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ORIGINAL STUDY

Safe zones in volar portals for wrist arthroscopy, evaluation of central portal : a cadaveric study

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The purpose of this cadaveric study is to determine safe zones utilizing volar portals for wrist arthroscopy, by quantitatively describing the neurovascular relationships of a volar radial and a volar ulnar wrist arthroscopy portals in comparison with those of a newly described volar central portal *(7)*, considering the advantages in visualization of volar portals for wrist arthroscopy over the standard dorsal *(19)*. The neurovascular structures and the tendons of nine frozen human cadaveric upper limbs were exposed, while the aforementioned volar portal sites were pointed out with pins. The horizontal distance between the portals and the closest neurovascular branch or tendon was measured with a digital caliper, followed by statistical analysis of the data. The median interquartile range distances from portals to structures at risk were measured and safe zones around each portal were established. This study provides a safe approach to the volar radial and ulnar aspects of the radiocarpal and midcarpal joints, while volar radial and ulnar portals should be considered for inclusion in the arthroscopic examination of any patient with radial and ulnar sided wrist pain respectively *(17,18)*. Regarding the volar central portal, it is reproducible, safe and both the above joints can be inspected through one single incision *(7)*.

Keywords : wrist arthroscopy ; volar portals ; volar approach

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INTRODUCTION

Wrist arthroscopy, a constant evolving essential diagnostic and therapeutic tool *(3)*, nowadays has a wide range of indications for several wrist disorders *(10,2)*, permitting the observation in the cartilage of the radiocarpal, midcarpal and distal radioulnar joint, the synovium, the capsular ligaments and the triangular fibrocartilage complex [tFCC] *(13,25,4)*. Due to the relative lack of neurovascular structures on the dorsum *(5,23)*, the standard arthroscopic portals *(9)* have been developed on the dorsal side of the wrist *(8,12,15)*, despite the fact that recent kinematic and biomechanical studies *(11)* underlined the importance of the dorsal capsular structures *(24)* and the palmar subregions of the interosseous ligaments in maintaining carpal stability *(20)*. However, using dorsal portals an important sector of the radiocarpal joint remains partially hidden in most wrists *(25)*, while visualization of the dorsal

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aspect of the distal radial articular surface is limited, particularly during arthroscopic synovectomy, arthroscopic radial styloidectomy and arthroscopic reduction of dorsal lip fractures of the radius *(22)*.

On the contrary, dorsal radiocarpal ligament and palmar subregion of the scapholunate interosseous ligament [SLIL] are more easily seen from a volar perspective, whereas the use of a volar portal also facilitates arthroscopic reduction of intra-articular fractures of the distal radius fractures by providing a clear view of the dorsal rim fragments *(20)*. Furthermore, there is growing evidence that the aforementioned structures need also to be evaluated in any patient who is undergoing arthroscopy for wrist pain, gradually increasing the need of viewing the wrist from a palmar perspective *(19)*. Currently the wrist joint can be thought of as a "box" which can be visualized from almost every perspective and it is not limited to a dorsal visualization. While volar radial [VR] and volar ulnar [VU] portals, may be useful in some situations to visualize and treat the different structures of the radial and ulnar sides of the wrist respectively, the complete evaluation of the wrist is difficult through only one of them, taking into consideration the difficult access into the midcarpal joint without causing damage to certain important ligaments. Hence, a volar central portal allows a complete evaluation of both the midcarpal and radiocarpal joints, and could be utilized when performing certain surgical techniques *(7)*.

The purpose of this cadaveric study is to quantitatively describe the anatomy and compare the safety of the VR, VU and volar central radiocarpal and midcarpal wrist arthroscopy portals, stressing the neurovascular relationships in the hope of minimizing injury to volar wrist structures at risk by establishing safe zones.

MATERIALS AND METHODS

In this prospective study, a total of nine frozen human cadaver upper limbs, six right and three left, were examined. There were four male and five female random cadaveric limbs, without available clinical histories of the cadavers. An anatomical study was performed in order to check the safety of the discussed portals. The arterial system was preinjected with a gelatin and lead oxide mixture *(14)* to highlight the arterial anatomy and to further enhance visualization. The specimens were dissected, using standard dissection tools, under 3.0 and 2.5 power loupe magnification to study the periportal anatomy.

