An Anatomical Study to Demonstrate the Proximity of Kirschner Wires to Structures at Risk in Percutaneous Pinning of Distal Radius Fractures

John A. Santoshi¹ · Prashant N. Chaware² · Abhijit P. Pakhare³ ·
Bertha A. D. Rathinam²

Received: 15 September 2014 / Accepted: 21 April 2015 / Published online: 1 May 2015
© Society of the Hand & Microsurgeons of India 2015

Abstract Distal radius fractures are often treated using percutaneous Kirschner wires (K-wires). The sensory nerves in this area, extensor tendons, radial artery and cephalic vein are at risk of injury in this procedure. We undertook a cadaveric investigation to identify probability of damage to these ‘at risk’ structures by measuring their distances in relation to standard K-wire sites. Nine upper limbs from six formalin-preserved cadavers were studied. Four K-wires were placed percutaneously simulating fixation of a distal radius fracture. Careful dissection was done preserving the original position of neurovascular and tendinous structures. Distances to relevant soft-tissue structures from each K-wire were measured using an electronic digital caliper. Distance of superficial nerves from radial styloid and Lister’s tubercle was measured to determine their ‘safe distance’ from these fixed landmarks. None of the superficial nerves were injured by a K-wire. Cephalic vein had been pierced on 4 occasions (4/18) and extensor tendons on 3 occasions (3/18). Wilcoxon signed-rank test was used to compare distance of the superficial nerves from radial styloid and Lister tubercle, and the latter was found to be the safer option. This study highlights the inherent danger in percutaneous K-wire fixation of wrist fractures. Limited size of the area, where K-wires can be positioned, and anatomic variations of neurovascular structures pose obstacles in

developing guidelines for reducing risk of injury. We advocate use of mini-open approach and guiding devices to avert complications of inadvertent impalement and damage to these structures.

Keywords Distal radius · Percutaneous · Kirschner wire · Complication · Superficial radial nerve · Lateral cutaneous nerve of forearm · Dorsal branch of ulnar nerve · Cephalic vein · Radial artery

Introduction

Percutaneous Kirschner (K-) wire fixation is an accepted modality of managing distal radius fracture especially when the fracture is extra-articular. It not only provides sufficient fixation to minimize radial collapse and shortening, but also allows immobilization of the wrist at a neutral position compared to plaster cast or external fixator alone. Percutaneous K-wires are at times used as ‘joy-sticks’ under fluoroscopic control to aid reduction of intra-articular fragments [1–3]. Temporary percutaneous pinning is also done when these fractures are managed by a minimally invasive method [4].

The branches of various nerves, including superficial branch of radial nerve (SRN) [3, 5–18], lateral cutaneous nerve of forearm (LCNFA) [7, 10, 12], dorsal branch of ulnar nerve (DBUN) [9], the radial artery [5, 10, 12] and cephalic vein [10, 12], and the extensor tendons [6, 11, 15, 19, 20] (dorsal wrist extensor compartments EI to EV) are at risk of injury during this procedure. Injury to the superficial nerves could lead to formation of painful neuromas and precipitate the dreaded complication of reflex sympathetic dystrophy [3, 15]. Injury to the radial artery could lead to acute ischemia of the hand leading to gangrene especially when the palmar arch is incomplete. Injury to the cephalic vein may lead to

✉ Bertha A. D. Rathinam
bertharathinam@gmail.com

¹ Department of Orthopaedics, All India Institute of Medical Sciences (AIIMS), Bhopal, MP 462020, India

² Department of Anatomy, All India Institute of Medical Sciences (AIIMS), Bhopal, MP 462020, India

³ Department of Community & Family Medicine, All India Institute of Medical Sciences (AIIMS), Bhopal, MP 462020, India

persistent oedema of the hand and subsequent loss of function. Injury to the extensor tendons may lead to tethering of the tendons or delayed attrition rupture leading to loss of function [1, 2, 5, 11]. Steinberg et al. [12], in their study of placing percutaneous K-wires in the anatomical snuff box, found injury to radial artery and SRN in 20 % specimens and injury to cephalic vein and LCNFA in 35 % specimens. According to Singh et al. [18] the incidence of superficial nerve injury in radial styloid pinning may be as high as 20 %. Most studies advocate making a stab incision and carefully retracting the soft-tissues out of harm's way while inserting K-wires percutaneously [5, 6, 8, 9, 11, 13, 15, 19–21]. However, in practice, it is often seen that K-wires are shoved in blindly through intact skin while performing percutaneous pinning [2, 6, 13].

