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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.

The posterior approach to the humeral shaft is commonly used for surgical procedures on the humeral shaft. We present the results of an established modification of the surgical exposure which we have found useful at the time of revision surgery.[9] Revision surgical procedures are frequently difficult in view of existing scarring, prior hardware, and infection. On occasions where the primary surgery has been performed elsewhere and if adequate documentation is unavailable, then the location of the radial nerve in relation to intraoperative landmarks requires a single predictable anatomic landmark to preserve and protect the integrity of the radial nerve during exposure.

Patients and methods

Data from six patients who underwent revision surgery for radial shaft nonunions between 2014 and 2019 were obtained from operation notes, hospital records, and intraoperative photographs if available. The average age was 32.6 (27-45) years, with five men and one woman. Altogether these six patients had undergone a total of eight surgical procedures before presentation at our center. The average time between the last surgical procedure and their presentation for revision was 14 months (9-27 months). All prior surgeries had been performed through a posterior incision, and all patients had hardware (failed implants) in situ at the time of presentation. This study was approved by the institutional review board (IRB No13311).

All surgeries were performed under general anesthesia by a single consultant well versed with the posterior approach. Exposure was performed with the patient positioned lateral and the upper extremity supported on a bolster. After appropriate preparation, the prior posterior incision was used for exposure. The lateral fasciocutaneous flap was elevated, and the lower lateral cutaneous nerve was identified (Fig. 1). The authors have noted that rotating the arm externally and adjusting the extension of the elbow allows for better visualization and retraction and can aid in locating the lower lateral cutaneous nerve (Fig. 2).

This cutaneous nerve was traced proximally dissecting through the triceps muscle to identify the radial nerve at the lateral border of the humeral shaft, which was then dissected proximally by

The Christian Medical College Vellore Ethics Committee approved this study (registration no: ECR/326/INST/TN201; Reg-2019 IRB Minute No 13311, dated August 26, 2020).

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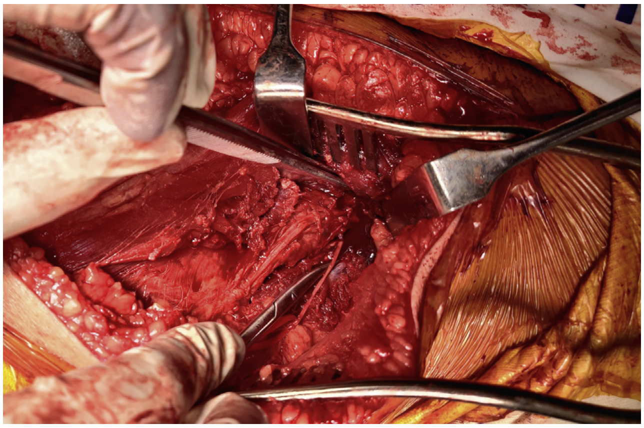

Figure 1 The lower lateral cutaneous nerve after retraction of the triceps and elevation of the lateral fasciocutaneous flap.

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

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

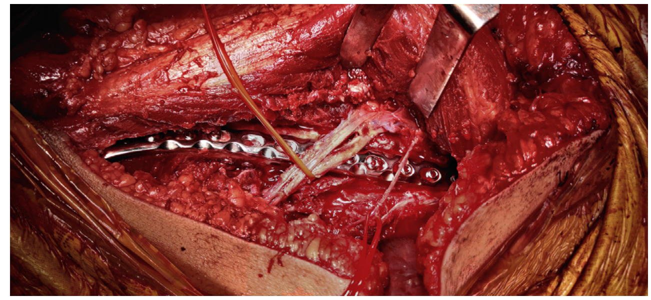

Figure 3 Internal fixation of humeral shaft with the radial n and the lower lateral cutaneous nerve of the arm lying over the implant.

