JOURNAL OF PLASTIC SURGERY AND HAND SURGERY
2021, VOL. 55, NO. 4, 226–231
https://doi.org/10.1080/2000656X.2020.1858841

ARTICLE

Management of posterior interosseous nerve (PIN) palsies after distal biceps tendon repair using a single incision technique- a conclusive approach to diagnostics and therapy

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ABSTRACT

Complete distal ruptures of the biceps brachii tendon are rather rare and surgical reinsertion is the gold standard. Recently, one incision approaches for the refixation of the distal biceps tendon have been popularized with the introduction of a single-incision approach employing a trans-radial cortical button fixation. Since the introduction of this fixation technique we have seen more iatrogenic lesions to the posterior interosseous nerve (PIN) after not having seen any PIN lesions with 2 incision biceps refixation techniques over the last 5 years. Several patients with iatrogenic PIN affections after one incision refixation techniques of the distal biceps tendon were referred to our level 1 department of Plastic surgery and hand surgery from different orthopedic surgeons. Over the course of 6 months we saw 5 patients with a similar history. We decided to analyze this problem and propose a course of action to regain function of the PIN innervated muscles as good and fast as possible. If there is a loss of function in the PIN innervated muscles after distal biceps refixation a neurological evaluation including electrophysiology needs to be conducted. An ultrasound assessment of the nerve itself should guide the clinician in the decision between a conservative and a surgical treatment in the early postoperative phase. If surgical exploration is warranted intraoperative neurography should be the basis on which ground (partial) grafting or solely neurolysis is performed. Postoperatively all patients need to follow a rehabilitation protocol to help with nerve regeneration and regaining of motor function.

ARTICLE HISTORY
Received 21 August 2020
Revised 24 November 2020
Accepted 29 November 2020

KEYWORDS
Posterior interosseus nerve; nerve ultrasound; intraoperative neurography; complications of biceps tendon refixation

Introduction

Distal ruptures of the biceps brachii tendon are rather rare and typically affect male patients between 30 and 60 years of age [1]. For these injuries surgical reinsertion has become the gold standard [2]. The two incision approach as described by Boyd et al. has been the preferred technique of fixation for several decades as it was regarded as safer with a lower rate of nerve related complications [3]. Recently, one incision approaches for the refixation of the distal biceps tendon have again been popularized with the introduction of a single-incision approach employing a trans-radial cortical button fixation [2]. A systematic review published by Watson et al. showed that complication rates did not differ significantly between one and two-incision distal biceps repairs [4]. However, since the introduction of the single approach technique we noticed more iatrogenic lesions to the posterior interosseous nerve (PIN). We decided to analyze this problem and propose a course of action to regain function of the PIN innervated muscles as good and fast as possible.

Anatomy

Musculus biceps brachii: The biceps brachii muscle arises with two heads proximally from the supraglenoid tubercle of the scapula and the coracoid process of the scapula. Distally the muscle inserts in a tendinous footprint on the radial tuberosity after giving of the lacertus fibrosus or bicipital aponeurosis which fans out in an ulnar direction before merging with the superficial fascia of the ulnar side of the forearm [5]

Posterior interosseous nerve (PIN): The PIN arises from the radial nerve at the radiohumeral joint line. It passes under the supinator muscle at the arcade of Frohse. It then winds around the radial neck within the substance of the supinator muscle into the posterior compartment of the forearm

Cadaveric studies have demonstrated that there is some local variability of the PIN at radial neck level. Tornetta et al. showed that the PIN originated 1.2 ± 1.9 mm from the radiocapitellar joint. The takeoff was distal to the joint in 38% in there study and was completely intramuscular in 98%, in 2% it lay directly on the radius [6].

The PIN gives motor innervation to the extensor digitorum communis (EDC), extensor digiti minimi (EDM) and extensor carpi ulnaris (ECU) and sometimes the extensor carpi radialis brevis (ECRB). It also supplies the deep extensors, specifically the supinator, abductor pollicis longus (APL), extensor pollicus brevis (EPB), extensor pollicis longus (EPL), extensor indicis proprius (EIP).

