COURSE OF THE RADIAL NERVE IN THE VULNERABLE AREA ALONG THE SHAFT OF THE HUMERUS: A CADAVERIC STUDY

Arkaphat Kosiyatrakul, Phongsak Phongthipakorn*, Malee Chanpoo**, Suriya Luenam**

***Department of Orthopedics, Phramongkutklao Hospital and Phramongkutklao College of Medicine, Bangkok, Thailand**

****Department of Anatomy, Phramongkutklao College of Medicine, Bangkok, Thailand**

Abstract

Background: The radial nerve is the most commonly injured nerve associated with humeral fracture. Moreover, the nerve could be iatrogenically injured during fixation of the humerus.

Objective: The study aimed to identify the course of the radial nerve on the posterior and lateral aspects of the humerus.

Methods: Thirty-three adult embalmed cadaveric specimens were included in the study. The humeral length was determined as the distance between the posterior lateral aspect of the acromion and the lateral epicondyle. The distance between the lateral epicondyle to the posterior and lateral course of the nerve were measured.

Results: The average humeral length was 27.7 (±1.8) cm. The mean distance between the lateral epicondyle and posteromedial point, midposterior point, posterolateral point, midlateral point and anterolateral point were 17.4 (±1.2), 15.2 (±1.0), 12.7 (±0.8), 9.5 (±1.0) and 6.4 (±0.8) cm, respectively.

Conclusion: The high variation of the course of the radial nerve along the humerus was confirmed. The results in the present study can be used as a guide to determine the posterior and lateral course of the radial nerve during surgical exploration and prevent the nerve from iatrogenic injury during orthopedic operation.

Keywords : Radial nerve, Course, Humerus, Posterior cortex, Lateral cortex

J Southeast Asian Med Res 2019; 3(1): 8-17.
http://www.jseamed.org

Correspondence to:

Kosiyatrakul A, Department of Orthopaedics, Phramongkutklao Hospital and Phramongkutklao College of Medicine, Bangkok 10400, Thailand.

E-mail : arkaphat@yahoo.com

Introduction

The radial nerve is the most commonly injured nerve associated with humeral fracture. The close relationship of the nerve to the posterior and lateral cortex of the humerus makes the nerve vulnerable to injury either by trauma such as fracture of the humerus [1-4] or iatrogenic injury during fixation of the humeral fracture using a plate, nail or external fixator. [5-13]

Indications for surgical exposure of the radial nerve include repairing the injured nerve, excising the nerve tumor, decompressing the nerve and identifying the radial nerve during some types of humeral fracture fixation. Thus, knowledge of the location of the radial nerve not only prevents iatrogenic injury but also guides a surgeon when exploring the nerve is necessary.[14]

The current literature has demonstrated a wide variety of reference surgical landmarks.[15-28] For this reason, the exact course of the nerve along the humerus is still inconclusive. The authors have studied the course of the radial nerve in the most vulnerable area and compared the finding with related studies. The authors have attempted to include the English literature regarding the anatomy of the radial nerve as much as possible and summarized them in one conclusion. The suggestions and tips to identify the radial nerve and prevent iatrogentic injury in each study were also included in the present study.

Methods

A total of 33 adult embalmed cadaveric specimens (11 males, 6 females; 16 right, 17 left) were included in the study. The mean age of cadavers was 72 years (range from 65 to 90 years). One specimen was excluded from the study because of a deformity of the humerus.

After removing the skin and subcutaneous fatty tissue of the upper extremity, the posterior course of the radial was identified between the long and lateral head of the triceps. Then the radial nerve was carefully traced along its course distally without disrupting its original position by dividing the lateral head of the triceps and lateral intermuscular septum. After identifying the entire posterior and lateral course of the radial nerve along the humeral shaft, the nerve was then pinned to the surrounding tissue at the postero- medial, postero-lateral and antero-lateral point according to the cortex of the humerus. The lateral epicondyle was used as a reference point to measure the location of the nerve because it serves as a constant anatomical landmark and is easy to identify.