The VR portal was established via a 2cm longitudinal incision made crossing the proximal wrist crease to expose the flexor carpi radialis [FCR] tendon sheath. Afterwards, the sheath was divided and the FCR tendon was retracted ulnarly. The radiocarpal joint space was identified with a 22-gauge needle and a pin was introduced through the floor of the sheath *(18,28)*. Respectively, the VU portal was established via a 2cm longitudinal incision made along the ulnar edge of the flexor digitorum superficialis [FDS] tendons at the proximal wrist crease. The finger flexor tendons were retracted radially and a pin was introduced into the radiocarpal joint *(17,28)*. The radiocarpal and midcarpal volar central portals were established via an incision that began at the distal wrist flexion crease and extended 1.5cm proximally, following the third intermetacarpal space. The first structures encountered were the FDS tendons. The fifth FDS tendon was identified and retracted with the rest of the flexor superficialis tendons toward the radial side. The next structures encountered were the flexor digitorum profundus [FDP] tendons. The plane between the third and fourth flexor profundus tendons was identified, and the fourth and fifth FDP tendons were retracted toward the ulnar side, while the third and second tendons were retracted toward the radial side. In this way, the capsular plane was reached. Pins in the radiocarpal and midcarpal portals were placed after the portals were identified *(7)*. A dorsal capsulotomy was performed in each specimen, with the pins left in place to assess their correct positioning and the ligamentous interval of the volar portals.

The structures considered at risk included the median nerve and its palmar cutaneous branch, the radial artery, the superficial radial nerve and the ulnar neurovascular bundle consisting of the ulnar artery and the ulnar nerve. The presence of any injury of the structures at risk and the distances to these structures from the volar portals were recorded

Table I. — Distances in millimeters (mm) from the VR portal to the volar structures at risk

Limb	Median Nerve	Palmar cutaneous branch of Median Nerve	Radial Artery	Superficial Radial Nerve
1	15.09	7.48	6.51	13.09
2	6.07	3.07	4.07	12.07
3	15.13	7.50	5.47	11.01
4	9.83	4.85	7.17	14.41
5	8.07	4.07	5.87	15.67
6	11.38	5.62	5.25	10.57
7	13.59	6.73	6.56	13.19
8	10.07	5.07	6.07	19.07
9	11.41	5.64	7.21	14.49
Median IQR (Q1-Q3)	**11.18 (9.83-13.59)**	**5.56 (4.85-6.73)**	**6.02 (5.47-6.56)**	**13.73 (12.07-4.49)**

and analyzed. The volar skin was excised and the distances were measured as the shortest distance from the pins located in the aforementioned portals to the corresponding pin located in the structure at risk, from the ulnar and the radial side accordingly, in the same anatomical plane of the structure. Measurements were taken using a universal digital caliper (Fowler 54-101-600-1), with centimeter accuracy of a millimeter, by A.G. and constantly observed by V.A. to ensure quality control. In particular, measures in the VR portal, were taken from the pin to the median nerve, the palmar cutaneous branch of median nerve, the radial artery and the superficial radial nerve. Respectively, in the VU portal measures were taken from the pin to the ulnar artery and the ulnar nerve. Considering the radiocarpal and midcarpal volar central portals, the measures were taken from the pin to the ulnar nerve, the ulnar artery, the median nerve and the palmar cutaneous branch of median nerve. Finally, it was decided to obtain the measures of all distances after removing the retractors, in order to notice which structure was at higher risk, despite the fact that in real practice the portals were created using retractors.

Statistical analysis of the measurements was performed with SPSS software for Windows (version 22.0.0.0). Nonparametric statistical tests were used because of the small sample and the fact that the values were not normally distributed. The values were expressed as median and interquartile range (IQR). The Friedman's rank test for K related samples and the Wilcoxon's matched pairs signed-rank test were used to perform paired comparisons of portals. Correction of statistical significance was not used. Statistical significance was defined as $p < 0.05$, while power analysis was not performed because it was not known what effect size to expect.

RESULTS

There were no iatrogenic damages to the flexor tendons, the median nerve and its palmar cutaneous branch, the radial artery, the superficial radial nerve and the ulnar neurovascular bundle in any of the cadaveric limbs.

