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Possibilities of Volume Multislice Computed Tomography in the Diagnosis of Ischemic Injury of the Brain

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Abstract: The aim of the article is to evaluate the clinical significance of volumetric computed tomography (CT) in the diagnosis of patients with acute cerebral ischemia. We examined 48 primary patients (mean age 47.4±8.1 years) with acute ischemic stroke. Stroke severity was assessed using the National Institutes of Health Stroke Scale (NIHSS) and the Glasgow Coma Scale. 32 (66.7%) patients met the criteria for mild stroke severity, moderate severity was diagnosed in 18.8% (9 of 48) cases, and severe severity was detected in the remaining 7 (14.6%) patients. The studies were carried out on a wide-detector 640-slice computed tomograph "Aquilion One - 640" Genesis version (Toshiba Medical Systems, Japan). Non-contrast CT in cases of moderate and severe stroke is a highly sensitive (77.8%-100%) method for diagnosing ischemic lesions. The sensitivity of the technique in cases of mild severity of the clinical course of ischemic stroke is defined as the lowest (46.9%). However, in such cases, with a high frequency (53.3%), it is possible to diagnose the average size (16-30 mm in diameter) of the ischemic lesion zones. The frequency of detection of characteristic CT signs is higher in severe (71.4%-100%) than in moderate (28.6%-100%) and mild (6.7%-100%) stroke. The study determined a high relationship between the severity of ischemic stroke and the occurrence of CT signs. As the severity of cerebral ischemia increases, cases of a combination of radiological signs in direct proportion will increase. The results obtained in the course of the study once again confirm the expediency of including volumetric CT in the multimodal diagnostic protocol for acute ischemic stroke.

Keywords: ischemic stroke, diagnostics, neuroimaging, non-contrast computed tomography, sensitivity.

Introduction

According to WHO, stroke continues to rank second in the world in terms of mortality and the main cause of disability in the world, leading to an annual global economic burden [1, 2, 3]. Over the past decade, significant advances have been made in the ability to diagnose and treat stroke to minimize its consequences. A key step in first aid for stroke is the early identification of patients with acute cerebrovascular accident (CVA) and their triage to centers capable of providing specialized treatment as quickly as possible [4, 5, 6].

Computed tomography (CT) remains the most widely used imaging modality for evaluating patients with acute ischemic stroke and selecting for intravenous thrombolysis and endovascular treatment. Although evaluation with anatomical CT techniques is sufficient for patients with a “therapeutic window”, more advanced imaging techniques should be used after 6 hours from the onset of symptoms to quantify the ischemic nucleus and evaluate the penumbra [2, 4].

The quality of stroke diagnostics has improved significantly, but it remains obvious that the development of more effective and affordable methods of examination with a decrease in radiation exposure to the patient and obtaining high-quality images of the vascular bed of the brain, as well as optimization of the multimodal approach will contribute to the choice of optimal tactics and improve the results of treatment of patients with acute stroke. cerebral circulation [7, 8].

This article presents the results of studying changes in cerebral blood flow in the acute period of ischemic stroke using non-contrast CT imaging, and also determines the clinical significance of the technique in a multimodal approach to detecting ischemic stroke of the brain.

Material, Research Methods and Results

The study was based on the results of radiodiagnosis of 48 patients with ischemic cerebral stroke (34 men and 14 women aged 25 to 75 years, mean age 47.4±8.1 years). All patients were examined at the State Institution "RSSPMTSH named after Academician V. Vakhidov" for the period from 2017 to 2022. Stroke severity was assessed using the National Institutes of Health Stroke Scale (NIHSS) and the Glasgow Coma Scale. The studies were carried out on a wide-detector 640-slice computed tomograph "Aquilion One - 640" Genesis version (Toshiba Medical Systems, Japan).