The following distances were evaluated: (1) the humeral length, the posterior tip of the acromion to the lateral epicondyle, (2) the lateral epicondyle to the point where the radial nerve passes the posteromedial margin of the humerus, (3) the lateral epicondyle to the point where the nerve passes the mid-posterior aspect of the humerus, (4) the lateral epicondyle to the point where the nerve passes the posterolateral margin of the humerus, (5) the lateral epicondyle to the point where the nerve passes the midlateral portion of the humerus and (6) the lateral epicondyle to the point where the nerve passes the anterolateral margin of the humerus (**Fig.1**). Each distance was measured and recorded in centimeters by two different surgeons. The mean values, range and standard deviation were calculated. Unpaired t-test was used to compare the data with related studies that used the same anatomical landmarks. A p-value below 0.05 indicated a statistical significance.

Results

The results of measurements are shown in **Table 1**. The comparisons of each parameter to the related studies are shown in **Table 2**. The average humeral length in the present study was 27.7 (± 1.8) cm. The mean distance between posteromedial point and lateral epicondyle in the present study was 17.4 (±1.2) cm. The mean distance between the midposterior point and the lateral epicondyle was 15.2 (±1.0) cm. The mean distance between the posterolateral point and the lateral epicondyle was 12.7 (±0.8) cm. The mean distances from the midlateral point and the anterolateral margin to the lateral epicondyle were 9.5 (±1.0) cm and 6.4 (±0.8) cm, respectively. The average distances from the lateral epicondyle to the point where the radial nerve passes the measuring points along the posterior shaft of the humerus are presented in the **Table 3**. A wide variety of the reported course of the radial nerve in the literature is shown in **Figure 2**.

Fig 1. The anatomic landmarks used to locate the course of the radial nerve along the humeral shaft. (PA = posterior tip of the acromion, PM = posteromedial margin, MP = mid-posterior point, PL = posterolateral margin, ML = mid-lateral point, AL = anterolateral margin, LE = lateral epicondyle)

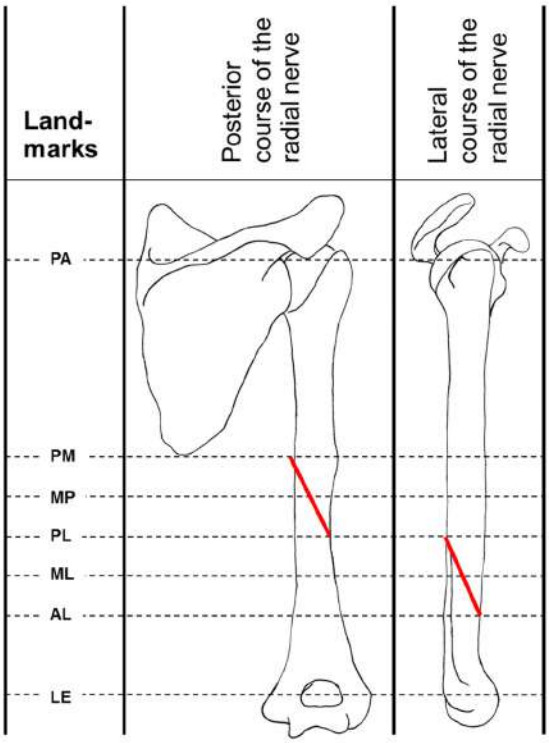


Table 1. Distance from the lateral epicondyle to the measuring point of the radial nerve

	Mean ± SD (cm)	Median (cm)	Min - Max (cm)	Range in % of humeral length
HL	27.7 ± 1.8	27.7	235 - 317	
LE to PM	17.4 ± 1.2	17.5	149 - 202	62.8 ± 4.3
LE to MP	15.2 ± 1.0	15.3	129 - 180	54.9 ± 3.6
LE to PL	12.7 ± 0.9	12.5	113 - 142	45.8 ± 3.2
LE to ML	9.5 ± 1.0	9.5	75 - 110	34.2 ± 3.6
LE to AL	6.4 ± 0.8	6.3	52 - 80	23.1 ± 2.9