The median interquartile range [IQR] distances from the VR portal to the median nerve, the palmar cutaneous branch of median nerve, the radial artery and the superficial radial nerve were 11.18 (9.83-13.59), 5.56 (4.85-6.73), 6.02 (5.47-6.56) and 13.73 (12.07-14.49) mm, respectively (Table I). There was a greater than 4.85 mm safe zone surrounding the VR portal that was free of any neurovascular structures.

The median IQR distances from the VU portal to the ulnar artery and the ulnar nerve were 4.80 (3.74-5.16) and 5.78 (4.60-6.08) mm, respectively (Table II). There was a greater than 3.74 mm safe zone surrounding the VU portal that was free of any neurovascular structures.

Table II. — Distances in millimeters (mm) from the VU portal to the volar structures at risk

Limb	Ulnar Artery	Ulnar Nerve
1	3.74	4.60
2	3.67	4.40
3	4.32	5.85
4	4.27	5.12
5	5.07	6.08
6	3.58	4.23
7	5.16	5.67
8	6.67	8.00
9	6.73	8.08
Median IQR (Q1-Q3)	**4.80 (3.74-5.16)**	**5.78 (4.60-6.08)**

The median IQR distances from the volar central radiocarpal portal to the ulnar nerve, the ulnar artery, the median nerve and the palmar cutaneous branch of median nerve were 8.36 (6.76-8.48), 6.93 (5.30-7.07), 9.39 (6.56-10.47) and 16.46 (13.05-20.27) mm, respectively (Table III). There was a greater than 5.30 mm safe zone surrounding the volar central radiocarpal portal that was free of any neurovascular structures.

The median IQR distances from the volar central midcarpal portal to the ulnar nerve, the ulnar artery, the median nerve and the palmar cutaneous branch of median nerve were 6.84 (4.64-10.55), 5.70 (3.87-8.79), 7.21 (4.87-9.82) and 15.07 (13.51-18.93) mm, respectively (Table IV). There was a greater than 3.87 mm safe zone surrounding the volar central

Table III. — Distances in millimeters (mm) from the volar central radiocarpal portal to the volar structures at risk

Limb	Ulnar Nerve	Ulnar Artery	Median Nerve	Palmar cutaneous branch of Median Nerve
1	8.32	6.93	10.33	20.59
2	6.08	5.07	7.77	15.77
3	12.52	10.43	14.83	21.07
4	7.69	6.41	6.56	13.05
5	8.48	7.07	10.47	18.47
6	6.79	5.30	5.63	11.19
7	6.76	5.67	6.31	12.55
8	12.68	10.57	14.97	20.27
9	5.92	4.93	7.63	15.19
Median IQR (Q1-Q3)	**8.36 (6.76-8.48)**	**6.93 (5.30-7.07)**	**9.39 (6.56-10.47)**	**16.46 (13.05-20.27)**

Table IV. — Distances in millimeters (mm) from the volar central midcarpal portal to the volar structures at risk

Limb	Ulnar Nerve	Ulnar Artery	Median Nerve	Palmar cutaneous branch of Median Nerve
1	4.64	3.87	4.87	9.67
2	4.48	3.73	4.73	14.73
3	10.88	9.07	10.10	20.13
4	5.15	4.29	6.79	13.51
5	5.32	4.43	6.93	15.93
6	4.31	3.59	4.59	9.11
7	5.48	4.57	7.07	14.07
8	10.72	8.93	9.96	18.93
9	10.55	8.79	9.82	19.57
Median IQR (Q1-Q3)	**6.84 (4.64-10.55)**	**5.70 (3.87-8.79)**	**7.21 (4.87-9.82)**	**15.07 (13.51-18.93)**

Table V — Results of statistical analysis using the Friedman's rank test for K related samples to perform comparisons for VR and volar central portals regarding their distance to the structures at risk

	VR portal	Volar central radiocarpal portal	Volar central midcarpal portal	p
	n = 9	n = 9	n = 9	
Median Nerve	11.18 (9.83-13.59)	9.39 (6.56-10.47)	7.21 (4.87-9.82)	**0.018**
Palmar cutaneous branch of Median Nerve	5.56 (4.85-6.73)	16.46 (13.05-20.27)	15.07 (13.51-18.93)	**0.001**

