CURRENT STATE OF DIAGNOSING AND TREATMENT OF CLOSED DYAPHISEAL FRACTURES OF THE HUMERUS COMPLICATED BY RADIAL NERVE PALSY

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| Abstract | Traumatic radial nerve palsy is a frequent complication of humerus fractures. Significant amount of unacceptable results of treatment for this impairment motivates the physicians for ongoing investigation on optimization of diagnostic and therapeutic procedures. In this article we discuss various ideas of diagnosis and treatment of traumatic neuropathies, methods and terms of treatment for fractures of the humerus, complicated by radial nerve palsy. |
| **Keywords:** | humerus, shaft fracture, radial nerve, traumatic palsy. |

AO/ASIF — Association of Ostheosynthesis/Association for Study ofInternal Fixation Internal Fixation

КТCT — computed tomography

DASH — The Disabilities of the Arm, Shoulder and Hand (score)

DCPDCP — dynamic compression plate

EMG — electromyography

ЭНМГEMNG — electromyoneurography

ЛГMIPOMIPO — minimally invasive percutaneous ostheosynthesis

ММГMMG — mechanical myography

МРТMRI — magnetic resonance imaging

СРВNCV — nerve conduction velocity

TE — therapeutic exercises

ТГTG — thermography

УВЧUF — ultrahigh-frequency (therapy)

УЗИUS — ultrasonography

ЭМГ

*AO/ASIF*

*DASH*

Лечение закрытых диафизарных переломов плечевой кости в сочетании с травматической нейропатией лучевого нерва до настоящего времени остается актуальной проблемой неотложной травматологии. Treatment for humerus closed diaphyseal fractures complicated with traumatic neuropathy of the radial nerve still remains an urgent problem in acute traumatology.Травматическая нейропатия лучевого нерва при переломах плечевой кости встречается, по данным разных авторов, в 3,1–18,8% случаев. According to various authors, traumatic neuropathy of the radial nerve in fractures of the humerus occurs in 3.1-18.8% of cases.Наиболее часто она развивается при локализации перелома в средней (60%) и нижней (40%) третях диафиза, что связано со взаиморасположением плечевой кости и лучевого нерва [1 –3]. Most often it develops if the fracture is in the middle (60%) and lower (40%) third of the diaphysis, which is associated with the interposition of the humerus and the radial nerve [1-3]. Доля неудовлетворительных результатов лечения, обусловленных стойким неврологическим дефицитом, достаточно велика, достигая 22% [4, 5].The proportion of unsatisfactory results of treatment, due to persistent neurological deficit, is high enough, reaching 22% [4, 5].Число пациентов с длительно сохраняющимися двигательными и чувствительными расстройствами составляет 46% [6]. The number of patients with long-lasting motor and sensory disorders is 46% [6].

Рассматриваемая патология находится на стыке нескольких дисциплин: травматологии, невроло This impairment is an object of several disciplines: traumatology, neurology, neurosurgery and microsurgery.Травма Traumatologists studied the treatment for uncomplicated fractures of the humerus well. Диагностикой и лечением периферических нейропатий, в том числе лучевого нерва, чаще занимаются неврологи.Neurologists are better involved in the diagnosis and treatment of peripheral neuropathies, including the radial nerve palsy. При этом в травматологическом сообществе не существует единства взглядов по ряду вопросов тактики и методов лечения переломов плеча, сочетающихся с травмой лучевого нерва.At the same time, there is no a single idea of tactics and methods for treatment of humerus fractures, complicated with radial nerve neuropathy.

Представляет интерес адаптация диагностических и лечебных схем, принятых в травматологии и неврологии, к такому сочетанному повреждению. Adaptation of diagnostic and therapeutic schemes from traumatology and neurology for such multisystem injuries is of interest. Уточнения требуют такие аспекты диагностики нейропатии, как выбор оптимального метода визуализации и оценки функции поврежденного нерва. Such aspects of diagnosis of neuropathy, as the choice of an optimal method of visualization and evaluation of the damaged nerve function should be defined.На основе данных о характере и уровне повреждения лучевого нерва, а также о взаимоотношениях нерва и костных отломков целесообразно принимать решение о тактике лечения как перелома, так и нейропатии. It is advisable for the tactics of management for a fracture and neuropathy to be decided upon according to the type and extent of damage to the radial nerve, as well as the relation between nerve and bone fragments. Вопрос о сроках выполнения визуализирующих и функциональных исследований нерва также нуждается в уточнении.The proper time for functional and imaging study of a nerve also needs to be clarified.

В свою очередь, представляет интерес возможность и целесообразность использования многочисленных методик лечения перелома плеча (как консервативных, так и оперативных) при рассматриваемом сочетанном повреждении. In turn, the possibility and reasonability of using numerous methods of treatment for humerus fractures (both conservative and operative) remains in question as well.

Таким образом, актуальность данной темы определяется значительной распространенностью сочетанных повреждений плечевой кости и лучевого нерва, отсутствием единого подхода к диагностике и лечению подобных повреждений и сравнительно большим количеством неудовлетворительных результатов. Thus, the relevance of the topic is determined by the significant prevalence of associated injuries of the humerus and the radial nerve, the lack of a uniform approach to the diagnosis and treatment of these lesions and the relatively large number of unsatisfactory results.

