Radial nerve entrapment after fracture of the supracondylar humerus: a rare case of a 6-year-old

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ABSTRACT
Supracondylar fracture of the humerus is one of the most common fractures seen in children, and postero-medial displacement of the distal fragment in extension-type supracondylar humerus fractures can cause injury to the radial nerve. A 6-year-old girl who presented with symptoms of radial nerve injury after a supracondylar fracture of the right humerus with complete postero-medial displacement of the distal fragment (Gartland type III) underwent surgery where closed reduction and percutaneous pinning was performed. The patient was routinely followed up and at 6 months postoperatively no neurological improvement was seen. Exploratory surgery revealed complete discontinuation of the radial nerve at the fracture site and entrapment of the nerve stumps in healed bone callus. A gap of 2 cm was observed between nerve stumps, and sural nerve cable grafting was performed with good results. If neurological symptoms do not improve over time, appropriate differential diagnosis and, if necessary, exploratory surgery should be considered. Despite limited reports and their conflicting outcomes, sural nerve cable grafting could be a useful option to bridge the gap of discontinued nerve injury.

Level of Evidence: Level IV, Case Report

Introduction
A supracondylar humerus fracture is one of the most common fractures seen in children. It is predominantly an extension type. As the median and radial nerves travel anterior to the distal metaphysis of the humerus at the elbow region, they are at risk for injury in a displaced supracondylar humerus fracture. Postero-medial displacement of distal bony fragments usually causes a radial nerve injury. Postero-lateral displacement is more likely to cause a median nerve injury. In a flexion type, an ulnar nerve injury predominates.1,3

According to recent reports, 10%-20% of supracondylar humerus fractures demonstrate neurological symptoms.4 Radial nerve injury accounts for 5%-29% of these neural injuries.4 Nevertheless, most nerve injuries resolve spontaneously by conservative treatment. Surgical treatment can be considered in a few cases without improvement of neurological symptoms. The main surgical methods are nerve exploration and neurolysis.5 Nerve grafting is only needed in cases involving discontinued nerve lesions such as high-energy trauma and open fractures.8

Furthermore, reports on nerve grafting have been limited to isolated case reports with conflicting pediatric population outcomes. We experienced a rare pediatric patient condition that the radial nerve was completely entrapped in the supracondylar humerus fracture site. It was successfully treated by sural nerve cable graft. In this report, we describe the patient’s clinical course and surgical method with a good outcome.

Case Presentation
A 6-year-old girl presented to the emergency department with severe pain in the right elbow after a fall onto outstretched hand from a 2-feet height while playing in the playground. The elbow was severely swollen. Gross deformity of the elbow was observed. Without external open wound, the radial pulse was palpable. She was not able to extend the wrist or fingers. Radial nerve palsy was highly suspected, although it was unclear because of the irritability. The initial radiograph showed a supracondylar fracture of the right humerus with a complete postero-medial displacement of the distal fragment (Gartland type III). Closed reduction of the fracture was made only to correct the gross deformity. Gentle traction followed by elbow flexion in forearm pronation position was done (Figure 1A). After closed reduction, emergency surgery was planned. Closed reduction and fixation using 3 Kirschner wires (2 lateral pins and 1 medial pin) were done for the fracture. However, nerve exploration was not done considering the spontaneous resolution of nerve symptoms (Figure 1B). After the operation, there was no sign of vascular insufficiency. Weekly follow-up was done until postoperative 1 month. The radial nerve palsy did not recover after the operation. After that, monthly follow-up was done for routine check-ups of plain radiographs and nerve symptoms. At postoperative 5 weeks, we removed Kirschner wires. The initial fracture was fully united at postoperative 2 months (Figure 1C). However, neurological symptoms did not improve at all over the follow-up period (Figure 2).
Nerve conduction study and electromyography performed 5 months after the first surgery confirmed a severe loss of radial nerve. Magnetic resonance imaging showed an invisible radial nerve at the supracondylar level of the humerus and mild atrophy of the supinator muscle (Figure 3). An additional operation was planned with nerve exploration and a possible sural nerve graft.

Intraoperative findings revealed that the radial nerve was completely discontinued in the previous fracture site with proximal and distal nerve stumps entrapped in healed bone callus (Figure 4A). The nerve was carefully detached from the bone callus and surrounding tissues. Marginal debridement and resection of unhealthy nerve stump were performed. There was about a 2 cm gap between proximal and distal stumps (Figure 4B). Direct repair without bone shortening was impossible due to a large gap and excessive tension when approximated.

To bridge the gap between proximal and distal stumps, sural nerves of the contralateral calf were harvested using separate incisions. Based on the surgeon’s experience and judgment, bone shortening was not considered concerning that the patient was young with remaining potential for growth. We harvest an 11 cm sural nerve and divided it into 4 cables of nerve graft that could fit the entire surface of proximal and distal stumps. Nerve coaptation was performed under a microscope using 9-0 monofilament sutures in a tension-free position (Figure 4C).

No major problems were encountered in the postoperative period. Long arm splint was applied to protect the repaired nerve until postoperative 2 weeks. Weekly follow-up was advised during this period. After removing the splint, a gentle active range of motion of the elbow was allowed and a passive range of motion of the wrist was encouraged. Monthly follow-up was performed for routine check-ups of nerve symptoms. At postoperative 2 months, neurological symptoms showed signs of recovery. “Tinel to distal” sign was detected on radial nerve dermatome. The patient could extend the wrist against gravity at postoperative 6 months. At 1 year after the nerve graft, she obtained a full active range of motion of the wrist joint. The motor strength of the wrist extension was recovered to grade 5 on the British Medical Research Council (BMRC) rating scale. Only 10 degrees of extension lag remained on the second metacarpophalangeal joint. The motor strength was grade 4 on the British Medical Research Council (BMRC) scale (Figure 5).

