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Perspective: Early Sensorimotor Intervention in Neonatal Brachial Plexus Injury to Mitigate Developmental Apraxia

Eileen Graessle*

Senior Lead OT, Shriners Hospitals for Children, St. Louis, USA

***Corresponding author**: Eileen Graessle, Senior Lead OT, Shriners Hospitals for Children, 4400 Clayton Avenue, St. Louis, MO 63110, USA, Tel: 6366756899; E-mail: eigraessle@gmail.com

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Abstract

This perspective article expands on the home program described with use of a crawling orthosis to strengthen a neurologically impaired arm, including Neonatal Brachial Plexus Injury (NBPI), and provides support for an intent focus on providing sensory input to promote sensorimotor mapping of the arm to increase motor output. Research with animals demonstrates impaired motor control of a forelimb with early sensory deprivation postnatally, even with reversal of the impairment, leading one to conclude the lack of development of early motor patterns including the limb impairs future motor control of the limb. This phenomenon has also been found in children post NBPI, demonstrating an inability to recruit motor units available in the affected arm, termed developmental apraxia. The implications support a proposal that a therapeutic program heavy in sensory input post NBPI has the potential to increase motor control of the affected arm by taking advantage of the nervous system plasticity and the developmental window for establishing motor planning, through detailed sensory mapping of the arm during this critical period.

Keywords: Developmental apraxia; Neonatal brachial plexus injury; Sensorimotor intervention; Pediatric motor development; Pediatric neuroplasticity

Introduction

Unresolved Neonatal Brachial Plexus Injury (NBPI) can lead to a number of functional limitations as a child ages [1]. With therapy and surgery post birth trauma to the brachial plexus between cervical level five and thoracic level one, weakness through the effected arm may remain, leading to shoulder deformities, limitations in range of motion in multiple joints, and coordination impairments [2-4].

Bimanual activities are a challenge, with the dysfunction beginning early with the inability to meet milestones for prone positions and rolling, passing a toy between the hands, or bilateral reaching. The same lack of motor experience also deprives the arm of sensory input essential to advancing functional use of the arm [5,6]. Both the sensory and motor cortexes lack sufficient information for effective initiative and feedback loops for mapping of the weak limb to engage it in motor activity and challenges [7]. The entire arm and corresponding upper quadrant of the body may be ignored completely, causing a profound dearth of sensorimotor input.

Evolving Therapeutic Intervention and Sensorimotor Mapping

Current focus in therapeutic intervention post NBPI is in supporting return of nerve function, advancing developmental motor skills and milestones, providing sensory opportunities, as well as preventing joint deformities and muscle contractures which increase resistance to motion [4,8]. Clinical intervention and instruction for home include passive range of motion of every joint, with emphasis on external rotation, most frequently limited in a shoulder with NBPI, restricting the ability to move the arm into positions of function away from the body and contributing to shoulder joint deformity [2,9]. Home programs include positioning the child and arm in developmentally appropriate positions, such as hands on a toy at midline, hands to mouth, and involving the arm in gross motor challenges with active motion. An orthosis may be indicated to stabilize distal joints of the arm by decreasing degrees of freedom of motion, for weight bearing to maxime proprioceptive input, and increase sensory opportunities for the arm [1,10].

Perhaps the greatest problems with functional use of the arm are apparent after the first three years, when daily activities involve more complex motor actions that the arm cannot perform. One root cause may be contractures or active insufficiency from progressive loss of range of motion. However, another factor is that children with unresolved NBPI may exhibit developmental apraxia, a weakness and clumsiness of the affected arm with inability to recruit the motor units available [5,11-15]. This apraxia is attributed to a lack of development of motor patterns using the arm during a critical window of brain development postnatally. Studies on kittens depriving the brain of the sensory input of a forelimb in the early postnatal period demonstrate impaired motor control post removal of the neural blockade [16-20]. Skilled motor motions similar to the unaffected side did not develop.

Initially the proximal arm joints, the shoulder and elbow, are sparsely represented in the primary motor cortex (M1) in studies of young animals, with expansion of these areas and new representation to include more distal joints [21]. However, M1 does not necessarily represent delineated individual muscles or joints, but rather may represent a mosaic of muscles, postures, complex and bimanual movements, and kinetic and dynamic parameters of voluntary movement [22]. During the first two years of life, experience and environmental enrichment determine synaptic reinforcement or elimination, which target end plates are established, and development of the brain circuits [23]. This developing nervous system in children is more vulnerable to sensory deprivation than adults, and without activity-based therapy, a disadvantaged corticospinal system may be unable to catch up or regain lost connections and function after sensory deprivation of a limb [16,24].

Activity and experience-dependent mechanisms during the initial development of the corticospinal system assure that neural events at the time of motor circuit formation are intended to be a basis for later function of mature patterns [16]. Cortical representations are continuously modified by experience and representation is allocated to input sources which are proportionally most used and behaviorally important [25]. Somatosensory regions adjacent to the deprived cortex region expand at the expense of region designated for the weaker extremity [22]. Thus expanding the weak arm in the somatosensory cortex becomes a primary concern and focus with intervention in NBPI. Corticospinal plasticity can be tapped for a robust effect and functional gains in the first two years of life during high apoptosis and central nervous system remodeling [16].

