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Role of cerebral reserve assessed using diffusion-weighted magnetic resonance imaging in determining the rehabilitation potential of acute ischemic stroke

Fractional anisotropy (FA) estimated using diffusion tensor magnetic resonance imaging (dMRI) is considered as a promising biomarker in ischemic stroke (IS). The basis of this study is the assumption that the assessment of FA indices for different white matter tracts will be able to predict the main aspects of the rehabilitation potential even without determining the structural and functional bases of these influences.

***Objective:** to study the diagnostic significance of changes in FA indices to assess various aspects of the rehabilitation potential in acute IS.*

***Patients and methods.** Examinations were made in 100 patients with IS and in 10 individuals without stroke and cognitive impairment. All the patients underwent dMRI and assessments of rehabilitation potential indicators on days 3 and 10 of the disease and at discharge.*

***Results and discussion.** The indices of FA of the ipsilateral upper longitudinal and cingulum bundles, FA and the size of an infarct focus, asymmetry of FA of the cingulum bundle (rFA), corticospinal tract (at the level of the knee of the internal capsule and bridge) and the anterior limb of the internal capsule, as well as the FA of the splenium and knee of the internal capsule of the intact hemisphere are of the most value for the functional outcome of acute IS. The microstructure of these zones determines the state of most rehabilitation domains. With respect to global outcome, the integrity of the associative tracts of the affected hemisphere is more valuable than the microstructure of the intact hemisphere and rFA. The tracts of the intact hemisphere are of particular importance for the restoration of complex rehabilitation spheres, such as cognitive status and daily living and social skills, which is necessary to ensure patient independence.*

***Conclusion.** The FA indices of the tracts under study seem to be a clinically acceptable biomarker of various aspects of the rehabilitation potential in acute IS.*

***Keywords:** ischemic stroke; diffusion-weighted magnetic resonance imaging; fractional anisotropy; rehabilitation potential.*
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***For reference:** Kulesh AA, Drobakha VE, Sobyanin KV, et al. Role of cerebral reserve assessed using diffusion-weighted magnetic resonance imaging in determining the rehabilitation potential of acute ischemic stroke. Nevrologiya, neiropsikhiatriya, psikhosomatika = Neurology, Neuropsychiatry, Psychosomatics. 2019;11(3):26–34.*
***DOI:** 10.14412/2074-2711-2019-3-26-34*

Introduction. Rehabilitation success after IS is expressed in normalization of various functional aspects, with the main in the acute period including: motor skills, in particular, hand function and walking, postural and cognitive abilities, which determine the safety of everyday activities and the degree of independence. More and more studies show a high potential of diffusion-weighted MRI (dMRI) as a modern technique for non-invasive quantitative assessment of microstructural integrity of the brain white matter.

One of the main application areas of dMRI is prognostic assessment of motor functions after IS based on diffusion-tensor visualization and calculation of diffusion tensor indices (in particular, fractional anisotropy, FA). Neurophysiological and structural neuroimaging studies reliably show that motor stroke outcome strongly depends on the integrity of motor fibers, and the degree of CST damage limits the functional restoration [1]. FA is the most commonly used dMRI parameter, reflecting the degree of spatial restriction for water molecules diffusion in tissues. Higher FA values are thought to reflect better axonal integrity and higher myelination, while FA decreases may reflect violation of these white matter properties [2]. In stroke a decrease in white matter integrity, in particular in CST, is observed [3].

In the last decade, FA and other diffusion tensor parameters (MD, AxD, RxD) measured in the CST have been proven to be useful as predictors of motor function recovery [4, 5]. Thus, FA asymmetry (the ratio between FA on the side of infarction and FA of the intact hemisphere) at the level of the brainstem or pons t CST (FA ASY), estimated in subacute or chronic period of stroke, is associated with the severity of motor deficit after 3 months [6, 7]. FA asymmetry is included in the PREP hand function prediction algorithm [8], although in PREP2 it gave way to motor evoked potentials [9]. Similarly, assessment of arcuate fasciculus integrity has a certain value for prediction of speech recovery after stroke [10]. In previous studies, the authors of this article evaluated the role of microstructure violations of various tracts in the development of post-stroke cognitive impairment [11, 12].