Большинство авторов высказывается в пользу максимально раннего полноценного неврологического обследования пациента, заключающегося в оценке различных видов чувствительности (болевой, тактильной, температурной, дискриминационной), выявлении двигательных расстройств, выполнении специфических неврологических тестов [7–9]. Most authors are in favor of a full neurological examination of the patient, performed as early as possible which evaluates the different types of sensitivity (pain, tactile, thermal, discriminatory), identifies movement disorders, includes special neurological tests [7-9]. При этом в некоторых работах отмечается, что из-за наличия выраженного болевого синдрома, отека мягких тканей диагностика степени неврологических расстройств сильно затруднена в первые часы и дни после травмы.Ayt tAt the same time, some studies indicated that diagnosis of neurological disorders is very difficult in the first hours and days after the injury due to severe pain syndrome and soft tissue edema.В связи с этим предлагается подробное неврологическое исследование отложить на 3–4 сут, а при необходимости — и на более длительный срок [10]. In this regard, neurological examination should be delayed for 3-4 days or even longer, if necessary [10].

Хотя известно около 20 тестов для оценки состояния двигательной функции лучевого нерва, для скринингового обследования пациентов целесообразно использовать наиболее простые из них в плане выполнения и интерпретации, а именно: тесты разгибания кисти и отведения одного пальца [8]. Although there are about 20 tests for the assessment of motor function of the radial nerve, it is advisable to use the most simple of tests in terms of performance and interpretation for screening of patients, such as wrist extension and finger abduction tests [8].Выполнение этих тестов не связано с движениями в поврежденном сегменте конечности, а следовательно, они могут выполняться пациентом через короткое время после получения травмы. Implementation of these tests does not involve the affected part of the limb, and therefore, it can be performed by a patient in a short time after the injury.

Топическая диагностика на современном этапе, конечно, не должна быть ограничена лишь физикальными методами , позволяющими лишь ориентировочно судить о патологических изменениях в лучевом нерве. Certainly, the diagnosis at this stage should not be limited only by physical methods, allowing only abstract conclusion on pathological changes in the radial nerve. Для качественной и количественной оценки степени травматической нейропатии были предложены различные инструментальные методы исследования поврежденного нерва.Various methods of instrumental studies of the damaged nerve have been proposed for the qualitative and quantitative assessment of traumatic neuropathy.

Все многообразие методов исследования можно разделить на 2 группы: результатом первой из них является оценка анатомической целостности поврежденного лучевого нерва, второй — суждение о его функциональном состоянии. All methods can be divided into 2 groups: the result of the first one evaluates the anatomic integrity of the damaged radial nerve, the second - a functional state.

Классическим методом исследования анатомической составляющей повреждений периферических нервов является **ультразвуковое исследование** (УЗИ) нерва. The classic method for studying the anatomical component of peripheral nerve injuries is ultrasonography (US) of a nerve. На современном этапе развития ультразвуковых методов исследования использование высокоразрешающего УЗИ периферических нервов позволяет заменить такие сложные и дорогостоящие исследования, как компьютерная томография (КТ) и магнитно-резонансная томография (МРТ), не снижая при этом точность диагностики [11].At the present stage of development, high-resolution ultrasonography of peripheral nerves can replace such complex and costly research, as computed tomography (CT) and magnetic resonance imaging (MRI), without compromising diagnostic accuracy [11].

УЗИ лучевого нерва на протяжении плеча позволяет определить непрерывность нерва или выявить его анатомическое повреждение. US of the radial nerve within the humerus determines the continuity of the nerve or reveals its anatomical damage. При наличии повреждения исследование позволяет провести дифференцировку уровня и типа повреждения (нейротмезис, аксонотмезис, нейропраксия).If there is a damage, the study may differentiate the level and type of damage (neurothmesis, axonothmesis, neuropraxia). В случае нейропраксии также возможно установление ее причины (тракция, компрессия отломком кости или рубцами).If case of neuropraxia it is also possible to confirm its causes (traction, compression with bone fragments or scars). Таким образом, УЗИ решает задачи определения локализации, степени и характера поражения нерва.Thus, the US solves the problem of determining location, extent and type of the nerve lesion.

Преимуществами метода являются неинвазивность, относительная простота, возможность повторных исследований в динамике и получение изображения в режиме реального времени. The advantages of the method are non-invasiveness, relative simplicity, the ability to re-study over time and real time imaging.

Ряд исследователей отмечают высокую информативность УЗИ, подтверждаемую затем в ходе оперативных вмешательств [12, 13]. Several researchers have noted high informativeness of ultrasound, which is confirmed during surgical interventions [12, 13].

Альтернативным методом визуализации лучевого нерва является **магнитно-резонансная томография** . An alternative method of imaging the radial nerve is the magnetic resonance imaging.Метод обладает высокой разрешающей способностью, возможностью многоплоскостного исследования, его несомненные достоинства — неинвазивность и отсутствие ионизирующего излучения. The method has a high resolution, the possibility of omnidirectional research. The advantages are non-invasiveness and lack of ionizing radiation. TheПри помощи МРТ можно дифференцировать разрыв нервного ствола от его контузии, визуализировать внутриствольные повреждения. MRI may help differentiate nerve trunk rupture from its contusion, visualize intranerval damage. К недостаткам метода относятся трудоемкость и высокая стоимость, сложность укладок для исследования.The disadvantages include the complexity of the method and the high cost, complexity of setups for the study.Значимым противопоказанием для МРТ является наличие в теле пациента металла, обладающего ферромагнитными свойствами. A significant contraindication to MRI is the presence of metal in the body of a patient, having ferromagnetic properties.