Concentrated Sensorimotor Intervention

Thus, a priority in early intervention may be in maximizing sensory input to the extremity for sensory-motor mapping of the arm as a working model for motor control and M1 mapping through feedback loops [6,7]. Active motion is superior to passive motion for motor mapping and has the benefit of triggering mechanoreceptors in joints, muscles and skin when combined with weight bearing through the weak arm [26]. Proprioceptive training is associated with cortical reorganization, especially with longer lasting interventions, supporting use in improving motor function [7,26]. Adding visual guidance enhances success in constructing motor patterns for reach and grasp [5,26].

Therapeutic intervention can be designed to provide sensory information most relevant to the brain's predisposition to attend to specific input, and expand neurological connections within the framework of developmental progression. This strategy includes a baby's inherent motivation to move the body and extremities to secure an object of interest, and gain control over the environment while expanding on self-knowledge of the complex body which achieves these intrinsic goals. Tapping into the child's motivations to play, reach, and explore contributes to cognitive advancement [27] and perception of the body essential to placing the arm in the right place at the right time, instead of learning motor patterns to bypass its use. During this period of development of automatic motor actions, patterns are established for how to shift weight, roll, reach and crawl that may leave the weak arm out completely in the process of adaptation for most efficient and rapid goal attainment. This tendency to bypass involvement of the arm in basic motor patterns for rapid and effective goal attainment is linked with developmental apraxia.

Pediatric therapy is task-specific, meaningful and individualized to the child, with the environment arranged for successful completion [28,29]. Intrinsic feedback is generated through the brain's interpretation of sensory, visual, and auditory experiences, sometimes augmented with auditory feedback and the bare minimum of manual guidance to maximize learning [29]. Achieving involvement of the affected arm in crawling is a highly valuable experience which provides sensory input repeatedly throughout the day while promoting symmetric and asymmetric core and extremity strengthening [27,30,31]. Additional strategies with high potential to increase sensory awareness, muscle strength, and motor control through distributions of intact brachial plexus nerves include those in Table 1.

Type of Stimulation	Suggestions
Skin stimulation to activate receptors.	· Hand to mouth
	· Hand to hand
	· Kisses to arm from caregiver, have child try to hold arm out for kisses or attention
	· Toys with texture pressed into hand or rolled over the arm
	· Brushing the skin with large bristle paintbrush to "paint" the arm
	· Water play washing hands, toys with texture, with weight bearing through elbow or forearm of affected arm
Providing visual input of the arm in action. (Especially important if the child tends to avoid play on the affected side or midline, or does not seem to recognize the arm or upper quadrant as part of their body.)	· Assisted symmetric and asymmetric motions with play in front of a large mirror
	· Help position the arm in bimanual tasks with assist disguised or hidden so the brain "sees" the arm working
	· Choosing many different bimanual tasks to show use of the weak arm in different contexts: stabilizing containers, holding a bubble bottle for other hand, holding a container against arm and body
	· Place stickers all along the arm and call child's attention to them (as appropriate)
Proprioceptive input through inclusion of arm. Use in gross motor transitions with minimal support to control some of the degrees of freedom in the arm.	· Propping on the arm during play and reaching
	· Propping on elbow or forearm to transition to sitting or during rolling
	· Propping on arm to reach outside base of support in sitting
	· Position arm and provide support during attempts to crawl or climb over surfaces, people, stairs or the floor
Proprioceptive play/activites	· Banging a drum with symmetric and asymmetric motions
	· Clapping hands together with song
	· Rubbing weak hand over body or opposite extremity with light pressure added
	· Holding weak hand on the bottle with light pressure, as well as unaffected
	· Tap together toys small enough to fit in each hand using a rhythm

	· Flex and extend thumb interphalangeal joint repeatedly while drawing child's attention to thumb with play or singing

Table 1: Somatosensory stimulation ideas for an arm with weakness due to NBPI.

High sensory stimulation to promote somatosensory mapping follows a predictable course toward motor output, from being unaware of the sensory input, being annoyed at stimulation that draws attention to their unrecognized arm, acceptance and interest in the arm with attempts to include it passively, and active inclusion with gains in strength. Note sometimes the child may start biting the hand or arm, and this therapist has worked with caregivers on providing a substitute sensory stimulation to train, such as a textured ball, brushing with a chunky paintbrush, or other safe alternative.

Conclusion

The key to mitigating developmental apraxia is therapeutic intervention designed to include the weak arm in as many automatic motions as possible in the first months of life, when motor patterns for the body are configuring and refining based on sensory input and motor learning. Some patterns remain relevant and self-reinforcing throughout childhood, such as using both arms in prone and crawling, using an arm to prop while the other reaches, and stabilizing an object for the other hand to use. These patterns form a motor base for engagement in more complicated daily activities which propel and motivate the child as they age and develop. Early therapeutic intervention with a strong sensorimotor home program for caregivers may facilitate progressive voluntary motor pattern options, and skill refinement of the neurologically impaired arm in bimanual and gross motor foundations.

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