Its terminal branch, which is located on the floor of the 4th extensor compartment provides sensory fibers to the dorsal wrist capsule.

Complete isolated injury to proximal PIN will result in inability to extend the fingers, however wrist extension (typically in a

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slight radial deviation) and sensation on the dorsum of the hand will be intact.

Indications/contraindications

Loss of motor function of finger or wrist extensors after distal biceps tendon reinsertion always warrants a diagnostic work up. Surgical exploration should be indicated based on a diagnostic work up described below

Technique

Technique of distal biceps repair using the "Biceps Button and Tension-Slide Technique

A transverse incision 3 cm distal to the elbow flexion crease is performed. The retracted distal end of the biceps tendon is identified and after debridement a Whipstitch of 2.5 cm of the distal end of the biceps tendon is placed with a loop suture. The loop suture is attached to the biceps button in a way that lets the button slide freely. A 3.2 mm bi-cortical tunnel is drilled through the radial tuberosity, aiming 30° ulnar with the forearm in full supination to maximize the distance from the posterior interosseous nerve (PIN). Slow and controlled drilling is important to minimize the risk of thermal damage and to be able to just pass the distal cortex but not to traumatize structures in the dorsal compartment. Awareness of the complex anatomy on the dorsal side of the forearm is essential. The nerves in the dorsal compartment are very close to the bone and cannot be visualized by this one incision approach.

Then an 8 mm uni-cortical tunnel over the 3.2 mm guide pin is drilled. The Biceps-Button is inserted through both cortices of the radial tuberosity and the button is seated against the radius. Before knotting the suture we recommend confirming snug placement of the button on the bone by fluoroscopy. After the loop suture is knotted a Tenodesis Screw is inserted on the radial side of the bone tunnel, pushing the tendon more ulnar.

When patients present with a loss of extensor function after distal biceps repair the following steps are warranted:

Clinical examination

A thorough patient history needs to be taken with focus on symptoms and especially time of onset. Clinical examination should focus on muscle strength assessment and should be documented according to the MRC classification from M0 to M5 [7]. Special note should be taken of sensation within the area innervated by the superficial branch of the radial nerve. If there is a loss of PIN function directly postoperatively we have a low threshold for ultrasound [8] and electrodiagnostic studies [9]. However these diagnostic steps should be undertaken at the latest after 6 weeks if no improvement of function is noted.

Ultrasound

Nerve ultrasound is a technique regularly employed in our department. It is conducted starting proximal to a suspected lesion typically at the distal upper arm following the radial nerve distally towards its division in superficial and deep branch. The deep branch is then followed through its insertion in the supinator tunnel after which by definition it is referred to as the posterior interosseous nerve. Edema and volume changes throughout the nerve's course can visualized by ultrasound as well as a general change in nerve caliber or a continuity interruption. As Agarwal et al. pointed out technological advances in ultrasonography allow for direct visualization of the involved nerve with assessment of the exact site, extent and type of injury. It yields unmatched information about anatomical details of the nerve [10]. This way lesions to the nerve can be identified.

MRI

If ultrasound is not available, MRI can be helpful. However often the PIN itself may not be visible due to artefacts but rather indirect signs of nerve damage like muscle edema due to denervation. The biceps button plate itself might also cause a certain amount of artefacts.

From a hand surgeon's perspective ultrasound will provide superior information in this particular setting due to its high spatial resolution and dynamic characteristics without distortion from the implant [11].

Neurological work up

A neurological work up should always be combined with the before mentioned imaging modalities. Electroneurography will provide information about the axonal or demyelinating pathophysiology of a lesion and thereby the prognosis while electromyography can determine the extent of an axonal lesion and the temporal course (acute vs chronic) [12]. It is important to be aware that depending on the time of evaluation in respect to the time of surgery (less than 3 weeks) pathological spontaneous activity in the evaluated muscles might not yet be present.

If PIN continuity is compromised or if there is severe axonal affection documented by the neurological work up at 6 weeks postoperatively we recommend revision surgery within 3 months postoperatively [13].

