SO YOU THINK YOU HAVE READ THIS JOURNAL?

1) Which three portals place the dorsal branch of the ulnar nerve at greatest risk?

The 6 Ulnar, 6 Radial and ulnar midcarpal portals.

2) Which two portals place the superficial branch of the radial nerve at greatest risk?

The 1-2 and 3-4 portals.

3) Which two portals place the posterior interosseous nerve at greatest risk?

The 3-4 and 4-5 portals.

Assessment of the structures at risk during wrist arthroscopy; a cadaveric study and systematic review

ABSTRACT

We assessed the proximity of neurological structures to arthroscopic portals in a cadaveric study and through a systematic review. Arthroscopy was performed on ten cadaveric wrists. Subsequently the specimens were dissected to isolate the superficial branch of the radial nerve, the dorsal branch of the ulnar nerve, the posterior interosseous nerve and the extensor tendons. We measured the distances from the nerves to common portals. For the systematic review Pubmed and EMBASE were searched on the 31st May 2014 for cadaveric studies reporting the proximity of neurological structures to any arthroscopic wrist portal. In the cadaveric study, partial injuries were seen to six extensor tendons and one posterior interosseous nerve; it was assumed this was due to creation of the portals. Seven published studies were included in the systematic review. The dorsal sensory branch of the ulnar nerve was found to be at risk by performing the 6 Ulnar, 6 Radial and ulnar midcarpal portals, the sensory branch of the radial nerve by the 1-2 and 3-4 portals and the posterior interosseous nerve by the 3-4 and 4-5 portals.

Level of evidence: V

INTRODUCTION

Important extra-articular soft tissues especially nerves and tendons are at risk at wrist arthroscopy (Ahsan and Yao, 2012; Culp, 1999; De Smet, 2002). A recent systematic review reported that the prevalence of complications following wrist arthroscopy as 4.7% (Ahsan and Yao, 2012), although the authors suggested this may be an underestimate because of the low number of documented studies. Previous studies have reported injuries to the dorsal sensory branch of the ulnar nerve (DBUN) (Lourie et al., 1994; Gallego and Mathoulin, 2010; Tsu-Hsin et al., 2006; Nguyen et al., 2011), the sensory branch of the radial nerve (SBRN) (Gallego and Mathoulin, 2010; Chen et al., 2010), the posterior interosseous nerve (PIN) (del Pinal et al., 1999) and extensor tendons (Hofmeister et al., 2001). Complications can be due to traction, positioning of the arm, establishing the portals and procedure-specific injuries (Culp, 1999; Warhold and Ruth, 1995). Poor positioning of portals may risk damage to articular cartilage, ligaments, tendons, cutaneous nerves and vascular structures (De Smet, 2002). The knowledge of nerve anatomy can help to prevent injury (Root et al., 2013).

The aims of this study were to evaluate the proximity of neurological structures and tendons to arthroscopic portals in a cadaveric study and to conduct a systematic review of injuries following wrist arthroscopy.

METHODS

Ten thawed fresh frozen forearm cadaver specimens underwent wrist arthroscopic procedures as part of a practical cadaveric course for surgeons who perform wrist arthroscopy in their daily practice. The duration of arthroscopic surgery ranged from 60 to 180 minutes and included a diagnostic procedure followed by a repair of the triangular fibrocartilaginous complex. These procedures were performed sequentially by two surgeons. During these procedures 1-2, 3-4, 4-5, 6 Radial (6R) and 6 Ulnar (6U) radio-carpal portals, and radial and ulnar midcarpal portals were created. Initially a 22-gauge needle was used to establish the correct position and orientation for the portals. A small incision was made in the skin centred over the needle and then careful dissection through the deep tissues using tenotomy scissors to separate the soft tissues and enter the joint capsule.

Subsequently we dissected the cadaver limbs to assess the positions of the superficial sensory nerves (DBUN, SBRN and PIN) and extensor tendons relative to the arthroscopic portals. Each portal was marked with a hypodermic needle wire before a careful open dissection was performed by one fellowship trained wrist surgeon without magnification. A dorsal midline incision was made from the head of the middle finger metacarpal proximally to the mid forearm; all dorsal skin and subcutaneous tissues were excised to expose the extensor tendons and nerve branches. Digital calipers were used to record the closest distances from the structures and each arthroscopic portal (marked by a hypodermic needle). The measurements were performed, whilst the forearm was in a neutral position, by two surgeons independently and the mean recording used. Any damage to nerves or extensor tendons was recorded.

