

# Risk of nerve injury during arthroscopy portal placement in the elbow joint

## A cadaveric study

Prashant N Chaware, John A Santoshi<sup>1</sup>, Abhijit P Pakhare<sup>2</sup>, Bertha A D Rathinam

### ABSTRACT

**Background:** Elbow arthroscopy has become a routine procedure now. However, placing portals is fraught with dangers of injuring the neurovascular structures around elbow. There are not enough data documenting the same amongst the Indians. We aimed to determine the relative distances of nerves around the elbow to the arthroscopy portals and risk of injury in different positions of the elbow. **Materials and Methods:** Six standard elbow arthroscopy portals were established in 12 cadaveric upper limbs after joint distension. Then using standard dissection techniques all the nerves around the elbow were exposed, and their distances from relevant portals were measured using digital vernier caliper in 90° elbow flexion and 0° extension. Descriptive statistical analysis was used for describing distance of the nerves from relevant portal. Wilcoxon-signed rank test and Friedman’s test were used for comparison. **Results:** There was no major nerve injury at all the portals studied in both positions of the elbow. The total incidence of cutaneous nerve injury was 8.3% (12/144); medial cutaneous nerve of forearm 10/48 and posterior cutaneous nerve of forearm 2/24. No significant changes were observed in the distance of a nerve to an individual portal at 90° flexion or 0° extension position of the elbow. **Conclusion:** This study demonstrates the risk of injury to different nerves at the standard portals of elbow arthroscopy. In practice, the actual incidence of nerve injury may still be lower. We conclude that elbow arthroscopy is a safe procedure when all precautions as described are duly followed.

**Key words:** Arthroscopy portals, complication, elbow, nerve injury

**MeSH terms:** Arthroscopy, peripheral nerve injury, elbow joint, intraoperative complications

### INTRODUCTION

Arthroscopy has become an invaluable diagnostic and therapeutic tool for a variety of intraarticular disease processes.<sup>1</sup> Arthroscopic surgery offers the potential advantages of improved articular visualization, decreased postoperative pain, decreased morbidity and faster postoperative recovery.<sup>2</sup> The presence of soft tissues and nerves all around elbow precludes an easy and safe access to the joint arthroscopically and the technique

requires thorough knowledge of neurovascular structures as well as appreciation of the protective layers including the capsule and surrounding muscles.<sup>3</sup> Elbow arthroscopy is a demanding procedure<sup>1,4,5</sup> compared to the more accessible knee and shoulder joints<sup>5</sup> and involves a steep learning curve.<sup>6,7</sup> The indications for elbow arthroscopy are removal of loose bodies, joint contracture release, osteochondritis dissecans, fractures of the capitellum, coronoid process, and radial head in managing elbow trauma, synovectomy, synovial chondromatosis and debridement of osteoarthritic elbow, pain without a diagnosis, instability, lateral epicondylitis, plicae, chronic valgus overload, posteromedial impingement and septic arthritis.<sup>1-5,8-12</sup>

Departments of Anatomy, <sup>1</sup>Orthopaedics and <sup>2</sup>Community and Family Medicine, AIIMS Bhopal, Madhya Pradesh, India

**Address for correspondence:** Dr. Bertha AD Rathinam, Department of Anatomy, AIIMS, Bhopal, Madhya Pradesh, India. E-mail: bertharathinam@gmail.com

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

**For reprints contact:** reprints@medknow.com

| Access this article online   |   |
|--|---|
| <b>Quick Response Code:</b><br> | <b>Website:</b><br><a href="http://www.ijoonline.com">www.ijoonline.com</a> |
|  | <b>DOI:</b><br>10.4103/0019-5413.173510                                     |

**How to cite this article:** Chaware PN, Santoshi JA, Pakhare AP, Rathinam BA. Risk of nerve injury during arthroscopy portal placement in the elbow joint: A cadaveric study. Indian J Orthop 2016;50:74-9.

