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Plate Positioning Affects the Pressure on the Axillary Nerve Following a Deltopectoral Approach

Umístění dlahy ovlivňuje tlak na *n. axillaris* při deltoideopektorálním přístupu

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ABSTRACT

PURPOSE OF THE STUDY

To investigate the pressure levels on the axillary nerve at different plate positions after plate fixation of a proximal humerus fracture.

MATERIAL AND METHODS

Eight fresh-frozen cadaveric specimens were used. The plates were applied on the lateral side of the humerus. A FlexiForce pressure sensor was placed between the nerve and the plate, and the pressure on the nerve was measured (Group 1). The plates were then placed in two different positions such that distal portion of the plates would have 30° anterior and 30° posterior angles to the anatomical axis of the humerus (Group 2 and 3). The anterior of the distal attachment of the deltoid muscle was then elevated and the plates were placed in the middle of the anatomical axis of the humerus (Group 4). The position of the plates were controlled by fluoroscopy and the pressure was measured for each configuration sequentially.

RESULTS

The mean age of the cadavers was 70.5 ± 6.8 years (range: 61–80 years). Mean pressure values of the groups were 2.65 ± 0.8, 2.52 ± 0.8, 5.65 ± 1.4, and 2.56 ± 0.9 N, respectively. Group 3 had statistically highest-pressure values than the other groups, while no difference was found among groups 1, 2, and 4.

DISCUSSION

Numbness and weakness of the shoulder muscles are other clinical findings. If numbness on the deltoid muscle is reported, then atrophy is noted in the deltoid muscle in later stages. Persistent pain may be seen even if fracture union occurs after PHF surgery. Axillary nerve entrapment may be considered after the removal of common complications such as avascular necrosis due to fracture, screw migration, infection, and biceps tendon and rotator cuff problems. The sensory branch of the axillary nerve provides the sensation of the anterior joint capsule and lateral part of the deltoid muscle.

CONCLUSIONS

Proximal humerus plates, which are angled posteriorly along, lead to an increased pressure on the axillary nerve. Anterior orientation of the plate or elevation of deltoid insertion may be used to prevent the possible complications related to axillary nerve.

Level of evidence Level II.

Key words: proximal humerus fracture, Philos, axillary nerve, nerve injury.

INTRODUCTION

Plate fixation of proximal humerus fractures (PHFs) using a deltopectoral approach has become a viable treatment method worldwide (13). In addition to successful results, various complications may be observed such as loss or insufficiency of reduction, misplacement of the plate, osteonecrosis, and axillary nerve injury depending on the type of fracture following an open reduction and internal fixation (16, 17). Although direct injury of the axillary nerve is rare following a deltopectoral approach, sensational complaints related to axillary nerve are usually seen after the surgery.

It may be necessary to use relatively longer plates particularly in the fractures extending to the surgical neck of the humerus and medial calcar region. In such cases, Frankenhauser F et al. reported that deltoid insertion may have to be released to be able to place the plate in an appropriate position (5). The importance of repair or preservation of the distal insertion of the deltoid muscle is well understood (5, 10, 18). Removal of the distal insertion of the deltoid muscle presents some technical challenges. Furthermore, the release of the anterior half of the deltoid distal insertion causes weakness in the anterior part of the deltoid muscle (1, 8, 14). Surgeons tend to avoid the removal of the distal deltoid insertion, in these cases, distal pole of the plate may be oriented to anteriorly or posteriorly. Besides recent studies investigated that one third of intraoperative axillary nerve injuries occur during plate placement after a proximal humerus fracture (22). Although stretching of the axillary nerve reported after traumatic shoulder dislocations or PHFs no study has been investigated the increased pressure upon the axillary nerve due a plate misplacement (2).

In this study, we aimed to investigate changes in pressure levels of the axillary nerve due to anterior or posterior angulation of the plate to evaluate the effect of technical errors in positioning of the plate after the treatment of PHFs. The hypothesis was that posterior angulation of the distal part of the plate would cause proportionally greater pressure upon axillary nerve than the other configurations.

MATERIAL AND METHODS

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the Institutional Review Board in April 2019 with the number 2019-10/4; 23.05.2019.

Fig. 1. Axillar nerve pressure evaluation.

Fig. 2. 30° anterior direction of the plate.

