Signature: © Pol J Radiol, 2013; 78(3): 28-34
DOI: 10.12659/PJR.889460

Polish Journal of Radiology
www.PolRadiol.com
ORIGINAL ARTICLE

Received: 2013.06.14
Accepted: 2013.07.26

MDCTA diagnosis of cerebral vessel disease among patients with arterial hypertension

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Source of support: The source of financing of this research was Kalush City Council and Kalush Central District Hospital.

Summary

Background: to study changes involving cerebral vessels in patients with hypertension and various levels of total cardiovascular risk.

Material/Methods: One hundred and thirty-four patients underwent CT-angiography of intracranial vessels. Ninety-eight of them were diagnosed with hypertension. Taking into consideration high blood pressure, presence of risk factors and target organ damage subjects were divided into 4 groups: with low, medium, high and very high total cardiovascular risk. Control group included 36 patients. They were not diagnosed with hypertension at the time of examination. One hundred and five patients were examined using a 4-slice CT scanner (Toshiba Asteion 4, Toshiba Medical System, Japan), and 29 patients were examined using a 128-slice scanner (Siemens Definition AS+, Siemens Healthcare, Germany) with an injection system. We used iodine-containing contrast agents such as iodixanol and iopromide for angiography.

Results: Anatomical and topographic changes of cerebral vessels were most frequently found in hypertensive patients with high and very high total cardiovascular risk. Narrowing of vertebral vessels was the most common change (27 patients (27.55%), 21 patients (21.43%) had narrowing of the right artery, and 6 (6.12%) subjects – of the left one). Tortuous course of internal carotid arteries at the neck level was visualized in 11 patients (11.22%). Narrowing of A1 segment of anterior cerebral artery was noted in 9 patients (9.18%), of the right one – in 8 patients (8.16%), of the left one – in 1 patient (1.02%). Aneurysmal dilation of intracranial vessels was visualized in 6 patients (6.12%). Saccular aneurysm of left internal carotid artery was diagnosed in 2 patients (2.04%), one patient (1.02%) had right internal carotid artery aneurysm and one patient (1.02%) had an aneurysm of the basilar artery.

Discussions: the most common changes of cerebral vessels diagnosed in MDCTA among patients with hypertension included various degrees of narrowing of vertebral vessels, anterior, posterior and posterior communicating arteries and internal carotid arteries. Changes of middle cerebral arteries and basilar arteries were extremely rare, thus we can say that these vessels are influenced by high blood pressure to lesser extent. We established the relationship between changes in cerebral blood vessels and total cardiovascular risk. Therefore, we believe that findings will be useful for establishing prognosis in hypertension and prevention of complications such as stroke.

Conclusions: MDCT angiography is a highly informative method to study changes of cerebral vessels in patients with hypertension. The relationship between changes in cerebral blood vessels diagnosed through MDCT angiography and the level of total cardiovascular risk among patients with hypertension had been established.

Key words: **CT angiography • cerebral vessels • arterial hypertension • total cardiovascular risk • diminution • S-shaped deviation • saccular aneurysm • stenosis • hypoplasia • trifurcation • fenestration**

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Background

Cardiovascular disease constitutes one of the most significant medical and social problems of modern society, being the leading cause of morbidity, mortality, temporary and permanent disability in most developed countries.

Arterial hypertension (AH) occupies the first place in terms of prevalence and morbidity from diseases of circulatory system among adults and teenagers in Ukraine. Mortality among people with high blood pressure (BP) is nearly twice as high as among people with normal BP.

Vascular brain disease is one of the most recent problems of modern cardiology and neurology considering high prevalence of this pathology in the population as well as rapid aging of the society [1]. Nowadays, cerebrovascular disease occupies the second place in amongst the causes of mortality in Ukrainian population following ischemic heart disease, while in Europe and the USA it occupies the third place. According to the statistics, mortality from cerebrovascular disease reaches 11–12% in developed countries. During the last 10 years prevalence of these diseases has increased 1.6 times (in 1995 it was diagnosed in every 25th inhabitant of Ukraine and in every 12th one in 2005) [2].