TheПрименение МРТ позволяет определить целостThe MRI determines the integrity ­of theность нерва на протяжении сегмента конечности у пострадавших с закрытыми переломами диафиза плеча, выявить наличие гематомы, рубцов в проекции нервных стволов при свежих и застарелых повреждениях, произвести дифференциальную диагностику между травмой нервных стволов и капсульно-связочного аппарата суставов [10]. nerve of within a limb in patients with closed fractures of the humerus diaphysis, reveals the presence of hematoma, scarring in the projection of the nerve trunks in fresh and old injuries, makes a differential diagnosis between the injury of nerve trunks, joints and ligaments [10].

Нами не было найдено литературных источников, в которых обсуждалось бы сравнение МРТ и УЗИ с точки зрения чувствительности и специфичности данных методов применительно к периферическим нейропатиям. In the literature we have not found any information on a comparison of the MRI and ultrasound in terms of sensitivity and specificity of these methods for peripheral neuropathy. Этот вопрос, очевидно, нуждается в дальнейшем исследовании.This issue obviously requires further study.

Наряду с методами визуализации поврежденного нерва большое значение имеют методы функциональной диагностики. In addition to imaging techniques of a damaged nerve, functional diagnostic methods are important. Для прямой или косвенной оценки функционального состояния нерва предложен ряд методов исследования.There are some research methods for direct or indirect assessment of the functional state of a nerve.

Для исследования периферических нервов используются методики как стимуляционной, так и игольчатой **электронейромиографии** (ЭНМГ) [14]. To investigate the peripheral nerves, stimulating and needle electromyoneurography (EMNG) is performed [14]. При этом авторы расходятся в оценке эффективности конкретных ЭНМГ-методик для изучения поврежденного нерва.The authors differ in assessing the effectiveness of specific EMNG techniques for the study of a damaged nerve. Так, в работах Л.Ф. For example, reports of L.F. Касаткиной (2010) и В.Г. Kasatkina (2010) and V.G. Салтыковой (2013) показано, что для определения локализации повреждения использование одной методики стимуляционной ЭНМГ недостаточно, так как при нарушении проведения импульса по нерву резко падает амплитуда *М* -ответа, что приводит к невозможности определить скорость распространения возбуждения (СРВ) по двигательным нервам. Saltykova (2013) show that a single technique is not sufficient for determining the location of lesions, since the M-response amplitude falls sharply under the impaired impulse conduction that makes it impossible to determine the nerve conduction velocity (NCV) of motor nerves. В связи с этим наряду со стимуляционной ЭНМГ применяли метод игольчатой ЭНМГ, выявляя признаки денервации мышц [1 1, 14].In this regard, needle EMNG was used together with stimulating EMNG, in order to identify muscle denervation signs [11, 14]. В то же время М.М.At the same time, experimental studies of M.M.Одинак и соавт. Odinak et al.(2009) в экспериментальных работах убедительно доказывают достаточность методики стимуляционной ЭНМГ для полноценной диагностики повреждения нерва [15]. (2009) convincingly demonstrate the adequacy of stimulating EMNG for a full diagnosis of a nerve damage. [15]

При использовании методики стимуляционной ЭНМГ обычно анализируют следующие параметры *М* -ответа: латентность, амплитуда, форма, длительность и площадь потенциала, а также скорость распространения возбуждения по моторным и сенсорным волокнам. In stimulating EMNG the following parameters of *M*–response are normally studied: latency, amplitude, shape, length and area of the potential, as well as the nerve conduction velocity (NCV) of motor and sensory nerves. Считается, что эти параметры наиболее информативно отражают функциональное состояние нервно-мышечного аппарата и позволяют характеризовать как динамику дегенеративных и регенеративных процессов в травмированном нерве, так и степень тяжести денервационного синдрома [4, 15].It is believed that these parameters are the most informative to reflect the functional state of neuromuscular apparatus and allow to characterize changes of degenerative and regenerative processes in the injured nerve, and the severity of the denervation syndrome as well [4, 15].

Хотя паттерны ЭНМГ при различных степенях травматического поражения нерва описаны достаточно подробно, однако, по мнению некоторых авторов, при выполнении ЭНМГ могут иметь место как ложноположительные, так и ложноотрицательные результаты [14, 16]. Although electromyoneurographic patterns at different degrees of traumatic nerve lesions are described in detail, according to some authors, EMNG may give either false-positive or false-negative results [14, 16].В связи с этим необходимо уточнить оптимальные сроки проведения исследования, чтобы свести к минимуму ложные результаты, обусловленные реакцией нерва на одномоментное повреждение. In this connection, it is necessary to clarify the optimal timing of the study to minimize false results due to nerve response to an instantaneous injury.

В недавнем времени широкое распространение имела **классическая электродиагностика** — методика электрофизиологического обследования, позволяющая оценить функциональное состояние нерва и мышцы в зависимости от их реакции на электрическое раздражение [10]. Theclassic electrodiagnosishas been widely performed recently**.** This is a method of electrophysiological examination in order to assess the functional state of the nerve and the muscle, depending on its response to electrical stimulation [10].Однако с развитием ЭНМГ, обладающей лучшей чувствительностью и специфичностью, эта методика уходит в прошлое [15]. However, with the development of EMNG having the best sensitivity and specificity this technique goes back [15].

