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Relationship between axillary nerve and percutaneously inserted proximal humeral locking plate: a cadaver study

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Objective: The aim of this study was to investigate the relationship between the axillary nerve and the percutaneously inserted proximal humeral locking plate and to evaluate the risk of axillary nerve injury during percutaneous plate insertion.

Methods: The study included 50 shoulders of 25 fresh frozen cadavers. A 5 cm incision was made from the anterolateral border of the acromion to the arm and a 5-hole 3.5-mm proximal humeral plate was inserted. The axillary nerve was then dissected. Plate holes which crossed the axillary nerve were noted. The distance between the axillary nerve and the lateral edge of the acromion and the length of the arm were measured and their relations evaluated with a correlation test.

Results: The average arm length was 319 mm. The average distance between the axillary nerve and the lateral edge of the acromion was 60 mm. There was a significant correlation between the arm length and acromion-axillary nerve distance ($p<0.05$). The plate was inserted under the deltoid fascia in all shoulders except one. There were no axillary nerve lesions. In 1 case, the distal end of the plate was inserted in the deltoid muscle. No constant relationship between the plate holes and the axillary nerve was detected.

Conclusion: There is a risk of axillary nerve injury during percutaneous plate insertion. It must be ensured that the plate is inserted under the deltoid fascia during the surgery. The axillary nerve must be visible during application of the screws due to the impossibility of knowing which holes cross the axillary nerve.

Key words: Axillary nerve; axillary nerve injury; fracture; percutaneous; percutaneous plate; plate fixation; proximal humeral fracture; proximal humerus.

Proximal humeral fractures represent approximately 4% to 5% of all fractures and are usually treated conservatively.[1,2]

Displaced and unstable proximal humeral fractures are commonly treated by operative reduction and fixa-

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tion with various techniques.[3-15] Plating has been associated with high complication rates and poor outcomes.[16,17] However, the introduction of locking plates and fixed-angled screws has created the possibility of new treatment techniques for osteoporotic bone in proximal humerus fractures.[9] Traditionally, a standard deltopectoral approach has been used to perform open reduction and internal fixation of the proximal humeral fractures, which puts the ascending branch of the anterior circumflex humeral artery at risk. This may lead to avascular necrosis of the humeral head.[18]

A percutaneous approach for the insertion of a locking plate theoretically addresses the issue of humeral head necrosis.[9,18] The minimally invasive technique allows limited disruption of soft tissue with application of the plate on the lateral side of the humeral head away from the primary vascular supply, as the anterior humeral circumflex artery runs in the bicipital groove.[19] However, fracture configuration is the most important determining factor for development of avascular necrosis.

Anatomic reduction, stable fixation of the fracture and protection of the soft tissue and vascular supply of the humeral head are important.

This aim of this study was to determine the risk of axillary nerve injury during the insertion of a locking plate through the lateral deltoid-splitting approach. Proximity of the plate and screw to the axillary nerve and their respective surgical tracks were quantified and the relationship between the screw holes and axillary nerve was determined.

Patients and methods

Approval of the Science Institute of Forensic Medicine was obtained prior to the study.

The study included 50 shoulders of 25 fresh frozen cadavers. With the cadaver in a supine position and the arm in internal rotation, a direct longitudinal incision was made extending from the anterolateral border of the acromion for 5 cm (Fig. 1a). The skin, subcutaneous tissue, fascia and deltoid were sharply dissected to partially expose the tubercles and the humeral head. Then, the axillary nerve was palpated with an index finger during the insertion of the plate. A 5-hole low-profile 3.5-mm locking compression proximal humeral plate (TST, Istanbul, Turkey) was inserted in line with the humerus through this incision. The plate was placed in an acceptable position abutting the inferior portion of the greater tuberosity. The medial edge of the plate was positioned lateral to the bicipital groove. There was no fracture and the anatomy was intact. Fluoroscopy was not used and