Table VI. — Results of statistical analysis using the Friedman's rank test for K related samples to perform comparisons for VU and volar central portals regarding their distance to the structures at risk

	VU portal	Volar central radiocarpal portal	Volar central midcarpal portal	p
	n = 9	n = 9	n = 9	
Ulnar Artery	4.80 (3.74-5.16)	6.93 (5.30-7.07)	5.70 (3.87-8.79)	**0.008**
Ulnar Nerve	5.78 (4.60-6.08)	8.36 (6.76-8.48)	6.84 (4.64-10.55)	**0.008**

Table VII. — Results of statistical analysis using the Wilcoxon's matched pairs signed-rank test to perform paired comparisons for VR and volar central radiocarpal portals regarding their distance to the structures at risk

	VR portal	Volar central radiocarpal portal	p
	n = 9	n = 9	
Median Nerve	11.18 (9.83-13.59)	9.39 (6.56-10.47)	**0.214**
Palmar cutaneous branch of Median Nerve	5.56 (4.85-6.73)	16.46 (13.05-20.27)	**0.008**

Table VIII. — Results of statistical analysis using the Wilcoxon's matched pairs signed-rank test to perform paired comparisons for VR and volar central midcarpal portals regarding their distance to the structures at risk

	VR portal	Volar central midcarpal portal	p
	n = 9	n = 9	
Median Nerve	11.18 (9.83-13.59)	7.21 (4.87-9.82)	**0.008**
Palmar cutaneous branch of Median Nerve	5.56 (4.85-6.73)	15.07 (13.51-18.93)	**0.008**

midcarpal portal that was free of any neurovascular structures.

Comparisons using the Friedman's rank test for K related samples, applying nonparametric statistics, showed that VR portal was safer than volar central portals in terms of the distance to the median nerve ($p = 0.018$) but volar central portals were safer than VR portal in terms of the distance to the palmar cutaneous branch of median nerve ($p = 0.001$) (Table V). Furthermore, volar central portals were safer than VU portal in terms of the distances to the ulnar artery ($p = 0.008$) and ulnar nerve ($p = 0.008$) (Table VI).

Paired comparisons using the Wilcoxon's matched pairs signed-rank test, applying nonparametric statistics, showed that the volar central radiocarpal portal was safer than VR portal in terms of the distance to the palmar cutaneous branch of median nerve ($p = 0.008$), however due to the small number of limbs examined no significant differences were

Table IX. — Results of statistical analysis using the Wilcoxon's matched pairs signed-rank test to perform paired comparisons for VU and volar central radiocarpal portals regarding their distance to the structures at risk

	VU portal	Volar central radiocarpal portal	p
	n = 9	n = 9	
Ulnar Artery	4.80 (3.74-5.16)	6.93 (5.30-7.07)	**0.028**
Ulnar Nerve	5.78 (4.60-6.08)	8.36 (6.76-8.48)	**0.021**

Table X. — Results of statistical analysis using the Wilcoxon's matched pairs signed-rank test to perform paired comparisons for VU and volar central midcarpal portals regarding their distance to the structures at risk

	VU portal	Volar central midcarpal portal	p
	n = 9	n = 9	
Ulnar Artery	4.80 (3.74-5.16)	5.70 (3.87-8.79)	**0.173**
Ulnar Nerve	5.78 (4.60-6.08)	6.84 (4.64-10.55)	**0.173**

Table XI. — Results of statistical analysis using the Wilcoxon's matched pairs signed-rank test to perform paired comparisons for volar central radiocarpal and midcarpal portals regarding their distance to the structures at risk

