Original Article

Preoperative Determination of the Position of the Radial Nerve in the Posterior Approach to the Humerus using the Transepicondylar Width: A Cadaveric Study

Anupong Laohapoonrungsee MD[1], Phornphong Isariyaphruet MD[1]

[1] Department of Orthopaedics, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand

Background: Iatrogenic radial nerve injury following posterior approach of the humerus has been reported from 3 to 11%. The surgeon's awareness of nerve location may lower this complication.

Objective: The objective of this study was to evaluate a system to preoperatively determine the location of the radial nerve using superficial osseous landmarks to help avoid radial nerve injury, a potential complication in fixation of a fracture of the humerus.

Materials and Methods: Twenty-six fresh frozen upper extremities from adult cadavers were dissected and the distances from the radial nerve at the midhumeral axis to the medial epicondyle, to the lateral epicondyle and to the ulnar border of the olecranon were measured and the correlation with the transepicondylar width [TW] was calculated.

Results: The radial nerve was located an average of 2.33 times the TW from the medial epicondyle, 2.27 times the TW from the lateral epicondyle and 2.74 times the TW from ulnar border of olecranon. The correlation between those distances and the radial nerve was found to be statistically significant.

Conclusion: The transepicondylar width is an easily accessed bony reference which can be used to calculate the location of the radial nerve in the posterior MIPO approach, allowing the surgeon to protect the nerve by limiting exposure at the point predicted by the transepicondylar width.

Keywords: Radial nerve, Posterior approach to humerus, Distal humeral shaft fracture

J Med Assoc Thai 2018; 101 [Suppl. 3]: S81-S86
Website: http://www.jmatonline.com

Although functional bracing of humeral shaft fractures yields a good rate of fracture union and functional results, complications such as varus or anteroposterior angulation and limitation of shoulder and elbow motion due to prolonged immobilization have been reported[1,2]. Surgical treatment, either by intramedullary nailing or plating, is commonly used to avoid these complications. However, intramedullary nailing may result in delayed union or nonunion and shoulder or elbow pain at the entry point[3-6]. Plating has been demonstrated to have advantages over nailing, including less shoulder or elbow pain, better alignment of fracture reduction and better fracture union[7,8]. Open reduction and internal fixation may be associated with radial nerve palsy. In addition, the concomitant extensive soft tissue stripping during the operation may interfere with the fracture healing process resulting in delayed union or nonunion[9-12].

The MIPO technique has been reported to reduce these problems[13-15]. Various MIPO approaches are currently used to treat humeral shaft fractures. The anterior approach is suitable for fractures at least 6 cm below the surgical neck and 6 cm above the coronoid or olecranon fossa. In cases where the fracture is very close to the coronoid or olecranon fossa, however, stable fixation cannot be achieved with the anterior approach. In those cases, the posterior approach is

Correspondence to:
Laohapoonrungsee A, Department of Orthopaedics, Faculty of Medicine, Chiang Mai University, Chiang Mai 50200, Thailand.
Phone: +66-53-935544
E-mail: anuponglao@gmail.com

How to cite this article: Laohapoonrungsee A, Isariyaphruet P. Preoperative Determination of the Position of the Radial Nerve in the Posterior Approach to the Humerus using the Transepicondylar Width: A cadaveric study. J Med Assoc Thai 2018;101;Suppl.3: S81-S86.

considered a better option[16,17].

Iatrogenic radial nerve palsy has been reported in between 3 and 11% of cases following the posterior approach[16-18]. To avoid this complication, it is critical that the surgeon be aware of the location of the nerve during application of the plate and screws. Several studies of the anatomy of the radial nerve and its position relative to the triceps aponeurosis or to other bony landmarks have been published[19-28]. However, these landmarks can only be accessed when using an open surgery technique. This study evaluated a method for preoperatively locating the radial nerve in relation to superficial osseous structures even with minimally invasive techniques.

Objective

The purpose of the present study was to determine how to locate the position of the radial nerve relative to superficial osseous landmarks to minimize the risk of iatrogenic radial nerve injury during posterior MIPO surgery.