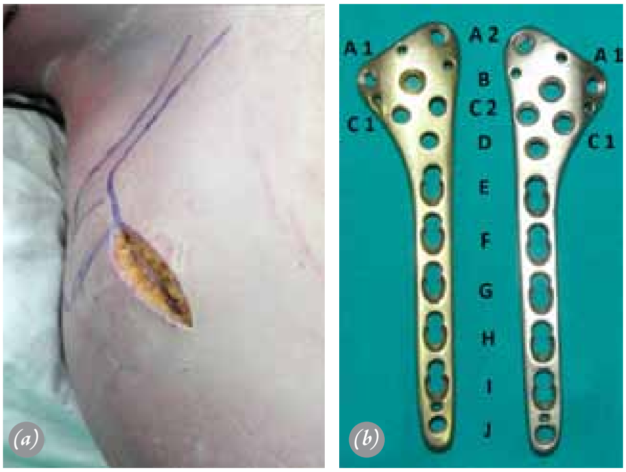

Fig. 1. **(a)** The incision. **(b)** Proximal humeral plate manufactured by TST company. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

plate position was determined by both palpation and direct visualization. A right-sided plate was used and in the right shoulder and a left-sided plate in the left shoulder. Proximal fixation of the plate was achieved with a Kirschner wire. A second longitudinal skin incision was made at the deltoid insertion and the distal plate was held with another Kirschner wire. The holes on the plate were labeled in rows from proximal to distal (A to J). Where there were two holes in one row, the anterior hole was designated 1 and the posterior hole 2 (Fig. 1b). After plate insertion, the skin and deltoid muscle were dissected and axillary nerve exposed. The relationship between the axillary nerve and the location of the plate was noted. The distance between the axillary nerve and the lateral edge of the acromion was measured. In addition, the length of the arm from the lateral edge of the acromion to the lateral humeral condyle was measured.

Instrumentation and dissection of the proximal humerus was performed by the same author.

Correlation analysis was performed between the arm length and the acromion-axillary nerve distance using SPSS for Windows Release v.17.0 (SPSS Inc., Chicago, IL, USA) software. All data were analyzed with correlation testing. P values of less than 0.05 were considered statistically significant.

Results

The average arm length was 319 (range: 240 to 335) mm. The average distance between the axillary nerve and the lateral edge of the acromion was 60 (range: 50 to 68) mm. There was a significant correlation between the arm length and acromion-axillary nerve distance ($p<0.05$).

Table 1. Number of shoulders in which the axillary nerve crossed the holes of the plate.

Screw holes	Number of shoulders	Percentage (%)
C	8	16
D	17	34
E	20	40
F	3	6
G	2	4

In all cadavers, the axillary nerve was palpated under the deltoid, 1 to 3 cm distal to the end of the proximal wound margin. In all cases, the axillary nerve crossed directly over the plate. The plate was inserted under the deltoid fascia in all shoulders except one shoulder in which the distal end of the plate was inserted in the deltoid. In all specimens, the axillary nerve was normal and undamaged. There was no constant relationship between the plate holes and the axillary nerve. The axillary nerve came into contact with all holes of the proximal plate. The two superior holes (A and B) were both away from the axillary nerve. The axillary nerve crossed over the holes labeled C, D, E, F, and G. Hole C was covered with the axillary nerve in 8 shoulders, Hole D in 17, Hole E in 20, Hole F in 3 and Hole G in 2 (Table 1) (Fig. 2a-c).

Discussion

The standard deltopectoral approach has been used to perform open reduction and internal fixation of proximal humeral fractures. However, the ascending branch of the anterior circumflex humeral artery is at risk in this approach. As a result of extensive soft tissue stripping and periosteal compression, there is increased risk of avascular necrosis of the humeral head.[9,18,20] Therefore, minimally invasive techniques have been designed and developed to allow limited disruption of soft tissue with application of the plate on the lateral side of the humeral head away from the primary vascular supply, as the anterior humeral circumflex artery runs in the bicipital groove.[13,18]

