Journal of Plastic, Reconstructive & Aesthetic Surgery (2020) 73, 209–213

ELSEVIER
EURAPS
JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

Exploration of the axillary nerve through an open posterior endoscopic-assisted (OPEA) approach: First clinical experience

Andrés A. Maldonado[a,b,*], Robert J. Spinner[b], Johannes Frank[c], Michael Sauerbier[a]

[a] *Department of Plastic, Hand and Reconstructive Surgery, BG Trauma Center Frankfurt am Main, Academic Hospital of the Goethe-University Frankfurt am Main, Friedberger Landstraße 430, 60389 Frankfurt am Main, Germany*
[b] *Department of Neurological Surgery, Mayo Clinic, Rochester, MN, USA*
[c] *Department of Trauma, Hand and Reconstructive Surgery, University Hospital Frankfurt, Goethe-University, Frankfurt am Main, Germany*

Received 28 May 2019; accepted 27 July 2019

KEYWORDS
Axillary nerve;
Axillary nerve exploration;
Blind zone;
Open posterior endoscopic-assisted approach;
Arthroscopy

Abstract *Introduction:* Previous studies have described a segment of the axillary nerve (AN) that cannot be surgically explored through the deltopectoral and posterior surgical open approaches (blind zone). We present the first two cases using an endoscopic-assisted approach to explore the AN through a posterior approach.
Material and methods: Two patients were evaluated, in whom clinical, electrodiagnostic testing, and MRI could not localize the level of the AN dysfunction. An open posterior endoscopic-assisted (OPEA) approach was performed 4 and 9 months after injury in an attempt to visualize all segments of the AN. Photographs and videos were taken to evaluate the intraoperative visualization of the AN and provide long-term clinical follow-up.
Results: Almost the entire AN was visualized with the scope through the OPEA approach, avoiding the deltopectoral approach. No AN lesion was found during the nerve exploration. A triceps branch to AN transfer, using the previous posterior approach, was performed. Patients in both groups achieved a deltoid muscle function of BMRC grade 4 after 24 and 9 months, respectively.

This work was partially presented at the EURAPS meeting, 25 May 2019.
* Corresponding author at: Department for Plastic, Hand and Reconstructive Surgery, BG Trauma Center Frankfurt am Main, Academic Hospital of the Goethe-University Frankfurt am Main, Friedberger Landstraße 430, 60389 Frankfurt am Main, Germany.
E-mail addresses: andres.maldonado@bgu-frankfurt.de, mail@andresmaldonado.es (A.A. Maldonado).

https://doi.org/10.1016/j.bjps.2019.07.026

Conclusion: The exploration of the AN through the OPEA approach was a useful strategy to visualize the blind zone of the AN without requiring the addition of a deltopectoral approach. We believe this novel technique has a role in selected cases of AN injury.

Introduction

The axillary nerve (AN) is reported to be one of the most commonly injured nerves during surgical procedures of the shoulder.[1,2] Surgical approaches to explore and manage AN injuries have been previously reported.[3-5] Recently, it has been shown that there is a segment of the AN that cannot be surgically evaluated through the standard anterior deltopectoral or posterior approaches.[6] This segment is labeled the "blind zone" (zone B)[7] and is reported to be localized to the quadrilateral space and in proximity to the glenohumeral joint. We have defined two additional zones of the AN: zone A ("anterior," from the origin of the AN to the triangle formed by the subscapularis muscle, conjoined tendon and axillary fat) and zone C ("circumflex" from the posterior border of the quadrilateral space to the entry into the deltoid muscle).

The use of the "dry-scope" (defined as arthroscopy performed without infusing water into the explored cavity) has been popularized in the surgery of the wrist and elbow in the last decade by del Piñal and co-workers[8-10]. More recently, an anatomical study of the AN using an open posterior endoscopic-assisted (OPEA) approach was described.[11] In this technique, almost the entire AN can be visualized by inserting an arthroscope through a previously created standard posterior approach.

The aim of this study was to evaluate the clinical application of the OPEA approach for patients with suspected AN injuries.

Patients and methods

Patients

After institutional review board approval, two patients were evaluated in whom clinical and electrodiagnostic testing could not localize the level of the AN dysfunction (Table 1).

Table 1 Patient demographics, BMRC grades, and DASH scores.

