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Evaluation of pediatric upper extremity peripheral nerve injuries

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ABSTRACT

Introduction: The evaluation of motor and sensory function of the upper extremity after a peripheral nerve injury is critical to diagnose the location and extent of nerve injury as well as document functional recovery in children.
Purpose: The purpose of this paper is to describe an approach to the evaluation of the pediatric upper extremity peripheral nerve injuries through a critical review of currently used tests of sensory and motor function.
Methods: Outcome studies on pediatric upper extremity peripheral nerve injuries in the Medline database were reviewed.
Results: The evaluation of the outcome in children less than 10 years of age with an upper extremity peripheral nerve injury includes careful observation of preferred prehension patterns, examination of muscle atrophy and sudomotor function, provocative tests, manual muscle testing and tests of sensory threshold and tactile gnosis.
Conclusion: The evaluation of outcome in children with upper extremity peripheral nerve injuries warrants a unique approach.

Peripheral nerve injuries in children

Peripheral nerve injuries in children are most commonly seen from lacerations to the upper extremity from glass or sharp objects.[1–5] Traumatic injury may also occur in conjunction with fractures and dislocations.[1] This association is often found with supracondylar fractures where neurapraxia occurs in 11% of those injured.[6]

Evaluation of motor and sensory function of the upper extremity after a peripheral nerve injury is critical to diagnose the location and extent of nerve injury as well as documenting functional recovery.[7] The literature is decorated with discussion and debate over the optimal battery of sensory and motor tests for adults with peripheral nerve injuries.[7–10] The same attention has not been given to the systematic evaluation of the upper extremity in children with peripheral nerve injuries.

Age related factor in peripheral nerve recovery

The well-documented age related effect on nerve recovery has inadvertently drawn interest away from outcomes research in children with upper extremity peripheral nerve injuries. Multiple studies have reported that younger patients have better sensory and motor outcomes after complete transection and repair of the median and/or ulnar nerves.[5,11–18] There are several cited reasons for this remarkable recovery in children.[16,19] Objectively, the axons in the upper extremity of children have a relatively shorter distance to grow to reach the distal end target. This may contribute to better outcomes.[16,19] However, it was Almquist et al[20] that conducted the landmark study that highlighted how central plasticity plays a significant role in sensory functional recovery after nerve injuries. This study demonstrated in monkeys that axonal count and conduction velocity did not differ between nerves repaired in infancy and adulthood.[20] Lundborg and Rosen[21] provided clinical evidence of this central plasticity theory in patients with peripheral nerve injuries. Their study found that the rapid decline in tactile gnosis function in patients over 10 years of age with median and/or ulnar nerve injuries was analogous to the learning process experienced in the acquisition of a second language.[21] Anand and Birch also reported the remarkable sensory recovery in children with obstetrical brachial plexus palsy after surgical grafting of the distal roots from avulsed spinal roots of the lower trunk in infancy.[22] This was a stark contrast to adults with similar injuries who not only had poor sensory outcome, but significant debilitating pain that interfered

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with sensory response with root avulsions.[23] Therefore, central nervous system plasticity is a major contribution to nerve recovery in children.

It is important to recognize that despite better outcomes, children with peripheral nerve injuries do not evade permanent impairments in the upper extremity.[3,4,24–28] Current microsurgical nerve repair techniques cannot completely restore function. However, our understanding of these deficits is limited due to the paucity and lack of rigor in current pediatric studies. Outcomes in children are often reported as a subgroup of larger study involving adults.[5,12–15,17,18,21,29,30] Typically, the pediatric patients make a small portion of the sample evaluated and isolated outcomes of these younger patients are not reported. A few pediatric studies have been published, but most have small sample sizes (range: 7–27).[3,4,25,26,28] Atherton et al published the largest series ($n = 49$) of children with nerve injuries.[24] However, 33 of the 49 children studied had digital nerve injuries. The remainder had median, ulnar or radial nerve injuries. Further, these pediatric studies include samples of children from infancy to teenage years (range: 1–18 years). Again, Lundborg and Rosen's findings emphasized the need to distinguish the outcomes of children younger and older than 10 years of age.[21] Current studies have not provided such comparisons. Lastly, there is a myriad of tests used to report sensory and motor functional outcome in children with peripheral nerve injuries.[3,4,24–26,28] A consolidated systematic approach to evaluation facilitates comparative outcomes in this rare and understudied population. The purpose of this paper is to describe an approach to the evaluation of the upper extremity peripheral nerve injuries in children through a critical review of currently used tests of sensory and motor function.

