Research Article
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Sarcopenia in Patients After Severe Brain Injury

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INTRODUCTION This article deals with the problem of sarcopenia in patients after severe brain injury. It presents the results of the comparative analysis of a group of patients and a group of volunteers with performed muscle fiber ultrasound.

RELEVANCE Sarcopenia is a serious complication in a critically ill patient. It appears early and progresses rather quickly during the patient's critical condition.

In order to diagnose sarcopenia, both radiation and ultrasound methods can be used. The use of ultrasound methods is less labor-intensive, energy-consuming, and economically costly and does not involve an increase in radiation exposure to the patient. The paper highlights the use and comparison of these methods in patients after severe brain injuries.

AIM OF STUDY To assess the severity of sarcopenia in patients after severe brain injuries.

MATERIALS AND METHODS 25 patients were included in this study with an average age of 56.75±19.84 years, ranging from 22 to 82 years, after severe brain injury in a minimally conscious state according to the FOUR (Full Outline of Unresponsiveness) scale, median 12 (12; 15) points. The assessment was carried out in the first 3 days from the moment of admission to the Federal Research and Clinical Center of Intensive Care Medicine and Rehabilitology. For comparison purposes, the study included 19 volunteers aged 35.63±7.02 years, ranging from 21 to 47 years.

RESULTS The data obtained indicate that patients after severe brain injuries had pronounced muscle fiber disorders affecting its thickness and echogenicity. The thickness of the biceps on the side of the brain injury was 0.93±0.27 cm (min 0.5; max 1.58) and the thickness of the biceps on the side opposite to the brain injury was 0.62±0.2 cm (min 0.27; max 0.93) with p=0.0007, statistically significant. In terms of echogenicity, the differences were not statistically significant (p=0.1). The thickness of the triceps on the side of the brain injury was 0.5±0.17 cm (min 0.25; max 0.82) and the thickness of the triceps on the opposite side to the brain injury was 0.38±0.14 cm (min 0.2; max 0.8) with p=0.028, statistically significant, while the degree of echogenicity according to the Modified Heckmatt scale on the side of the brain injury was 2.5 [2.0; 3.0] (min 2.0; max 4.0), and on the opposite side — 3.0 [3.0; 4.0] (min 2.0; max 4.0), p=0.01, statistically significant. The thickness of the brachioradialis on the side of the brain injury was 0.59±0.15 cm (min 0.39; max 0.92), on the opposite side — 0.50±0.17 cm (min 0.25; max 0.86), p=0.06, statistically significant; while the degree of echogenicity was 2.0 [2.0; 3.0] (min 1.0; max 4.0) on the side of the brain injury and on the opposite side to the brain injury — 2.5 [2.0; 4.0] (min 2.0; max 4.0), p=0.03, statistically significant. Pronounced statistically significant differences were also obtained in the thickness of the rectus femoris muscle (p=0.06) and its echogenicity (p=0.017). In comparing these indicators with the muscles of healthy volunteers for all indicated parameters p<0.05, in most cases p=0.000001, statistically significant. Using computed tomography of the lumbar spine, a decrease in the cross-sectional area of the psoas muscle was revealed. The following values were obtained from the patients: psoas muscle cross-sectional area on the right side: 7.66±2.72 cm^2 (min 3.84; max 12.95), psoas muscle cross-sectional area on the left side: 7.85±2.64 cm^2 (min 3.7; max 12.6), Skeletal Muscle Index: 53.33±15.34 (min 28; max 81).

CONCLUSION Diagnostic ultrasound methods to assess sarcopenia in patients after severe brain injuries have confirmed their effectiveness. In the present study, this method received a pronounced correlation with radiological techniques to identify patients affected by sarcopenia. We obtained statistically significant differences in the group of volunteers and patients, and some parameters differed by more than 2 times, which indicates the presence of severe sarcopenia in this group of patients.

Keywords: critical illness; diagnostic ultrasound; brain injury; rehabilitation, chronic disorders of consciousness

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BMI - body mass index
CT - computed tomography
US - ultrasound
SMI - Skeletal Muscle Index

INTRODUCTION

Intensive care of patients suffering from severe brain injuries is associated with a struggle with many complications, in particular, the loss of muscle mass and the development of protein-energy undernutrition in such patients play a special role.

