Research Article

Risk of Radial Nerve Injury in Anterolateral Humeral Shaft Plating

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ABSTRACT

Purpose: The purpose of this study was to evaluate and compare the risk of iatrogenic radial nerve injury between arm positionings of 45° and 60° abduction in anterolateral humeral plating using a 4.5-mm narrow dynamic compression plate.

Methods: Fifty-six humeri of cadavers in the supine position with 45° of arm abduction were exposed through the anterolateral approach. A hypothetical fracture line was marked at the middle of the humerus, and a precontoured ten-hole 4.5-mm narrow dynamic compression plate was applied and fixed to the anterolateral surface. After the fixation, the radial nerve was exposed through a triceps-splitting approach. Screws in contact with or which had penetrated the radial nerve were deemed to be injuries. Then, the screws and plate were removed, the arm changed to the 60° arm abduction position, and the steps of applying the plate and inserting the screws were followed as in the 45° arm abduction step.

Results: The screws which could potentially injure the radial nerve were those of the second to sixth screw holes in both the 45° and 60° of arm abduction positions. The incidences of iatrogenic radial nerve injury of the second to sixth screw holes in the 45° position were 5.36%, 39.29%, 80.36%, 60.71%, and 10.71%, respectively, and at the 60° position were 5.36%, 53.57%, 83.93%, 60.71%, and 7.14%, respectively. There were no statistically significant differences in risk of injury between the two positions in all screw holes (all *P*-values > 0.05).

Discussion: In anterolateral humeral shaft fixation, arm abduction position did not affect the risk of iatrogenic radial nerve injury, with the main risk from certain screw holes. The surgeon should be careful in screw insertion, especially at the fourth and fifth screw holes.

Level of evidence: IV; cadaveric study.

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C. Chuaychoosakoon, S. Chirattikalwong conceived the study idea. C. Chuaychoosakoon, S. Chirattikalwong, S. Suwannaphisit, and W. Wuttimanop developed the theory and performed the cadaveric dissections. C. Chuaychoosakoon verified the analytical methods. All authors discussed the results and contributed to the final manuscript.

Each author certifies that the Ethics Committee of Prince of Songkla University (REC 62-434-11-1) has already approved this study protocol.

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A humeral shaft fracture occasionally results in radial nerve palsy, which can occur after the initial injury or during reduction or surgical fixation.[1-8] The possible causes of radial nerve injury during humeral shaft plating include compression from entrapment between the proximal and distal fracture fragments, penetration of the nerve while drilling the screw holes or inserting the screws, or stretching from a retractor such as placing a Hohmann retractor in the distal shaft of the humerus.[1-4,6,9] Previous studies have reported incidences of radial nerve palsy during this type of surgery ranging between 3.57% and 18.2%.[6,10-12]

In proximal-to-middle humeral shaft plating, there are two common factors that the surgeon needs to consider before surgery concerning arm and plate position. First is plate location. There are two common locations used in applying the plate, the anterolateral and posterior humerus. Some surgeons prefer to do anterolateral plating because it is not necessary to explore and identify the radial nerve, in contrast to the posterior approach, during which potential injury to the radial nerve from drilling the screw holes or inserting the screws is a factor.[13] In anterolateral humeral shaft fixation with a 4.5-mm narrow dynamic compression plate (DCP), drilling the screw holes or inserting the screws can cause injury to the radial nerve because the direction of the screws is toward the radial nerve, which crosses the posterolateral aspect of the humerus. The second factor is the arm position which can be either 45° or 60° of arm abduction. The degree of arm abduction may affect the tension of the radial nerve, and the risk of iatrogenic radial nerve injury is different in each arm position.

To date, there have been no studies which have evaluated and compared the risk of iatrogenic radial nerve injury in anterolateral humeral shaft plating with the 4.5-mm narrow DCP between 45° and 60° of arm abduction with a fully supinated forearm. The purpose of this study was to evaluate and compare the risk of iatrogenic radial nerve injury between the 45° and 60° arm abduction positions in anterolateral humeral plating with the 4.5-mm narrow DCP.