A systematic review was performed using the online databases Pubmed and EMBASE on 31st May 2014. The systematic review was conducted in accordance with the PRISMA guidelines (Appendix 1). However, as the authors are unaware of a validated quality assessment scale

for cadaveric studies, only a narrative critical appraisal was performed. The search terms used are shown in Appendix 2. The inclusion criteria were a cadaveric study reporting the proximity of a neurological structure to a wrist portal, there was no restriction on the number of portals reported in each study or the technique used to establish or mark the portal sites for measurement. The exclusion criteria were cadaveric studies reporting the anatomy of superficial nerves without specific measurement of proximity to these neurological structures. The eligibility of studies was assessed independently by two authors and any disagreements resolved by discussion.

Cadaveric study analysis

We analysed data for each nerve separately and so fitted three separate models corresponding to the three nerves (DBUN, SBRN and PIN). Each model, corresponding to each nerve, was fitted to estimate distances to each nerve from multiple portals; the fitted statistical model included distances to each nerve from multiple portals. The distances of each nerve to the different portals are likely to be correlated as they are taken from the same specimen. To account for this correlation between distances obtained from the same specimen, we analysed the cadaveric study data by fitting linear mixed models, which are multivariate statistical models appropriate for analysing correlated data. The explanatory variable in all models is the portal. Consequently, for a model, the estimate for intercept gives the estimated distance to the nerve from the reference category portal. Linear mixed models require data to be distributed normally. The presence of many zero distances i.e. where the nerve directly lies over the portal, is an indication that the data may not be distributed normally. Therefore, for

each nerve, we did not include data for a portal in the linear mixed model if distances to the nerve were zero in numerous samples. To ascertain whether data used in the statistical models were normally distributed, we assessed the histograms of the residuals. The data showed that the distances from a nerve to different portals e.g. the distances from DBUN to portal 1-2 and from DBUN to portal 4-5, varied considerably. Therefore, we fitted linear mixed models that allowed for heterogeneous (unequal) variances for distances between a nerve and each portal. We assumed that a correlation existed between the distances from a nerve to any two given portals. We report estimated mean distances, 95% confidence intervals (CI) and the standard deviations (SD) of the distances, taken as the square root of the estimated variances. For a nerve to be considered safe, in normally distributed data, 99% of the data should be above the value obtained by subtracting 2.33 SDs from the mean. Therefore, for each portal and nerve, we calculated this value. A value above zero indicates that the portal is 99% safe. If it is below zero it implies an appreciable risk of nerve injury.

Systematic review analysis

In the papers each nerve (DBUN, SBRN or PIN) was analysed separately. If more than one study reported distances to a specific portal, the ranges of the distances, means and standard deviations (SD) were noted. If the range of at least one study included a zero value or the mean minus two SDs was less than zero we report that this portal is very close to the nerve without performing a formal statistical analysis to obtain the aggregate mean based on all the studies. If the value obtained from subtracting two SDs from the mean corresponds to the point below which 5% of data are contained this is an indication that there is a high probability that a portal crosses the nerve. Likewise if this value corresponds to the point

above which 5% of data are contained this is an indication that the nerve is very unlikely to be injured. We then combined the results of all the studies to obtain a pooled mean and a 95% CI using meta-analysis technique. Some studies used frozen specimens and other used fresh specimens. We used a random effects meta-analysis technique to account for this.

RESULTS

Cadaveric study

In nine of the ten cadaveric specimens the DBUN had two main branches with the tenth specimen having three. The DBUN branched at a mean of 5.8cm (range 4.6 – 7.2cm) proximal to the ulnar head. The median number of branches of the SBRN was 2.5 (range 2-4); the SBRN branched at a mean of 4.6 (range 3-7) cm proximal to the radial styloid. The range of distances in mm from the portals to the DBUN, SBRN and PIN are reported in Table 1.