A number of elbow arthroscopy portal sites have been described with each portal having distinct advantages, disadvantages and risks of complications. The three major nerves viz., ulnar, median and radial nerves and the numerous sensory nerves in the elbow region are at risk during portal placement.<sup>1,13-15</sup> Moreover, elbow arthroscopy is a dynamic procedure with change in the relationship of neurovascular structures and the portals in different elbow positions.<sup>14</sup> The prevalence of neurological complications after elbow arthroscopy has ranged from 0% to 14%.<sup>5</sup>

The present study aimed at determining the relative distances of neural structures to the standard elbow arthroscopy portals and risk of injury to these structures in different positions of the elbow amongst the Indians. The findings of this study will be an invaluable tool for the operating surgeon not only for choosing and placing appropriate portals during elbow arthroscopy but also help in minimizing the risk of nerve injury.

## MATERIALS AND METHODS

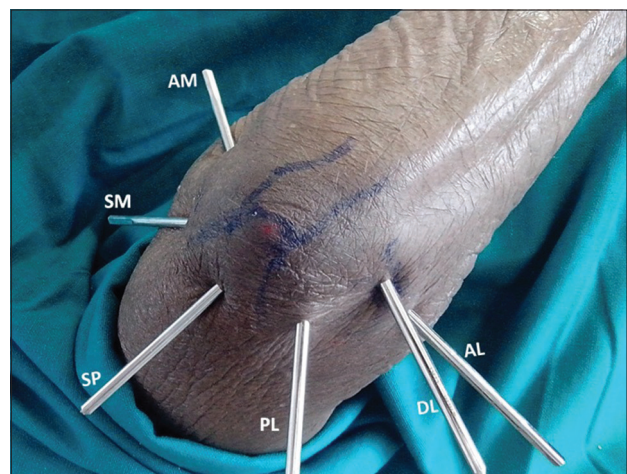
We performed a cadaveric investigation after Institutional Human Ethics Committee approval. Twelve undissected upper limbs from six formalin embalmed cadavers (three male and three female) were obtained from the Department of Anatomy for the study. All the elbows were free of prior trauma or deformity and this was confirmed by measuring and comparing the three-bony landmark relationship (medial epicondyle – olecranon – lateral epicondyle) on both upper limbs of each cadaver. The joints were distended with saline before establishing the portals. The portals were established using 4-mm Steinmann pins, corresponding to the size of elbow arthroscopy portals, by an orthopaedic surgeon. Six standard portals, as per the description by Plancher and Bishai,<sup>7</sup> were studied; these included: Direct lateral (DL), antero-lateral (AL), supero-medial (SM), antero-medial (AM), postero-lateral (PL) and straight posterior (SP). The anterior portals were placed with the elbow in 90° of flexion, but posterior portals required some extension.

The DL portal (mid-lateral or “soft spot” portal) was placed at the center of the triangle made of the radial head, lateral epicondyle, and the olecranon. The AL portal was placed in the sulcus (between the radial head and capitellum) 1 cm distal and 1 cm anterior to the lateral epicondyle; this portal is used as the initial portal by some surgeons. The SM (or proximal medial) portal was placed approximately 2 cm proximal to the medial epicondyle. The AM portal was placed 2 cm distal and 2 cm anterior to the medial epicondyle. The PL portal was placed approximately 3 cm proximal to tip of the olecranon, superior and posterior to

the lateral epicondyle at the lateral border of the triceps muscle. The SP (or trans-triceps) portal was placed 3 cm medial to the PL portal; in the midline of the triceps.<sup>7</sup>

After the portals were established, the pins were left in place [Figure 1]. Then using standard dissection tools, skin, and subcutaneous fat were removed around the elbow region. Dissection was done carefully preserving the original position of the nerves by avoiding disruption of the soft tissue under these structures and therefore maintaining the support of each nerve at its original position. The nerves studied were median nerve, ulnar nerve, radial nerve, lateral cutaneous nerve of forearm (LCNF), medial cutaneous nerve of forearm (MCNF) and posterior cutaneous nerve of forearm (PCNF). The distances from each nerve to the relevant portals were measured using digital vernier caliper with a measuring range of 0–150 mm, resolution of 0.01 mm, accuracy  $\pm 0.02$  mm of linear capacitive measuring system. For example, for ulnar nerve, its distance from SP, SM, and AM portals were recorded, as it is obviously at a safe distance from the lateral portals (PL, DL and AL). However, it may still get injured by instruments through any portal.<sup>15-18</sup> Similar data for other nerves was recorded. All measurements were carried out by two observers to avoid intra observer error. Measurements were taken from the edge of the portal to the closest border of the nerve “at risk.” In the case of actual impalement or displacement of a nerve with any pin, it was deemed to be injured, and the distance was recorded as zero (0.00 mm).

