Analysis of opportunities 3DFFE CE-MRA brain vessels compared with 3DTOF MRA

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Aims and objectives

High occurrence of cerebrovascular diseases, high disability rate and mortality evidence urgent need for accurate diagnostic methods of cerebrovascular diseases, which have been an important medical and medical-social problem [Ternovoy S.K., Epanova A. A., 2007]. Imaging diagnostics of cerebrovascular disease includes traditional craniography, computed tomography (CT) and angiography, MR angiography, and digital subtraction angiography (DSA) [Trufanov G.E., et al., 2005]. Some authors believe that X-ray CT and MRI with angiography are informative noninvasive methods for diagnostics of aneurysms and arteriovenous malformations [Belenkov Y. M. et al., 1996; Belichenko O.I. et al., 1998; Ternovoy S. K., Sinitsyn V.E., 1998; Trufanov E. E., 1999; Konovalov A. N. et al., 2001; Fokin V.A., 2003]. Contemporary Russian publications do not recommend using contrast agents in MRA of cerebral vessels because of the agents' inefficiency in 3D TOF [Epanova A. A., 2010]. In other hand, comparative diagnostics of stenoses shows that in 50-69% 3D TOF MRA does not have high diagnostic value for any part of stenosis in the ostium of vertebral artery[Chechotkin A. O., et al., 2011].

The available data about capabilities of diagnostics of vascular malformations have not included diagnostics of venous and cavernous malformations but have been focused on the diagnostics of mixed AVMs. Nevertheless, more than 80% of intracranial and subarachnoid hemorrhages have in their genesis venous and cavernous angiomas undetected by any studies with any diagnostic methods (DSA, CTA, MRI + MRA in 3DTOF).

By far, capabilities of contrast enhanced MRA of cerebral vessels and especially of venous vascular malformations have not been studied. A certain role of contrast enhanced MRA in the diagnostics of aneurysms and cerebral vascular malformations have not been identified.

Thus, the objective of this work was to develop and improve the range of methods of contrast enhanced MR angiography of cerebrum for patients with aneurysms and with cerebral vascular diseases.
Methods and materials

473 MRA divided into groups: 1-2D MRI with 3DTOF (n=327), 2-2D MRI with 3DFFE CE-MRA (n= 57), 3-2D MRI with 3DTOF and 3DFFE CE-MRA (n=89). The majority of patients (75,1 ± 20,2%) were aged 20 to 59 years old in all groups, male to female ratio was 33,8 ± 18,5 ÷ 66,2 ± 18,5 (%). All the patients in this groups had been referred to the examination by neurologists and neurosurgeons from specialized city hospitals of Tomsk from January 2007 to may 2012.
Results

In group 1 (n=327) 21 aneurysms were found in 18 patients (detection frequency - 5%). Moreover, there were 19 malformations found (detection frequency -5.8%). Ten of them were found in the structure of cavernous angiomas, 5 - in venous angiomas (52.6 and 26.3%), in 4 arteriovenous malformations (21.1%). Thus, most of the detected brain vascular malformations were venous (78.9%); they prevailed significantly over the arteriovenous malformations (21.1%) and were not visualized during time-of-flight angiography (3DTOF).

In group 2 (n=57) there were 30 arterial aneurysms registered in 22 patients (detection frequency - 38.6%) in only 1 case out of them multiple different-size aneurysms and an arteriovenous malformation were detected simultaneously. In this group 27 malformations were found (detection frequency in the group - 47.4%): cavernous angiomas -17.2% (n = 10), venous angiomas -1 2.0% (n = 7), arteriovenous malformations - 17.2% (n = 10). We carried out a statistical analysis of detection frequencies between groups 1 and 2 using non-parametric two-tailed Fisher's exact test; 2 x 2 table was created showing significant differences between groups 1 and 2 for aneurisms and malformations (p <<0.05 in both cases). Revealed differences suggest a different distribution of vascular disease in groups 1 and 2 with and without contrast MRA. Neurologist more often correctly suspects vascular pathology when appointing contrast MRA.

In group 3 (n=86) included complex magnetic resonance imaging studies of cerebral vessels with the use of time-of-flight 3DTOF angiography combined with 3D fast field echo (3DFFE) angiography. Vascular arterial aneurysms were detected in 22 cases, and vascular malformations in 23 cases (detection frequency in the group was 24.7%-with aneurysms and 25.8%-with vascular malformations). Kappa analysis showed from "medium" to "good" levels of reproducibility of aneurysm diagnostics (k= 0.46, 95% ## from 0.11 to 0.8). There were no significant differences found between the contrast enhanced and non-contrast MRA concerning vascular aneurysm diagnostics.

