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ORIGINAL COMMUNICATION

Anatomic Relationship of the Radial Nerve to the Elbow Joint: Clinical Implications of Safe Pin Placement

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The percutaneous placement of lateral distal humeral pins risks injury to the radial nerve. We aimed to provide a reliable and safe parameter for the insertion of lateral distal humeral pins. A secondary aim of this study was to investigate the effect of pin/screw placement in the intended zone of fixation at the lateral distal humerus. We dissected 70 fresh cadaveric upper limbs and the radial nerve was identified and its course followed into the anterior compartment. The point where the radial nerve crosses humerus in mid lateral plane was identified and the distance between this point and lateral epicondyle was measured, as was the maximum trans-epicondylar distance, along with the olecranon fossa height. Statistical analysis was performed using the Pearson correlation coefficient. The average trans-epicondylar distance was measured at 62 ± 6 mm (range 52–78 mm), and the average lateral radial nerve height was 102 ± 10 mm (range 75–129 mm). The ratio of the lateral nerve height to the trans-epicondylar distance was an average of 1.7 ± 0.2 (range 1.4–2.0). The Pearson correlation coefficient between the lateral nerve height and the trans-epicondylar distance was $r = 0.95$. A relative dimension, the trans-epicondylar distance is both reliable and easily accessible to the operating surgeon. The absolute safe zone for pin entry into the lateral distal humerus is that area lying within the caudad 70% of a line, equivalent in length to the patient's own trans-epicondylar distance, when projected proximally from the lateral epicondyle. Clin. Anat. 22:684–688, 2009.

Key words: radial nerve; elbow joint; trans-epicondylar distance; distal humerus; external fixation anatomy

INTRODUCTION

After supplying the relevant muscles in the extensor compartment of the arm, the radial nerve traverses deep to the lateral head of the triceps, under its fibrous aponeurotic arch, before piercing the lateral intermuscular septum (Gray's Anatomy, 1980). After piercing the lateral intermuscular septum, the radial nerve comes to lie between the brachialis and brachioradialis, in the flexor compartment of the arm.

Nerve injuries are not infrequent, and under reported, during lateral percutaneous pin insertion of the distal humerus. Various fixation modalities such

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as external fixator pins, distal interlocking bolts (e.g., Antegrade humeral nailing), and transfixing wires (e.g., Ilizarov) are utilized in the distal humerus, and the structure most at risk is the radial nerve.

The zone in which the radial nerve is vulnerable to iatrogenic injury during pin placement is from the crossing point, at which it is tethered by the intermuscular septum, to the lateral epicondyle. The literature has reported various strategies to ensure safety during percutaneous lateral distal humeral pin insertion:

1. Effective humeral length (Gausepohl et al., 2000)
2. Tether point distance (Uhl et al., 1996; Mazurek and Shin, 2001)
3. Joint line to radial groove distance (Uhl et al., 1996; Mazurek and Shin, 2001)
4. Somato-sensory evoked potentials (Makarov et al., 1997; Mills et al., 2000)

All of these previous methods are of value, but are difficult to practically apply.

Our aim was to define a safe parameter which can be simply applied intra-operatively whilst hypothesising that an absolute numerical safe zone dimension cannot be transferred to all patients thereby eliminating the risk to the radial nerve, as was previously noted in the literature.

Therefore, a methodology was adopted with clinical relevance, the conclusions of which, if followed, should enhance the ability to place pins in the humerus without injuring the radial nerve.