The main inclusion criteria for the study were:

- the patient has a newly developed hemispheric ischemic stroke within 24 hours;
- age from 18 to 80 years,
- and the degree of neurological deficit ≥5 points on the US National Institutes of Health Stroke Scale (NIHSS);
- as well as the absence of contraindications for MRI and / or CT examination.

Patients were distributed in the process of statistical processing of data according to the characteristics of the clinical course and the data of the primary radiological examination of the brain.

Among the patients included in the study, 32 (66.7%) patients without impairment of consciousness, without brain edema, with focal neurological symptoms (NIHSS score on the 1st day <8 points) met the criteria for mild stroke severity. The average severity of the clinical course of stroke with impaired consciousness (NIHSS score 8-16 points, Glasgow scale 11-14 points) was diagnosed in 18.8% (9 of 48) cases. Severe stroke (NIHSS score over 16 points on day 1 with impaired consciousness in the form of stupor (9-10 points on the Glasgow scale) and coma (3-8 points on the Glasgow scale) was detected in the remaining 7 (14 ,6%) of patients. The subdivision of patients according to the clinical course of ischemic stroke was necessary to identify differences in the features of the CT picture of the brain and determine the possibilities of volumetric CT diagnostics in various clinical situations. The average severity of neurological deficit at admission was 11.5 points according to NIHSS scale (7.3–16.0 points).

The clinical picture was dominated by motor disorders - limb paresis of varying severity, which occurred in 93.8% of patients, speech impairment (45.8%). Among the background pathology, arterial hypertension (84%), atherosclerosis with damage to the main arteries of the carotid system (79%), cardiac arrhythmias, as a rule, atrial fibrillation and extrasystole (58%), type 2 diabetes mellitus (26%), less commonly, structural changes in the heart, such as an open foramen ovale (2 cases), myxoma of the left atrial appendage (1 case), infectious lesions of the valvular heart apparatus (bacterial endocarditis - 1 case) and disorders of the blood coagulation system (antiphospholipid syndrome - 2 cases).

The time from the onset of clinical manifestations of stroke to the initial examination on non-contrast CT averaged 14.2±3.2 hours, i.e. this direction is based on the analysis of the results of diagnosing ischemic stroke in the acute phase.

So, for example, from Fig. Table 1 shows that in 53.1% (17 out of 32) of cases among patients with mild stroke, no focal changes were detected on native CT, while the remaining 15 patients showed changes in blood flow in one area or another. Among patients with moderate ischemic stroke, the frequency of cases with an undetectable CT picture was 22.2% (2 out of 9). And in the severe course of the disease with obvious clinical signs of stroke, in all cases, volumetric CT was effective and revealed lesions.

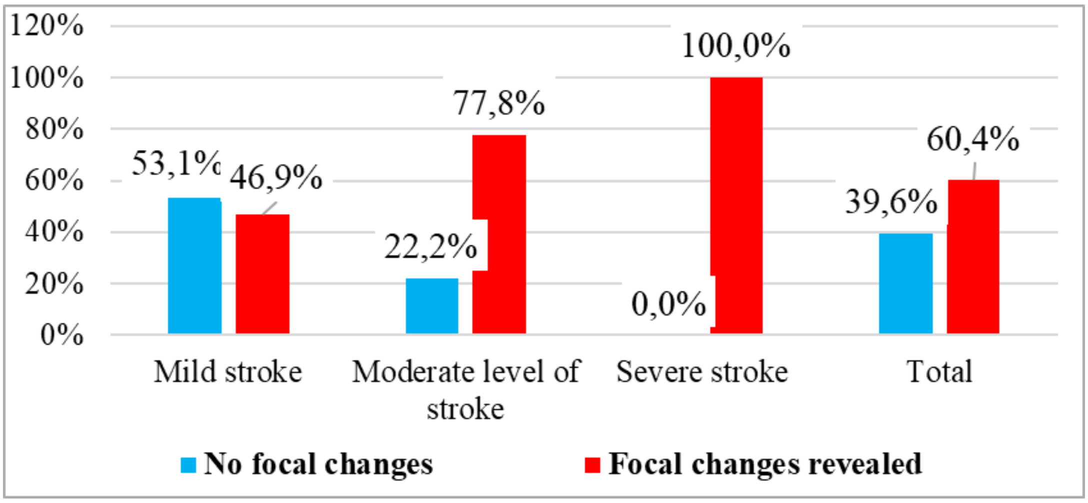

Fig. 1. The frequency of detection of focal changes in cerebral ischemia in various clinical degrees of severity of stroke

