석 사 학 위 논 문

# Anatomical study of the deltoid muscle and its innervation

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이 논문을 석사학위 논문으로 제출함

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# 강윤진의 석사학위 논문을 인준함

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# 1. Introduction

The deltoid muscle forms the rounded contour in shoulder region. This muscle originates from the anterior and upper surface of the clavicle, acromion, and the spine of the scapulae [1]. It is inserted into the deltoid tuberosity of the humerus. The deltoid muscle is innervated by the axillary nerve which originates from the anterior rami of C5 and C6 spinal nerve through the superior trunk, posterior division of the superior trunk, and posterior cord of the brachial plexus [2]. The deltoid is supplied by the acromial and deltoid branches of the thoracoacromial artery, circumflex humeral artery, and the deltoid branch of the profunda brachii artery [1,2].

As the deltoid muscle is an intramuscular injection site, the deltoid muscle and axillary nerve have considerable clinical significance [3]. The axillary nerve innervates the deltoid muscle; therefore, caution should be exercised when medications are injected in to this muscle. Damage to this nerve can cause severe nerve problems, such as numbness in the deltoid area [3-5].

The brachial plexus is formed from the anterior division of the spinal nerve roots at C5 - T1. It comprises the roots, trunks, divisions, cords, and branches [4,5]. The brachial plexus terminates in the ulnar nerve, musculocutaneous nerve, median nerve, axillary nerve, and radial nerve, which supplies motor and sensory innervation to the upper extremity. The axillary nerve is injured frequently during orthopedic surgeries, such as shoulder arthroscopy, thermal shrinkage of the shoulder capsule, and plate fixation of the proximal humerus [6,7]. These possible iatrogenic injuries may be caused by anatomical variations of the axillary nerve and its branches for the deltoid muscle.

A lack in proper anatomical knowledge of the nerve can result in increased risk for nerve injury while administering intramuscular, intra-articular, and intra-bursal injections into the deltoid region [8]. It is required to appreciate the precise anatomy of axillary nerve and its course to avoid iatrogenic injury and to protect the nerve during surgery and injection [9]. Therefore, the aim of my study was to discover typical anatomy and possible variations of the deltoid muscle and the axillary nerve to guide clinicians to be aware of them and to have precise knowledge of safe zones. It will reduce the incidence of iatrogenic nerve damage and will enhance the good clinical outcome during shoulder surgeries or intramuscular deltoid injections [5,8].

In this study, the shoulders of 45 cadaveric arms were dissected to identify the topography of the deltoid muscle and its innervation in order to analyze the correlation between these structures. The findings of this study have clinical and embryological implications, and can be helpful for accurate diagnostic interpretation.

# 2. Materials and Methods

## 2.1 The measurement of the deltoid muscle and the axillary nerve:

In this study, 45 cadaveric arms (27 donated cadavers) were dissected. Each cadaver was placed in a supine position and the arms were extended. All cadavers were fixed in formalin as per the standard procedure, and those with shoulder pathologies or history of surgical procedures were excluded. The skin and fascia were removed in shoulder region to expose the deltoid muscle and axillary nerve.

The reference line represents the distance between the coracoid process and the medial epicondyle, which is the distal tip of the humerus [10]. The proximal and distal insertion sites of the deltoid muscle were measured. The axillary nerve passes through the quadrangular space and crosses the surgical neck of the humerus. The vertical level was measured at the proximal (upper) and distal (lower) points. The length of each variable was described by the reference line as the percentile. After measuring each point, the value was divided by the reference line (Figure 1).

## 2.2. Classification of the variation:

The axillary nerve was classified based on the pattern of its direction. It was classified as upward, straight, or downward. The number of branches of the axillary nerve under the humerus varied from one to four. Therefore, it was divided into two groups: one group with one or

two branches and the other with over three branches.

