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Portal placement in elbow arthroscopy and risk of injury to major nerves and vessels: a cadaveric study

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ABSTRACT

Background: Elbow arthroscopy is one of the popularly used surgical procedures in treating various elbow pathologies. Cadaveric data on the safety of arthroscopic portals and data on outcome following an arthroscopic procedure of elbow is lacking. This study aimed to measure the distance of 5 arthroscopic portals from 7 selected neurovascular structures in cadaveric elbow in 3 different elbow positions.
Methods: Observational study was conducted at the All India Institute of Medical Science (AIIMS) Rishikesh, Uttarakhand India. A total 20 soft embalmed cadaveric elbow were dissected following placement of arthroscopic portals at different elbow positions. Data were compared and analysed using SPSS software with ANOVA test.
Results: Medial cutaneous nerve of forearm (MCNF) was injured (5/1020) which is <0.5% when using superomedial (SM) and anteromedial (AM) portals. Statistically significant change was found while considering Lateral cutaneous nerve of forearm (LCNF) from anterolateral (AL) portal at various angles of the elbow and brachial artery (BA) from AM portal. Rest of all structures did not show any statistical significance on changing angles of elbow flexion.
Conclusions: Minor nerves are at risk in certain portals. Position of AL portal is safer when compared to AM portal. With proper surgical guidelines, elbow arthroscopy is safe and much useful procedure which help the operating surgeon to choose the appropriate portal and also may aid in minimizing trauma to underlying structures during intervention.

Keywords: Portal placement, Elbow arthroscopy, Cadaver, Nerve injury

INTRODUCTION

Elbow arthroscopy has increased its popularity only in the last few decades. Initially, the technique was considered a tool only for diagnosing elbow pathology, but later it became a tool to get rid of loose bodies, and by now it has become one among various treatment methods for a wide variety of elbow problems. These consist of golfer's elbow and tennis elbow, loose body removal, joint contracture release, Arthralgia without a diagnosis, osteochondritis dissecans, debridement of the osteoarthritic elbow, joint instability, chronic valgus overload and many more. Since the variety of indications has increased, it is being used by a larger number of surgeons.[1-7]

The three major nerves, ulnar nerve (UN), median nerve (MN), radial nerve (RN) and various sensory nerves and vessels are at risk during portal insertion in the elbow joint. Because of the possibility of damage to the underlying nerves and arteries, it is likely one of the most hazardous arthroscopies. This is due to the proximity of these

structures and portals and due to a limited articular working space. Furthermore, at varying degrees of elbow flexion, the relationship between the portals and neurovascular systems changes during elbow arthroscopy, making it a dynamic operation.[8,9]

The neurovascular structures of the elbow identified for distance measurement in our study included all three major nerves (UN, MN and RN); these include the forearm's lateral cutaneous nerve (LCNF), medial cutaneous nerve (MCNF), and posterior cutaneous nerve (PCNF). [10]

Cadaveric data on the safety of elbow arthroscopic portals are lacking in the Indian population. We performed this study to determine the safety standards of the elbow arthroscopic procedure by cadaveric dissection and tried to focus on whether there is any risk of injury to these neurovascular structures while performing elbow arthroscopy.

METHODS

This observational study was carried out at the All India Institute of Medical Sciences' Department of Anatomy in Rishikesh, after proper approval from the institute ethical committee (Ref. No. AIIMS/IEC/18/503). The sample consisted of twenty soft embalmed adult cadaveric elbows of both right and left sides, aged more than 25 years. Traumatic elbows, previous elbow surgery, large scars, gross malformations and joint contractures were excluded from cadavers.

Procedure

Surface landmarks, the medial epicondyle, lateral epicondyle, and olecranon, were marked with a marker on the cadaver. Following that, the positions for establishing arthroscopic portals were also made (Figure 1). Five standard elbow arthroscopic portals, which were commonly used, were superolateral (SL), AL, straight posterior (SP), SM, and AM. In order to create the portals, 4 mm Steinmann pins were used, which are the same size as elbow arthroscopy portals (Figure 2).