Insert Table 1

The presence of numerous zero values precluded the inclusion of the following distances whilst fitting the linear mixed models; the DBUN to the 6U portal (7 zero values) and the SBRN to the 1-2 portal (4 zero values). The remaining data were included in three linear mixed models that indicated that an assumption that the data were normally distributed was reasonable.

DBUN: The 6R portal had the smallest mean distances from the DBUN (Table 2). When 2.33 SDs were subtracted from the estimated means there were negative values for the 6R and ulnar midcarpal portals. There were seven zero values for the 6U portal. Therefore these portals are potentially so close to the DBUN that their use places the nerve at risk.

SBRN: The radial midcarpal portal was the closest portal to the SBRN. When 2.33 SDs were subtracted from the estimated means, all values are greater than zero which indicate that only use of the 1-2 portal, which had four zero values, places the SBRN at risk.

PIN: The 3-4 portal had the shortest mean distance from the PIN. When 2.33 SDs were subtracted from the estimated means there were negative values for the 3-4 and 4-5 portals suggesting these portals place the PIN at risk.

In summary, none of the seven portals seem to be sufficiently far from all the three nerves DBUN, SRN and PIN to be certain of avoiding nerve injury. Despite the proximity of the portals to nerve branches previously described in only one cadaveric specimen was a nerve injury identified; this occurred during the introduction of a capsulodesis stitch resulting in tethering of the PIN.

Insert Table 2

At dissection all three nerves that we studied were found to run directly under a skin portal in at least one specimen. In addition six extensor tendons were noted to have been injured: in three cases the tendon sheath was scuffed (extensor digitorum communis (EDC) to the index finger, EDC to the middle finger and extensor carpi ulnaris (ECU); in two cases there was an appreciable laceration to an extensor tendon (30% of the ECU tendon through placement of

the 6U portal and 50% to the EDC to the index finger through the 3-4 portal); and in one case the extensor digitii minimi had been included in a stitch passed through the 6R portal during TFCC repair.

Systematic review

During the systematic review 359 studies were identified. After exclusion of duplicates and implementation of inclusion and exclusion criteria seven studies were included for review (Fig 1). The data from these studies is shown in Tables 3 and 4 and Figure 2.

Of the seven studies included in the review, three were performed on fresh cadavers (Abram et al., 1994; Auerbach et al., 1994; Slutsky et al., 2002) and four on preserved specimens (Tryfonidis et al., 2009; Tindall et al., 2006; Kilic et al., 2009, Ehlinger et al., 2005). Comparison of the mean distances from the DBUN and SBRN to the portals is shown in Tables 3 and 4. Five studies attempted to imitate the arthroscopic portals; three used a pin and the other two used an arthroscope (Slutsky, 2002; Abram et al., 1994).

Insert Figure 1 and 2, Table 3 and 4

DBUN: Three studies reported the proximity of the DBUN to commonly used arthroscopic portals (Tryfonidis et al., 2009; Tindall et al., 2006; Abram et al., 1994). One study (Ehlinger et al., 2005) reported only on the transverse branch of the DBUN. Tindall et al. (2006) assessed 20 wrists. They marked a line between the ulnar styloid and the fourth webspace and

measured where the DBUN crossed this line. They reported that the DBUN crossed the line at a mean of 2.4 (range 1.8-2.8) cm from the ulnar styloid. They concluded that insertion of portals in the proximal fifth of this line was "safe". Overall the DBUN is at risk from use of the 6U and 6R portals with reported cases of the nerve running in the line of the respective portals.