We undertook a cadaveric investigation to identify the probability of damage to the vulnerable neurovascular and tendinous structures by measuring their distances in relation to commonly used K-wire sites used for fixation of distal radius fractures. This study differs from the previous studies wherein for the first time possible injury to all relevant soft-tissue structures – superficial nerves, tendons, cephalic vein and radial artery – with the 4 commonly used pin insertion sites has been studied. We also measured the relative distances of superficial nerves to fixed bony landmarks viz., radial styloid (RS) and Lister tubercle (LT).

Materials and Methods

Institutional Human Ethics Committee approval was obtained prior to commencing the study. Six (two male and four female) formalin-preserved cadavers were included for the study. Nine upper limbs (four right and five left) from these six cadavers were studied; three limbs had obvious post-traumatic deformity of the wrist and these were not included. Four 1.5 mm K-wires were placed percutaneously (without skin incision), in the distal radius of the specimens, simulating fixation of a distal radius fracture following closed reduction by an experienced Orthopaedic surgeon (Fig. 1). The K-wires were pushed through intact skin and soft-tissues and then drilled into the distal radius. Two K-wires were inserted through the RS – starting point of the first K-wire was immediately dorsal to the tendons of the first dorsal wrist extensor compartment, one from the LT and one between the fourth and fifth dorsal wrist extensor compartments, starting at the ulnar corner of the distal radius, avoiding the sigmoid notch simulating fixation of a fracture fragment involving the dorso-ulnar aspect of the lunate facet. Then, using standard dissection tools, skin and subcutaneous fat were removed around the wrist region. Dissection was done carefully by avoiding disruption of the soft tissue underneath the neurovascular structures, and therefore maintaining the support of each structure at its original position. The K-wires were numbered from 1 to

Fig. 1 Image of the left wrist showing the four K-wires in place

4, starting from the radial aspect; first two K-wires in the RS (KW1 was the palmar wire), 3rd in the LT and 4th in the dorsal ulnar lip of distal radius. Distances to the relevant soft-tissue structures from each K-wire were measured. From the two RS K-wires (KW1 and KW2), distance to LCNFA, SRN, cephalic vein, radial artery in the anatomical snuff-box, and EI and EII tendons were measured. From the 3rd K-wire (KW3), distance to SRN, and EII, EIII and EIV tendons were measured. From the 4th K-wire (KW4), distance to DBUN, and EIV and EV tendons were measured. An electronic digital caliper with a measuring range of 0–150 mm, resolution of 0.01 mm, accuracy ± 0.02 mm of linear capacitive measuring system was used for all measurements which were carried out by two observers. Measurements were taken from the edge of the K-wire to the closest border of the structure ‘at risk’. In case of actual impalement or displacement of a structure with any K-wire, it was deemed to be injured and the distance was recorded as zero (0.00 mm). Mean of the value was calculated and then tabulated. We also measured the distance of SRN and LCNFA from the tip of RS and LT to determine their ‘safe distance’ from these fixed bony landmarks. These distances were also tabulated.

Statistical analysis was performed using SPSS 21 software (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) Descriptive statistical measures like mean, median, standard deviation, minimum and maximum values for each variable are described. We used the Wilcoxon signed-rank test to compare distance of LCNFA and SRN from RS and LT. A p-value of <0.05 was considered statistically significant.

Results

The distances from the K-wires to the ‘at risk’ soft-tissue structures are shown in Table 1. KW1 was found to have impaled the cephalic vein (Fig. 2) on two occasions (2/9) and EI (one slip of abductor pollicis longus) on one occasion

Table 1 Distance from the K-wires to the soft-tissue structures 'at risk' of injury

		Mean	Median	Standard deviation	Minimum	Maximum
KW1	LCNFA	8.54	7.69	4.63	3.77	16.08
	SRN	4.23	2.88	3.32	0.82	10.90
	CV	2.16	1.86	2.55	0.00	8.40
	RA	5.65	4.28	2.85	3.53	11.47
	EI	1.86	0.71	2.37	0.00	6.41
	EII	9.87	9.88	4.57	4.29	16.30
KW2	LCNFA	13.93	13.64	4.39	8.94	20.41
	SRN	2.39	1.93	1.86	0.22	5.48
	CV	2.74	1.05	4.99	0.00	14.81
	RA	7.42	6.10	5.04	2.58	18.82
	EI	5.75	4.25	2.65	3.22	9.92
	EII	5.65	4.95	4.48	0.00	12.36
KW3	SRN	12.11	12.23	5.10	2.54	20.43
	EII	2.69	2.40	1.69	0.97	4.84
	EIII	0.79	0.77	0.32	0.35	1.14
	EIV	6.49	6.00	2.60	3.89	9.95
KW4	DBUN	19.02	18.57	3.59	15.04	24.33
	EIV	1.58	1.22	1.68	0.00	4.80
	EV	2.93	2.94	1.38	0.84	5.11

