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ANATOMICAL FEATURES OF THE SOFT TISSUE STRUCTURES OF THE PROXIMAL HUMERAL DIAPHYSIS REVEALED BY THE MAGNETIC RESONANCE IMAGING

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Treatment of humeral diaphysis fractures requires in-depth knowledge of the variant anatomy of the muscular component and other soft tissue structures. The analysis of the findings of magnetic resonance imaging enables the study of the anatomical features without the use of cadaveric material. The aim of the study is to determine the anatomical features of the soft tissue structures of the proximal humeral diaphysis based on the findings of magnetic resonance imaging. 73 consecutive standard MRI scans of the humerus of patients aged 17 to 72 years have been analyzed. The average age of the patients was 48 years; the average age of women and men was 49 and 47 years, respectively. Methods of nonparametric statistics have been used in data processing. After studying and processing the MRI-resulting data, three groups of patients were identified depending on the age and gender. Individual anthropometric parameters of deltoid muscle, greater pectoral muscle, teres major muscle and the broadest muscle of the back have been determined, namely, the width, thickness, and distance from the apex of the greater tubercle to the upper boundary of the insertion site on the humeral diaphysis. Age and gender differences in anthropometric data have been differentiated. The examination of the greater pectoral muscle revealed a clear laminarity of the muscle portions and the retrograde nature of the points of its attachment to the humeral diaphysis relative to their sites of origin. Teres major muscle, in all subjects, had a single-vector fiber structure. The site of insertion of the teres major muscle, in all subjects, was below the site of attachment of the broadest muscle of the back to the humerus. Elderly women, as compared to men of this age group and young and middle-aged women, have a dramatic decrease in anthropometric biofunctional parameters of the deltoid muscle, greater pectoral muscle, teres major muscle and the broadest muscle of the back. This phenomenon indicates the clear age and gender distribution of bone fragment displacement in humeral diaphysis fractures.

Key words: *magnetic resonance imaging, muscle component, humeral diaphysis, soft tissue structures.*

Relationship between the publication and planned research work. The paper has been written within the scientific research work, made at the Department, «Functional treatment of humerus fractures», State registration № 0117u004682.

Introduction. Treatment of humeral diaphysis fractures requires extensive knowledge of the variant anatomy of the soft tissue structures of this area [1, 2]. Understanding the biomechanical vector and strength of muscle contraction, antagonism and synergism of their action, age aspects of the development and dystrophy of muscle tissue reduces the risk of iatrogenic damage to important anatomical structures, both during surgery and during conservative treatment [3, 4, 5, 6].

Consideration of the anthropometric data of the muscles with regard of the age category and gender distribution enables increasing the quality and velocity of closed and open repositions of bone fragments, as well as biomechanical awareness of traumatologists [7].

In most cases, reliable anthropometric data of the muscular component of the proximal humerus are studied *in vitro* using cadaveric materials [8, 9, 10]. Notably, variant anatomy and individual age and gender features are often revealed intraoperatively.

Magnetic resonance imaging at the current level of its development enables studying the soft tissue structures *in vivo*, which expands the range of preoperative planning and provides with the study of the anatomical features of a large number of patients. MRI scanning is an accessible and atraumatic method of diagnostics [11, 12, 13, 14].

Purpose. To determine the anatomical features of the soft tissue structures of the proximal humeral diaphysis based on the findings of magnetic resonance imaging.

Object and methods of research. 73 consecutive standard MRI scans of the humerus, which were performed using the MRI system MAGNETOM Skyra of the SIEMENS company with induction of magnetic field 3 Tesla. Scanning was performed in the sagittal, frontal and axial planes. T1, T2 and Pd scan modes were used for each of the planes. The study and analysis of the MRI scans was performed on the licensed software RadiAnt DICOM Viewer using the LG imaging system.

Magnetic resonance imaging of the humerus was performed in 73 patients aged 17 to 72 years in the form of a single study, as well as during scanning of the shoulder joint, other organs and systems. The average age of the patients was 48 years; the average age of women and men was 49 and 47 years, respectively. According to gender distribution, men accounted for 61.6 % (45), women – 38.4 % (28). The subjects, aged 17 to 44 years old accounted for 38 % (28), 45 to 59 years old – 36 % (26), over 60 years old – 25 % (18).

The target points of the study were:

– differentiation of the anatomical features of the structure of the greater pectoral muscle, deltoid muscle, teres major muscle and the broadest muscle of the back;

– determination of the height of the insertion points of the deltoid muscle, greater pectoral muscle, teres major muscle and the broadest muscle of the back on

the humeral diaphysis from the apex of the greater tubercle of the humerus;

– determination of the width of the deltoid muscle, greater pectoral muscle, teres major muscle and the broadest muscle of the back near the insertion sites on the humerus.

