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SNI: Pediatric Neurosurgery

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Case Report

The use of ultrasound-guided imaging to localize peripheral nerve injury in pediatric patients: A case report

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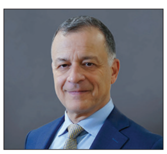

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Received: 14 July 2024
Accepted: 30 August 2024
Published: 27 September 2024

DOI
10.25259/SNI_580_2024

Videos available on:
https://doi.org/10.25259/SNI_580_2024

Quick Response Code:

ABSTRACT

Background: The use of ultrasonography to diagnose and manage peripheral nerve injury is not routinely performed, but is an advantageous alternative to magnetic resonance imaging (MRI) in the pediatric population.

Case Description: The authors report a case of a toddler-aged female who sustained a supracondylar fracture and subsequent median and ulnar nerve injuries. All preoperative and postoperative imaging was performed through high-resolution ultrasound as opposed to MRI. Starting at 6 months post-nerve repair and with 18 months of follow-up, the patient exhibited substantial improvement in motor strength and sensory function. This case demonstrated a successful outcome while providing an imaging alternative that is portable, relatively low-cost, lacks ionizing radiation, provides additional information on vascular integrity, and obviates the need for general anesthetic such as MRI.

Conclusion: The authors conclude that the use of ultrasonography to diagnose and manage traumatic peripheral nerve injury is advantageous, particularly in the pediatric population.

Keywords: Median nerve, Pediatrics, Peripheral nerve, Ulnar nerve, Ultrasounds

INTRODUCTION

Peripheral nerve injuries can cause severe impairment and disrupt regular activities of daily living in patients. Including brachial and lumbar plexus injuries, the global prevalence of peripheral nerve injuries is 5% and can present acutely as a result of a trauma or chronically due to issues such as overstretching.[10,15] A study by Aman *et al*. described that 5.7% of patients who presented to their level 1 trauma center from 2012 to 2021 with peripheral nerve injury were pediatric patients.[1] Of those pediatric patients, the most common lesions were found in digital nerves, followed by the median nerve and ulnar nerve.[1] Missios *et al*. analyzed 245,470 pediatric patients with peripheral nerve lesions from 2009 to 2011 and observed that most peripheral nerve injuries were caused by falls (n = 126,832) and motor vehicle accidents (n = 50,211).[13] Traumatic peripheral nerve injury is a frequent issue in the pediatric population and can lead to significant morbidity and mortality.[4] As a result, it is important to identify safe and efficacious methods of management to produce optimal outcomes.

Advanced imaging modalities such as computerized axial tomography (CT) scans and magnetic resonance imaging (MRI)-neurography are indicated in the management of various musculoskeletal pathologies; however, alternative imaging methods exist and are under-utilized. Advancements in high-resolution ultrasound have proven to be advantageous in the diagnosis and management of traumatic peripheral nerve injury in pediatrics.[9,22] It also provides the ability for clinicians to assess the extent of injury dynamically and gives valuable information about nerve integrity and the flow of nearby vessels.[11] While ultrasound is sometimes used in the management of adult peripheral nerve injury, there is limited literature documenting the efficacy of this technique in the pediatric population. The purpose of this report is to describe the role and benefits of high-resolution ultrasound when managing pediatric peripheral nerve injury, as demonstrated by a case. Informed consent was obtained before publication.

CASE PRESENTATION

A 4-year-old female was diagnosed with a left supracondylar fracture after falling from a bouncy castle. The diagnosis was made at an outside hospital, and at that time, the patient underwent a closed reduction and percutaneous pinning of the left supracondylar fracture. The patient's cast and pins were removed 1 month later, and it was noted that she was experiencing left hand weakness with associated claw deformity. Nerve conduction studies showed absent potentials on the left median nerve and left ulnar nerve, and she subsequently presented to the outpatient clinic for evaluation of her left upper extremity weakness.