At the final follow-up (postoperative 4 years), the Disabilities of Arm, Shoulder, and Hand (DASH) score was 24, the grip power was 38 lbs, not significantly different from 40 pounds on the left side. There was no discomfort in daily life activity. The extension lag of the second metacarpophalangeal joint also showed improvement. There was no significant difference in the power of pinch grip, wrist extension, thumb extension, or index finger extension force at both sides. The patient had no paresthesia or sensory impairment around the harvested sural nerve dermatome (Figure 6). Written informed consent was obtained from the patient to report this case.

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**HIGHLIGHTS**

- Radial nerve injury accounts for 5%-29% of the neural injuries in pediatric supracondylar humerus fractures. Most nerve injuries resolve spontaneously by conservative treatment. However if radial nerve symptoms are persistent for more than 6 months it may require nerve exploration.
- This report describes a 6-year-old patient with total entrapment of the radial nerve in the supracondylar humerus fracture site.
- A sural nerve cable grafting was performed and a promising outcome was obtained in a 4-year follow-up.
In children with neurological symptoms after a supracondylar humerus fracture, the appropriate timing to perform surgical exploration has been a subject of controversy. Neurological symptoms accompanying supracondylar humerus fractures in children are generally thought to be neurapraxia that will resolve spontaneously within 2-3 months, or it may extend to as long as 7-8 months. Thus,
most surgeons choose conservative treatment to progress the nerve healing and only consider exploration surgery if there was no evidence of improving neurological symptoms. Anuar et al\(^2\) argue that primary nerve exploration will allow early assessment of the injured nerve and minimize subsequent surgery. Previous studies have suggested that 86%-90% of these nerve injuries are neuroapraxia that can resolve spontaneously within 6 months, with the mean time to recovery being 2-3 months. The rest of the patients who did not show improvement in their neurological symptoms spontaneously showed improvement in symptoms only after neurolysis, in which nerves detached from the surrounding fibrotic scar tissue. It is very rare for such cases to require a nerve repair or graft.\(^3\) In our case, we waited for 5 months to see whether there might be a spontaneous recovery of neurological symptoms. However, there was no improvement over time, which made us perform an exploration surgery. Compared with adults, children show better results following the repair of peripheral nerve injuries owing to their greater capacity for peripheral nerve regeneration and neural plasticity.\(^1\) Thus, we believe that surgery should be delayed for a minimum of 3-6 months in the pediatric population to allow a longer time for spontaneous recovery and be more confident that exploration surgery is inevitable.\(^1,7\)

In the diagnosis of a nerve lesion, physical examinations are most crucial. The presence of Tinel’s sign is the most valuable clinical indicator in determining whether a nerve lesion is discontinued or not.\(^7\) However, clinical examinations are less reliable in children. Electrophysiological studies are not reliable for the identification of injuries requiring nerve graft. Furthermore, it is difficult to perform these studies on children due to its invasiveness. In this case, we were able to complete this study, thanks to the child’s good cooperation. We also performed magnetic resonance imaging for preoperative planning, which has emerged as the most far-reaching modality for diagnosing peripheral nerve injury.\(^7\) If electrophysiological examination is performed after neurological symptoms have recovered, it will provide evidence of objective improvement. However, the patient did not want to repeat the invasive examination since she had no discomfort in daily life. The lack of a follow-up study is a limitation of this case report.

Bertelli et al have published case series of 7 pediatric patients similar to this case and reported functionally satisfactory results after 2 years of follow-up. They argued that the most common sequela after a radial nerve graft was extension lag of the thumb indicating low functions of extensor pollicis longus.\(^1\) Dolan et al\(^8\) have recently shown 2 cases of radial nerve compression at the supracondylar fracture site. In the present study, neurophysiological studies prior to exploration indicated nerve in continuity, with partial nerve palsy failing to recover after more than 3 months. Exploration was performed. Compressed nerve was excised and sural nerve graft was done. However, long-term permanent extensor carpi radialis longus sequelae was shown, and patients have to undergo pronator teres tendon transfer.\(^3\) In our patient at postoperative 1 year, thumb function was completely recovered. However, extension delay of the index finger remained. Extension lags at the first and second Metacarpophalangeal (MCP) joints reflect poor functions of the extensor pollicis longus and extensor indicis proprius tendon, respectively, which are the most distally innervated muscles by radial nerve and the most difficult to reinnervate.\(^1\) As a related point, the extension lag of the index finger showed the latest recovery in our case. It took about 4 years after the surgery.

Conclusion

In a displaced supracondylar humerus fracture, a common fracture in children, radial nerve symptoms are often seen. In patients with neurological symptoms, it is not recommended to explore the nerve primarily. However, if neurological symptoms do not improve over time, electromyography and magnetic resonance imaging should be performed to determine the degree of damage to the radial nerve. Differentiation is needed. If necessary, exploration surgery with the preparation of nerve graft should be considered. We found entrapped radial nerve injury in the fracture site by nerve exploration. Thus, we performed a sural nerve cable graft and obtained a good outcome.

Informal Consent: Written informed consent was obtained from the patient to report this case.

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