Data Processing. Statistical analysis of anthropometric values of the muscles of the proximal humeral diaphysis, according to magnetic resonance imaging, the methods of non-parametric statistics were used, namely, determination of the median, interquartile range, minimum and maximum values. Statistical processing of the resulting data was performed using the Excel software, Microsoft Office 2019.

The results of the research and their discussion. After a detailed study and processing of the findings of the MRI scans of the humerus, 3 groups of patients were identified depending on the age and gender.

Male patients (67.9 %) prevailed over the female patients (32.1 %) in Group I (n=28 (38 %), aged 17 to 44 yrs). The average age of all subjects was 34.2 years; men – 32.5 years, women – 35.9 years.

The number of male patients (50 %) was similar to the number of female patients (50 %) in Group II (n=26 (36 %), aged 45 to 59 yrs). The average age of all subjects was 51.4 years; men – 51.5 years, women – 51.2 years.

Male patients (66.7 %) also prevailed over the female patients (33.3 %) in Group III (n=18 (25 %), aged 60 to 72 yrs). The average age of all subjects was 64.6 years; men – 64.4 years, women – 64.8 years.

The general characteristics of the groups are presented in the **table 1**.

Table 1 – The general characteristics of the groups

Group No.	Total number of patients in the group, persons	Men, n (%)	Women, n (%)	Average age, years	% from the total number of observations
1	28	67.9	32.1	34.2	38
2	26	50	50	51.4	36
3	18	66.7	33.3	64.6	25

In patients of Group I, the average width of the deltoid muscle (DM) in the sagittal projection (SP) was 8.54 cm. In the frontal projection (FP), the thickness of the deltoid muscle was on the average of 2.11 cm. The length of the deltoid muscle from the proximal apex of the greater tubercle (GT) of the humerus to the proximal insertion point (PIP) on the humeral diaphysis (HD) was on the average of 10.88 cm. The thickness of the greater pectoral muscle (GPM) near the insertion site (IS) in the frontal projection was on the average of 2.69 cm. The distance from the apex of the greater tubercle of humerus to the upper edge of the insertion site of the greater pectoral muscle to the humeral diaphysis was on the average of 4.29 cm. The thickness of the teres major muscle (TMM) in the frontal projection near the insertion site was on the average of 0.95 cm. The distance from the apex of the greater tubercle to the proximal edge of the insertion site on the humeral diaphysis was 2.99 cm. The width of the broadest muscle of the back (BMB) near the point of attachment to the humeral diaphysis was on the average of 0.9 cm. The average distance from the upper pole of the greater tubercle to the upper border of the insertion site of the broadest muscle of the back was 2.48 cm.

Detailed anthropometric average data for deltoid and the greater pectoral muscles for Group I are shown in **table 2**. Detailed anthropometric average data of the teres major muscle and the broadest muscle of the back of patients of Group I are shown in **table 3**.

Table 2 – Anthropometric average data for deltoid and the greater pectoral muscles for Group I

DM width in SP, cm.		DM thickness in FP, cm.		DM length from the GT apex to PIP on the HD, cm.		GPM thickness in FP at the IS on the HD, cm.		Distance from the GT apex to GPM PIP of the HD, cm.	
men	women	men	women	men	women	men	women	men	women
8.79	7.99	2.20	1.91	11.08	10.45	2.75	2.54	4.21	4.45

Table 3 – Anthropometric average data of the teres major muscle and the broadest muscle of the back of patients of Group I

TMM thickness in FP at IS, cm.		Distance from the GT apex to TMM PIP, cm.		BMB thickness in FP at IS on the HD, cm.		Distance from the GT apex to BMB PIP on the HD, cm.	
men	women	men	women	men	women	men	women
0.99	0.88	2.95	3.07	1.03	0.62	2.32	2.83

The anthropometric average values of patients of the Group II were showed the following. The width of the deltoid muscle in the sagittal plane was 9.0 cm, the thickness of the deltoid muscle in frontal projection was 2.16 cm, the length of the deltoid muscle from the apex of the greater tubercle of the humerus to the proximal edge of the site of diaphyseal insertion was 11.83 cm; the thickness of the greater pectoral muscle near the site of attachment to the humerus was 2.58 cm, the distance from the upper pole of the greater tubercle to the upper edge of the insertion site on the humerus was 4.73 cm; the thickness of the teres major muscle near the site of attachment was 1.13 cm, the distance from the apex of the greater tubercle to the proximal point of the insertion site was 3.13 cm; the width of the broadest muscle of the back near the point of attachment on the humeral diaphysis was 0.69 cm, the distance from the apex of the greater tubercle of the humerus to the proximal point of the insertion site was 2.64 cm.

