DOI 10.29254/2077-4214-2022-3-166-216-219
UDC 616.717.4-001.1-071

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ASPECTS OF PREDICTION OF VASCULAR DISORDERS IN HUMERUS FRACTURES

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A prognostic assessment of the occurrence of damage to the brachial arteries and veins requires in-depth knowledge of their anatomical and topographic features in normal conditions and alterations. When predicting the risk of developing hemodynamic disorders in patients with humeral diaphysis fractures, the biomechanical effect of the muscle component is practically not taken into account. Methods of transport immobilization of the injured extremity play a significant role in the prevention of vascular damage. The purpose of the study was to identify the alternative topographical and anatomical features of the location of humeral vessels with subsequent planning of prognostic and diagnostic measures to prevent their damage depending on the type of displacement of bone fragments in humerus fractures. The findings of the study revealed individual and gender features of the location of the brachial artery, as well as brachial and basilar veins. Their spatial positional relationship with the groups of muscles of the proximal humerus have been differentiated. The age-related relationship between the level of the fracture and the type of displacement was revealed. The risk of damage to the vessels of the proximal part of the humerus is high in the adduction type of fracture of the humeral diaphysis. In-depth knowledge of clinical anatomy and the interrelationships of various types of soft tissue structures of the humeral diaphysis will prevent the possibility of direct or indirect damage to the brachial vessels, shorten the period of patients' incapacity and reduce the degree of disability.

Key words: *humerus fractures, brachial vessels, stepped therapy, humeral diaphysis.*

Connection of the publication with planned research works. The paper has been written within the scientific research work, made at the Department, "Development of the advanced scientifically based principles of stratification, monitoring and prognosis of the course of surgical diseases and injuries", state registration № 0120U101176.

Introduction. The publications report that vascular complications in skeletal bone fractures occur in 1.5% of cases. They can be caused both by direct traumatization by bone fragments and by long-term compression by soft tissue structures, which leads to hemodynamic disorders and the occurrence of arterial and venous thrombotic complications. The number of scientific works devoted to the occurrence of post-traumatic venous or arterial thrombosis of the upper extremity is quite small [1, 2, 3, 4].

Prognostic assessment of the occurrence of damage to the brachial arteries and veins requires in-depth knowledge of their anatomical and topographic features in normal condition and alterations. Magnetic resonance imaging greatly facilitates the study of individual anatomical features of a large number of patients *in vivo*. This type of instrumental study is atraumatic and available diagnostic method. It enables obtaining multi-section and multi-plane scans of the humerus, evaluate the positional relationship and anthropometric features of the osseous and soft tissue structures [5, 6].

When predicting the risk for the development of hemodynamic disorders in patients with humeral diaphysis fractures, the biomechanical effect of the muscle component is practically not taken into account. The muscle group of the proximal humerus has the greatest impact on the displacement of bone fragments in diaphyseal fractures [7].

Methods of transport immobilization of the injured extremity play a significant role in the prevention of vascular damage. The optimal choice of the method of primary immobilization minimizes the pathological mobility of bone fragments and prevents their critical displacement [8].

Purpose. Study of alternative topographical and anatomical features of the location of the brachial vessels with subsequent planning of prognostic and diagnostic measures to prevent their damage depending on the type of displacement of bone fragments in humerus fractures.

Object and research methods. The topographical and anatomical features of the location of the brachial vessels have been studied based on the data of magnetic resonance imaging (MRI) of patients made for indications not related to the presence of pathological disorders of the vascular, muscular, and osseous components of the humerus. The object of the study was 32 patients aged 18 to 68 years. The average age of the subjects was 46.5 years with the average age of men and women of 46 years and 47 years, respectively. According to the gender distribution, men (53% (17)) prevailed over women (47% (15)).

Scanning was performed using the MRI system with induction of a magnetic field of 3 Tesla in the axial, frontal and sagittal planes with the involvement of Pd, T1 and T2 modes. The analysis and study of the MRI scans were performed using the Dell imaging system and the involvement of Sante Dicom Viewer 3.0 official license software.

The clinical group involved 36 patients with closed fractures of the humeral diaphysis with displacement of bone fragments. The age of the patients ranged from 23 to 85 years. According to the gender distribution, women (66.7% (24)) prevailed over men (33.3% (12)). The average age among female patients was 59 years, among male patients – 47 years.