HL = humeral length, LE = lateral epicondyle, PM = posteromedial margin, MP = mid-posterior point, PL = posterolateral margin, ML = mid-lateral point, AL = anterolateral margin

Table 2. Location of the radial nerve relative to the lateral epicondyle in the present study compared with previous studies that used the same reference point

	Measurement in cm					
	HL	LE to PM	LE to PL	LE to LIS	LE to ML	LE to AL
This study	27.7 ± 1.8	17.4 ± 1.2	12.7 ± 0.8		9.5 ±1.0	6.4 ± 0.8
33 arms	(23.5 -31.7)	(14.9-20.2)	(11.3-14.2)		(7.5-11.0)	(5.2-8.0)
Guse and Ostrum [15]	30.2 ± 1.8*		12.6 ± 1.1			
24 arms	(26.9-33.5)		(10.1-14.8)			
Gerwin et al [17]			14.2 ± 0.6*			
10 arms						
Fleming et al [19]				10.2 ± 0.8*		
20 arms				(9.1-11.4)		
Carlan et al [20]	28.7 ± 2.5	17.1 ± 1.6		10.9 ± 1.5*		
27 arms						
Chou et al [21]			10.4 ± 2.5*			
120 arms			(6.0-15.6)			
Kamineni et al [22]				10.2 ± 1.0*		
70 arms				(7.5-12.9)		
Artico et al [23]	29.0 ± 0.6*		12.1 ± 1.3*	11.0 ± 2.3*		
30 arms						
Cox et al [26]				11.8 ± 2.1*		
34 arms				(8.9-19.0)		
Wegmann et al [28]			13.5 ± 1.3*		9.7 ± 1.6	6.0 ± 1.8
95 arms			(9.9-17.2)		(6.2-13.9)	(2.7-10.2)

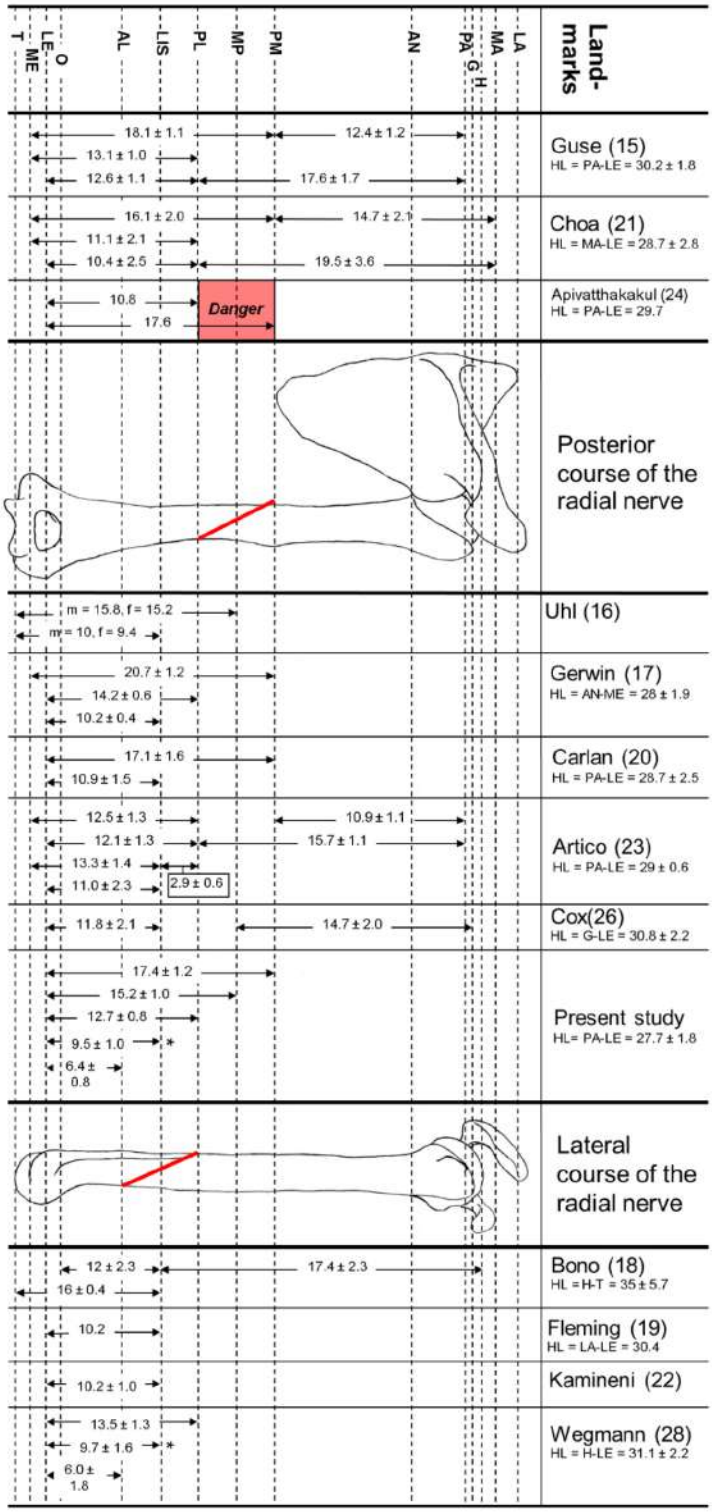
Values expressed as mean ± standard deviation, with range in parentheses, * significant difference ($p < 0.05$), HL = humeral length, LE = lateral epicondyle, PM = posteromedial margin, PL = posterolateral margin, LIS = lateral intermuscular septum, ML = mid-lateral point, AL = anterolateral margin

