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Original article

Designing a 20 mm incision to protect the dorsal branch of the ulnar nerve during arthroscopic repair of triangular fibrocartilage complex injuries: Cadaver study and preliminary clinical results

Conception d'une incision de 20 mm pour protéger le rameau dorsal du nerf ulnaire pendant la réparation arthroscopique des lésions complexes du fibrocartilage triangulaire : étude cadavérique et résultats cliniques préliminaires

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ABSTRACT

The ulnar-sided approach for arthroscopic peripheral triangular fibrocartilage complex (TFCC) repair may be associated with injury to the dorsal branch of the ulnar nerve (DBUN). The goal of this study was to develop a small incision to help minimize DBUN injury. Ten cadaveric upper limbs were used to measure the anatomic parameters of the DBUN. Based on these measured anatomical relationships, a 20 mm longitudinal incision with the ulnar styloid process as the midpoint was designed to explore and protect the DBUN. Three additional cadaveric upper limbs were used to test the feasibility of this method. Then this method was applied in 15 patients with TFCC injury (IB type). In 10 cadavers, the DBUN was located volar to the ulnar styloid process. The mean linear distance between the DBUN and the ulnar styloid process was 8.04 mm (range: 7.02–8.82 mm) in the transverse-volar direction and 13.78 mm (range: 11.06–16.02 mm) in the longitudinal-distal volar direction. In three additional cadavers, the DBUN was successfully explored and retracted with this incision, creating a safer space for passing sutures and tying knots. This modified method was used successfully in 15 patients, and the DBUN was protected during surgery. There were no complications, and most importantly, no injuries to the DBUN at the 6-month follow-up visit. Therefore, we recommend that a 20 mm longitudinal incision with the ulnar styloid process as the midpoint be made prior to passing sutures during the arthroscopic repair of TFCC tears to avoid injuring the various branches of the DBUN.

Mots clés :
Rameau dorsal du nerf ulnaire
Incision
Complexe fibrocartilagineux triangulaire
Arthroscopie du poignet
Complications nerveuses

RÉSUMÉ

L'abord ulnaire pour la réparation arthroscopique des lésions périphériques du complexe fibrocartilagineux triangulaire (TFCC) peut être responsable de lésions du rameau dorsal du nerf ulnaire (RDNU). Le but de cette étude était d'utiliser une petite incision pour minimiser les blessures du RDNU. Dix membres supérieurs de cadavres ont été employés pour mesurer les paramètres anatomiques du DBUN. Selon les rapports anatomiques mesurés, une incision longitudinale de 20 mm avec le processus styloïde ulnaire comme point médian a été conçue pour explorer et protéger le RDNU. Trois membres supérieurs de cadavres supplémentaires ont été employés pour tester la faisabilité de cette méthode. Puis cette

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méthode a été utilisée chez 15 patients atteints de lésions du TFCC (type IB). Chez 10 cadavres, le RDNU a été localisé en avant du processus styloïde ulnaire, et la distance linéaire moyenne entre le DBUN et le processus styloïde ulnaire était palmaire de 8,04 mm (7,02–8,82 mm) et distale de 13,78 mm (11,06–16,02 mm). Chez 3 cadavres supplémentaires, le DBUN a été cherché avec succès et récliné avec cette incision, créant plus d'espace sûr pour passer des sutures et les nouer. Cette méthode modifiée a été utilisée avec succès chez 15 patients, et le RDNU a été protégé utilisant cette incision pendant la chirurgie. Il n'y a eu aucune complication, y compris de possibles lésions au RDNU au suivi clinique de 6 mois. Par conséquent, nous recommandons qu'une incision longitudinale de 20 mm avec le processus styloïde ulnaire comme point médian soit faite avant le passage des sutures dans la réparation arthroscopique des déchirures de TFCC pour éviter de blesser les différentes branches du RDNU.

1. Introduction

The triangular fibrocartilage complex (TFCC) is the most important stabilizer of the distal radioulnar joint (DRUJ) [1,2]. TFCC injury may be associated with DRUJ instability and is a common reason for ulnar-sided wrist pain. It can also cause decreased grip strength and impaired function. Therefore, a properly functioning TFCC is important for normal wrist function. TFCC lesions are divided into traumatic (type I) and degenerative (type II) origins [1,3]. Degenerative TFCC lesions are associated with age [4], and central lesions are considered unrepairable. The TFCC's periphery is said to be well vascularized [5]. Surgical repair is more realistic for traumatic injuries at the TFCC periphery.