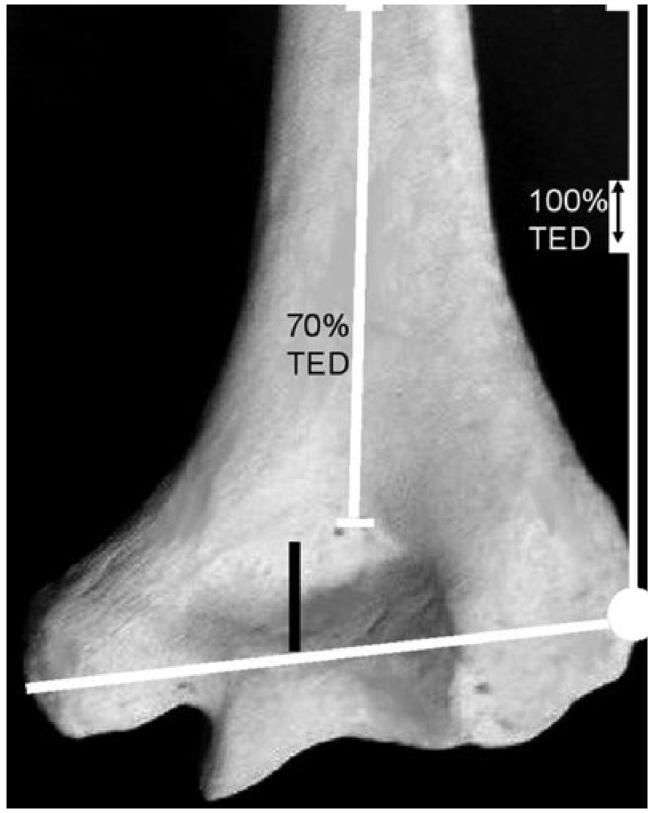

Fig. 1. The transepicondylar distance (horizontal white line) is projected proximally from the lateral epicondyle. The effective olecranon fossa height (vertical black line), which represents 30% of the transepicondylar distance.

MATERIALS AND METHODS

Preliminary pilot studies were performed during which we studied the point at which the radial nerve is tethered by the lateral intermuscular septum. This distance was correlated to the absolute humeral length, arm length, and distance from acromion. However, these parameters did not have any consistent correlative value, with wide inter-observer variability. Furthermore, parameters such as these are difficult for the surgeons to access intraoperatively.

We utilized 70 fresh cadaveric upper limbs (35 pairs) from 20 males and 15 females for limited dissection; all were Caucasian with an average age of 67 years (range 52–85). The radial nerve was identified as it traversed the posterior humeral compartment to the anterior compartment, but it was not dissected free from its surrounding septal arch and adherent tissues.

Specific anatomic landmarks were measured and their dimensions quantified. Two pins were placed to replicate those for external fixators. We sought to develop correlation between the varied anatomic parameters, the location of the radial nerve and pin placement. We used a digital calliper to measure the following parameters: (1) trans-epicondylar distance (TED)—defined as the distance between the two most prominent points of medial and lateral epicondyles (mm) (Fig. 1); this measurement was taken with the skin intact and in addition, with the digital callipers compressing the skin on the epicondyles when the measurements were taken. The TED was the greatest distance separating the apices of the medial and lateral epicondyles. (2) radial nerve lateral height—defined as the distance between the most prominent point of lateral epicondyle and the point at which the radial nerve crosses the humerus in the mid lateral plane. This was the point at which the radial nerve traversed the lateral intermuscular septum. (3) Effective olecranon fossa height—defined as the height of olecranon fossa is perpendicular to and above the trans-epicondylar plane (mm), Figure 1. (4) Antero-posterior distal humeral width at the olecranon fossa apex (mm). Each measurement was repeated on three separate occasions double blinded between two observers, and an average of these measurements was then used for further analysis. A direct comparison between the right and left limbs of each individual was also made.

In addition to the primary aim, a secondary aim of this study was also to investigate the effect of pin/screw placement in the intended zone of fixation at the site of the lateral distal humerus. Standard surgical techniques dictate that the entry is at the point lateral to the supra-condylar ridge, for the distal pin. This entry point is precarious due to the inadvertent skating of the screw from the sharp ridge onto the anterior humeral surface. This poses a potential risk