Detailed anthropometric average data for deltoid and the greater pectoral muscles for Group II patients are shown in **table 4**. Detailed anthropometric average data of the teres major muscle and the broadest muscle of the back of patients of Group II are shown in **table 5**.

Table 4 – Anthropometric average data for deltoid and the greater pectoral muscles for Group II

DM width in SP, cm.		DM thickness in FP, cm.		DM length from the GT apex to PIP on the HD, cm.		GPM thickness in FP at the IS on the HD, cm.		Distance from the GT apex to GPM PIP of the HD, cm.	
men	women	men	women	men	women	men	women	men	women
9.64	8.36	2.41	1.91	11.65	12.01	2.56	2.6	4.89	4.58

Table 5 – Anthropometric average data of the teres major muscle and the broadest muscle of the back of patients of Group II

TMM thickness in FP at IS, cm.		Distance from the GT apex to TMM PIP, cm.		BMB thickness in FP at IS on the HD, cm.		Distance from the GT apex to BMB PIP on the HD, cm.	
men	women	men	women	men	women	men	women
1.18	1.08	3.28	2.97	0.66	0.71	2.59	2.69

The anthropometric average values of patients of the Group III were: the width of the deltoid muscle in the sagittal plane – 9.28 cm, the thickness of the deltoid muscle in frontal projection – 2.16 cm, the length of the deltoid muscle from the apex of the greater tubercle of the humerus to the proximal edge of the site of diaphyseal insertion – 12.1 cm; the thickness of the greater pectoral muscle near the site of attachment to the humerus – 2.47 cm, the distance from the upper pole of the greater tubercle to the upper edge of the insertion site on the humerus – 5.12 cm; the thickness of the teres major muscle near the site of attachment – 1.13 cm, the distance from the apex of the greater tubercle to the proximal point of the insertion site – 3.32 cm; the width of the broadest muscle of the back near the point of attachment on the humeral diaphysis – 0.69 cm, the distance from the apex of the greater tubercle of the humerus to the proximal point of the insertion site – 2.63 cm.

Detailed anthropometric average data for deltoid and the greater pectoral muscles for Group III patients are shown in **table 6**. Detailed anthropometric average data of the teres major muscle and the broadest muscle of the back of patients of Group III are shown in **table 7**.

The average width of the deltoid muscle in the sagittal projection was 9.39 cm and 8.08 cm in men and women, respectively. The gender difference in the size of the width was on the average of 1.31 cm. The highest median values of the width of the deltoid muscle were observed among men of Group II and III, accounting for 9.64 cm and 10.11 cm, respectively. The greatest gender discrepancy was observed among patients of Group III, where the width of the deltoid muscle was by 2.5 cm greater among men over 60 years and by 1.19 cm greater than the similar average values of other study groups.

The average thickness of the deltoid muscle in the frontal projection was 2.34 cm and 1.85 cm in men and women, respectively. The difference in thickness of the above muscle was 0.49 cm. The maximum average values were observed among men of Group II and III, accounting for 2.41 cm and 2.42 cm, respectively. The greatest gender discrepancy was observed among patients of Group III and accounted for 0.78 cm, which is by 0.29 cm greater than the similar average values of other study groups.

The average length of the deltoid muscle from the apex of the greater tubercle to the proximal insertion point on the humeral diaphysis was 11.81 cm in men and 11.09 cm in women. This parameter was by 0.72 cm greater among men. The maximum length of the deltoid muscle was observed among men of Group III and women of Group II, accounting for 13.14 cm and 12.01 cm, respectively. The maximum gender discrepancy was recorded among patients of Group III (3.11 cm).

The average thickness of the greater pectoral muscle near the site of its insertion was greater among men (2.71 cm) compared to women (2.43 cm). The maximum average thickness was observed among men of Group I and III, accounting for 2. 75 cm, which was by 0.15 cm greater than the average values of the studied groups. The maximum gender discrepancy was observed among patients of Group III, accounting for 0.85 cm in men.