## 2.3. Statistical analysis:

All statistical analyses were conducted using SPSS (version 22.0; IBM SPSS®; Chicago, IL, USA). The Mann - Whitney U and Chi-square tests were used to compare non-continuous variables. The Pearson correlation test was used to analyze the correlation between the muscle and nerve structures. All statistical significance was set at $P < 0.05$.

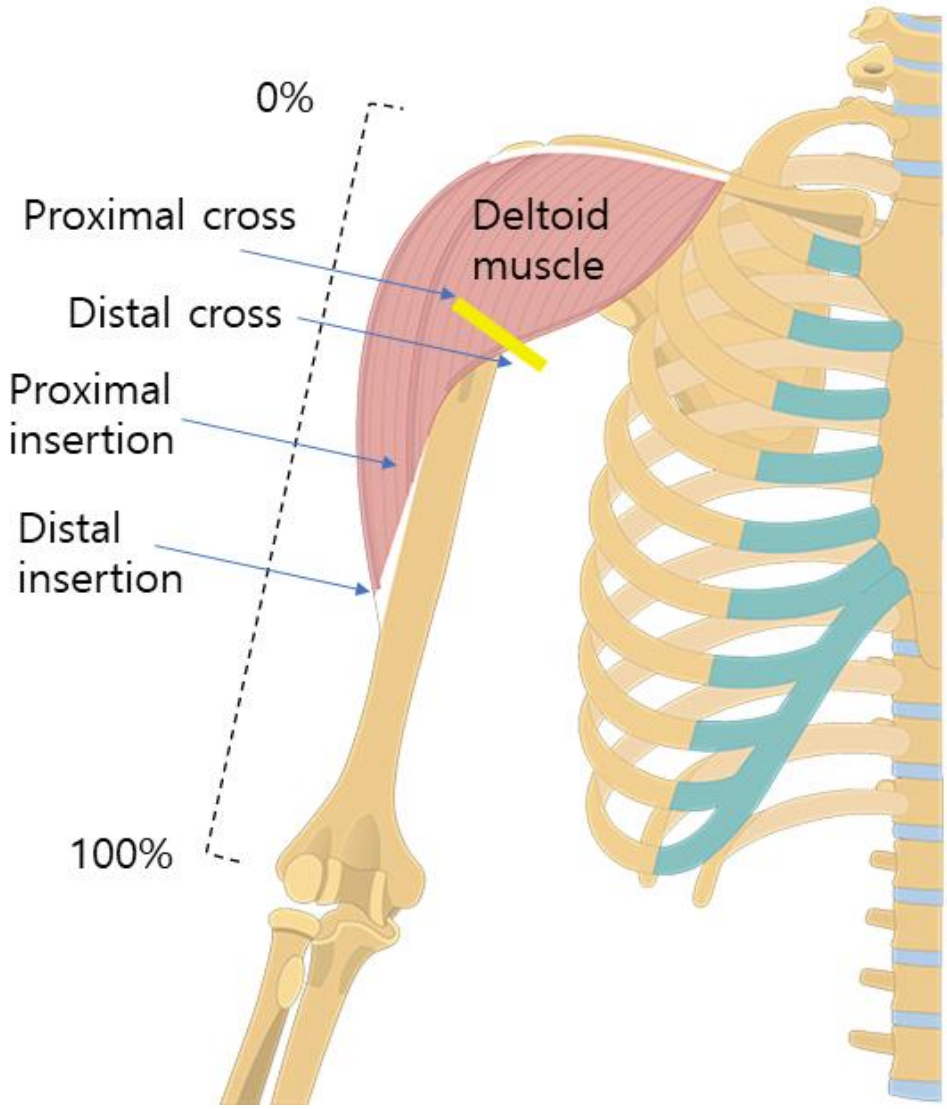


Figure 1. The measurement of the deltoid muscles and the axillary nerve by the length of the reference line as a percentile.