Minimally invasive techniques performed through a lateral deltoid-splitting approach can result in axillary nerve lesion. When performing surgery through a lateral approach, it is important to protect the axillary nerve.[20,21] The nerve is located in the posterior aspect of the wound as it exits the quadrangular space. The axillary nerve then runs on the undersurface of the deltoid around the humerus as it supplies the deltoid muscle with motor fibers (Fig. 2d, e).[22] Improper identification of this nerve makes such a procedure dangerous.[22] Although the nerve was easily found in every case in our study, the presence of fractures may make the nerve difficult to find. Therefore, it is important to palpate the axillary nerve after deltoid splitting. Laflamme et al. also stated that they easily palpated the axillary nerve in all 34 patients with proximal humeral fracture during plate insertion.[9]

It has previously been shown that the center holes E and F of the 3.5 mm proximal humerus locking com-

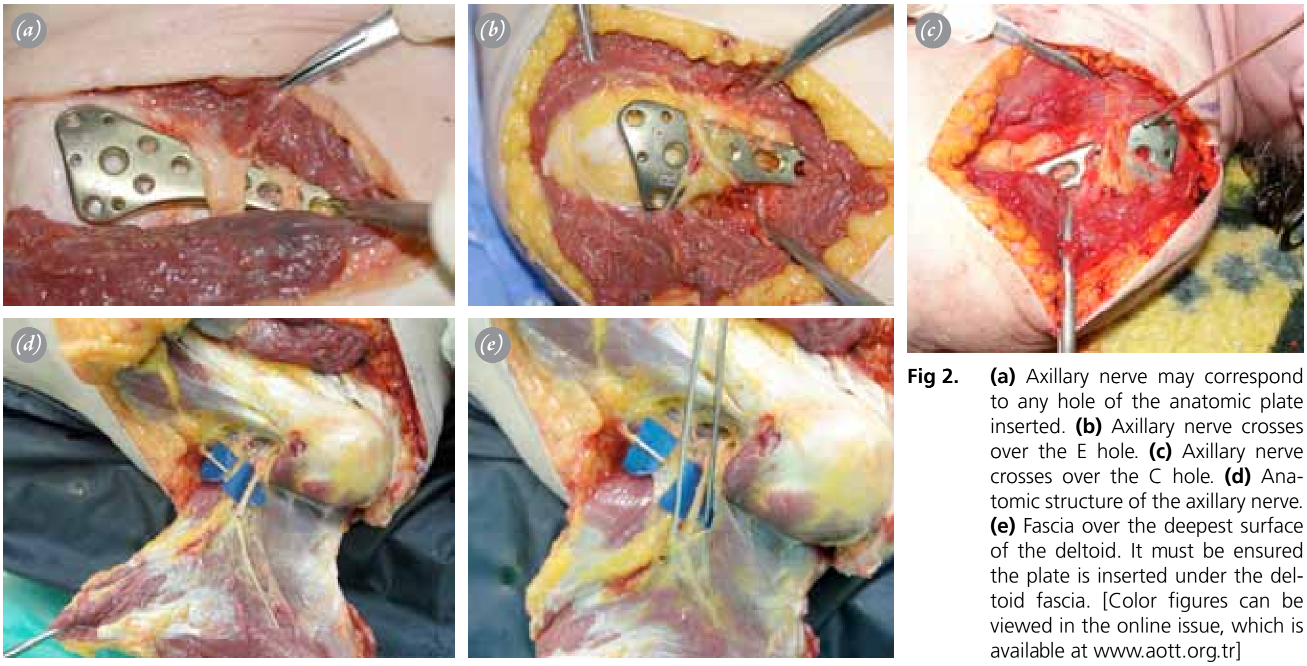

Fig 2. **(a)** Axillary nerve may correspond to any hole of the anatomic plate inserted. **(b)** Axillary nerve crosses over the E hole. **(c)** Axillary nerve crosses over the C hole. **(d)** Anatomic structure of the axillary nerve. **(e)** Fascia over the deepest surface of the deltoid. It must be ensured the plate is inserted under the deltoid fascia. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

