MAGNETIC RESONANCE ANGIOGRAPHY – A NEW AND USEFUL IMAGISTIC METHOD IN THE DIAGNOSIS OF CEREBRAL ANEURYSMS

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SUMMARY:
Cerebral aneurysm represents a vascular malformation that can result into a serious condition when it is ruptured inducing neurological disfunctionalities and different coma stages. 50 percent of these patients could die within the first 48 hours, and those that stay alive present severe neurological sequela. The purpose of this study was to evaluate implementation of a new non-invasive technique for vascular imaging diagnosis - Cerebral magnetic resonance angiography (MRA) – in the patients hospitalized by Neurosurgery Clinic from Timișoara. The number of diagnosed cases by means of MRA progressively grew up to a maximum in 2006-2008. MRA presents many advantages: the procedure is non-invasive and the patient is not exposed to radiation, and it could be performed even in patients allergic to iodine contrast medium material, there is no need of arterial puncture, the technique produces images in axial section, coronal or sagittal plane and oblique sections with 2D or 3D reconstructions without any ionizing radiations. The disadvantages of MRA consist in the followings: it could not be performed in patients with cardiac stimulator, mechanic valvular prosthesis or other implants of ferromagnetic medical devices. It is difficult to perform MRA in patients with psychomotor disturbances comatose and claustrophobic patients because the acquisition time is too long and the patients must sit still.

Key Words: Cerebral aneurysm, Imaging by Angio Magnetic Resonance – MRA

ANGIOGRAFIA PRIN REZONANTA MAGNETICA - O METODA IMAGISTICA NOUA SI FOLOSITOARE IN DIAGNOSTICUL ANEVRISMELOR CEREBRALE

Rezumat
Anevrismul cerebral reprezintă o malformație vasculară ce poate deveni o afecțiune foarte gravă în cazul ruperii producând semne neurologice și diverse grade de comă. 50% dintre acești bolnavi pot decede în primele 48 de ore, iar cei ce supraviețuiesc pot rămâne cu secchele neurologice foarte severe. Lucrarea de față studiază implementarea unei noi metode de diagnostic imagistic neinvazivă - AngioRMN cerebral - la bolnavii Clinicii de Neurochirurgie Timișoara. Numărul cazurilor diagnosticate numai prin această metodă a crescut progresiv ajungând la un maxim în 2006-2008. Avantajele metodei constau în lipsa de iradiere a pacientului, lipsa funcționării arteriale, posibilitatea efectuării la pacienții alergici la substanțe de contrast iodate, obținerea fără radiații ionizante de imagini în secțiune în plan axial, coronal sau sagital și cupe oblice, cu reconstrucții 2D sau 3D. Dezavantajele metodei constau în imposibilitatea efectuării ei la pacienții cu stimulator cardiac, proteze valvulare mecanice sau alte implanturi de dispozitive medicale feromagnetic. Datorită timpului de achiziție lung în care pacientul trebuie să stea nemișcat este greu sau imposibil de efectuat la pacienții comatoși, agitați psihomotor sau claustrofobi care trebuie sedați.

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INTRODUCTION

The vascular aneurysm represents a malformation (blood-filled dilation, balloon-like bulge) of a blood vessel localized on an artery trajectory that results from the dilation of a portion of the artery walls and which communicates with the arterial lumen.

In terms of anatomo-pathology, vascular aneurysms are ecstasies of arterial walls that could be described as sessile, “saccular”, “berry aneurysm” (resembling a small sac), “fusiform” (resembling a narrow cylinder) or a dissecting aneurysms.

The blood-filled dilation of the aneurysm communicates with the artery lumen, the blood being stagnant, thus forming blood clots that organize. Aneurysms occur in those areas of the vessel walls that have a low resistance because of flow disorders, organic lesions, structural abnormalities or trauma and then grow in size due to an increase in blood pressure of the vessel (fig.1).

Cerebral aneurysms can occur anywhere in the brain, but most are located along a loop of arteries that run between the underside of the brain and the base of the skull, subarachnoid, where blood flow disorders are present.

Aneurysms may burst and bleed into the brain, their rupture may cause a subarachnoid haemorrhage (SAH), haemorrhage into basal cisterns, intraparenchimatous haematoma or intraventricular efraction, causing serious complications including hemorrhagic stroke, permanent nerve damage, or death of 50 percent of the patients within the first 48 hours (fig.2).