Arterial hypertension (AH) and atherosclerosis lead to acute cerebrovascular events as well as chronic, progressive brain damage. Impairment of cognitive function is one of its main symptoms. AH is considered a risk factor of both the acute event [3,4] as well as impairment of memory and other cognitive functions.

Nowadays, we can visualize vessels using a variety of useful methods such as transcranial color Doppler sonography [5], multislice computed tomography [6], magnetic resonance imaging and angiography [3,6] or digital subtraction angiography [7,8].

Computed tomography, CT angiography in particular, is widely used in clinical practice. At present, it is one of the most important methods used for diagnosis of vascular disorders [7,9] and occupies one of the leading positions among methods of imaging of intracerebral hemorrhages. Besides, it is the most common method of diagnosing early, irreversible ischemic changes in the brain [3]. CT angiography is a highly informative method for imaging of vessels, giving the possibility to acquire comprehensive information about the vessel lumen and its topographic relationships to adjacent structures. Taking into consideration both native anatomy of the brain and CT perfusion studies, computed tomography is a simple, useful and fast method for the diagnosis of acute ischemic insult. Location of arterial occlusion and formation of collateral cerebral arteries may be visualized in these examinations. They provide the information necessary to decide on further treatment strategy of the insult and cerebral vasospasm [10].

The purpose of this work

To study the changes of cerebral vessels among patients with hypertension and various levels of total cardiovascular risk on the basis of MDCTA angiography data.

Material and Methods

We examined 134 subjects aged between 20 and 78 years. Cerebral vessels were screened using computed angiography method in Kalush city polyclinic and Kalush Central District Hospital between 2008 and 2013.

Thirty-six patients aged between 23 and 66 years were included in a control group. They were examined for the presence of diseases other than hypertension. At the time of examination they were not diagnosed with hypertension. Sixteen patients were male and 20 were female.

Other 98 patients were divided into 3 groups. The main criterion for the selection was the level of total cardiovascular risk (TCR), which depended on patient blood pressure and stage of hypertension, presence or absence of risk factors, target organ damage and identified cardiovascular or renal disease.

The first group of patients with low level of total cardiovascular risk included 16 patients aged between 20 and 46 years, including 7 males and 9 females. The average patient age was 34.5±11.5 years.

The second group of patients with intermediate total cardiovascular risk consisted of 32 subjects aged between 22 and 64 years, including 13 males and 19 females. Average age of patients in this group was 43±21 years.

The third group consisted of 50 patients aged 44–78 years with high and very high total cardiovascular risk. Thus, average age was 61±17 years. There were 22 males and 28 females in this group.

One hundred and five patients were examined using a 4-slice scanner (Toshiba Asteion 4, Toshiba Medical System, Japan), and 29 patients were examined with a 128-slice scanner (Siemens Definition AS+, Siemens Healthcare, Germany) with an injection system. Comparing 4-slice and 128-slice scanners used in the course of our study we concluded that the 128-slice scanner has several advantages. Namely:

- Less contrast agent - on average 30% less compared to the cost of the study with a 4-slice scanner.
- Radiation dose is reduced by 47.4% on average and it captures a larger scanning area in a transverse plane.

During the examination using a 4-slice scanner we used two methods, particularly the Cerebral CTA protocol. Examined area extended from the neck (the level of C2 cervical vertebra - the aim was to visualize merging of vertebral arteries with the basilar artery) to the level above corpus callosum to display the vessels of Circle of Willis and their main branches. Cerebral CTA protocol was applied in the 1st, partially in the 2nd group and in control groups – 68 patients (50.75%) in total, as these patients were not hemodynamically unstable and had no severe pathologies of the heart. We automatically started the examination with a preset scanning delay [11] of 16–18 seconds, average time to appearance of contrast in cerebral beds and adequate contrasting of vessels in the Circle of Willis. In all cases we received adequate contrasting of major cerebral vessels and their branches.