SBRN**:** Five studies reported the proximity of the SBRN to the commonly used portals (Tryfonidis et al., 2009; Kilic et al., 2009; Slutsky, 2002; Abram et al., 1994; Auerbach et al., 1994). (Table 4). The distance from the 1-2 portal was assessed in four studies. The ranges in two studies, one using preserved specimens (Tryfonidis et al. 2009) and the other using fresh frozen specimens (Shyamalan et al. 2015) include values of zero. In addition there were means of the distances minus two SDs which were less than zero meaning that the SBRN is at risk from use of the 1-2 portal. The SBRN is also at risk from use of the 3-4 portal as shown by two studies including zero values and means minus two SDs of less than zero (Tryfonidis et al., 2009; Auerbach et al., 1994). Volar portals and other standards dorsal portals are sufficiently distant from the SBRN as to present no risk of injury to the nerve

DISCUSSION

In our cadaveric study, the SBRN was at risk from use of the 1-2 portal; the mean distance was 1.6mm (0-8). The systematic review revealed that of three studies analysing the

proximity of the SBRN to the 1-2 portal, one also reported the nerve to be at risk (Tryfonidis et al., 2009). In addition, of four studies analysing the proximity of the SBRN to the 3-4 portal, two (Auerbach et al., 1994 and Tryfonidis et al., 2009) reported the SBRN at risk according to our criteria. However in our cadaveric study the SBRN was not at risk from use of the 3-4 portal.

The DBUN was at risk in our cadaveric study from use of the 6U, 6R and ulnar midcarpal portals; the 6U portal had numerous zero values whilst the 6R and ulnar midcarpal portals had a negative value when subtracting 2.33 SDs from the mean. In the systematic review one study (Tryfonidis et al. 2009) reported the DBUN to be at risk from use of the 6U portal. The DBUN was not placed at risk from use of the 6R or the ulnar midcarpal portals.

The PIN was found to be at risk in our cadaveric study with use of both the 3-4 and 4-5 portals with mean distances of 4.4 (range 0-10) mm and 12.6 (range 2-25) mm respectively. This has not previously been reported in the literature.

The methodology of the studies reviewed did vary limiting our ability to compare the results. The choice of which portals and nerves to report varied considerably; some studies used a trocar or arthroscope to imitate the procedure whereas others inserted pins into the sites. Insertion of an arthroscope may alter anatomy and is more likely to damage structures then pins alone; it more accurately reflects clinical practice. Three studies were performed on fresh specimens whereas the others specimens were preserved. The variable numbers of portals reported in each study and the small numbers for each meant that there was insufficient data to compare results between preserved and fresh frozen specimens. There are problems in these cadaveric studies. Cadaver specimens may respond differently to live patients. The effect of preservation as opposed to freezing on the mobility of the soft tissues is not known and may have affected measurements. The wrist was not placed in traction in any of the

reviewed studies and in only one was an attempt made to replicate the position of wrist during the procedure.

Our cadaveric study was designed to address some of these limitations. Fresh frozen specimens were used and portals created whilst the limb was held in finger traction to resemble the clinical situation. Measurements were made and recorded between the nerves and all portals before inspection of the extensor tendons for injury. However there are limitations: the care taken in making the portals in a cadaver may have varied from true clinical practice making damage to surrounding structures more likely; the specimens had undergone prolonged arthroscopic procedures which might have increased the chance of injury; during the dissection the nerves and tendons may have displaced resulting in inaccurate readings, a limitation present in most cadaveric studies. Assessment of nerve and tendon damage was performed without magnification so there is a possibility that minor injuries to these structures may have been overlooked. Although the systematic review was performed according to the PRISMA criteria, improvements could have been made by prior registration of the review and production of a tool to measure the quality of cadaveric studies.

Despite the limitations described cadavers provide additional data on the proximity the SBRN and DBUN to the wrist portals. This study demonstrates that use of the 1-2 portal places the SBRN at risk and use of the 6U, 6R and ulnar midcarpal portals place the DBUN at risk. This study provides the first cadaveric data on the proximity of the PIN to wrist portals and has shown that use of the 3-4 and 4-5 portals place the PIN at risk.

