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Safe zones in dorsal portals for wrist arthroscopy: a cadaveric study

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The standard dorsal portals are the most commonly used in wrist arthroscopy. This cadaveric study aims to determine safe zones, by quantitatively describing the neurovascular relationships of the dorsal wrist arthroscopy portals: 1-2, 3-4, midcarpal radial, midcarpal ulnar, 4-5, 6-radial and 6-ulnar. The neurovascular structures of twenty-one fresh frozen human cadaveric upper limbs were exposed, while the aforementioned portals were established with needles through portal sites. The minimum distance between portals and: dorsal carpal branch of radial artery, superficial branch of radial nerve, posterior interosseous nerve and dorsal branch of ulnar nerve, were measured accordingly with a digital caliper, followed by statistical analysis of the data. The median and interquartile range for each portal to structures at risk were determined and a safe zone around each portal was established. Free of any neurovascular structure safe zones surrounding 1-2, 3-4, midcarpal radial, midcarpal ulnar, 4-5, 6-radial and 6-ulnar portals were found at 0.46mm, 2.33mm, 10.73mm, 11.01mm, 10.38mm, 5.95mm and 0.64mm respectively. Results of statistical analysis from comparisons between 1-2, 3-4 and midcarpal radial portals, indicated that 1-2 was the least safe. The same analysis among 3-4, midcarpal radial, midcarpal ulnar and 4-5 portals indicated that midcarpal portals were safer, while 3-4 was the least safe. Results among midcarpal ulnar, 4-5, 6-radial and 6-ulnar portals indicated that 6-radial and specifically 6-ulnar were the least safe. This study provides a safe approach to the dorsal aspect of the wrist, enhancing established measurements and further examining safety of the posterior interosseous nerve.

Keywords: wrist arthroscopy, dorsal portals, safe zones.

INTRODUCTION

The constant evolving wrist arthroscopy, especially with the continuous development of more efficient and smaller equipment, is an essential diagnostic and therapeutic tool[1], applying to a wide spectrum of wrist disorders. Arthroscopy is now performed to repair lesions of the triangular fibrocartilage complex (TFCC), assist to anatomic reduct intra-articular distal radius and scaphoid fractures, assist in treatment of scapholunate advanced collapse (SLAC) or scaphoid nonunion advanced collapse (SNAC), treatment of dorsal-wrist ganglion cysts and interosseous ligament disruptions, facilitate bone excisions such as radial styloidectomy and distal ulnar excision (wafer procedure), proximal row carpectomy such as in aseptic necrosis of carpal bones, debridement of chondral lesions, septic wrist irrigation and debridement, removal of loose bodies and diagnosis in unexplained mechanical wrist pain[2,3,4,5].

The standard wrist arthroscopic portals[6] were initially developed on the dorsal side of the wrist[7], considering the relative lack of neurovascular structures of the area[8,9,10,11,12]. This cadaveric study aims to compare the safety of the 1-2, 3-4, midcarpal radial (MC-R), midcarpal ulnar (MC-U), 4-5, 6-radial (6-R) and 6-ulnar (6-U) dorsal arthroscopy portals, emphasizing neurovascular relationships and especially those of posterior interosseous nerve [PIN], minimizing possible injuries to dorsal wrist structures by eventually establishing safe zones.

MATERIALS AND METHODS

A total of twenty-one fresh frozen human cadaver upper limbs, ten left and eleven right, were examined in this study. Clinical history of the cadavers was not available. In order to check the safety of the discussed dorsal wrist arthroscopy portals, an anatomical study was performed. To enhance visualization further, the arterial system was pre injected with a lead oxide and gelatin mixture[13].

After positioning the limbs in prone position with the elbow fixed to 90º, bony landmarks and tendons were addressed on the dorsum and eventually dorsal arthroscopy portal sites were identified by palpation and marked.

