Echography-Guided Pinning for Prevention of Iatrogenic Injuries to the Radial Nerve during Fixation of Extra-articular Distal Radius Fracture: An Anatomical Study

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Abstract

This study assesses the usefulness and feasibility of an osteosynthesis of the lower end of the radius under ultrasound imaging to avoid the superficial branch of the radial nerve (SBRN). A single operator performed an initial echography of the wrist of 12 cadaveric upper limbs to identify the three main branches of the SBRN and the tendons. Then, three pins were placed according to Kapandji's procedure, avoiding the structures spotted under ultrasound imaging. After dissection, the safety distances for the branches of the SBRN, dorsal extensor tendons, and veins were measured, and injuries to these structures were noted. No lesion of the SBRN was found with an average safety distance of 8.1 for the third branch of the radial nerve (SR3) and 1.3 mm for the first and the second branches of the radial nerve (SR1–2). Three tendons were spiked. The average operative time was 38.3 minutes. Ultrasound secures percutaneous surgery to avoid the branches of the SBRN but requires a learning curve.

Keywords

- surgical technique
- ultrasound
- radius
- pin

Despite development of distal radius plating, pinning is still common for traumatic distal radius fracture, such as the Kapandji's procedure.¹ This technique subsequently was developed using three intrafocal Kirschner wires (K-wires) and one wire into the radial styloid.² However, percutaneous pinning increases the risk of iatrogenic injury to the extensor tendons, the veins and the superficial branches of the radial nerve (SBRN).³ Iatrogenic injury to the branches of the SBRN induces frequently neuroma and dysesthesia up to 16%.⁴ These structures can be detected by ultrasound imaging and the purpose of this anatomical study was to evaluate the feasibility and interest of using ultrasound-guided pinning for extra-articular distal radius fractures in particular to avoid iatrogenic injury to the SBRN.

Materials and Methods

Twelve upper limbs of fresh cadavers (L = 7, R = 5) were used in this study. No traumatic or surgical antecedent had been noted on the wrists (no scar, no obvious osseous injury under ultrasound imaging). An osteosynthesis of a distal radius fracture was simulated by a single operator for each wrist. Three 1.8-mm K-wires were inserted to the radius. The PHILIPS HDI 5000 SonoCT (Bothell, WA) ultrasound (2001) enabled a guided technique with a 12-Hz probe and a contact aqueous gel.

An initial echography of the dorsum of the wrist was performed to identify tendons and the radial nerve. The first operating time consisted of palpating Lister's tubercle that was the transversal landmark for the osteosynthesis. The

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dorsal veins were recognized with the probe on the dorsal aspect of the wrist with a 20-degree palmar flexion. Then, three pins were placed through the dorsal aspect of the wrist, avoiding the structures spotted by the echography. Each pin was positioned directly with cutaneous incision over the retinaculum. The position from the pin to the Lister's tubercle was monitored in the ultrasound imaging (►Fig. 1). Then, the K-wire was directed between the compartments until osseous contact. The SBRN and the veins were detected on the external face of the radius before positioning the pin in the radial styloid (►Fig. 2). The pins were positioned to the opposed cortex with a power drill at an angle of 45 degrees according to Kapandji's procedure.² A virtual transversal fracture line was defined, and two dorsal pins and one styloid pin were positioned at the level of this line. After inserting the K-wires, a dynamical examination was performed to detect a spiked tendon.

Subsequently, the anatomical dissection verified position of the pins to the three main branches of the SBRN. The following distances were measured using digital caliper:

- Distance from the bifurcation of the SBRN and the styloid process of the radius
- Distance from the pin to the three main branches of the SBRN (SR1, SR2, and SR3 according to the definition of Steinberg et al⁵)

Each compartment was dissected after opening the dorsal retinaculum (►Figs. 3 and 4) and followings were measured:

- Distance from the pin to extensor tendons in the five different compartments
- Distance from the pin to the dorsal veins
- Distance from the pin to the radial artery (safe distance)

Finally, operating time was reported for each wrist.

Fig. 1 Echographic control of the position from the pin to the Lister's tubercle (transversal view).

Fig. 2 Echographic visualization of the superficial branches of the radial nerve (transversal view).

Fig. 3 Dissection of the superficial branches of the radial nerve.

Fig. 4 Dissection showing the position between the pins and the compartments. Two dorsal pins, the lateral pin placed between the Lister's tubercle and the second compartment (C2) and the medial pin placed between the third compartment (C3) and the fourth compartment (C4).

Results

Dissection verified positioning of the pins. The results were in ►Table 1. The K-wire fixation was in the area of the common trunk of the first and two principal branches (SR1–2) and the third principal branch (SR3) of the radial nerve. The mean distance from the bifurcation of the SBRN to the styloid process of the radius was 51.54 mm (median distance = 52 mm, standard deviation [SD] $\pm$ 6.36 mm). The mean distance from the pin to the trunk of the branches SR1 and SR2 was 1.36 mm (median distance = 1 mm, SD $\pm$ 0.67 mm). The mean distance from the pin to the branch SR3 was 8.27 mm (median distance = 7 mm, SD $\pm$ 4.58 mm). No nerve branch was injured. A contact with the pin was noted in one case with SR1–2 and one case with SR3.