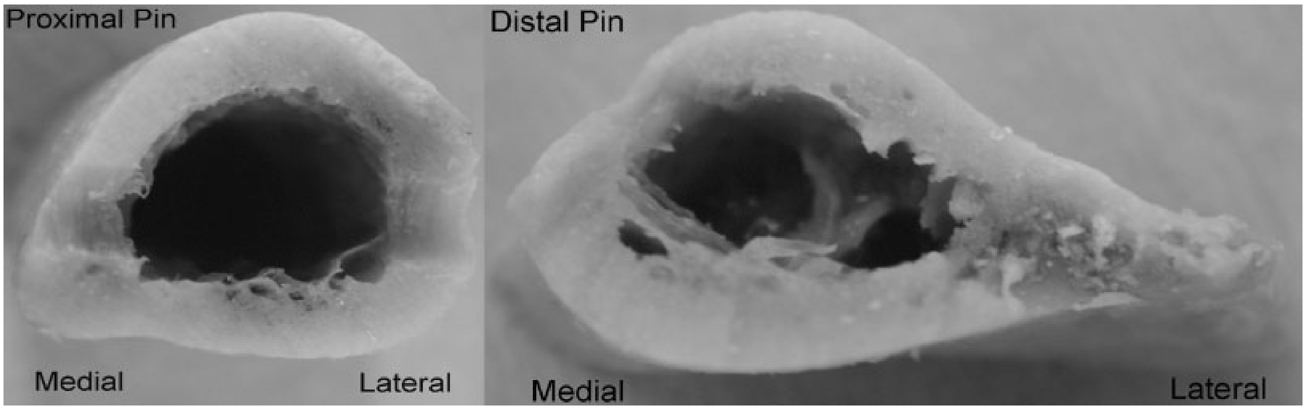

Fig. 2. Cross-sections through the distal humerus demonstrating the trajectory of the proximal and distal pins. There is adequate bone to accommodate the 4 mm pins at both sites. Note the entry point of the distal pin is posterior to the lateral epicondyle and supracondylar ridge.

to the radial nerve, since the anterior soft tissues may become coiled in the screw thread. We observed that when the anterior soft-tissues become entangled in the pin thread the radial nerve can become taut, even if not directly in contact with the pin. Hence, the trajectory of pin placement was modified, from the standard lateral to medial trajectory, to a lateral entry point just posterior to the supra-condylar ridge exiting the anteromedial humeral cortex (Fig. 2).

Statistical Methods

The measurements were statistically analyzed with a Pearson correlation coefficient.

RESULTS

The average TED was 62 ± 6 mm (range 52–78 mm) (Fig. 3). Variability between the two limbs of a pair was an average of 4.8 mm (5.1%) (range 0.3 mm [0.25%] to 17 mm [19.1%]. The TED, when projected proximally from the most prominent point of the lateral epicondyle along the mid-lateral humeral longitudinal axis, never approached the radial nerve, as the nerve crossed from the posterior to the anterior humeral compartments. The lateral radial nerve height was an average of 102 ± 10 mm (range 75–129 mm), Figure 3. We could not find a statistically significant correlation between the two limbs of a pair, and the side to side difference ranged from 0.1 to 7.9 mm. However, a positive Pearson correlation coefficient between the TED and the radial nerve lateral height distance on each specimen was found ($r = +0.95$).

The height of the olecranon fossa above the trans-epicondylar plane (effective height) was an average of 16 ± 2.1 mm (13–19.5 mm or 25–30% of TED). The average antero-posterior diameter of the distal humerus at the apex of the olecranon fossa was 15.8 ± 1.9 mm (range 12.7–19.9 mm), Figure 2.

Our observations regarding pin trajectory are that a proximal lateral to medial trajectory is consistent, since the humeral cortex at this level is relatively smooth and more circular, and more in keeping with a tubular long bone. However, for ease of fitting the pins to the body of an external fixator, it may be simpler to follow the same entry point for the proximal and distal pins, Figure 2. A more distal pin cannot be consistently placed without posing a neurological risk, as a consequence of skidding forward on the initial attempt insertion. However, with a change of trajectory entering posterior to the supra-condylar ridge, a safe placement is possible, with a better purchase, on a flatter surface, the posterior cortex, as opposed to the sharp supra-condylar ridge. With this latter trajectory, if the anteromedial cortex is over penetrated, it can pose a risk to the median nerve.