A digital vernier calliper with a measuring range of 0-150 mm, resolution of 0.01 mm, and accuracy±0.02 mm of the linear capacitive measuring system was used to measure the distances from UN, MN, and RN to the relevant portals because it is not necessary to measure the distance of all neurovascular structures from all selected portals.

Field of view of portals

SM portal

A magnificent view of the ventral, lateral portion of the joint is offered by this portal. Its field of view is effective for both radio-humeral and radio-ulnar joints, and it is easily accessible. Supination and pronation improve the angle of visibility to 260 degrees, with around 100 degrees of the radial head's rim visible. Due to the instrument's proximity to the humerus, the most medial region of the ulno-humeral joint, near the portal, cannot be examined with this portal. The trochlea's curvature prevents an arthroscope from penetrating deeply into the joint space, as seen in Figure 3 (A and B).

AM portal

With the exception of the radio-ulnar joint, which is partially hidden by the coronoid process, this portal provides a great view of the ventral, lateral portion of the joint. It's easily accessible and has enough room to observe the radio-humeral joint. Similar to the supero-medial portal, the radial head's rim may be seen for about 100 degrees, and this angle grows to 260 degrees when the forearm is supinated and pronated. It is nearly impossible to examine the most medial portion of the ulno-humeral joint near the portal using this entry point. When utilised as a functioning portal, the radio-humeral joint offers outstanding accessibility and a clear field vision, as seen in Figure 3 (A and B).

SL portal

The lateral and dorsolateral aspects of the radio-humeral joint, the articular surface of the radial head, and the dorsolateral portion of the ulno-humeral joint up to the tip of the olecranon process can all be seen through this portal. During pronation and supination, this entry point shows about ¼ of the radial joint surface and ½ of the radial head's rim. Additionally, this location is used to inject fluid for joint distension prior to arthroscopy, as seen in Figure 3 (C and D).

AL portal

The ventral and medial portions of the joint can be seen through this portal. Only a small portion of the radio-ulnar joint and the ventromedial aspect of the radio-humeral joint were visible. Supination and pronation of the forearm increase the visibility of the radial head's rim circumference. When using the antero-lateral portal as a working portal, the majority of the observed area could be accessible, with the exception of the radio-ulnar and radio-humeral joints, as illustrated in Figures 3 (C and D).

DP portal

The medial and lateral portions of the posterior capsule, as well as the olecranon fossa, are visible through this portal. It is difficult to see the olecranon tip and the farther-reaching areas of the posterior compartment. The joint space is extremely small even at maximum joint distension, which limits the arthroscope's access. When the elbow flexion is greater than 60 degrees, this portal is rarely used. However, the SP portal might be a great working portal when the arthroscope is in any of the lateral portals, as shown in Figure 3 (E).

