The risk injury to the posterior interosseous nerve in standard approaches to the proximal radius: a cadaver study

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Abstract

Purpose The aim of this study was to provide guidance on the safe zones for the exposure of the proximal radius by measuring the distance from the PIN to various anatomical landmarks in the proximal forearm in pronation and supination.

Methods Twenty cadaveric arms were used for this study. On the anterior aspect of the forearm, the distance between the insertion of the biceps tendon and the arcade of Frohse as well as the shortest distance between the PIN and the ulnar aspect of the radial neck were measured. On the posterior aspect of the forearm, the shortest distance between the PIN and the radial border of the interosseous membrane was measured at 30 and 50 mm distal to the articular surface of the proximal radius.

Results The distance between the PIN and ulnar aspect of the radial neck had a mean of 21.6 mm in supination and 13.3 mm in pronation. The distance between the radial tuberosity and the arcade of Frohse was 18.6 mm. The mean distance between the PIN and the radial border of ulna at 30 mm distal to the articular surface of the proximal radius was 12.3 mm in supination and 22.3 mm in pronation. At 50 mm distal to the articular surface of the proximal radius the mean distance was 8 mm in supination and 16.2 mm in pronation.

Conclusions The course of this nerve is variable as it winds around the radial neck within the belly of the supinator muscle. Safe distances for dissection have been presented in our study.

Keywords Radial nerve · Posterior interosseous nerve · Deep branch of radial nerve · Approach to the radius · Henry’s approach · Thompson approach

Introduction

Detailed knowledge of the anatomy of radial nerve and its deep branch, the posterior interosseous nerve (PIN), is essential in the safe surgical approach to the proximal radius. Procedures in this region, either elective or emergent, place the posterior interosseous nerve at the risk of iatrogenic injury. The PIN is the motor nerve of the posterior compartment of the forearm. It supplies extensor carpi radialis brevis, extensor digitorum, extensor carpi ulnaris, supinator muscle, abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus and extensor indicis.

There are two standard approaches described for the radius: the volar extensile approach described by Arnold Henry's approach and the Thompson approach.
Henry and the dorso-lateral approach of Thompson [7]. Both approaches are used in open reduction and internal fixation of fractures as well as bone grafting and fixation of non-unions. Other indications include radial osteotomy, biopsy and resection of bone tumours as well as excision of sequestra in chronic osteomyelitis. With the anterior approach the anterior exposure of the radial tuberosity is possible. The posterior approach is also used to expose the posterior interosseus nerve for decompression of the nerve as it passes through the arcade of Frohse, where it may be compressed [11]. The arcade of Frohse, named after the German anatomist Fritz Frohse, is the proximal edge of the superficial layer of the supinator muscle [11].

In both approaches, access to the proximal portion of radius is achieved by sharp dissection and subperiosteal elevation of supinator from its origin on the ulnar border of the fully supinated radius. The PIN is thus protected in the belly of the supinator muscle in between the deep and superficial portions of the muscle.

In the presence of a fracture in the proximal third of the forearm, supination of the proximal fragment is difficult to achieve by manipulation at the wrist and may only be possible by reduction forceps applied directly to the radius. If the radial fracture is comminuted and the local soft tissues are contused the anatomy becomes distorted. In these circumstances knowledge of the relation of the PIN to recognisable anatomical landmarks is invaluable in allowing safe surgical dissection. It is well recognised that the PIN changes its position on the radial neck with pronation and supination of the forearm and the safest method to approach the volar aspect of the proximal radius is with the radius in the fully supinated position.

The aim of this study was to provide guidance on the safe zones for the exposure of the proximal radius by measuring the distance from the PIN to various anatomical landmarks in the proximal forearm in pronation and supination.

Materials and methods

Twenty unpaired adult upper limbs (10 left and 10 right) preserved with the method of Thiel were used for this study [13]. This unique embalming procedure was developed over a period of 30 years in the Department of Anatomy at the University of Graz, Austria. It preserves tissue colour and consistency as well as allowing an almost full range of movement at articular joints. None of the limbs had signs of previous injury, abnormality, or disease. The mean age of the donors had been 69 years (range 44–82 years) at the time of death. Eight limbs were from male and 12 from female donors.