DISCUSSION

There is a great deal of radial nerve variation as it courses through the neural groove of the humerus. This variation, thus, places the nerve at risk under certain surgical procedures. When inserting distal lateral humeral pins/screws the area of concern is

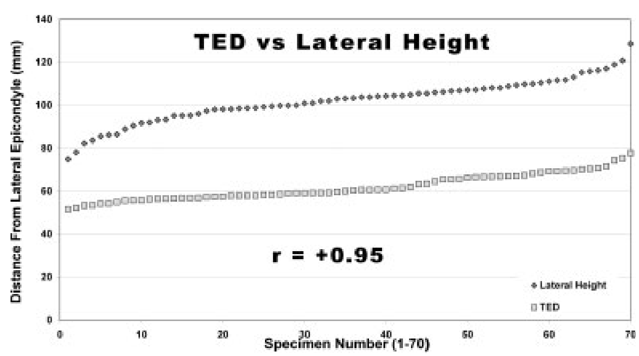

Fig. 3. Graph showing the relation between the trans-epicondylar distance and the lateral radial nerve height. The correlation coefficient is +0.95.

where the radial nerve pierces the lateral intermuscular septum and traverses into the anterior compartment. This septal crossing point is recognized to be an area where the nerve is relatively tethered, and prone to injury, due to its restricted excursion. Various cadaveric studies have reported the risk of radial nerve injury from lateral to medially inserted distal interlocking screws with intramedullary humeral nails (Faruqui and Hutchins, 1996; Port el al., 1996; Rupp et al., 1996). The radial nerve is at direct risk with lateral to medial screw placement and the ulnar nerve and median nerve/brachial artery bundle are at risk with significant over-penetration of the medial cortex.

According to the literature radial nerve injuries are not infrequent, and probably under-reported. In a retrospective study, Mostafavi et al. (1997) reported nine cases of radial nerve injury following external fixation in 23 cases of open humeral fractures (39%). Seventy eight percent of this patient series had associated neurologic injury, of which nine involved multiple nerves. The radial nerve was affected in nine cases. Makarov et al. (1997), reviewing various literature reports on the role of external fixators in the management of upper limb lengthening, reported 7–43% incidence of neurologic complications. Stavlas et al. (2004) reported one radial nerve palsy in eight patients (12.5%) treated with external fixators around the elbow. Li et al. (2005) reported two out of 33 patients (6%) with postoperative radial nerve palsies, following unilateral external fixation around the distal humerus.

Various authors have attempted to landmark the radial nerve, at the septal tether point, in different ways. Uhl et al. (1996) measured where the radial nerve pierced the intermuscular septum in 75 cadavers. It was found that the nerve laterally located at an average of 10 cm from the distal humeral articular surface in men and 9.4 cm in women; however, in some cadavers the nerves were as close as 7.5 cm. The posterior distance from the articular surface to the nerve averaged 15.8 cm in men and 15.2 cm in women, with a minimum distance of 13 cm in one woman. It was concluded that when proximal humeral dissection beyond 7.5 cm laterally or 13.0 cm posteriorly from the articular surfaces is required, care should be taken to isolate and protect the radial nerve.

Gerwin et al. (1997) concluded that a safe exposure could be performed 15.4 cm from the lateral epicondyle posteriorly, 20 cm proximal to the medial epicondyle, and 14 cm proximal to the lateral epicondyle. For lateral approaches to the humerus, Mazurek et al. (2001) quoted a mean safe distance of 7.5–10 cm from lateral epicondyle to the radial nerve crossing point. The radial nerve pierced the lateral intermuscular septum at 122 mm (range 88–152 mm) from the lateral epicondyle. When normalization of the data to patient height was attempted, no statistical correlation was found to exist.

More recently Foxall et al. (2007) used ultra sound imaging to localise the position of the radial nerve in order to improve accuracy of local anaesthetic blockade. However, they used a primary axis, along which measurements were taken, between the acromion and the lateral epicondyle, which is not convenient when performing distal humeral surgery. Most frequently, when performing distal humeral surgery, the proximal aspect of the humerus and shoulder are draped, and out of the immediately accessible surgical field, making the use of the acromion for such measurements more difficult. They identified the radial nerve to be located in the radial groove at the mid point of this axis, and between the brachialis and brachioradialis at the junction of the proximal two and distal thirds of the axis line.