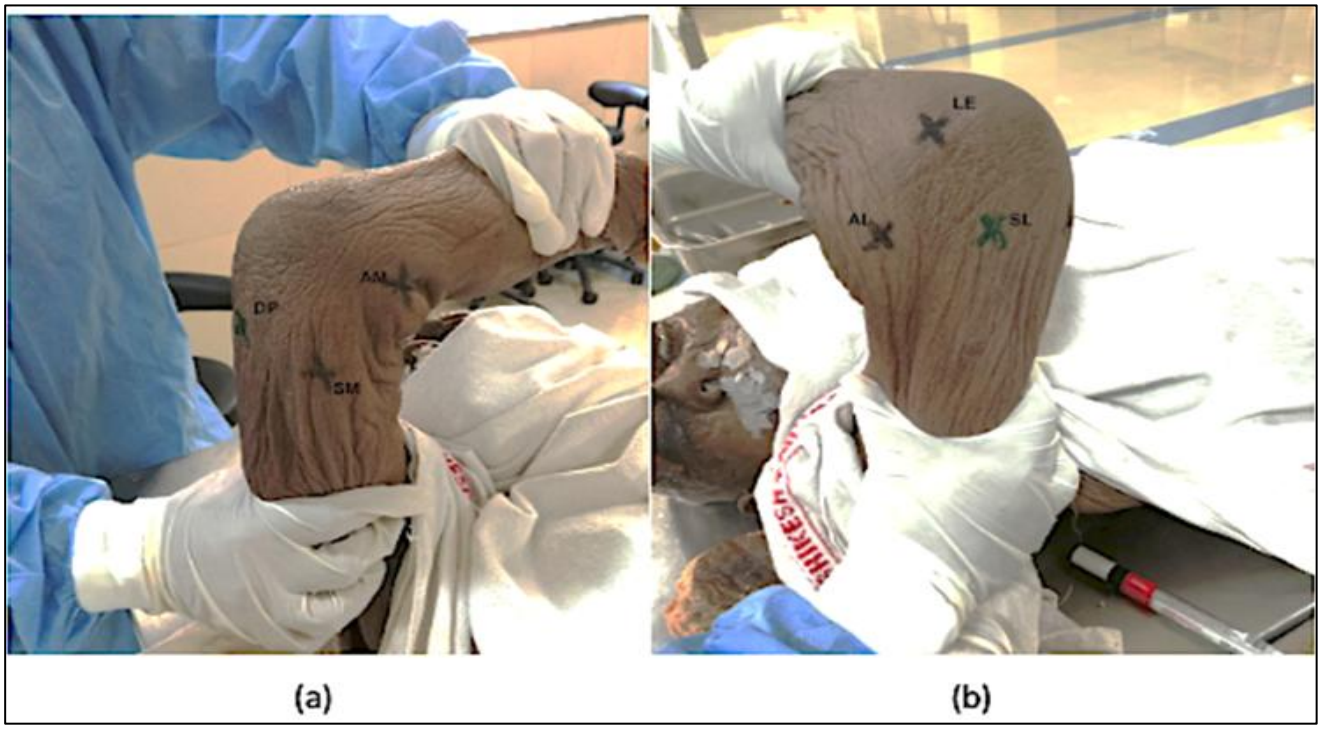

Figure 1 (a and b): Surface marking for positions for establishing arthroscopic portals (lateral view).
*LE: Lateral epicondyle, DP: Direct-posterior; SM: Superomedial; AM: Anteromedial; AL: Anterolateral; SL: Superolateral.

Figure 2: Steinmann pin on portal sites.
*SL-Superolateral, AL-Anterolateral, SM-Superomedial, AM-Anteromedial and SP-straight posterior.