Materials and Methods

Both arms of thirteen fresh frozen adult cadavers (5 males and 8 females, average age 63.4 years) were dissected. None of the specimens had deformities or previous surgical procedures to the arms or elbows. With the cadaver in the prone position, the shoulder was placed at 90 degrees abduction with 90 degrees elbow flexion (Figure 1). The arm was dissected to expose the entire radial nerve along the spiral groove. The distance from the radial nerve at the midhumeral axis to the medial epicondyle (medial nerve distance or MND) to the lateral epicondyle (lateral nerve distance or LND) and to the ulnar border of the olecranon (olecranon nerve distance or OND) were measured. The distance between the medial and lateral epicondyle (transepicondylar width or TW) was also recorded. Measurements of each of the parameters were performed independently by three orthopaedics residents and the average values were calculated.

Results

The average medial and lateral distances were 142.29 and 136.79 mm, respectively. The average olecranon nerve distance was 161.07 mm. The average transepicondylar width was 59.57 mm (Figure 2 and Table 1).

The Pearson's correlation coefficient was used to analyse the data. Statistical analysis revealed that the associations between the MND, LND and OND

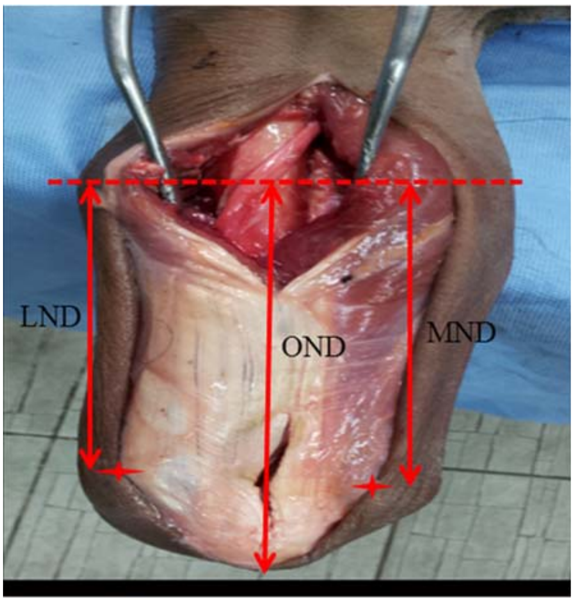

Figure 1. The shoulder was placed at 90 degrees abduction with 90 degrees elbow flexion. LND (Distance from lateral humeral epicondyle to radial nerve at midhumeral axis). OND (Distance from tip of olecranon to radial nerve at midhumeral axis). MND (Distance from medial humeral epicondyle to radial nerve at midhumeral axis).

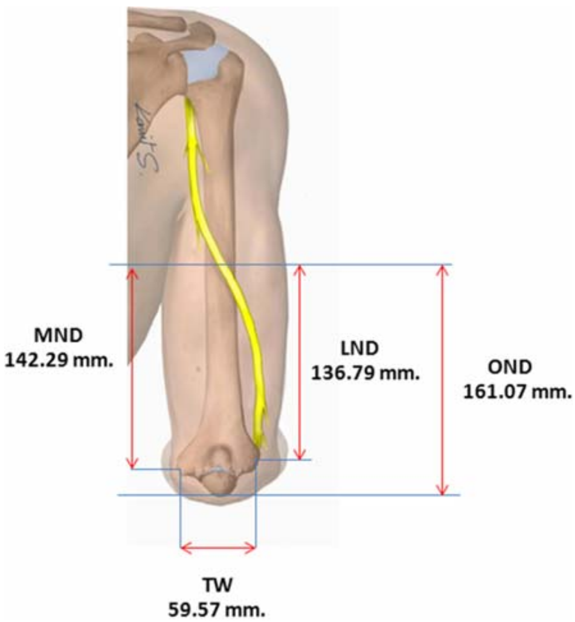

Figure 2. The average distance of each parameter.

Table 1. Average MND, LND, OND and TW

	Average (range) mm	SD
Medial nerve distance [MND]	142.29 (128 to 160)	9.33
Lateral nerve distance [LND]	136.79 (123 to 153)	8.99
Olecranon nerve distance [OND]	161.07 (137 to 184)	12.82
Transepicondylar width [TW]	59.57 (53 to 68)	5.26

Table 2. Correlation between MND, LND, OND and TW

	R	*p*-value	Ratio
MND/TW	0.43	0.03	2.33±0.21
LND/TW	0.38	0.05	2.27±0.19
OND/TW	0.48	0.01	2.74±0.21

and the transepicondylar width were statistically significant (Figure 3 to 5 and Table 2). The Pearson's correlation coefficient was 0.43 ($p = 0.03$) for MND, 0.38 ($p = 0.05$) for LND and 0.48 ($p = 0.01$) for OND. The MND/TW ratio was 2.33±0.21, the LND/TW ratio was 2.27±0.19, and the OND/TW ratio was 2.74±0.21.