The role of FA in predicting the recovery in other rehabilitation domains is currently not well understood. On the one hand, this seems logical due to impossibility of structural determination of such complex functional areas; on the other hand, in routine practice, a pragmatic tool is needed to predict the main components of the rehabilitation potential, the use of which in first 10 days of stroke could allow for individual rehabilitation planning. The basis of this study is the idea that FA assessment of various white matter tracts will make it possible to predict the main aspects of the rehabilitation potential even without defining structural and functional basis of these contributions.

Objective: to study the diagnostic significance of FA changes in assessing various aspects of the rehabilitation potential in acute period of IS.

Patients and methods. 100 patients (68.3 ± 11.1 years, min 30, max 86; 53 men / 47 women) with IS and 10 individuals without stroke and cognitive impairment, comparable in their main characteristics, were examined. The inclusion criteria were: full MRI study and acute period of IS. All patients underwent clinical, laboratory, and instrumental examination according to the current guidelines and protocols of care.

All patients were evaluated for rehabilitation potential indicators by domains on the 3rd, 10th day and at discharge: severity of neurological deficit (NIH Stroke Scale, NIHSS), hand function (Frenchay Arm Test, FAT), postural functions (Berg Balance Scale, BBS), walking (Hauser Ambulation Index, HAI), mobility (Rivermead Mobility Index, RMI), cognitive functions (Montreal cognitive assessment scale, MoCA), motor and intellectual skills (Functional Independence Measure, FIM), and degree of disability (modified Rankin Scale, mRS).

All patients were scanned between the 5th and 10th days using a GE Helthcare Brivo MR355 MRI scanner, 1.5T. The study protocol included the following pulse sequences: T2, T1, FLAIR; gradient sequence T2 Star Weighted ANgiography (SWAN); for white matter tracts evaluation and calculation of FA dMRI was performed with the following parameters: b-value=1000s / mm2 (+b=0), 12 diffusion gradients, 5 mm isotropic voxel. All images were processed on an AW VolumShare 5 workstation using the main (Viewer, Reformat) and specialized (Ready View) software applications.

The size of infarction was determined manually on DWI data by its maximum diameter in mm. The obtained data were processed in OsiriX v5.8.2 using the DTImap application for FA mapping, the ADCmap application for calculating average diffusion coefficient, and also the 3D Sliser v4.10 program for the three-dimensional reconstruction of brain paths. Estimated CST FA (at the level of posterior limb of internal capsule (PLIC) and pons), GIC, ALIC, cingulum, superior longitudinal fasciculus(SLF) and in inferior fronto-occipital fasciculus(IFOF), splenium of corpus callosum (SCC), infarction and the area in 3 cm from it, as well as in symmetric areas of the intact hemisphere. FA asymmetry (FA ASY) in each of them was calculated.

Statistical processing was performed using STATISTICA 8.0, libraries Pandas, Scipy and Statsmodels. Quantitative comparative analysis of two independent groups was performed using the Mann-Whitney test, for qualitative comparative analysis the Chi-square test was used. Correlation analysis was performed using Spearman correlation. To eliminate a possible linear relationship between clinical scales, the principal component approach was used. The tables shows the median and interquartile range. Regression analysis of the clinical scales was carried out using a generalized least squares method, the model quality was assessed using the Fisher F-criterion and the coefficient of determination, the significance of the model coefficients was evaluated by the Student's t-criterion. Mediation analysis was performed according to Baren and Kenny [13], the significance of mediation was assessed using the Fisher z-test.

Table 1. *FA in stroke and control group*

Area	Stroke		Control	$p_{(I-C)}$ / $p_{(I-Control)}$ / $p_{(C-Control)}$
	I	C		
3 cm near the infarction	0.37 (0.33–0.42)	0.41 (0.35–0.45)	–	<0.001
PLIC	0.69 (0.64–0.73)	0.71 (0.67–0.74)	0.74 (0.69–0.76)	0.001/NS/NS
GIC	0.68 (0.62–0.72)	0.70 (0,67–0,75)	0.72 (0.69–0.77)	0.001/0.006 /NS
ALIC	0.64 (0.60–0.70)	0.68 (0.64–0.71)	0.71 (0.69–0.72)	0.008/0.004/NS
Pons	0.61 (0.53–0.66)	0.65 (0.58–0.70)	0.59 (0.52–0.62)	<0.001/NS/NS
Cingulum	0.65 (0.62–0.70)	0.70 (0.65–0.73)	0.71 (0.65–0,72)	<0.001/0.026
IFOF	0.62 (0,55–0,67)	0.65 (0,59–0,71)	0.72 (0,68–0,72)	<0.001/<0.001/0.014
SLF	0.61 (0.54–0.67)	0.66 (0.59–0.70)	0.69 (0.68–0.72)	0.001/<0,001/NS
		rFA		
IFOF	0.93 (0.85–1.06)		1.02 (1.0–1.05)	0.029/NS/NS
SLF	0.92 (0.86–1.07)		1.01 (1.0–1.06)	0.033/NS/NS