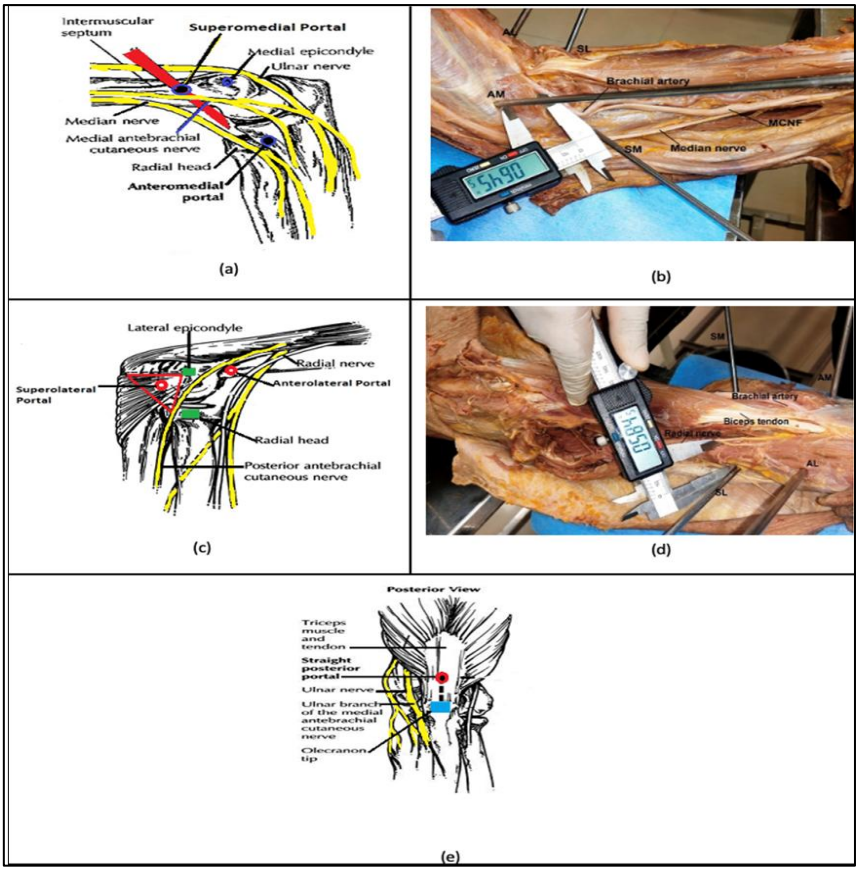

Figure 3 (A-E): Different sites of portals. (A and B)-schematic and cadaveric images of SM portal and AM portal. (C and D)-schematic and cadaveric images of SL portal and AL portal. (E)-schematic diagram of DP portal.

RESULTS

SPSS (Statistical package for the social sciences) version 21 software (IBM Corp., Released 2012. IBM SPSS Statistics for Windows, version 21.0. Armonk, NY, USA: IBM Corp.) was used for analysing the collected data. ANOVA test was used for statistical analysis (Table 1).

SM portal

This portal is located in front of the intermuscular septum, 2 cm proximal to the medial epicondyle. The UN, MN, MCNF, and BA were evaluated using this portal. Two individual cadavers' elbows were found to have MCNF injuries in every elbow position. In flexion, semi-flexion, and extension, the mean distance of MCNF from the portal was determined to be 4.31 mm, 4.50 mm, and 4.53 mm, respectively. At flexion, the minimum distances for UN, MN, and BA were 8.39 mm, 7.92 mm, and 11.86 mm, respectively. Furthermore, the minimum measurements for UN, MN, and BA were 7.96 mm, 8.36 mm, and 8.19 mm, respectively.

AM portal

This portal is located 2 cm anterior to the medial epicondyle and 2 cm distal to it. The UN, MN, MCNF, and BA were also evaluated via the SM portal. One cadaveric elbow with MCNF damage was discovered to be injured in both extension and semi-flexion; in the flexion position, it was 0.45 mm from the portal. The average MCNF position from the portal was 5.47 mm in flexion, 6.05 mm in semi-flexion, and 6.54 mm in extension. The minimal distances for UN, MN, and BA were 6.32 mm, 15.75 mm, and 5.50 mm for extension, and 7.65 mm, 14.25 mm, and 7.90 mm for flexion, respectively.

AL portal

This portal is situated 1 cm anterior to lateral epicondyle and 1-2 cm proximal to it. This portal provided access to the RN, PCNF, and LCNF. Although there was no evidence of nerve damage, minimal distances in flexion, semi-flexion, and extension between PCNF and portal were 1.24 mm, 1.24 mm, and 1.28 mm, respectively. In same series, minimum distance of LCNF from portal was measured at 22.32 mm, 22.88 mm, and 23.54 mm. RN's minimal distance from portal in flexion, semi-flexion, and extension was 20.26 mm, 20.90 mm, and 21.88 mm.

DP portal

Located over the triceps midline, 3 cm proximal to the olecranon. UN, RN and PCNF were assessed from this portal. The mean distance of the UN was recorded as 17.85 mm, 20.36 mm and 21.32 mm at extension, semi-flexion

and flexion, respectively. Mean distance of RN and PCNF was measured above 25 mm at all positions of elbow.

SL portal

This portal is located at "soft spot", i.e. in the triangle formed by olecranon, radial head and lateral epicondyle. PCNF was found to be placed at a distance of 0.58 mm on flexion on a specimen. At more obtuse angles, the distance was increased to 1.25 mm and 1.35 mm.