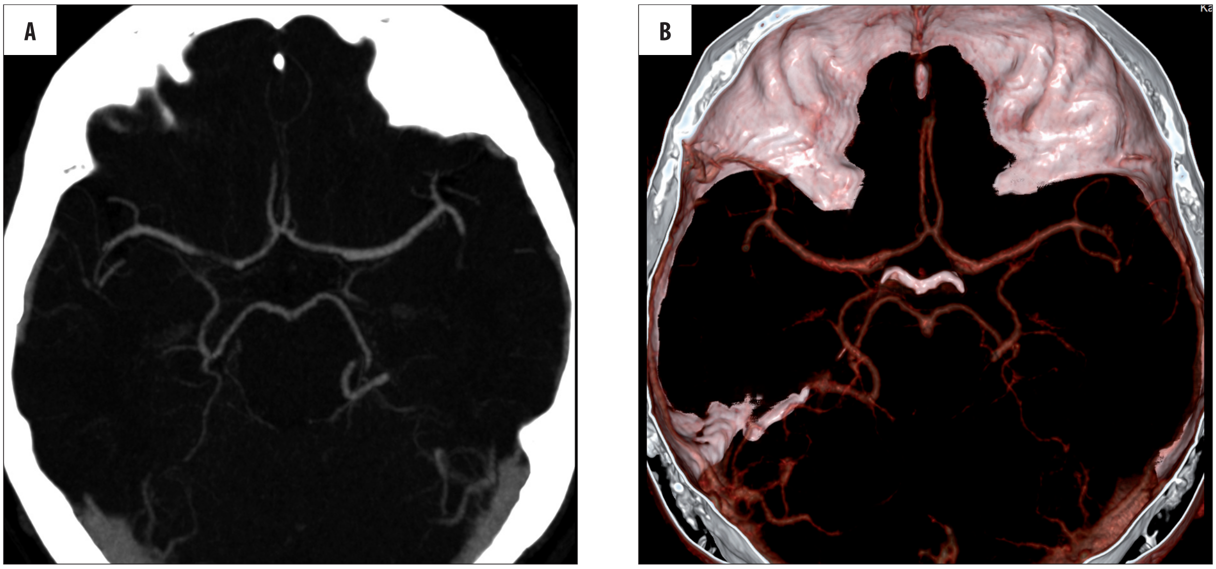

Figure 1. CTA of the cerebral vessels of the patient V, aged 43 y.o. (**A**) Axial slices; (**B**) 3D reconstruction of the cerebral blood vessels. **Conclusion:** Pathology of intracranial vessels not found.

Group 2 and 3 included some subjects with diagnosed hemodynamic disorders and some people with heart disease. These factors affect the speed of contrast diffusion in blood, which is why we used the CTA technique in these patients – bolus-tracking. Using this protocol, we observe inflow of contrast into one of the internal carotid arteries, as the zone of interest (ROI) was located within the lumen of an artery. Starting with setting the density (density threshold, on reaching which starts scanning), we then chose to scan and set it at 100 HU. A dynamic low-dose scan was performed on one of the levels of our zone of interest in order to determine the time of administration of contrast agent. When contrast agent reaches the level of the zone of interest (ROI), density measurement is performed. Spiral CT scanning begins after reaching the lumen of a vessel at a set trigger threshold density. This is the Cerebral CTA Sure Start protocol for the 4-slice scanner [4,11].

Two protocols were used for the 128-slice CT depending on the studied area. They included: Neuro DSACT (when the studied area involved the part from the level of C2 cervical vertebra up to the level above corpus callosum to display the vessels of Circle of Willis and their main branches) and Carotid DSACT (area of examination started at the level of aortic arch at the point of emergence of main arteries of the neck (carotid artery in particular) and ended at the level of corpus callosum). In this case the region of interest (ROI) was set in the aortic arch, where appearance of contrast agent was closely monitored [6].