Note. CST – corticospinal tract, PLIC – posterior limb of internal capsule, GIC – genu of internal capsule, ALIC – anterior limb of internal capsule, SLF – superior longitudinal fasciculus, IFOF – inferior fronto-occipital fasciculus, I – ipsilateral hemisphere; C – contralateral hemisphere.

Results. The severity of stroke assesed with NIHSS at admission varied from 1 to 26 points and with the average of 5.5 (3–8) points. 30 patients (30%) underwent intravenous thrombolysis. According to the results of the examination, 18 patients (18%) were diagnosed with atherothrombotic, 19 patients (19%) – cardioembolic, 14 patients (14%) – lacunar, and 49 patients (49%) – unspecified etiology of IS. The minimum size of acute cerebral infarction was 5 mm, the maximum – 80 mm (average size 11 (5–24) mm). In 65 patients (65%) cerebral infarction was located in the middle cerebral artery territory, in 13 patients (13%) in the posterior cerebral artery territory and in 22 (22%) patients in the brainstem or cerebellum.

The differences of FA between stroke patients and control group are presented in Table. 1. As presented in Table. 1, compared to control subjects, stroke patients had lower FA in GIC and CF on the affected side, as well as in IFOF of the intact hemisphere. In all studied areas, FA was lower on the side of the affected hemisphere compared to symmetric structures. Lower FA ASY was observed in IFOF and SLF compared to the control.

Correlations of FA and FA ASY with the dynamics of the rehabilitation potential indicators were analysed (Table 2, Fig. 1).

Table 2. *Correlations of FA and FA ASY with the dynamics of the rehabilitation potential indicators*

	Results of clinical scales							
	NIHSS	RMI	BBS	HAI	FAT	MoCA	FIM	mRS
Infarction size	0.43; <0.001	-0.32; 0.002	-0.34; 0.006	NS	-0.35; 0.002	-0.39; 0.002$^{3-10}$ -0.45; 0.0003	NS	0.33; 0.001
3 cm	NS	NS	NS	NS	-0.29; 0.039	NS	NS	NS
M	0.27; 0.032	NS	NS	NS	NS	NS	NS	0.30; 0.014
FA ASY	NS	NS	NS	NS	-0.29; 0,039	NS NS		NS
PLIC								
FA ASY	-0,27; 0.007	0.26; 0.012	NS	NS	NS	NS	NS	-0.25; 0.013
ALIC								
I	-0.34; 0.001	0.27; 0.009	NS	NS	NS	0.25; 0.019	NS	-0.25; 0.017
C	0.26; 0.026$^{3-10}$ 0.24; 0.038^{3-d}	NS	NS	NS	NS	NS	NS	NS
FA ASY	-0.22; 0.029	NS	NS	NS	NS	NS	NS	-0.21; 0.039
GIC								
I	NS	NS	NS	NS	NS	NS	NS	-0.25; 0.015
C	NS	NS	NS	NS	NS	NS	0.32; 0.020	NS
FA ASY	NS	NS	0.34; 0.0073-10	NS	NS	NS	NS	NS
Cingulum								
I	NS	NS	0.27; 0.035	NS	NS	NS	NS	NS
C	0.27; 0.021$^{3-10}$ -0.28; 0.007	0.28; 0.007	NS	NS	0.30; 0.008	NS	0.45; 0.001	-0.22; 0.030
FA ASY	NS	NS	NS	NS	NS	NS	-0.28; 0.037	NS
IFOF								
I	NS	NS	NS	NS	0.30; 0.010	NS	NS	NS
C	-0.21; 0.044	NS	NS	NS	NS	NS	0.34; 0.010^{10-d} 0.36; 0.008	NS
FA ASY	NS	NS	NS	NS	0.34; 0.002	NS	NS	NS
SLF								
I	-0.35; 0.001	0.32; 0.002	0.26; 0.046$^{3-10}$ 0.38; 0.002	-0.46; 0.0004$^{3-10}$ -0.41; 0.002^{3-d} 0.44; 0.001	0.33; 0.004	NS	0.27; 0.049^{3-d}	0.32; 0.002
C	NS	NS	NS	-0.32; 0.016$^{3-10}$ -0.29; 0.031^{3-d}	NS	NS	NS	NS
FA ASY	-0.30; 0.004	0.24; 0.023	0.31; 0.014	-0.30; 0.024$^{3-10}$ -0.27; 0.044^{3-d} 0.27; 0.047	0.38; 0.001	NS	NS	-0.28; 0.007
SCC								
I	-0.22; 0,036	NS NS NS			NS	0,24; 0.025	0.36; 0.007^{10-d}	NS
C	NS	NS	NS	NS	0.25; 0.030	NS	NS	NS
FA ASY	NS	NS	NS	NS	NS	0.27; 0.033$^{3-10}$	0.26; 0.048^{10-d}	NS

