The radial nerve danger zone: A cadaver study

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Abstract

Certain distal humerus fractures and elbow fracture dislocations warrant early fixation with an external fixator. The distal humerus is close to the radial nerve and a hazardous area for the placement of an external fixator. No known safe zone for the placement of an external fixator has been identified on the lateral border of the humerus. We record the incidence of radial nerve damage following external pin fixation and note the relation of the radial nerve to each pin.

A total of 39 cadavers were dissected for this study. Two 4 mm pins were placed with a multi-pin clamp into the lateral border of the right and left humerus at 100 mm and 70 mm proximal to the lateral epicondyle. We dissected the upper limbs and recorded the incidence of radial nerve damage and the position of the nerve in relation to the two pins. Data for right and left sides were combined. The radial nerve was damaged by the proximal and distal pin in 56.4% and 20.5% respectively. The radial nerve was located anterior to the proximal pin (41%) and distal pin (79.5%). The radial nerve was located posterior to the proximal pin (2.6%) and distal pin (0.0%). We were unable to identify a safe zone from this study. We propose that pins should be placed less than 100 mm proximally from the lateral epicondyle and as posterior as possible to minimise the risk of radial nerve damage.

Key words: radial nerve, external fixation, humerus fractures

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Introduction

Distal humerus fractures are uncommon, comprising 2% of all fractures and a third of all humerus fractures.[1] Open fractures, comminuted fractures and fracture dislocation of the elbow are often accompanied by severe soft tissue damage. External fixation of the humerus is indicated when severe soft tissue damage or the presence of infection warrants initial alternative immobilisation of the fractures around the elbow.[2] External fixation allows for easy access for wound cleaning and dressing,[3] stabilises fractures where vascular and nerve repair was done[4] and allows for frame adjustments to improve alignment. External fixation allows for early mobilisation of adjacent joints and mobilisation of the patient.[5] External fixation can cause pin tract sepsis,[6] and injury to nerves and blood vessels and the surrounding soft tissue.[7] The radial nerve is situated close to the humerus, and placing external fixation around the distal humerus may lead to nerve damage.

The upper limb is innervated by a plexus of nerves arising from the ventral rami of the C5–T1 nerve roots. The ventral rami of the upper, middle and lower trunks divide into anterior and posterior divisions. The posterior divisions of all three trunks form the posterior cord.[8] In the axilla, the radial nerve is located posterior to the axillary artery from where it runs inferiorly along the medial aspect of the proximal humerus. The radial nerve then descends along the radial groove to pierce the lateral inter-muscular septum proximal to the lateral epicondyle where it runs between the brachialis and brachioradialis muscles.

As the radial nerve approaches the lateral epicondyle it divides into the superficial radial and posterior interosseous nerves.[8]

The highest risk of injury to the radial nerve is at the point where the nerve pierces the lateral intermuscular septum.[9] Bodner *et al*.[10] identified the radial nerve at 100 mm proximal to the epicondyle using ultrasonography. Artico *et al*.[11] performed a study on fresh cadavers and found that the mean distance between the lateral epicondyle and the point where the nerve pierces the lateral intermuscular septum was 110 mm.[11] Kamineni *et al*.[12] described the safe zone for placing pins in relation to the trans-epicondylar distance. They concluded that 100% of the trans-epicondylar distance along the lateral border of the humerus was a safe zone for external fixation.[12] Clement *et al*.[13] stated the risk of radial nerve damage by external fixation may be due to the variation in the course of the nerve and that wide incision and blunt dissection to the cortex was necessary to prevent nerve damage.

Our study aims to identify a safe zone for the surgical placement of pins and records the location of the radial nerve in relation to the two pins placed.

Method

Our sample consisted of 39 cadavers (28 male and 11 female), between 18 and 99 years of age. Cadavers were dissected by second year medical students in the Department of Anatomy at the University of Pretoria. The use of cadavers for research is covered under the South African National Health Act 41 of 2003.

The cadavers were positioned supine with the palms of both hands facing up. The lateral epicondyle was palpated and the two half pins (4 mm in diameter) were inserted at 100 mm (proximal pin) and 70 mm (distal pin) to the epicondyle. A hand drill and a multi-pin clamp (*Figures 1a and 1b*), similar to those used in most external fixators around the elbow, was used to insert the pins. Once the pins were placed, the upper limbs were dissected. The radial nerve was identified at the lateral border of the humerus and the incidence of nerve damage caused by the pins and the relation of the nerve to the pins was recorded.

Statistical analysis was done using the chi-square and mixed model test estimated along a 95% confidence interval. The overall results adjusted dependence between left and right sides and this proportion, together with its confidence interval was analysed using the statistical software Stata. Testing was carried out at the 0.05 level of significance. A Fisher's exact test was used to identify the incidence of radial nerve damage relative to pin insertion.