We used 80–100 ml of contrast agent during the examination with a 4-slice CT scanner. During the examination with a 128-slice scanner the quantity of contrast depended on the scan protocol and equaled to 50–60 ml for Neuro DSACT and 70 ml for Carotid DSACT protocol. We used iodine-containing contrast agents such as iodixanol (Visipaque-320, Nycomed, Ireland) and iopromide (Ultravist-370, Bayer Schering Pharma, Germany) in our study. At the beginning of our work we used iodixanol (Visipaque-320, Nycomed, Ireland), but due to patients' complaints of pain along the vein during intravenous administration and several allergic reactions such as skin rash, the head of radiology department and the hospital chief decided to change contrast agent to iopromide (Ultravist-370, Bayer Schering Pharma, Germany) for all examinations including CT angiography. In order to increase contrast efficiency we immediately gave a bolus of 40 ml of 0.9% NaCl solution.

Irradiation dose (DLP) was determined individually for every single patient and varied between 1695.1 and 1895.3 mGycm, which is equivalent to 3.8–4.37 mSv in a 4-slice CT scanner. In 128-slice tomography DLP ranged from 592 to 958 mGycm, which is equivalent to 1.4–2.20 mSv.

Data processing was performed on VITREA and LEONARDO workstations. The following variables were assessed: course of major intracranial vessels such as the vertebral artery, basilar artery, anterior, middle and posterior cerebral arteries, anterior as well as posterior communicating arteries, intra-cerebral segments of the internal carotid artery. Vessel diameter and innate characteristics of the course and branches were also evaluated.

Results and Discussion

Analysis of the data shows that patients with hypertension have topographic and anatomic changes of cerebral vessels.

We studied normal MDCT anatomy of cerebral vessels and normal diameter values of intracranial vessels among patents from the control group (Figure 1). Average diameter of anterior cerebral arteries (ACA) was 1.34±0.29 mm, mean diameter of middle cerebral arteries (MCA) – 1.59+0.30 mm, posterior cerebral arteries (PCA) – 1.38±0.24, internal carotid arteries (ICA) – 3.85±0.48 mm, basilar artery – 2.31±0.51 mm, vertebral artery – 2.65±0.51 mm. All of our findings correspond to the literature data [12,13].

Narrowing of vertebral artery was often visualized in CT angiography of cerebral vessels in patients with