Note. NIHSS – NIH Stroke Scale, FAT – Frenchay Arm Test, BBS – Berg Balance Scale, HAI – Hauser Ambulation Index, RMI – Rivermead Mobility Index, MoCA – Montreal cognitive assessment scale, FIM – Functional Independence Measure, mRS – modified Rankin Scale, M – mirror area. NS – correlations are statistically insignificant. The superscripts show the dynamics of the scale result (3 – 3th day, 10 – 10th day, d – discharge).

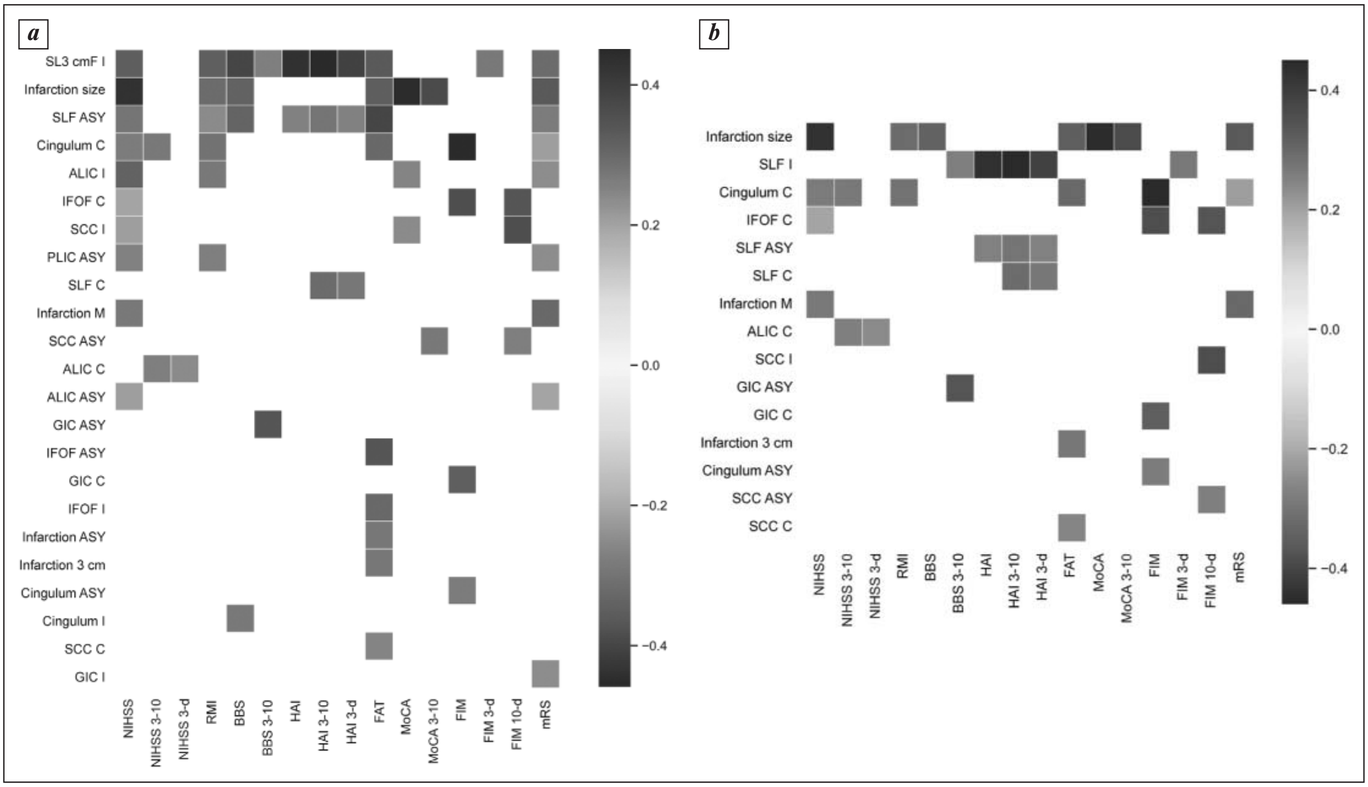

Figure 1. *A. Correlation matrix. B. Correlation matrix without the contralateral tracts, which duplicated the correlations of infarction size. The tracts are arranged in decreasing order of rating, which was determined by the strength of the correlation with clinical indicators.*