Each upper extremity was dissected to demonstrate the radial nerve as it emerges from the lateral intermuscular septum into the anterior compartment of the arm to the distal margin of the supinator. The radial nerve was identified in the interval between the brachioradialis and brachialicus and then carefully traced to the arcade of Frohse. The nerve and its branches were exposed through their intramuscular course in supinator. Measurements of the distance between the nerve and various anatomical landmarks were recorded in full supination and pronation [8]. The following measurements were made on the anterior aspect of the proximal forearm (Fig. 1):

1. the shortest distance between radial neck and the PIN in supination (RNS),
2. the shortest distance between radial neck and the PIN in pronation (RNP),
3. the shortest distance from the insertion of the biceps tendon onto the radial tuberosity to the Arcade of Frohse where the deep PIN pierces supinator (BA).

A distance of 50 mm distal to the articular surface of the radial head is the usual limit of exposure required for the exposure of the radial head and neck through the posterior or posterolateral approaches. In order to investigate the course of the PIN in this region the following measurements were made on the posterior aspect of the forearm (Fig. 2):

1. the shortest distance between the lateral ulnar cortex at a distance of 30 mm (denoted as X) from the articular surface of the radial head and the PIN in pronation (XP) and supination (XS),
2. the shortest distance between the lateral ulnar cortex at a distance of 50 mm (denoted as Y) from the articular surface of the radial head and the PIN in pronation (YP) and supination (YS).

All these distances were measured using a vernier caliper and recorded in millimetres. The measurements were performed by one author to reduce the chances of interobserver variability.

Results

On the anterior aspect of the forearm (Fig. 1), the distance from the PIN to the ulnar border of the radial neck was greater in supination (RNS) when compared to pronation (RNP). We chose the ulnar aspect of the radial neck as this landmark is a fixed point in space and not dependent on forearm rotation. The varying distance of the PIN to this landmark with the rotation of the forearm demonstrates this. It is also easily identified intraoperatively with the use of fluoroscopy.
The RNS distance had a mean of 21.6 mm with a standard deviation of 6.2 mm. The median was 20 mm (range 16.0–37.0 mm). The RNP distance had a mean of 13.3 mm with a standard deviation of 7.0 mm. The median was 11.0 mm (range 5.0–32.0 mm). In going from full supination to full pronation the distance between the radial nerve and radial neck was reduced by a mean of 8.3 mm with a standard deviation of 4.2 mm.

The mean distance between the biceps insertion and the Arcade of Frohse was 18.6 mm with a standard deviation of 4.5 mm. The median was 18.0 mm (range 10.0–26.0 mm).

On the posterior aspect of the forearm (Fig. 2), the distance between the lateral cortex of ulna and PIN increased by pronating the forearm. In the supinated forearm XS distance had a mean of 12.3 mm with a standard deviation of 6.8 mm. The median was 13.5 mm (range 0.0–27.0 mm). The YS distance had a mean of 8 mm with a standard deviation of 4.7 mm. The median was 7.0 mm (range 0.0–18.0 mm).

In the pronated forearm the XP distance had a mean of 22.3 mm with a standard deviation of 5.1 mm. The median was 23.5 mm (range 8.0–30.0 mm). The YP distance had a mean of 16.2 mm with a standard deviation of 7.5 mm. The median was 17.5 mm (Range 0.0–32.0 mm).

There was no statistically significant relationship between our measurements and side or gender.

Discussion

Iatrogenic nerve lesions sustained during surgery are unfortunate but avoidable. In a report by Birch et al., [3] 3% of all complete nerve injuries referred to their unit were as a result of an operation. Of these, 6% involved the posterior interosseous nerve. In this study we describe and quantify the relation of the PIN to the anatomical landmarks of the radial neck and the radial tuberosity anteriorly in the proximal forearm and its relation to the lateral cortex of ulna posteriorly in order to provide dimensions of a safe window in the approach to the proximal radius. We hope these data will improve surgical precision in this region and reduce surgical morbidity due to iatrogenic injuries.