Performing an adequate neurological physical examination to assess for peripheral nerve damage is difficult in any patient population but is especially challenging in the pediatric setting. Factors that contribute to its difficulty in pediatric patients include their low attention span, difficulty understanding cues and commands, increased irritability, and disinterest. Peripheral nerve injury is largely a clinical diagnosis, so it is imperative to conduct an effective and accurate physical exam. In the patient's initial neurological examination, the right upper extremity demonstrated 5/5 strength throughout, which provided a reliable baseline. Her left upper extremity motor strength examination showed 5/5 deltoid, 5/5 triceps, 5/5 biceps, 2/5 handgrip, 2/5 interosseous, 0/5 wrist flexion, 0/5 wrist extension, 4/5 thumb flexion, and 4/5 finger extensors. She displayed mild swelling of her left fingers with appropriate capillary refill and denied tenderness to the affected limb. The authors also noted the difference between the strength of wrist extension versus finger extension. The radial nerve controls these movements; there was no evidence of damage on surgical exploration and no complaints signaling radial nerve injury. The authors postulate that the wrist extension strength test findings that were documented could be due to local injury to the wrist and surrounding tissue. Physical examination findings suggested potential ulnar and median nerve injuries [Video 1]. This video demonstrates an effective way to elicit important physical examination findings in children while maintaining interest and engagement.

A preoperative ultrasound of the left upper extremity was conducted 9 weeks post-injury to rule out ulnar nerve, median nerve, and/or radial nerve injury. The impression of the preoperative ultrasound was as follows: chronic fracture of the left distal humerus with extensive soft-tissue scarring, mild focal hypoechoic echotexture of the left ulnar nerve, complete discontinuity and scar encasement of the left median nerve at the level of the distal humerus deformity [Figure 1], and complete thrombosis, interruption, and scarring encasement of the left brachial artery with diminished blood flow extending from the left forearm to the left hand [Figure 2]. There was adequate perfusion of the ulnar and radial arteries noted distally, as well as intrinsic changes of the left ulnar and radial nerves. The deformity

Video 1: Preoperative physical exam of a pediatric patient with left upper extremity weakness after a supracondylar fracture. Physical examination demonstrates impairment in wrist extension, wrist flexion, and fourth- and fifth-digit extension. Findings favored injury of the left median and ulnar nerves.

elicited by the left distal humerus fracture onto the median nerve measured up to 1.3 cm in length and the deformity of the brachial artery measured up to 2.6 cm in craniocaudal length. The decision to solely use ultrasound as opposed to MRI was made because this 4-year-old patient would have required general anesthetic in an MRI, and ultrasound successfully provided all of the necessary information, such as the extent of injury and vascular flow data.

The patient's surgical procedure was performed 12 weeks following her initial injury. Preoperative planning was performed through ultrasound guidance in an interdisciplinary fashion, with neurological surgery and vascular surgery immediately before the operation. The procedure began with an exploration of the left ulnar nerve at the antecubital fossa. Neurolysis of the left ulnar nerve was performed, and the nerve was in continuity. The left median nerve was then identified. The patient was found to have direct penetration and injury of the median nerve secondary to a fracture of the distal humerus [Figure 3a]. Manual exploration was then performed by following the ulnar nerve around the cubital tunnel and into the flexor carpi ulnaris and the median nerve into the distal left forearm to assess for further injury and deformity [Figure 3b]. Intraoperative nerve action potentials and stimulation at 10 milliamps recorded no response at the area of the severely compressed median nerve. The left median nerve neuroma was identified, and excision was performed [Figure 3c]. Primary anastomosis of the median nerve was achieved by suturing the epineurium under the magnification of the operating microscope [Figure 3d]. Throughout the operation, the patient received frequent intraoperative nerve stimulation. A left arm spica cast was placed at the conclusion of the procedure to prevent elbow flexion and extension. There were no complications. The patient's postoperative diagnoses were left median and ulnar nerve injuries status-post distal humeral fracture pinning and possible vascular injury. A biopsy of the neuroma was obtained, and histopathology showed disorganization of the left median nerve, consistent