Methods

Fifty-six humeri of 28 full-body fresh frozen cadavers, 14 male and 14 female with a mean age at death of 67.21 years (range 54 to 78 years), were used in this study. The average lengths of the cadavers and the humeri were 165.01 cm (range 155 to 178 cm) and 275.58 mm (range 245 to 317 mm), respectively. Each cadaver was thawed at room temperature for 10 to 12 hours before the procedures were conducted.

Each cadaver was placed in the supine position with 45° of arm abduction and full forearm supination. All procedures were done with an anterolateral approach,

Figure 1

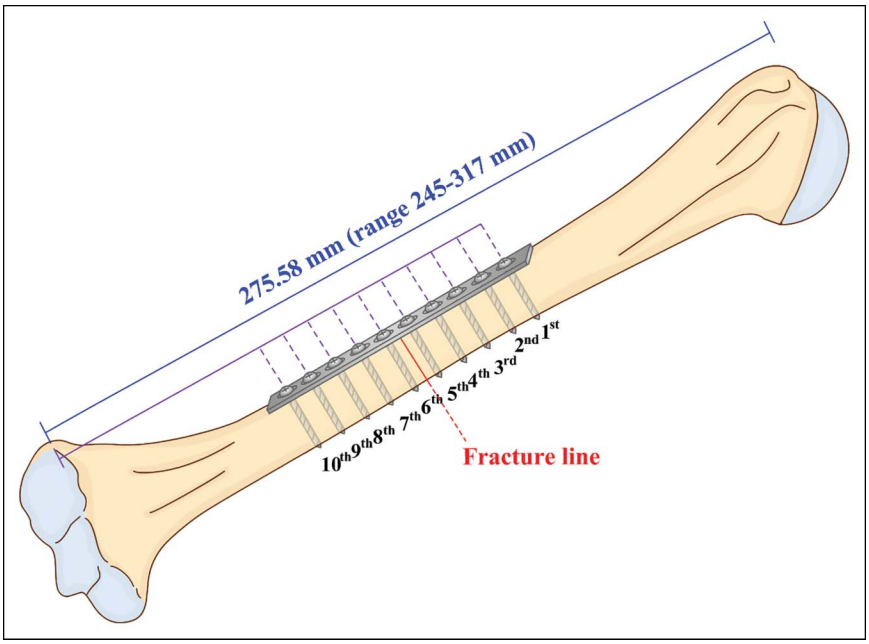


Diagram showing the measurement of the distances from each screw hole to the lateral epicondyle of the humerus (purple line) and the greater tuberosity of the humerus to the lateral epicondyle (blue line).

conducted by a single experienced orthopaedic surgeon with more than 10 years of experience in orthopaedic trauma. The skin incision was created from the tip of the coracoid process to 5 cm proximal to the elbow crease. The pectoralis major and deltoid muscles were retracted medially and laterally, respectively. The humeral shaft was exposed distally after splitting the brachialis muscle. An imaginary fracture line was created at the midpoint between the tip of the greater tuberosity and the lateral epicondyle using a permanent marker. A ten-hole 4.5-mm narrow DCP was contoured and applied to the anterolateral surface of the humerus using the imaginary fracture line to position the center of the plate. Ten screw holes were then drilled and tapped, and cortical screws inserted. To decrease potential bias from potentially inconsistent drill and screw directions, a drill sleeve was applied perpendicular to the plate and centered to the bone by the surgeon and the assistant. The screw holes were numbered from the proximal to distal humerus. The most proximal and distal screw holes were defined as the first and the 10th screw holes, respectively. After the fixation, the distance from each screw hole to the lateral epicondyle of the humerus was measured for calculating the relative ratios with the entire humerus (Figure 1). When the measurements were completed, the skin was closed with nylon 3-0.