Standard approaches to the proximal radius include the volar extensile approach of Henry and the dorsolateral approach of Thompson [7]. Henry’s approach is through a skin incision over the volar aspect of the forearm. The deep fascia is incised over the ulnar border of brachioradialis which is mobilised and the plane between it and pronator teres developed. Pronator teres is then released from its insertion of the biceps tendon onto the radial (bicipital) tuberosity to the Arcade of Frohse where the deep PIN pierces supinator.
radial insertion to allow access to the deeper structures. The recurrent branch of the radial artery and the accompanying vein must be ligated so as to avoid haematoma formation. The biceps tendon is then identified and followed to its insertion onto the radial tuberosity. With the radius fully supinated, supinator can be subperiosteally elevated from its radial insertion to expose the proximal radius. Thompson’s approach utilises a posterolateral incision over the forearm. The deep fascia is incised over the intermuscular septum of extensor digitorum communis and the extensors carpi radialis brevis and longus. Extensor digitorum communis is retracted towards the ulna to expose the supinator muscle beneath it. Much in same fashion as with Henry’s approach it is careful subperiosteal elevation of supinator that yields access to the radius [7].

The structure at risk during dissection of the proximal portion of the radius is the PIN [8, 11]. By fully supinating the forearm the PIN adopts a more radial position allowing safe subperiosteal dissection of supinator from the ulnar border of the radius anteriorly. We have demonstrated that the PIN moves up to 15 mm more radial by this manoeuvre (Fig. 3).

Boyd [4] described the posterior approach to both ulna and radius for the surgical treatment of Monteggia fractures. This is a combined approach to the proximal radius and ulna by retracting anconeus medially and extensor carpi ulnaris laterally. The forearm is then fully pronated and supinator is elevated subperiosteally with the PIN protected within it laterally. This approach requires extensive soft tissue stripping and is associated with radioulnar synostosis [2]. Our data show the PIN to be perilously close to the radial border of the ulna in the distal part of this approach and extreme care must be taken when exposing the radius. At 30 mm distal to its articular surface of the radius PIN was on the radial border of the ulna, if the forearm was supinated, in one specimen. We recommend that the radius must be fully pronated in this approach as clearly described by Boyd and the dissection not to be extended distally farther than 50 mm from the articular surface of the radial head to avoid injury to the PIN. The position of the PIN is highly variable at the level of the radial neck and changes its relation to the surrounding landmarks with forearm rotation in the anterior [8, 12] as well as the dorsolateral approach [5, 14]. Diliberti et al. [5] described a zone of safety on the dorsolateral surface of the proximal radius. They showed that by pronating the forearm, a safe exposure of at least the proximal 38 mm of the lateral aspect of the radius was safe. Supination decreased...
this proximal safe zone to as little as 22 mm. Strachan et al. [12] showed that the PIN moved up to 1 cm medial to the radius on pronation of the forearm, and recommended this position during operations for excision of the radial head. Mekhail et al. [9, 10] showed that the PIN is in danger of injury from placement of screws in the proximal radius but they did not measure the position of PIN from various landmarks. They did recommend that the Thompson approach for conditions requiring more than 3 cm of proximal radius exposure would endanger the PIN.

The distance from the insertion of biceps tendon to the entrance of the PIN into the Arcade of Frohse was highly variable with a mean distance of 18.6 mm. We felt this measurement to be useful as it is not dependent on forearm rotation. In the anterior approach to the radial neck the biceps tendon can act as a guide for dissection in the traumatised tissues of the proximal forearm. The shortest distance between the insertion of the biceps tendon at the radial tuberosity and the arcade of Frohse was 10.0 mm. This means that the PIN is at great risk from surgical dissection. The origin of supinator muscle in this region skirts around the radial tuberosity and continues along the shaft of the radius. This implies that the proximity of the PIN may be as little as a few millimetres away during the subperiosteal dissection of supinator and its elevation at this level. Great care must be taken to first resect the bursa between the biceps tendon and part of the tuberosity that forms part of the insertion, so that the supinator muscle and its origin can be fully visualised allowing safe elevation to reveal the proximal radius. The course of the PIN through supinator muscle and its course after it emerges in the posterior compartment of the forearm is not constant. The variation in the number of branches and the location of the origin of these branches has been reported in the literature [1, 6].

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Meticulous attention to surgical technique in this region is critical, particularly in the traumatised limb as the familiar landmarks maybe distorted following the injury.

**Conflict of interest** The authors declare that they have no conflict of interest.

**References**

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