Sarcopenia is the most severe complication of critical conditions. The term "sarcopenia" refers to a syndrome characterized by progressive and generalized loss of skeletal muscle mass and disruption of its normal functioning with an increased risk of such adverse outcomes as a pronounced decrease in physical activity, declining quality of life and an increased risk of death [1, 2].

Sarcopenia appears early and progresses quite quickly during the patient's stay in a critical condition, the longer the patient's stay in a critical condition, the less muscle mass they have left. In the report by Puthucheary et al. a loss of 12.5% of the rectus femoris mass was noted within 7 days after admission to the intensive care unit, and a pronounced imbalance in protein synthesis and consumption was also revealed [3]. Muscle mass decrease in critically ill patients may play a significant role in diagnosing patients at increased risk of negative outcomes of the course of the disease, given the research evidence that skeletal muscle loss in critically ill patients leads to prolongation of mechanical ventilation, lengthening of hospital stay and mortality. Given these data, it is important to measure muscle mass and its structure, which can help identify patients who are more promising in terms of rehabilitation prognosis, and accordingly focus on their therapy.

In order to assess muscle mass, the following methods are currently used: anthropometric ones - accessible to any attending physician and not requiring expensive medical equipment - include the measurement of body weight, height and, based on them, the calculation of body mass index (BMI); measurement of the muscle circumference of the shoulder, forearm, hips, skinfold thickness on the triceps and abdomen [4, 5]. These methods have found a significant place in the work of clinical specialists due to their simplicity, low labor and time costs, and relative independence from the experience of the researcher. These methods evaluate the patient's total body weight and the individual thickness of the limbs and subcutaneous fat layer. However, it is impossible to reliably speak about the change in the muscle fiber and its structure, at the same time, its initial changes can give us the opportunity to make assumptions about the future fate of the patient's muscle mass - its loss or growth, depending on the measures taken.

In the modern world, methods of medical diagnostic radiology, which have high sensitivity and specificity and in practice have shown clinical validity, play a significant role in the diagnosis of sarcopenia [6, 7]. However, these methods are labor-intensive, energy-consuming, and economically costly and are associated with increased radiation exposure to the patient.

In addition to methods of medical diagnostic radiology, bio-impedancemetry can be used to assess muscle mass, but this method is still not widely used [8].

Of the least expensive, and most importantly, bedside methods, one can single out diagnostic ultrasound (US), given its undoubted advantages in the form of the speed of procedure, low cost, availability of ultrasound devices in almost any intensive care unit, and correlation of its results with medical diagnostic radiology. Recently, the use of ultrasound diagnostic methods in clinical practice has been increasing, there are various bedside methods for diagnosing patient condition, such protocols as FAST (Focused Assessment with Sonography for Trauma), BLUE (Bedside Lung Ultrasound in Emergency), assessment of vena cava filling after diagnosing the patient's water load and the placement of various ultrasound-guided catheters [9–11]. A special advantage is that these procedures can be performed - with proper training and practice - not only by a functional diagnostic doctor, but also by doctors of other specialties.

Assessment of the level of sarcopenia in patients after severe brain injuries can help in developing further therapy strategies, determining rehabilitation potential and prognosis.

MATERIAL AND METHODS

The study included patients in a minimally conscious state after severe brain injuries, undergoing treatment at the Federal Research and Clinical Center of Intensive Care Medicine and Rehabilitology (the Center) in the intensive care units for patients with brain injuries in 2021.

Given the lack of diagnostic criteria for ultrasound diagnosis of sarcopenia, a group of volunteers was evaluated [12]. In 2021, volunteers from the medical staff of the Center were selected as a control group: junior medical staff, doctors and heads of the departments. The study was approved by the Ethics Committee of the Federal Research and Clinical Center of Intensive Care Medicine and Rehabilitology, protocol No. 5/20/7 dated December 23, 2020. All the volunteers signed an informed voluntary consent for the research.

A total of 25 patients and 19 volunteers were included in the study. The distribution by sex and age among patients was as follows: men — 16 (64%), and women — 9 (36%). The mean age was 56.75±19.84 years (range 22 to 82 years).

Among the volunteers, men made up 7 (37%), and women - 12 (63%). The mean age was 35.63±7.02 years (range 21 to 47 years).