Table. 2 shows that the largest number of correlations with rehabilitation metrics was for FA of ipsilateral SLF, FA ASY of a given tract and FA of contralateral cingulum. According to the rating of the studied areas, based on the strength of correlation with rehabilitation metrics, FA of ipsilateral SLF had the greatest clinical significance (Fig. 1A).

The anatomical location of SLF, which predominantly connects frontal and parietal cortices, as well as other studied tracts, predisposes them to be damaged during a stroke in the middle cerebral artery territory (Fig. 2).

For this reason, ipsilateral tracts for which FA correlations with the rehabilitation metrics were duplicated by the size of infarction were excluded from the correlation matrix (Fig. 1B).

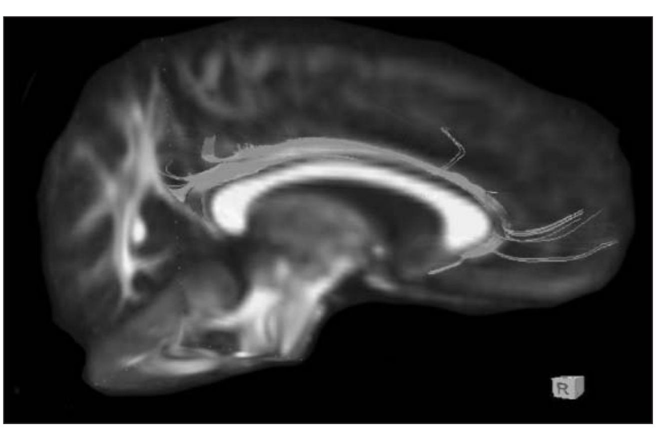

Figure 2. *Diffusion-tensor reconstruction of SLF*

For the same purpose the mediation analysis for FA and infarction size was performed and showed a negative result. Further, in order to eliminate the possible linear dependence between clinical metrics, the space of scales was transformed using principal component approach. The contents of the component are shown in fig. 3A.

Fig. 3B reflects the proportion of dispersion attributed to each of the main components. First five components account for 60% of the variance and, as indicated above, are not specific to individual clinical scales. The PCA5 component and the subsequent ones explain a smaller proportion of the variance and are predominantly specific to certain clinical scales (for example, PCA5 reflects the dynamics of the BBS, and PCA15 reflects the dynamics of the NIHSS). The last three components account for less than 0.15% of the variance.

As follows from Fig. 3A, PCA0 reflects the results of NIHSS, RMI, Hauser, FIM, and mRS on discharge, and BBS, MoCA, and FIM scales over time. The components PCA1–PCA3 mainly reflect the dynamics of NIHSS, MoCA and FIM, as well as the dynamics and the final result of HAI. PCA4 reflects the dynamics of NIHSS, MoCA and FIM, as well as the final result of RMI and mRS. In the resulting space, a rating of tracts is constructed according to the strength of the correlations with the main components, taking into account their share of dispersion (Fig. 4).

As shown in Fig. 4, the greatest strength of correlations with the main components, taking into account their proportion of dispersion, is characteristic (in descending order) for the FA of ipsilateral SLF, cingulum and IFOF, FA and the size of the infarction, FA ASY in cingulum, GIC and pons, ALIC,