The average length from the apex of the greater tubercle to the proximal border of the insertion site of the greater pectoral muscle was 4.8 cm in men and 4.44 cm in women. The highest values were in male patients of Group III (5.6 cm), which was by 0.94 cm greater than the average value among all groups. The maximum gender discrepancy was recorded among patients of Group III and accounted for 1.45 cm, which was by 1.09 cm greater than the average values.

The average thickness of the teres major muscle near the site of its insertion was 1.12 cm in men and 0.98 cm in women. The highest values of

Table 6 – Anthropometric average data for deltoid and the greater pectoral muscles for Group III

DM width in SP, cm.		DM thickness in FP, cm.		DM length from the GT apex to PIP on the HD, cm.		GPM thickness in FP at the IS on the HD, cm.		Distance from the GT apex to GPM PIP of the HD, cm.	
men	women	men	women	men	women	men	women	men	women
10.11	7.61	2.42	1.64	13.14	10.03	2.75	1.9	5.6	4.15

Table 7 – Anthropometric average data of the teres major muscle and the broadest muscle of the back of patients of Group III

TMM thickness in FP at IS, cm.		Distance from the GT apex to TMM PIP, cm.		BMB thickness in FP at IS on the HD, cm.		Distance from the GT apex to BMB PIP on the HD, cm.	
men	women	men	women	men	women	men	women
1.24	0.91	3.65	2.66	0.7	0.67	2.83	2.24

the thickness of the teres major muscle were recorded among men of Group III and I, accounting for 1.24 cm and 1.18 cm, respectively. The maximum gender discrepancy was observed among patients of Group III in men and was 0.33 cm.

The average length from the apex of the greater tubercle to the proximal border of the teres major muscle insertion site was 3.24 cm in men and 2.94 cm in women. The highest values were observed in men of Group III and II, accounting for 3.65 cm and 3.28 cm, respectively. The maximum gender discrepancy was 0.99 cm and was found among patients Group III.

The average thickness of the broadest muscle of the back near the site of its insertion on the humerus was 0.82 cm in men and 0.67 cm in women. The maximum values were recorded among young men of Group I (1.03 cm).

The average length from the apex of the greater tubercle to the proximal border of the insertion site of the broadest muscle of the back was 2.53 cm in men and 2.64 cm in females. The greatest gender discrepancy was observed among patients of Group I and accounted for 0.51 cm in women.

In 6.85 % (5) of the subjects, no traditional differentiation of the deltoid muscle into three portions, namely, anterior, medial and posterior, was noted. In 2.7 % (2) of cases, no clear separation of the anterior and medial portions of muscle fibers was found, as well as their complete adhesion at the level of the middle third of the greater tubercle of the humerus. In 4.1 % (3) no differentiation of the medial and posterior portions of the deltoid muscle fibers, and their complete adhesion at the level of the lower pole of the humerus was noted.

The study of the greater pectoral muscle revealed a clear laminarity of the muscle portions and the retrograde nature of the points of attachment to the humeral diaphysis relative to their sites of origin. Thus, the clavicle of the greater pectoral muscle is attached to the humerus distally, the sternocostal part – medially, the abdominal – proximally.

The teres major muscle in all cases had a single-vector fiber structure. The site of insertion of the teres major muscle in all cases was below the site of attachment of the broadest muscle of the back to the humerus. The width of the teres major muscle was about by 1.4 times greater than the width of the broadest muscle of the back near the insertion site of each of them.

Coclusions. Magnetic resonance imaging enables studying the individual anatomical features of the soft tissue structures of the humeral diaphysis *in vivo* and without the use of invasive research methods. This allows to increase the level of preoperative planning and intraoperative anatomical topography for surgeons, expand the range of studies of variant anatomy of soft tissue structures and reduce the risk of anatomically induced iatrogenic complications.

Elderly women, as compared to men of this age group and young and middle-aged women, have a dramatic decrease in anthropometric biofunctional parameters of the deltoid muscle, greater pectoral muscle, teres major muscle and the broadest muscle of the back. This phenomenon indicates the clear age and gender distribution of bone fragment displacement in humeral diaphysis fractures.

The study of variant musculoskeletal relationships of the humeral diaphysis in the proximal part deepens the understanding of the biomechanical variability of displacement of bone fragments in simple and multifragmental fractures of the humeral diaphysis.

The prospects of further research. Further study of anatomical features of the soft tissue structures of the proximal humeral diaphysis revealed by the magnetic resonance imaging.