Patient number	Patient 1	Patient 2
Sex	Male	Male
Age	20	51
Time from injury to surgery	9 months	4 months
Follow-up	24 months	9 months
Deltoid preoperative BMRC grade	M0	M0
Deltoid postoperative BMRC grade	M4 (5 kg)	M4 (0.5 kg)
Preoperative DASH score	39.2	26.7
Postoperative DASH score	1.7	17.5

BMRC, British Medical Research Council; DASH, Disabilities of the Arm, Shoulder and Hand.

Patient #1

A 20-year-old man presented in our clinic with left (non-dominant) shoulder weakness and complete deltoid muscle atrophy (British Medical Research Council (BMRC) Grade 0) after a motorcycle accident 9 months earlier (Video 1A). This patient worked as a car mechanic and the strength of the shoulder was a high priority in order for him to perform his job. The electromyogram (EMG) showed no deltoid muscle reinnervation, and the MRI did not localize an AN injury. An OPEA approach was utilized to help identify a definitive reconstruction: due to the late presentation of the injury, we planned a sural nerve interpositional graft if there were a distal AN injury (zone B or C) and a Leechavengvongs nerve transfer for a more proximal AN injury (zone A). The AN was explored, and no distal abnormality was noted (Video 1B), thereby establishing an injury to the AN in zone A, or even more proximally. A standard Leechavengvongs end-to-end nerve transfer was performed.[5,12]

Patient #2

A 51-year-old man presented to our clinic with a left (dominant) shoulder range of motion deficit (active flexion and abduction = 30°) after a motorbike accident with anterior shoulder subluxation 4 months earlier (Video 2A). The elbow flexion and shoulder external rotation had improved during this time from BMRC Grade 0 to Grade 4 in the biceps, brachialis, and supra- and infraspinatus muscles). Deltoid muscle was BMRC Grade 0 and EMG showed no deltoid muscle reinnervation. MRI showed an upper trunk injury without any AN injury. We planned a supraclavicular plexus exploration. A neuroma-in-continuity was identified intraoperatively in the upper trunk. Intraoperative nerve action potentials were obtained across the lesion, and EMGs demonstrated motor unit potentials and an evoked contraction in the biceps, but not in the deltoid muscles. An OPEA approach to the AN was done in the same surgery to search for a possible second zone of injury to explain the lack of recovery in the AN distribution at 4 months (Video 2B). The AN was evaluated, and no abnormality was found. A standard Leechavengvongs end-to-end nerve transfer was performed in an attempt to reinnervate the deltoid muscle.[5,12]

Surgical technique

The AN was dissected through a standard posterior approach.[5] The dissection was carried out with the patient in the lateral position and his shoulder in 90° of abduction. An 8 cm incision along the posterior border of the deltoid muscle was performed. The deltoid muscle was superiorly retracted to expose the quadrilateral space that is bordered by the teres minor superiorly, teres major inferiorly, long head of the triceps tendon medially, and proximal humerus laterally. Next, dry endoscopy was performed. A nasal speculum was used for local tissue retraction and an arthroscope (2.4 mm, Karl Storz, Tuttlingen, Germany) was introduced through a subaxillary incision (Figure 1). This technique allowed viewing through the arthroscope while performing the dissection. Gentle traction placed on the AN with a vessel loop facilitated the dissection. We attempted to dissect the AN as anteriorly as possible (Videos 1B and 2B).

Outcome measures

Photographs and videos were taken to record the intraoperative visualization of the AN for long-term clinical follow-up. Muscle strength was assessed using a modified BMRC grade.[13,14] To obtain a BMRC grade of 3, the patient had to have active motion equal to passive motion against gravity. Additionally, a higher grade could not be obtained unless the criteria were met for the lower grade. The DASH questionnaire was used to measure patient-related outcomes (a scale score ranging from 0 [no disability] to 100 [most severe disability].[15,16] The scores were obtained preoperatively and postoperatively in both patients. The DASH surveys were completed in the clinic at preoperative appointments and postoperative follow-ups.

Results

Almost the entire AN could be visualized with the scope through the OPEA approach, avoiding the need to use the deltopectoral approach (Videos 1B and 2B). AN dissection was performed up to the anterior zone (zone A) of the AN (note the light of the scope through the anterior skin of the shoulder in Figure 1(B)) with the arthroscope. The posterior cord was not visualized. No AN injury was found during the nerve exploration.

