The Correlation between Acromion-Axillary Nerve Distance and Upper Arm Length; A Cadaveric Study

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Background: *Deltoid splitting is one of common and useful approaches in proximal humerus surgery. The disadvantage of this approach is high risk of axillary nerve injury. Nowadays, there is no consensus in the proper mean of the individual's axillary nerve location.*

Objective: *The present study aim to determine the correlation between the axillary nerve and the upper arm length that may create equations to calculate the nerve location.*

Material and Method: *Seventy shoulders were measured the distance from lateral acromial edge to axillary nerve and compared with upper arm length in three positions of the shoulder (adduction 30°, abduction 45° and 90°). The authors used distance of lateral acromial edge to lateral epicondyle and tip of greater tuberosity to lateral epicondyle as the upper arm length.*

Results: *The average distance of shoulder adduction 30°, abduction 45° and 90° were 57.9, 57.1 and 52.9 mm, respectively. All of three positions showed linear correlation to upper arm length from both of reference sites. From acromion edge reference, where "Y" is axillary nerve distance in mm and "x" is upper arm length in cm, the relation were Y = 2.3x-10, Y = 2x-2 and Y = 2x-7 with the accuracy rate were 88.57%, 85.71% and 81.43%, respectively. From greater tuberosity reference, the relations were Y = 2.54x-14, Y = 2x and Y = 2.3x-12 with the accuracy rates 87.14%, 80% and 84.29%, respectively.*

Conclusion: *There is linear correlation between distance from the lateral acromial edge to axillary nerve and the upper arm length. The authors can predict the danger zone in the location of the anterior upper branch of the axillary nerve. However, further clinical study may helpful to prove the equations.*

Level of evidence: *Basic science anatomy study.*

Keywords: *Axillary nerve, Safe zone, Deltoid split approach, Axillary nerve injury, Shoulder, Correlation, Proximal humerus*

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There are many surgical approaches for the shoulder joint. Lateral deltoid splitting is one popular approach because of its simplicity and familiarity, depending on the surgical condition and surgeon's preference. This approach is easily extendable to both anterior and posterior shoulders but has high risk of axillary nerve damage because of the anatomic location of the axillary nerves that cross in this surgical field.

The anterior upper branch of the axillary nerve is a very vulnerable part. It ascends around the surgical neck of the humerus where very high risk of injury is present during distally extended incisions or screw insertions(1-3). Injured, this nerve can result in postoperative numbness, shoulder weakness or deltoid muscle atrophy that can result in a poor surgical outcome.

In practicing this approach, extension should be less than 5 cm from the lateral acromial edge to avoid of axillary nerve injury. There were studies which vary in the results of the location of axillary nerves and safe zones. Cetik et al found the correlation between upper arm length and distance from acromion to axillary nerve, but did not clarify the correlation(4). Rotari et al found the correlation in linear pattern(5). In Asia, there are no studies to define this correlation.

The purpose of the present study is to determine the correlation between the axillary nerve and the upper arm length that may create equations to calculate the nerve location.

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Material and Method

The authors evaluated 70 shoulders of 35 embalmed cadavers (16 males, 19 females) at Division of Anatomy, Department of Preclinical Science, Faculty of Medicine, Thammasat University from December 2011 to April 2012 (the calculated sample size was 51, type 1 error (α) = 0.05 type 2 error (β) = 0.20, $p_0 = 0.6$, $p_1 = \pm 0.3$). Inclusion criteria were proper consent embalmed cadavers for education and age more than 20 years old, no history of shoulder injury or operation. Exclusion criteria were failure to explore axillary nerve, humeral fracture and could not measure the upper arm length.

The dissections were done with deltopectoral approach on all shoulders. First, skin incision was made from deltopectoral triangle to axilla, then elevated and reflected skin. The pectoral is major and the clavicular part of the deltoid was exposed. The origin of deltoid was cut and retracted. At this stage, lateral acromial edge could be identified. The next step was blunt dissecting sub-deltoid plane to the insertion of deltoid muscle then retracting laterally. When the yellow fiber of the axillary nerve was exposed, axillary nerve location was identified and measured.