In all patients, the cause of the fracture of the humeral diaphysis was a low-energy injury, namely as a result of a fall from own height. Injuries were received during a fall on an outstretched arm, the area of the elbow joint, a mechanical obstacle, and on the side.

All injured individuals were present to the clinic by emergency medical teams. At the pre-hospital stage of medical care, 35 patients underwent transport immobilization.

At the preoperative stage, all patients with humerus fractures underwent a general clinical and laboratory examination, radiography of the damaged segment in standard two-plane projections.

At the stages of preoperative planning, 47.2% (17) patients underwent spiral computed tomography of the damaged area of the humerus and the anatomical 3D modeling technique was applied to develop a fracture reposition scheme to prevent iatrogenic intraoperative injury to the soft tissue structures of the specified area and to assess the relative location of the vascular and bone components.

In the statistical analysis of anatomotopographic and anthropometric data of the brachial vessels, the displacement vector of bone fragments in humeral diaphysis fractures, methods of non-parametric statistics have been used, namely, determination of the median, interquartile range, minimum and maximum values. Statistical processing of the resulting data was carried out using the "Excel" software from the Microsoft Office 2019 package.

Research results and their discussion. In the patients of the anatomotopographic group, it was found that the average diameter (AD) of the proximal humeral diaphysis was 3.1 cm. The distance from the anatomical axis of the humerus (AAH) to the brachial vein (BRV) was on the average of 2.3 cm. The distance from the outer edge of the medial cortical layer (MCL) of the diaphysis to the brachial vein was on the average of 0.84 cm. The average diameter of the brachial vein was 0.34 cm. The distance from the anatomical axis of the humerus to the brachial artery (BRA) was on the average of 3.2 cm. The distance from the outer edge of the medial cortical layer of the diaphysis to the brachial artery was 1.69 cm. The average diameter of the brachial artery was 0.51 cm. The distance from the anatomical axis of the humerus to the basilar vein (BV) was 4.05 cm. The distance from the outer edge of the medial cortical layer of the diaphysis to the basilar vein was 2.53 cm. The average diameter of the basilar vein was 0.53 cm.

In the proximal humeral diaphysis, the brachial artery, brachial and basilar veins were located in the planes of projections of the insertion sites of the greater pectoral muscle, teres major muscle and the broadest muscle of the back on the medial surface. From the lateral side – in the projection of the insertion site of the deltoid muscle.

The detailed average anthropometric data for the humerus, brachial artery, brachial and basilar veins in the proximal portion of the humeral diaphysis are shown in **table 1**.

The detailed average anthropometric data for the brachial artery, brachial and basilar veins to the proximal humeral diaphysis ratio are shown in **table 2**.

The analysis of the data of the clinical study group has established that transport immobilization at the pre-hospital stage was carried out with the use of inflatable air splints (8 cases), standard Kramer's wire splints (21 cases), fixing bandages (7 cases).

Table 1 – The average anthropometric data for the humerus, brachial artery, brachial and basilar veins in the proximal portion of the humeral diaphysis

AD of the humerus, cm.		AD of the brachial vein, cm.		AD of the brachial artery, cm.		AD of the basilar vein, cm.	
men	women	man	women	men	women	man	women
3,2	3,0	0,36	0,32	0,56	0,46	0,58	0,48

58% (21) of patients were diagnosed with diaphyseal fractures of the proximal portion of the humerus with displacement of fragments by adduction type. In 42% (15) patients, the abduction type of displacement of bone fragments of the humeral diaphysis was found.

The adduction type of displacement of bone fragments was characteristic of patients aged 23 to 58 years. Among them, women prevailed (36% (13)). Abduction type of displacement of bone fragments was characteristic of elderly patients aged 62 to 85 years. Female patients also predominated among them (30.5% (11)).

Table 2 – The average anthropometric data for the brachial artery, brachial and basilar veins to the proximal humeral diaphysis ratio

Distance from AAH to BRV, cm.		Distance from AAH to BRA, cm.		Distance from AAH to BV, cm.		Distance from MCL BRV, cm.		Distance from MCL BRA, cm.		Distance from MCL BV, cm.	
men	women	man	women	men	women	man	women	men	women	man	women
2,38	2,22	3,25	3,15	4,12	3,98	0,86	0,82	1,72	1,66	2,54	2,52

The detailed gender-age characteristics of the clinical group depending on the type of displacement of bone fragments in humeral diaphysis fractures are shown in **table 3**.