Thus, among all patients included in the study, the detection rate of focal brain lesions according to native CT was 60.4% (29 out of 48). With mild severity among patients with a detected focal pattern, the left and right middle cerebral arteries were affected with equal frequency - 40.0% (6 out of 15), and in the remaining 3 (20%) cases, damage to the vertebrobasilar basin was noted. With moderate stroke, focal changes were most often noted in the basin of the right middle cerebral artery - 57.1% (4 out of 7), ischemia of areas along the left middle cerebral artery was detected in 2 (28.6%) patients, and in 1 (14, 3%) of the case, the zone of the anterior cerebral artery was affected (Fig. 2).

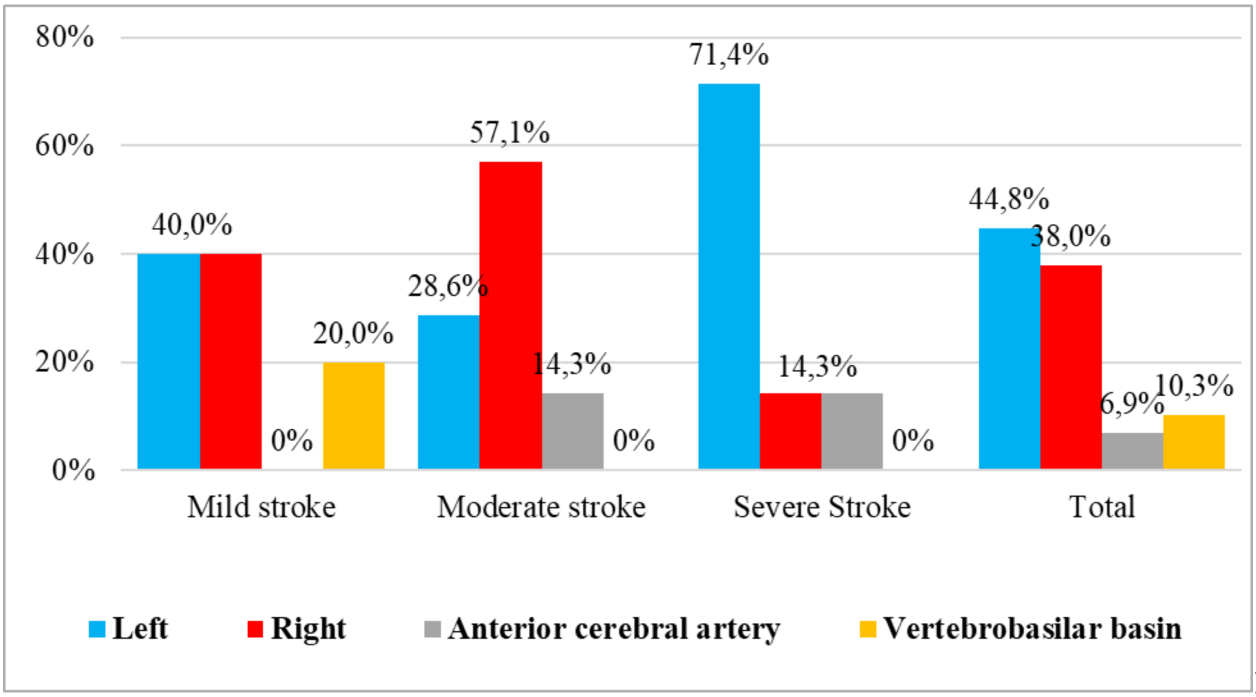

Fig. 2. Distribution of patients depending on the affected basin of the intracerebral artery

Severe stroke was characterized in 71.4% (5 out of 7) of cases by the detectability of focal changes in cerebral blood flow in the left middle cerebral artery, and in 1 (14.3%) case, CT signs of cerebrovascular accident were noted in the right middle cerebral and anterior cerebral arteries (Fig. .2).