The measurements were done by two observers, an orthopedic resident and a qualified orthopedic surgeon. The location of axillary nerve was measured using digital vernier with an accuracy of at least 0.01 mm. Measurement from the lateral acromial edge to the anterior branch of axillary nerve that tethered into the deltoid muscle. Three positions of the shoulder in adduction 30°, abduction 45° (as neutral) and abduction 90° were arranged. The upper arm length was measured with a tape measure in cm using two proximal references, lateral acromial edge and tip of greater tuberosity, and one distal reference, lateral epicondyle of the humerus (Fig. 1). All measurements were done by both observers and measured three times in each position.

The authors analyzed all data records with program SPSS Statistics 17.0.0 (23 August 2008). Statistic value for quantitative data were mean, SD and t-test 99%CI, $p<0.01$. Statistic value for defined correlation was linear regression then correlation equation was created in pattern "Y = ax + b". The authors calculated accuracy of the equation by re-calculating axillary nerve distance from upper arm length. If the predicted distance is in true distance $\pm$ 5 mm, it will be accepted as accurate. Accuracy rate was analyzed as a percentage.

The present study was approved from the human research ethics committee of Thammasat University, Faculty of Medicine.

Ethical consideration

Human research ethical committee of Thammasat University, Faculty of Medicine approval number 133/2555.

Results

Seventy of cadaveric shoulders (16 males, 19 females) were studied. None of these cadavers was excluded. The ages of the cadavers were 41-87 years old, average age is 71 years old. There were height records in 13 cadavers, which varied from 150-172 cm; average height is 160.85 cm. The weight records were in 14 cadavers, which varied from 45-80 kg, average weight is 60.57 kg.

The data from two observers were explored. The extreme differences between two observers were removed as missing data and the remaining data were as described as in Table 1. The mean distances between two observers were compared and there were some differences as in Table 2. In upper arm length, the mean difference from lateral acromial edge group was 1.4 cm and from tip of greater tuberosity group was 1.2 cm. When the authors allowed a difference at 1.2 cm, there was no difference between two observers in both groups (Lateral acromial edge p = 0.042, greater tuberosity p = 0.731, Table 3). Concerning the distance from lateral acromial edge to axillary nerve in each shoulder positions, the mean difference between two observers in shoulder adduction 30°, abduction 45° and 90° were 3.1 mm, 4.1 mm and 3.7 mm, respectively.

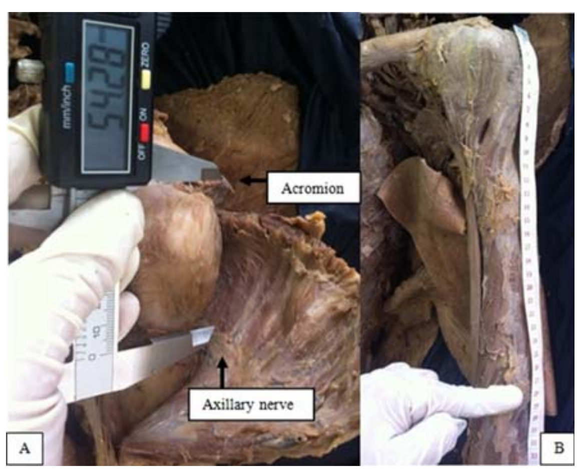

Fig. 1 Distance from acromial edge to axillary nerve was measured using digital vernier (A) and upper arm length using measurement tape (B).

When the authors allowed difference at 3.5 mm, there was no difference between two observers in all groups ($p = 0.628$, $p = 0.117$ and $p = 0.084$, respectively, Table 4).

The distances from lateral acromial edge to the axillary nerve varied in different shoulder positions. At 30° shoulder adduction, the average distance was 57.9±5.0 mm (48.9-67.1 mm). At 45° shoulder abduction, the average distance was 57.1±4.8 mm (47.1-66.1 mm). At 90° shoulder abduction, the average distance was 52.9±5.2 mm (42.0-71.2 mm) (Fig. 2).