Table 3. Average and range of the distance from the lateral epicondyle to the measuring point of the radial nerve

Distance	Average (cm)		Range (cm)	
	Min	Max	Min	Max
LE to PM	17.1 ± 1.6 [20]	17.4 ± 1.2 [PS]	14.9 [PS]	20.2 [PS]
LE to MP	15.2 ± 1.0 [PS]		12.9 [PS]	18 [PS]
LE to PL	10.4 ± 2.5 [21]	13.5 ± 1.3 [28]	6 [21]	17.2 [28]
LE to LIS	10.2 ± 1.0 [19]	11.8 ± 2.1 [26]	7.5 [22]	19.0 [26]
LE to ML	9.5 ± 1.0 [PS]	9.7 ± 1.6 [28]	6.2 [28]	13.9 [28]
LE to AL	6.0 ± 1.8 [28]	6.4 ± 0.8 [PS]	2.7 [28]	10.2 [28]

LE = lateral epicondyle, PM = posteromedial margin, MP = mid-posterior point, PL = posterolateral margin, LIS = lateral intermuscular septum, ML = mid-lateral point, AL = anterolateral margin, [ ] = reference number, PS = the present study

Fig 2. A wide variety of the reported course of the radial nerve in the literature. HL = humeral length, LA = lateral acromion, MA = middle point of acromion, H = proximal humerus, G = greater tuberosity, PA = posterior tip of the acromion, AN = medial aspect of anatomical neck, PM = posteromedial margin, MP = mid-posterior point, PL = posterolateral margin, LIS = lateral intermuscular septum, AL = anterolateral margin, o = olecranon fossa, LE = lateral epicondyle, ME = medial epicondyle, T = trochlear,



Discussion

The proximity of the radial nerve to the humeral shaft makes it vulnerable in two areas: posteriorly, where it runs in the spiral groove and laterally, where it passes from the posterior compartment to the anterior through the lateral intermuscular septum. [1-4] The course of the radial nerve in these two areas has been documented in various studies but the results are inconsistent. One possibility for this phenomenon is the difference in using the reference bony landmark in the literature reviewed (**Fig. 2**).

The distal reference point, for instance, includes the olecranon fossa [18], lateral epicondyle [15, 17, 19-24, 26, 28] medial epicondyle [15, 17, 21, 23], trochlea [16-18] and triceps aponeurosis. [25, 27] Among them, the lateral epicondyle is used the most commonly. With this reference point, some conclusions about the course of the radial nerve along the humeral shaft have been made.