Thus, according to the results of native CT of the brain among patients with identified foci of ischemic stroke, in most cases (44.5%; 13 out of 29), lesions of the brain tissue in the basin of the left middle cerebral artery were diagnosed. Next, in terms of frequency, blood flow disturbances were noted in the right middle cerebral artery (28.0%; 11 out of 29), foci in the vertebrobasilar basin (10.3%; 3 out of 29) and in the anterior cerebral artery (6.9%; 2 out of 29). 29).

We also studied the features of the radiological picture according to native CT data in relation to the layered localization of the stroke focus (Fig. 3).

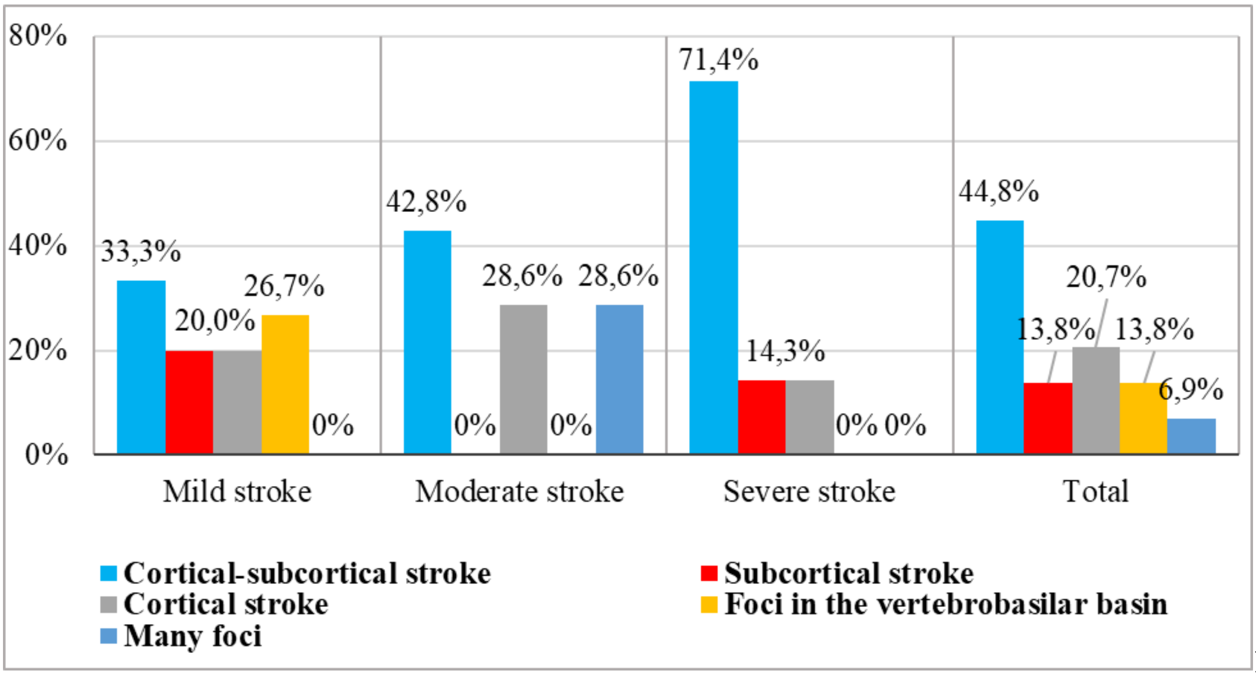

Fig. 3. Distribution of patients according to the localization of the focus of stroke

Thus, in the group of patients with mild severity and ischemic foci detected on native CT in more than half of the cases, the stroke zones were located in the cortical (20.0%; 3 out of 15) and subcortical (20.0%; 3 out of 15) structures of both hemispheres, as well as a combined cortical-subcortical stroke (33.3%; 5 out of 15) of the circulatory systems of the left and right middle cerebral arteries, which accounted for the majority, followed by stroke foci in the vertebrobasilar basin (26.7%; 4 out of 15).