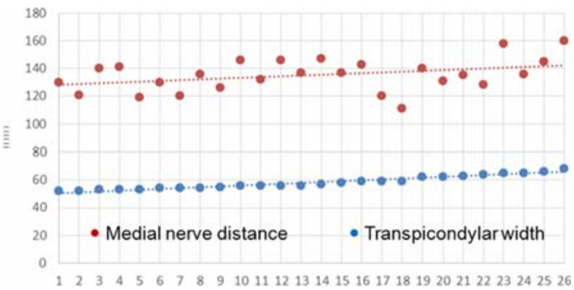

Figure 3. Statistical analysis between Medial nerve distance and Transepicondylar width.

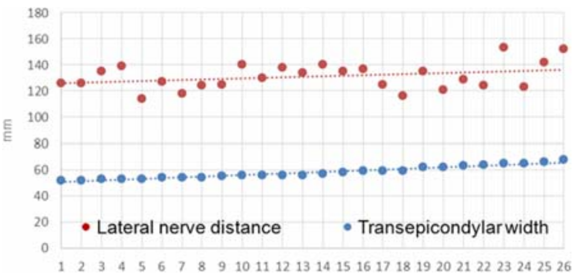

Figure 4. Statistical analysis between Lateral nerve distance and Transepicondylar width.

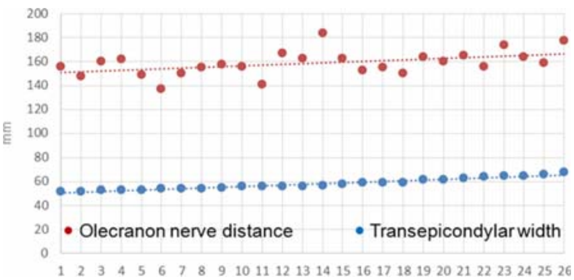

Figure 5. Statistical analysis between Olecranon nerve distance and Transepicondylar width.

Discussion

The posterior approach is commonly used in fixation of distal humeral shaft fractures. Conventional open reduction and plating may cause extensive dissection and devascularization of fracture fragments resulting in disturbance of the healing process(10). That problem may be reduced by using a minimally invasive surgical technique(13-15). Unfortunately, iatrogenic radial nerve palsy complications have been found in up to 11% of MIPO cases(16-18). The radial nerve, which is the continuation of the posterior cord of the brachial plexus, courses along the axilla posterior to the axillary artery and descends downward posterior to the humerus. After crossing the humeral shaft in the spiral groove, the nerve pierces the lateral intermuscular septum and enters the anterior compartment. Knowledge of the anatomy and location of the radial nerve may help minimize radial nerve injury during plate and screw application. Various methods of intraoperative radial nerve localization during the posterior approach have been reported, but none have been as accurate as could be desired.

The triceps aponeurosis has been used as a soft tissue landmark in many studies because it is not affected by shortening or malalignment of the humerus in a fracture situation. Arora located the radial nerve 2.2 cm proximal to the apex of the aponeurosis(20). Seigerman located the nerve two finger breadths proximal to the intersection point created by the confluence of the long and lateral heads of the triceps and the aponeurosis[21]. However, McCann warned surgeons to consider that this relationship is altered in different elbow positions during manipulation of the limb[23].

The point where the radial nerve pierces the lateral intermuscular septum was identified as a reference point in a study by Uhl, Bono and Mazurek. They reported that the distance from that point to the lateral articular surface varied from 7.5 to 10 cm, while the posterior articular surface was between 13 and 15.8 cm from the nerve[24]. Bono and Mazurek studied the distance from the same point to the lateral epicondyle, reporting distances of 16 and 12.2 cm, respectively[27,28]. In a study by Guse, the nerve was reported to be 18 cm proximal to the medial epicondyle and 12 cm proximal to the lateral epicondyle[25]. Gerwin studied similar parameters, reporting that the nerve was 20 and 14 cm proximal to the medial and lateral epicondyle, respectively[26].

