Danger zone for locking screw placement in minimally invasive plate osteosynthesis (MIPO) of humeral shaft fractures: A cadaveric study

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ABSTRACT

Several recent reports have described the minimally invasive plate osteosynthesis (MIPO) technique in the treatment of humeral shaft fractures by the anterior approach. The purpose of this study is to identify the danger zone for locking screw placement to avoid musculocutaneous nerve injury in the anterior compartment and radial nerve injury in the posterior compartment of the humerus relative to the humeral length. Eighteen arms of fresh cadavers were fixed with 10-hole locking compression plate (LCP) by anterior approach using the MIPO technique. Two locking screws on each end were fixed by the open technique; the rest of the screws were inserted percutaneously. The arms were dissected both anterior and posterior to identify musculocutaneous and radial nerve injuries. Humeral length with a simple palpable bony landmark was measured from the posterior tip of the acromion process to the lateral epicondyle. Damage or direct contact of the locking screws to the musculocutaneous or radial nerve was recorded, and the distance between the screws and the radial nerve was measured.

The average humeral length was 29.71 cm (99% confidence interval (CI): 28.54–30.86 cm). The danger zone for the musculocutaneous nerve averaged 18.37% (99% CI: 17.06–19.60) to 42.67% (99% CI: 42.33–43.03) of the humeral length from the lateral epicondyle. The danger zone for the radial nerve averaged 36.35% (99% CI: 35.81–37.07) to 59.20% (99% CI: 59.00–59.46) of the humeral length, and the most dangerous screws that penetrated or touched the radial nerve lay 47.22% (99% CI: 45.27–49.17) to 53.21% (99% CI: 51.16–55.33) of the humeral length from the lateral epicondyle. An anteroposterior locking screw placed percutaneously endangered the musculocutaneous and radial nerves.

From this cadaveric study, the danger zone for the musculocutaneous and radial nerves could be determined as a percentage of the humeral length. Since the zone with radial nerve injuries shows a large variation, this procedure should only be done by experienced surgeons.

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Introduction

Minimally invasive plate osteosynthesis (MIPO) of the humeral shaft was first described by Livani et al.9 in the treatment of 15 humeral shaft fractures with successful outcomes. Apivatthakakul et al.1 described the feasibility of MIPO of the humerus by using the anterior approach in a cadaveric study and demonstrated the surgical technique to avoid radial nerve injury. Jiang et al.8 and Zhiquan et al.11 described MIPO in the treatment of complex humeral shaft fractures and concluded that it is a safe alternative treatment for humeral shaft fractures.

Regarding surgical techniques, it is possible to injure the musculocutaneous nerve, which lies between the biceps and brachialis muscles in the anterior compartment, and the radial nerve, which lies on the posterior in the spiral groove. Gardner et al.5 described the danger zone of the musculocutaneous nerve during MIPO of the humerus using the helical plate. The musculocutaneous nerve crossed anterior to the plate at an average of 13.5 cm (range 12.2–14.8 cm) from the greater tuberosity and was at risk from percutaneous screw placement. In MIPO of the humerus shaft by the anterior approach, the radial nerve can be injured by the drill or the tip of the screw that penetrates the posterior cortex of the humerus around the spiral groove.1

The purpose of this cadaver study is to identify the danger zone for locking screw placement during MIPO of the humeral shaft to avoid injury to the musculocutaneous nerve in the anterior compartment or to the radial nerve in the posterior compartment, measured as a percentage of the humeral length from the posterior tip of the acromion process to the lateral epicondyle.

Materials and methods

Nine fresh adult cadavers, which had been donated to the anatomy department, were obtained within 72 h of death,
providing 18 upper extremity specimens for the study in which there were no deformity or previous surgery. Six were male and three were female. The average age of the cadaver was 58 years (range 28–75 years).

The first author has done this MIPO technique on more than 40 cases in clinical practice. The procedure was performed with the torso supine, the arm in 60° abduction and the forearm in full supination. The posterior tip of the acromion process and the lateral epicondyle were palpated and measured as the humeral length. Proximally, the interval between the lateral border of the proximal part of the biceps and the medial border of the deltoid muscle was palpated. A 4-cm proximal incision was then made approximately 6 cm distal to the anterior part of the acromion process, and dissection was carried down to the proximal humerus.

Distally, a 4-cm incision was made along the lateral border of the biceps muscle approximately 5 cm proximal to the flexion crease of the elbow. The interval between the biceps brachii and the brachialis was identified, and the biceps was retracted medially to expose the musculocutaneous nerve lying on the brachialis. The brachialis was then split longitudinally along its midline to reach the periosteum of the anterior cortex of the distal humerus.

A sub-brachialis extraperiosteal tunnel was then created by passing a 10-hole LCP attached with two-threaded drill sleeves into the two most distal holes and using the handle for tunnelling and plate insertion deep to the brachialis from the distal to the proximal incision (Fig. 1).