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[13] 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.[11,24] 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.[1-4,6-9,10,12,14,15,17,19,22,23]

These have either been predominantly cadaveric studies or intraoperative observation. It is interesting to note that only two studies by Arora et al[1] (60 patients) and Gerwin M et al[9] (7 patients) have used intraoperative observations along with concurrent cadaveric studies. Studies by Demirkale et al,[7] Park et al,[16] Simone et al,[21] and Seigerman et al[19] have used intraoperative images to

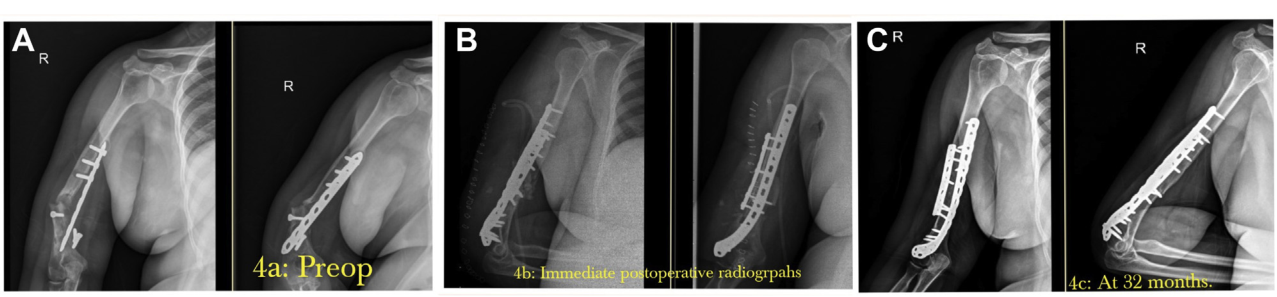

Figure 4 (**A-C**) Preoperative, immediate postoperative and radiological outcome at 32 months. The modified posterior approach provides adequate exposure of the humeral shaft in the treatment of complicated nonunions.

Table I
Existing literature detailing the anatomy of the radial nerve in relation to a variety of anatomic landmarks (in alphabetical order).

S.No	Authors	Year	Cadaveric/anthropometric/ intraoperative/radiological	Landmarks used	Brief description of relevant findings and conclusion
1	Arora S, Goel N, Cheema GS, Batra S, Maini L.[1]	2011	Cadaveric (10) and intraoperative measurements(60)	Apex of the aponeurosis used to determine position of the radial n.	Mean distance and SD was 2.51 cm ± 0.2 in cadaveric and 2.53 ± 0.4 cm intraoperative group
2	Carlan D, Pratt J, Patterson JMM et al[3]	2007	Cadaveric (27)	Bony landmarks – lateral epicondyle and deltoid tuberosity	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.
3	Chaudhry T, Noor S, Maher B et al.[4]	2010	Cadaveric(55)	Lateral border of triceps aponeurosis	The radial nerve was adjacent to the lateral border of the triceps aponeurosis at a distance of 22-27 (62) mm
4	Cox CL, Riherd D, Tubbs RS[6]	2010	Cadaveric (17)	Bony landmarks (measuring the entire length of the humerus), division of the radial N, lateral intermuscular septum, division of posterior interosseous n.	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.
5	Gerwin M, Hotchkiss RN, Weiland AJ[9]	1996	Cadaveric and intraoperative(10)	The lower lateral brachial cutaneous nerve	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.
6	Guse TR, Ostrum RF[10]	1995	Cadaveric (24)	Bony landmarks – tip of the olecranon and medial and lateral epicondyles.	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.)
7	Demirkale İ, İmamoğlu H, Şık S, et al[7]	2019	Radiological/ anthropometric ultrasound assessment on healthy volunteers (100)	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	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.
8	Fleming P, Lenehan B, Sankar R, et al[8]	2004	Cadaveric(20)	Bony landmarks – line joining lateral epicondyle and the most lateral point of the acromion process.	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.
9	Kamineni S, Ankem H, Patten DK[12]	2009	Cadaveric (70)	Used the transepicondylar distance as a marker for safe placement of lateral pins for external fixation.	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.
10	McCann PA, Smith GCS, Clark D et al.[14]	2015	Cadaveric (10)	Triceps aponeurosis	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