The level of patient consciousness at the time of the study was minimal. According to the FOUR (Full Outline of Unresponsiveness) scale, the median was 12 (12; 15) points.

Inclusion Criteria:

For volunteers: practically healthy faces, absence of pronounced musculoskeletal disorders.

For patients: (the patients were assessed in the first 3 days from the moment of admission to the Center):

— more than 30 days from the moment of primary injury to admission to the Center for further treatment;
— disorders of consciousness - minimally conscious state;
— prolonged immobilization, more than 30 days;
— independent breathing through a tracheostomy tube;
— stage 1 and 2 pressure injuries.

Exclusion Criteria:

— need for vasopressor or inotropic support;
— need for procedural sedation;
— liver or kidney failure, including need for renal replacement therapy;
— muscular dystrophy in history;
— diabetes;
— pronounced spastic dysfunction of the limbs.

Research methods: Volunteers were evaluated according to the following program:

1. Anthropometric measurements - height, weight, BMI, circumference of the shoulder, forearm, triceps skin fold thickness.

2. Diagnostic ultrasound: measurement of the thickness of biceps, triceps, rectus femoris, brachioradialis and their echogenicity.

Patients were evaluated according to the following scheme:

1. Anthropometric measurements - height, weight, BMI, circumference of the shoulder, forearm, triceps and abdominal skinfold thickness.

2. Diagnostic ultrasound: measurement of the thickness of biceps, triceps, rectus femoris, brachioradialis and their echogenicity.

3. Computed tomography (CT) at the level of L3 vertebrae: measurement of psoas muscle cross-sectional area, skeletal muscle index (SMI).

4. Measurement of biochemical parameters in blood serum: total protein, albumin, prealbumin, transferrin, glucose, cholesterol and triglycerides.

5. Determination of nitrogen loss in urine and calculation of nitrogen balance.

Determination of biochemical parameters in blood was carried out on an AU480 chemistry analyzer (Beckman Coulter, USA).

For indirect calorimetry, a Medgraphics CPX Ultima gas exchange analysis system (MGC Diagnostics Corporation, USA) was used.

Daily urinalysis parameters were measured using an AU480 chemistry analyzer (Beckman Coulter, USA).

Nitrogen loss was evaluated by assessing 24-hour urine and measuring the level of nitrogen in it. 4 g were added to the obtained values of the nitrogen level due to the existence of non-urea nitrogen losses in the urine and excretion with the stool and through the skin [13].

Weighing was carried out using a Linet Eleganza 3XC scale bed (Linet, Czech Republic).

Height was measured with a metric tape measure, forearm and shoulder circumference - with a tape measure, triceps skin fold thickness - with a caliper.

Ultrasound examination was performed with the help of a Logiq S7 Expert R3 device (General Electric Ultrasound Korea, Korea) using a multifrequency linear transducer with light pressure on the skin. Ultrasound machine settings were as follows: frequency: 12–15 MHZ, the frequency was selected dynamically, taking into account the depth of the muscle fiber. All studies were conducted by the same physician. Preparation for the study: all the patients were in a horizontal position on their backs, in a relaxed state, with the lower and upper limbs extended along the body, the upper limbs rotated with the palm up during the study.

First of all, a pilot study was conducted with the selection of the necessary settings and assessment of the repeatability of the study as a whole.

All the studies were performed using a sufficient amount of gel between the sensor and patient skin.

The study of the biceps was carried out at a point located in the middle between the greater tubercle of the humerus and the ulnar fold; for the triceps, a point was chosen in the middle between the olecranon and the scapular spine; for the rectus femoris, in the middle between the lateral epicondyle of the femur and the anterior superior iliac spine. To measure the brachioradialis, we used a point in the proximal third between the lateral margin of the humerus and the lateral surface of the radius [14].

Echogenicity was measured according to the Modified Heckmatt scale: Grade 1 — normal echogenicity in more than 90% of the muscle that is distinct from bone echo; Grade 2 — increased muscle echogenicity in 10%-50% of tissue, but with distinct bone echo and areas of normal muscle echo; Grade 3 — marked increase in muscle echogenicity between 50% and 90% of tissue with reduced distinction of bone echo from muscle; Grade 4 — very strong muscle echogenicity with near complete loss of distinct bone echo from muscle in more than 90% of the muscle fiber [15, 16].