The proximal thread drill sleeve was removed from the hole and attached to the most proximal hole. By adjusting both drill sleeves, the distal end of the plate was aligned on the anterior surface of the humerus, perpendicular to the transepicondylar axis of the distal humerus. The distal end of the plate lay approximately 5 cm proximal to the flexion crease of the elbow. Both ends of the plate were fixed with two locking screws using the open technique. All screw holes between the proximal and distal incisions were fixed percutaneously using stab incisions.

This study used the LCP with locking screw to reduce the variability of screw direction. The direction of the locking screw was limited by the plate hole. The long locking screw was inserted with a length of 40–50 mm to allow bicortical penetration with the tip of the screw penetrating 5 mm beyond the posterior cortex to observe the radial nerve injury. This also left the anterior part of the screw penetrating the brachialis muscle to observe the musculocutaneous nerve injury.

Next, the anterior MIPO tunnel was exposed by joining the proximal and distal incisions, and deep dissection was carried down on the plane between the biceps and the brachialis to expose the musculocutaneous nerve.

The distance between the lateral epicondyle and each locking screw was measured with the first screw located in the most distal hole and the 10th screw located in the most proximal hole. Damage or direct contact to the musculocutaneous nerve by the locking screws was recorded (Fig. 2). All measurements were made once by the second author using a digital caliper with an accuracy of 0.1 mm.

The cadaver was then moved into a prone position and arm was abducted 60° with the forearm in supination resembling its previous position. The posterior incision was made from the posterior tip of the acromion process to the olecranon process. Deep dissection was performed by the triceps-splitting approach between the long head and the lateral head of the triceps to expose the radial nerve from the triangular space to the point where the radial nerve pierced the lateral intermuscular septum. Damage or direct contact to the radial nerve by the locking screw tip was recorded (Fig. 3), and the distances between the screws and the radial nerve were measured in millimetres. In addition, the number of the plate hole which was closest to the radial nerve was determined. Average distances were calculated for all measurements, and results were recorded as a percentage of humeral length.
helical plate was first described by Fernandez. Gardner et al. in the anteroposterior direction. MIPO of the humerus using a lateral cutaneous nerve of the forearm by the distal locking screw with the Russell–Taylor intramedullary nail had injuries to the muscle mass of the deltoid or soft-tissue swelling. The danger zone for the radial nerve was 30.2 ± 18 mm. The radial nerve crossed onto the posterior shaft of the humerus, never closer than 97 mm, and never within 100 mm above the medial or lateral condyle. On the other hand, the danger zone for the radial nerve lies between the proximal and distal third of the humeral length. The results of our study are close to this study on humeral length and the zone in which the radial nerve can be injured on the posterior shaft of the humerus.

Table 1

<table>
<thead>
<tr>
<th>Hole number</th>
<th>Mean distance (mm)</th>
<th>Min–max (mm)</th>
<th>S.D. (mm)</th>
<th>% injured</th>
<th>Number of screws</th>
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<tbody>
<tr>
<td>1</td>
<td>5.3</td>
<td>1.2–27.5</td>
<td>7.4</td>
<td>2.7</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4.3</td>
<td>0.6–21.5</td>
<td>6.5</td>
<td>2.1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>3.1</td>
<td>0.3–22.5</td>
<td>5.2</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1.9</td>
<td>0–18</td>
<td>4.1</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
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<td>1.8</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0.5</td>
<td>0–0.9</td>
<td>0.9</td>
<td>0.2</td>
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<tr>
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<td>0.4</td>
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</tr>
<tr>
<td>8</td>
<td>1.7</td>
<td>0–13</td>
<td>2.9</td>
<td>1.0</td>
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<td>0.8–26</td>
<td>7.1</td>
<td>2.5</td>
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</tr>
</tbody>
</table>

Results

The average humeral length was 29.71 cm (99% confidence interval (CI): 28.54–30.86). The fixation zone of the first to the 10th locking screw was 5.46–21.06 cm [18.38% (99% CI: 16.39–20.36) to 70.89% (99% CI: 68.60–73.17) of the humeral length] from the lateral epicondyly.

On the anterior aspect, the fixation zone of musculocutaneous nerve injury averaged 5.46–12.68 cm [18.38% (99% CI: 17.06–20.36) to 70.89% (99% CI: 68.60–73.17)] of the humeral length] from the lateral epicondyly. Six screws in the first hole, eight screws in the second, three screws each in the third and fourth and one screw in the fifth hole had direct contact with the musculocutaneous nerve.

On the posterior aspect, the fixation zone of the radial nerve injury averaged 10.8–17.59 cm [36.35% (99% CI: 35.81–37.07)] to 59.20% (99% CI: 59.00–59.46) of the humeral length] and the most dangerous screws that penetrated or touched the radial nerve were in the sixth and seventh holes, which lie 14.03–15.8 cm [47.22% (99% CI: 45.27–49.17)] to 53.21% (99% CI: 51.16–55.33) of the humeral length] from the lateral epicondyly. Three screws in the fourth hole, seven in the fifth, nine in the sixth, eight in the seventh and three in the eighth hole had direct contact with the radial nerve. The distances between the screws and the radial nerves were measured (Table 1).