All distances in millimetres (mm). *Abbreviations:* KW1 to KW4 Position of K-wires from radial to ulnar aspect, LCNFA Lateral Cutaneous Nerve of Forearm, SRN Superficial Radial Nerve, DBUN Dorsal Branch of Ulnar Nerve, CV Cephalic Vein, RA Radial Artery, EI to EV First to fifth extensor compartments on the dorsal aspect of wrist

(1/9); no nerves were injured. KW2 was also found to have impaled the cephalic vein on 2 occasions (2/9) and EII (extensor carpi radialis longus tendon) on 1 occasion (1/9). KW3 had produced no injuries (Fig. 3). KW4 was found to impale the EIV (extensor digitorum slip to the little finger; ED 4) (Fig. 4) on 2 occasions (2/9). The SRN was not injured by any of the K-wires; however, its minimum distance from KW1 and KW2 was 0.82 and 0.22 mm respectively. Similarly, EIII was not injured but its distance from KW3 ranged from 0.35 mm to 1.14 mm (mean

0.79 mm). The LCNFA, radial artery, EV and DBUN were also not injured by any of the K-wires by a safe distance of at least 3.77, 2.58, 0.84 and 15.04 mm respectively. The cephalic vein was injured on 4 occasions by 2 different K-wires (KW1 and KW2) (4/18).

Table 2 shows the distance of superficial nerves from fixed bony landmarks. The average distance from the tip of the RS to LCNFA and SRN was 9.69 and 2.31 mm, respectively. The average distance from the LT to the LCNFA and SRN was 24.58 and 15.20 mm, respectively.

Fig. 2 Anatomic dissection of a left wrist following elevation of skin showing KW1 piercing the cephalic vein (CV). Radial artery (RA) marked with the tip of the dissecting forceps

Fig. 3 Anatomic dissection of a left wrist showing the location of the KW3 at the Lister tubercle (LT). The extensor pollicis longus (EPL) tendon is seen uninjured under the K-wire

Fig. 4 Anatomic dissection of a right wrist showing the KW4 piercing the extensor digitorum slip to the little finger (ED 4)

Discussion

Extra-articular distal radius fractures are routinely treated with percutaneous K-wire fixation. While it is mentioned time and again in literature to make stab-/ mini-incisions and going up to the bone surface before drilling the K-wires, in practice, it is often seen that K-wires are shoved in blindly through intact skin while performing percutaneous pinning [2, 6, 13].

The complex anatomy of the superficial nerves at the wrist, their branching pattern, overlap, and intercommunication has been extensively studied [6, 7, 9, 10, 17, 21–24]. Some of these patterns are not well known to the wrist surgeons and may easily be missed. This could explain the high incidence of nerve lesions despite the surgeons being aware of the presence of these superficial nerves in the region [23]. Studies have also documented concomitant injury to both the SRN and LCNFA,

when only the injury to SRN is addressed (while missing the LCNFA) and having persistent symptoms [7, 23].

The cephalic vein and radial artery share a close anatomical relationship with both the LCNFA and SRN. These superficial nerves have variable patterns, lying on either side of the vessels or over the vessels along their course in the distal forearm and wrist [7, 10, 12, 22, 24]. This relationship explains the pain often experienced during cephalic vein or radial artery cannulation. Such a close association also endangers these structures during percutaneous K-wire insertion. We had 4 instances of cephalic vein impalement with the two RS K-wires (KW1 and KW2) (4/18) though we did not have any instance of LCFNA injury. The radial artery was found to be at an average distance of 5.65 mm from KW1, and 7.42 mm from KW2. Steinberg et al. [12] in their study found the radial artery crossing the snuff box at a mean distance of 7.5 mm distal to the RS which is consistent with our findings. Chia et al. [6] in their study reported that the volar radial styloid, transverse radial and dorso-ulnar K-wires all penetrated either tendons or nerves. The probability of injury to 'at risk' soft-tissues is higher when multiple K-wires are inserted in a relatively small area [6] as also demonstrated in our study.