Posterior course of the radial nerve

Other than the knowledge of the reported distance, many methods can help to identify or protect the radial nerve in this area. Guse and Ostrum [15] described the mid-posterior point was close to the point midway between the posterior tip of the acromion and medial epicondyle. Cox et al.[26] showed the radial nerve at the posterior spiral groove was located at 50% of the distance between the greater tuberosity and lateral epicondyle. Carlan et al.[20] demonstrated that the center of the posterior course of the nerve, 6.3 ± 1.7 cm in distance, was close to the level of the distal aspect of the deltoid tuberosity. The triceps aponeurosis can also be used as a surgical landmark. Chaudhry et al.[25] found that posteriorly, the radial nerve ran 2.2 to 2.7 mm lateral to the lateral triceps aponeurosis and was always greater than 13 ± 1 mm from this boundary. They proposed that the immediate area parallel (<10 mm) to the aponeurosis represented a "safe zone". Arora et al.[27] described the radial nerve as lying 2.5 cm proximal to the apex of the triceps aponeurosis. This information and these techniques are useful when the posterior approach of the humerus is indicated either for operative fixation or radial nerve exploration. Moreover, the radial nerve can also be injured from drills or screws when anterior plating is applied either by a standard open technique or minimally invasive plate osteosynthesis (MIPO). Apivatthakakul et al. [24] described the danger zone of the radial nerve during placement of the locking screw in fixating the humeral shaft fracture using the MIPO technique, as an area 10.8 to 17.59 cm proximal to the lateral epicondyle. In their study, the most dangerous area lay 14.03 to 15.8 cm proximal to lateral epicondyle. They suggested that a uni-cortical screw should be used in this danger zone.

Lateral course of the radial nerve

The average distances from the lateral epicondyle to the point where the radial nerve passes the measuring points along the lateral shaft of the humerus are presented in **Table 3.** The two most commonly used landmarks to describe the lateral course of the radial nerve include the point where the radial nerve traverses the lateral intermuscular septum [16-20, 22, 23, 26] and the point where the radial nerve passes the midlateral point of the humerus. [28] The mean distance from the mid-lateral point to the lateral epicondyle is shorter than the distance between the point where the nerve traverses the lateral intermuscular septum and lateral epicondyle. [19-21, 23, 28]

In the present study, the midlateral aspect of the humerus was used as a reference point and the nerve passes this point near the junction between the middle and distal thirds. This point is lower than the point where the radial nerve traverses the lateral intermuscular septum.

Fleming et al.[19] found that the point where the radial nerve pierces the lateral intermuscular septum is within 5 mm of the junction of the distal and middle thirds of the distance between the lateral epicondyle and lateral point of the acromion. Artico et al.[23] reported that the point where the nerve crosses the lateral aspect of the humeral shaft was close to the middle of a line drawn from the acromion angle to the lateral epicondyle. Cox et al. [26] described that when the humeral length was defined as the distance between the greater tuberosity and lateral epicondyle, the radial nerve passes the lateral intermuscular septum at a location 40% of this length proximal to the lateral epicondyle. Kamineni et al.[22] used transepicondylar distance to define a safe zone for the radial nerve. In their study, the average transepicondylar distance (62 ± 6 mm, range 52 to 78 mm) was less than the distance measured from the lateral epicondyle to the point where the nerve traverses the lateral intermuscular septum (102±10 mm, range 75 to 129 mm).