Our study is able to partially reject our original hypothesis, since there is considerable variation in the actual dimensions and a reasonable single safe numerical value cannot be transferred to all patients. Whereas it is possible to conclude that an absolute safe distance of 75 mm from the lateral epicondyle apex can be transferred to all patients, this would limit the amount of bony purchase afforded to larger patients. Pins limited to the proximal 70% of 75 mm in larger patients would considerably decrease their biomechanical lever arm advantage, whereas, in smaller patients this would be acceptable. An additional 40% proximal to that point is where the radial nerve crosses, but not that an additional 40% is necessarily safe. Instead a more normalized value i.e., TED proximally projected from the lateral epicondyle, gives a predictable safe measure, that accounts for inter-individual variation of nerve location. Such normalization also optimizes the biomechanical advantage, in proportion to the patient size.

The trajectory of insertion was also addressed in this study. The narrow lateral supracondylar ridge, during pilot studies, defied safe pin insertion. The disadvantage of such a direct lateral entry point is the potential for the drill bit or screw to either skate off anteriorly and damage the radial nerve or wrap soft tissues around itself, thereby causing a traction injury. Although we did not observe any direct radial nerve injuries, we did observe radial nerve traction generated as surrounding soft-tissues were wrapped around the pin. We found that during pin insertion, the proximal pin entry point should effectively be parallel to the posterior cortex having entered the lateral cortex and the distal of two pins effectively maintaining the screw in a trajectory between posterior and antero-lateral cortices. This observation that the entry portal for distal pins posterior to septum directed as previously stated merely corroborates previous literature (Port et al., 1996; Gausepohl et al., 2000).

The cause of iatrogenic nerve injury is tri factorial. The first is lack of knowledge of the normal anatomy and also an appreciation of its variations, and is the primary focus of this current study. The second is the surgical technique, which should include blunt dissection to bone and the use of soft tissue protective drill sleeves placed directly onto bone. The sleeve should be maintained such that no motion is allowed between the sleeve and bone during pin insertion. Finally, and less appreciated, are the constraints placed on the surgeon by the implants being used. Implants often dictate the position of the pin/

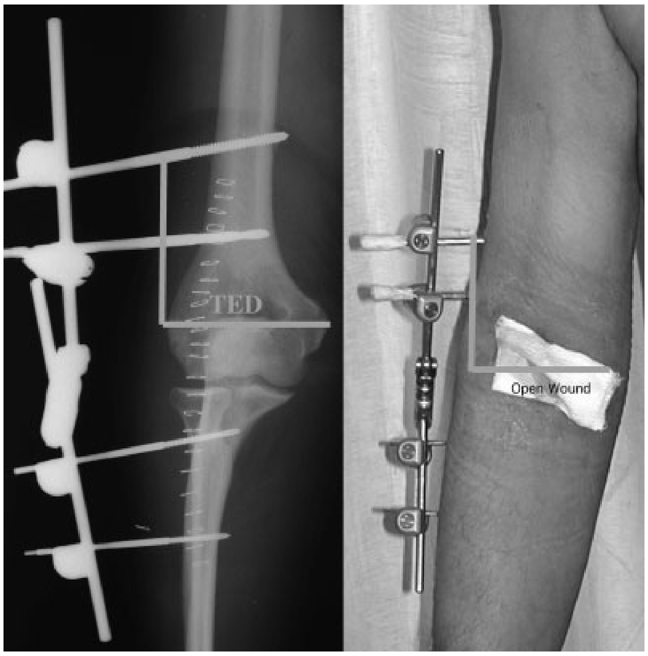

Fig. 4. Example of a dynamic external fixator for the elbow (DJD II™—Stryker–Howmedica) that allows the surgeon to place two humeral pins within the proximal 70% of a TED projected along the mid-lateral line of the humerus. An example of an unstable terrible triad fracture dislocation treated with limited internal fixation and external fixator augmentation.

screw placements and manufacturers need to be more aware that their designs can adversely influence surgical outcome. Of the four commercially available dynamic hinged external fixators for the elbow only two allow this safe placement of the humeral pins (Fig. 4).

We have concluded that first, the TED projected proximally along the lateral humeral shaft, from the lateral epicondyle, defines the absolute safe zone for avoiding radial nerve injury; second, this method of pin placement takes into account inter-individual variations; third, TED is a straightforward measurement that the operating surgeon can palpate and utilize intraoperatively; and lastly, this 100% TED method is safe and an extra 40% TED locates the radial nerve and can be afforded by the surgeon as a safety margin to avoid radial nerve injury.

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