Arthroscopic TFCC repair techniques are considered standard procedures with good results [6,7]. The dorsal branch of the ulnar nerve (DBUN) is often at risk during arthroscopic TFCC repair since the ulnar side of the wrist is usually used for passing sutures and tying knots. Haugstvedt and Soreide made an incision where the needle exited and debrided down to the capsule to avoid damaging the nerve before the needle was advanced through the portal when making an outside-in repair with horizontal loop sutures [8]. But this method can damage the DBUN during the needle passing and it is not sufficient when more than one suture is needed to repair the TFCC.

The DBUN provides sensory inputs to the dorsal-ulnar side of hand, the dorsal aspect of the fourth finger, and the dorsum of the little finger. Many anatomic variations exist [9,10] that increase the risk of iatrogenic injury to the DBUN branches [9,11]. McAdams et al. conducted a cadaver study of arthroscopic TFCC repair and discovered that the sutures were as close as 0.4 mm to the main trunk of the DBUN, which increases the risk of nerve branch strangulation unless the nerve is identified and protected when passing sutures [12].

Anatomical relationships and branching patterns of the DBUN have been described in previous studies [9,11], but there are few clinical studies on reducing DBUN injury during arthroscopic TFCC repair. The goal of this study was to design a modified incision to minimize DBUN injury. We first studied the anatomical relationship between the DBUN and the ulnar styloid process in 10 cadavers. Using the measured anatomical relationships, we designed a longitudinal incision to explore the DBUN. This modified method was used in three additional cadavers to validate its feasibility. Then we used this technique clinically in 15 patients to assess its safety and clinical efficacy.

2. Materials and methods

2.1. Anatomical study

Ten adult cadaveric upper limbs (five right and five left) with a mean age of 70 years (range: 53–85 years) were dissected to measure the anatomic parameters of the DBUN, and then three additional adult cadaveric upper limbs (two right and one left) were used to test the feasibility of the proposed incision. The cadaver study was conducted in the Department of Anatomy, Histology, and Embryology at the Medical College of Fudan University. The cadaveric upper limbs used in this study were macroscopically intact and amputated in the middle of the upper arm. A visual examination was conducted to confirm there were no signs of trauma or prior surgery. The cadaveric upper limbs were embalmed with 4.4% formalin solution. The skin was excised from the distal third of forearm to the metacarpal base. Using surgical loupes, we carefully explored the DBUN and traced it distally over the ulnar styloid process. We then dissected the branches of the DBUN. To avoid changing the primary position, the DBUN was not dissected free. With the forearm placed in pronation to ensure consistency with the intraoperative configuration, we measured the linear distance between the DBUN and the ulnar styloid process both transversely and longitudinally with a Vernier caliper (Fig. 1). The Vernier caliper was produced by the Santo Company (China) and had an accuracy of 0.02 mm.

Using the distances measured, we designed a 20 mm longitudinal incision to explore and protect the DBUN (Fig. 2). The surface projection of the ulnar styloid process was used as the midpoint of this incision. The incision direction was consistent with the forearm's longitudinal axis.

In three additional adult cadaveric upper limbs, the proposed incision was made to explore and retract the DBUN to test the feasibility of this method. These three cadaveric upper limbs were mounted upright on a wrist arthroscopy traction tower with finger traps placed on the second, third, and fourth fingers, respectively, during the feasibility test.

2.2. Clinical case series

TFCC lesions were classified as traumatic (I) or degenerative (II) according to Palmer [3]. Palmer IB injuries involve traumatic avulsion of the TFCC from its insertion at the distal ulna [13,14]. Patients diagnosed with a type IB TFCC injury were included in this case series. The average time from injury to surgery was 13 months (range: 3 months–5 years). All the patients were right-handed. The procedures were carried out through the proposed incision by two hand surgeons, each with more than 5 years of wrist arthroscopy experience. After surgery, a long arm plaster cast was used to immobilize the upper limb with the forearm in neutral position for 3 weeks, and then a short arm plaster cast was used to immobilize the forearm for an additional 3 weeks.

The patients were reviewed regularly. We evaluated the possibility of DBUN injury based on sensory symptoms including dysesthesia or pain on the ulnar-dorsal hand and fingers. Two-point discrimination was also assessed during the preoperative visit and postoperative follow-up period. The patients underwent regular rehabilitation for 6 weeks after surgery. Rehabilitation mainly including hand therapy (to improve the ROM of wrist flexion, extension, and forearm rotation) and physical therapy (to help reduce swelling).