Then, the cadaver was rolled to the prone position with 45° of arm abduction and full forearm supination. A posterior incision was made from the posterolateral corner of the acromion process to the tip of the olecranon. To identify the radial nerve, a triceps-splitting approach was used. Only the medial and lateral borders of the radial nerve were dissected to maintain a near-normal relationship between the nerve and the adjacent bone. The area of contact between the nerve and the bone was carefully examined, and any screws which had penetrated or touched the radial nerve were considered to be injuries and recorded (Figure 2). For the screws which did not touch the radial nerve, the closest distances were measured from the screw tip to the radial nerve (Figure 3). Then, the skin was closed with nylon 3-0.

Then the cadaver was rolled back to the supine position. The anterolateral wound was reopened, and the plate and screws were removed. Then, for the second stage of this study, the same arm of the same cadaver was positioned in the arm-at-side position, but this time abducted to 60° with full forearm supination. The steps of applying the plate and inserting the screws were followed as in the 45° arm abduction step, and the anterolateral wound was closed with nylon 3-0. Then, the cadaver was again rolled to the prone position, and the posterior wound was reopened. The path of the radial nerve was then reexamined, the screws penetrating or touching the radial nerve were noted, and the distances measured as in the 45° arm abduction step. All

Figure 2

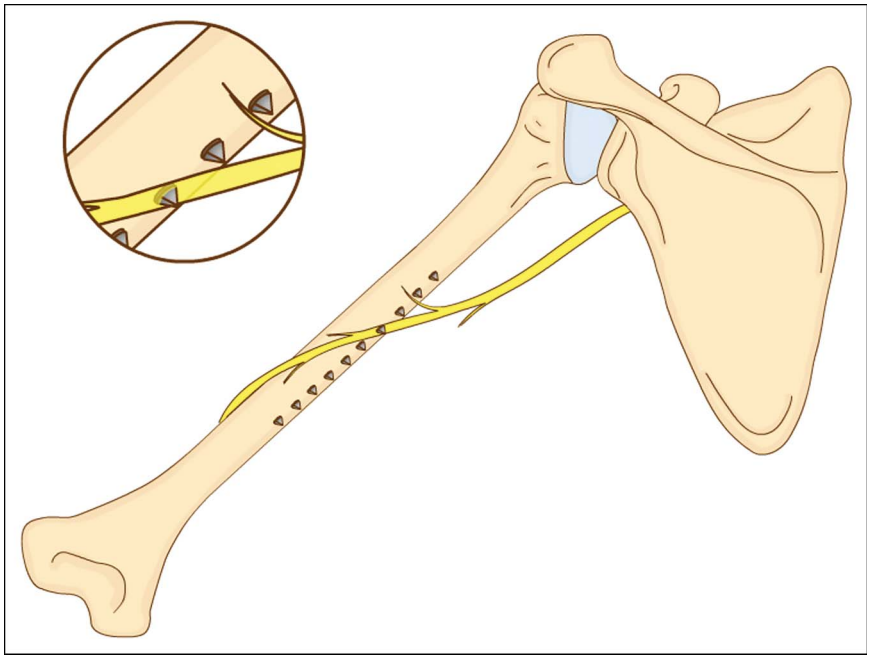
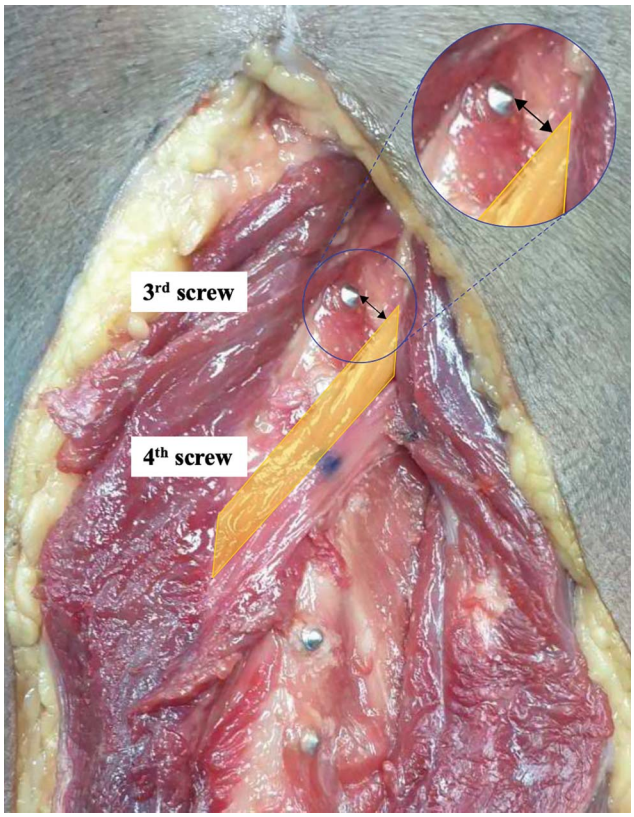