Results

The radial nerve was damaged by the proximal pin in 56.4% of cases and by the distal pin in 20.5% of cases (*Table I*).

Results of bilateral radial nerve damage by the proximal and distal pin for males and females are shown in *Table II*.

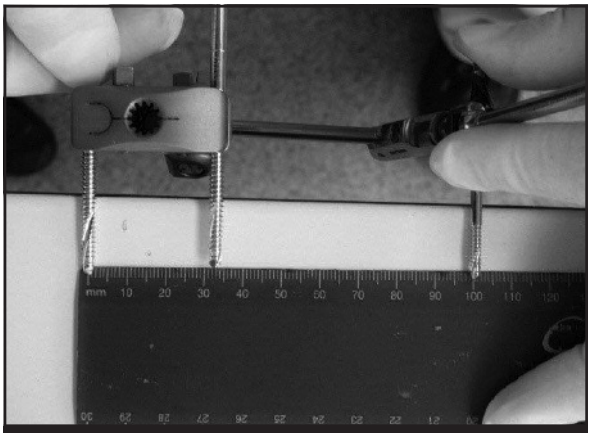

Figure 1a. Multi-pin clamp. The pin on the right is used as a marker, thus making the pin of the left the proximal pin situated at 100 mm proximal to the lateral epicondyle and the middle pin would be situated 30 mm distal to the proximal pin.

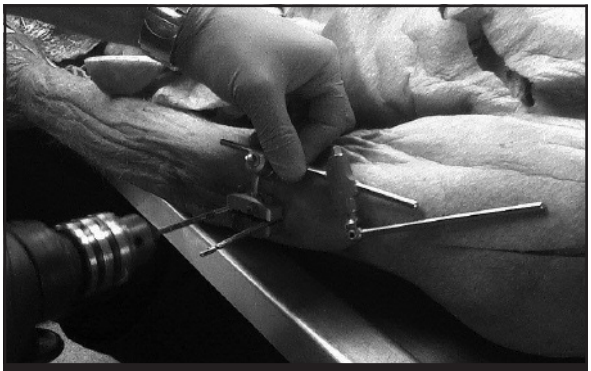

Figure 1b. Insertion of the proximal and distal pin with the use into the left arm of a cadaver

Table I: Incidence (%) of radial nerve damage in a South African cadaver sample (n = number of cases out of total sample)

Pin	Nerve hit % (n)	Nerve non-hit % (n)
Proximal	56.41 (44)	43.59 (34)
Distal	20.51 (16)	79.49 (62)
N=78 (total sample) n=number of cases		

The radial nerve was anterior to the proximal pin on the left humerus (43.5%) compared to the right (38.5%) for both males and females. The radial nerve was anterior to the proximal pin more often in male cadavers (50.0%) than in females (27.3%). These findings were not statistically significant (p=0.29).

The radial nerve was anterior to the distal pin in 79.5% of cases irrespective of side.

The radial nerve was damaged by the proximal pin more often in female right sides (81.8% of cases)

Table II: Comparison of the incidence (%) of radial nerve damage (hit) versus not damage (non-hit) relative to pin placement for males (M) and females (F) using the Fisher's exact test

Pin	Relation of nerve	Arm	Male hit % (n)	Female hit % (n)	Male non-hit % (n)	Female non-hit % (n)	Total hit % (n)	Total non-hit % (n)	p-value
Proximal	Anterior	right	46.43 (13)	18.18 (2)	53.57 (15)	81.82 (9)	38.46 (15)	61.54 (24)	0.15
		left	50.00 (14)	27.27 (3)	50.00 (14)	72.73 (8)	43.59 (17)	56.41 (22)	0.29
	Direct	right	53.57 (15)	81.82 (9)	46.43 (12)	18.18 (2)	61.54 (24)	38.46 (15)	0.15
		left	46.43 (13)	63.64 (7)	53.57 (15)	36.36 (4)	51.28 (20)	48.72 (19)	0.48
	Posterior	right	0.00 (0)	0.00 (0)	100.00 (28)	100.00 (11)	0.00 (0)	100.00 (39)	0.00
		left	3.57 (1)	9.09 (1)	96.43 (27)	90.91 (10)	5.13 (2)	94.87 (37)	0.49
Distal	Anterior	right	17.86 (5)	27.27 (3)	82.14 (23)	72.73 (8)	20.51 (8)	79.49 (31)	0.66
		left	10.71 (3)	45.45 (5)	89.29 (25)	54.55 (6)	20.51 (8)	79.49 (31)	0.03
	Direct	right	17.86 (5)	27.27 (3)	82.14 (23)	72.73 (8)	20.51 (8)	79.49 (31)	0.66
		left	10.71 (3)	45.45 (5)	89.29 (25)	54.55 (6)	20.51 (8)	79.49 (31)	0.09
	Posterior	right	0.00 (0)	0.00 (0)	100.00 (28)	100.00 (11)	0.00 (0)	100.00 (39)	0.00
		left	0.00 (0)	0.00 (0)	100.00 (28)	100.00 (11)	0.00 (0)	100.00 (39)	0.00