The upper arm length had two proximal reference points. Upper arm, from lateral acromial edge to lateral epicondyle of humerus, average length was 29.8±1.7 cm (26.3-33.0 cm). The second reference was tip of greater tuberosity, average length was 28.3±1.6 cm (24.2-31.1 cm) (Fig. 3).

From the present study, we found that the distance from lateral acromial edge to the axillary nerve was different in each shoulder position. Although the distance varied in every shoulder position, the results showed it had relationship between the distance and

Table 1. Missing data from extreme difference from normal population in each group

	Missing data	Percentage of missing	Remaining data
Distance in shoulder adduction 30°	0/70	0	70
Distance in shoulder abduction 45°	3/70	4.3	67
Distance in shoulder abduction 90°	4/70	5.7	66
Upper arm length: lateral acromial edge	0/70	0	70
Upper arm length: greater tuberosity	4/70	5.7	66

Table 2. Compare measurement data between two observers

	Mean of 1st Observer	Mean of 2nd Observer	Mean difference
Distance in shoulder adduction 30° (mm)	57.8	58.0	3.1
Distance in shoulder abduction 45° (mm)	55.6	58.6	4.0
Distance in shoulder abduction 90° (mm)	52.1	53.7	3.7
Upper arm length: lateral acromial edge (cm)	30.3	29.2	1.4
Upper arm length: greater tuberosity (cm)	28.8	27.9	1.2

Table 3. Compare upper arm length between two observers with condition: allowed difference at 1.2 cm (t-test, 99%CI, $p<0.01$)

	Mean difference (allowed at 1.2 cm)	*p*-value	99% CI
Upper arm length: lateral acromial edge	0.23	0.042	(-0.64)-0.52
Upper arm length: greater tuberosity	-0.04	0.731	(-0.31)-0.24

Table 4. Compare distance in each of shoulder positions between two observers with condition: allowed difference at 3.5 mm (t-test, 99%CI, $p<0.01$)

	Mean difference (allowed at 3.5 mm)	*p*-value	99% CI
Distance in shoulder adduction 30°	0.17	0.628	(-0.74)-1.08
Distance in shoulder abduction 45°	0.54	0.117	(-0.34)-1.43
Distance in shoulder abduction 90°	-0.40	0.084	(-1.00)-0.20

the upper arm length. From the hypothesis, the authors suggested that there should be correlation between the distance from lateral acromial edge to axillary nerve and upper arm length in linear regression pattern. The result showed that there were significant co-relationships in linear regression pattern. When the authors used lateral acromial edge as reference and shoulder at adduction 30° position, the distance and the upper arm length had linear regression relationship ($R^2 = 0.527$, $p<0.001$) (Fig. 4). The authors translated linear regression into an equation where Y = 2.3x-10 ("Y" is distance from lateral acromial edge to axillary nerve in mm and "x" is upper arm length in cm). After the authors reverse-calculated the data, the accuracy of this equation was 88.57% (62 TRUE, 8 FALSE).

At abduction 45° position, there was linear regression relationship ($R^2 = 0.406$, $p<0.001$) (Fig. 5). The equation was Y = 2x-2 and the accuracy was 85.71% (60 TRUE and 10 FALSE). When shoulder was in abduction 90°, there was a linear regression relationship ($R^2 = 0.408$, $p<0.001$) (Fig. 6). The equation was Y = 2x-7 and the accuracy was 81.43% (57 TRUE, 13 FALSE).