Eight fresh-frozen cadaveric specimens, consisting of the entire upper extremity from the scapula to the hand, were used in this study. Cadavers that had a deformity, a previous shoulder dissection, or contracture in the shoulder region were excluded from the study.

The specimens were positioned anatomically with the scapula secured into a special holder, and dissections were performed with the arm in 60° of abduction and the forearm in full supination to examine the anterior region of the arm and glenohumeral joint. Once the skin and subcutaneous tissue were removed, the proximal origin of the deltoid muscle was marked and elevated, and the rotator cuff was exposed. The axillary nerve was then dissected extending transversely from the quadrangular space towards the humerus and the closest portion of the nerve to the humerus was marked with dye (Fig. 1).

All measurements were performed after the proximal origin of the deltoid was temporarily reattached with sutures. The load on the axillary nerve was measured by creating 4 different configurations with two different length plates. The Proximal Humeral Internal Locking System Plate (PHILOS® – 3.5 mm, **90 mm**, **3 holes**, Synthes, Switzerland) was placed 1 cm distal to the tuberculum majus and 5 mm posterior to the bicipital groove on the lateral side of the humerus. A FlexiForce pressure sensor (Nitta Co., Ltd., Osaka, Japan) was placed between the nerve and the plate to record the pressure on the nerve (Group 1). The distal pole of the plates (PHILOS® system – 3.5 mm, **114 mm**, **5 holes**, Synthes, Switzerland) was then placed in two different positions

Fig. 3. 30° posterior direction of the plate.

Fig. 4. Appropriate position of the plate.

with an anatomical axis of the humerus using a goniometer. In group 2 the distal portion of the plates were angled at 30° anterior direction whereas in group 3 the plates were angled at 30° posterior direction (Figs. 2 and 3). Once the plates were placed, contact pressure on the axillary nerve was recorded (Groups 2 and 3). The anterior of the insertion of the deltoid muscle was then elevated on the same cadavers. The distal end of the plate (PHILOS® system – 3.5 mm, **114 mm**, **5 holes**, Synthes, Switzerland) was placed along the anatomical axis of the humerus using a fluoroscopy. After determining the appropriate position, contact pressure on the axillary nerve was measured and recorded (Group 4).

Statistical method

Statistical analysis was performed using SPSS version 12 (SPSS Inc, Chicago, IL, USA). Means and standard deviations were calculated to summarize the study data. Normal distribution was investigated using the Shapiro–Wilk test. Friedman test was used to investigate the relationship between pressure measurements to axillary nerve obtained in four groups. Wilcoxon signed rank tests were performed for pairwise comparison. The threshold for significance was set at $p < 0.05$

RESULTS

Eight cadaveric specimens (4 men, 4 women) were included in the study. Of the cadavers, 8 were right upper extremity. The mean age of the cadavers was 70.5 ± 6.8 years (range: 61–80 years). Mean values of the groups were 2.65 ± 0.8 N, 2.52 ± 0.8 N, 5.65 ± 1.4 N, and 2.56 ± 0.9 N, respectively (p = 0.001; Table 1). Group 3 presented the statistically highest-pressure values than the other groups in pairwise comparisons, while no difference was found among groups 1, 2, and 4 (Table 2 and Fig. 5).

Table 1. Descriptive statistics

	N	Mean	SD	Minimum	Maximum	*P*
Group 1	8	2.65	0.8	1.25	3.80	.001[a]
Group 2	8	2.52	0.8	1	3.60	
Group 3	8	5.65	1.4	4	8	
Group 4	8	2.56	0.9	1	3.90	

a. Friedman test
SD – standard deviation

Table 2. Pairwise comparisons between groups

	Group 1–2	Group 1–3	Group 2–3	Group1–4	Group2–4	Group3–4
P	.236	.012	.012	.612	.498	.012

a. Wilcoxon signed ranks test

DISCUSSION

Our primary results showed that the pressure upon the axillary nerve was higher in the group where the distal part was angled posteriorly, while no difference was found between the other configurations.

There are studies on iatrogenic axillary nerve injury in arthroscopic shoulder capsulorrhaphy and shoulder arthroplasty surgeries (4, 15). Smith J et al. indicated that there is a risk of axillary nerve injury in proximal humeral fracture surgery performed with a lateral approach (20). In this approach, during the submuscular placement of the plate, the axillary nerve may be injured by compression under the plate or by direct injury in incisions 6 cm distal to the acromion. Stretching or compression on the nerves has been considered a possible factor for nerve related symptoms. In an experimental study, cavernous nerves of rats were crushed or tractioned with force of 0.2 N for 2 min; these rats showed irreversible erectile dysfunction compared with others that had less time or less pressure (12). In similar, in our study, in cases where the plate was directed posteriorly, approximately 5 N pressure was placed on the axillary nerve.

