The radial nerve at revision/redo surgery – using the lower lateral cutaneous nerve to prevent a postoperative radial nerve deficit

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Background: The posterior approach to the humeral shaft is commonly used for surgical procedures on the humeral shaft. We present our experiences using the modification of the surgical exposure described by Gerwin M. which we have found useful at the time of revision surgery.

Methods: Between 2014 and 2019, six patients who underwent a revision surgical procedure for a nonunion of the humeral shaft where a prior surgical procedure was performed through a posterior incision were included. The approach used a modification of the posterior approach described by Gerwin M. where the lower lateral cutaneous nerve branch of the radial nerve is used to identify, trace, mobilize, retract, and protect the radial nerve to achieve adequate exposure of the humeral shaft.

Results and Discussion: None of the patients had a postoperative nerve deficit. Adequate exposure to aid hardware removal, osteosynthesis, and bone grafting was achieved in all patients.

Conclusion: The modification of the posterior approach described by Gerwin M. is useful at the time of revision or redo surgery on the humeral shaft where other bony and soft tissue landmarks are altered to prevent an iatrogenic injury to the radial nerve while providing adequate exposure to treat a nonunion.

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elevating the triceps off the posterior surface of the humerus and distally by adequate release of the lateral intermuscular septum (Fig. 3).

Multiple deep intraoperative cultures were routinely obtained. With adequate exposure of the posterior aspect of the humerus, treatment of the nonunion was performed as planned preoperatively using established principles with removal of the hardware, debridement of the nonunion and rigid internal fixation supplemented with local and autologous bone graft. Closure was performed ensuring that no repair of the lateral intermuscular septum was performed. The radial nerve was clinically assessed in the immediate postoperative period as the patient recovered from the general anesthetic in the recovery room (Uploaded video file).

Results and discussion

None of the patients sustained an iatrogenic nerve injury or had a postoperative neuropraxia, with all patients having normal wrist and finger dorsiflexion with no sensory symptoms.

Adequate and satisfactory exposure of the humeral shaft was obtained to treat the nonunion which ultimately contributes to healing of the nonunion (Fig. 4).

The radial nerve with its serpentine course over the humeral shaft is of importance in any chosen surgical approach to the humerus. Several landmarks exist in literature to help ascertain the location of the radial nerve in the posterior approach. Existing methods and landmarks in literature include the acromion process, the deltoid tuberosity, the distal epicondyles, the distal articular surface, the origin of brachioradialis, the tricipital aponeurosis, indirect anthropometric landmarks, measurement using software reconstructed data from computed tomography scans and the lower lateral cutaneous nerve. A summary of prior studies is given in Table I. These have either been predominantly cadaveric studies or intraoperative observation. It is interesting to note that only two studies by Arora et al (60 patients) and Gerwin M et al (7 patients) have used intraoperative observations along with concurrent cadaveric studies. Studies by Demirkale et al, Park et al, Simone et al, and Seigerman et al have used intraoperative images to

Figure 1 The lower lateral cutaneous nerve after retraction of the triceps and elevation of the lateral fasciocutaneous flap.

Figure 2 Rotation of the arm to aid visualization and retraction.

Figure 3 Internal fixation of humeral shaft with the radial nerve and the lower lateral cutaneous nerve of the arm lying over the implant.