Data analyses were done using SPSS version 21 software (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, version 21.0. Armonk, NY, USA: IBM Corp.). Descriptive statistical measures were used for



**Figure 1:** A cadaveric left elbow showing placement of all the standard elbow arthroscopy portals. Antero-medial (AM), supero-medial (SM), direct-lateral (DL), antero-lateral (AL), postero-lateral (PL), straight-posterior (SP)

describing distance of the nerves from relevant portal. We used Wilcoxon-signed rank test for comparison where only two portals were relevant for corresponding nerves and Friedman's test for comparison where three or more portals were relevant for corresponding nerves. Statistical significance was considered at  $P < 0.05$ . *Post-hoc* tests were applied for pair wise comparison whenever Friedman's test  $P < 0.05$ .

## RESULTS

Table 1 shows descriptive statistics of distances of each nerve from relevant portals. No significant changes were observed in the distance of a nerve to an individual portal at 90° flexion or 0° extension position of the elbow.

### Direct lateral and anterolateral portals

At the DL portal, PCNF was injured in one specimen in both positions of the elbow (2/24) and was found to be the nerve closest to the portal with a mean distance of 8.86 mm with elbow in extension. The minimum distance from the portal to the radial nerve in elbow extension was 2.49 mm and LCNF in elbow flexion was 21.41 mm. At the AL portal, PCNF, radial nerve and LCNF were at a minimum distance of 2.38 mm, 16.13 mm and 23.11 mm respectively, in elbow flexion.

### Superomedial and anteromedial portals

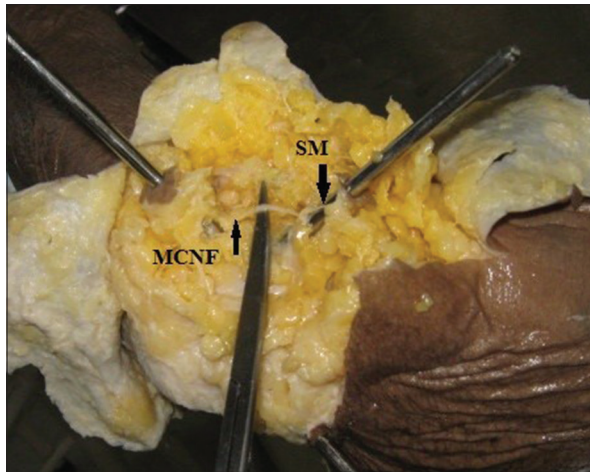
At the SM portal, the MCNF was found to be the most commonly injured nerve (5/24, 3 in flexion and 2 in extension) [Figure 2] and it was closer to the portal