The differences were the most vivid in details, for example (Fig.1), at 3DTOF angiography the intensity from the content of an aneurysm was identified lower than the intensity of the artery itself, probably, due to significantly slower blood flow. At the same time in at contrast enhanced MRA intensity from aneurysm cavity was high of two closely located aneurysms (Fig.2).

In other clinical case data showed high efficacy of contrast-enhanced magnetic resonance angiography (MRA) with a 3D fast field echo (3DFFE) in establishing diagnosis of cerebrovascular disease: in Fig.3 shows the ruptured aneurysm of the middle meningeal artery with hematoma, in Fig.4 visualized aneurysm lumen using 3DFFE CE-MRA, in Fig.5 shows the MRA after treatment by embolization coils which revealed critical stenosis of the middle meningeal artery and at Fig. 6 on 3DFFE CE-MRA images
shows that the inner lumen of the artery is not changed, probably on 3DTOF MRA it was associated with artifacts from the coil's metal.

Thus, in both cases (3DTOF and 3DFFE MRA) the aneurysms were detected and no significant differences in sensitivity or specificity (p>0.05, between 3DTOF and 3DFFE angiography) were found (100%).

In Kappa-comparative analysis of detection vascular malformations a medium rate was noticed concerning malformation sizes (K = 0.49; 95% CI from 0.17 to 0.8), poor rate - concerning supplying arteries (K = 0.27; 95% CI 0.02 to 0.5). Analyzing diagnostic capabilities we found that 3DTOF angiography did not allow to identify venous drainage while 3DFFE MRA allowed for efficient identification of venous bed of malformations in each case.

Sensitivity and negative predictive value (NPV) for the assessment of feeding arteries was 70.6% for 3DFFE and 90.2%, 29.4 and 79.3% for 3DTOF (p < 0.03) ; for the sizes measurement - 82.4 and 93.9% for 3DFFE, 41.2 and 82.1% for 3DTOF (p < 0.01); for the description of draining veins - 82.4 and 93.9% for 3DFFE, 11.8 and 75.4% for 3DTOF (p < 0.0001). The data of sensitivity and negative prognostic value were calculated regarding the results of the complex clinical and roentgenological study.

Clinical cases of the AV malformation (Fig.7, 8) and cavernous-venous angioma (Fig.9, 10) especially clearly demonstrated the imaging capabilities and limitations of the diagnostic techniques based on 3D time-of-flight (3DTOF) MRA and contrast-enhanced 3DFFE MRA.
Fig. 1: MIP 3DTOF MRA of brain probably with two aneurisms

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Fig. 2: MIP 3DFFE MRA of the brain with two aneurisms of the left MCA.

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Fig. 3: Curved MPR 3DTOF MRA ruptured aneurysm of the middle meningeal artery with hematoma

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Fig. 4: Curved MPR 3DFFE CE-MRA of the aneurysm's lumen of the middle meningeal artery without hematoma.

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**Fig. 5:** Curved MPR 3DTOF MRA of the middle meningeal artery after treatment by embolization coils which revealed two critical stenosis

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**Fig. 6:** Curved MPR 3DFFE CE-MRA shows that the inner lumen of the middle meningeal artery is not changed and artifacts from coil's metal lower than it was at 3DTOF MRA.

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**Fig. 7:** MIP 3DTOF MRA of the AVM in right occipital and temporal lobe: white arrow shows feeding arteries from the right anterior and middle cerebral arteries, black arrow demonstrate multiple aneurysms from basilar and middle cerebral arteries.

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Fig. 8: At MIP 3DFFE MRA images well defined all characteristics of AVM's anatomy and venous outflow in superficial and deep veins.

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**Fig. 9:** T2 TSE image shows cavernous malformation in right occipital lobe

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Fig. 10: At MIP 3DFFE CE-MRA shows venous angioma (white arrow) revealed in addition to cavernous angioma (not visualised). Venous angioma represented as converging veins draining into a single vessel (Medusa's head) associated with cerebral vein.

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Conclusion

1. Complex CE-MRI of brain vessels involving sequential use of 2D studies before and after contrast enhancement, as well as 3D TOF MRA and three-phase 3D FFE MRA has been developed and is most effective in the assessment of cerebral vessels in diagnosis of arterial aneurism and malformation.

2. 3DTOF MRA and 3DFFE CE-MRA for the diagnosis of arterial aneurysms has sensitivity of 81.3-100% and specificity of 100%, and for the diagnosis of vascular malformations sensitivity for 3DTOF is 29.4% and for 3DFFE CE-MRA 82.4% (p<<0.05) and specificity is 100% in both cases.

3. For the first time there has been presented semiotics of 3DFFE CE-MRA for venous angioma, advantages of visualization of arterial aneurysms before and after treatment by embolization metal coils and possibilities to verification revealed vascular changes in a single MRI.
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