When the greater tuberosity served as reference and shoulder adduction 30°, there was linear regression relation pattern ($R^2 = 0.512$, $p<0.001$) (Fig. 7). The equation was Y = 2.54x-14 and the accuracy was 87.14% (61 TRUE, 9 FALSE). At shoulder abduction 45°, there was linear regression relation ($R^2 = 0.420$, $p<0.001$) (Fig. 8). The equation was Y = 2x and the accuracy was 80.00% (56 TRUE, 14 FALSE). There was the same relation pattern at shoulder abduction 90°, ($R^2 = 0.432$, $p<0.001$) (Fig. 9) and the equation was Y = 2.3x-12 and the accuracy was 84.29% (59 TRUE, 11 FALSE).

Discussion

Shoulder surgeries have risks in iatrogenic

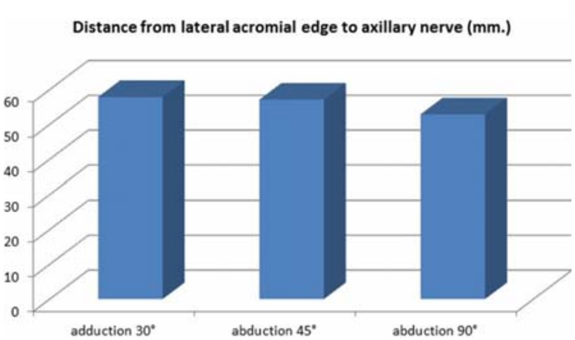

Fig. 2 Distance from lateral acromial edge to axillary nerve in three positions of shoulder.

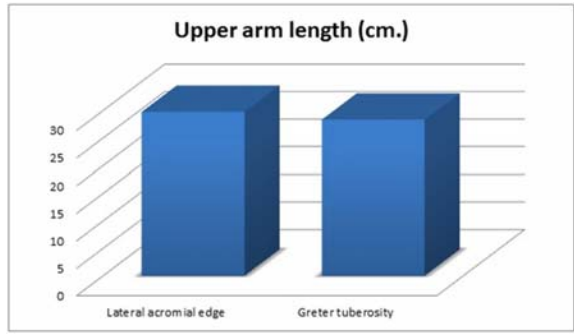

Fig. 3 Upper arm length when used lateral acromial edge and greater tuberosity as proximal reference to lateral epicondyle.

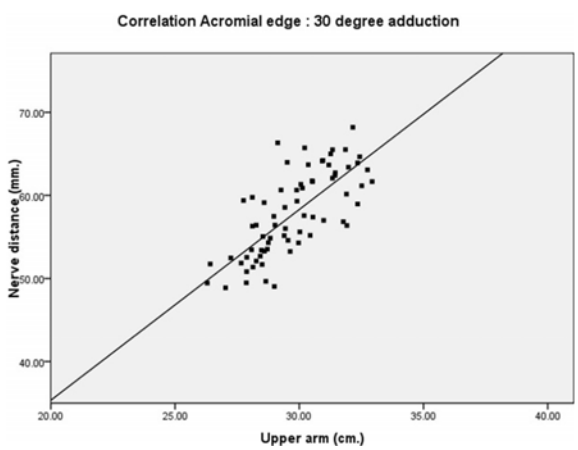

Fig. 4 Show the linear regression relation of distance from lateral acromial edge to axillary nerve and upper arm length at 30° shoulder adduction.

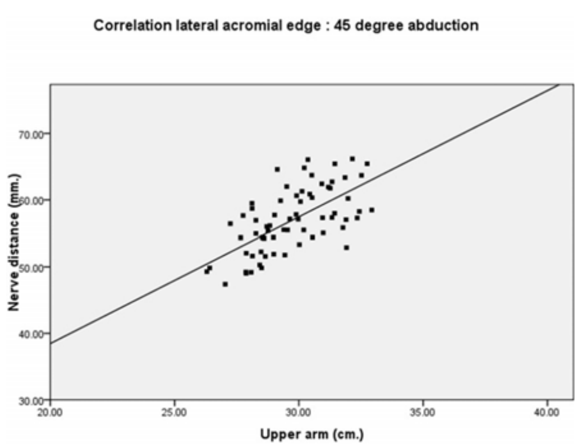

Fig. 5 Show the linear regression relation of distance from lateral acromial edge to axillary nerve and upper arm length at 45° shoulder abduction.