Specifically, the 1-2 portal was identified in the dorsal aspect of snuffbox, between the tendons of abductor pollicis longus (APL) along with extensor pollicis brevis (EPB) on the radial side and extensor carpi radialis brevis (ECRB) along with extensor carpi radialis longus (ECRL) on the ulnar side, bounded proximal by the styloid process of radius and distal by the scaphoid and extensor pollicis longus (EPL)[14,15]. The 3-4 portal was identified 1cm distal to Lister's tubercle, in the soft spot between the tendons of EPL on the radial side and extensor digitorum communis (EDC) on the ulnar side, in line with the radial border of 3rd metacarpal, bounded proximal by the distal aspect of radius[14,15]. The MC-R portal was identified 1cm distal to 3-4 portal along the axis of radial border of 3rd metacarpal, between the tendons of ECRB on the radial side and EDC on the ulnar side[14,15]. The 4-5 portal was identified in line with 4th metacarpal, between the tendons of EDC on the radial side and extensor digiti minimi (EDM) on the ulnar side, distal to 3-4 and 1cm radial to 6-R portal, bounded proximal by the radius and distal by the lunate[14,15] The MC-U portal was identified 1cm distal to 4-5 portal along the axis of 4th metacarpal, between the tendons of EDC on the radial side and EDM on the ulnar side[14,15]. Finally, the 6-R and 6-U portals were identified just radial and ulnar to the extensor carpi ulnaris (ECU) tendon respectively, with 6-R bounded distal by the lunate and 6-U by the triquetrum, while both bounded proximal by the TFCC just above styloid process of ulna[14,15]. Thereinafter, needles were inserted through the marked dorsal portal sites.

Wrist arthroscopy procedures were not fully replicated with arthroscopy instruments, nor the adequate positions of the portals were verified by introducing a camera. The dissection, that followed, was performed using standard dissection tools and under 3.0 loupe magnification. The dorsal skin and subcutaneous tissue were excised to expose nerve branches, blood vessels and extensor tendons. During the dissection, needles were carefully remained in place to assess their correct positioning, perforating the joint capsule and reaching radiocarpal and midcarpal joints accordingly.

Figure 1. — Right cadaver upper limb, needles form radial to ulnar side : a) white – portals: 1-2, 3-4, MC-R, 4-5, MC-U, 6-R, 6-U; b) yellow – nerves: SBRN, DBUN; c) red – arteries: DCBRA.

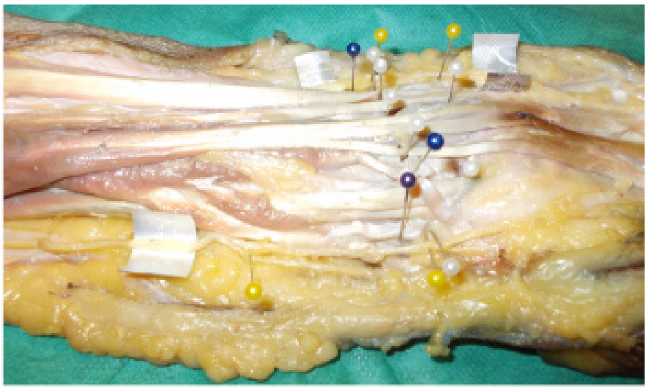

Figure 2. — Left cadaver upper limb, needles form radial to ulnar side : a) white – portals: 1-2, MC-R, 3-4, 4-5, MC-U, 6-R, 6-U; b) yellow – nerves: SBRN , DBUN.

Subsequently, distances were measured as the shortest distance from the needles located in the aforementioned dorsal portals to a corresponding needle placed in the neurovascular structure at risk, in the same anatomical plane of the structure, from the ulnar and the radial side accordingly. All measurements were taken by an author using a universal digital caliper with centimeter accuracy of a millimeter and constantly observed by a different author to ensure quality control, in the same manner as a previous study of ours[16].

The structures considered at risk included the dorsal carpal branch of radial artery (DCBRA), the superficial branch of radial nerve (SBRN), the posterior interosseous nerve (PIN) with its terminal branch located on the floor of the fourth extensor compartment and the dorsal branch of ulnar nerve (DBUN). Particularly, the distance of these structures from the dorsal portals and the presence of any injury, were recorded and analyzed[11,14,15].