	Volar central radiocarpal portal	Volar central midcarpal portal	p
	n = 9	n = 9	
Ulnar Artery	6.93 (5.30-7.07)	5.70 (3.87-8.79)	**0.11**
Ulnar Nerve	8.36 (6.76-8.48)	6.84 (4.64-10.55)	**0.11**
Median Nerve	9.39 (6.56-10.47)	7.21 (4.87-9.82)	**0.066**
Palmar cutaneous branch of Median Nerve	16.46 (13.05-20.27)	15.07 (13.51-18.93)	**0.314**

found regarding the distance to the median nerve (p = 0.214) (Table VII). VR portal was safer than volar central midcarpal portal in terms of the distance to the median nerve (p = 0.008), but volar central midcarpal portal was safer than VR portal in terms of the distance to the palmar cutaneous branch of median nerve (p = 0.008) (Table VIII). Volar central radiocarpal portal was safer than VU in terms of the distances to the ulnar artery (p = 0.028) and ulnar nerve (p = 0.021) (Table IX). Moreover, due to the aforementioned small number of limbs examined, no significant differences were found regarding the distances to the ulnar artery (p = 0.173) and ulnar nerve (p = 0.173) between VU and volar central midcarpal portals (Table X), as well the distances to the ulnar artery (p = 0.11), ulnar nerve (p = 0.11), and palmar cutaneous branch of median nerve (p = 0.314) between volar central radiocarpal and midcarpal portals. Finally, volar central radiocarpal portal was safer than midcarpal in terms of distances to the median nerve (p = 0.066) (Table XI).

DISCUSSION

Wrist arthroscopy, considered a relatively safe procedure, has undergone many advances since it was initially described *(27)* and the range of treatments that is implied is expanding, yet bringing

new controversies and challenges *(6)*. Currently, it is regarded as the gold standard *(16)* in the diagnosis and treatment of a variety of conditions, such as scapholunate instability, while its clinical applications continue to expand with more complex reparative, reconstructive, and salvage procedures *(3)*. In comparison to open techniques, arthroscopic procedures significantly improve the post-operative management, considering early movement and pain, permitting earlier resumption of daily activities and return to work. Furthermore, wrist arthroscopy should now be viewed not as primary procedure, but rather as an adjunctive technique, which in many cases does not preclude open surgery *(21)*. Future developments, such as robotic surgery and minimally invasive techniques, are likely to expand its role by adapting open reconstructive procedures into arthroscopic procedures *(26)*. Utilizing volar portals in wrist arthroscopy is considered a safe and successful technique when dealing with various kinds of wrist disorders, expanding the therapeutic options, while posing a valuable and safe alternative, especially for dorsal capsular problems *(25)*. Therefore, it is highly recommend that all wrist arthroscopists become familiar with the volar approach *(1)*.

In this study, safe zones, free of any neurovascular structures, were established around each described volar arthroscopic portal, taking into consideration the median IQR distances from every portal to each seperate structure at risk. It was found that there was a greater than 4.85 safe zone surrounding the VR portal, compared to Slutsky *(18)* with a greater than 3 mm safe zone, while also considering palmar cutaneous branch of median nerve the structure at greater risk. Respectively, there was a greater than 3.75 safe zone surrounding the VU portal, compared to Slutsky *(17)* with a greater than 5 mm safe zone, where ulnar artery was found the structure at greater risk. In regard to the newly described central portals *(7)*, there was a greater than 5.30 and 3.87 mm safe zone surrounding the volar central radiocarpal and midcarpal portals respectively, with ulnar artery the structure at greater risk.

Moreover, Friedman's rank test showed that volar central portals were in general safer than VR and VU portals in terms of the distance to the respective structure at risk. Specifically, volar central portals were safer than VR portal in terms of the distance to the palmar cutaneous branch of median nerve and safer than VU portal in terms of the distances to the ulnar artery and ulnar nerve, while VR portal was safer than volar central portals in terms of the distance to the median nerve. On the contrary, Wilcoxon's matched pairs signed-rank test between the portals, showed no significant differences in the majority of pairs, due to the small number of the limbs examined. However, as demonstrated in this study, volar central radiocarpal portal was safer than VR portal in terms of the distance to the palmar cutaneous branch of median nerve and safer than VU in terms of the distances to the ulnar artery and ulnar nerve. In addition, volar central midcarpal portal was safer than VR portal in terms of the distance to the palmar cutaneous branch of median nerve, while VR portal was safer than volar central midcarpal portal in terms of the distance to the median nerve. Finally, volar central radiocarpal portal was safer than midcarpal in terms of distances to the median nerve, confirming Corella et al *(7)*.

To conclude, this study further improves the results considering the safety of volar central portals over VR and especially VU portals. A future research including a greater amount of limbs is expected to enhance the results of this study.

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