In the adduction type of displacement of bone fragments, the leading role was played by the greater pectoral muscle, teres major muscle and the broadest muscle of the back, displacing the proximal bone fragment inwards. The fracture line was located below the insertion site of the abovementioned muscles and above the insertion site of the deltoid muscle.

In the abduction type of displacement of bone fragments, the key role was played by the deltoid muscle, deflecting the proximal bone fragment outwards. This is due to the passage of the fracture line below the site of attachment of the deltoid muscle and its biomechanical vector action.

The probability of traumatization of the brachial artery, brachial and basilar veins in the area of the proximal portion of the brachial segment by bone fragments in the abduction type of displacement is not biomechanically determined, since the bone fragments will have a laterally directed deflection vector.

In the adduction type of displacement, the risk of damage to the deep vessels in the proximal humerus is quite high, since the dominant action of the greater

Table 3 – Gender-age characteristics of the clinical group

Type of displacement of bone fragments	Men, n (%)	Women, n (%)	Average men age, years	Average women age, years
Adduction	22,3	36	39	44
Abduction	11,2	30,5	67	76

pectoral muscle, teres major muscle and broadest muscle of the back creates a potentially dangerous medial biomechanical vector of displacement of bone fragments.

Damage to the blood vessels of the humerus with disintegration of its walls was not observed in the clinical group of the study. Due to severe edema and the inability to clinically determine vascular damage, ultrasound examination was performed in 11 cases, according to which, in 4 cases, thrombosis of the brachial vessels was diagnosed. In 3 of these cases, the adduction fracture of the humerus was established. After pathogenetic treatment, the above complication was eliminated during preoperative preparation.

All 36 patients underwent metal osteosynthesis with positive functional results.

Conclusions. Based on the analysis of clinical and instrumental methods of study, a clear correlative relationship was established between the type of displacement of bone fragments leading to the threat of traumatizing the brachial artery, brachial and basilar veins. This risk increases in the adduction type of displacement, which is characteristic of patients of working age from 28 to 58 years.

Hemodiscirculatory processes can occur both during the initial impact of the traumatic factor and at the stages of transportation to the hospital, primary repositioning, violation of the technique of operative or conservative treatment, which provoked the deviation of the axis of the proximal bone fragment inwards.

In-depth knowledge of clinical anatomy and the interrelationships of various types of soft tissue structures of the humeral diaphysis will prevent the possibility of direct or indirect damage to the brachial vessels, shorten the period of incapacity for work of patients and reduce the degree of disability.

The prospects of further research. Further study of anatomical features of the vessels of the humeral diaphysis revealed by the magnetic resonance imaging and in clinical.

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АСПЕКТИ ПРОГНОЗУВАННЯ СУДИННИХ ПОРУШЕНЬ ПРИ ПЕРЕЛОМАХ ПЛЕЧОВОЇ КІСТКИ

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Резюме. Ушкодження судин при переломах кісток скелету виникають у 1,5% випадків. Причиною цих порушень можуть виступати як прямі так і опосередковані фактори впливу кісткових відламків на судинний компонент. Це призводить до гемодинамічних порушень, виникнення артеріальних та венозних тромботичних ускладнень. Прогностична оцінка виникнення ушкодження артерій та вен плеча потребує глибоких знань їх анатомо-топографічних особливостей в нормі та при варіантних змінах. Магнітно-резонансна томографія значно полегшує вивчення індивідуальних анатомічних особливостей великої кількості пацієнтів. Під час прогнозування ризику розвитку гемодинамічних розладів у пацієнтів з переломами діафізу плечової кістки практично відсутнє урахування біомеханічної дії м'язового компоненту. Значну роль у попереджені пошкодження судин відіграють методи транспортної іммобілізації ушкодженої кінцівки.

Мета дослідження. Дослідження варіантних топографо-анатомічних особливостей розташування судин плеча з подальшою розробкою плану прогностичних та діагностичних заходів попередження їх ушкодження в залежності від типу зміщення кісткових відламків при переломах плечової кістки.