Diagram showing the fourth screw penetrating the radial nerve.

Figure 3



Photograph showing the closest distance (black arrow) measured from the third screw tip to the radial nerve. The fourth screw has touched and thus injured the radial nerve.

distances were measured with 0.001 mm precision using a vernier caliper (Insize).

Statistical Analysis

To minimize possible measurement bias, each distance was measured three times by two orthopaedic surgeons who had not participated in the dissection of the cadavers, and the mean ± SDs were calculated and used for the analysis. The statistical analysis was conducted using the R program and "epicalc" package (version 3.4.3; R Foundation for Statistical Computing). The different risks of iatrogenic radial nerve injury between the two arm positions were determined using the chi square or Fisher exact test. A *P*-value of 0.05 was considered significant.

Ethics, Funding, and Potential Conflicts of Interest

This study was approved by the Ethics Committee of our University, and the need for informed consent for this study was waived (REC 63-174-11-1). This study was conducted in accordance with the STROBE guidelines.[14] This study was supported by our University. No competing interests were declared.

Results

The incidences of iatrogenic radial nerve injury and the closest distance between each screw tip and the radial nerve with 45° and 60° of arm abduction are summarized in Table 1. With 45° of arm abduction, the incidences of radial nerve injury were lower than those with 60° of arm abduction in the third and fourth screw holes, but the incidence was higher in the sixth screw hole. There were no statistically significant differences between the 45° arm abduction and 60° arm abduction positions in the second to sixth screw holes, for which the *P*-values were 1, 0.185, 0.805, 1, and 0.740, respectively.

The relative distance ratios of the entire humeral length for the distances between the lateral epicondyle of the humerus and the proximal and distal parts of the radial nerve were 0.64 and 0.44, respectively. The relative distance ratios of the entire humeral length between the lateral epicondyle of the humerus and the second to sixth screw holes are presented in Table 2.

Discussion

Anterolateral humeral shaft fixation with a 4.5-mm narrow DCP can endanger the radial nerve when the arm is positioned in either 45° or 60° of abduction. There are however slightly greater risks in some of the plate holes in some arm positions, and to decrease the risk as much as possible, we recommend positioning the arm at 45° abduction in proximal half fixation (third and fourth screw holes) and at 60° abduction in distal half fixation (sixth screw hole) of the humerus.

In our study, we found that there was no risk of iatrogenic radial nerve injury while drilling holes and inserting screws at the 1st, 7th, 8th, 9th, and 10th screw holes, but there was a chance of radial nerve injury at the second to sixth screw holes. The results of our study are different from an earlier study by Apivatthakakul et al,[5] which evaluated the risk of iatrogenic radial nerve injury in anterior humeral plating with a 4.5-mm narrow locking compression plate (LCP), which is preferred in the case of osteoporotic humeral shaft fracture.[15,16] That study found chances of radial nerve injury while drilling the holes and inserting the screws in the fourth to ninth screw holes, with incidences of 22.2%, 38.9%, 50%, 44.4%, and 16.7%, respectively. The reasons for

Table 1. The Incidences of Iatrogenic Radial Nerve Injury With 45° and 60° of Arm Abduction