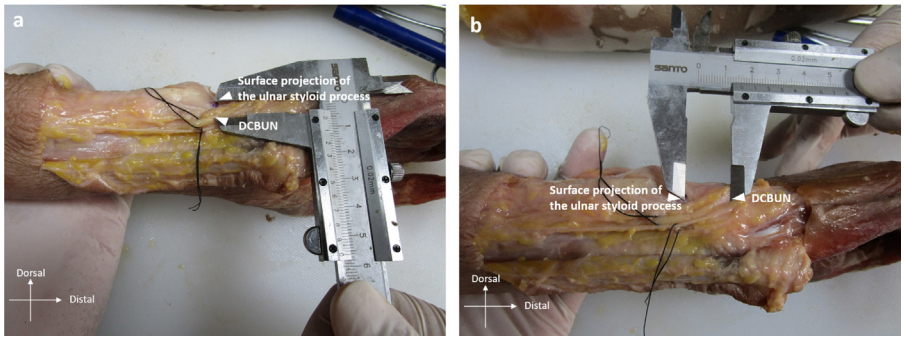

Fig. 1. a: Measuring the linear distance between the DBUN and the ulnar styloid process. Transverse-radial distance. b: Longitudinal-distal distance. *DCBUN*: dorsal branch of the ulnar nerve.

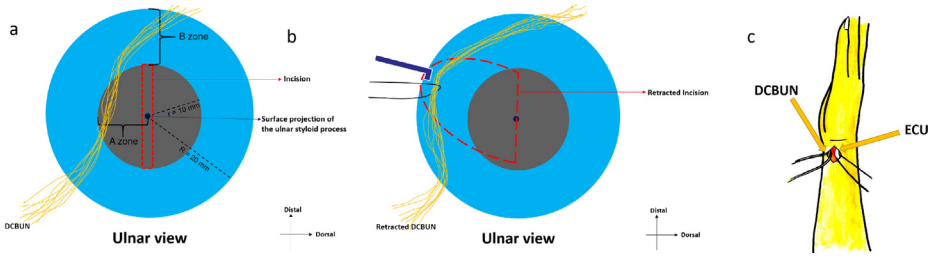

Fig. 2. Sketch of an ulnar view of the wrist. The DBUN was located in the A zone volar to the ulnar styloid process and the B zone distal to the ulnar styloid process. a: A 20 mm incision was made with the surface projection of the ulnar styloid process as the midpoint. b: The DBUN was explored and retracted volarly through the incision, creating more safe space for passing sutures and tying knots. c: Diagram showing how the DBUN and ECU are retracted to create more safe space for TFCC repair. *DCBUN*: dorsal branch of the ulnar nerve.

Table 1
Distance between the DBUN and the ulnar styloid process both transversely and longitudinally in 10 cadaveric upper limbs.

Specimen number	Side (left/right)	Transverse-volar distance (mm)	Longitudinal-distal distance (mm)
1	Left	8.36	13.04
2	Right	7.02	16.02
3	Left	8.04	11.06
4	Right	7.68	11.48
5	Right	8.38	13.48
6	Right	7.52	14.26
7	Left	8.2	15.28
8	Left	7.82	13.68
9	Right	8.54	14.12
10	Left	8.82	15.36
Mean	/	8.04	13.78
SD	/	0.54	1.61
Range		7.02–8.82	11.06–16.02

3. Results

3.1. Anatomic findings

The analytical results are shown in Table 1. In the 10 adult cadaveric upper limbs, the DBUN was located transverse-ulnar to the ulnar styloid process. The transverse-radial mean linear distance between the DBUN and the ulnar styloid process was 8.04 mm, ranging from 7.02 to 8.82 mm, with a standard deviation of 0.54 mm. The longitudinal-distal mean linear distance between the DBUN and the ulnar styloid process was 13.78 mm, ranging from 11.06 to 16.02 mm, with a standard deviation of 1.61 mm. Thus the transverse distance was less than 10 mm and the longitudinal distance was more than 10 mm in all the adult cadavers. In the additional three adult cadaveric upper limbs, the DBUN and the extensor carpi ulnaris (ECU) tendon were explored and retracted by making a 20 mm longitudinal incision with the ulnar styloid process as the midpoint, creating a larger safe space for passing sutures and tying knots during arthroscopic TFCC repair. The DBUN could not be explored within the longitudinal 10 mm both proximal and distal to the ulnar styloid process, indicating that the DBUN would not be injured in this area when passing sutures and tying knots during TFCC repair.