Specifically, measures in the 1-2 portal were taken from the needle to the DCBRA and in the 1-2, 3-4 and MC-R portals from the needle to the SBRN (Fig. 1)

(Fig. 2). Respectively, in the 3-4, MC-R, MC-U and 4-5 portals measures were taken from the needle to the PIN. Additionally, measures in the MC-U, 4-5, 6-R and 6-U portals were taken from the needle to the DBUN (Fig. 1) (Fig. 2).

Finally, statistical analysis of the measurements was performed with SPSS software (v.28.0.1). The values were expressed as interquartile range (IQR). Non-parametric statistical tests were used because of the small sample and the fact that the values were not normally distributed. Friedman's test and Wilcoxon's test were used to perform comparisons of dorsal wrist arthroscopy portals. Statistical significance was defined as $p < 0.05$ and power analysis was not performed, because it was not known what effect size to expect.

RESULTS

During the study there were no iatrogenic damages to the extensor tendons, dorsal carpal branch of radial artery, superficial branch of radial nerve, posterior interosseous nerve and dorsal branch of ulnar nerve in any of the specimens.

Median IQR distances from the 1-2 portal to the dorsal carpal branch of radial artery and the superficial branch of radial nerve were found 1.51mm (0.76-2.24) and 1.26mm (0.46-1.76), respectively (Table I). The safe zone, free of any neurovascular structures, surrounding the 1-2 portal was greater than 0.46mm.

Furthermore, median IQR distances from 3-4 and MC-R portals to the superficial branch of radial nerve and the posterior interosseous nerve were 26.13mm (22.56-28.5), 3.59mm (2.33-5.77) regarding the 3-4 portal and 21.20mm (18.58-30.83), 12.66mm (10.73-13.53) for the MC-R portal (Table I). There was a greater than 2.33mm safe zone surrounding the 3-4 portal and a safe zone of 10.73mm surrounding the MC-R portal.

Table I. — Distances in millimeters (mm) from 1-2, 3-4, MC-R, MC-U, 4-5, 6-R and 6-U portals to dorsal structures at risk

Dorsal Portal	Structure at risk	Median IQR (Q1-Q3)
1-2 portal	DCBRA	**1.51** (0.76-2.24)
	SBRN	**1.26** (0.46-1.76)
3-4 portal	SBRN	**26.13** (22.56-28.50)
	PIN	**3.59** (2.33-5.77)
MC-R portal	SBRN	**21.20** (18.58-30.83)
	PIN	**12.66** (10.73-13.53)
MC-U portal	PIN	**12.62** (11.01-13.16)
	DBUN	**25.83** (16.82-31.65)
4-5 portal	PIN	**14.01** (10.38-16.16)
	DBUN	**20.42** (16.07-25.00)
6-R portal	DBUN	**7.81** (5.95-11.58)
6-U portal	DBUN	**1.04** (0.64-1.47)

DCBRA: the dorsal carpal branch of radial, SBRN: the superficial branch of radial nerve, PIN: the posterior interosseous nerve, DBUN: the dorsal branch of ulnar nerve.

Subsequently, the median IQR distances from MC-U and 4-5 portals to the posterior interosseous nerve and the dorsal branch of ulnar nerve were 12.62mm (11.01-13.16), 25.83mm (16.82-31.65) and 14.01mm (10.38-16.16), 20.42mm (16.07-25.0) respectively, for MC-U and 4-5 portals (Table I). Free of any neurovascular structures safe zone surrounding the MC-U portal was greater than 11.01mm and 10.38mm for the 4-5 portal.

Lastly, the median IQR distances from 6-R and 6-U portals to the dorsal branch of ulnar nerve were 7.81mm (5.95-11.58) regarding the 6-R portal and 1.04mm (0.64-1.47) for the 6-U portal (Table I). The safe zone, free of any neurovascular structures, surrounding the 6-R portal was greater than 5.95mm and only 0.64mm for the 6-U portal.

Table II. — Results of statistical analysis using Friedman's test for 1-2, 3-4 and MC-R portals regarding the SBRN at risk, 3-4, MC-R, MC-U and 4-5 portals regarding the PIN at risk, MC-U, 4-5, 6-R and 6-U portals regarding the DBUN at risk.