Revision surgery with intraoperative neurography

To approach the PIN a longitudinal incision over the interval between the brachioradialis muscle (BR) and ECRL is marked. The posterior cutaneous nerve of the forearm will be encountered during subcutaneous dissection. Then the interval between BR and ECRL is opened with a sharp incision and BR and ECRL muscle bellies are retracted ulnarly and radially. The first nerve that will be encountered is the radial sensory nerve, transversely passing vessels over the radial sensory nerve need to be clipped. Then the nerve to ECRB comes into sight running parallelly to the radial sensory nerve. The bigger nerve in this area running towards the ulnar side of the forearm is the PIN. The ECRB fascia is then released and below will be the tendinous leading edge of the supinator, the so-called arcade of Frohse. The PIN needs to be inspected and neurolysed as needed taking care not to damage the two veins that typically run alongside the PIN. The tourniquet then needs to be released in preparation for the intraoperative electroneurography which can then be started after at least 15–20 min. We measure direct nerve conduction nerve to nerve where the nerve is exposed using hook électrodes. In addition we perform nerve to muscle neurographies directly stimulating the exposed nerve and recording in the muscles with needle electrodes.

With the PIN in continuity at exploration this diagnostic tool provides us with objective measurements concerning fascicular damage and conduction impairment. The results from this diagnostic will guide our further decision making in regard to sole neurolysis versus nerve grafting.

The radial nerve is stimulated proximal to the suspected lesion and nerve action potentials (NAPs) are registered.

In addition, the radial nerve is stimulated percutaneously on the distal upper arm and NAPs are recorded from the specific nerve branches specifically the ECRB branch and the PIN itself. A needle electromyography can be performed providing additional information for the nerve branches that cannot be visualized within the operative field, specifically EDC and EPL.

Neurolysis vs grafting

When axonal continuity is documented and NAPs of at least 30 μV can be registered a neurolysis will allow for a good postoperative recovery in our experience. Patients returned to office work wearing a splint between two and four weeks postoperative. A full return to sports or manual labor was usually possible by 6 months postoperative. If the nerve is disrupted or only minimal NAPs can be registered the nerve should be reconstructed with grafts.

If the nerve is in continuity internal neurolysis should be performed thereby allowing for separate measurements of singular fascicles and thus guaranteeing that only affected nerve components will be resected and grafted while leaving healthy fascicles in place. We still use sural nerve grafts. A conclusive algorithm to our preferred treatment approach is illustrated in Figure 1.

Postoperative regime

For a successful outcome all patients should be referred to a skilled hand therapist.

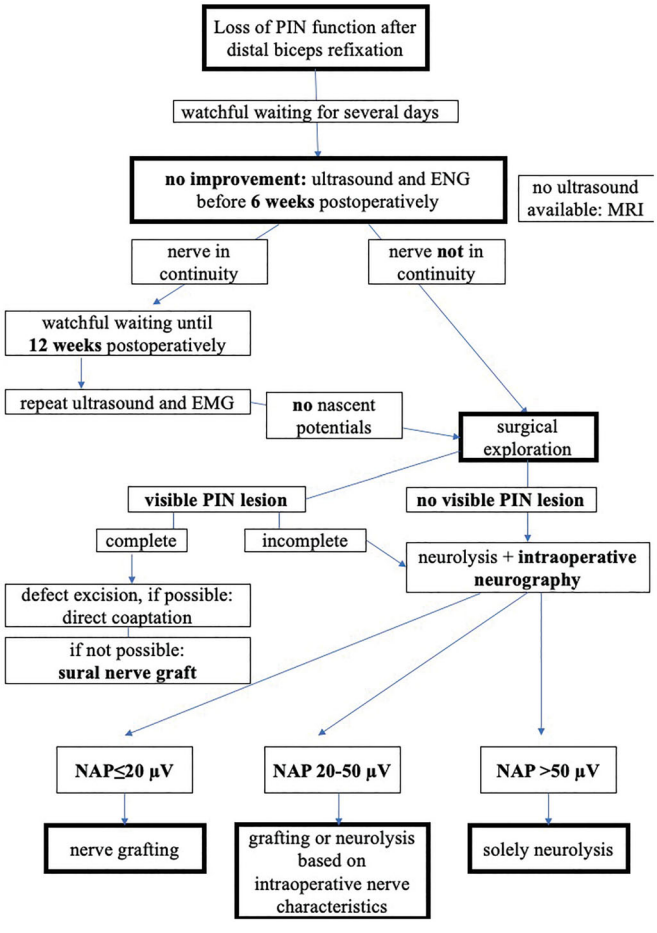

Figure 1. Treatment algorithm.