Among patients with moderate severity of stroke, according to the results of native CT, depending on the location of the foci, cortical-subcortical foci prevailed (42.8%; 3 out of 7). Cortical strokes, as well as many foci, were noted with equal frequency - 28.6% (2 out of 7) of cases. Thus, no foci of cerebral infarction in the subcortical layer and vertebrobasilar basin were detected on native CT in patients with moderate ischemic stroke (Fig. 3.3).

Severe infarction was characterized by the vast majority (71.4%; 5 out of 7) of cases of cortical-subcortical strokes detected using volumetric MSCT (Fig. 3).

Thus, among patients with stroke and diagnosed foci of cerebral ischemia, cases with cortical-subcortical stroke prevailed, which amounted to 44.8% (13 out of 29). Next in frequency, cortical stroke was diagnosed (20.7%; 6 out of 29). And only 2 (6.9%) patients had multiple foci of infarction.

When distributing patients depending on the size of the identified stroke focus, we used the following classification. Thus, foci with a maximum diameter of 71 to 100 mm were assigned to extensive or massive infarcts, which are formed mainly when the intracranial part of the internal carotid artery is damaged. Large infarcts with lesions of the main trunks of the cerebral arteries were identified with a focus diameter of 31 to 70 mm. The average infarct was differentiated when the size of the focus was from 16 to 30 mm in diameter. Such foci are usually formed by occlusion of the cortical or deep branch of one of the cerebral arteries of the carotid system. Finally, in cases of detection of an infarct ranging in size from 5 to 15 mm, cases were recorded with small foci, which are characteristic of damage to the systems of intracerebral arteries extending from the anterior, middle, or posterior cerebral arteries.

According to the primary native CT scan performed within the first 24 hours from the onset of clinical manifestations of the disease, among patients with mild stroke, medium-sized foci prevailed, amounting to 53.3% (8 out of 15), no large foci were noted, and large foci amounted to 33, 3% (5 of 15) and 13.3% (2 of 15) of cases were diagnosed with small infarcts (Fig. 4).