Given its high sensitivity, CT scan was chosen as a control method of research. CT examination was performed on a 64-slice Siemens Somatom Perspective (Siemens, Germany) CT scanner in axial planes with multiplanar reconstruction (MPR), with reformative slice thickness of up to 1.0 mm. Native CT scanning was performed at the level of L3–L5 vertebrae, study parameters: field of interest width — FoV 200 mm, X-ray tube voltage— 110 kV, mass — 180 mAs. The loading dose averaged 0.8 mSv. Lumbar muscle segmentation was performed on axial sections of native CT images at the level of the L3 vertebra manually using a Syngo.via workstation. The skeletal muscle index (SMI) was calculated as psoas muscle cross-sectional area (cm2) divided by the square of the patient's height (m2) [17]. The measurements were made by a radiologist with 10 years of experience. The threshold SMI values used to assess the degree of sarcopenia were 52–55 cm2/m2 for men, and 39–41 cm2/m2 for women [18, 19].

Methods of statistical analysis. Statistical analysis was performed using the Statistica 12.5 software package (Tibco Software, USA).

Normality of continuous distribution was assessed using the Shapiro–Wilks test. Data distributed according to the law of normal distribution are presented as: mean ± standard deviation, and for data distributed not according to the law of normal distribution, median values and 25%, 75% quartiles are indicated.

Pearson's chi-squared test was used to assess correlations in data distributed according to the law of normal distribution. The Spearman's Rank Correlation Coefficient was used for data not corresponding to a normal distribution.

The Mann Whitney U test was used to compare two samples with non-normal distribution. The t-test was used to compare two samples with a normal distribution; the equality of variances was determined using Levene's test.

RESULTS AND DISCUSSION

For the group of volunteers, the anthropometric data obtained are given in Table 1, and diagnostic ultrasound parameters - in Table 2.

Table 1

Anthropometric data of volunteers

Indicators	Me [Q1 ;Q3] (min; max)
Body mass index, kg/m2	24.39 [21.96; 27.14] (min 19.56; max 36.72)
Triceps skinfold thickness, mm	18.0 [8.0; 22.0] (min 6.0; max 46.0)
Forearm circumference, cm	25,0 [23.4; 28.0] (min 22.5; max 34.0)
Shoulder circumference, cm	28,5 [26.5; 30.5] (min 24.5; max 36.0)

Table 2

Indicators of ultrasound measurements of muscle fiber in volunteers

Indicators	M±m (min; max)
Biceps, cm	1.69±0.34 (min 1.0; max 2.33)
Biceps echogenicity, degree	1 (no scatter)
Triceps, cm	1.31±0.3 (min 0.7; max 1.8)
Triceps echogenicity, degree	1 (no scatter)
Brachioradialis, cm	1.38±0.21 (min 1.0; max 1.8)
Brachioradialis echogenicity, degree	1 (no scatter)
Rectus femoris, cm	1.6±0.18 (min 1.3; max 2.0)
Rectus femoris echogenicity, degree	1 (no scatter)

For the volunteers, data on the right limb are indicated (all volunteers were right-handed). During the study, data between the right and left limbs of volunteers did not differ significantly ($p > 0.05$), as a result, data for volunteers are given only on one limb. The body mass index of the majority of volunteers corresponded to the norm (18.5-24.99 kg/m2), while 3 volunteers had a pronounced degree of obesity (II-III). Triceps skinfold thickness value varied greatly, due to the fact that a larger thickness was noted in overweight women over 30 years old, and as volunteers we had young 21 year old females and males whose triceps skinfold thickness was minimal, even if the body weight was similar to the older age group. Greater shoulder and forearm circumference corresponded to heavier volunteers.

As can be seen from the table, ultrasound measuring of muscle fiber parameters showed that the group of volunteers did not have pronounced abnormalities of muscle echogenicity.

As can be seen from Table 3, according to anthropometric data when comparing volunteers with patients, there was a statistically significant difference at $p<0.05$ in shoulder circumference on the side of the brain injury, shoulder circumference on the opposite side of the brain injury, forearm circumference on the opposite side of the brain injury, and forearm circumference on the side of the brain injury. These figures were significantly lower in patients than in volunteers. The obtained values indicate an unfavorable change in the musculoskeletal structure of patients.