**Table 1: Descriptive statistics of distances of each nerve from relevant elbow arthroscopy portals**

| Portal | Nerve  | Position | Distance from corresponding nerve (in mm) |       |         |                        | Comparison with similar approach (P)          | Post-hoc test (P)                             |
|--------|--------|----------|---|-------|---------|------------------------|---|---|
|        |        |          | Mean                                      | SD    | Minimum | Maximum                |   |   |
| SP     | Ulnar  | Flex     | 20.76                                     | 6.93  | 11.29   | 37.81                  | SP, SM, AM (0.004)                            | SP versus SM (0.003)                          |
|        |        | Ext      | 19.72                                     | 5.92  | 10.51   | 29.33                  | SP, SM, AM (0.017)                            | SP versus SM (0.024)                          |
|        | Radial | Flex     | 45.97                                     | 3.88  | 43.22   | 48.71                  | SP, PL, AL, DL (0.241)                        |   |
|        |        | Ext      | 43.98                                     | 1.00  | 43.27   | 44.69                  | SP, PL, AL, DL (0.145)                        |   |
|        | PCNF   | Flex     | 33.77                                     | 8.27  | 20.82   | 44.53                  | SP, PL, AL, DL (0.002)                        | SP versus PL (0.016),<br>SP versus DL (0.002) |
| Ext    |        | 30.66    | 8.08                                      | 19.87 | 44.09   | SP, PL, AL, DL (0.001) | SP versus PL (0.016),<br>SP versus DL (0.001) |   |
| PL     | Radial | Flex     | 34.62                                     | 6.07  | 26.45   | 44.14                  |   |   |
|        |        | Ext      | 36.26                                     | 6.12  | 28.42   | 44.29                  |   |   |
|        | PCNF   | Flex     | 14.6                                      | 7.50  | 4.59    | 29.41                  |   | SP versus PL (0.016)                          |
|        |        | Ext      | 13.02                                     | 8.21  | 2.86    | 29.42                  |   | SP versus PL (0.016)                          |
| DL     | Radial | Flex     | 28.13                                     | 8.56  | 5.92    | 38.52                  |   |   |
|        |        | Ext      | 28.57                                     | 9.86  | 2.49    | 40.53                  |   |   |
|        | PCNF   | Flex     | 10.32                                     | 7.92  | 0.00    | 29.08                  |   | SP versus DL (0.002)                          |
|        |        | Ext      | 8.86                                      | 7.37  | 0.00    | 26.13                  |   | SP versus DL (0.001)                          |
|        | LCNF   | Flex     | 39.27                                     | 8.27  | 21.41   | 51.15                  | DL versus AL (0.008)                          |   |
|        |        | Ext      | 38.37                                     | 7.64  | 21.91   | 48.11                  | DL versus AL (0.010)                          |   |
| AL     | Radial | Flex     | 26.19                                     | 5.81  | 16.13   | 34.25                  |   |   |
|        |        | Ext      | 26.96                                     | 4.83  | 18.91   | 36.99                  |   |   |
|        | PCNF   | Flex     | 17.09                                     | 11.31 | 2.38    | 32.03                  |   |   |
|        |        | Ext      | 16.31                                     | 10.9  | 3.78    | 33.97                  |   |   |
|        | LCNF   | Flex     | 32.01                                     | 5.14  | 23.11   | 41.06                  |   |   |
|        |        | Ext      | 33.8                                      | 5.91  | 25.00   | 44.17                  |   |   |
| SM     | Ulnar  | Flex     | 13.16                                     | 3.73  | 7.76    | 21.4                   |   | SP versus SM (0.003)                          |
|        |        | Ext      | 12.84                                     | 4.60  | 6.63    | 21.39                  |   | SP versus SM (0.024)                          |
|        | Median | Flex     | 19.45                                     | 7.42  | 9.49    | 32.73                  | SM versus AM (0.209)                          |   |
|        |        | Ext      | 20.69                                     | 7.16  | 10.52   | 33.25                  | SM versus AM (0.084)                          |   |
|        | MCNF   | Flex     | 5.14                                      | 5.08  | 0.00    | 14.51                  | SM versus AM (0.875)                          |   |
|        |        | Ext      | 5.54                                      | 5.68  | 0.00    | 18.97                  | SM versus AM (0.695)                          |   |
| AM     | Ulnar  | Flex     | 16.03                                     | 4.86  | 8.54    | 24.87                  |   |   |
|        |        | Ext      | 14.56                                     | 5.49  | 7.97    | 26.76                  |   |   |
|        | Median | Flex     | 22.12                                     | 6.64  | 14.26   | 31.70                  |   |   |
|        |        | Ext      | 24.77                                     | 6.56  | 17.09   | 34.66                  |   |   |
|        | MCNF   | Flex     | 4.99                                      | 5.03  | 0.00    | 13.78                  |   |   |
|        |        | Ext      | 5.35                                      | 4.94  | 0.00    | 15.64                  |   |   |

SP=Straight-posterior, PL=Postero-lateral, DL=Direct-lateral, AL=Antero-lateral, SM=Supero-medial, AM=Antero-medial, LCNF=Lateral cutaneous nerve of forearm, MCNF=Medial cutaneous nerve of forearm, PCNF=Posterior cutaneous nerve of forearm, Flex 90° flexion of the elbow, Ext=Neutral extension position of the elbow, SD=Standard deviation