В отличие от ЭНМГ, **механомиография** (ММГ) основана на измерении вызванных механических мышечных ответов. Unlike EMNG, mechanical myography (MMG) is based on the measurement of mechanical muscle responses. Метод позволяет изучить сократительную функцию мышц и является существенным дополнением к широко внедренным в клиническую практику электромиографическим методам [6].The method allows to study the contractile muscle function and is an essential complement to the widespread introduction of electromyographic methods into clinical practice [6].

Причинами нарушений сократительной способности мышц могут быть ишемические расстройства или нарушение трофического влияния нерва на мышцу, но самая частая причина нарушений сокращения скелетных мышц — денервационные расстройства. The causes of muscular contractility disorders may be ischemic disorders or disturbance of the trophic effect of a nerve onto a muscle, but the most common cause of disorders of skeletal muscle contraction is denervation disorders. Показатели механического ответа зависят не только от числа активных мышечных волокон, но и от функционального состояния сократительного аппарата, что демонстрируется фактом изменения характеристик механического ответа независимо от показателей электрического ответа [6].The mechanical response depends not only on the number of active muscle fibers, but also on the functional state of the contractile apparatus, which is demonstrated by the fact that changes in the mechanical response characteristics do not depend on the electric response characteristics [6].

**Термография** , или тепловидение — метод регистрации инфракрасного излучения тела человека, позволяющий, в частности, оценить нарушения микроциркуляции и нейрососудистой регуляции при по The thermography**,** or thermal imaging is a method of registration of the infrared radiation of the human body, allowing, in particular, to evaluate microcirculatory disorders and neurovascular regulation in injuries of nerve trunks due to changes in skin temperature in the respective areas of innervation.

The computedВ настоящее время в современных клиниках широко используется компьютерная термография (ТГ) с применением высокоточных азотных тепловизоров, позволяющих определить разницу температур до 0,01The c thermography (TG) with high-precision nitrogen thermal imagers are widely used in modern hospitals, allowing to determine the temperature difference up to 0.01 градуса по Цельсию.degrees Celsius. Благодаря высокой разрешающей способности, встроенной системе калибровки, неинвазивности данный метод исследования возможно использовать не только с диагностической целью, но и для контроля за процессом регенерации нерва [10].Due to its high resolution, built-in system of calibration, and non-invasiveness this method may be used not only for diagnostic purposes, but also to monitor nerve regeneration [10].

При этом использование данного метода имеет ряд ограничений. The use of this method has several limitations.Так, ТГ позволяет определить локализацию изменения температуры в пораженных тканях конечности и таким образом качественно оценить наличие повреждения нерва. Thus, the TG determines the location of temperature changes in the affected limb tissues and thus qualitatively assesses the presence of nerve damage. Однако судить по косвенным данным о характере и степени повреждения нерва, а также о точной локализации повреждения нельзя [10, 11].However, we cannot conclude upon the type and extent of the nerve damage as well as the precise location according to indirect findings [10, 11].

Также в качестве дополнительных методов исследования могут быть использованы реовазография, лазерная допплеровская флуометрия, исследования вызванных потенциалов нервов и мышц и регистрация соматосенсорных вызванных потенциалов, вызванных симпатических кожных потенциалов [10]. Also, rheovasography, laser Doppler flowmetry, the study of induced potentials of nerves and muscles, recording of somatosensory induced potentials, induced cutaneous sympathetic potentials can be used as additional research methods [10].

Таким образом, взгляды авторов на объем и сроки выполнения визуализирующих и функциональных исследований поврежденного нерва значительно различаются. Thus, the authors' views on the volume and timing of imaging and functional studies of the damaged nerve are significantly different.Между тем, тактика лечения сочетанного повреждения плечевой кости и лучевого нерва определяется именно по результатам проведенного обследования, что показывает необходимость совершенствования диагностического алгоритма. Meanwhile, the tactics of treatment for the associated damage of the humerus and the radial nerve is determined by the results of examination, which shows the need to improve the diagnostic algorithm.

При лечении неосложненных переломов диафиза плечевой кости вполне успешно используется ряд методик, как консервативных, так и оперативных. In the treatment of uncomplicated fractures of the humerus diaphysis a number of techniques, both conservative and operative, is quite successfully used.Обсуждения заслуживает возможность использования этих методик в случае сопутствующего повреждения лучевого нерва. The opportunity to use these methods in the case of collateral damage to the radial nerve deserves to be discussed.

В настоящее время раннее восстановление функции конечности является непременным атрибутом консервативного лечения [17, 18, 20, 21]. Currently, early recovery of limb function is an essential feature of conservative treatment [17, 18, ​​20, 21].Применительно к лечению диафизарных переломов длинных трубчатых костей, в том числе плеча, в 1960–80 гг. With regard to the treatment of diaphysis fractures of long bones, including the humerus, theметод функционального лечения был детально разработан *A.* functional treatment method was worked out in detail by *A.* *Sarmiento* и заключался в наложении гипсовой повязки на плечо при свободных плечевом и локтевом суставах, что позволяло осуществить ранние активные движения в них в процессе консолидации.*Sarmiento* in 1960-80s and consisted of applying plaster bandage on the humerus with free shoulder and elbow joints, which allowed for early active motion in them in the process of consolidation.Метод привлекает легким весом повязки, хорошим косметическим результатам и быстрой реабилитацией поврежденной конечности. The method is attractive due to the lightweight bandage, good cosmetic results and faster rehabilitation of the affected limb. The Восстановление функции травмированной руки достигает 95% по сравнению с неповрежденной [17].recovery of the injured arm function reaches 95% as compared to intact [17].