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Table 1: Range of distances in mm from the portals to the DBUN, SBRN and PIN

Table 2: Parameter estimates for distance between each portal and each nerve

Figure 1: PRISMA Flow diagram

Table 3: Summary of distances of various portal to DBUN

Table 4: Summary of distances of various portals to SBRN

Figure 2: Mean distance (95% Confidence Interval) from various portals to dorsal branch of ulnar nerve and superficial branch of the radial nerve

Appendices

Appendix 1 – Demonstration of compliance with PRISMA checklist for systematic reviews

Appendix 2 - Search strategy for Pubmed

Table 2: Parameter estimates for distances between each nerve and each portal (mm)

Portal	Dorsal branch of ulnar nerve			Superficial Branch of radial nerve			Posterior Interosseous Nerve		
	Mean (95% CI)	**SE**	**SD**	**Mean (95% CI)**	**SE**	**SD**	**Mean (95% CI)**	**SE**	**SD**
1-2	69 (63-76)	2.95	9.3	†	†	†	26 (22-31)	2.09	6.6
3-4	44 (38-50)	2.78	8.8	25 (22-29)	1.60	5.1	4 (2-7)‡	1.11	3.5
4-5	21 (18-25)	1.70	5.4	43 (36-50)	2.99	9.5	13 (7-18)‡	2.44	7.7
6 Radial	8 (4-11)‡	1.55	4.9	61 (54-69)	3.21	10.1	25 (19-31)	2.62	8.3
6 Ulnar	†	†	†	70 (62-78)	3.74	11.8	34 (29-39)	2.26	7.1
Ulnar midcarpal	25 (16-35)‡	4.18	13.2	40 (33-48)	3.27	10.3	12 (10-14)	0.77	2.4
Radial midcarpal	41 (35-46)	2.53	8.0	24 (17-30)	2.96	9.3	13 (9-17)	1.66	5.2
	Estimated correlation = 0.33			Estimated correlation = 0.49			Estimated correlation = 0.08		

CI: Confidence interval

SE: Standard error for the estimated mean

SD: Standard deviation of the distances from the portal; SDs are obtained by taking square roots of estimated variances.

† Data for this portal was not included in the model because of the many zero distances

‡ When subtracting 2.33 SD from the estimated mean there were values less than zero

Table 3: Summary of distances from dorsal branch of ulnar nerve to various portal

Study	n	Portal: Mean distance in mm (standard deviation), Range			
		4-5	**6 Ulnar**	**6 Radial**	**Ulnar Metacarpal**
Preserved specimens					
Tryfonidis *et al. 2009*	20	18 (5.2), 9-27	3 (2.8), 0-11*	ND	ND
Tindall *et al. 2006*	20	ND	ND	Safe area described	ND
Ehlinger *et al. 2005*	45	4 (‡), 1-11	5 (‡), 1-12	4 (‡), 1-15	ND
Fresh frozen specimens					
Abram *et al. 1994*	19	ND	5 (2.7), 2-12†	8 (3.6), 0-14†	15 (4.6), 4-25
Shyamalan *et al. 2015*	10	21 (5.2), 13-32	1 (2.4), 0-8*	8 (4.2), 2-14	25 (12.4), 9-56

ND=Not done;
* Many zeros and mean and SD suggest data are not normally distributed;
† Although the range includes 0, mean and SD suggest data are symmetric and so the study was included in the meta-analysis;
‡ SD unavailable and so the study was not included in meta-analysis.

Table 4: Summary of distances of various portals to the superficial branch of the radial nerve

Study	n	Portal: Mean distance in mm (standard deviation), range			
		1-2	**3-4**	**Radial Midcarpal**	**Volar**
Slutsky *et al. 2002*	5	ND	ND	ND	16‡, 12-19
Auerbach *et al. 1994*	20	ND	4 (4.3), 0-14*	ND	ND
Tryfonidis *et al 2009.*	20	3 (4.5), 0-19*	9 (13.7), 0-48*	10 (5.6), 1-20	ND
Kilic *et al. 2009*	6	5 (3), 2-12	9 (5), 2-19	8 (5), 1-16	ND
Abram *et al. 1994*	19	3 (1.5), 1-6†	16 (5.8), 5-22	16 (6.3), 5-26	ND
Shyamalan *et al. 2015*	10	2 (2.3), 0-8*	25 (5.1), 15-33	24 (8.0), 13-42	ND

ND=Not done;
* Many zeros and mean and standard deviation (SD) suggest data are unlikely to be normally distributed;
† Sample size for this portal is 14;
‡ This is a median as the mean and SD were not reported.

Figure 2: Mean distance (95% Confidence Interval) from various portals to the dorsal branch of the ulnar nerve and the superficial branch of the radial nerve