	% Injured		Closest Distance ± SD (mm.)	
	Arm Abduction		Arm Abduction	
Hole Number	45°	60°	45°	60°
1	0 of 56 (0%)	0 of 56 (0%)	38.33 ± 19.24	34.71 ± 16.24
2	3 of 56 (5.36%)	3 of 56 (5.36%)	23.69 ± 16.79	21.03 ± 14.33
3	22 of 56 (39.29%)	30 of 56 (53.57%)	10.12 ± 13.61	8.16 ± 11.54
4	45 of 56 (80.36%)	47 of 56 (83.93%)	3.05 ± 7.58	2.13 ± 5.94
5	34 of 56 (60.71%)	34 of 56 (60.71%)	3.80 ± 6.50	4.02 ± 5.97
6	6 of 56 (10.71%)	4 of 56 (7.14%)	16.53 ± 11.43	16.16 ± 10.55
7	0 of 56 (0%)	0 of 56 (0%)	32.56 ± 15.03	31.34 ± 14.01
8	0 of 56 (0%)	0 of 56 (0%)	49.39 ± 20.29	46.58 ± 18.09
9	0 of 56 (0%)	0 of 56 (0%)	65.18 ± 24.66	61.81 ± 22.55
10	0 of 56 (0%)	0 of 56 (0%)	77.57 ± 32.41	77.68 ± 27.63

the differences in their study and ours are likely related to the actual location of the plate and the direction of the screws. The 4.5-mm narrow DCP is commonly used in humeral shaft plating because it is inexpensive, available in all hospitals, and provides good stability of fixation when compared with the 4.5-mm narrow LCP.[15] The 4.5 mm-narrow DCP used to determine the risk of radial nerve injury in our study was applied at the anterolateral aspect of the humerus, whereas the 4.5-mm LCP used in the study of Apivatthakakul et al was applied at the anterior aspect of the humerus. Therefore, the direction of the screws of the 4.5-mm narrow DCP pointed to the posteromedial humerus while the direction of the screws of the 4.5-mm narrow LCP projected to the mid-posterior humerus.

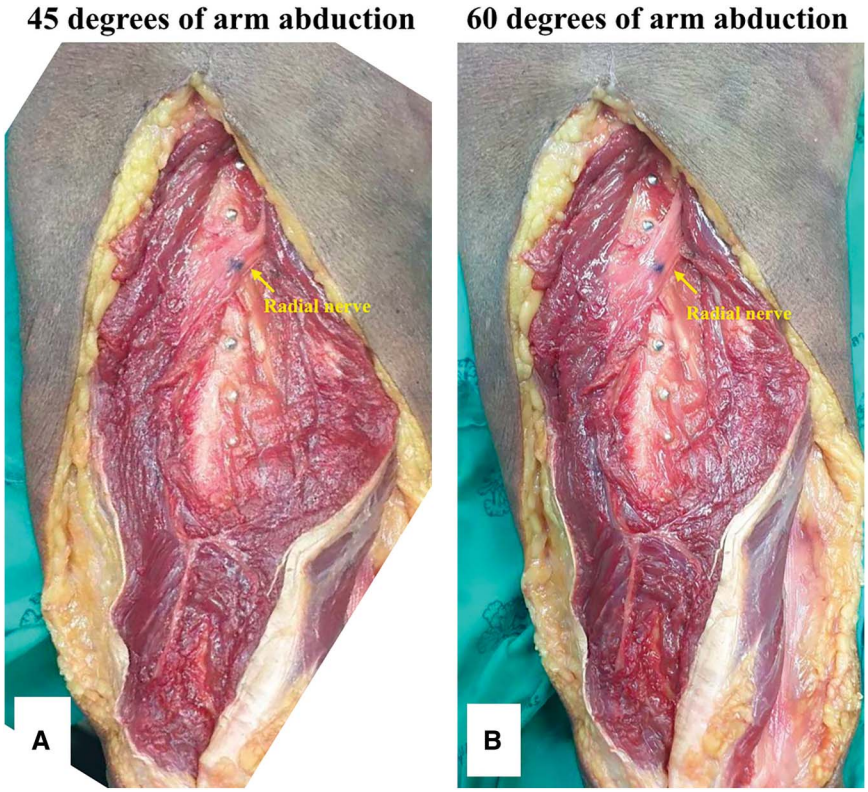
We found that the plate position affected the incidence of radial nerve injury while the arm position did not affect the risk. There were , however, slightly greater risks in some holes in some positions. This is probably because of the fact that the nerve crosses the posteromedial humerus at a fixed point, and when the arm is placed in an increasing arm abduction position, there is increased tension and excursion of the proximal part of the radial nerve (Figure 4, A and B). Our study found that with the third and fourth screw holes, it was slightly safer to drill the holes and insert the screws at 45° of arm abduction, with risks of 39.29% and 80.36%, respectively, but with the sixth screw hole, 45° of arm abduction was slightly more dangerous in both drilling the hole and inserting the screw than with 60° of arm abduction, with incidences of 10.71% and 7.14%, respectively. The results from this study are easy to apply to other areas of humeral shaft fracture. For screw holes located at the proximal half of the humerus, we suggest creating the holes and inserting the screws with 45° of arm abduction, while with distal half screw fixation, we suggest positioning the arm at 60° abduction. The surgeon can apply the results of this study to minimize the risk of radial nerve injury as long as the condition is followed that each half of the plate should cover a minimum of six cortices.[17] In proximal half fixation, the surgeon can decrease the risk of radial nerve injury by inserting unicortical screws in the fourth and fifth screw holes and adding a fourth cortex on the same side while for the distal half of the plate, the surgeon should insert a unicortical screw at the sixth screw hole and add a fifth cortex on the same side. In cases in which the fracture site is not within the middle part of the humerus, the surgeon can use the