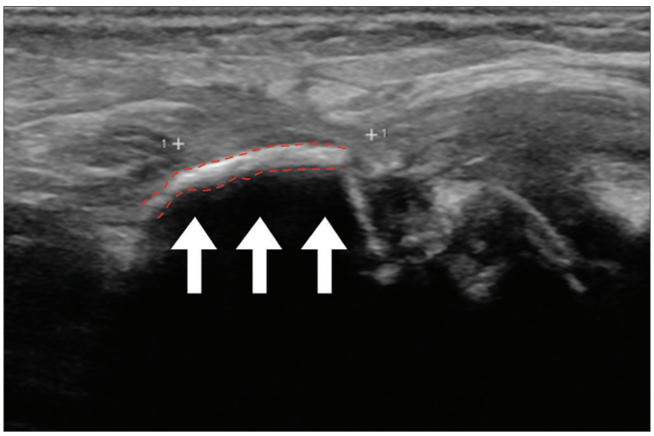

Figure 1: Sagittal high-resonance ultrasound view of the left antecubital fossa showing displacement of the distal humerus (arrows) onto the median nerve (yellow) with extensive soft-tissue scarring. The median nerve deformity was measured to be 1.3 cm in craniocaudal length, respectively.

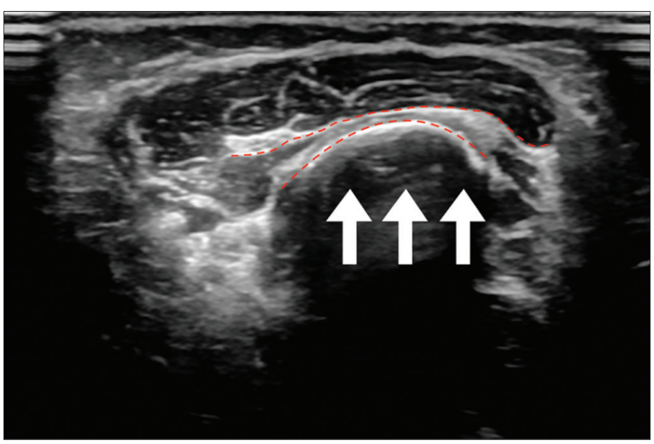

Figure 2: Sagittal high-resonance ultrasound view of the left antecubital fossa showing displacement of the distal humerus (arrows) onto the brachial artery (red) with extensive soft-tissue scarring. The brachial artery deformity measured to be 2.6 cm in craniocaudal length.

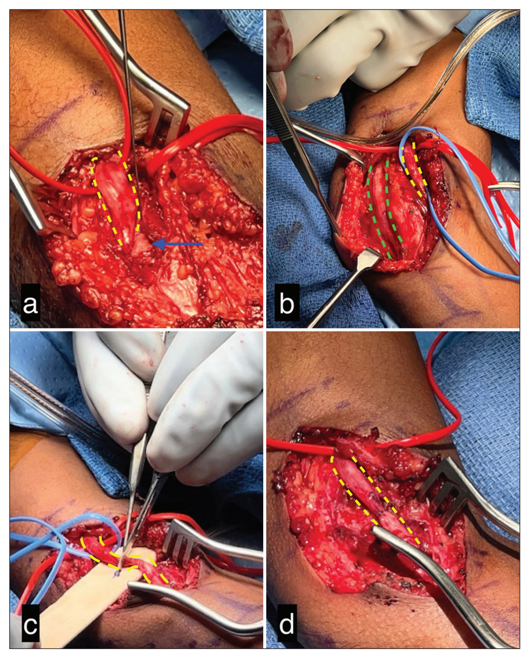

Figure 3: Intraoperative image sequence. (a) Depicts severe compression of the left median nerve (yellow) by the distal humerus bone fragment (blue arrow) on initial intraoperative assessment. (b) Decompression and exploration of the left median (yellow) and ulnar (green) nerves in the cubital tunnel to assess for injury. (c) Excision of the left median nerve (yellow) neuroma status-post decompression from bone fragment. (d) Suture of the left median nerve (yellow) to perform primary coaptation.

with traumatic neuroma. A bedside follow-up ultrasound was performed postoperatively after coaptation to visualize the repair and to ensure that no surgical complications were present.