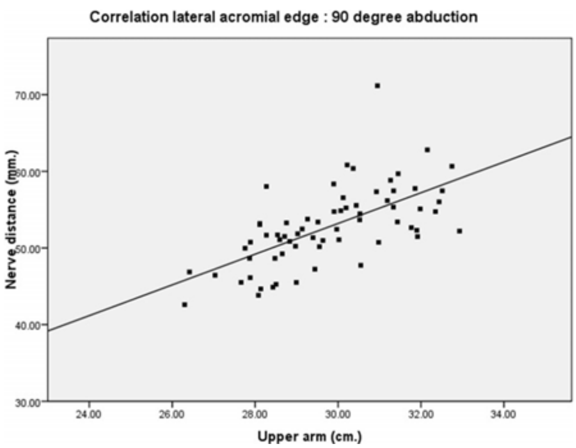

Fig. 6 Show the linear regression relation of distance from lateral acromial edge to axillary nerve and upper arm length at 90° shoulder abduction.

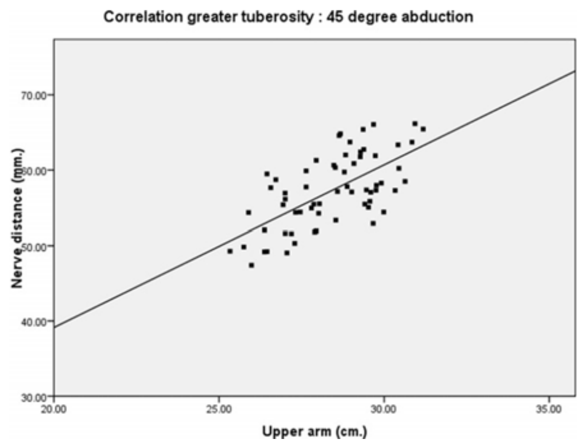

Fig. 8 Show the linear regression relation of distance from greater tuberosity to axillary nerve and upper arm length at 45° shoulder abduction.

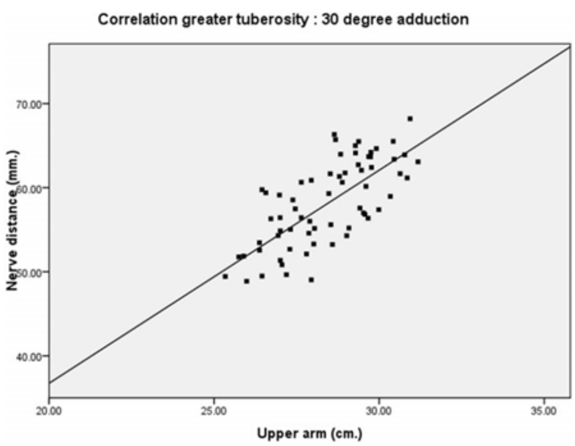

Fig. 7 Show the linear regression relation of distance from greater tuberosity to axillary nerve and upper arm length at 30° shoulder adduction.

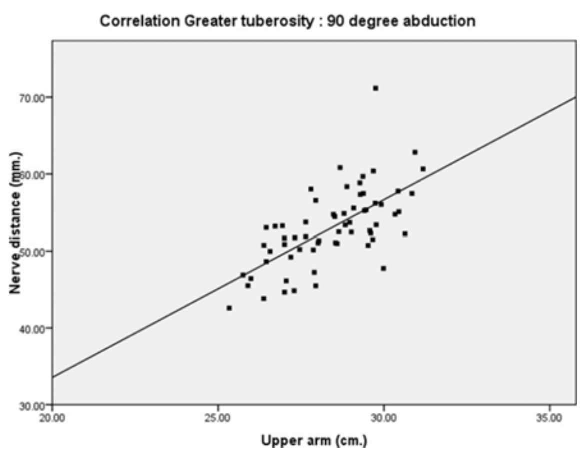

Fig. 9 Show the linear regression relation of distance from greater tuberosity to axillary nerve and upper arm length at 90° shoulder abduction.

the anterior branch of axillary nerve injury, especially in deltoid split approach. The average distance of 5 cm from the lateral acromial edge that can locate the axillary nerve is not always accurate because of its variableness. Stecco et al[3], Nijs et al[2] and Uz et al[6] found distances from nerve to acromion were between 5.6 and 7.8 cm. Loukas et al found anterior axillary nerve at 5.5 cm from tip of head of humerus[7].