(n=21)	1-2 portal	3-4 portal	MC-R portal		P
SBRN	**1.26** (0.46-1.76)	**26.13** (22.56-28.50)	**21.20** (18.58-30.83)		< 0.01
(n=21)	**3-4 portal**	**MC-R portal**	**MC-U portal**	**4-5 portal**	**P**
PIN	**3.59** (2.33-5.77)	**12.66** (10.73-13.53)	**12.62** (11.01-13.16)	**14.01** (10.38-16.16)	< 0.01
(n=21)	**MC-U portal**	**4-5 portal**	**6-R portal**	**6-U portal**	**P**
DBUN	**25.83** (16.82-31.65)	**20.42** (16.07-25.00)	**7.81** (5.95-11.58)	**1.04** (0.64-1.47)	< 0.01

SBRN: the superficial branch of radial nerve, **PIN:** the posterior interosseous nerve, **DBUN:** the dorsal branch of ulnar nerve.

Table III. — Results of statistical analysis using Wilcoxon's test between 3-4 and MC-R portals, MC-U and 4-5 portals, 3-4 and 4-5 portals, MC-R and MC-U portals, 6-R and 6-U portals regarding distances to structures at risk.

(n=21)	3-4 portal	MC-R portal	P
SBRN	**26.13** (22.56-28.50)	**21.20** (18.58-30.83)	0.063
PIN	**3.59** (2.33-5.77)	**12.66** (10.73-13.53)	< 0.01
(n=21)	**MC-U portal**	**4-5 portal**	**P**
PIN	**12.62** (11.01-13.16)	**14.01** (10.38-16.16)	0.114
DBUN	**25.83** (16.82-31.65)	**20.42** (16.07-25.00)	< 0.01
(n=21)	**3-4 portal**	**4-5 portal**	**P**
PIN	**3.59** (2.33-5.77)	**14.01** (10.38-16.16)	< 0.01
(n=21)	**MC-R portal**	**MC-U portal**	**P**
PIN	**12.66** (10.73-13.53)	**12.62** (11.01-13.16)	0.093
(n=21)	**6-R portal**	**6-U portal**	**P**
DBUN	**7.81** (5.95-11.58)	**1.04** (0.64-1.47)	< 0.01

SBRN: the superficial branch of radial nerve, **PIN:** the posterior interosseous nerve, **DBUN:** the dorsal branch of ulnar nerve.

Applying non-parametric statistics, comparisons utilizing Friedman's test, indicated that 3-4 and MC-R portals were safer than the 1-2 portal regarding their distance to the superficial branch of radial nerve (p< 0.01) (Table II). Additionally, MC-R, MC-U and 4-5 portals were safer than 3-4 portal considering their distance to the posterior interosseous nerve (p< 0.01) (Table II), while MC-U and 4-5 portals were safer than 6-R and 6-U portals in terms of the distance to the dorsal branch of ulnar nerve (p< 0.01) (Table II).

Similarly, applying non-parametric statistics, paired comparisons utilizing Wilcoxon's test, indicated that the MC-R portal was safer than the 3-4 portal regarding its distance to the posterior interosseous nerve (p< 0.01), but 3-4 portal was relatively safer than MC-R portal taking into consideration the superficial branch of radial nerve (p= 0.063) (Table III). Likewise, the 4-5 portal was safer than the MC-U portal in terms of the distance to the dorsal branch of ulnar nerve (p< 0.01), but due to the aforementioned small number of specimens examined, no significant differences were indicated resulting from the distances to the posterior interosseous nerve (p= 0.114) (Table III). Moreover, considering the distance to the posterior interosseous nerve, the 4-5 portal was safer than 3-4 (p< 0.01) (Table III), while the MC-U portal was relatively safer than MC-R (p= 0.093) (Table III). Finally, the 6-R portal was far more safe than the 6-U portal in regard to its distance from the dorsal branch of ulnar nerve (p< 0.01) (Table III).