Метод, предложенный *A.* The method proposed by *A.* *Sarmiento* , нашел широкое распространение в ряде стран, в том числе в бывшем СССР.*Sarmiento,* was widely adopted in a number of countries, including the former Soviet Union. Различными авторами предложены методики консервативного лечения диафизарных переломов плеча, основанные на применении метода *A.*Various authors proposed methods of conservative treatment of diaphysis fractures of the humerus based on the method of *A.Sarmiento* и отличающиеся материалом и формой повязок, а также сроками их применения [18–20]. *Sarmiento* and differed in the material and shape of bandages, as well as the timing of its application [18-20].

Сообщается также об успешном опыте лечения этим методом больных с диафизарными переломами плечевой кости в составе политравмы, а также осложненных повреждением лучевого нерва [21]. It is also reported on successful treatment with this method in patients with diaphyseal fractures of the humerus as a part of polytrauma and complicated with an injury of the radial nerve [21].

Методика *A.* The method of *A.* *Sarmiento* имеет ряд ограничений в применении.*Sarmiento* has some limitations in the application.Оскольчатый характер перелома или расположение перелома близко к суставу препятствует адекватной иммобилизации поврежденного сегмента конечности укороченной повязкой. The comminuted fracture of location of the fracture close to the joint prevents adequate immobilization of the damaged part of a shortened limb bandage. В связи с этим были разработаны методики фиксации конечности на различных шинах, как с применением скелетного вытяжения, так и без него.Therefore, techniques for various limb frame fixation either with skeletal traction or without it were developed. Для лечения переломов плеча постоянным вытяжением было предложено большое количество шин и аппаратов (Приорова, Богданова, Ланда, Созон-Ярошевича, Белера, Семенова, Реутова, Назаретского и др.).A large number of frames and devices were suggested for the treatment of humeric fractures with constant traction (Priorov, Bogdanov, Land, Sozon-Yaroshevich, Beler, Semenov, Reutov, Nazaretsky et al.).Общими недостатками таких аппаратов являются громоздкость, неудобство для пациента и несовершенство узла вытяжения [22–24]. Наибольшее распространение получила отводящая шина Центрального института травматологии и ортопедии им. General disadvantages of such devices are massiveness, inconvenience for a patient and the imperfection of the traction unit [22-24]. The abducting frame of the Central Institute of Traumatology and Orthopedics n.a. Н.Н. тюфю N.N.Приорова, не лишенная, впрочем, вышеупомянутых недостатков. Priorov appeared to be mostly widespread. However, it is not devoid of the above-mentioned drawbacks.После предварительной фиксации руки на шине под местной анестезией выполняется одномоментная репозиция отломков, после чего производится скелетное вытяжение с постепенно уменьшающейся тягой, общим сроком 4–6 After the pre-fixation of an arm on the frame under local anesthesia, simultaneous reposition of bone fragments is performed, followed by skeletal traction gradually decreasing within the 4-6нед [23]. weeks [23].Также описаны методики двухэтапного консервативного лечения переломов плечевой кости, когда после скелетного вытяжения применяются короткие функциональные повязки [22]. Also, two-step procedures of conservative treatment of fractures of the humerus are described, when the short-functional bandages are applied after skeletal traction [22].

Лечение при помощи аппаратов без чрескостной фиксации было предложено Ю.А. Treatment using devices without transosseous fixation was suggested by Y.A. KaloiКалои (1987) и А.Ф.ЛЛ (1987) and A.F.Лимоновым (1997). Limonov (1997). Недостатком таких конструкций является отсутствие полноценного вытяжения по оси сегмента конечности, а также постоянное давление опорных элементов на кожу и мягкие ткани. The disadvantage of such structures is the lack of a full traction along a limb segment axis, as well as the constant pressure of supporting elements on the skin and soft tissues.Сдавление мягких тканей является тем более нежелательным в случае имеющейся нейропатии, так как может усилить ишемию нерва [23, 24]. Compression of soft tissue is especially undesirable in the case of existing neuropathy, since it can aggravate nerve ischemia [23, 24].В настоящее время отводящие конструкции используются сравнительно редко. Today, abducting constructions are used relatively rarely.

Очевидно, что консервативный метод может быть применим только при уверенности в анатомической целостности нерва и в том случае, если поврежденный нерв не находится в интерпозиции между костными отломками, что с высокой вероятностью приведет к его вовлечению в костную мозоль. Obviously, the conservative approach may be applied only when the nerve anatomical integrity is confirmed and the damaged nerve is not in the interposition between the bone fragments, which may involve it when forming the callus.В связи с этим вопрос о визуализации лучевого нерва на ранних сроках лечения перелома плеча приобретает особо важное значение. In this regard, visualization of the radial nerve in the early stages of treatment for fractures of the humerus is particularly important.