**Figure 2:** Dissected specimen showing injury to medial cutaneous nerve of forearm at the supero medial portal

with a mean distance of 5.14 mm in elbow flexion. The median and ulnar nerves were at a minimum distance of 9.49 mm and 6.63 mm from the portal in elbow flexion and extension, respectively. At the AM portal, similar to the SM portal, the MCNF was found to be the most commonly injured nerve (5/24, 3 in flexion and 2 in extension) and its mean distance was 4.99 mm with the elbow in flexed position. The median and ulnar nerves were at minimum distances of 14.26 mm and 7.97 mm, in elbow flexion and extension, respectively.

#### Posterolateral and straight posterior portals

At the PL portal, the PCNF was at a minimum distance of 2.86 mm in elbow extension while the radial nerve was at a minimum distance of 26.45 mm in elbow flexion. At the SP portal, the PCNF, ulnar nerve were at minimum distances of 19.87 mm, 10.51 mm with elbow in extension and radial nerve was at a mean distance of 43.22 mm with elbow in flexion.

Distance of ulnar nerve was statistically different between SP, SM and AM portals (flexion  $P = 0.004$ , extension  $P = 0.017$ ) and pairwise comparison showed that distance from SP portal was statistically greater than SM portal (flexion  $P = 0.003$ , extension  $P = 0.024$ ). There was no difference between SP versus AM portals, AM versus SM portals, thereby implying that SP portal is relatively safer than SM and AM portals for the ulnar nerve.

Distance of PCNF was statistically greater from SP portal compared with PL and DL portals (flexion  $P = 0.016$ , extension  $P = 0.016$ ), (flexion  $P = 0.002$ , extension  $P = 0.001$ ). Distance of LCNF was statistically greater from DL portal than AL portal (flexion  $P = 0.008$ , extension  $P = 0.010$ ). We did not find any significant differences

between relevant portals and distances to radial nerve, median nerve and MCNF.

#### DISCUSSION

Arthroscopy of the elbow joint is, perhaps, the most risky arthroscopic procedure in terms of its potential for causing injury to important nearby nerves and vessels.<sup>14</sup> Injuries to the nerves crossing the elbow joint are the most frequently reported complications of elbow arthroscopy. Although often transient, these neurologic injuries may be devastating. These nerves are susceptible during the portal creation, after local use of motorized instruments, and after the use of multiple nearby portals.<sup>1,5,7,16,18,19</sup>

Several authors have described various strategies to avoid nerve damage during elbow arthroscopy, these include avoiding suction close to the nerves, keeping the arthroscope and instruments close to bone, limiting tourniquet time to <2 h, avoiding excessive retraction of nerves, change in the set up to avoid visual paradox by keeping the monitor at the head end of the table, and following a safety driven step wise strategy in a standardized sequence.<sup>5,6,17,18</sup> Placing the patient's elbow in 90° of flexion before portal placement and prone position during arthroscopy are also said to be helpful as the gravity assists in displacing the anterior neurovascular structures away from the joint;<sup>7</sup> prone position also offers the benefit of easier conversion to an open procedure, if required, without changing patient position and re draping.

In the present study, the three major nerves were not injured at any of the portals and in different positions of the elbow. However, MCNF was found to be the most injured nerve at the AM (5/24) and SM (5/24) portals. On two occasions, extended position of the elbow took the nerve to a safe distance of 1.41 mm and 0.60 mm from AM and SM portals, respectively, though the distance was 0.00 mm on both occasions with elbow in 90° flexion. PCNF was injured on one occasion at the DL (2/24) portal in both flexed and extended positions of the elbow.

There is an ongoing debate in previous studies on whether to commence the arthroscopic procedure through AM or AL portals.<sup>1,2</sup> Observations from the present study indicate that the AL portal is safer as MCNF was injured in AM portal (5/24). At both AM and AL portals the relevant major nerves, median and radial, were at a safe distance of 14.26 mm and 16.13 mm in flexed elbow, respectively.