Other studies have used the transepicondylar width as a reference. In a study by Kamineni, the radial nerve was found to cross the humerus at the midlateral axis at a distance of 1.7 times the transepicondylar width from the lateral epicondyle[19]. Hackl stated that the nerve was 12.7$\pm$1.6 cm from the proximal border of the olecranon fossa at the midhumeral axis, which was 1.9 times the transepicondylar width[22].

Most of the various reference structures for locating the radial nerve which have been reported in the literature can be used to identify the nerve intraoperatively during conventional open surgery. The parameters in each study, however, were reported to vary with both the length of the humerus and the patient's height. In this study, the authors identified parameters to determine the position of the nerve in MIPO surgery preoperatively using easily palpable bony landmarks. Specifically, the nerve can be located at the midhumeral axis at a distance of about 2.3 times the transepicondylar width from the medial or the lateral epicondyle and 2.7 times the transepicondylar width from the ulnar border of the olecranon process at 90 degrees of elbow flexion. In our opinion, the olecranon is much easier to palpate and the statistical correlation analysis of the OND is better than the LND and MND, the authors prefer to use the predicted distance from the olecranon to locate the radial nerve than the epicondyle. The ratio of those distances remains constant and is not affected by the height of the patient or the length of the humerus. The transepicondylar width is also possible to measure in the anteroposterior view of elbow radiography when the epicondyles are obscured by the swollen soft tissue. In cases of shortening or malalignment of fracture fragments, the humerus can be realigned by longitudinal traction using fluoroscopic imaging to achieve the proper length of the bone. The nerve can then be visualized and protected by means of a separate incision at the predicted location. After that the plate can be passed safely under the nerve in a distal to proximal direction. After restoration of the bone length and rotation, the plate can be fixed to the bony fragments.

Conclusion

Avoidance of iatrogenic radial nerve injury is of paramount importance in treatment of distal humeral shaft fractures. With the posterior open surgery approach, the triceps aponeurosis is commonly used as a reference landmark for locating the radial nerve. The method of locating the radial nerve in MIPO surgery developed in this study allows for the location of the nerve preoperatively using easily accessible osseous landmarks. This method allows the surgeon to explore and protect the nerve under direct vision at a precise location, minimizing soft tissue damage and helping to insure good results in treatment of distal humeral fractures.

What is already known on this topic?

The anatomy of the radial nerve was studied and was related to the soft tissue and bony landmarks. The triceps aponeurosis was commonly used by several studies to predict the radial nerve position during posterior approach of the humerus. While in other studies, the radial nerve location was determined by the distance from the nerve to the osseous landmarks such as the proximal border of the olecranon fossa, the medial and lateral humeral epicondyle.

What this study adds?

The authors demonstrates a technique to predict the location of the radial nerve preoperatively by using a ratio between the distance from the nerve to the palpable bony landmarks and the transepicondylar width. The ratio are not effected by the height of the patient and length of the humerus.

Fund & Bebefit

No funds were received in support of this work. No benefits in any form have been or will be

received from a commercial party related directly or indirectly to this manuscript.

Potential conflicts of interest

The authors declare no conflict of interest.