In the first case, because of the late presentation of the injury, a more proximal exploration through an infraclavicular approach was not carried out, and an end-to-end triceps branch to AN transfer, using the previous posterior approach, was performed. Reinnervation of the deltoid muscle was found in the EMG after 3 months. After 24 months, the patient achieved a BMRC grade 4 (5 kg) in his deltoid muscle with complete shoulder abduction and flexion (Video 1C).

In the second case, a more proximal injury (upper trunk) was visualized during the standard supraclavicular dissection and a triceps branch to AN transfer, using the posterior approach, was performed. Reinnervation in the deltoid muscle was found in the EMG after 5 months. After 9 months, the patient achieved BMRC grade 4 (0.5 kg) in his deltoid muscle with complete shoulder abduction and flexion (Video 2C). A summary of patients' demographics, BMRC grades, and DASH scores is presented in Table 1.

Discussion

In our previous anatomical study,[11] we were able to explore almost the entire AN using the OPEA approach. The visualized zones of the AN were marked with surgical clips. In our present clinical study, although we could not mark with surgical clips the actual visualized length of the AN, we were able to pass the arthroscope proximal to the quadrilateral space, visualizing at least the zones B (blind) and C (circumflex – the most distal) of the AN. The length of zone A (the most proximal zone of the AN), which was able to be visualized, could not be quantified in this clinical study.

We describe in this study two cases in which zones B and C of the AN were important to explore. Wolfe et al.[17] demonstrated that in a mixed cohort of isolated axillary and combined nerve injuries, there was no statistically significant difference in functional outcomes between patients who had either the Leechavengvongs' procedure or long nerve grafts. Other studies failed to demonstrate earlier reinnervation or better functional recovery with the triceps motor nerve transfer technique compared to nerve grafts.[18] Although further studies are needed to determine which of the two techniques (nerve transfer versus nerve graft) has better outcomes, the Leechavengvongs' nerve transfer theoretically permits a more direct deltoid reinnervation for scenarios in which more rapid reinnervation is critical (injuries between 6 and 12 months or very proximal (zone A) injuries). Using the OPEA approach, we were able to visualize completely zones C and B of the AN. If an injury in these two zones had been seen (more proximal to the deltoid muscle), a sural nerve graft (even combined with an end-to-side triceps to axillary nerve transfer) should have been considered.

AN injuries in zone B are the most difficult to explore through standard deltopectoral and posterior approaches.[6] We believe that the OPEA approach has a specific application, in cases where an AN injury in zone B is suspected (due to trauma mechanism, MRI images, etc.). To visualize this blind zone of the AN through the posterior approach, we previously reported in an anatomical study that the tendon of the long head of the triceps tendon needed to be transected to allow this visualization.[6] However, this technique has two potential morbidities: (1) transection of the origin of the long head of the triceps; and (2) the need to perform an additional deltopectoral approach to evaluate zone A of the AN. Another option to visualize zone B of the AN is to perform an axillary approach as described by Bertelli et al.[4] With this approach, zone B of the AN is visualized. However, the most proximal (zone A) and distal segments of the AN (zone C) are not visualized as described in our previous anatomical study.[6] We think the surgical technique here presented (OPEA approach) requires a less degree of dissection than the axillary approach, and it allows visualization of zone C, zone B, and part of zone A of the AN nerve.

This novel surgical technique presented here has two potential limitations. First, if a proximal AN injury is found and a long nerve graft is needed, it may be necessary to perform a deltopectoral approach. Performing a nerve coaptation through the OPEA approach is technically not possible. However, our OPEA approach could avoid the deltopectoral approach in certain specific scenarios (as in the two patients here presented), and it could reduce the risks and morbidity associated with the deltopectoral approach. Second, the two ANs explored were not injured in zones B and C. A more difficult dissection could be expected if the scar tissue had been present or bleeding had occurred. More clinical experience is necessary to evaluate the utility of this novel approach.