3.2. Clinical findings

Fifteen patients (8 females and 7 males; mean age 38.5 ± 10.5 years) with TFCC injury were included in this study. They all had ulnar wrist pain preoperatively. Physical and MRI examination indicated that the patients had TFCC IB type injuries. They were hospitalized in our surgical ward and underwent arthroscopic repair of their TFCC tear between June 2017 to June 2018. Joint cavity cleaning and synovectomy of inflammatory tissue were performed concurrently based on the findings of the arthroscopic examination. During the surgery, we first conducted a thorough diagnostic examination to clarify the diagnosis through

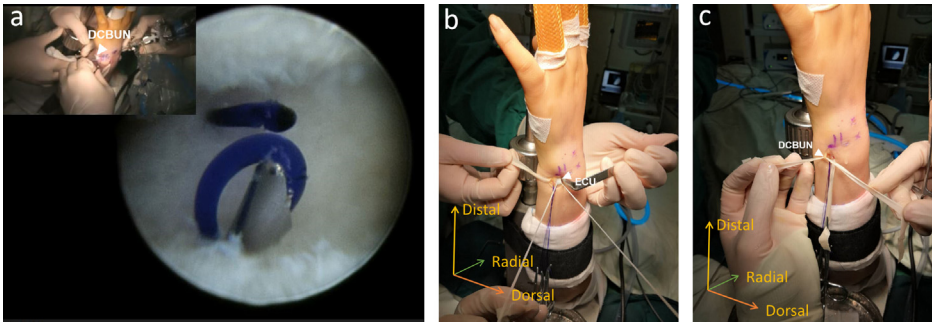

Fig. 3. Intraoperative photos of the application of the proposed incision. a: An integrated camera photograph showing that the PDS suture was loaded in a needle and inserted under the ECU tendon and the DBUN. b: The ECU tendon was explored and retracted by a vessel loop before passing the sutures. c: The DBUN was also explored and retracted by a vessel loop carefully before passing the sutures. *DCBUN*: dorsal branch of the ulnar nerve. *ECU*: extensor carpi ulnaris.

the 3-4 and 6-R portals and performed a hook test with the probe inserted through the 6-R portal. Then we performed the repair portion of the procedure. An outside-in technique was used as described by Haugstvedt et al. [8]. We created a 20 mm longitudinal incision before passing the sutures (Fig. 3a). The ECU tendon was explored and retracted by a vessel loop dorsally (Fig. 3b). The DBUN was also explored and retracted by a vessel loop volarly (Fig. 3c). This helps to create a larger safe space for passing sutures and tying knots. The surgery was successfully completed. Adhesive strips (Steri-Strips, 3 M, St. Paul, MN, USA) were used to close the portals, and 5-0 Prolene sutures were used to close the incision.

The patients were followed for an average of 10 months postoperatively (range, 6–20 months). No sensory symptoms including dysesthesia or pain in the ulnar-dorsal side of the hands and fingers were reported. In addition, there were no complications with the proposed incision, including wound infection, poor healing, or re-operation. There were no significant differences between preoperative and postoperative (at last follow-up) two-point discrimination (4.13 ± 0.74 vs. 4.33 ± 0.82, $P = 0.61$, Wilcoxon matched-pairs signed-rank test). All the patients returned to their daily activities after rehabilitation.

4. Discussion

Generally, arthroscopic repair of TFCC tears can be considered a safe procedure. However, there are known complications. Nerve damage has been reported frequently after arthroscopic procedures [15]. Some injuries may be temporary, but complete nerve transection and neuroma formation may be long-lasting [16,17]. Among the potential nerve injuries, DBUN lesion seems to be most frequent complication [18]. The anatomy of the DBUN at the ulnar side of the wrist near the location for the 6R and 6U portal used in TFCC repair is dense and complex [9,11], indicating that the DBUN is at high risk during the placement of the 6R and 6U portals and TFCC repair with sutures.

Goto et al. [19] identified two division patterns of the DBUN, including proximal and distal types. The proximal type typically goes around the ulna proximal to the ulnar styloid process, directed toward the ulnar-dorsal aspect [19]. The distal type goes around the ulnar-dorsal aspect, distal to the styloid process [19]. The proximal type is more common. Knowing the anatomic characteristics of the DBUN is useful when spreading the soft tissues and moving the nerve away when surgeons create the portals. Skin incisions are usually recommended and can spread directly down to the capsule, which can reduce the chances of DBUN injury while creating the 6U, 6R, and other portals. At the locations of the 6U and 6R portals, all the nerves run proximal to distal, so a longitudinal incision is also recommended [9,11]. These recommendations are mainly based on the examination of cadavers, so they have not been verified clinically. Even if portals are placed in the correct position, the DBUN may be compressed by the sutures during TFCC repair.