Об'єкт і методи дослідження. Було проведено дослідження 32 МРТ-скани, які були виконано пацієнтам віком від 18 до 68 років з причин, не пов'язаних із з наявністю патологічних порушень судинного, м'язового та кісткового компонентів плечового сегменту. До клінічної групи увійшло 36 пацієнтів віком від 23 до 85 років із закритими переломами діафізарної ділянки плечової кістки. При обробці даних використовувалися методи непараметричної статистики.

Результати. Після обробки та вивчення результатів досліджень анатомо-топографічної групи виявлено індивідуальні та гендерні особливості розташування плечової артерії, плечової та базилярної вен. Диференційовано їх просторове взаєморозташування з групами м'язів проксимального відділу плечового сегменту. При дослідженні клінічної групи проведено диференціацію застосованих методів транспортної іммобілізації на дошпитальному етапі, проведено аналіз вектору та характеру зміщення кісткових відламків при переломах діафізу плечової кістки. Виявлено віковий взаємозв'язок між рівнем перелому та типом зміщення. Ризик ушкодження судин проксимального відділу плеча є високим при аддукційному типі перело-

му діафізарної ділянки. Поглиблення знань клінічної анатомії та взаємозв'язків різних типів м'якотканинних структур з діафізарною ділянкою плечової кістки дозволить попередити виникнення можливості прямого чи опосередкованого ушкодження судин плеча, скоротити термін періоду непрацездатності пацієнтів та знизити рівень інвалідизації.

Ключові слова: переломи плечової кістки, судини плеча, діафіз плечової кістки.

ASPECTS OF PREDICTION OF VASCULAR DISORDERS IN HUMERUS FRACTURES

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Abstract. Vascular damage in skeletal bone fractures occurs in 1.5% of cases. The cause of the disorders can be both direct and indirect factors affecting the bone fragments on the vascular component. This leads to hemodynamic disorders and the occurrence of arterial and venous thrombotic complications. A prognostic assessment of the occurrence of damage to the brachial arteries and veins requires in-depth knowledge of their anatomical and topographic features in normal conditions and alterations. Magnetic resonance imaging greatly facilitates the study of individual anatomical features of a large number of patients. When predicting the risk of developing hemodynamic disorders in patients with humeral diaphysis fractures, the biomechanical effect of the muscle component is practically not taken into account. Methods of transport immobilization of the injured extremity play a significant role in the prevention of vascular damage.

Purpose. Study of the alternative topographical and anatomical features of the location of humeral vessels with subsequent planning of prognostic and diagnostic measures to prevent their damage depending on the type of displacement of bone fragments in humerus fractures.

Object and Methods. 32 MRI scans, performed in patients aged 18 to 68 years for reasons not related to the presence of pathological disorders of the vascular, muscular and osseous components of the humeral segment, have been studied. The clinical group included 36 patients aged 23 to 85 years with closed fractures of the humeral diaphysis. The data was processed by the methods of non-parametric statistics.

Results. The findings of the study of the anatomotopographical group revealed individual and gender features of the location of the brachial artery, as well as brachial and basilar veins. Their spatial positional relationship with the groups of muscles of the proximal humerus have been differentiated. During the study of the clinical group, differentiation of the applied methods of transport immobilization at the pre-hospital stage has been made, and the analysis of the vector and nature of the displacement of bone fragments in humeral diaphysis fractures has been carried out. The age-related relationship between the level of the fracture and the type of displacement was revealed. The risk of damage to the vessels of the proximal part of the humerus is high in the adduction type of fracture of the humeral diaphysis. In-depth knowledge of clinical anatomy and the interrelationships of various types of soft tissue structures of the humeral diaphysis will prevent the possibility of direct or indirect damage to the brachial vessels, shorten the period of patients' incapacity and reduce the degree of disability.

Key words: humerus fractures, brachial vessels, stepped therapy, humeral diaphysis.

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Conflict of interest:
The authors of the paper confirm the absence of conflict of interest.

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A – Work concept and design, **B** – Data collection and analysis, **C** – Responsibility for statistical analysis, **D** – Writing the article, **E** – Critical review, **F** – Final approval of the article.

Received 20.03.2022
Accepted 10.09.2022