Early use of shortened bandages allows to start physiotherapy with installation of electrodes in the area of ​​the shoulder joint and the forearm/wrist without loss of immobilization, and start early therapeutic exercises [25].

Such conservative treatment deficiencies, as the need for prolonged immobilization, lack of precision repositioning of bone fragments, the possibility of secondary displacement, inconvinience of abducting structures, gradually push the method out of active use in traumatology. Since Lorenz Böhler in his work "Against the surgical treatment of recent diaphyseal fractures of the humerus", published in 1964, argued that the operative treatment of fractures of the humerus was carried out only in exceptional cases, a lot has changed. Today, the surgery becomes the rule, the conservative treatment is relatively rare [27]. The surgical treatment has become the "gold standard" due to the development of modern fixators such as intramedullar pins without reaming and plates with angular stability [19, 26, 27].

In terms of quality of life of patients, the surgical treatment has several advantages as well. Properly performed osteosynthesis allows painless postoperative rehabilitation to be carried out, provides a comfortable condition of the patient, in some cases, allowing earlier return to work [26, 27].

In fact, the range of opinions about the use of the best methods of surgical treatment, is reduced to a choice between the different modifications of plates, pins or external fixation devices. Arguments of supporters of each of these techniques, as well as given results, are almost equally convincing. However, each technique has well known drawbacks.

Discussion on various methods of external fixation for the treatment of diaphyseal fractures of the humerus continues today. Either rods or wires have supporters. Some authors promote a hybrid design. Some authors also believe that the external fixation device should be installed in rare cases: severe soft tissue injuries, gunshot fractures, polytrauma and complications after internal fixation [19].

Supporters of wires note its minimal invasiveness, almost full absence of contraindications and the possibility of eliminating all kinds of bone fragments displacement. In Russian literature the undisputed leader is the Ilizarov apparatus and its modifications proposed by different authors [29, 30]. Numerous works have been devoted to various configurations of devices, the combination of transosseous rods and wires and transosseous elements and casts [28-32].

The disadvantages of wire devices include transsegmental installation, which doesn’t exclude the possibility of damage to the neurovascular bundles, the complexity of use, significant dimensions. Under excessive distraction of the humerus traction radial nerve neuropathy may develop [33].

Reporting on the results of treatment of 40 patients with fractures of the diaphysis of the humerus using the rodapparatus of external fixation, V.D. Shischuk et al. (1991) point out the following advantages of the method:

- Ease of operation and a short time (30-40 minutes);

- The possibility of applying for a medical transport immobilization;

- A slight risk of damage to major vessels and nerve trunks;

- Quick recovery of the affected mobility;

- Facilitation of wound care in open lesions [1].

At the same time, greater number of inflammatory (7.1% and 5.3%, respectively, of which osteomyelitis - 3.55% and 1.3%, respectively), and mechanical (traction radial nerve injury 6.8% and 2.6% respectively, destruction of transosseous elements - 10.7% and 2.0%, respectively) complications is noted compared to the wire apparatus [34].

If necessary, operative exploration of the radial nerve is performed through a separate incision, according to the location of a nerve damage [37].

The question of the patients’ life quality has been particularly important recently. Disadvantages of external fixators, based upon inconvenience for patients, the need for long-term care for the area with transosseous elements incline doctors to opt for internal fixation [40, 46].

The success of plate osteosynthesis is largely associated with an adequate access [19, 37]. In the presence of traumatic neuropathy of the radial nerve, the fracture of the humerus is usually located at the level of the middle and lower third of the diaphysis. Accordingly, the access to the fracture site is at a level of close contact of the humerus and the radial nerve. When planning the operation, the question of the radial nerve exploration is extremely important. Then, the access is selected taking into account the convenient visualization of the nerve [36, 37]. Currently, there is no consensus about the need to separate the nerve during the surgery. Nevertheless, considering various approaches to the humerus (anterolateral, posterior, medial, lateral), authors mention the convenience of examination and separation of the radial nerve [19, 35-37].

However, the presence of the radial nerve in the projection of the interventional access may cause complications associated with its intraoperative injury. The radial nerve may be injured, even completely cut. It may also appear compressed with tools or between the plate and the bone [19, 38, 39]. According to *H. Paris et al.*, in patients with fractures of the humeral diaphysis operated on using plate osteosynthesis, postoperative radial nerve neuropathy was observed in 4-5.1% of cases, also in 1.5-3% of cases infectious and inflammatory complications developed [40].

In unstable comminuted fractures, as well as in patients with severe osteoporosis, the so-called minimally invasive osteosynthesis *(Minimally Invasive Percutaneous Osteosynthesis – MIPO)* is performed. The *LCPs (Locking Compression Plates)* are implanted through a small incision without exposure of the fracture area. This minimally invasive technique allows to get good functional results with minor trauma of soft tissues [41, 42]. The *MIPO* hasalso been successfully used for the treatment of fractures of the humerus, complicated with damage to the radial nerve. The radial nerve is explored through a separate small incision on the outer surface of the upper arm [43].

Speaking of intramedullary osteosynthesis, following advantages are normally noted: it minimally affects muscles and periosteal structure, does not prevent the formation of periosteal callus, does not require additional external immobilization, allows early load and movement at adjacent joints [44-48]. The operation's success is largely determined by adequate reposition of bone fragments. In some cases, the main difficulty is elimination of the rotational displacement [49].