Adolfsson<sup>20</sup> examined 16 fresh cadaver elbows by arthroscopy and dissection to evaluate the anatomic

relationships of the portals. He found that the distance of PCNF to the PL portal was an average of 16 mm (range 13–20 mm) which increased to 18 mm in elbow flexion. Similarly, in the present study, at the PL portal, the PCNF was at an average distance of 13.02 mm (range 2.86–29.42 mm) in elbow extension, which increased to an average distance of 14.60 mm in elbow flexion. At the SP portal, our findings were similar, we found the ulnar nerve and PCNF were the closest nerves and their distance increased further in elbow flexion. At the DL portal, he recorded the PCNF at an average distance of 7 mm (range 3–17 mm). We had PCNF injury at this portal in one specimen in both positions of the elbow. At the AL portal, our findings were comparable except that we found the PCNF to be closer to the portal compared to the radial nerve. Our observations were similar with regard to MCNF to the AM and SM portals; he found the MCNF very close to these portals (2–3 mm) while we had 10 instances of MCNF injury.

Marshall *et al.*<sup>18</sup> studied the anatomical relationships of the nerves to the common AL, AM and PL portals in 20 cadaver elbows. At the AL portal, they found the radial nerve at an average distance of 5 mm (range 1–13 mm); while we observed the radial nerve to be safe at a distance of at least 16.13 mm. At the AM portal, they found the median nerve at an average distance of 6.5 mm (maximum 14 mm); while we observed the median nerve to be at least 14.26 mm away from the portal. They also noted that the MCNF branches were at risk at the AM portal, which we observed on five occasions in our study. At the PL portal, they cautioned against ulnar nerve damage by avoiding compressing the nerve against the medial epicondyle.

Unlu *et al.*<sup>14</sup> evaluated the proximity of neurovascular structures to the six arthroscopic portals of the elbow at different positions in 20 fresh cadaveric elbows. At the AL portal, they observed nerve-pin contact in 20% and 10% of the elbows in the extended and flexed positions, respectively, whereas, we did not observe any instance of radial nerve-pin contact at this portal. The PCNF, in their observations, came closer to the AL portal in elbow extension, whereas our observations were to the contrary. At the AM portal, the median nerve was closest at  $7.9 \pm 4.6$  mm in full extension and the distance increased with flexion; our observations were contrary with median nerve closest to the portal at 14.26 mm with elbow flexion. The ulnar nerve, similar to their observation, came closer to the AM portal in elbow extension. They recorded two instances of MCNF-pin contact at the SM portal; our observation was 5/24 nerve-pin contact at this portal. At the DL portal, our findings were contrary, as we found the PCNF injured on two occasions, whereas, they recorded the

LCNF to be the closer nerve at risk of injury at this portal in elbow flexion. At the posterior portals (PL and SP), the nerves were at a safe distance in any position of the elbow of at least 10 mm except in one specimen where they noted the medial cutaneous nerve of arm to be injured at the SP portal.

Joint distension has been shown to be protective to nerve damage<sup>7,19,20</sup> as distension of the joint displaces the neurovascular structures anteriorly allowing safe positioning of the instruments. Though joint distension was performed prior to establishing the portals, the degree to which the joint could be distended may have been limited as the cadavers were formalin-preserved, and the elasticity of embalmed tissues is reduced. The relative motion of the structures and portal sites in the formalin-preserved specimens during flexion-extension and pronation-supination maneuvers, and during cannula insertion is limited. Elbow arthroscopy is a dynamic procedure with change in the relationship of neurovascular structures and the portals in different elbow positions;<sup>14</sup> measurements were taken in elbow positions of 90° flexion and full extension, however, we could not take measurements in different forearm positions as few specimens had the forearm fixed in different degrees of pronation and supination. Change in forearm position may alter the nerve relationship to the portals, especially at the lateral portals and may be protective against nerve damage; as has been demonstrated by Unlu *et al.*<sup>14</sup> that the posterior interosseous branch of radial nerve displaces away from the radiocapitellar joint in forearm pronation. As our body donation program has only recently commenced, we do not have the facilities to perform the study on fresh or alcohol-preserved cadavers.