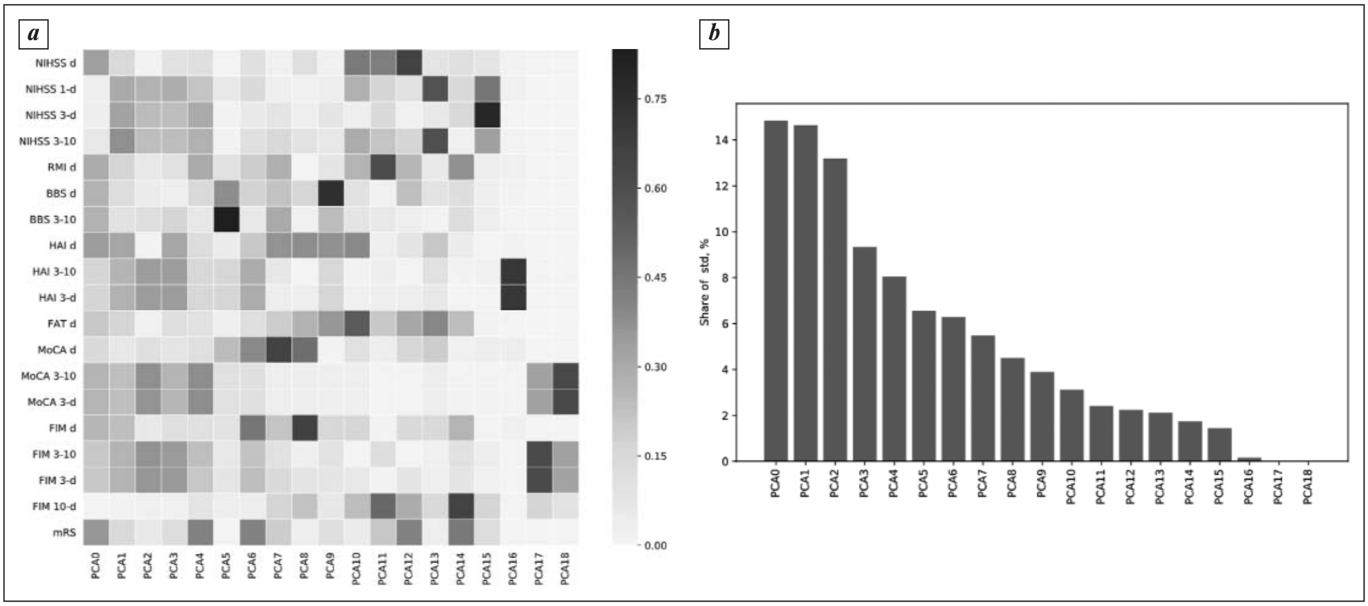

Figure 3. *A. Matrix, reflecting the contribution of clinical metrics to major components. B. The distribution of the dispersion of the main components*

IFOF, and FA contralateral GIC, IFOF, SLF, PLIC and cingulum.

The next step was to perform a regression analysis with the clinical scales. Regression analysis did not allow to build a statistically significant model that would satisfactorily explain the observed clinical scales, possibly indicating the non-linear relashionship between scale values and FA, as well as the necessity to take into account other predictors.

Discussion. In patients with IS lower FA of CST at the level of GIC and CF on the side of infarction, as well as lower FA of IFOF on the opposite side compared with controls, were revealed. Within the affected hemisphere FA of the studied tracts was found to be lower compared to the intact hemisphere. In addition, the FA ASY differed from the control only for IFOF and SLF. Thus, when assessing the microstructure of the eight areas of the brain, significant FA asymmetry is observed in the acute period of IS in two long intracerebral tracts – IFOF and SLF. The lack of asymmetry of FA PLIC, often detected in the recovery period of IS, is associated with a small number of patients in whom the infarction involved this area (13%).

Correlation analysis with rehabilitation scales made it possible to identify multiple correlations of FA with both the final results of scales and dynamics of their results. The largest number of correlations with rehabilitation metrics was found for FA of the ipsilateral SLF, FA ASY of this tract and FA of the contralateral CF. A SLF, consisting of three bundles – SLF I (assessed in the present study), SLF II and SLF III, along with the arcuate fasciculus, forms the superior longitudinal system, which contains fibers connecting the frontal cortex to the parietal, temporal and occipital cortices [14]. Due to high damage probability for this and other examined tracts instroke in the middle cerebral artery territory (observed in 65% of patients), we excluded from analysis the ipsilateral tracts whose correlation with rehabilitation metrics were duplicated by the size of infarction.

Additionally, mediation analysis was carried out. To eliminate possible linear dependence of metrics, the space of scales was transformed using principal component approach. In the resulting space, a rating of tracts was constructed according to the strength of the correlations with the main components, taking into account the fraction of the explained variance.