They concluded that the distance of 75 mm from the lateral epicondyle could be applied as a safe zone to all patients. Interestingly, iatrogenic injuries to the radial nerve below these reported points have been reported. Baumann et al. [12] reported 3 cases of iatrogenic radial disruption following the surgical technique using a hinge elbow external fixator. The distance, where the injury occurred from the distal pin, ranged from 3.2 to 4.7 cm proximal to the lateral epicondyle. Caldwell et al.[13] reported a case of radial nerve injury using the distal half pin of a hinge elbow external fixator. The nerve was undisrupted but was tensioned by the distal pin at 3.5 cm proximal to the lateral epicondyle. These reported cases confirmed the risk of radial nerve injury found in a cadaveric study conducted by Clement et al.[29] In their study, the radial nerve passed at or below the point 5 cm proximal to the lateral epicondyle in more than one half (14 of 20) of their specimens. Moreover, among 25% their specimens, the nerve was found at or distal to the point 3 cm proximal to the lateral epicondyle. Wegmann et al. [28] emphasized a high variety of the distal portion of the radial nerve. Therefore, these relative safe zones should be applied with caution especially in the case of humeral fracture, especially fracture around the elbow and elbow dislocation with or without fracture. Displacement of the bony structure can distort the normal anatomy of the nerve. Moreover, disruption to the supporting tissue around the nerve, swelling of the surrounding tissue and hematoma from the fracture all can create challenges to locate the nerve. Thus, the authors agree with the recommendation that an open incision followed by a carefully blunt dissection, allowing direct visualization to the cortex of the humerus, should be performed before drilling and aligning the pin. A drill sleeve or soft tissue protector must be used when the drill or half pin was drilled in to the humeral shaft to prevent spinning soft tissue nearby the nerve. This technique should also be applied when inserting the distal locking bolt of the intramedullary locking nail. Applying a medial plate can damage the radial nerve on the lateral cortex by drills, taps or screws that are inserted from the medial to the lateral direction. In this situation, a subperiosteal or submuscular retraction should be used to protect the nerve along the lateral aspect of the humerus.[20] Identifying the radial nerve during open reduction and internal fixation of a humeral fracture using plates is recommended for both the posterior or anterolateral approach in some literature. [11, 14,16-18, 27, 30] However, this maneuver does not promise the postoperative recovery will be free of radial nerve dysfunction. Instead, it can provide a high level of confidence to the surgeon that the radial nerve would not be directly damaged and full recovery of the nerve function could follow. [9-11]

One limitation in the present study was being conducted using the embalmed cadaveric humeri, so surgeons should keep in mind that these measured anatomical landmarks could be distorted in the case of humeral fracture.

Conclusion

The high variation in the course of the radial nerve along the humerus was confirmed. Even though some contrasts were found regarding related reports, the present study could create simple guidelines. The radial nerve passed the midposterior point of the humerus at just above the middle of the distance between the lateral epicondyle and posterior tip of the acromion. In addition, the nerve passed the midlateral point of the humerus around the junction between the middle and distal thirds of the interval between the described bony landmarks. These guidelines could help surgeons when identifying the radial nerve is needed especially in cases without humeral fracture or elbow injury. However, in cases associated with elbow injuries or fracture of the humerus, this information should be used with caution to avoid iatrogenic radial nerve injury.

Disclosure

No conflicts of interest were declared by the authors.

References

1. Pollock FH, Drake D, Bovill EG, Day L, Trafton PG. Treatment of radial neuropathy associated with fractures of the humerus. J Bone Joint Surg Am 1981; 63: 239-43.
2. Shah JJ, Bhatti NA. Radial nerve paralysis associated with fractures of the humerus. A review of 62 cases. Clin Orthop Relat Res 1983; 172: 171-6.
3. Mohler LR, Hanel DP. Closed fractures complicated by peripheral nerve injury. J Am Acad Orthop Surg 2006; 14: 32-7.