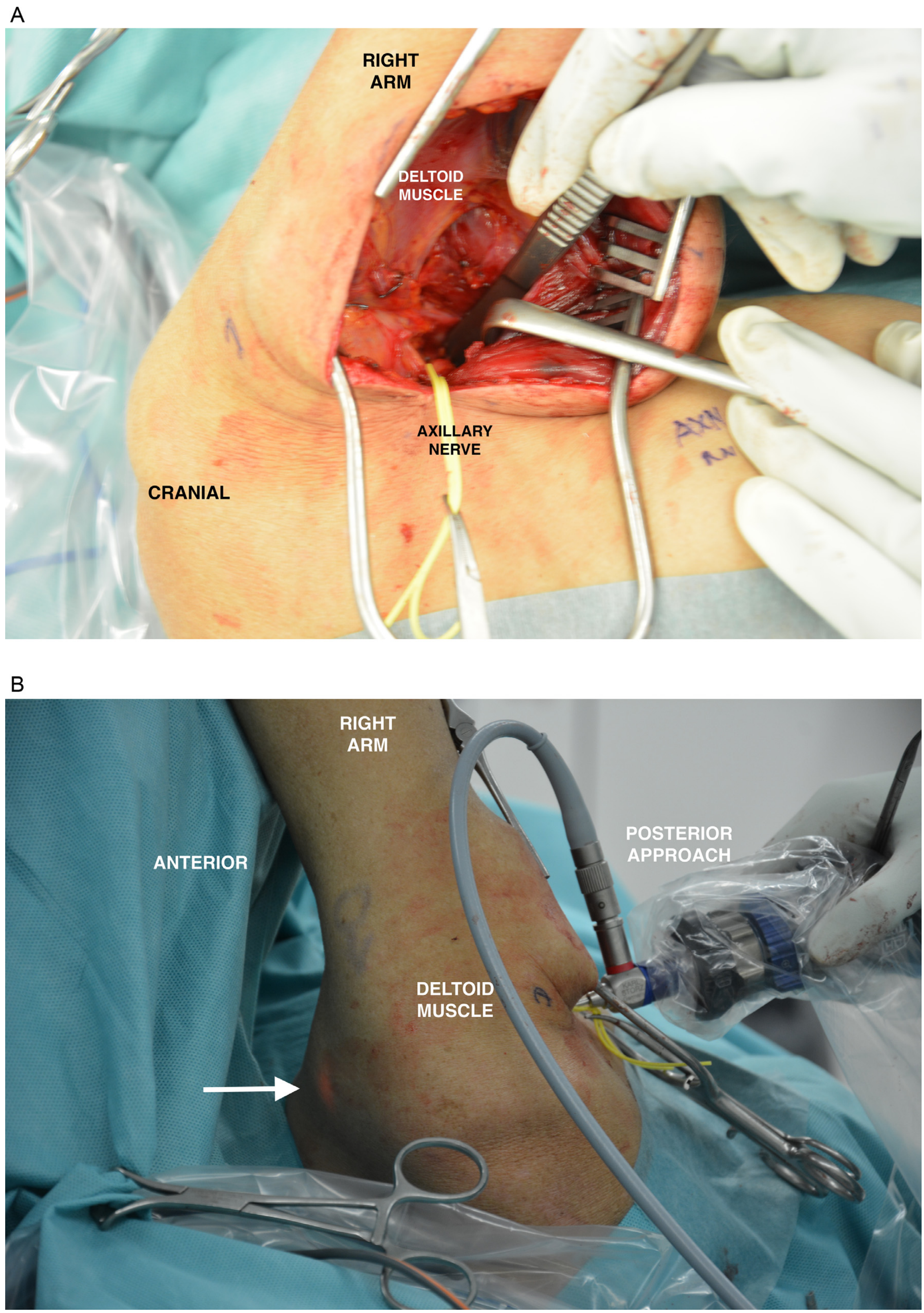

Figure 1 Example of introducing the arthroscope (2.4 mm, Karl Storz, Tuttlingen, Germany) through a posterior subaxillary incision. (A) Dissection of the axillary nerve through a standard posterior approach. (B) Introduction of the arthroscope through the posterior approach. Note the light of the scope through the anterior skin of the shoulder (white arrow).

Conclusion

The exploration of the AN through an open posterior endoscopic-assisted (OPEA) approach is a useful strategy to visualize the AN (especially zones B and C) without the need for a deltopectoral or an extended approach. We believe this technique has a role in selected cases of AN injury. Further clinical studies will help determine the utility, reliability, and specific applications of this novel technique.

Funding

None.