References

1. Sarmiento A, Zagorski JB, Zych GA, Latta LL, Capps CA. Functional bracing for the treatment of fractures of the humeral diaphysis. J Bone Joint Surg Am 2000;82:478-86.
2. Kapil Mani KC, Gopal S, Rijal L, Govinda KC, Shrestha BL. Study on outcome of fracture shaft of the humerus treated non-operatively with a functional brace. Eur J Orthop Surg Traumatol 2013;23:323-8.
3. Ajmal M, O'Sullivan M, McCabe J, Curtin W. Antegrade locked intramedullary nailing in humeral shaft fractures. Injury 2001;32:692-4.
4. Simon P, Jobard D, Bistour L, Babin SR. Complications of Marchetti locked nailing for humeral shaft fractures. Int Orthop 1999;23:320-4.
5. Sanzana ES, Dummer RE, Castro JP, Diaz EA. Intramedullary nailing of humeral shaft fractures. Int Orthop 2002;26:211-3.
6. Fernandez FF, Matschke S, Hulsenbeck A, Egenolf M, Wentzensen A. Five years' clinical experience with the unreamed humeral nail in the treatment of humeral shaft fractures. Injury 2004;35:264-71.
7. Chapman JR, Henley MB, Agel J, Benca PJ. Randomized prospective study of humeral shaft fracture fixation: intramedullary nails versus plates. J Orthop Trauma 2000;14:162-6.
8. Tingstad EM, Wolinsky PR, Shyr Y, Johnson KD. Effect of immediate weightbearing on plated fractures of the humeral shaft. J Trauma 2000;49:278-80.
9. Leunig M, Hertel R, Siebenrock KA, Ballmer FT, Mast JW, Ganz R. The evolution of indirect reduction techniques for the treatment of fractures. Clin Orthop Relat Res 2000;(375):7-14.
10. Perren SM. Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: choosing a new balance between stability and biology. J Bone Joint Surg Br 2002;84:1093-110.
11. Claessen FM, Peters RM, Verbeek DO, Helfet DL, Ring D. Factors associated with radial nerve palsy after operative treatment of diaphyseal humeral shaft fractures. J Shoulder Elbow Surg 2015;24:e307-11.
12. Wang JP, Shen WJ, Chen WM, Huang CK, Shen YS, Chen TH. Iatrogenic radial nerve palsy after operative management of humeral shaft fractures. J Trauma 2009;66:800-3.
13. Concha JM, Sandoval A, Streubel PN. Minimally invasive plate osteosynthesis for humeral shaft fractures: are results reproducible? Int Orthop 2010;34:1297-305.
14. Zhiquan A, Bingfang Z, Yeming W, Chi Z, Peiyan H. Minimally invasive plating osteosynthesis (MIPO) of middle and distal third humeral shaft fractures. J Orthop Trauma 2007;21:628-33.
15. Kobayashi M, Watanabe Y, Matsushita T. Early full range of shoulder and elbow motion is possible after minimally invasive plate osteosynthesis for humeral shaft fractures. J Orthop Trauma 2010;24:212-6.
16. Gallucci G, Boretto J, Vujovich A, Alfie V, Donndorff A, De Carli P. Posterior minimally invasive plate osteosynthesis for humeral shaft fractures. Tech Hand Up Extrem Surg 2014;18:25-30.
17. Balam KM, Zahrany AS. Posterior percutaneous plating of the humerus. Eur J Orthop Surg Traumatol 2014;24:763-8.
18. Gausden EB, Christ AB, Warner SJ, Levack A, Nellestein A, Lorich DG. The triceps-sparing posterior approach to plating humeral shaft fractures results in a high rate of union and low incidence of complications. Arch Orthop Trauma Surg 2016;136:1683-9.
19. Arora S, Goel N, Cheema GS, Batra S, Maini L. A method to localize the radial nerve using the 'apex of triceps aponeurosis' as a landmark. Clin Orthop Relat Res 2011;469:2638-44.
20. Kamineni S, Ankem H, Patten DK. Anatomic relationship of the radial nerve to the elbow joint: clinical implications of safe pin placement. Clin Anat 2009;22:684-8.
21. Seigerman DA, Choung EW, Yoon RS, Lu M, Frank MA, Gaines LC, et al. Identification of the radial nerve during the posterior approach to the humerus: a cadaveric study. J Orthop Trauma 2012;26:226-8.
22. Hackl M, Damerow D, Leschinger T, Scaal M, Muller LP, Wegmann K. Radial nerve location at the posterior aspect of the humerus: an anatomic study of 100 specimens. Arch Orthop Trauma Surg 2015;135:1527-32.
23. McCann PA, Smith GC, Clark D, Amirfeyz R. The tricipital aponeurosis—a reliable soft tissue landmark for humeral plating. Hand Surg

2015;20:53-8.
24. Uhl RL, Larosa JM, Sibeni T, Martino LJ. Posterior approaches to the humerus: when should you worry about the radial nerve? J Orthop Trauma 1996;10:338-40.
25. Guse TR, Ostrum RF. The surgical anatomy of the radial nerve around the humerus. Clin Orthop Relat Res 1995;(320):149-53.
26. Gerwin M, Hotchkiss RN, Weiland AJ. Alternative operative exposures of the posterior aspect of the humeral diaphysis with reference to the radial nerve. J Bone Joint Surg Am 1996;78:1690-5.
27. Bono CM, Grossman MG, Hochwald N, Tornetta P 3rd. Radial and axillary nerves. Anatomic considerations for humeral fixation. Clin Orthop Relat Res 2000;(373):259-64.
28. Mazurek MT, Shin AY. Upper extremity peripheral nerve anatomy: current concepts and applications. Clin Orthop Relat Res 2001;(383):7-20.