# 3. Results

## 3.1. The topography of the deltoid muscle and the axillary nerve:

The topography of the muscle and nerve structures in the upper limb was successfully confirmed in 45 cadaveric arms (Figure 2). The average length of the reference line of the upper limb was found to be 295.85 (± 16.80 mm). The proximal point where the deltoid muscle was attached was 116.09 (± 8.70 mm), and the distal insertion of the deltoid muscle was 164.57 (± 9.86 mm). The proximal and distal cross points of the axillary nerve were 64.55 (± 10.10 mm) and 78.94 (± 9.20 mm), respectively. The relative values were obtained when these variables were divided by the reference line (Table2). The proximal and distal points of the deltoid muscle were located at 39.31 (± 3.14) and 55.71 (± 3.26) percentiles, respectively (Table1).

## 3.2. The association between the number and direction of the axillary nerve:

The axillary nerve classification was determined by the pattern of its direction. The axillary nerve was classified as upward, horizontal or downward. Also, branch number of the axillary nerve under humerus varied from 1 to 4. So, I classified into two groups, one or two branches and over three branches and it is presented in Table 3.

In cases with one or two axillary nerve branches, the nerve continued

upward (66.7%). It crossed the humerus in horizontal (29.2%) or downward (4.2%) directions. In all the cases with more than three branches, the axillary nerve passed upward (100%).

## 3.3. Topography of the deltoid muscle and the axillary nerve according to the axillary nerve branch:

The number of branches of the axillary nerve is associated with the topography of the deltoid muscle and axillary nerve. Its difference is presented in Table 4. The proximal deltoid insertion was significantly closer in the group with more than three axillary nerve branches (112.12 ± 9.35 mm) than in the group with one or two branches (118.33 ± 7.58 mm, p = 0.017). The distal deltoid insertion also showed a similar tendency. However, this difference did not have statistical significance (p = 0.249). The proximal point of the axillary nerve was significantly closer in the group with more than three axillary nerve branches (60.18 ± 9.82 mm) than in the group with one or two branches (67.03 ± 9.54 mm, p = 0.024). However, other anatomical points and percentile data did not show any association with the number of axillary nerve branches.

## 3.4. Anatomical correlation between the deltoid muscle and the axillary nerve:

Correlation analysis of the anatomical variables was performed, and results were presented in Table 5. The proximal insertion of the deltoid muscle had positive correlation with its distal insertion (R = 0.442, p =

0.002) and the distal crossing point of the axillary nerve (R = 0.410, p = 0.004). The proximal crossing point of the axillary nerve was positively correlated with the distal crossing point (R = 0.597, p < 0.001). The other variables did not show any association.