Maintaining cortical representation of the affected hand is important as cortical reorganization happens rapidly and could adversely affect over all functional outcome after nerve regeneration [14] Patients need to be coached to integrate the affected extremity as much as possible. Naturally muscles innervated by the PIN atrophy and undergo interstitial fibrosis. It is important to prevent this process as much as possible. The initial phase of treatment focusses on passive range of motion exercises to preserve joint mobility. Functional electrical stimulation can be used to maintain motor function in absence of nerve function [15] and custom made splints replicate the function of the extensor muscles.

Expected outcomes

Even though the review by Watson et al. could not find significant differences in complications rates between one and two-incision approaches for distal biceps repairs [4] there is an obvious risk to one incision repairs as part of the surgical field cannot be visualized. While the overall complication rate might not be significantly different Amin et al. attributed a higher rate of PIN injuries to a single-incision approach as compared with a double-incision technique (1.7% vs 0.2%) [16]

Also a review by Amarasooriya et al. demonstrated that the rate of sensory nerve injuries was significantly higher in single-incision approaches (9.3%) as compared with the double-incision group (5.8%) [17].

In addition a prospective randomized controlled trial by Grewal et al. showed that the single-incision technique resulted in a significantly higher overall complication rate, primarily due to a high number of early transient neurapraxias involving the lateral antebrachial cutaneous nerve [18]. When excluding lateral antebrachial cutaneous nerve palsies, there was no significant difference in the overall nerve palsies between single-incision and double-incision in a retrospective Level 3 study by Dunphy et al. [19].

Still it appears that these risks must be weighed against the benefit of just one scar.

If a single incision approach is chosen and the patient suffers PIN related complications afterwards nerve ultrasound will guide the clinicians decision towards revision surgery or a primarily conservative approach as it will provide the best information regarding nerve continuity due to its high spatial resolution.

In patients that do not require nerve grafting we expect to see signs of recovery within the first 12 weeks. Electrophysiological follow-up EMG recordings may provide subclinical evidence for reinnervation. Full rehabilitation will depend on the severity of the nerve damage. In patients that receive a nerve graft we expect to start seeing signs of reinnervation in EMG in the exetensor digitorum communis (the first branch of the PIN) between 4 and 6 weeks postoperative.

Illustrative case

A 54-year-old male patient was referred to our department after having undergone distal biceps tendon refixation as described above. Postoperatively he suffered from a complete loss of finger extension, wrist extension was intact, sensation on the dorsum of the hand was also present. A nerve conduction study was performed by a board-certified neurologist showing a severely reduced Compound muscular action potential (CMAP) amplitude (0.1mV), a substantially elongated Distal motor latency (DML) and

a severely reduced motor nerve conduction velocity of the radial nerve on forearm level.

An EMG of Extensor digitorum and ECU showed no pathological spontaneous activity, which of course we would not have expected only 11 days postoperatively. The findings were interpreted as a severe axonal lesion of the radial nerve at the proximal forearm level.

We then performed an additional ultrasound study which showed a prolonged focal edema of the PIN after entering the supinator tunnel, which was interpreted as neuroma in continuity (Figure 2). Dorsal to said neuroma the biceps button was visualized.

Due to these finding surgical exploration was warranted and performed in the technique described (Figure 3).

Intraoperatively the PIN was found in continuity with a relevant scar tether and a neuroma in continuity. Intraoperative PIN neurography showed NAPs of 35–40 µV (Figure 4). An additional EMG of EPL and EDC showed an amplitude-reduced but reproducible muscle of 0.2 (EPL) and 0.1(EDC) mV (Figure 5). Thorough neurolysis of the PIN was performed. As the biceps button was not the source of irritation we assume that the nerve was traumatized during drilling of the button plate canal.