pression plate are unsafe during percutaneous insertion and should not be used.[12] Saran et al.[20] stated that the C and G holes were located a minimum of 13 mm away from the nerve and the F hole was located within 2 mm of the axillary nerve in two specimens although it did not transect the nerve at any point. The authors recommended avoiding the center holes (D, E, and F) when inserting screws percutaneously. In our study, we observed that holes C, D, E, F, and G transected the nerve and should be avoided. However, in proximal humerus fractures, the use of these holes is necessary for the stable fixation of the fractured bone. Therefore, we suggest that the axillary nerve be explored and screws inserted under direct visualization when the deltoid split approach is used. Additionally, Smith et al.[12] stated that the screw-in guide block cannot be safely inserted percutaneously because of impingement of the axillary nerve caused by its size.[12]

Previous anatomic studies on the relationship of the axillary nerve to the placement of the plate have been performed.[12] Hoppenfeld et al. stated that the axillary nerve crosses the humerus posteriorly approximately 7 cm distal to the acromion.[23] Bono et al. dissected 50 fresh human cadaveric upper extremities and indicated that the axillary nerve was located an average of 6 cm from the most superior aspect of the humeral head.[21] Similarly, in the current study, we found that the average distance between the axillary nerve and the lateral edge of the acromion was 60 mm.

Deltoid length is related to the distance from the axillary nerve to the acromion.[24,25] During surgery, it is difficult to measure the deltoid length. Çetik et al. dissected 24 cadaveric upper extremities and reported that the average arm length was 30.4 cm. and there was a correlation between anterior distance (anterior edge of the acromion to the course of the axillary nerve) and posterior distance (posterior edge of the acromion to the course of the axillary nerve).[22] Chen et al.[26] found that the mean distance between the anterior-inferior border of the acromion and the superior border of the axillary nerve was 6.3±0.5 (range: 5.7 to 7.0) cm. This was identical to the 6.3 cm reported by Vathana et al.(27) Burkhead et al. reported a distance of 5.7 (range: 4.1 to 7.1) cm.(28) This discrepancy may be attributed to the oblique course of the nerve (Fig. 2a) or the different point of the acromion from which the distance was measured.(26) In the present study, the average arm length was 31.9 cm and there was a significant correlation between the arm length and acromion-axillary nerve distance ($p<0.05$). Because of this, the position of the axillary nerve on the plate was changed. In addition, Chen et al.[26] stated that the distance between the anterior-inferior border of the acromion to the superior border of the axillary nerve and the distance from the prominence of the greater tuberosity to the superior border of the axillary nerve are not always constant. Since its course is irregular, surgical instruments such as drag hooks and interlocking screws should not be placed too deeply in order to avoid damage. Liu et al. showed that iatrogenic injury to the axillary nerve can occur, even within the safe zone and after following appropriate instructions when placing pins and screws under fluoroscopic guidance.[29]

Recent studies have demonstrated that placement of a locking proximal humerus plate via a minimally invasive lateral transdeltoid approach is safe if the locking screws are limited to the superior and inferior holes.[12,18,20,30] In our study, there was no constant relationship between the plate holes and the axillary nerve. The axillary nerve came into contact with all holes of the proximal plate.

There were some limitations to this study. We used intact humeri rather than reproducing a proximal humerus fracture. Different anatomic locations of the axillary nerve may have produced some bias due to the individual fracture itself or to closed reduction methods. Additionally, as we applied the plate and dissected the nerve in fresh cadavers that were into rigor mortis, the nerves may differ from those in living humans. Finally, it is difficult to identify the bony landmark of the fractured proximal humerus during surgical exposure, which is not a problem in fresh cadavers with intact proximal humeri.

In conclusion, placement of a locking proximal humerus plate via a minimally invasive lateral transdeltoid approach appears to be a safe technique if the axillar nerve is dissected and seen during the surgery. Following traumatic injuries, anatomy of the humerus and fascia may be disrupted, causing damage to the axillary nerve during fixation using the minimally invasive lateral transdeltoid approach. During the surgery, it must be ensured the plate is inserted under the deltoid fascia and the axillary nerve dissected during screw application as it is impossible to know which holes cross the axillary nerve.

Conflicts of Interest: No conflicts declared.

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