Glanvil et al. [8] in a cadaveric study placed percutaneous pins in the RS and LT, and then performed an open dissection to determine if a nerve injury had occurred. Eleven out of 92 wires inserted in the RS produced a probable nerve injury, compared with only two wires inserted in LT. Hochwald et al. [13] conducted a comparison of percutaneous and limited open insertion of K-wires in 44 fresh cadaveric distal radii. In the percutaneous group, the SRN was touching the K-wires (potentially injured) in 8/22 cases in comparison to 1/22 in the limited open technique.

Kirmani et al. [19] reported attritional ruptures of the extensor tendons to the index and middle fingers following percutaneous K-wire placement for a distal radial fracture. Harrison et al. [20] reported two cases of EPL tethering following percutaneous K-wire insertion to treat unstable distal radius fractures. In our study, KW3 (3rd K-wire) was inserted though the LT. Care was taken to insert it just radial to the tip of the tubercle so as to prevent tendon impalement.

We agree with Tryfonidis et al. [9] and have demonstrated in this study (Table 2) that LT is a safer option than RS for

Table 2 Distance between superficial nerves and anatomical landmarks

		Mean	Median	Standard deviation	Minimum	Maximum	<i>p</i> -value (Wilcoxon signed-rank test)
LCNFA	RS	9.69	9.48	5.00	3.43	17.74	0.012
	LT	24.58	25.38	2.75	19.81	27.37	
SRN	RS	2.31	1.85	1.98	0.11	6.03	0.008
	LT	15.20	15.10	4.10	8.49	21.85	

All distances in millimetres (mm). *Abbreviations:* LCNFA Lateral Cutaneous Nerve of Forearm, SRN Superficial Radial Nerve, RS Radial Styloid, LT Lister Tubercle

percutaneous pinning for avoiding superficial nerve injury as well as extensor tendon impalement. We did not have EPL impalement in any cadaver even though the distance to the tendon from KW3 ranged from 0.35 to 1.14 mm. We did have impalement of abductor pollicis longus slip on one occasion (KW1) (1/9), extensor carpi radialis longus tendon on one occasion (KW2) (1/9) and extensor digitorum slip to the little finger (ED 4) on two occasions (KW4) (2/9).

The main limitation of this study was small sample size. Even of the limbs that were available to us, we were unable to utilize three due to obvious post-traumatic deformity at the wrist; as the anatomy would have been altered due to the traumatic event or its subsequent treatment during the individual's lifetime about which we were unaware. We assumed that we attain anatomical reduction in all cases of extra-articular distal radius fractures; however, the bony landmarks could be altered in less than anatomical reduction. In a clinical scenario, the wires are often reinserted/ re-sited in case of improper placement, which may lead to a traumatic soft-tissue injury due to the initial wire placement itself and this may be compounded by the subsequent wire placement. We used 1.5 mm K-wires as is the usual practice; using larger, 2.0 mm, K-wires may give different results.

Living tissues have higher water content and so the distances between K-wire and the structures at risk may be greater than that measured in formalin preserved cadavers as they lose their original mobility for averting unintended injury to neurovascular and tendinous structures; the results of present study show the relative risk of injury to structures.

This study highlights the inherent danger in blind percutaneous K-wire fixation of wrist fractures, a technique that is practically used daily. The limited size of the area where the K-wires can be positioned and the anatomic variations of neurovascular structures pose obstacles in developing guidelines for reducing the risk of injury to these structures. From the present study it is inferred that 0.11 mm around RS and 8.49 mm around the LT are safe with regard to the superficial nerves for blind percutaneous pinning. However, the authors would be wary of suggesting safe transcutaneous corridor as anatomical variations especially among the superficial structures are frequent and inevitable. We strongly advocate extreme care during percutaneous K-wire insertion. Mini-open approach or use of guiding devices which have a sheath around the wire should be used to avert complications of inadvertent impalement and damage to these structures during K-wire insertion.

Acknowledgments The authors are grateful to the staff in the Department of Anatomy at the All India Institute of Medical Sciences, Bhopal for their assistance during the study and in cadaver maintenance.