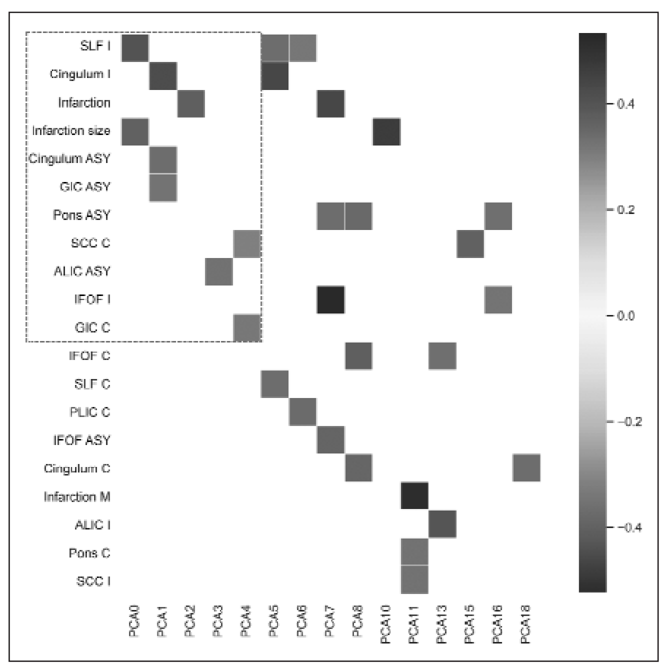

Figure 4. *The final matrix of correlation analysis of tracts with the main components. The tracts are arranged in decreasing order of the rating, which was determined by the strength of the correlation links with the main components, taking into account their share of dispersion*

According to the rating based only on correlation analysis, the size of the infarction was the strongest predictor, determining degree of independence and disability of the patient, severity of the neurological deficit, mobility, postural capabilities and hand function at discharge, as well as dynamics of cognitive status. At the same time, the size of infarction was not related to the walking, resulting cognitive status and functional independence. Thus, the size of acute lesion is mainly associated with the final results of rehabilitation scales, evaluating more "simple" domains, without affecting such integrative areas as walking, cognitive status and independence in the context of motor and intellectual functions. This conclusion is partially consistent with data from Schiemanck S.K. et al. (2006), demonstrated that correlation between infarction volume and clinical outcomes are stronger for NIHSS than for the Bartel scale [15].

The second important parameter (after the size of infarction) was FA of ipsilateral SLF. This parameter is associated with the dynamics of walking and its final indicator, as well as dynamics of functional independence. That is, the microstructural integrity of ipsilateral SLF determines the effectiveness of retraining in terms of walking, social and everyday motor and intellectual functions in acute IS. It is quite natural, since the tract participates in the initiation of motor activity, organization of spatial attention and spatial working memory [16]. Unilateral damage of SLF is known to be associated with the development of ideomotor apraxia [17], and bilateral damage – with Balint syndrome [18]. For acute stroke, the correlation of SLF FA ASY with cognitive part of FIM [19] are shown as well as interaction of SLF damage with attention deficit in recovery period of disease [20], which corresponds to our results. At the same time, it is not possible to completely exclude a possible increase of FA in SLF during the first stage of rehabilitation, as it is shown that a change in the microstructure of tract is observed even in response to a 6-day training, consisting in an active Internet search [21]. SLF FA ASY was associated only with the restoration of walking. It is noteworthy that the size of infarction and the FA of ipsilateral SLF are collectively related to the state of all rehabilitation domains, which justifies the need for their joint assessment.

FA CF are associated with the neurological deficit and its dynamics, hand function, mobility and degree of independence and FIM at discharge. It should be noted that the correlation of the tract is in many respects similar to the correlation of the infarction. CF is a long complex intracerebral bundle connecting the frontal, parietal and medial temporal lobes, as well as subcortical nuclei and cingulate gyrus. The tract is involved in the executive functions, in particular cognitive control, emotions, pain and episodic memory [22]. CF FA reaches a peak only by 42 years, which explains its importance in the development of cognitive and emotional skills throughout life and allows us to be considered as one of the markers of cerebral reserve [23,22]. Previously, we have shown that in the acute period of IS, patients with dysregulatory and mixed cognitive impairments differ from patients with normal cognitive status, including a decrease in FA of contralateral CF [11], and before that Santiago C. et al. (2014) demonstrated the association of FA indicators of the left parahippocampal CP with executive functions in elderly patients with ischemic heart disease [24]. FA of cingulum and SLF decrease with age, which also allows us to consider the microstructure of the tracts as a marker of age-associated disconnection [25]. A diffusion-perfusion model was developed, taking into account the independent effect on the degree of neurological deficit in extracting four factors: initial severity of stroke (clinical indicator), infarction size (macrostructural indicator), perfusion of M2 according to ASL-MRI (perfusion indicator) [26]. Thus, the similarity of the clinical associations of cingulum and infarction may indicate an important role of the tract in compensating for the negative functional influence of the latter.