Table 2. The Relative Distance Ratios of the Entire Humeral Length Between the Lateral Epicondyle of the Humerus and the Second to Sixth Screw Holes

Hole Number	Relative Distance Ratios
2	0.64
3	0.60
4	0.56
5	0.52
6	0.48

(Showing the relative distance ratios of only the second to sixth screw holes because there was no risk of iatrogenic radial nerve injury in the 1st, 7th, 8th, 9th, and 10th screw holes.)

Figure 4



Photographs showing that the degree of arm abduction affects the tension and thus position of the radial nerve: (**A**) 45° of arm abduction and (**B**) 60° of arm abduction.

relative distance ratios of the entire humeral length between the lateral epicondyle and the greater tuberosity of the humerus to determine the risk of iatrogenic radial nerve injury. For example, when the surgeon inserts a screw into a screw hole for which the relative distance ratio is 0.56, the surgeon should insert the screw with caution because this screw hole position carries the highest risk of radial nerve injury.

The main strength of this study is that this is the first study to identify the risk of radial nerve injury in various screw hole positions in anterolateral plating with a 4.5-mm narrow DCP by simulating a mid-humeral fracture. In cases of different fracture locations, we have calculated relative distance ratios of the entire humeral length between the lateral epicondyle and the greater tuberosity of the humerus, which can be used to determine the risk of iatrogenic radial nerve injury.

Our study had some limitations. First, the anatomic relationship between the radial nerve and the humerus may not reflect the actual injury, which depends on the fracture pattern, reduction alignment, and/or degree of soft-tissue trauma. Second, the average length of our cadavers may not reflect the actual risk of injury to unusually tall or short patients. In this study, we report the positions of screw holes and the relative distance ratios of the screw holes, which can be applied to patients with different humeral lengths.

In conclusion, using both 45° and 60° of arm abductions in anterolateral humeral shaft fixation with a 4.5-mm narrow DCP involves a chance of iatrogenic radial nerve injury. There are however slightly greater risks in some holes in some positions, and to decrease the risk as much as possible, we recommend positioning the arm at 45° abduction in the proximal half (third and fourth screw holes) and at 60° abduction in the distal half of humeral fixation (sixth screw hole) (http://links.lww.com/JAAOS/A797).

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