Declaration of Competing Interest

The authors have no financial interest/funding to declare in relation to the content of this article.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2019.07.026.

References

1. Bono CM, Grossman MG, Hochwald N, Tornetta P. Radial and axillary nerves. Anatomic considerations for humeral fixation. *Clin Orthop Relat Res* 2000(373):259–64.
2. Apaydin N, Tubbs RS, Loukas M, Duparc F. Review of the surgical anatomy of the axillary nerve and the anatomic basis of its iatrogenic and traumatic injury. *Surg Radiol Anat* 2009;**32**(3):193–201.
3. Jerome JTJ. Long head of the triceps branch transfer to axillary nerve in C5, C6 brachial plexus injuries: anterior approach. *Plast Reconstr Surg* 2011;**128**(3):740–1.
4. Bertelli JA, Kechele PR, Santos MA, Duarte H, Ghizoni MF. Axillary nerve repair by triceps motor branch transfer through an axillary access: anatomical basis and clinical results. *J Neurosurg* 2007;**107**(2):370–7.
5. Leechavengvongs S, Witoonchart K, Uerpairojkit C, Thuvasethakul P. Nerve transfer to deltoid muscle using the nerve to the long head of the triceps, part II: a report of 7 cases. *J Hand Surg Am* 2003;**28**(4):633–8.
6. Maldonado AA, Spinner RJ, Bishop AT, Shin AY, Elhassan BT. Effectiveness of the extended surgical approach to visualize the axillary nerve in the blind zone in an arthroscopic axillary nerve injury model. *J Plast Reconstr Aesthet Surg* 2016;**69**(12):1697–703.
7. Maldonado AA, Howe BM, Lawton R, Bishop AT, Shin AY, Spinner RJ. Anatomical study of the axillary nerve: description of a surgical blind zone. *Plast Reconstr Surg* 2016;**138**(2):419–26.
8. del Piñal F, Tandioy-Delgado F. (Dry) arthroscopic partial wrist arthrodesis: tips and tricks. *Handchir Mikrochir Plast Chir* 2014;**46**(05):300–6.
9. del Piñal FD. Dry arthroscopy and its applications. *Hand Clin* 2011;**27**(3):335–45.
10. del Piñal F, García-Bernal FJ, Pisani D, Regalado J, Ayala H, Studer A. Dry arthroscopy of the wrist: surgical technique. *J Hand Surg Am* 2007;**32**(1):119–23.
11. Maldonado AA, Spinner RJ, Bishop AT, Shin AY, Elhassan BT. Arthroscopic-assisted exploration of the axillary nerve through a posterior open approach: a novel technique. *J Plast Reconstr Aesthet Surg* 2017;**70**(5):625–7.
12. Witoonchart K, Leechavengvongs S, Uerpairojkit C, Thuvasethakul P, Wongnopsuwan V. Nerve transfer to deltoid muscle using the nerve to the long head of the triceps, part I: an anatomic feasibility study. *J Hand Surg Am* 2003;**28**(4):628–32.
13. Giuffre JL, Kakar S, Bishop AT, Spinner RJ, Shin AY. Current concepts of the treatment of adult brachial plexus injuries. *J Hand Surg Am* 2010;**35**(4):678–88.
14. O'Brien M. *Aids to the examination of the peripheral nervous system*. China: Saunders Limited; 2010.
15. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the dash (disabilities of the arm, shoulder and hand). The upper extremity collaborative group (UECG). *Am J Ind Med* 1996;**29**(6):602–8.
16. Beaton DE, Katz JN, Fossel AH, Wright JG, Tarasuk V, Bombardier C. Measuring the whole or the parts? Validity, reliability, and responsiveness of the disabilities of the arm, shoulder and hand outcome measure in different regions of the upper extremity. *J Hand Ther* 2001;**14**(2):128–46.
17. Wolfe SW, Johnsen PH, Lee SK, Feinberg JH. Long-nerve grafts and nerve transfers demonstrate comparable outcomes for axillary nerve injuries. *J Hand Surg Am* 2014;**39**(7):1351–7.
18. Baltzer HL, Kircher MF, Spinner RJ, Bishop AT, Shin AY. A comparison of outcomes of triceps motor branch-to-axillary nerve transfer or sural nerve interpositional grafting for isolated axillary nerve injury. *Plast Reconstr Surg* 2016;**138**(2):256e–264e.