After 3 weeks, the patient returned to the clinic for cast removal. Physical examination revealed hypersensitivity to touch at the incision site and along the distribution of the left ulnar nerve, no intrinsic muscle function, left long finger flexor tightness, decreased active flexion of the left thumb and index finger, and mild weakness of wrist extensors. She was subsequently fitted for two left forearm-based orthoses to promote functional positioning and prevent contractures. Six months postoperatively, the patient demonstrated noticeable improvements in wrist strength, hand grip, and pincer grasp. She regained the ability to perform a pincer grasp with her left hand, which was exhibited by fastening buttons. Improved grip strength and wrist movement were also noted, as she was able to brush her teeth with minimal difficulty. At 18 months postoperatively, the patient has regained most of her strength and ability to perform most tasks. Mild sensory impairment is present, as she occasionally experiences intermittent numbness and tingling that radiates from her left hand to her left forearm.

DISCUSSION

In this article, we describe a case of a 4-year-old patient who was seen initially for a left supracondylar fracture but was then found to have accompanying left medial and ulnar nerve lesions leading to profound weakness of her left upper extremity. Preoperative high-resolution ultrasonography was performed 9 weeks post-injury in combination with neurophysiologic studies (i.e., nerve stimulation and action potential generation) to explore the extent of peripheral nerve damage. It was found that this patient had experienced left median and ulnar nerve damage. Twelve weeks post-injury, surgical repair of the left median and ulnar nerves was performed. At 6- and 18-month follow-up, the patient had significant improvement in wrist strength and hand grip.

Trauma is the most common cause of pediatric mononeuropathy, and many of these injuries result in neuroma formation.[3] The majority of these traumatic neuropathies require surgical intervention.[15] In 1988, Fornage first described the use of ultrasound in diagnosing peripheral nerve injury.[8] Since then, there have been multiple reports of successfully using ultrasound as the sole imaging modality in pediatric peripheral nerve injury.[7,11,12] As described in this case, the authors were able to utilize high-resonance ultrasonography to accurately diagnose and manage median and ulnar nerve injuries in a pediatric patient following a traumatic injury. Ultrasound can detect anatomic variations in the fascicles, perineurium, epineurium, and surrounding soft tissue.[21] Classically, MRI has been used to study structural abnormalities in peripheral nerves.[18] However, ultrasound has proven to be a dynamic diagnostic tool for grading and mapping peripheral nerve injury and is furthermore complementary to electromyography and nerve conduction studies.[17] Clinicians can follow the anatomical course of a nerve with the aid of ultrasound and can determine the segment length of nerve injury.[11] A study by Zaidman *et al*., evaluated nerve pathology in 53 patients who had imaging done by both MRI and ultrasound and showed that ultrasound was more sensitive than MRI (93% vs. 67%) and had an equivalent specificity (86%).[24] The authors concluded that ultrasound better identifies suspected peripheral nerve lesions and is, therefore, the preferred imaging modality for such pathology.[24] Similarly, a study by Nischal *et al*. found that the confidence level (as determined by their methods) for detecting nerve discontinuity and change in nerve caliber was higher for ultrasound compared to that of an MRI (100% vs. 70% and 100% vs. 50%, respectively).[14] They also demonstrated that submillimeter caliber nerve pathology could be accurately detected by ultrasound but could not by MRI.[14] Furthermore, these studies demonstrate that ultrasound is a useful first-line imaging modality for peripheral nerve pathology.