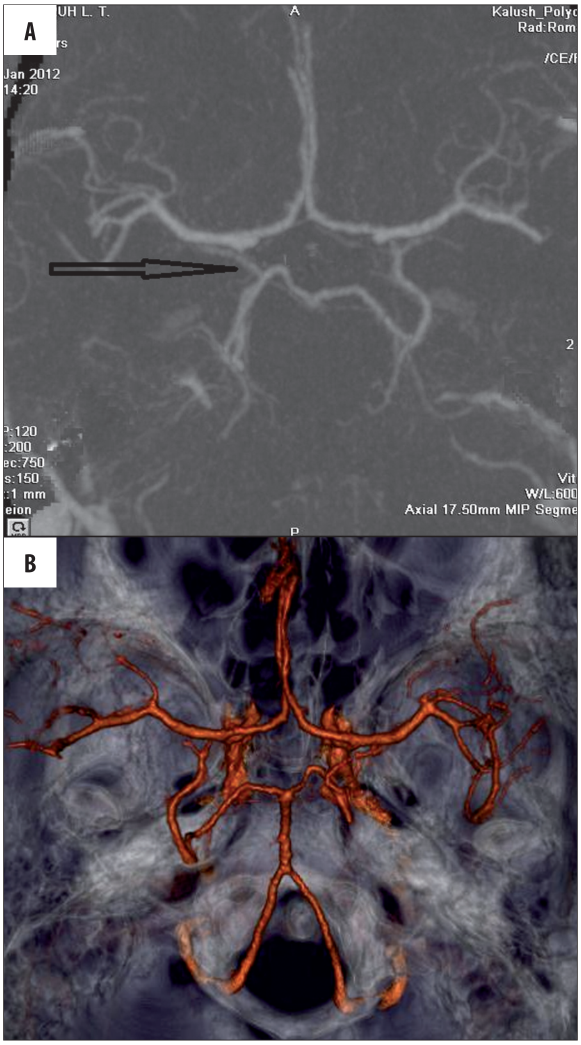

Figure 2. CTA of the cerebral vessels of the patient Zh., aged 33 y.o. (**A**) Axial slices; (**B**) 3D reconstruction of the cerebral blood vessels. **Conclusion:** stenosis of right posterior communicating artery (black arrow).

hypertension and low total cardiovascular risk Vertebral artery narrowing at the level of a particular segment or throughout it was estimated by comparing the diameters of right and left VA at similar levels in the event one artery lumen being reduced by 1 mm or more in relation to the other. That was the case in 6 patients (37.5%). Arteriosclerosis of posterior communicating arteries was the second most frequently encountered change of intracranial vessels: the right one – 3 patients (Figure 2), the left one – 3 patients (18.75%).

Changes of internal carotid arteries (both at the level of the neck and at the intracranial level) were frequent among patients from the first group. According to Weibel and Fields classification, tortuosity is an S- or C-shaped elongation or undulation in the course of internal carotid artery (ICA). Coiling was defined as elongation or redundancy of the ICA resulting in an exaggerated S-shaped curve or in a circular shape. Tortuous course of internal carotid arteries was noted in 3 patients and two (18.75%) of them had changes in both the right and the left artery, while one

Figure 3. 3D reconstruction of the cerebral vessels of the patient S., aged 33 y.o. **Conclusion:** S-shape deviation of the left internal carotid artery on the neck level; stenosis of the right vertebral artery on the level of V1-V4 segments.

patient had tortuous left ICA. S-shaped curve of the left ICA was visualized in one patient (6.25%) from the group. One patient presented with stenosis of C3-C4 segments of right ICA. It was best visible in the simple axial pictures.

Changes of posterior cerebral arteries were rare. Stenosis of P1 segment of right posterior cerebral artery was found only in 2 hypertensive patients (12.5%) with low total cardiovascular risk.

Beside acquired changes of intracranial vessels we verified innate characteristics of the cerebral vessels, namely hypoplasia of posterior communicating arteries (PcA), which was found in 5 patients (31.25%), including the right PcA in 3 patients (18.75%) and left PcA in 2 patients (12.5%); hypoplasia of P1 segments of posterior cerebral vessels was noted in 2 patients (12.5%); hypoplasia of A1 segment of left ACA was found in the images obtained from one patient (6.25%). Duplication of posterior communicating arteries was found in 3 patients (18.75%), changes of right arteries were found in 2 patients (12.5%) and of the left in one person (6.25%). Anatomical variants of vascularization were found in 2 patients (12.5%). One patient had an additional branch of anterior cerebral artery – the so-called trifurcation of ACA, and another patient had fenestration of A1 segment of the left ACA.