The minor trauma of osteosynthesis is essential in humerus fractures complicated by neuropathy of the radial nerve, as it allows the nerve not to be additionally affected in the course of making the access and manipulation with fragments [36]. However, closed osteosynthesis shall probably initiate traction injuries or contusion of the nerve during reposition. In cases of long oblique or spiral fractures of the middle third of the diaphysis, the nerve may stuck in the callus if it locates between bone fragments. Finally, if the wrong length of the inter-locking nail is selected there is a risk of damage at the distal radial nerve in distal fixation on the lateral side [50].

The last complication doesn’t occur when *Fixion* expandable nails without interlocking screws are used. This nail is inserted in a reduced diameter configuration and then expanded with the saline administered under high pressure. Then, the nail adapts to the intramedullary canal ("hour-glass" shape). The method, however, may only be used in fractures of type A located at some distance from metaphyses [51].

According to foreign publications, flexible (elastic) nails are also used widely. Particular, flexible precurved nails by *AO/ASIF*, Enders, *Hackethal* and *Marchetti* are used, allowing to achieve stable osteosynthesis [52, 53]. The absence of distal locking prevents damage to the radial nerve in the lower third of the upper arm [53]. Unfortunately, we did not find available publications, describing the deliberate use of such nails in fractures of the humerus complicated with the radial nerve palsy.

There is no significant difference between the retrograde and anterograde insertion of nails regarding possible effects on the radial nerve either noninvolved or damaged [52, 54]. Complications of nails insertion in some way are mainly associated with possible damage to the rotator cuff in antegrade installation of a nail, or the formation of large bone defect in retrograde installation [53-55].

Considering the therapy for traumatic neuropathy, we cannot ignore two major contentious issues discussed in the literature: how soon it should be initiated and in what amount.

In papers written by traumatologists, neurologists, neurosurgeons, there is a variety of therapy for the damaged nerve. Traumatologists, as a rule, face with this problem at early stages after injury. However, they focus primarily on the treatment of a fracture [5]. Classical drugs used in the treatment of neuropathy, are cholinesterase inhibitors (Proserin) and vitamins of group *B* [10].

Some authors mentioned neurotrophic drugs of different groups, rheology-active drugs, analgesics. However, in the majority of studies they have not analyzed phasing and pathogenetic relevance of the proposed schemes [5, 10, 58].

Neurologists and neurosurgeons, who usually see such victims at later stages, months after the injury, are paying more attention the issue of treatment of neuropathy. The choice of drugs used by them is considerably wider [15, 56, 57]. Many papers mentioned cholinesterase inhibitors (Galantamine, Proserin, Ipidacrine) [56, 59]. S.A. Zhivolupov et al. (2010) points out the advantages of Neiromidin (Ipidacrine) due to the presence of both peripheral and central mechanisms of influence on neuroplasticity, which allows not only stimulating the recovery of neuromotor apparatus, but also affecting the diasсhisis arrest, developing as a result of nerve trunk injury [57]. M.N. Sharov et al. (2008) writes about advantages of Neiromidin over Proserin noting the possibility of early treatment, fewer side effects, good tolerance, and most importantly, the blockade of potassium permeability of the membrane, which leads to an increased activity of the presynaptic axon and then to increased stimulation of post-synaptic nerve cell [59].

In the paper of E.I. Sholomova et al. (2012) neuroprotector Cortexin was used. They noted confirmed positive changes during neuropathic lesions compared to patients treated with standard therapy [60].

Drugs improving microcirculation (Pentoxifylline, nicotinic acid drugs, Rheopolyglukin) are widely used [10, 58].

V.I. Pankiv (2006), referring to works of German authors, describes the use of physiological pyrimidine nucleotides (Keltican-N) in the complex therapy of neuropathies. The drug is administered orally and parenterally. He concludes about the positive effect – quickly relieved symptoms and improved quality of life [61].

D.S. Afanasyev (2004) made intraosseous blockades by local anesthetics, glucocorticoids, and autologous blood at the level of nerve damage. According to the author, the mechanism of blockades effect is associated with the anesthetic influence on the intraosseous nerve endings, resulting in a reduced pathological nociceptive afferentation at the segmental level. As a result, it improves microcirculation and metabolism, stimulates reparative regeneration, resolve fibrotic and scar tissue [10].

For the treatment of pain, analgesics of different groups are used. In the presence of autonomic pain, some authors recommend phenothiazine drugs – Tisercin, Etaperazin [10], as well as Gabapentin or Pregabalin [15].

Opinions of the authors on the question of the possible progress of the recovery of the damaged nerve are often completely opposed: on the one hand, for example, M.M. Odinak (2009) argues that the regenerative sprouting can be accelerated by more than 6 times using drugs. On the contrary, S.A. Chistichenko (2005) says that the nerve recovery cannot be accelerated, and the aim of the treatment for neuropathy is elimination of factors preventing recovery at the early stage. In this case, nerve regeneration time will not exceed the normal physiological time [15, 58].