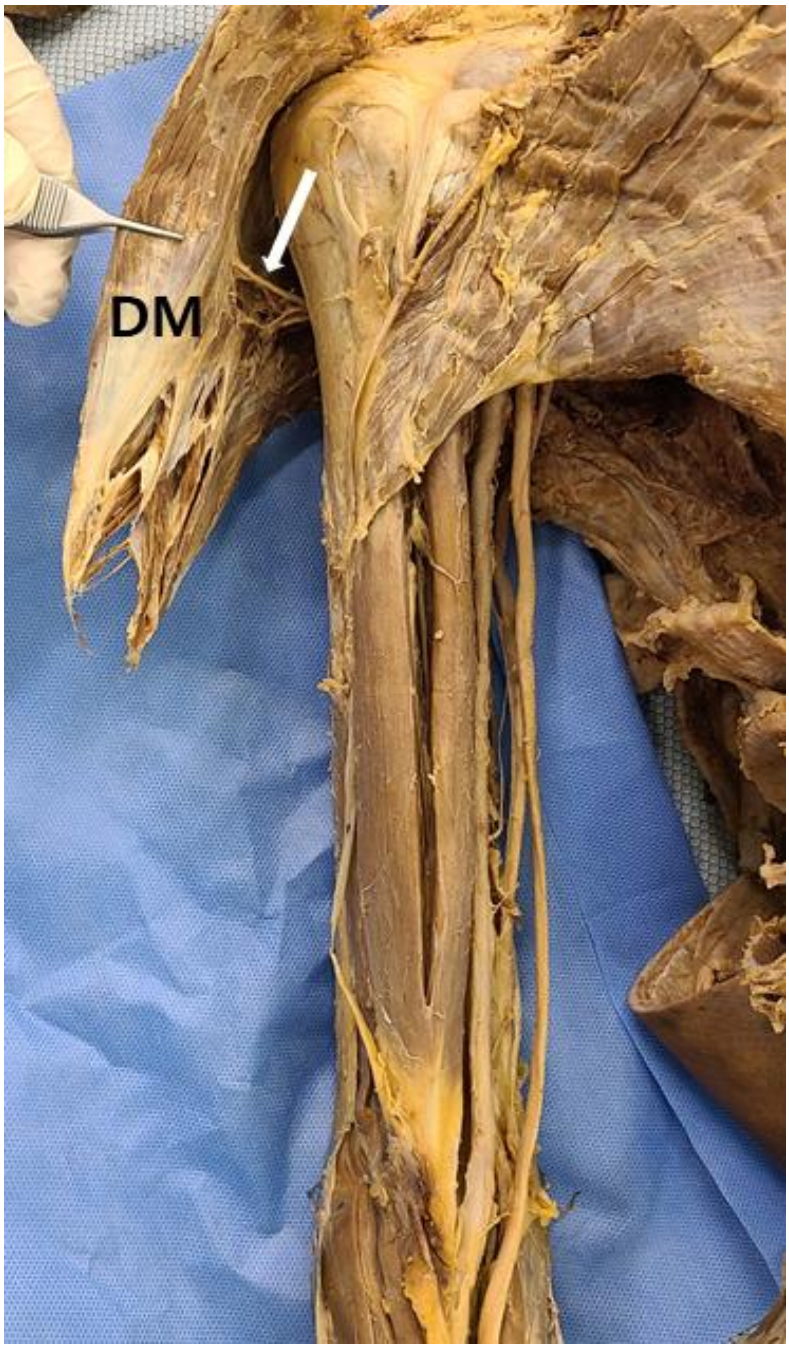


Figure 2. Identification of the deltoid muscle and the axillary nerve. DM, deltoid muscle; white arrow, axillary nerve.

Table 1. Topography of the deltoid muscle and the axillary nerve

| | Mean | Min-Max |
|---|---|---|
| Reference line | 295.85 ± 16.80 mm | 262-335 |
| Deltoid insertion (proximal) | 116.09 ± 8.70 mm | 100-135 |
| Deltoid insertion (distal) | 164.57 ± 9.86 mm | 144-186 |
| Axillary nerve level (proximal) | 64.55 ± 10.10 mm | 40-81 |
| Axillary nerve level (distal) | 78.94 ± 9.20 mm | 60-99 |

Table 2. Topography of the deltoid muscle and the axillary nerve as percentile

| | Mean |
|---|---|
| Deltoid insertion (proximal) | 33.31 ± 3.14 |
| Deltoid insertion (distal) | 55.71 ± 3.26 |
| Axillary nerve level (proximal) | 21.80 ± 3.14 |
| Axillary nerve level (distal) | 26.72 ± 3.18 |

Table 3. The association between the number and direction of the axillary nerve

| | Branch number of the Axillary nerve | |
|---|---|---|
| | N =1 or 2 | N ≥ 3 |
| Upward | 16 (66.7) | 14 (100) |
| Horizontal | 7 (21.2) | 0 (0) |
| Downward | 1 (4.1) | 0 (0) |