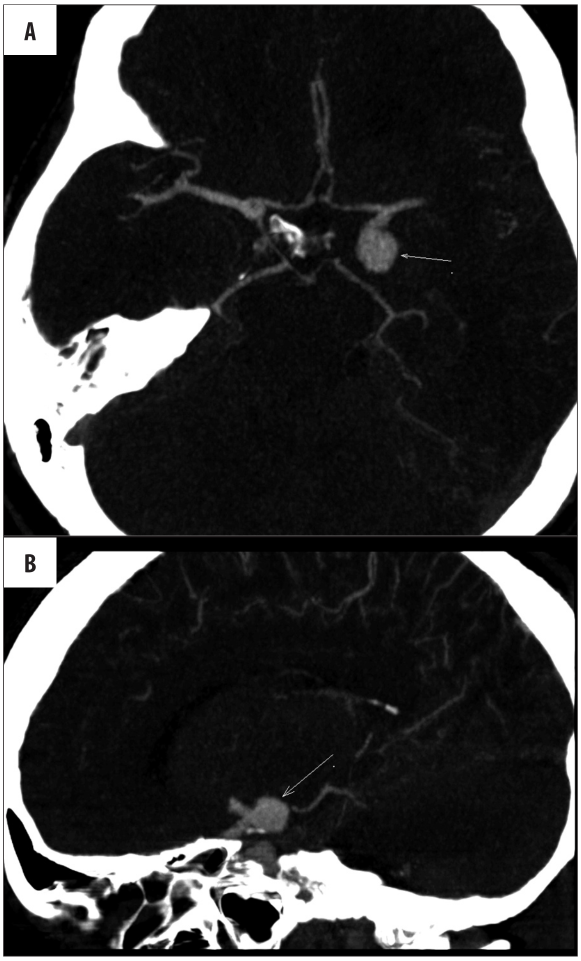

Figure 4. CTA of cerebral vessels of patient M., aged 61 y.o. (**A**) Axial slices; (**B**) sagittal MIP reconstruction; (**C**) 3D reconstruction of the cerebral vessels. **Conclusion:** saccular aneurysm of the left internal carotid artery (arrow).