(continued on next page)

Table I (*continued*)

S.No	Authors	Year	Cadaveric/anthropometric/ intraoperative/radiological	Landmarks used	Brief description of relevant findings and conclusion
11	Park KJ, Romero BA, Ahmadi S[16]	2019	Cadaveric(17)	Deltoid tuberosity and brachioradialis	The radial nerve was identified within the distal 2/3 of the distance between the deltoid tuberosity and the origin of brachioradialis.
12	Park J-K, Choi S-M, Kang S-W, Kim K-J, Min K-T[15]	2020	Radiological CT–based reconstructed images (652)	In vivo anatomic study using a 3D reconstruction technique and CT scan images. A rendered course of the radial n plotted and distance to the olecranon fossa measured.	The radial nerve may be in direct contact with the posterior humeral shaft from 76.8 mm to 198.2 mm proximal to the olecranon fossa.
13	Patra A, Chaudhary P, Malhotra V et al[17]	2020	Cadaveric(40)	Triceps aponeurosis – point of confluence	Similar to Seigerman et al (2012). The radial nerve was consistently identified approximately two finger breadths proximal to the point of confluence with a mean of distance of 3.59 ± 0.16 cm and was the most reliable marker as compared to upper arm length vs. condyloradial and acromioradial distance.
14	Seigerman DA, Choung EW, Yoon RS et al[19]	2012	Cadaveric(30) Intraoperative	Triceps aponeurosis	Nerve was identified two fingerbreadths above the confluence of the Triceps aponeurosis with a mean distance of 38.9 ± 2.3 mm
15	Simone JP, Streubel PN, Sánchez-Sotelo J et al[21]	2019	Cadaveri(10)	Anthropometric/fingerbreadth	Four fingerbreadths above lateral epicondyle for the radial nerve and two fingerbreadths for the posterior interosseous nerve.
16	Theeuwes HP, van der Ende B, Potters JW[22]	2017	Cadaver(20)	Radio-opaque tags used to identify course of the nerve after which measurements on radiographs. Center of the capitellum-trochlea (CCT) was the distal radiological landmark in lateral view and the medial epicondyle in the AP view, and safe zones were measured proximally.	Measurement obtained using radiologicl landmarks to evaluate safe zone while using different humeral nailing systems. Safe zone for Lateral pin(interlock) placement was 48 mm proximal to the center of the CCT. No clear safe zones for AP pin(interlock) placement-distal fixation unsafe from 21 and 101 mm when measured from the medial epicondyle.

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 intraoperatively and difficult to corroborate in studies.

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 which prevents inadvertent iatrogenic injury or neuropraxia while providing adequate exposure for osteosynthesis.

Data from multiple studies had shown that a postoperative radial nerve deficit can occur between 8% and 25%.[18,20] Data reviewed across six major centers by Femke et al showed that transient radial nerve deficits occurred in 1 in 5 patients treated with lateral exposure of the humerus, in 1 in 9 patients treated with posterior exposure and in 1 in 25 patients with an anterolateral exposure.[5]

Nearly all data on radial nerve deficits, including the original modification by Michelle et al, are on patients in whom the posterior approach was the index surgical procedure. This was a modification of the predominantly used triceps split approach to the humeral shaft. Revision surgeries for a nonunion can be a daunting task especially when the surgical territory is complicated by extensive scarring, obliterating important anatomic landmarks. This study is not a modification of the description by Michelle et al but has relied on the technique described, in patients requiring revision surgery.

At present, there are no data on radial nerve deficits in patients who have undergone prior surgical procedures irrespective of the approach. No other approach (anterior and anterolateral) requires as much exposure and manipulation of the radial nerve as the posterior approach.

This article hopes to highlight the potential benefit of using the lower lateral cutaneous nerve which we have found useful at revision surgery.

An obvious pitfall of this study is its small number, retrospective design, and the inherent bias as all procedures were performed by a single surgeon.

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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