Review of the literature: tests of sensory and motor function

The literature was reviewed for measures of sensory and motor tests used to measure outcomes in pediatric upper extremity peripheral nerve injuries using the Medline database between 1946 and week 3 of March 2014. Using Lundborg and Rosen's[8] model instrument for the documentation of outcomes after nerve injury as a framework, only studies with outcomes after transaction and repair of median and/or ulnar nerve injuries were retained. Reference lists of combined adult outcome studies were included to widen the search. Eight studies were found with samples including pediatric cases of upper extremity peripheral nerve injuries and repair. A summary of the patient characteristics and the measures of sensory and motor outcome reported is reported in Table 1.

The critical appraisal of a measurement tool includes an evaluation of the common sense aspects of the tool, reliability, validity and responsiveness.[32,33] A second search strategy was conducted to find studies of measurement properties of the outcome measures found in the first search strategy. The measurement properties searched for included reliability, validity and responsiveness.[32] Evaluation of reliability examines whether that test is consistent in producing the same results and is free of error.[34] Most typically, measures are evaluated for its internal consistency, inter-rater, intra-rater and test retest reliability.[34] It is important that sensory tests are reliable to aid in the diagnosis of the location and extent of nerve injury as well as to allow for the comparison of outcomes over time. Evaluation of validity examines the extent to which a test accurately evaluates what it purports to measure.[35] Therefore, a test of sensory function is valid if it demonstrates the ability to measure the type of sensory function it claims to measure. The comparison of one or more tests that measure the same aspect of sensory function is an appropriate application of concurrent validity to demonstrate the test's construct validity.[32] Lastly, responsiveness considers a test's ability to measure change when it has occurred within the population of interest.[36] It is important that a tool's measurement properties are evaluated in the context of the specific target population. Thus, the measurement review focused on children with upper extremity peripheral nerve injuries. Again, reference lists were examined to expand the search. Six studies of measurement properties were found that included pediatric cases. Two studies of normative values in pediatrics were also found and are included in this review. A summary of these studies is found in Table 2. The above review of the literature establishes a comprehensive list of sensory and motor tests of the upper extremity after peripheral nerve injury and their respective measurement properties that provide the foundation for the clinical pearls recommended in the following section.

Evaluation of upper extremity peripheral nerve function in children

There is general evidence that children greater than 6 years of age have the ability to complete the tests of sensory and motor function applied to adults with peripheral nerve injuries.[26,37,39] The ability to comply and understand the assessment procedure is critical to obtain a reliable result. However, this should not lead to the assumption that an adult model should be applied if a child is competent. The approach to evaluation and choice of measures used in children should best capture the sensory and motor outcomes specific to this population. This divergence in outcomes occurs at 10 years of age.[21] The following is an approach to the evaluation of the upper extremity function in children less than 10 years of age who sustain upper extremity peripheral nerve injuries.

The first and most important step in the evaluation of a pediatric patient is careful observation of the child's spontaneous use of the affected upper extremity.[19] Observation of how the child integrates the affected hand into activities, the preferred prehension patterns, and the general posture and appearance of the hand provide key information regarding nerve impairment.[43] Young children typically use the available hand function to spontaneously manipulate toys bimanually. Therefore, the introduction of toys allows bilateral hand function to be observed and increases the likelihood of a successful evaluation. Observation of avoidance patterns can also be made. Key posture and prehension patterns often observed with peripheral nerve injuries are outlined in Table 3. The observational assessment should also include an examination of muscle atrophy and sudomotor function,[43] (Table 3) and include a comparison of the affected and unaffected hands. Absent sudomotor function is characterized by dry and smooth finger pulps in the affected digits. Children are typically compliant with anatomical clinical examination, however a small sticker in the palm may provide an incentive for the child to keep their hands open for the evaluation.

A provocative test such as the Tinel's sign is an important indicator of nerve compression and recovery.[7,44] The Tinel's sign may be used with children, but recommended at the end of the testing session. The intrusive nature of this test may end the evaluation prematurely. A Tinel's sign is conducted by applying 4 to 6 digital taps over the entrapment site (Table 3). It is recommended to evaluate the most distal entrapment sites first and progress proximally as stimulating the proximal site may provoke distal symptoms.[7] For evaluation of nerve recovery, gentle sequential tapping distally from the site of injury can provide information regarding the progression of nerve recovery towards the target end point. A positive Tinel's sign will elicit a tingling sensation. In children, it is important to provide qualitative descriptors of the sensation expected. Words such as 'lightning bolts', 'pins and needles', 'shocks', and 'feeling when your foot wakes up from falling asleep' are helpful. It is also helpful to ask the child to use their