Table 3

Anthropometric data of patients

Indicators	Patients M±m/ Me [Q1; Q3](min; max)	*p*-value when compared with the group of volunteers
Body mass index, kg/m2	22.31 [20.62; 27.44] (min 18.48; max 31.2)	0.16
Abdominal skinfold thickness, mm	17.1±11.22 (min 4.0; max 32.0)	–
Triceps skinfold thickness on the opposite side of the brain injury, mm	14.0 [9.0; 23.0] (min 6.0; max 36.0)	0.63
Triceps skinfold thickness on the side of the brain injury, mm	13.0 [9.0; 25.0] (min 6.0; max 40.0)	0.54
Forearm circumference on the opposite side of the brain injury, cm	22.5 [21.0; 26.0] (min 20.0; max 29.0)	0.015
Forearm circumference on the side of the brain injury, cm	22.0 [21.0; 25.25] (min 18.0; max 27.0)	0.009
Shoulder circumference on the opposite side of the brain injury, cm	24,0 [21,25; 29,75] (min 19.0; max 35.0)	0.012
Shoulder circumference on the side of the brain injury, cm	23.75 [22.25; 27.25] (min 21.0; max 36.0)	0.003

As can be seen from Table 4, in addition, the patients have a radically different picture according to diagnostic ultrasound. A pronounced increase in the degree of echogenicity according to the Modified Heckmatt scale (reaching 2 and above). At the same time, a decrease in the thickness of the muscle fiber was observed, mainly on the opposite side of the brain injury (Fig. 1).

Table 4

Indicators of ultrasound measurements of muscle fiber in patients

Indicators	Patients, on the side of the brain injury, M ± m/ Me [Q1; Q3] (min; max)	Patients, on the opposite side of the brain injury, M ± m/ Me [Q1; Q3] (min; max)	*p-value*
Biceps, cm	0.93±0.27 (min 0.5; max 1.58)	0.62±0.2 (*min* 0.27; *max* 0.93)	0.0007
Biceps echogenicity, degree	2.0 [1.0; 2.0] (min 1.0; max 3.0)	2.0 [1.0; 3.0] (*min* 1.0; *max* 4.0)	0.1
Triceps, cm	0.5±0.17 (min 0.25; max 0.82)	0.38±0.14 (*min* 0.2; *max* 0.8)	0.028
Triceps echogenicity, degree	2.5 [2.0; 3.0] (min 2.0; max 4.0)	3.0 [3.0; 4.0] (*min* 2.0; *max* 4.0)	0.01
Brachioradialis, cm	0.59±0.15 (min 0.39; max 0.92)	0.50±0.17 (*min* 0.25; *max* 0.86)	0.06
Brachioradialis echogenicity, degree	2.0 [2.0; 3.0] (min 1.0; max 4.0)	2.5 [2.0; 4.0] (*min* 2.0; *max* 4.0)	0.03
Rectus femoris, cm	0.55±0.25 (min 0.26; max 1.16)	0.49±0.19 (*min* 0.23; *max* 0.86)	0.06
Rectus femoris echogenicity, degree	3.0 [1.0; 4.0] (min 1.0; max 4.0)	3,0 [2.5; 4.0] (min 1.0; *max* 4.0)	0.017

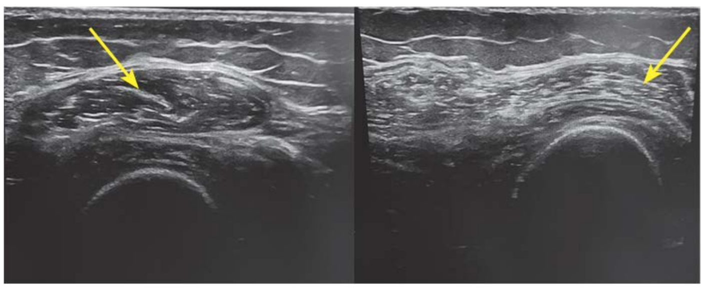

Fig. 1. Ultrasound diagnostics of the rectus femoris muscle on the left and right (indicated by arrows) of patient L., 53 years old. Consequences of stroke. The side of the brain injury is left. Changes are visualized in the echogenicity of the muscle fiber, its thickness mainly in the side opposite to the side of the brain injury

The data obtained indicate a muscle mass loss in the patients, moreover, it is important to note that it is predominantly the opposite side of the brain injury that suffers due to nerve fiber decussation in the brain. This may indicate neuromuscular transmission failure.