The biceps button was found within the supinator muscle tissue and was resected. Postoperatively the patient received

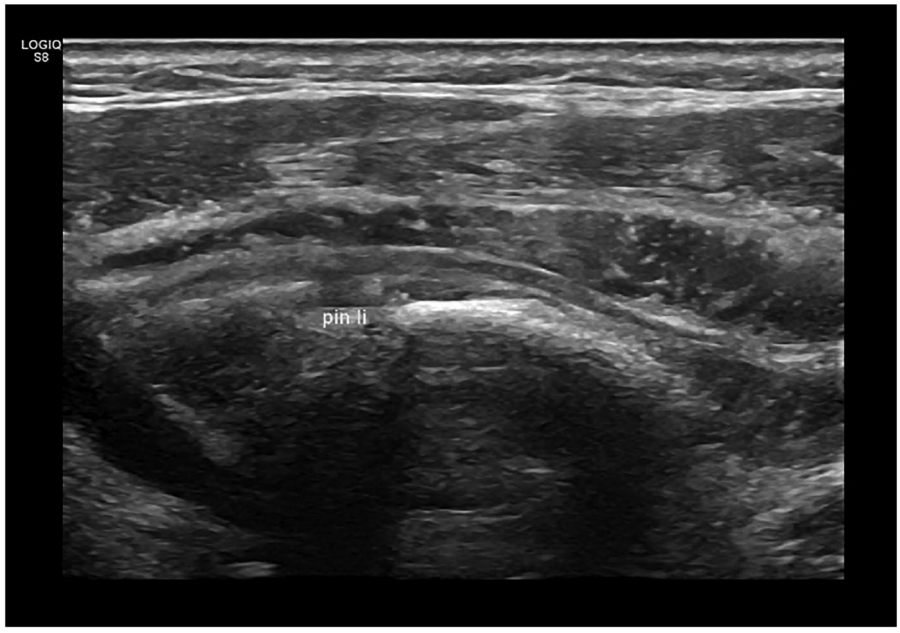

Figure 2. The ultrasound study showed a prolonged focal edema of the PIN after entering the supinator tunnel, which was interpreted as neuroma in continuity.