Discussion

Musculocutaneous nerve

The musculocutaneous nerve is at risk in percutaneous insertion of the screw in the distal part of the humerus. Blyth et al. reported that 5 of 51 cases of humeral shaft fracture treated with the Russell–Taylor intramedullary nail had injuries to the lateral cutaneous nerve of the forearm by the distal locking screw in the anteroposterior direction. MIPO of the humerus using a helical plate was first described by Fernandez. Gardner et al. described the danger zone for the musculocutaneous nerve in the MIPO of the humerus using a helical plate. A screw placed through the stab incisions in the danger zone would have a risk of injury to the musculocutaneous nerve. The danger zone for the nerve location was found to be at an average of 13.5 cm from the greater tuberosity (99% CI: 12.2–14.8 cm) but they did not measure the humeral length. This danger zone was measured from the greater tuberosity, which sometimes cannot be easily palpated due to the muscle mass of the deltoid or soft-tissue swelling.

We described the danger zone from the lateral epicondyly, a superficial bony landmark, to allow surgeons to identify its position during surgery. In our study, the danger zone from the first to the fourth screw was found to be an average of 5.46–12.68 cm [18.37% (99% CI: 17.06–19.60)] to 42.67% (99% CI: 42.33–43.03) of the humeral length] from the lateral epicondyly. However, the first and second screws were inserted using the open approach to identify the musculocutaneous nerve and retract it medially, which means that only the third and fourth screws would endanger the nerve by percutaneous screw placement. It is advisable to make a longer skin incision and use an open approach to protect the musculocutaneous nerve during screw insertion.

Radial nerve

The radial nerve crossed the posterior aspect of the humerus from an average of 20.7 ± 1.2 cm proximal to the medial epicondyly to 14.2 ± 0.6 cm proximal to the lateral epicondyly. The mean length of the radial nerve in the spiral groove varied from 4.26 cm to 6.5 cm. In this area, the radial nerve could be injured by the screw inserted from anterior to posterior.

Bono et al. described anatomical considerations for humeral fixation of the radial nerves. The average humeral length measured from the proximal articular surface to the most distal aspect of the trochea was 35 ± 5.7 cm, and the length from the proximal articular surface to the olecranon fossa was 33 ± 0.28 cm. They recommended inserting the AP pin or screws in the distal 30% of the humerus to decrease the risk of radial nerve injury. However, these bony landmarks cannot be palpated during surgery or may require wide exposure. We described the humeral length measured from the posterior tip of the acromion and the lateral epicondyly, which are easily palpated and can be used as anatomical landmarks during surgery.

Guse et al. described the surgical anatomy of the radial nerve on the posterior aspect of the humerus related to the posterior tip of the acromion and the lateral epicondyly. The humeral length was 30.2 ± 18 mm. The radial nerve crossed onto the posterior shaft of the humerus, never closer than 97 mm, and never within 100 mm above the medial or lateral condyle. On the other hand, the danger zone for the radial nerve lies between the proximal and distal third of the humeral length. The results of our study are close to this study on humeral length and the zone in which the radial nerve can be injured on the posterior shaft of the humerus.

Apivatthakakul et al. described a cadaveric study of the feasibility of MIPO of the humerus and suggested that no screw should be inserted in the part of the radial nerve that runs along the spiral groove. However, this danger zone was not identified.

From our study, the zone that had radial nerve injuries averaged 10.8–17.59 cm [36.35% (99% CI: 35.81–37.07)] to 59.20% (99% CI: 59.00–59.46) of the humeral length] and the most dangerous screws that penetrated or were closest to the radial nerve were in the sixth and seventh holes, which lie 14.03–15.8 cm [47.22% (99% CI: 45.27–49.17)] to 53.21% (99% CI: 51.16–55.33) of the humeral length] from the lateral epicondyly. In this danger zone, bicortical screw placement from anterior to posterior should be avoided; if screw insertion is needed, unicortical screw placement is recommended. The plate length should be long enough to bridge the fracture over the danger zone of the radial nerve. For clinical application during surgery, when the humeral length is divided into eight parts, the danger zone for the radial nerve is approximately 3/8 (37.5%) to 5/8 (62.5%) of the humeral length measured from the tip of the acromion process to the lateral epicondyly.

The limitation of this study is that the measurements were made in intact humeri, whereas in a patient with humeral fractures the anatomical landmarks are usually distorted. To overcome this problem, it is recommended that the reduction and initial fixation should be done firstly on the two proximal and distal screws; then the additional screws can be inserted outside the danger zone as described by our study.

The future of this technique depends on data from prospective clinical studies. MIPO of the humerus is a clinical option for the
treatment of humeral shaft fractures. This procedure should be
done by experienced surgeons who have a large trauma load.

Conflict of interest

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