Ultrasound also allows for qualitative analysis of tissues using color elastography. This modality showcases the relative difference in tissue stiffness, with a red color representing increased tissue stiffness and a blue color representing decreased tissue stiffness.[19,22] The ultrasound can also give information on damage to arteries and veins, including flow characteristics. The use of preoperative ultrasound has proven to be useful in localizing the direct site of injury, visualizing proximal and distal nerve stumps, and determining the extent of nerve swelling.[2] When used in combination with neurophysiologic studies, a more comprehensive picture of the extent of injury can be established.[16] The ability to detect these pathologic changes qualitatively allows for improved therapeutic interventions, surgical planning, and readjustments. Postoperative ultrasound also grants the ability to evaluate anatomic changes immediately following surgical intervention. This allows for rapid detection of potential intraoperative complications, thus minimizing delay in care.[16] Additional benefits include the widespread availability of ultrasound, portability, short procedure time, and the ability to repeat follow-up studies without significant risks easily.[20]

Historically, MRI has been the imaging modality of choice when diagnosing potential peripheral nerve lesions. However, in the pediatric setting, there are instances during which the use of MRI to evaluate the extent of peripheral nerve damage is potentially contraindicated. Examples include acute-phase multi-trauma, the presence of cardiac pacemakers and neurostimulators, and neonatal age and renal injury if contrast must be used.[6,23] Therefore, it is important to report on cases that use ultrasonography to diagnose and treat peripheral nerve injury in this demographic. Although the use of MRI to manage pediatric peripheral nerve injury is common and safely performed, there are several disadvantages, such as the extended length of time, required immobilization, and the potential need for sedation or general anesthesia.[3,5,20,25] In addition, ultrasound lacks ionizing radiation, making it a good alternative to other methods such as CT and plain-film radiography.[21]

While recognizing the setbacks of MRI in the pediatric population, it is also important to be critical of the limitations of ultrasound. For example, ultrasound cannot see through air, bone or other objects that differ in composition from body tissue.[23] This includes bandages, plaster casts, plastic wound foil with air underneath, drains, metal wiring, screws, or plates.[23] It is also more difficult to evaluate anatomy in patients with a larger body habitus, as adipose tissue tends to interfere with ultrasonic wave transmission.[21] In cases of acute trauma, using ultrasound may be complicated in fresh wound areas secondary to hematoma formation.[23] The result is a diffuse gray-tinged shadowing of the image that could obstruct key landmarks to identify peripheral nerves.[23] An additional potential complication that may arise is the necessary skillset required to operate high-resolution ultrasound. Ultrasound is very operator-dependent and is, therefore, more likely than other imaging modalities to have missed findings and false-negative interpretations. In cases when sonograms are difficult to interpret, other forms of imaging, such as MRI and CT, are necessary.

CONCLUSION

As described in this article, high-resolution ultrasonography is highly useful in the diagnosis, preoperative management, and surgical decision making of traumatic peripheral nerve injury in pediatric patients. It is a safe and reliable imaging modality that also offers the ability to evaluate damage dynamically and interactively. While studies have previously documented the success of using ultrasound to manage peripheral neuropathy, the application of this strategy remains under-utilized. The benefits of ultrasound are numerous, and it is critical to recognize its role in enhancing the management of pediatric patients with peripheral nerve injury.

Acknowledgment

The authors give special thanks to Roberto Suazo and Linda Alberga, Department of Neurological Surgery at the University of Miami Miller School of Medicine, for their figure design and editorial assistance.

Ethical approval

The Institutional Review Board approval is not required.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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How to cite this article: Sowah MN, Klein BR, Attiah M, Perez Pereda NI, Murray RA, John DL, *et al*. The use of ultrasound-guided imaging to localize peripheral nerve injury in pediatric patients: A case report. Surg Neurol Int. 2024;15:347. doi: 10.25259/SNI_580_2024