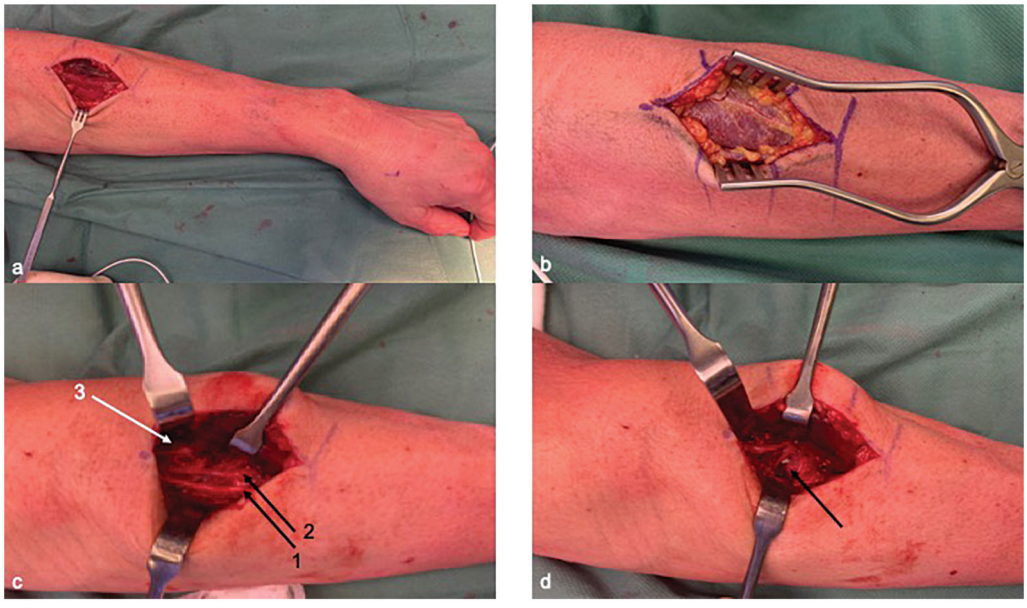

Figure 3. To approach the PIN a longitudinal incision over the interval between the brachioradialis muscle (BR) and ECRL was performed (a). The posterior cutaneous nerve of the forearm was encountered during subcutaneous dissection (b). Then the interval between BR and ECRL is opened with a sharp incision and BR and ECRL muscle bellies are retracted ulnarly and radially. The first nerve that will be encountered is the radial sensory nerve, transversely passing vessels over the radial sensory nerve need to be clipped. Then the nerve to ECRB comes into sight running parallelly to the radial sensory nerve. The bigger nerve in this area running towards the ulnar side of the forearm is the PIN. The PIN was found to be in continuity but showed a neuroma in continuity (c). Dorsal to said neuroma the biceps button was visualized (d).

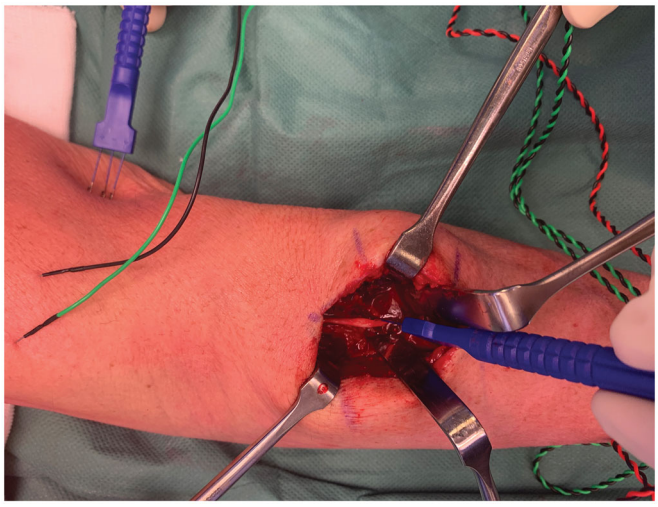

Figure 4. Intraoperative neurography. The radial nerve is stimulated percutaneously on the distal upper arm and NAPs are registered just distal to the neuroma.

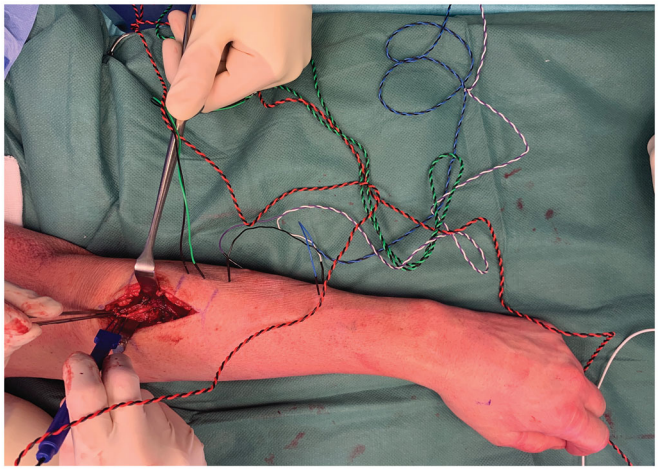

Figure 5. An EMG of EPL and EDC was performed. Electrodes are placed percuanteoulsyin the appropriate muscles and the nerve is stimulated proximal to the neuroma.

hand therapy. The patient improved continuously. At 4 months postoperatively he had regained full function of all extensors with M5.

Conclusion

Overall complications with the one incision distal biceps refixation techniques seem to be rare. Damage to the PIN is a severe potential complication. Postoperative loss of extensor motor function warrants a thorough work up by a team of hand surgeon and neurologist. Ultrasound should play a key role in the diagnostic process. Surgeons should have a low threshold for revision surgery with exploration of the PIN. Intraoperative electroneurography aids the surgeon in deciding whether grafting of the nerve is necessary. Postoperatively all patients need to follow a rehabilitation protocol to help with nerve regeneration and regaining of motor function.