In Asia, Liu et al studied embalmed Chinese adult cadaveric and found distance from humeral head to axillary nerve was 5.2 cm[8]. Vathana P et al dissected Thai cadavers, used tip and angle of acromion as landmark and distance to axillary nerve was 63 and 67 mm, respectively[9].

The shoulder positions also affect the distance. With more adduction, the longer distance occurs. In contrast, shoulder abduction makes the axillary nerve come closer to lateral acromial edge. Bailie et al found that the distance from posterolateral corner of acromion to axillary nerve decrease in abduction and extension[10]. Cheung et al reported that shoulder abduction more than 60° could move the axillary nerve closer to acromion[11].

Cetik et al[4], Rotati et al[5] and Abhinav et al[12] found strong correlation between the acromion-axillary nerve distance with upper arm length, but the equation cannot be created due to high variability.

From the present study, there is correlation between the axillary nerve distance and upper arm length from both reference sites. Every correlation is in linear regression with R^2 is between 0.4-0.5. These average R^2 values did not show very strong prediction in linear regression equation. The authors allowed 5 mm proximal and distal margins to the predicted spot as dangerous area, all of the linear regression equation showed very good accuracy prediction (from lateral acromial edge: adduction 30° = 88.57%, abduction 45° = 87.14%, abduction 90° = 81.43% and from greater tuberosity: adduction 30° = 87.14%, abduction 45° = 82.86%, abduction 90° = 84.29%). These results could be applied to practical surgery and shoulder abduction 45° close to neutral position that is popular in shoulder surgical position. The authors suggested equation Y = 2x-2 to make center of 1 cm dangerous area.

A limitation of the present study was that the dissections were performed on embalmed cadavers that were stiff, causing some error in positioning of the shoulders. Another limitation was some shoulders had torn rotator cuff that could have made the acromion-humerus space narrower than in the normal shoulder, so the axillary nerve distance could be shorter. The present study had two observers for minimizing bias but the authors found few extremely different in data and these were excluded as missing data. Two observers had no significant different data in that upper arm lengths were allowed 1.2 cm and the axillary nerve distance were allowed 3.5 mm error in measurement. The authors assumed each shoulder of the cadavers were different.

Conclusion

In conclusion, there are linear correlations between distance from the lateral acromial edge to the axillary nerve and the upper arm length. In shoulder surgery, most surgeons prefer beach chair position with shoulder abduction about 45°. The appropriate equation for the axillary nerve prediction is Y = 2x-2 (x = upper arm length). This can predict location of the axillary nerve with 87.14% accuracy. However, further study on fresh cadaver may help to eliminate the soft tissue contracture and joint stiffness problem in embalmed cadavers and further clinical study may be helpful for proof of the equations.

Acknowledgement

Research funding was granted from Thammasat University.

What is already known on this topic?

The distance from acromion to the axillary nerve varied in the general population (5.5-7.8 cm). There was co-relationship between this distance and upper arm length, but it could not define a pattern because of high variability.

What this study adds?

The present study described the linear co-relationship between the distance from acromion to the axillary nerve and upper arm length. Furthermore, this study added the equation and accuracy of axillary nerve location for pre-operative evaluation. At shoulder abduction 45°, the appropriate equation for the axillary nerve prediction is Y = 2x-2 (x = upper arm length). This can predict 1cm-area of axillary nerve location with 87.14% accuracy.

Potential conflicts of interest

None.