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АНАТОМІЧНІ ОСОБЛИВОСТІ М'ЯКОТКАНИННИХ СТРУКТУР ПРОКСИМАЛЬНОГО ВІДДІЛУ ДІАФІЗАРНОЇ ДІЛЯНКИ ПЛЕЧА ЗА ДАНИМИ МАГНІТНО-РЕЗОНАНСНОЇ ТОМОГРАФІЇ

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Резюме. Анатомічні особливості м'якотканинних структур проксимального відділу діафізарної ділянки плеча за даними магнітно-резонансної томографії. Лікування переломів діафізу плечової кістки глибоких знань варіантної анатомії м'язового компоненту та інших м'якотканинних структур. Дослідження за допомогою аналізу результатів магнітно-резонансних томографій дозволяє дослідити анатомічні особливості без використання кадавер-матеріалу. *Метою дослідження* є визначення анатомічних особливостей м'якотканинних структур проксимального відділу діафізарної ділянки плеча на основі результатів магнітно-резонансної томографії. *Об'єкт і методи дослідження.* Було проаналізовано 73 послідовних стандартних МРТ-скани ділянки плеча пацієнтів віком від 17 до 72 років. Середній вік пацієнтів складав 48 років, середній вік жінок – 49 років, чоловіків – 47 років. При обробці даних використовувалися методи непараметричної статистики. *Результати.* Після вивчення та обробки даних виділено три групи пацієнтів в залежності від віку та статі. Було визначено індивідуальні антропометричні параметри дельтоподібного, великого грудного, великого круглого м'язів та найширшого м'язу спини, а саме – ширину, товщину та відстань від верхівки великого горбика до верхньої межі місця інсерції на діафізі плечової кістки. Диференційовано вікову та гендерну розбіжність антропометричних даних. Під час дослідження великого грудного м'язу виявлено чітку ламінарність м'язових порцій та ретроградність точок їх прикріплення до діафізу плечової кістки відносно місць їхнього початку. Великий круглий м'яз у всіх досліджуваних випадках мав одновекторну волоконну структуру. Місце інсерції великого круглого м'язу у всіх випадках було нижче місця прикріплення найширшого м'язу спини до ділянки плечової кістки. *Висновки.* У жінок похилого віку, у порівнянні з чоловіками даної вікової категорії та жінками молодого, та середнього віку, спостерігається різке зменшення антропометричних біофункціональних показників дельтоподібного, великого грудного, великого круглого м'язів та найширшого м'язу спини. Це пояснює чіткий віковий та гендерний розподіл зміщення кісткових відламків при переломах діафізу плечової кістки.

Ключові слова: магнітно-резонансна томографія, м'язовий компонент, діафіз плечової кістки, м'якотканинні структури.

ANATOMICAL FEATURES OF THE SOFT TISSUE STRUCTURES OF THE PROXIMAL HUMERAL DIAPHYSIS REVEALED BY THE MAGNETIC RESONANCE IMAGING

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Abstract. Treatment of humeral diaphysis fractures requires in-depth knowledge of the variant anatomy of the muscular component and other soft tissue structures. The analysis of the findings of magnetic resonance imaging enables the study of the anatomical features without the use of cadaveric material. *The aim of the study* is to determine the anatomical features of the soft tissue structures of the proximal humeral diaphysis based on the findings of magnetic resonance imaging. *Methods and Material.* 73 consecutive standard MRI scans of the humerus of patients aged 17 to 72 years have been analyzed. The average age of the patients was 48 years; the average age of women and men was 49 and 47 years, respectively. Methods of nonparametric statistics have been used in data processing. *Results.* After studying and processing the data, three groups of patients were identified depending on the age and gender. Individual anthropometric parameters of deltoid muscle, greater pectoral muscle, teres major muscle and the broadest muscle of the back have been determined, namely, the width, thickness, and distance from the apex of the greater tubercle to the upper boundary of the insertion site on the humeral diaphysis. Age and gender differences in anthropometric data have been differentiated. The examination of the greater pectoral muscle revealed a clear laminarity of the muscle portions and the retrograde nature of the points of its attachment to the humeral diaphysis relative to their sites of origin. Teres major muscle, in all subjects, had a single-vector fiber structure. The site of insertion of the teres major muscle, in all subjects, was below the site of attachment of the broadest muscle of the back to the humerus. *Conclusions.* Elderly women, as compared to men of this age group and young and middle-aged women, have a dramatic decrease

in anthropometric biofunctional parameters of the deltoid muscle, greater pectoral muscle, teres major muscle and the broadest muscle of back. This phenomenon indicates the clear age and gender distribution of bone fragment displacement in humeral diaphysis fractures.

Key words: magnetic resonance imaging, muscle component, humeral diaphysis, soft tissue structures.

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