P = 0.052

Table 4. Topography of the deltoid muscle and the axillary nerve according to the branches of the axillary nerve

| | Branch number of the Axillary nerve | | |
|---|---|---|---|
| | N =1 or 2 | N ≥ 3 | P |
| Deltoid insertion (proximal) | 118.33 ± 7.58 mm | 112.12 ± 9.35 mm | 0.017 |
| Deltoid insertion (distal) | 165.83 ± 9.27 mm | 162.35 ± 9.82 mm | 0.249 |
| Axillary nerve level (proximal) | 67.03 ± 9.54 mm | 60.18 ± 9.82 mm | 0.024 |
| Axillary nerve level (distal) | 79.47 ± 9.42 mm | 78.00 ± 8.99 mm | 0.605 |
| Deltoid insertion (proximal) | 39.50 ± 2.87 % | 38.97 ± 3.63 % | 0.587 |
| Deltoid insertion (distal) | 55.35 ± 3.50 % | 56.35 ± 2.79 % | 0.315 |
| Axillary nerve level (proximal) | 22.36 ± 3.19 % | 20.82 ± 2.88 % | 0.107 |
| Axillary nerve level (distal) | 26.49 ± 3.04 % | 27.13 ± 3.48 % | 0.515 |

Table 5. Anatomical correlation between the deltoid muscle and the axillary nerve

| | | DM insertion Proximal | DM insertion distal | AN Proximal | AN Distal |
|---|---|---|---|---|---|
| DM insertion Proximal | R | 1 | .442* | .018 | .410* |
| | P | | .002 | .906 | .004 |
| DM insertion distal | R | .442* | 1 | .154 | .218 |
| | P | .002 | | .303 | .141 |
| AN Proximal | R | .018 | .154 | 1 | .597* |
| | P | .906 | .303 | | .000 |
| AN Distal | R | .410* | .218 | .597* | 1 |
| | P | .004 | .141 | .000 | |