Naturally these diagnostic and therapeutic steps can be applied to all types of PIN injuries.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

[1] Miyamoto RG, Elser F, Millett PJ. Distal biceps tendon injuries. J Bone Joint Surg Am. 2010;92(11):2128–2138.
[2] Camp CL, Voleti PB, Corpus KT, et al. Single-incision technique for repair of distal biceps tendon avulsions with intramedullary cortical button. Arthrosc Tech. 2016;5(2): e303–e307.
[3] Boyd HB, Anderson LD. A method for reinsertion of the distal biceps brachii tendon. JBJS. 1961;43:1041–1043.
[4] Watson JN, Moretti VM, Schwindel L, et al. Repair techniques for acute distal biceps tendon ruptures: a systematic review. J Bone Joint Surg Am. 2014;96(24):2086–2090.
[5] Eames MHA, Bain GI, Fogg QA, et al. Distal biceps tendon anatomy: a cadaveric study. J Bone Joint Surg Am. 2007; 89(5):1044–1049.
[6] Tornetta P, Hochwald N, Bono C, et al. Anatomy of the posterior interosseous nerve in relation to fixation of the radial head. Clin Orthop. 1997;345:215–218.
[7] Clarkson HM. Musculoskeletal assessment: joint range of motion and manual muscle strength. Philadelphia: Lippincott Williams & Wilkins; 2000.
[8] Dietz AR, Bucelli RC, Pestronk A, et al. Nerve ultrasound identifies abnormalities in the posterior interosseous nerve in patients with proximal radial neuropathies. Muscle Nerve. 2016;53(3):379–383.
[9] Bevelaqua A-C, Hayter CL, Feinberg JH, et al. Posterior interosseous neuropathy: electrodiagnostic evaluation. HSS J Musculoskelet J Hosp Spec Surg. 2012;8:184–189.
[10] Agarwal A, Chandra A, Jaipal U, et al. A panorama of radial nerve pathologies- an imaging diagnosis: a step ahead. Insights Imaging. 2018;9(6):1021–1034.
[11] Dettori N, Choudur H, Chhabra A. Ultrasound-guided treatment of peripheral nerve pathology. Semin Musculoskelet Radiol. 2018;22(3):364–374.
[12] Chung T, Prasad K, Lloyd TE. Peripheral neuropathy: clinical and electrophysiological considerations. Neuroimaging Clin N Am. 2014;24(1):49–65.
[13] Bulstra LF, Schep NWL, van der Vlies CH. Posterior interosseous nerve palsy after closed proximal forearm fractures. Trauma Case Rep. 2019;23:100240.
[14] Merzenich MM, Jenkins WM. Reorganization of cortical representations of the hand following alterations of skin inputs induced by nerve injury, skin island transfers, and experience. J Hand Ther off J Am Soc Hand Ther. 1993;6(2): 89–104.
[15] Arakawa T, Katada A, Shigyo H, et al. Electrical stimulation prevents apoptosis in denervated skeletal muscle. NeuroRehabilitation. 2010;27(2):147–154.
[16] Amin NH, Volpi A, Lynch TS, et al. Complications of distal biceps tendon repair: a meta-analysis of single-incision versus double-incision surgical technique. Orthop J Sports Med. 2016;4(10):232596711666813.

[17] Amarasooriya M, Bain GI, Roper T, et al. Complications after distal biceps tendon repair: a systematic review. Am J Sports Med. 2020;48(12):3103–3111.

[18] Grewal R, Athwal GS, MacDermid JC, et al. Surgical technique for single and double-incision method of acute distal biceps tendon repair. JBJS Essent Surg Tech. 2012;2: PMC6554083.

[19] Dunphy TR, Hudson J, Batech M, et al. Surgical treatment of distal biceps tendon ruptures: an analysis of complications in 784 surgical repairs. Am J Sports Med. 2017;45(13):3020–3029.