The dorsal exploration of the wrist (►Table 2) indicated that contact of the dorsal veins to a pin was noted in one case. No tendon was damaged by a pin on the dorsal aspect of the wrist. The tendons in the first compartment were injured in three specimens: the abductor pollicis longus (APL) in two specimens and extensor pollicis brevis (EPL) in one specimen were penetrated by the pins. In the first compartment, contact of the tendons with pins was observed in 42% of the cases. Safety distances of the pin to the tendon for the

Table 1 Results: measured distances for the branches of the SBRN (mm)

	d SBRN/SPR (mm)	d SR1-2 (mm)	d SR3 (mm)
Wrist 1	52	1	8
Wrist 2	48	2	7
Wrist 3	42	1	15
Wrist 4	43	0	15
Wrist 5	56	1	13
Wrist 6	50	2	6
Wrist 7	49	2	4
Wrist 8	52	2	0
Wrist 9	64	1	7
Wrist 10	61	1	6
Wrist 11	58	2	9
Wrist 12	53	1	7
Mean	51, 54	1, 36	8, 27
Median	52	1	7
Standard deviation	± 6.36	± 0.67	± 4.58

Abbreviations: d SBRN/SPR, distance from the bifurcation of the superficial branch of the radial nerve to the styloid process of the radius; d SR3, distance from the pin to the branch SR3; d SR1-2, distance from the pin to the trunk of the branches SR1 and SR2.

compartments 2, 3, 4, and 5 were 1.54, 1.54, 2.09, and 11.36 mm, respectively, in mean.

No injury to the veins or the radial artery was observed. Safety distance of the pin to the veins was 2.91 mm and to the radial artery was 17.64 mm in mean.

The operating time decreased from 55 to 20 minutes between the first and the last interventions (average time = 38.3 minutes; ►Fig. 5). The anatomy of the branches of the radial nerve is described in ►Fig. 6.

Discussion

Among the complications of the K-wire fixation for distal radius fracture reported in the literature, injuries to the sensory branches of the radial nerve and the extensor tendons are most common.⁶⁻⁸ Nervous injuries range from temporary dysesthesia⁹ to neuroma,¹⁰ and the tendinous injuries range from tendinitis to rupture. These complications are also related to the number of pins used. Hochwald et al demonstrated the major risks of percutaneous surgery: 41% tendons penetration and 31% of the superficial branches of the radial nerve were injured.¹¹

The sensory distribution in the dorsum of the hand is also variable.¹² The anatomical variations of the sensory branches of the radial nerve can be potential for the risk of K-wire penetration of the sensory branches. Thus, visualization of the three main branches of the SBRN during K-wire fixation is very important. Measurement of safe distance of the pin to the nerve, tendons or vein, artery from the certain landmark, such as the Lister's tubercle or the radial styloid, was already

Table 2 Results: measured distances for the tendons, radial artery, and dorsal veins (mm)

	d1 (mm)	d2 (mm)	d3 (mm)	d4 (mm)	d5 (mm)	d radial artery (mm)	d dorsal veins (mm)
Wrist 1	X APL	2	0	3	12	21	5
Wrist 2	X APL	1	0	3	14	20	3
Wrist 3	0	0	3	0	9	18	2
Wrist 4	3	0	2	0	11	28	0
Wrist 5	2	0	1	3	13	14	2
Wrist 6	X EPB	0	2	0	12	13	4
Wrist 7	1	1	1	1	11	16	3
Wrist 8	4	0	0	3	13	13	2
Wrist 9	0	0	5	7	18	17	6
Wrist 10	0	0	0	8	19	13	5
Wrist 11	0	10	3	1	0	18	2
Wrist 12	0	3	0	2	12	16	3
Mean	0, 91	1, 54	1, 54	2, 09	11, 36	17, 64	2, 91
Median	0	0	1	2	12	17	3
Standard deviation	± 1.44	± 2.98	± 1.63	± 2.07	± 4.39	± 4.32	± 1.64

Abbreviations: d dorsal veins, safety distance for the dorsal veins; d radial artery, safety distance for the radial artery; d1, safety distance for the 1st compartment; d2, safety distance for the 2nd compartment; d3, safety distance for the 3rd compartment; d4, safety distance for the 4th compartment; d5, safety distance for the 5th compartment; X, spiked tendon.

Fig. 5 Evolution of the operating time.

Fig. 6 Anatomy of the three branches of the superficial radial nerve. Median distance from the styloid radial to the trunk of the superficial branch of the radial nerve.

done^{13,14}; however, those were analyzed under fluoroscopic control.

In the present study using ultrasound control, no injury to the SBRN was noted. The positioning of the pins by ultrasound was well controlled and confirmed by the anatomical dissection. The safe distances were in average 8.2 mm for SR3 and 1.3 mm for SR1–2. Ultrasound enabled the surgeon to avoid iatrogenic injury to the sensitive branch of the radial nerve.

No tendon injury was noted in the second to fifth compartments in this study. However, some tendons were penetrated with the K-wire in the first compartment. Inserting the wire(s) into the first compartment should be careful. No injury to the vein or artery was also noted.

The limitation of our study was that the intervention was done in intact wrists. The anatomical landmarks could be modified in the fractured wrist, and swelling of the soft tissue may affect the measurements of the distance of the pin to the nerve, tendons, and artery/veins.

We concluded that ultrasound in the treatment of distal radius fractures presents several advantages. It can visualize the relationship between the pins and dorsal branches of the

radial nerve, the tendons in the second to fifth compartments, and vein/artery. K-wire insertion onto the first compartment should be careful even using the ultrasound.

Conflict of Interest

None.

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