DM, deltoid muscle; AN, axillary nerve

*P < 0.01

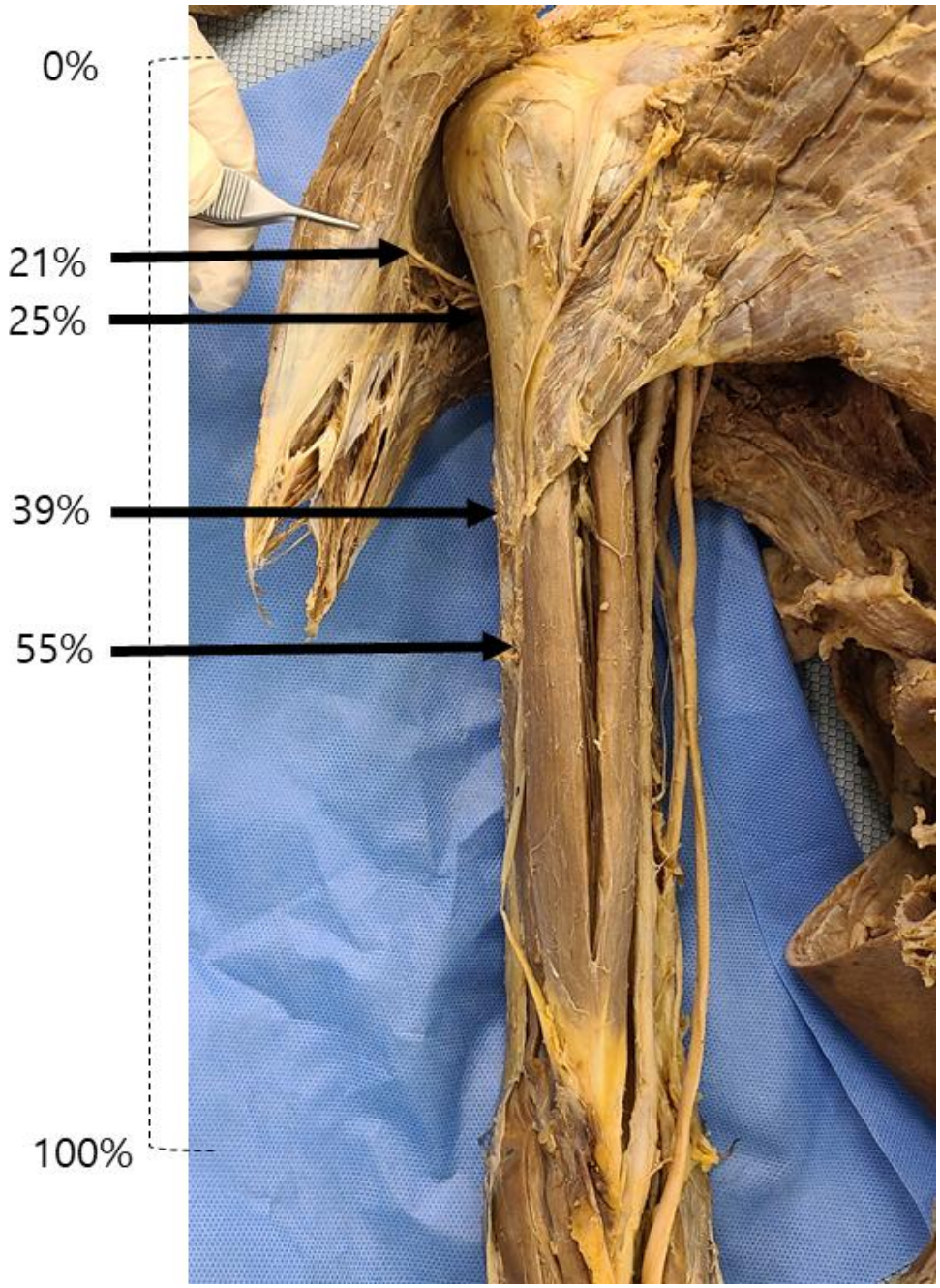


Figure 3. The topography of the deltoid muscles and the axillary nerve by the length of the reference line as a percentile.

# 4. Discussion

The deltoid muscle forms the shoulder curve. It originates from the clavicle, acromion, and scapular spine [1]. It is inserted into the deltoid tuberosity of the humerus. It functions as an abductor, a flexor and an extensor of the shoulder [9]. The axillary nerve innervates the deltoid muscle. The deltoid muscle is clinically significant because it is used as an intramuscular injection site [5]. However, a bunch of nerves, called the axillary nerve, passes under the deltoid muscle. Therefore, my study aimed to clarify topography of the deltoid muscle and the axillary nerve, then discuss the clinical importance of the presented findings.

This study showed that the insertion site of the deltoid muscle was similar to that reported in previous studies. The length of the upper arm from the coracoid process to the medial epicondyle was approximately 290 mm in the Korean population [10]. The deltoid tuberosity was located at a distance of 110 - 160 mm from the coracoid process. Chalmers et al. reported the deltoid length to be 16.2±1.7 cm and it was similar to that of our results [11]. The length of the deltoid tuberosity was approximately 50 mm, which corresponded to approximately 40 - 55% of the humerus bone (upper arm). Previous studies have demonstrated that the length of the deltoid tuberosity is 60 - 70 mm; however, our study showed a smaller size (approximately 50 mm) of the deltoid tuberosity [11-13]. This difference may have originated from the size of the deltoid muscle.

Subsequently, the topography of the axillary nerves was investigated. Previous studies analyzed the location of the axillary nerve using the acromion as reference line [14-16], and the average length was approximately 60 mm, which corresponded to approximately 20% of the

length of the upper arm. In my study, the location of the axillary nerve was calculated using the same reference line for the deltoid tuberosity. To use these topographic data during intramuscular injection, the axillary nerve had to be estimated based on the total arm length and the deltoid muscle. The distance from the coracoid process to the axillary nerve was approximately 65–75 mm, which corresponded to approximately 0–25% of the upper arm. This distance is longer than those reported in previous studies [14–16].