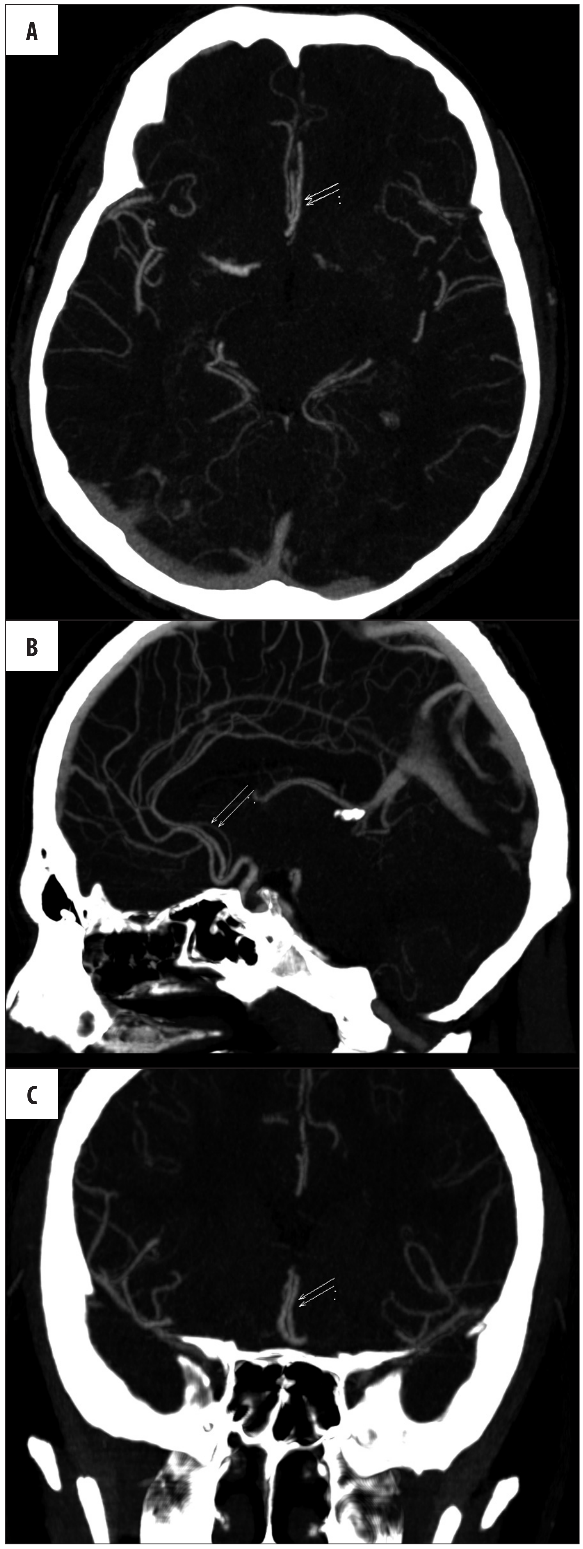

Figure 5. CTA of the cerebral vessels of the patient B., aged 22 y.o. (**A**) Axial slices in the maximum intensity projection, (**B**) sagittal MIP reconstruction; (**C**) Frontal MIP reconstruction; (**D**) 3D reconstruction of the cerebral vessels. **Conclusion:** the diminution of A1 segment of the right anterior cerebral artery(arrow). Trifurcation of the anterior cerebral artery on the level of A2-A5 segments(double arrow), aplasia of the both posterior communicating arteries.

During examination of the images acquired in the second group (with hypertension and intermediate total cardiovascular risk) we found that intracerebral arteries and cephalic arteries underwent changes due to high blood pressure. The most common were the following:

- Changes of vertebral arteries, arteriostenosis in particular, which was found in 20 patients (62.5%) from the group. Moreover, 16 patients (50%) had changes of the right artery (Figure 3), and 4 (12.5%) of the left vertebral artery;

- Stenosis of the posterior communicating arteries, was found in 11 patients (34.38%);

- Anterior cerebral artery damage in the form of stenosis was visualized in 13 patients (40.63%); 6 patients (18.75%) from this group had stenosis of the right ACA, and 7 subjects (21.88%) of the left artery.

In comparison to patients from other groups the greatest changes of cerebral vessels were found in hypertensive subjects with high and very high total cardiovascular risk that comprised the third group of this study.

The most common changes of the cerebral vessels and the vessels of the neck were the following:

1. Narrowing of vertebral arteries, which was found in 27 patients (54%) from this group. Moreover, 21 patients (42%) had right artery stenosis, and in 6 people (12%) it involved the left artery. As a rule, narrowing was seen throughout the vessel at the level of V1-V4 (right vertebral artery in 15 people (30%), left in 4 patients (8%). Arteriostenosis limited to the level of V1-V2, V1-V3, V2-V4, V3-V4, V4 segments of vertebral artery was rare;
2. S-shaped curving of internal carotid artery at the level of the neck was found in 11 patients (22%). Changes of the right ICA were found in 1 patient (2%), of the left in 2 (4%) subjects, and anomalies of both ICAs with abnormal kinking was identified in 8 patients (16%).
3. Narrowing of A1 segment of the anterior cerebral artery was identified in MDCT angiograms of 9 patients (18%), including 8 patients with right artery changes (36%) and 1 patient with left-sided lesions (2%). Narrowing of A2-A5 segments of left ACA was found in only 2 patients from this group (4%).
4. Aneurysmal dilation of intracranial vessels was visualized in 6 patients (12%). Saccular aneurysm of the anterior communicating artery was found in 2 patients (4%). Saccular aneurysm of the left internal carotid artery was identified in the images of 2 patients (4%) (Figure 4), and of the right ICA in one patient (2%), while one patient (2%) had a basilar artery aneurysm.
5. Narrowing of the proximal parts of posterior cerebral arteries was seen quite often - specifically in 6 patients (12%). P1 segment of the right PCA was narrowed in 2 patients (4%), the left one in 2 patients (4%), and 2 patients (4%) presented with narrowing of P1 segments of both right and left PCA.
6. Narrowing of internal carotid arteries was visualized in 6 patients (12%). Moreover, the right ICA was narrowed in 4 cases (8%), and the left one in 2 cases (4%). As a rule, narrowing was identified at the level of C1, but in some cases narrowing was also noted at the level of C3-C4 segments of ICA.
7. Narrowing of posterior communicating arteries was present in 5 patients. Diameter of left PcA was reduced in 4 patients (8%) and of the right in 1 patient (2%).
8. Presence of trombotic mass in intracranial vessels was quite rare – in 3 patients only (6%). They were visualized on the level of M2 segment of right middle cerebral artery in one patient, in one subject – at the level of A1 segment of the right anterior cerebral artery and in another man – at the level of A2-A4 segments of the right ACA. Areas of ischemia were visualized in regions supplied by respective vessels.