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การศึกษาเกี่ยวกับความสัมพันธ์ของระยะห่างระหว่างขอบนอกของ acromion และตำแหน่ง axillary nerve ที่ต้นแขนเปรียบเทียบกับความยาวของต้นแขนในศพดอง

ศุภวัชร สามารถ, อดินันท์ อภิวัฒน์การุญ, ขจร ลักษณ์ชยปกรณ์, บัญชา ชื่นชูจิตต์

ภูมิหลัง: *การผ่าตัดบริเวณกระดูกต้นแขนด้วยวิธี deltoid split นั้นแม้จะเป็นวิธีผ่าตัดที่ดีแต่ยังมีความเสี่ยงในการบาดเจ็บต่อเส้นประสาท axillary ได้มาก ที่ผ่านมาได้มีการพยายามศึกษาเกี่ยวกับตำแหน่งของเส้นประสาทนี้ อย่างมากมายแต่ไม่มีวิธีการใดที่จะสามารถบอกถึงตำแหน่งของเส้นประสาทนี้ในแต่ละคนได้อย่างแน่ชัด*

วัสถุประสงค์: *เพื่อหาความสัมพันธ์ระหว่างตำแหน่งของเส้นประสาท axillary และความยาวของต้นแขนและนำไปสร้างเป็นสมการเพื่อใช้คำนวนในการระบุตำแหน่งของเส้นประสาทก่อนทำการผ่าตัด*

วัสดุและวิธีการ: *ศึกษาในหัวไหล่ของศพดอง 70 ข้าง โดยวัดระยะห่างจากขอบทางด้านนอกของกระดูก acromion ไปยังเส้นประสาท axillary แล้วจึงนำไปเปรียบเทียบกับความยาวของต้นแขน โดยหัวไหล่อยู่ในตำแหน่งต่าง ๆ กัน คือ หุบแขนเข้าใน 30° กางแขนออก 45° และ90° ตามลำดับ ส่วนความยาวต้นแขนวัดจากขอบนอกของกระดูก acromion และ greater tuberosity ไปยังปุ่มกระดูก lateral epicondyle เป็นความยาวของต้นแขน*

ผลการศึกษา: *ระยะห่างที่วัดได้โดยเฉลี่ยของตำแหน่งที่หุบแขนเข้าใน 30° กางแขนออก 45° และ 90° เป็น 57.9 มม., 57.1 มม. และ 52.9 มม. ตามลำดับ โดยทั้งหมดนั้นมีความสัมพันธ์กับความยาวของต้นแขนในลักษณะเป็นเส้นตรงจริง โดยใช้การวัดความยาวต้นแขนทั้งสองแบบ ในกรณีที่ใช้ acromion เป็นจุดตั้งต้นนั้น สมการที่ได้ออกมาคือ Y = 2.3x-10, Y = 2x-2 and Y = 2x-7 โดยมีความแม่นยำเป็น 88.57%, 85.71% และ 81.43% ตามลำดับ โดย Y คือระยะห่างที่เป็นตำแหน่งของเส้นประสาท ส่วน x คือ ความยาวของต้นแขน ส่วนกรณีที่ใช้ greater tuberosity เป็นจุดตั้งต้น ได้สมการเป็น Y = 2.54x-14, Y = 2x และ Y = 2.3x-12 โดยมีความแม่นยำเป็น 87.14%, 80% และ 84.29% ตามลำดับ*

สรุป: *จากการศึกษาพบว่ามีความสัมพันธ์ระหว่างระยะห่างจากขอบนอกของกระดูก acromion ไปยังเส้นประสาท axillary กับความยาวของต้นแขนจริง และสามารถนำความสัมพันธ์นี้มาเขียนเป็นสมการเชิงเส้นได้ ทำให้สามารถทำนายตำแหน่งที่มีความเสี่ยงต่อการเกิดการบาดเจ็บของเส้นประสาทได้ แต่อย่างไรก็ตามควรมีการศึกษาเพิ่มเติมทางคลินิกต่อไป*