The FA of the contralateral PLIC were associated with the dynamics of the neurological deficit, but not with cognitive functions, which is quite surprising, since this projection tract, through frontal-subcortical communication, participates in organization of attention, memory, emotions and sensory processing [27]. Importantly, the microstructural integrity of intact hemisphere, which is equivalent to structural cerebral reserve, largely depends on the presence of chronic cerebral circulatory disorders, such as cerebral small vessel disease, which influence in this study was not evaluated [28, 29, 30].

mRS result depended on the lesion size, as well as FA of the contralateral cingulum and mirror area. Decrease in FA in mirror zone is associated with lower neurological deficit and greater independence. Granziera C. et al. (2012) showed that in mirror zone FA of the white matter is lower in chronic stage compared with the acute period [31], which is associated with the best functional outcome. According to researchers, the cause of this phenomenon can be both in axonal degeneration of hemispheric connections, which can serve as one of the mechanisms contributing to recovery [32], and in axonal remodeling of the contralateral hemisphere [33]. It remains unclear how these hypotheses are applicable in the first 5–10 days of IS.

After the application of the main component method, the significance of ipsilateral SLF and cingulum increased. At the same time, SLF is characterized by associations with components that reflect almost all aspects of the rehabilitation potential, with exception of dynamics of neurological deficit, which further confirms the multifunctionality of this associative tract. After exclusion of the dependence of the results of clinical scales from each other, ipsilateral cingulum became more important. The cingulum was also characterized by correlations with components reflecting the final state and the dynamics of almost all rehabilitation domains with an emphasis on the dynamics of neurological status, walking, cognitive and everyday functions. It is noteworthy that the clinical associations of the two tracts considered complement each other, and it seems that cingulum is especially important for restoring lost functions. FA in infarction turned out to be more functionally significant than its size. The size of lesion has a range of associations similar to those of SLF, whereas infarction FA are associated with dynamic of neurological, cognitive, functional status and walking. Considering the fact that MRI was performed on 5 to 10 days after the development of a stroke, the effect of the time factor on these associations cannot be excluded. Also, after the application of the principal component method, the FA ASY and FA of the intact hemisphere tracts began to have a smaller functional contribution. It is likely that the microstructural integrity of contralateral hemisphere creates backup capabilities for restoring complex areas, such as balance, cognitive functions, everyday and social skills, which is necessary to ensure patient independence.

The regression analysis did not allow building a statistically significant model with satisfactory predictive power, which indicates the non-linear nature of the scale relationships with FA, as well as the necessity to take into account other predictors. Perhaps one of these predictors is cerebral perfusion, the combined assessment of which with FA allowed us to construct an acceptable diffusion-perfusion model for the intact hemisphere [26].

One limitation of this study is that it did not take into account the localization of the infarction and its anatomical relationship with the investigated tracts. Since the latter is particularly relevant for SLF, some exaggeration of the clinical significance of SLF cannot be completely excluded, which, however, does not fundamentally affect the findings of the study. To clarify this issue in a future study, it is advisable to take into account the anatomical relationship of acute lesion and tract. In addition, a 5 mm voxel is large enough, and using a higher resolution would increase the accuracy of the results. Finally, the study did not assess other diffusion parameters, in particular, the mean (MD), axial (AxD) and radial (RxD) diffusivity.

The study showed that FA of ipsilateral SLF and cingulum, FA and infarct size, FA ASYof cingulum, CST (at the level of GIC and pons) and ALIC, as well as indicators of CC and GIC of intact hemisphere. The microstructure of these zones determines the state of the majority of rehabilitation domains, respectively, these tracts play an integral role in restoring functions after a stroke. Moreover, with respect to the global outcome, the integrity of the associative tracts of affected hemisphere is of greater value compared with the microstructure of intact hemisphere and relative values of FA. The tracts of intact hemisphere are of particular importance in restoring difficult rehabilitation areas, such as cognitive status, everyday and social skills, which is necessary to ensure patient independence.

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Received on 1.04.2019

Declaration about financial and relationships.
This is a non-funded investigation. The authors are fully responsible for submitting the final version of the manuscript for publication. The final version of the manuscript has been approved by all co-authors.