Physiotherapy has an important influence as part of the complex management for the damaged nerve. Generally, the literature mentions various techniques of exposure to electromagnetic fields and impulses, ultrasound, and heat [10, 15, 67]. Electrotherapy (impulse and continuous currents, UHF and decimeter wave therapy, alternating magnetic field), ultrasound and thermal procedures are performed. Some authors emphasize the leading role electroneurostimulation in terms of acceleration axonal regeneration and intensification of metabolic processes. More effective treatment and better results of direct electrical stimulation of the nerve or several nerve trunks through implanted electrodes during surgery or radiation by laser rays light implanted through the implanted light guide are noted.

The conscious participation of the patient in the rehabilitation process is extremely important, which is performed through therapeutic exercises (TE) [15]. The literature describes methods of TE, consisting in performing active and passive movements adjacent and remote joints, free from immobilization. The importance of early initiation of TE is emphasized. In the early period idiomotor exercises for denervated muscles with simultaneous movements in symmetrical muscles as well as systematically carried out full amplitude passive movements in a slow pace for stimulation of a damaged peripheral nerve segment are performed [10]. Authors also note prohibition of intense prolonged exercise, as paretic muscles are characterized by fatigue, and overdosed exercises lead to increased muscle weakness [56].

Among Russian and foreign authors there is no consensus about indications, timing and methods of surgical treatment of traumatic neuropathies. Some researchers offer to perform exploration of the radial nerve at later stages, not earlier than 6 months after the injury, in connection with the possibility of spontaneous recovery of nerve function within these terms [62-65]. On the contrary, some authors propose to perform obligatory decompression of the radial nerve during emergency surgery [19]. Alternatively, simultaneous surgical revision of the radial nerve and osteosynthesis are considered obligatory when symptoms of axonopathic damage occur. Preference should be given to the closed intramedullary fixation and revision of the nerve may be performed through a small incision on the exterior lateral surface of the upper arm [10].

A.A. Bogov et al. (2009), analyzing injuries in victims with concomitant fractures of the humerus and the radial nerve injury, marks discontinuity of the nerve in 11 cases of 45 (24.4%), previously operated on for a fracture of the humerus. At the same time, the radial nerve was operated on in 38 patients (84.4%). If the anatomical continuity of nerve was confirmed, endoneurolysis was performed, and in the presence of nerve defect (depending on the size of the defect), neurosuture or nonvascularized plastic surgery were performed. The authors recommended surgical treatment of neuropathy in the absence of positive changes of conservative treatment in 2-3 months [2].

To evaluate the results of treatment, most authors offer to use the same methods as for the diagnostic study of patients – physical and instrumental (ultrasound, MRI, EMNG) [4-6, 10, 16, 58].

Sensitive and motor functions of limbs are studied as a part of the physical examination. The technique of neurological examination of patients with radial nerve neuropathy over time is suggested [66]. Movement disorders and sensitivity are assessed according to a 6-score scale. The studies include assessment of algesthesia, two-point discrimination, tactile and thermal sensitivity, feeling of pressure. Quantitative assessment of movement disorders and sensitivity over time determines indications for surgery and objectively evaluates results of surgical treatment. To assess the sensitivity disorders in the autonomic innervation area of ​​the damaged nerve the following scale is used: S0 – anesthesia, S1 – vague pain, S2 – hypoesthesia with hyperpathia, S3 – hypoesthesia with decreasing hyperpathia, S4 – hypoesthesia without hyperpathia, S5 – normal sensitivity.

The scoring scheme proposed by L. McPeak(1996) and M. Weiss (1986) is used to assess muscular strength: M0 – no contractions (paralysis), M1 – barely noticable contractions, M2 – distinct contraction without joint movement, M3 – weak movement in joints (a useful degree of recovery), M4 – a full range of motion in the joint overcoming some resistance, M5 – complete range of motion against gravity of the limb overcoming resistance equivalent to a healthy symmetrical muscle.

It should be noted that the assessment is relative and largely depends on the experience and subjective faults of a physician. Consequently, the diagnosis either of the damage extent or the degree of recovery needs further development and refinement.

The complex assessment of the results considers clinical parameters (pain, lack of mobility of bone fragments at the fracture level, muscle strength, sensitivity, vegetative trophic disorders, symptoms of nerve regeneration), as well as objective methods characterizing fracture healing, nerve conduction, electrical excitability of muscles, the state of the peripheral circulation and thermoregulation of the skin [67]. In the study of the severity of pain and quality of life of the same author, V.G. Ninel scale was used to study the intensity of pain and *DASH Outcome Measure* [67]. The latter, in our opinion, has the disadvantage – the assessment of own capabilities in trauma of the right or left hand in right-handed patients will be significantly different (though, like the left-handed).

The analysis of the studied literature leads to the following conclusion.

The fracture of the diaphysis of the humerus combined with traumatic neuropathy of the radial nerve is the complex damage of the musculoskeletal system, both in terms of diagnosis and treatment. The main objective of the diagnostic phase is to assess the structure and function of the damaged radial nerve. On the basis of these data, it is advisable to plan the tactics of surgical or conservative treatment of humerus fractures, as well as to evaluate the need for surgical intervention on the radial nerve and determine the amount of neurotrophic therapy. In terms of the diagnosis of traumatic neuropathy, it is necessary to clarify the scope and the optimal timing of the research. The mostly discussed issues of treatment are the need for revision of the radial nerve in the osteosynthesis of the humerus, and the amount and timing of the therapeutic treatment of neuropathy. Indications for surgical intervention of the radial nerve in the long-term period in the absence of effective conservative treatment also need to be clarified.

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