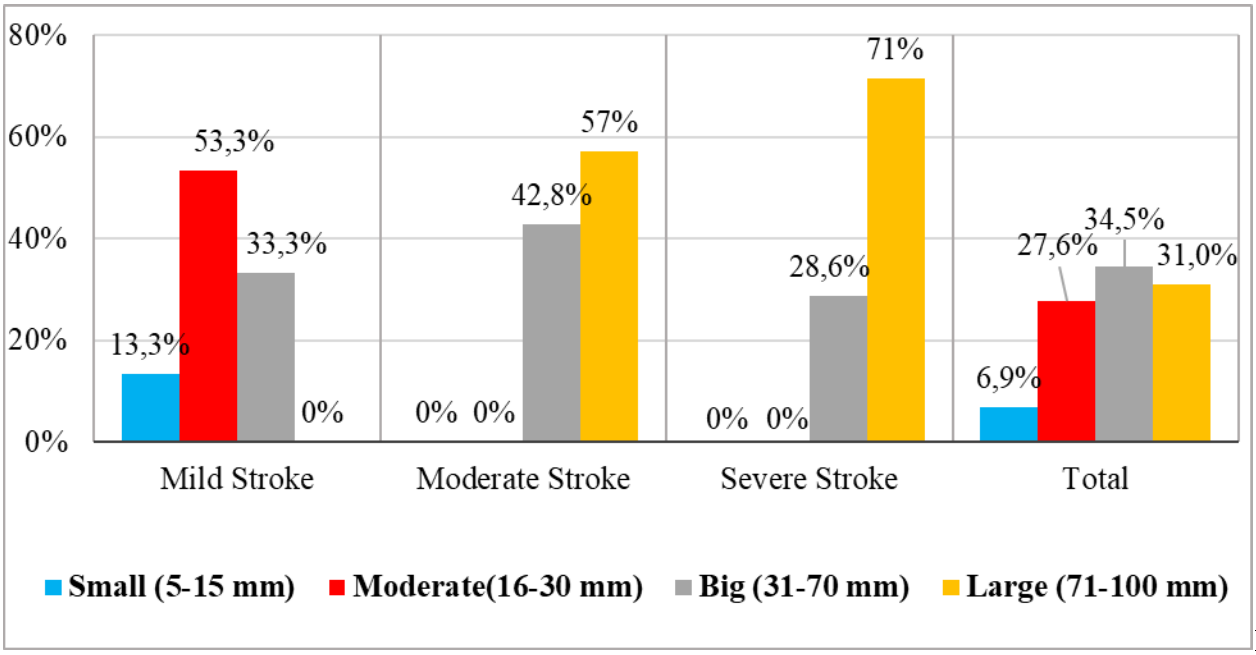

Fig 4. Distribution of patients according to the size of the focus of stroke

Medium-severity stroke was characterized by large (42.8%; 3 out of 7) and large (57.2%; 4 out of 7) foci of brain tissue infarction.

Also, with severe stroke, cases of large infarct sizes were detected, only with a lower frequency (28.6%; 2 out of 7) than with a moderate course of the disease. At the same time, the majority (71.4%; 5 out of 7) in severe cases of stroke were large foci.

Thus, among patients with identified foci of cerebrovascular accident (n=29), patients with large infarct sizes (34.5%; 10 out of 29) prevailed with a slight advantage, followed by cases with large ones (31.0%; 9 out of 29) and average (27.6%; 8 out of 29) sizes of the ischemic focus. And only 2 (6.9%) patients with mild stroke were diagnosed with minor strokes.

According to the categories of detected CT signs, in all severity levels, in all cases, foci with reduced density were noted, as well as a sign of a decrease in the coefficient of X-ray absorption by the gray matter of the brain (brain tissue hypodense) by 5–15 HU (Table 1).

Table 1. Occurrence of various CT signs of ischemic stroke

Characteristics of the CT sign	Frequency of occurrence (n, %)			
	Light stroke (n=15)	Average stroke (n=7)	Severe stroke(n=7)	Total (n=29)
Center with low density	15 (100%)	7 (100%)	7 (100%)	29 (100%)
Symptom of increased artery	5 (33,3%)	5 (71,4%)	6 (85,7%)	16 (55,2%)
Non-differentiation between gray and white matter of the brain	2 (13,3%)	3 (42,8%)	6 (85,7%)	11 (37,9%)
cerebral edema	1 (6,7%)	2 (28,6%)	5 (71,4%)	8 (27,6%)
Smoothness of the furrows in the focus of the stroke	1 (6,7%)	2 (28,6%)	5 (71,4%)	8 (27,6%)
Sign of the insular tape	3 (20%)	3 (42,8%)	5 (71,4%)	11 (37,9%)
Hypodensity of the basal ganglion	3 (20%)	3 (42,8%)	5 (71,4%)	11 (37,9%)
Decreased x-ray absorption coefficient of gray matter	15 (100%)	7 (100%)	7 (100%)	29 (100%)

The symptom of strengthening (hyperdense) of the artery with an increase in the absorption coefficient of X-ray radiation in the group of severe cases of stroke was noted with the highest frequency (85.7%; 6 out of 7). In patients with moderate stroke, this symptom was detected in 71.4% (5 out of 7) of cases. In the mild stroke group, arterial hyperdensity was detected in only 33.3% (5 out of 15) of cases, which was the smallest among all patients with stroke and diagnosed areas of cerebral blood flow disorders in native MSCT (Table 3.1).