Minimum distance of RN was found as 4.28 mm, 4.56 mm and 7.25 mm at extension, semi-flexion and flexion, respectively.

Table 1: Distances of each structure from relevant portals at three different elbow positions.

Portal	Structure	Position	Mean	SD	Min	Max	P value for comparison between different positions	Post-Hoc analysis
AL	RN	180°	26.22	3.28	21.75	34.23	0.953	-
		145°	26.00	3.22	20.89	32.94		
		90°	25.82	3.26	20.26	32.39		
	PCNF	180°	12.01	5.98	1.28	22.69	0.995	-
		145°	11.94	5.81	1.24	20.38		
		90°	12.04	5.88	1.24	20.32		
	LCNF	180°	27.62	4.69	23.54	41.13	<0.001	145° vs 180°: 0.016
		145°	27.40	4.44	22.88	39.59		90° vs 180°: <0.001
		90°	27.23	4.33	22.32	38.79		90° vs 145°: 0.016
SM	UN	180°	15.49	3.12	7.96	20.21	0.992	-
		145°	15.35	3.16	8.14	20.21		
		90°	15.39	3.12	8.39	20.24		
	MN	180°	16.42	5.53	8.36	28.53	0.962	-
		145°	16.16	5.54	8.13	28.10		
		90°	16.01	5.34	7.92	26.35		
	MCNF	180°	7.41	4.46	0.00	15.21	0.971	-
		145°	7.12	4.20	0.00	14.07		
		90°	6.94	4.20	0.00	13.98		
	BA	180°	17.72	4.87	8.19	26.54	0.959	-
		145°	17.53	4.57	9.36	25.33		
		90°	17.59	4.13	10.38	24.88		
AM	UN	180°	14.85	4.30	6.32	26.54	0.985	-
		145°	14.51	4.22	6.14	25.69		
		90°	14.60	3.87	7.65	24.32		
	MN	180°	22.46	4.99	12.64	31.78	0.949	-
		145°	22.14	4.87	12.59	30.51		
		90°	21.93	4.77	12.68	29.54		
	MCNF	180°	7.04	3.20	0.00	12.21	0.986	-
		145°	6.95	3.17	0.00	12.02		
		90°	7.20	3.33	0.45	12.96		
	BA	180°	11.97	3.00	5.50	16.54	0.023	145° vs 180°: 0.139
		145°	11.73	2.89	5.65	16.85		90° vs 180°: 0.025
		90°	12.25	3.23	6.78	21.25		90° vs 145°: 0.757
DP	UN	180°	18.39	4.55	12.64	27.54	0.764	-
		145°	18.67	4.74	12.59	29.69		
		90°	19.00	5.36	12.68	34.87		
	RN	180°	39.68	0.84	38.05	41.59	0.815	-
		145°	39.61	0.98	37.58	41.98		
		90°	39.68	1.25	37.54	43.73		
	PCNF	180°	25.76	5.36	18.65	42.65	0.006	145° vs 180°: 0.099
		145°	25.49	4.98	18.95	40.63		90° vs 180°: 0.004
		90°	25.57	4.97	19.36	40.55		90° vs 145°: 0.51
SL	RN	180°	16.11	7.41	4.28	29.54	0.992	-
		145°	15.99	7.17	4.56	27.44		
		90°	16.29	6.80	5.25	27.54		
	PCNF	180°	11.57	6.51	1.25	23.53	0.997	-
		145°	11.55	6.60	1.35	24.78		
		90°	11.46	6.69	0.58	25.65		
	LCNF	180°	17.67	7.34	5.58	34.45	0.975	-
		145°	17.77	7.34	5.74	34.90		
		90°	18.16	7.32	6.23	36.65		

DISCUSSION

Many European and American researchers have described various portals for elbow arthroscopy. All the portals were described concerning bony landmarks. Their correct localisation and establishment after surface markings are required to avoid any devastating results. Various authors have documented various master plans to prevent any neurovascular structure from being injured. These include the proper position of the patient on the operating table, which allows uninterrupted mobility to the joint while performing the procedure, to maintain the arthroscope and instruments closer to the bones and joint inflation to the extent of the joint capsule space. Superficial skin incision and blunt retraction help to avoid injury to cutaneous structures with sharp instruments. In the present study, we considered the following structures such as RN, the UN, MN, the PCNF, MCNF, LCNF of forearm and BA. The portals selected were SL, AL, SM, AM and DP.[8,10-12]