## CONCLUSION

This study demonstrates the relative risk of injury to different nerves at the standard portals around elbow joint. We did not encounter any injury to the major nerves. We observed an overall 8.3% incidence of nerve injury, which is comparable to earlier reports but only the cutaneous nerves were involved. In clinical practice, the actual incidence may still be lower. We conclude that elbow arthroscopy is a safe procedure when all precautions are duly followed.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

## REFERENCES

1. Elfeddali R, Schreuder MH, Eygendaal D. Arthroscopic elbow surgery, is it safe? *J Shoulder Elbow Surg* 2013;22:647-52.
2. Steinmann SP, King GJ, Savoie FH 3<sup>rd</sup>. Arthroscopic treatment of the arthritic elbow. *Instr Course Lect* 2006;55:109-17.
3. Ruch DS, Poehling GG. Anterior interosseus nerve injury following elbow arthroscopy. *Arthroscopy* 1997;13:756-8.
4. Schneider T, Hoffstetter I, Fink B, Jerosch J. Long term results of elbow arthroscopy in 67 patients. *Acta Orthop Belg* 1994;60:378-83.
5. Kelly EW, Morrey BF, O'Driscoll SW. Complications of elbow arthroscopy. *J Bone Joint Surg Am* 2001;83-A: 25-34.
6. Sinha A, Pydah SK, Webb M. Elbow arthroscopy: A new setup to avoid visual paradox and improve triangulation. *Arthrosc Tech* 2013;2:e65-7.
7. Plancher KD, Bishai SK. Basics of elbow arthroscopy: Setup, portals, and technique. *Tech Orthop* 2006;21:239-49.
8. Marti D, Spross C, Jost B. The first 100 elbow arthroscopies of one surgeon: Analysis of complications. *J Shoulder Elbow Surg* 2013;22:567-73.
9. Yeoh KM, King GJ, Faber KJ, Glazebrook MA, Athwal GS. Evidence-based indications for elbow arthroscopy. *Arthroscopy* 2012;28:272-82.
10. Wijeratna M, Bailey KA, Pace A, Tytherleigh-Strong G, Van Rensburg L, Kent M. Arthroscopic radial head excision in managing elbow trauma. *Int Orthop* 2012;36:2507-12.
11. Tanaka N, Sakahashi H, Hirose K, Ishima T, Ishii S. Arthroscopic and open synovectomy of the elbow in rheumatoid arthritis. *J Bone Joint Surg Am* 2006;88:521-5.
12. Yan H, Cui GQ, Wang JQ, Yin Y, Ao YF. Arthroscopic debridement of osteoarthritic elbow in professional athletes. *Chin Med J (Engl)* 2011;124:4223-8.
13. Rosenberg BM, Loebenberg MI. Elbow arthroscopy. *Bull NYU Hosp Jt Dis* 2007;65:43-50.
14. Unlu MC, Kesmezacar H, Akgun I, Ogut T, Uzun I. Anatomic relationship between elbow arthroscopy portals and neurovascular structures in different elbow and forearm positions. *J Shoulder Elbow Surg* 2006;15:457-62.
15. Reddy AS, Kvitne RS, Yocum LA, Elattrache NS, Glousman RE, Jobe FW. Arthroscopy of the elbow: A long term clinical review. *Arthroscopy* 2000;16:588-94.
16. Kamineni S, Hamilton DA Jr. Arthroscopic ulnar nerve identification during posterior elbow arthroscopy. *Arthrosc Tech* 2012;1:e113-7.
17. Blonna D, Wolf JM, Fitzsimmons JS, O'Driscoll SW. Prevention of nerve injury during arthroscopic capsulectomy of the elbow utilizing a safety-driven strategy. *J Bone Joint Surg Am* 2013;95:1373-81.
18. Marshall PD, Fairclough JA, Johnson SR, Evans EJ. Avoiding nerve damage during elbow arthroscopy. *J Bone Joint Surg Br* 1993;75:129-31.
19. Maak TG, Osei D, Delos D, Taylor S, Warren RF, Weiland AJ. Peripheral nerve injuries in sports-related surgery: Presentation, evaluation, and management: AAOS exhibit selection. *J Bone Joint Surg Am* 2012;94:e1211-10.
20. Adolfsson L. Arthroscopy of the elbow joint: A cadaveric study of portal placement. *J Shoulder Elbow Surg* 1994;3:53-61.