When comparing the results of diagnostic ultrasound of the muscles of healthy volunteers with the muscle parameters of the patients on the side of the brain injury, a pronounced statistically significant difference ($p<0.05$) was obtained for the following parameters: biceps, biceps echogenicity, triceps, triceps echogenicity, brachioradialis, brachioradialis echogenicity, rectus femoris, rectus femoris echogenicity. According to similar indicators, statistically significant differences ($p<0.05$) were obtained when comparing the muscles of volunteers with the muscles of patients on the opposite side of the brain injury. The level of significance (p-value) in most cases, both when comparing the muscles on the side of brain injury and on the opposite side of brain injury with the muscles of volunteers, was extremely low ($p=0.000001$, statistically significant). This indicates a big difference between the muscles of healthy volunteers and the muscles of patients.

Using CT of the lumbar spine, it was possible to detect a decrease in the psoas muscle cross-sectional area (Fig. 2). The following cross-sectional values of the lumbar muscle were obtained in patients, respectively: on the right (volume R): 7.66±2.72 cm2 (min 3.84; max 12.95), and on the left (volume L): 7.85±2, 64 cm2 (min 3.7; max 12.6), SMI: 53.33±15.34 (min 28; max 81). In the literature, the threshold value of SMI for men is considered to be 52.4 cm2/m2, and 38.5 cm2/m2 for women; a decrease in this indicator below the specified values is regarded as the presence of sarcopenia [18]. When assessed by gender, in male patients SMI was 58.24±12.65 (min 41.8; max 81), and values below the threshold of 52.4 cm2/m2 was detected in 43.75% of all male patients, and in female patients SMI was 43.31±14.84 (min 28; max 62), while values below the threshold of 38.5 cm2/m2 were detected in 66.6% of all female patients.

Fig. 2. CT diagnostics of the cross-sectional area of the psoas muscle on the right and left sides (indicated by arrows) of patient N., 60 years old. Consequences of stroke. The side of the brain injury is right

In the obtained laboratory data, the presence of protein-energy malnutrition is recorded in almost all the patients (Table 5). These changes are associated with the ongoing process of catabolism in this group of patients, despite the long time since the primary injury.

Table 5

Biochemical parameters of patients

Indicator (blood levels)	M±m /Me [Q1; Q3]	min–max	Reference values	Number of patients with indicators outside the reference values, n (%)
Total protein, g/l	57.59±8.17	47.8–73.7	66.0–83.0	20 (80%)
Albumin, g/l	29.88±5.2	22.3–38.8	35.0–52.0	19 (76%)
Prealbumin, g/l	0.15±0.07	0.03–0.32	0.2–0.4	19 (76%)
Transferrin mg/dl	145.2±57.6	84.0–209.0	200.0–360.0	23 (92%)
Glucose, mmol/l	5.87 [5.3; 6.4]	3.56–9.0	4.1–5.9	12 (48%)
Triglycerides, mmol/l	1.47±0.73	0.66–2.6	0.0–1.7	8 (32%)
Cholesterol, mmol/l	3.62±0.94	1.62–5.28	0.0–5.2	1 (4%)

According to indirect calorimetry, the resting energy expenditure (REE) level was 1420.35±380.05 kcal/day, while the nitrogen balance was 5.03±3.21 g/day. These parameters of energy exchange are typical for patients with a reduced level of consciousness, due to the relationship between a reduced level of consciousness and a decrease in metabolism.

In the group of patients, we have identified the following correlations between some indicators, namely:

1) A negative correlation between age and volume R (r=-0.68), volume L (r=-0.56), and SMI (r=-0.64), which is due to the tendency towards age-related decrease in muscle mass.

2) Indicators of protein metabolism and diagnostic ultrasound: between the level of total protein in the blood and echogenicity of the rectus femoris muscle on the side of the brain injury (r = -0.68); the level of total protein in the blood and the echogenicity of the rectus femoris muscle on the opposite side of the brain injury (r =0.55); the level of albumin in the blood and SMI (r=0.5); the level of transferrin in the blood and the thickness of the rectus femoris muscle on the side of the brain injury (r=0.52); the level of transferrin in the blood and the echogenicity of the rectus femoris muscle on the side of the brain injury (r=-0.67), the thickness of the triceps on the side of the brain injury and the daily nitrogen loss (r=-0.55). Probably, these correlations are due to the fact that the main protein pool in the body is contained in muscle tissue, and the main processes of protein anabolism occur directly in the muscles [20].