DISCUSSION

Safe zones were established in this study surrounding each mentioned standard dorsal arthroscopic portal, considering the median IQR distances from every portal to each separate neurovascular element at risk. It was indicated that there was a greater than 0.46mm safe zone surrounding the 1-2 portal, where SBRN was found the structure at great risk. In addition, There was a greater than 2.33mm, 10.73mm, 11.01mm and 10.38mm safe zone surrounding the 3-4, MC-R, MC-U and 4-5 portals respectively, where PIN was addressed the structure at greater risk. Regarding the 6-R and 6-U portals, a greater than 5.95mm and 0.64mm safe zone respectively was found from DBUN, the structure at risk.

The aforementioned confirm what was suggested by Abrams et al.[17] and Longo et al.[18], that the 1-2 and 6U portals were the "most perilous", due to their proximity to neurovascular structures. Whereas, the 3-4, 4-5 and also midcarpal portals measured in this study were "relatively safe", as they are the farthest away from the radial and ulnar neurovascular structures accordingly.

Observing Friedman's tests, showed that the 3-4 and MC-R portals were in general safer than the 1-2 portal in terms of distance to the SBRN, also referred previously from Auerbach et al.[19], Tryfonidis et al.[20], Longo et al.[18] and Shyamalan et al.[21]. Considering the safe distance from PIN, the 3-4 was found the least safe portal compared to the MC-R, MC-U and 4-5. Finally, the MC-U and 4-5 portals were far more safe portals, in terms of distance to DBUN, than the 6-R and 6-U portals that provided near zero safe zone according to Shyamalan et al.[21].

Furthermore, for PIN Wilcoxon's tests matching the portals were assessed. The MC-R and MC-U portals were safer than the more proximal 3-4 and 4-5 portals respectively, especially regarding their distance from PIN, in contrast with Pan et al.[8]. Specifically, between the MC-R and MC-U portals there was not great difference in the distance to the PIN. As demonstrated in this study, however, between 3-4 and 4-5 portals, PIN was at peril in the zone surrounding the first one, in agreement with Shyamalan et al.[21]. Comparing 6-R and 6-U portals regarding their distance to DBUN with

Wilcoxon's test, the first one provides the safer option, also confirmed by Tryfonidis et al.[20].

Considered a relatively safe procedure, since it was initially described, wrist arthroscopy has undergone many advances[22] that led to widespread uptake and exploration of new therapeutic possibilities[23,24]. The range of treatments implied is expanding, progressively allowing wrist surgeons to describe more ambitious and complex surgeries, yet bringing new challenges and controversies[25,26]. Regarded currently as the gold standard[27] in the diagnosis and treatment of a variety of conditions, wrist arthroscopy with its clinical applications continue to expand, introducing more complex reconstructive and salvage procedures[28,1]. In comparison to open techniques, arthroscopic procedures significantly improve the post-operative management considering pain and early movement, thus permitting earlier resumption of daily activities and return to work. Respectively, wrist arthroscopy is an efficient and minimal invasive technique with low complication rates and good clinical results for common wrist pathologies[29]. Another view is the implementation of wrist arthroscopy not as primary procedure, but rather as a supplementary technique, which in many cases, such as arthroscopy assisted open reduction and ligament reconstruction, does not preclude open surgery[30,31]. Conversely, upcoming developments are likely to expand its role by adapting open procedures into arthroscopic, possibly leading in near future to the conversion of all open wrist surgeries to arthroscopic fashion[28,32]. Notably, with the newly implemented nanoscope, compared to traditional 2.7mm, utilizing dorsal portals in wrist arthroscopy becomes an even more safe and successful technique[33]. Nonetheless, safe zones free of any neurovascular structures should constantly be evaluated around every described portal.

CONCLUSION

In conclusion, this study improves further the results considering the safety of dorsal wrist arthroscopy portal sites. Regarding the limitations of this study, a possible future research fully replicating wrist arthroscopy procedures with arthroscopy instruments, including a greater amount of limbs, is assumed to enhance our results. Moreover, a possible correlation of safe zones with anthropometric measurements and a safety classification for wrist arthroscopy portals, are expected to minimize iatrogenic damage when establishing portals in wrist arthroscopy procedures.

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