A study reported that the most common symptoms of the patients with axillary nerve injury are weakness of the shoulder girdle muscle and numbness or paresthesia in the lateral shoulder area (22). Although no study has been investigated the implant related pressure on adjacent nerves with deltopectoral approach, we believe that effect of the implants should be considered in case of an axillary nerve problem. The motor fibers of the axillary nerve innervate the deltoid and teres minor muscles, while the sensory fibers provide the sensation of the skin above the deltoid muscle (1). Although isolated axillary nerve injury is rare, it may result from post-traumatic compression with fibrous band, recurrent strain injuries, and muscle hypertrophy in the quadrangular space (3, 7). The clinical findings in axillary injury around the shoulder are often regarded as posterolateral shoulder pain, night pain, and inability to lie on the affected shoulder in sleep position (3, 11). Numbness and weakness of the shoulder muscles are other clinical findings. If numbness on the deltoid muscle is reported, then atrophy is noted in the deltoid muscle in later stages. Persistent pain may be seen even if fracture union occurs after PHF surgery. Axillary nerve entrapment may be considered after the removal of common complications such as avascular necrosis due to fracture, screw migration, infection, and biceps tendon and rotator cuff problems. The sensory branch of the axillary nerve provides the sensation of the anterior joint capsule and lateral part of the deltoid muscle. In cases of persistent pain or hypoesthesia in the postoperative period that may be evident in this region, iatrogenic axillary nerve damage or axillary nerve entrapment can be considered in the presence of deltoid muscle weakness (19, 21, 22). In spite of the fact that complaints due to axillary motor fibers are rare following a deltopectoral approach, sensorial complaints may be related to plate malposition after excluding other possible factors.

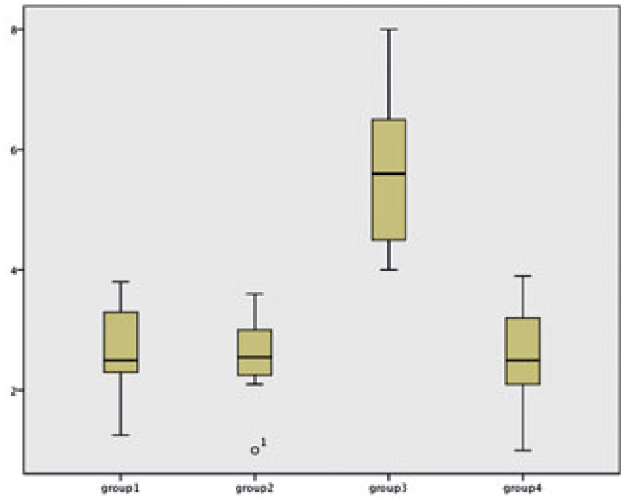

Fig. 5. Box-plots of the pressure values.

Many different designs of the proximal humerus plates are currently available in the market. The longest axes of the plates are designed flat. Since deltoid distal insertion begins approximately 6 cm distal to the tuberculum majus, flat designed plates may cause deltoid related problems (14). Although the plates can be placed along the humeral shaft by releasing the distal deltoid insertion, this may cause weakness in the deltoid muscle (6, 9). The authors believe that anatomic plates curved to anterior may be used to avoid stripping the distal deltoid insertion and axillary nerve compression.

This study had certain limitations. First, the number of cadavers was insufficient. Although the measurements of the four groups were achieved in the same cadavers, differences in the length and width of the cadaver humerus could affect the pressure on the axillary nerve. Measurements could be performed at different degrees of motion. Notably, as this work was not an in vivo study, we failed to demonstrate the clinical effects of increased pressure on the axillary nerve. Meanwhile, defining axillary nerve stretching using the quantitative measurement values and applying the surgical techniques as it is recommended in vivo are the strengths of our study.

CONCLUSIONS

Proximal humerus plates, which are angled posteriorly along the humeral shaft, lead to an increased pressure on the axillary nerve. Anterior orientation of the plate or elevation of deltoid insertion may be used to prevent the possible complications related to axillary nerve.

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