In our study, all three major nerves, along with BA, LCNF and PCNF, were spared from injury in any of the elbow positions. MCNF was found injured in 2 elbows of 2 different cadavers. Injuries were noted while measuring the distance from the AM and SM portals. Even if at flexion (90^0) the AM portal made a distance of 0.45 mm, the nerve was injured in all three positions, i.e. extension, semi-flexion and flexion in the SM portal. From the SM portal UN, MN and BA were at a safer mean distance of 11.65 mm, 18.20 mm and 15.21 mm, respectively, on extension and at a distance of 12.78 mm, 17.36 mm and 15.95 mm on flexion. This portal may be considered relatively safer for UN, MN and BA.

Stothers et al studied the elbow in 12 cadavers and described that the RN is the most important vital structure injured during elbow arthroscopy using the AL portal. He found that the mean distance of RN from the portal was only 1.4 mm in extension. But his findings from the same portal make a difference of 4.9 mm in the flexion position. But in our study, we found that the RN was at a mean position of 24.12 mm, 24.01 mm and 23.96 mm in extension, semi-flexion and flexion, respectively.[8]

Camp et al considered the DP portal as one of the safest portals. It is also termed as “SP” portal, “posterior central” portal and “trans-triceps” portal. It is established at 3 cm proximal to the olecranon on the midline of the triceps.[17]

Stothers et al described the DP portal as safe too. In our study, the structures considered from DP were UN, RN and PCNF. Even the closest structure, the UN, was at a mean distance of 17.85 mm, 20.36 mm and 21.32 mm in extension, semi-flexion and flexion position, respectively. RN and PCNF are at safer distances from the DP portal of above 40 and 25 mm, respectively, in all elbow positions. This strengthens the claim of the safety of the DP portal.[8]

Two lateral portals were described by Adolfsson et al in "Arthroscopy of the elbow joint: A cadaveric study of portal placement." The high postero-lateral portal was situated 2 cm lateral and 4 cm proximal to the olecranon process, while the low postero-lateral portal was situated approximately 1-2 cm proximal to the olecranon tip. On extension, he found that PCNF was separated from the high and low lateral portals by an average of 14 and 18 mm, respectively. On 90^0 flexion, he discovered that the PCNF distance from the high portal fell to an average of 12 mm, whereas on the same 90^0 flexion, the PCNF distance increased to an average of 18 mm from the low portal.[18] The AL portal was positioned 1 cm anterior to the lateral epicondyle and 1-2 cm proximal in the present study. We found that the mean distance of PCNF from the AL portal was 17.16 mm, 17.80 mm and 19.26 mm at 180^0, 145^0 and 90^0 positions. The minimum distances of 1.28 mm, 1.24 mm and 1.24 mm at the same positions raise doubts about the safety of this portal. Even if no injury to PCNF was found on establishing this portal, the surgeon should be more cautious while approaching the elbow through this portal. A comparative study on the safety of postero-lateral and antero-lateral is appreciable.

Many of the previous studies have reported that medial portals, superior or anterior, are injuring the MCNF in various elbow positions. The result of the present study also emphasised the above statement. Plancher et al Maak et al and Adolfsson et al described the advantages of joint distension. They found that the technique of inflating the joint with normal saline or distilled water displaced the nerves and vessels anteriorly, which eventually made a safe positioning of arthroscopic instruments. This is helpful only in the case of patients undergoing arthroscopic procedures or on soft embalmed or alcohol embalmed cadavers. Even if we tried inflating the joint space with normal saline in the first two specimens, due to the lack of elasticity of formalin embalmed structures, it was unsuccessful.[18,19]