A correlation study was performed to analyze this phenomenon. As expected, the proximal and distal insertion sites of the deltoid muscle correlated with each other. Interestingly, the proximal insertion site was positively associated with the distal point of the axillary nerve. This suggested that development of the deltoid muscle may contribute to the level of the axillary nerve.

Moreover, the number of branches of the axillary nerve was associated with the distal insertion site of the deltoid muscle and proximal crossing point of the axillary nerve. Therefore, the topographies of these neuromuscular structures may influence each other as previous study [17]. Further studies are needed to confirm these findings.

In this study, the topography of the deltoid muscle was significantly associated with that of the axillary nerve, which has clinical significance because it functions as an intramuscular injection site. This suggests their co-development during embryogenesis. Clinicians should perform their procedures or surgical approaches based on these anatomical data in the shoulder region.

# 5. Summary

As the axillary nerve innervates the deltoid muscle, caution should be exercised when medications are injected through this muscle. In this study, the shoulders of 45 cadaveric arms were dissected to identify the topography and innervation of the deltoid muscle. Correlations between these structures were studied. The insertion site of the deltoid muscle and the cross level of the axillary nerve were measured and their average level was demonstrated. Topography of the deltoid muscle was significantly associated with that of the axillary nerve suggesting their embryological correlation. However, it showed a difference according to the number of branches of axillary nerve. The findings of this study have clinical and embryological implications and can be helpful for accurate diagnostic interpretation.

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# Anatomical study of the deltoid muscle and its innervation

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**(Abstract)**

The deltoid muscle is the muscle forming the rounded contour of the human shoulder and it is innervated by the axillary nerve. Its anatomical study has not been studied thoroughly despite its clinical significance. The purpose of this study is to examine topography of the deltoid muscle and axillary nerve. Axilla region was dissected in 47 upper limbs (24 right, 23 left) and each length was divided by reference line, which was measured from the coracoid process to the medial epicondyle (295.8 mm). The deltoid muscle was inserted into humerus from 39.3 percentile (116.0 mm) to 55.7 percentile (164.6 mm). The axillary nerve transversed the humerus from 21.8 percentile (64.55 mm) to 26.7 percentile (78.9 mm). However, these variables did not have a

difference on whether it was right or left. The number of the axillary nerve branch diversed from one to three and its number was associated with its direction. Also, it had correlation with the insertion site of the deltoid muscle and the location of the axillary nerve. This result demonstrates useful data for intramuscular injection and surgical approach on upper limb region.

# 어깨세모근과 신경에 대한 해부학적 연구

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**(초록)**

어깨세모근은 사람의 어깨의 둥근 윤곽을 형성하는 근육이며, 겨드랑신경에 의해 움직인다. 이 연구의 목적은 어깨세모근과 겨드랑신경의 분포와 해부학적 위치를 조사하는 것이다. 본 연구에서는 어깨세모근과 겨드랑신경을 확인하기 위해 시신에서 45쪽의 어깨를 해부하였다. 어깨세모근의 닿는 곳과 겨드랑신경의 교차수준을 측정하여 평균값을 입증하였다. 어깨세모근의 해부학적 위치는 이들의 발생학적 상관관계를 시사하는 겨드랑신경의 위치와 유의하게 연관되어 있었다. 겨드랑신경의 가지의 수는 1개에서 3개 이상으로 다양했고 그 수는 신경의 주행 방향과 관련이 있었다. 또한, 어깨세모근의 닿는곳과 겨드랑신경의 위치와 상관관계가 있었다. 또한 겨드랑신경의 가지 수에 따라 어깨세모근의 닿는 곳과 신경의 주행위치의 차이를 보였다. 이 결과는 팔 부위에서 근육주사를 비롯한 술기 및 외과적 접근에 유용한 자료이다. 그리고 팔의 근육과 신경의 임상적, 발생학적 의미를 가지며 정확한 진단에 도움이 될 것이다.