Figure 4 (A-C) Preoperative, immediate postoperative and radiological outcome at 32 months. The modified posterior approach provides adequate exposure of the humeral shaft in the treatment of complicated nonunions.
<table>
<thead>
<tr>
<th>S.No</th>
<th>Authors</th>
<th>Year</th>
<th>Cadaveric/anthropometric/intraoperative/radiological</th>
<th>Landmarks used</th>
<th>Brief description of relevant findings and conclusion</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Arora S, Goel N, Cheema GS, Batra S, Maini L&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2011</td>
<td>Cadaveric (10) and intraoperative measurements(60)</td>
<td>Apex of the aponeurosis used to determine position of the radial n.</td>
<td>Mean distance and SD was 2.51 cm ± 0.2 in cadaveric and 2.53 ± 0.4 cm intraoperative group.</td>
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<td>2</td>
<td>Carlan D, Pratt J, Patterson JMM et al&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2007</td>
<td>Cadaveric (27)</td>
<td>Bony landmarks – lateral epicondyle and deltoid tuberosity</td>
<td>6.3 cm of the nerve was in direct contact with the posterior humerus, 17.1 cm ± 1.6 to 10.9 cm ± 1.5 cm proximal to lateral epicondyle, lie on the posterior midline of the humerus within 0.1 cm-0.2 of the level of the most distal palpable aspect of the deltoid tuberosity.</td>
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<td>3</td>
<td>Chaudhry T, Noor S, Maher B et al.&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2010</td>
<td>Cadaveric(55)</td>
<td>Lateral border of triceps aponeurosis</td>
<td>The radial nerve was adjacent to the lateral border of the triceps aponeurosis at a distance of 22-27 (62) mm.</td>
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<td>4</td>
<td>Cox CL, Riherd D, Tubbs RS&lt;sup&gt;5&lt;/sup&gt;</td>
<td>2010</td>
<td>Cadaveric (17)</td>
<td>Bony landmarks (measuring the entire length of the humerus), division of the radial N, lateral intermuscular septum, division of posterior interosseous n.</td>
<td>The radial n traversed the spiral groove 48% (36%-63%) of humeral length, distal to the greater tuberosity. It pierced the lateral intermuscular septum on average, 38% (29%-56%) of humeral length, proximal to the lateral epicondyle (LE). The posterior interosseous n. division occurred on average 1.0 cm distal to the lateral epicondyle.</td>
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<tr>
<td>5</td>
<td>Gerwin M, Hotchkiss RN, Weiland AJ&lt;sup&gt;7&lt;/sup&gt;</td>
<td>1996</td>
<td>Cadaveric and intraoperative(10)</td>
<td>The lower lateral brachial cutaneous nerve</td>
<td>The cutaneous branch was found to be a reliable landmark to identify and dissect the radial nerve. The intermuscular septum was divided distally for 3 cm over the radial nerve to permit operative mobilization of the nerve. Medial retraction of the medial and lateral heads of the triceps muscle allowed visualization of 26.4 cm of the diaphysis.</td>
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<td>6</td>
<td>Guse TR, Ostrum RF&lt;sup&gt;10&lt;/sup&gt;</td>
<td>1995</td>
<td>Cadaveric (24)</td>
<td>Bony landmarks – tip of the olecranon and medial and lateral epicondyles.</td>
<td>Crossed the posterior shaft 124 mm below the tip of the acromion, 131 mm above the medial epicondyle and 126 mm above the lateral epicondyle. (Never within 100 mm of either epicondyle.)</td>
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<tr>
<td>7</td>
<td>Demirkale I, Imamoğlu H, Şık S, et al&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2019</td>
<td>Radiological/anthropometric ultrasound assessment on healthy volunteers (100)</td>
<td>Distance between radial nerve at the midpoint of the spiral groove and the tip of the olecranon was compared with the distance between the most distal wrist flexion crease and fingertips</td>
<td>The distance between the Radial n at the midpoint of the sagittal groove and the tip of the olecranon correlated with the distance between the tip of the 5th finger and the distal wrist crease.</td>
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<td>8</td>
<td>Fleming P, Lenehan B, Sankar R, et al&lt;sup&gt;8&lt;/sup&gt;</td>
<td>2004</td>
<td>Cadaveric(20)</td>
<td>Bony landmarks – line joining lateral epicondyle and the most lateral point of the acromion process.</td>
<td>The radial nerve pierces the lateral intermuscular septum and enters the anterior compartment within 5 mm of the junction between the distal third and proximal two-third of a line joining lateral epicondyle and lateral most point of the acromion process.</td>
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<td>9</td>
<td>Kamineni S, Ankern H, Patten DK&lt;sup&gt;12&lt;/sup&gt;</td>
<td>2009</td>
<td>Cadaveric (70)</td>
<td>Used the transepicondylar distance as a marker for safe placement of lateral pins for external fixation.</td>
<td>An “absolute safe zone for pin entry” was within a distance measuring 70% of the patient’s own transepicondylar distance, measuring proximally from the transepicondylar axis.</td>
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<td>10</td>
<td>McCann PA, Smith GCS, Clark D et al.&lt;sup&gt;11&lt;/sup&gt;</td>
<td>2015</td>
<td>Cadaveric (10)</td>
<td>Triceps aponeurosis</td>
<td>Interval between the lateral border the triceps aponeurosis and nerve as it crossed the mid sagittal aspect of the humerus varied between 16.25 mm in full flexion and to 1 mm in 90° flexion and 6.6 mm in full extension.</td>
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illustrate their landmarks and have quoted from personal clinical experience but have not corroborated the benefit of using said landmarks as a surgical outcome in a series of patients.

When a prior surgical procedure has been performed through a triceps split and if the bony anatomy is altered by prior surgery and bone loss, these existing anatomic landmarks are of little use. Identifying the lower lateral cutaneous nerve is a reliable intraoperative landmark which is easy to identify and dissect proximally to the radial nerve. This approach provides adequate exposure of the humeral shaft and visualization of the radial nerve extending distally in patients requiring revision surgery. This technique provides adequate exposure of the humeral shaft to aid treatment in complicated nonunions. This needs to be corroborated in larger studies and across multiple surgical teams.

**Conclusion**

The use of the modification of the posterior approach reported by Gerwin M at the time of revision surgical procedures to the humeral shaft may be a reproducible technique to prevent an iatrogenic nerve deficit at the time of revision surgery. This technique provides adequate exposure of the humeral shaft to aid treatment in complicated nonunions. This needs to be corroborated in larger studies and across multiple surgical teams.
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Supplementary data

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References