenohumeral deformities are repairable in some children. At a certain age, however, the joint can no longer remodel. In those cases, a derotational humeral osteotomy might be necessary. This type of surgery moves the arm from a fixed position of internal rotation and rotates it to a more externally rotated position, which is more functional for hand-to-mouth and hand-to-head activities.

A survey of shoulder reconstruction surgery results at Gillette showed improved active external rotation, hand-to-head functions and hand-to-mouth functions. Improvement in radiographic measures appeared primarily in younger age groups. Using a scale of 0-5 in muscle strength, before surgery no patients scored 4 or 5 in external rotation strength; 25 patients had a score of less than 2.

Postoperatively, the majority had external rotation strength of 4 to 5 (near normal), and active external rotation averaged 60 to 80 degrees. The operation has been very successful. It not only helps patients functionally, but it also helps the skeletal growth of the shoulder joint. Our recommendation regarding this surgery is: Do not wait until it is too late.

Summary

Brachial plexus injuries present a complex problem. The earlier patients experience the return of full flexion of the elbow, the better the prognosis. Exploration is indicated at 6 months if patients have not experienced return of elbow flexion with the ability to bring their hand to their mouth while sitting. At that point, primary nerve surgery is indicated. In the toddler, rehabilitation is continued if needed and is sometimes augmented with botulinum toxin injections or constraint therapy. If dysfunction persists, tendon transfers or bone/joint correction are successful in improving shoulder function in children who do not recover fully otherwise.

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Gillette's Brachial Plexus Clinic Marks 10 Years of Service

Orthopaedic surgeon Ann Van Heest, M.D., and neurosurgeon Michael Partington, M.D., established the Brachial Plexus Clinic at Gillette Children's Specialty Healthcare in 1999 to take advantage of the overlap between neurosurgery and orthopaedics in treating the condition.

Marshall Taniguchi, M.D., pediatric rehabilitation medicine specialist, joined the clinic three years later, adding additional expertise with electromyography (EMG) and botulinum toxin therapy. Other members of the team include occupational therapists, nurses and social workers.

"It's been a very nice team collaboration," says Van Heest, "because it allows the multi-specialties to see children simultaneously and to bring our areas of expertise together."

Gillette's Brachial Plexus Clinic has treated more than 1,200 children. Although the clinic focuses on birth injuries to the brachial plexus, Gillette also sees patients with other peripheral nerve problems, including nerve trauma, nerve tumors, and brachial plexus injuries to older children.

Gillette's is one of a small number of multidisciplinary clinics nationwide to concentrate on brachial plexus injuries. The clinic offers treatment options including rehabilitation management, botulinum toxin injection therapy, constraint-induced movement therapy, primary nerve repair and musculoskeletal reconstructive surgery.

Authors' PROFILES

Marshall Taniguchi, M.D.

Marshall Taniguchi, M.D., is a pediatric rehabilitation medicine physician at Gillette, where he sees patients with brain injuries, cerebral palsy, spina bifida, brachial plexus injuries and other conditions.

Taniguchi received his medical degree from the University of Michigan in Ann Arbor. He completed a residency in physical medicine and rehabilitation at the University of Wisconsin in Madison and a fellowship in pediatric rehabilitation at Denver Children's Hospital in Denver. He joined Gillette in 2002.

He is a member of the American Academy of Physical Medicine and Rehabilitation, the American Academy of Cerebral Palsy and Developmental Medicine, and the American Association of Electrodiagnostic Medicine. He is board-certified by the American Academy of Physical Medicine and Rehabilitation and by the American Board of Electrodiagnostic Medicine.

Ann Van Heest, M.D.

Ann Van Heest, M.D., is a pediatric orthopaedic surgeon at Gillette. She specializes in treating congenital and acquired upper-extremity conditions in children and has a special interest in upper-extremity problems related to neuromuscular disorders, such as arthrogryposis, cerebral palsy and spinal cord injuries.

Van Heest received her medical degree from the University of Minnesota, where she later completed an orthopaedic surgery residency. At Harvard University, she completed a fellowship in hand and upper-extremity disorders. She joined Gillette in 1993.

She is board-certified by the American Board of Orthopaedic Surgery, with a certificate of added qualifications in hand surgery. Her professional memberships include the American Academy of Orthopaedic Surgeons and the American Society for Surgery of the Hand.

Michael Partington, M.D.

Michael Partington, M.D., is a pediatric neurosurgeon at Gillette, where he sees patients with conditions including brachial plexus injuries and lesions, hydrocephalus, congenital quadriplegia, seizure disorders and spina bifida.

Partington graduated from the University of Minnesota Medical School and completed a residency in general surgery and neurosurgery at Mayo Graduate School in Rochester, Minn. He held a research fellowship and a clinical fellowship in pediatric neurosurgery at Children's Memorial Hospital in Chicago and has practiced at The Children's Hospital in Denver. He began practicing at Gillette in 1998.

His professional associations include the Congress of Neurological Surgeons, the American Association of Neurological Surgeons and the American Society of Pediatric Neurosurgeons.

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For more information, visit the Gillette Web site at www.gillettechildrens.org. Or contact Jason Kelecic at 651-312-3176 or jkelecic@gillettechildrens.com.

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