N=78 (total sample)
n=number of cases

compared to male right sides (53.6% of cases). The right sides of both males and females had more nerve damage (61.5% of cases) than the left sides (51.3% of cases) although not statistically significant. Direct nerve damage by the distal pin on both the left and right sides of males and females was 20.5% irrespective of side. Male cadavers had more nerve damage on the right sides (17.9% of cases) than left sides (10.7% of cases), but female cadavers had more damage on the right sides (27.2% of cases) compared to left (45.5% of cases).

The radial nerve was posterior the proximal pin on the left side more often in females (9.1%) compared to males (3.6%), in 5.1% of cases on the left sides only. The radial nerve was never encountered posterior to the distal pin.

Table III indicates the location of the radial nerve in relation to the proximal and distal pin bilaterally.

Discussion

In the present study, the incidence of nerve damage at the proximal pin (100 mm) was significantly higher than the distal pin (70 mm). This suggests that the risk of radial nerve damage is greater at 100 mm than at 70 mm. The lower incidence of nerve damage at the distal pin relates to the anterior course of the nerve. Clement *et al*.[13] inserted pins into 20 cadaver arms at 50 mm and 30 mm proximal to the lateral epicondyle. The proximal pin (50 mm) damaged the radial nerve in five out of 20 cases (25.0%).[13] The distal pin damaged the radial nerve in four out of 20 cases (20.0%).[13] According to our results and those of Clement *et al*.,[13] the radial nerve is more likely to be damaged if the pin is inserted between 70 and 100 mm proximal to the lateral epicondyle. Although not clinically significant, we found nerve damage caused by the proximal pin in more female than male cadavers and more on the right than left side. No other studies have reported sex or bilateral differences. The higher incidence of nerve damage on the right side indicates that the proximal pin position is crucial to avoid hitting the nerve. The nerve was anterior to both pins in most cases but more so to the distal pin. The nerve changes course as it travels distally, eventually wrapping around the lateral epicondyle. The radial nerve was found at distances (our study) similar to Artico *et al*.,[11] who examined the topographical relation of the radial nerve to different anatomical landmarks in 20 fresh cadavers. They reported that the mean distance between the entry point of the nerve in the lateral intermuscular septum and the lateral epicondyle was 110 (±23) mm. Our findings reinforce that the high-risk area for pin insertion is 100 mm proximal to the lateral epicondyle.

Clement *et al*.[13] similarly placed pins in upper limbs and after dissection found that the radial nerve was anterior to the proximal pin in 13 cases and anterior to the distal pin in 14 cases. In three arms the nerve was posterior to the distal pin. We found similar results and conclude that pins should be placed more posteriorly as the radial nerve runs more anteriorly.

Table III: Incidence (%) of radial nerve position relative to pin placement in the right and left arm, using the Fisher's exact test

Pin	Relation of nerve to pin	Right arm (n)	Left arm (n)	Total (n)
Proximal	Anterior	38.46 (15)	43.59 (17)	41.03 (32)
	Direct	61.53 (24)	51.28 (20)	56.41 (44)
	Posterior	0.00 (0)	5.13 (2)	2.57 (2)
Distal	Anterior	79.49 (31)	79.49 (31)	79.49 (62)
	Direct	20.51 (8)	20.51 (8)	20.51 (16)
	Posterior	0.00 (0)	0.00 (0)	0.00 (0)

N=78 (total sample)
n=number of cases

Kamineni *et al*.[12] concluded that radial nerve damage is due to three causes: lack of anatomical knowledge and awareness of anatomical variations; surgical methods used; and clearly defined restricted areas for placement of external fixators. Chaundry *et al*.[14] performed a study on cadavers and concluded that the variations in the course of the radial nerve may account for damage.

Conclusion

No defined safe zone could be established from this study. The authors propose that pin placement at 100 mm from the lateral epicondyle is avoided and that pins should be positioned as posterior as possible to minimise the risk of radial nerve damage.

Wide incision and blunt dissection is still recommended to minimise the risk of radial nerve damage.

Compliance with ethics guidelines

We confirm there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all the authors.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We confirm that Dr Paterson has contributed in the writing of the protocol as well as the literature research and placing of the pins. He also contributed with writing the final draft of the article.

Dr Navsa contributed in the writing of the protocol and final draft of the article as well as the data collection.

The study was approved by the Faculty of Health Sciences Research Ethics Committee. The use of cadavers for research is covered under the South African National Health Act 41 of 2003.

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