A sign of the absence of differentiation of the gray and white matter of the brain in the ischemic zone was also noted with a higher frequency in severe cases of stroke (85.7%; 6 out of 7) than in moderate (42.8%; 3 out of 7) and mild cases (13 .3%; 2 out of 15) diseases.

Cerebral edema on native CT was diagnosed in only 1 (6.7%) patient with a mild course, in 2 (28.6%) cases of moderate stroke, and in 5 (71.4%) patients with severe stroke. Accordingly, with the same proportions of occurrence, the smoothness of the furrows in the area of ischemic brain damage was noted.

The next two CT signs, basal ganglion hypodense and insular band sign, were detected at a frequency of 20% (3 of 15), 42.8% (3 of 7), and 71.4% (5 of 7) in the mild, moderate, and severe stroke, respectively (Table 3.1).

Thus, radiation diagnostics using native CT makes it possible to determine characteristic radiological signs with a high frequency (from 71.4% to 100%) among patients with severe stroke, while the frequency of diagnosed CT signs among patients with moderate stroke varies from 28, 6% to 100%, and in mild cases from 6.7% to 100%.

Discussion

Non-contrast CT imaging of the brain parenchyma is of fundamental importance for the selection of patients for all types of therapy for acute stroke. In addition to ruling out intracranial hemorrhage, CT can also be used to assess the extent of early ischemic injury [9].

Early signs of ischemia on 3D CT include flattening of the sulci and reduced X-ray attenuation, resulting in loss of gray and white matter differentiation [10].

Isolated flattening of the sulci reflects venous dilatation and increased cerebral blood volume, which is not always associated with irreversible damage [10]. On the contrary, the loss of differentiation of gray-white matter tissues indicates cytotoxic edema, which occurs as a result of a violation of ATP-dependent processes in neurons/glia and subsequent cell death. Ultimately, this leads to the movement of fluid from the intravascular space to the brain parenchyma, which reduces tissue density and, consequently, attenuation of X-ray radiation [9, 10].

The rate of this process varies greatly, but always lags behind the changes observed on diffusion-weighted MRI. However, non-contrast CT remains the standard initial diagnostic test in most stroke centers around the world due to its ease of access and shorter acquisition times. The evaluation of early ischemic changes is highly subjective, and agreement between experts is often not reached.

Our data showed that non-contrast CT in cases of moderate and severe stroke is a highly sensitive (77.8%-100%) method for diagnosing ischemic lesions. The sensitivity of the technique in cases of mild severity of the clinical course of stroke is defined as the lowest (46.9%).

However, according to our data, in such cases, with a high frequency (53.3%), it is possible to diagnose the average size (16-30 mm in diameter) of ischemic lesions. The frequency of detection of characteristic CT signs is higher in severe (71.4%-100%) than in moderate (28.6%-100%) and mild (6.7%-100%) stroke.

The study determined a high relationship between the severity of ischemic stroke and the occurrence of CT signs. As the severity of stroke increases, the cases of a combination of radiological signs in direct proportion will increase.

Conclusion

Volumetric CT in acute ischemic brain damage is characterized by the possibility of an objective analysis of the status of the affected area of the brain, high significance in the choice of therapeutic tactics and in monitoring its effectiveness. The results obtained during the study once again confirm the expediency of including volumetric CT in the multimodal protocol for diagnosing ischemic stroke in the acute period of development, which makes it possible to identify the nature of the lesion at an early stage, exclude the hemorrhagic form of the disease, assess the severity of brain damage, localization, depth and volume of infarct foci , as well as the degree of impact of the ischemic focus on the surrounding brain tissue.

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