4. Shao YC, Harwood P, Grotz MR, Limb D, Giannoudis PV. Radial nerve palsy associated with fractures of the shaft of the humerus: a systematic review. J Bone Joint Surg Br 2005; 87: 1647-52.
5. Birch R, Bonney G, Dowell J, Hollingdale J. Iatrogenic injuries of peripheral nerves. J Bone Joint Surg Br 1991; 73: 280-2.
6. Rupp RE, Chrissos MG, Ebraheim NA. The risk of neurovascular injury with distal locking screws of humeral intramedullary nails. Orthopedics 1996; 19: 593-5.
7. Khan R, Birch R. Iatropathic injuries of peripheral nerves. J Bone Joint Surg Br 2001; 83: 1145-8.
8. Lin J, Shen PW, Hou SM. Complications of locked nailing in humeral shaft fractures. J Trauma 2003; 54: 943-9.
9. Chao TC, Chou WY, Chung JC, Hsu CJ. Humeral shaft fractures treated by dynamic compression plates, Ender nails and interlocking nails. Int Orthop 2005; 29: 88-91.
10. 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.
11. An Z, Zeng B, He X, Chen Q, Hu S. Plating osteosynthesis of mid-distal humeral shaft fractures: minimally invasive versus conventional open reduction technique. Int Orthop 2010; 34: 131-5.
12. Baumann G, Nagy L, Jost B. Radial nerve disruption following application of a hinged elbow external fixator: a report of three cases. J Bone Joint Surg Am 2011; 93: e51.
13. Caldwell JM, Kim HM, Levine WN. Radial nerve injury associated with application of a hinged elbow external fixator: a report of 2 cases. J Shoulder Elbow Surg 2013; 22: e12-6.
14. Hoppenfeld S, de Boer P. The humerus. In: Hoppenfeld S, de Boer P, editors. Surgical Exposures in Orthopaedics. The Anatomic Approach. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2003, p. 67-104.
15. Guse TR, Ostrum RF. The surgical anatomy of the radial nerve around the humerus. Clin Orthop Relat Res 1995; 320: 149-53.
16. 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.
17. 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.
18. 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.
19. Fleming P, Lenehan B, Sankar R, Folan-Curran J, Curtin W. One-third, two-thirds: relationship of the radial nerve to the lateral intermuscular septum in the arm. Clin Anat 2004;17: 26-9.
20. Carlan D, Pratt J, Patterson JM, Weiland AJ, Boyer MI, Gelberman RH. The radial nerve in the brachium: an anatomic study in human cadavers. J Hand Surg Am 2007; 32: 1177-82.
21. Chou PH, Shyu JF, Ma HL, Wang ST, Chen TH. Courses of the radial nerve differ between Chinese and Caucasians: clinical applications. Clin Orthop Relat Res 2008; 466: 135-8.
22. 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.
23. Artico M, Telera S, Tiengo C, Stecco C, Macchi V, Porzionato A, Vigato E, Parenti A, De Caro R. Surgical anatomy of the radial nerve at the elbow. Surg Radiol Anat 2009; 31: 101-6.
24. Apivatthakakul T, Patiyasikan S, Luevitoonvechkit S. Danger zone for locking screw placement in minimally invasive plate osteosynthesis (MIPO) of humeral shaft fractures: a cadaveric study. Injury 2010; 41: 169-72.
25. Chaudhry T, Noor S, Maher B, Bridger J. The surgical anatomy of the radial nerve and the triceps aponeurosis. Clin Anat 2010; 23: 222-6.
26. Cox CL, Riherd D, Tubbs RS, Bradley E, Lee DH. Predicting radial nerve location using palpable landmarks. Clin Anat 2010; 23: 420-6.
27. 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.

28. Wegmann K, Lappen S, Pfau DB, Neiss WF, Müller LP, Burkhart KJ. Course of the radial nerve in relation to the center of rotation of the elbow-the need for a rational safe zone for lateral pin placement. J Hand Surg Am 2014; 39: 1136-40.
29. Clement H, Pichler W, Tesch NP, Heidari N, Grechenig W. Anatomical basis of the risk of radial nerve injury related to the technique of external fixation applied to the distal humerus. Surg Radiol Anat 2010; 32: 221-4.
30. McKee MD, Larsson S. Humeral shaft fractures. In: Bucholz RW, Court-Brown CM, Heckman JD, Tornetta P III, editors. Rockwood and Green's Fractures in Adults. 7th ed. Philadelphia: Lippincott Williams & Wilkins; 2010, p. 999–1038.