Tsuhsin et al. [18] reported a case of direct injury to the DBUN caused by arthroscopic repair of a TFCC tear. The DBUN was compressed by one of the pull-out sutures of the joint capsule, ulnar to the ECU tendon. After they excised the injured nerve segment, dysesthesia and pain in the ulnar side wrist was relieved. They believe this complication can be avoided by exploring the DBUN prior to suturing during arthroscopy. However, they did not conduct further research to evaluate their hypothesis. Frank et al. [7] explored nerves after suture passage but did not report the complication rates. Atzei et al. [20] created incisions for protecting nerves, but still had five cases of DBUN neurapraxia (10.4%). DBUN neurapraxia occurred in relatively small wrists and resolved uneventfully in a mean of 3.7 months [20].

Incomplete DBUN injury has a chance of recovery. In our previous clinical experience with TFCC repair without this incision, a 34-year-old female patient had to undergo a second procedure to extract one knot because she felt severe dysesthesia and pain in her ulnar-dorsal hand and fingers 3 months after the first procedure. At the second postoperative visit at 6 months, slight tingling remained on the ulnar-dorsal aspect of her fourth finger (Fig. 4). This led us to modify our nerve exploration and protection method. We first studied the anatomical relationship between the DBUN and the ulnar styloid process in 10 cadavers and designed a

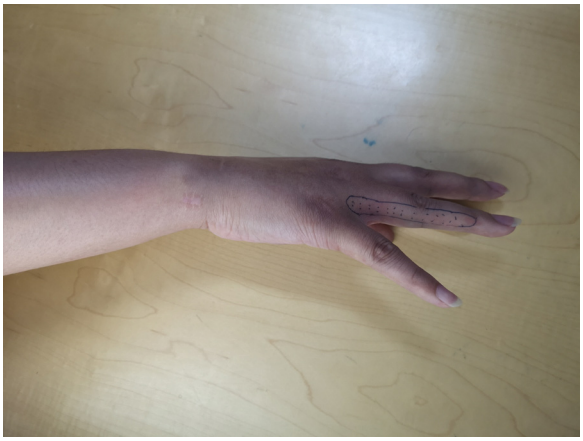

Fig. 4. A 34-year-old female patient underwent arthroscopic TFCC repair without exploration of the DBUN prior to the passage of sutures. She had to undergo a second procedure to extract one knot due to severe dysesthesia and pain in the ulnar-dorsal side of the hand and fingers 3 months later. After the second procedure, slight tingling remained on the ulnar-dorsal aspect of her fourth finger.

longitudinal incision to explore the DBUN. The feasibility of our proposed method was validated in additional three cadavers. Then we successfully used this technique in 15 patients. We explored and retracted the DBUN prior to suture passage during arthroscopic repair of TFCC tears instead of just separating the surrounding tissue using the sutures. In this way, the DBUN was well protected during TFCC repair. The clinical outcomes showed that this small incision did not produce complications, and the patients who underwent this modified procedure did not have symptoms of DBUN injury, indicating that this incision is safe and effective in our preliminary assessment.

Haugstvedt and Soreide often make incisions where the needle exits and debrides down to the capsule to avoid any nerve damage before the needle is advanced through the portal during the procedure, creating an outside-in repair using horizontal loop sutures [8]. This method cannot prevent DBUN injury caused by the passing needle and it does meet the requirement of having more than one suture to repair the TFCC. We recommend making the incision that we have designed before passing the needle, and the location remains the same. This can prevent DBUN injury caused by the passing needle, and it is easy for hand surgeons to learn. Lastly, this incision can create enough safe space for more than one suture to be used to repair the TFCC.

5. Conclusion

Our results have shown that the proposed 20 mm longitudinal incision with the ulnar styloid process as the midpoint can be used to explore and protect the DBUN, creating a larger safe space for passing sutures and tying knots during arthroscopic repair of TFCC tears without additional complications. Further clinical randomized controlled trials comparing the clinical outcomes between this proposed incision and traditional incisions for drilling and passing sutures should be conducted to verify the clinical effectiveness of this technique.

Ethical approval

This research was performed in compliance with ethical requirements, and all patients provided written informed consent.

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Disclosure of interest

The authors declare that they have no competing interests.

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