3) Indicators of fat metabolism and anthropometric data: between the level of triglycerides in the blood and the triceps skinfold thickness on the side of the brain injury (r=0.63), the level of triglycerides in the blood and the triceps skinfold thickness on the opposite side of the brain injury (r=0 ,62), the level of triglycerides in the blood and the shoulder circumference on the side of the brain injury (r=0.69), as well as between the level of triglycerides in the blood and the shoulder circumference on the opposite side of the brain injury (r=0.61). The revealed changes are probably associated with lipid metabolism disorders in critically ill patients [21].

4) Between the diagnostic ultrasound and CT of the lumbar spine data: Volume R and thickness of the rectus femoris on the side of the brain injury (r=0.51), Volume R and rectus femoris echogenicity on the side of the brain injury (r=-0.64), Volume R and rectus femoris echogenicity on the opposite side of the brain injury (r=-0.58); between Volume L and thickness of the rectus femoris on the side of the brain injury (r=0.56), Volume L and rectus femoris echogenicity on the side of the brain injury (r=-0.62), Volume L and rectus femoris echogenicity on the opposite side of the brain injury (r=-0.52). These connections confirm the effectiveness of ultrasound diagnosis of sarcopenia in patients after severe brain injuries, given their correlation with CT of the lumbar muscles data.

DISCUSSION

Pronounced changes in the muscle fiber and its structure were noted in patients after severe brain injuries, especially on the opposite side of the body. Concomitant abnormalities of protein metabolism indicate ongoing disruptions in the processes of anabolic and catabolic regulation in this group of patients with a predominance of catabolic processes. It is likely that these changes are associated with both difficulties in gaining muscle mass by patients and the development of protein-energy deficiency characteristic for this group of patients, which is often difficult to correct [22, 23].

Taking into account that here at the Center we already observe the consequences of primary damage and further progression of complications in these patients, it seems necessary for us to focus on the fight against sarcopenia at the initial stage of treatment. This is dictated by the fact that despite the ongoing rehabilitation measures - exercise therapy with instructors, massage therapy and the use of physiotherapeutic methods - muscular dystrophy is so pronounced that often we not only fail to achieve an increase in muscle mass, but note its further decrease.

The problem of rehabilitation of patients after severe brain injuries remains poorly understood, but nevertheless this group of patients is not incurable, since using a multidisciplinary and multicomponent approach, it is possible to achieve shifts in the neurological status of this group of patients, the restoration of minimal intellectual activity, muscle movements [24– 26]. The number of such patients will increase against the backdrop of further advances in intensive care, neurosurgical treatment strategies. And, therefore, further development of diagnostic methods and optimal therapy for these patients is necessary in order not to miss the moment of achieving a relatively favorable outcome of the disease.

CONCLUSION

The data obtained during the study confirm the possibility of using diagnostic ultrasound to assess sarcopenia in patients in a minimally conscious state after severe brain injury and their correlation with the methods of diagnostic radiology.

The revealed indicators provide evidence of catabolic/ anabolic imbalance with a shift towards catabolism and damage to muscles - triceps are predominantly affected, then the rectus femoris, biceps, and least of all the studied muscles - the brachioradialis.

These studies formed the basis for the creation of rehabilitation programs for these patients.

FINDING

1. Ultrasound diagnostic methods to assess sarcopenia in patients after severe brain injuries can be used to diagnose this condition. In our study, this method demonstrates a pronounced correlation with the results of radiological diagnosis of sarcopenia.
2. Statistically significant differences were obtained in the group of volunteers and patients when comparing the muscle fiber by ultrasound methods. Moreover, some indicators differed by more than 2 times (triceps), which indicates the presence of severe sarcopenia in this group of patients.
3. Indicators of protein metabolism are closely correlated with the values obtained by both diagnostic radiology and ultrasound methods. And it should be noted that a positive correlation is observed, thereby indicating an ongoing disruption of catabolic/anabolic processes.

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