Beside acquired changes of cerebral vessels we identified innate characteristics of intracranial vessels in patients from this group. Inborn changes of the posterior communicating arteries were most frequent. PcA aplasia was diagnosed in five patients (10%). Right PcA was absent in 2 patients (4%), the left one in 1 (2%) subject, and imaging of 2 patients (4%) showed neither right nor left posterior communicating artery. We considered narrowing of the artery to be innate when the lumen was reduced to 1.0 mm or less. In 9 patients posterior communicating arteries were hypoplastic: right PcA – in 4 patients (8%), left – in 3 patients (6%), in two cases both posterior communicating arteries were hypoplastic. Duplication of left posterior communicating artery was found in the scans of one patient only. Congenital anomalies of anterior and posterior cerebral arteries were much more rare. Aplasia of the part of left anterior cerebral artery proximal to the connection was found in one patient only. A P1 segment of right posterior cerebral artery was not found on the scans of a patient with hypertension and high total cardiovascular risk,. On that basis we diagnosed aplasia of this part of the vessel. Hypoplasia of P1 segment of left PCA was found in one patient. One patient from the group was diagnosed with a variant of normal anatomy of cerebral vessels – trifurcation of anterior cerebral artery at a level of A2-A5 segments (Figure 5).

We were able to detect these changes on axial slices in a maximum-intensity projection. The above cerebral vessels were clearly traced in the images and we were able to measure their diameters. However, axial pictures only partially visualize most of the arteries. A 3D reconstruction with removed bone structures was superior to axial CT in that regard, since it showed the entire length of intracranial arteries in parallel with other main intracerebral vessels and visualized cerebral vessels from different angles. It was also often necessary to create sagittal and frontal MIP reconstructions as well.

Discussion

The data obtained in this research study showed that, according to MDCT angiography, the most common changes of cerebral vessels in hypertensive patients involve varying degrees of narrowing of vertebral vessels. Changes were seen throughout the artery as well as at in individual segments. Changes of the anterior, posterior and posterior communicating arteries were frequent and usually involved varying degrees of their narrowing and sometimes tortuous course. Changes were common in internal carotid arteries, which resulted in stenosis, deviated course and often pathological kinking. Lesions of middle cerebral arteries and basilar arteries were extremely rare, indicating that these vessels are influenced by high blood pressure to lesser extent. We established the relationship between changes in cerebral blood vessels and the level of total cardiovascular risk, which depended on blood pressure, presence of risk factors and target organ damage. Therefore, we believe that these findings will be useful for assessing prognosis in hypertension and prevention of complications of hypertension such as stroke.

Conclusions

1. MDCT angiography is a highly informative method to study changes of cerebral vessels in patients with hypertension.
2. Cerebral vessels undergo changes in hypertensive patients with high and very high total cardiovascular risk.
3. Vertebral arteries, anterior and posterior cerebral arteries, and posterior communicating arteries were often pathologically changed, which usually involved varying degrees of narrowing and sometimes their tortuous course.

4. We established the relationship between changes in cerebral blood vessels, found in MDCT angiography and the level of total cardiovascular risk in patients with hypertension.

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