Conflict of Interest No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

References

1. Wolfe SW (2011) Distal radius fractures. In: Wolfe SW, Hotchkiss RN, Pederson WC, Kozin SH (eds) *Green's operative hand surgery*, 6th edn. Churchill Livingstone, Philadelphia, pp 561–638
2. Handoll HHG, Vaghela MV, Madhok R (2007) Percutaneous pinning for treating distal radial fractures in adults. *Cochrane Database of Syst Rev* CD006080
3. Rosati M, Bertagnini S, Digrandi G, Sala C (2006) Percutaneous pinning for fractures of the distal radius. *Acta Orthop Belg* 72:138–146
4. Xm W, Zz S, Yj R, Song XJ (2014) Minimally invasive plate osteosynthesis for distal radius fractures. *Indian J Orthop* 48:20–24
5. Davis DI, Baratz M (2010) Soft tissue complications of distal radius fractures. *Hand Clin* 26:229–235
6. Chia B, Catalano LW 3rd, Glickel SZ, Barron OA, Meier K (2009) Percutaneous pinning of distal radius fractures: an anatomic study demonstrating the proximity of K-wires to structures at risk. *J Hand Surg [Am]* 34:1014–1020
7. Beldner S, Zlotolow DA, Melone CP Jr, Agnes AM, Jones MH (2005) Anatomy of the lateral antebrachial cutaneous and superficial radial nerves in the forearm: a cadaveric and clinical study. *J Hand Surg [Am]* 30:1226–1230
8. Glanvill R, Boon JM, Birkholtz F, Meiring JH, van Schoor AN, Greyling L (2006) Superficial radial nerve injury during standard K-wire fixation of uncomplicated distal radial fractures. *Orthopedics* 29:639–641
9. Tryfonidis M, Charalambous CP, Mills SP, Jass GK, Jacob S, Stanley JK, Hayton MJ (2010) Distal radial and ulnar landmarks used in percutaneous pin fixation: anatomical relationship to the superficial radial and ulnar nerves. *Hand Surg* 15:161–164
10. Robson AJ, See MS, Ellis H (2008) Applied anatomy of the superficial branch of the radial nerve. *Clin Anat* 21:38–45
11. Stahl S, Schwartz O (2001) Complications of K-wire fixation of fractures and dislocations in the hand and wrist. *Arch Orthop Trauma Surg* 121:527–530
12. Steinberg BD, Plancher KD, Idler RS (1995) Percutaneous Kirschner wire fixation through the snuff box: an anatomic study. *J Hand Surg [Am]* 20:57–62
13. Hochwald N, Levine R, Tometta P (1997) The risks of Kirschner wire placement in the distal radius: a comparison of techniques. *J Hand Surg [Am]* 22:580–584
14. Calfee RP, Shin SS, Weiss AP (2008) Neurolysis of the distal superficial radial nerve for dysaesthesia due to nerve tethering. *J Hand Surg Eur Vol* 33:152–154
15. Allain J, le Guilloux P, Le Mouel S, Goutallier D (1999) Trans-styloid fixation of fractures of the distal radius. A prospective randomized comparison between 6- and 1-week postoperative immobilization in 60 fractures. *Acta Orthop Scand* 70:119–123
16. Das AK, Sundaram N, Prasad TG, Thanavelu SK (2011) Percutaneous pinning for non-communited extra-articular fractures of distal radius. *Indian J Orthop* 45:422–426
17. Khuroo YS, Babu RS, Bargawa HSM, Anand A, Rajendran M (2006) Anatomical variation of superficial branch of radial nerve—a cadaveric study. *JK-Practitioner* 13:169–172
18. Singh S, Trikha P, Twyman R (2005) Superficial radial nerve damage due to Kirschner wiring of the radius. *Injury* 36:330–332
19. Kimani SJ, Bhuva S, Lo W, Kumar A (2008) Extensor tendon injury to the index and middle finger secondary to Kirschner wire insertion for a distal radial fracture. *Ann R Coll Surg Engl* 90:W14–W16
20. Harrison MR, Hamilton S, Johnstone AJ (2004) Pseudo-rupture of Extensor Pollicis Longus following Kirschner wire fixation of distal radius fractures. *Acta Orthop Belg* 70:492–494

21. Folberg CR, Heitor JR, Ulson HJR, Scheidt RB (2009) The superficial branch of the radial nerve: a morphologic study. *Rev Bras Ortop* 44:69–74
22. Klitscher D, Muller LP, Rommens P (2007) Anatomical course of the superficial branch of the radial nerve and clinical significance for surgical approaches in the distal forearm. *Eur J Trauma Emerg Surg* 33:69–73
23. Poublon AR, Walbeehm ET, Coert JH, Kleinrensink GJ (2013) The branching pattern of the superficial branch of the radial nerve: description of a third branching type. *Eur J Anat* 17:237–242
24. Samarakoon LB, Lakmal KC, Thillainathan S, Bataduwaarachchi VR, Anthony DJ, Jayasekara RW (2011) Anatomical relations of the superficial sensory branches of the radial nerve: a cadaveric study with clinical implications. *Patient Saf Surg* 5:28