Chaware et al in their study found that there is no statistical significance in the change of elbow from flexion to extension in the distance of neurovascular structures from portals. 10 But in our study, we could find three portals with a statistically significant change in their position with certain structures on different elbow angles. They were AL with LCNF, AM with BA and DP with PCNF.[10]

Elbow arthroscopy is considered one of the hazardous procedures due to the risk of injury to structures around the joint. As described earlier, this is due to a small joint space and closely placed neurovascular structures. Moreover, this procedure is dynamic due to the change in position of structures in correspondence to portals at various elbow positions. Unlu et al studied 20 cadaveric elbows in $180^0$and 90^0 and found that changes in the position of the forearm altered the relation of nerves to the portals, mainly in the lateral portals.[14]

Chaware et al studied 12 elbows and found that supination and pronation of the forearm also changed the relation of nerves with arthroscopic portals. In our study, we

measured the distances of neurovascular structures from appropriate portals at three different positions. Even if significant changes were not found in most of the studied cadaveric elbows, PCNF injury risk from the SL portal was found to increase on flexing the elbow and in contrast, the risk of injury to the MCNF from the AM portal was decreased on flexing the elbow.[10]

Stothers et al used cadaveric dissection in 1995 to determine the proximity of the neurovascular systems to the more proximal medial and lateral portals as well as the AL and AM portals. On average, they found that the RN was only 1.4 mm from the AL portal when the elbow was extended and 4.9 mm when it was flexed. A proximal lateral portal, located directly on the anterior surface of the humerus and 2 cm proximal to the LE, was described by the authors. On average, the RN was 9.9 mm distant in flexion and 4.8 mm away in extension, whereas the PCNF was 6 mm away. The AM portal was on average 1 mm from the MCNF, 2 mm from the MN in extension, and 7 mm from the BA in flexion. It was located 2 cm distal and 2 cm anterior to the medial epicondyle (Table 2).[8]

Table 2: Discussion chart-comparison with previous cadaveric studies.

Reference	No. of elbows	No. of neurovascular injuries	Injured structure (Major)	Portal used in injured case	Rate of injury (%)	Injured structure (Minor)	Portal used in injured case	Rate of injury (%)
Santhoshi et al [10]	12	12/144	NIL			PCNF MCNF	SL SM AM	8.3
Classen et al[9]	10	1/10	MN	AM	10%	-	-	-
Thon et al[15]	10	4/30	RN	AL distal	13.3%	-	-	-
Stothers et al[8]	12	32/196	MN RN	AM AL	5.1%	PCNF MCNF	AL AM	7.3
Unlu et al[14]	20	4/20	RN	AL	10%	MCNF	SM	10
Present study	20	5/1020	-	-	-	MCNF	SM AM	0.5

The proximal medial portal is located just in front of the medial intermuscular septum and 2 cm proximal to the ME. The distance between the portal and the MCNF nerve is 2.3 mm. With the elbow extended and flexed, the MN was on average 7.6 mm away, whereas the UN was on average 12 mm away and covered by the medial intermuscular septum. The operative surgeon must verify that the UN does not subluxate or has not been transposed prior to the creation of this portal. Miller et al emphasised the above findings by examining the maximal distance of major structures from the joint's bone surface and capsule with joint distension. They observed that "the elbow's flexion and distension increased the MN's nerve-to-bone distance by 12 mm and the RN's by 6 mm." Since elbow extension brought the nerves closer to the bone, the protective benefits were lessened. Additionally, even with distension, there was no increase in the nerve to capsule distance.[1]

CONCLUSION

Based on our observations from the present study and previous literature, we found that the minor neurovascular structures around the elbow are at a relative risk of iatrogenic injury if portals are placed without proper precautions or guidelines. Since we could not find any injury to the major nerves and vessels, they are relatively safe. For making good skills in arthroscopic surgery, cadaveric training courses should be encouraged in the curriculum of postgraduate trainees in orthopaedics. Minor nerves are at risk in certain portals. Position of AL is safer when compared to the AM portal. Major structures are relatively safe when compared to cutaneous nerves.

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