All cerebral aneurysms have the potential to rupture and cause bleeding within the brain. The incidence of reported ruptured aneurysm is about 10 in every 100,000 persons per year most commonly in people between ages 30 and 60 years and it is an important medical and social issue.

PURPOSE

Diagnosis of ruptured cerebral aneurysms is a top priority in establishing the best form of treatment. In the past only one diagnostic method was available to provide information about the aneurysm - Cerebral Arteriography and it was performed by releasing a small amount of contrast dye (one that is highlighted on x-rays) into the bloodstream and allowing it to travel into the head arteries and a series of x-rays was taken and changes, if present, were noted.

This study analyzes implementation of a new imaging diagnostic method - Cerebral MRA a painless, non-invasive technique for vascular imaging and is thus widely used to screen for intracranial vascular lesions.

MATERIAL AND METHOD

The patients with cerebral aneurysms that were hospitalized between 2001 and 2008 in Neurosurgery Clinic from Timișoara were enrolled in the present study.

It was implemented Cerebral angiography by MR (“Magnetic Resonance Angiography - MRA”). There are used “Bright Blood” type techniques TOF (Time-Of-Flight) and PC-MRA (“Phase Contrast - M R Angiography”). „Black Blood” type techniques use in ponderate sequences T2 „spins flow” effect and have the advantage of avoiding artefacts due to turbulent flow or haematomas.
CE-MRA ("contrast enhanced MR Angiography") that is obtained by intravenously injecting a paramagnetic substance Magnevist, Gadovist or Omniscan type (it contains Gadolinium) in 1 ml/kg body-dosage.

Over this period cerebral MRA was performed in 286 patients. 310 cerebral aneurysms were detected in 255 patients and in 31 patients MRA image was irrelevant and had to be performed once again MRA, AngioCT or Cerebral Angiography because of the vascular spasm (fig. 3).

**Presentation of the new method**

In the past, diagnosis of SAH was set after the clinical exam and after haemorrhagic CSF was put into evidence by lumbar puncture and at present diagnosis of SAH is accurately set by native cerebral Computer Tomography (TC), a fast, non-invasive, painless diagnostic method.

MRI (Magnetic Resonance Imaging) detected SAH. MRI could show liquid material on move as "signal loss". In SE (spin echo) techniques the blood flow specifically determines a "signal void" for vessels with fast flow (large arteries and veins) but these processes are not homogenous and could not be used to get real vascular information. On MRI images this "signal void" is black as is shown in figure 4 that represents an aneurysm located in Basilar Artery.

Sometimes aneurysms could be visible on native TC. All the following Figures 1 to 8 represent images that were acquired in Neurosurgery Clinic from Timişoara.

Magnetic Resonance Angiography - MRA shows the blood column that flows inside the vessel and then spatially reconstructs those vessels.

There have been developed 2 conventional MRA methods, "Bright Blood" type that are based on gradient-echo techniques (FISP: Fast Imaging with Steady-state Precession, FLASH: Fast Low-Angle SHot, etc.). Signal acquisition could be done 2-dimensional (2D) or 3-dimensional (3D).

Time-of-flight (TOF) or Inflow angiography uses "inflow" effect (the effect of entering the slice/section plane) or the "flow void" effect (exit from the slice/section plane).

"Inflow" effect relies on the fact that all the time in the examined section fresh blood permanently flows and the blood contains unsaturated atoms (spins) that have not been excited as the surrounding tissue. This technique uses a short echo time and flow compensation to make flowing blood much brighter than stationary tissue. As flowing blood enters the area being imaged it has seen a limited number of excitation pulses so it is not saturated, this gives it a much higher signal than the saturated stationary tissue. The appearance/image of atoms is hyper-intensive „bright blood”, intensity depending on the movement angle of the circulant spins towards the plane of the magnetic field, on the repetition time of excitation signal RT and on the section thickness (fig.4).

When using SE images (spin-echo), that show fast flows, movement of the spins that leave the section plane between applying impulses of 90 and 180 degrees is
detected – “flow void” effect. The appearance/image is hypo-intensive („dark blood”).

In GE images (gradient echo) the fast flow is hyper-intense because there is no repolarization impulse of 180 degrees.

The second method Phase Contrast - MR Angiography (PC-MRA) the phase of the MRI signal is manipulated by special gradients (varying magnetic fields) in such a way that it is directly proportional to velocity. Thus, quantitative measurements of blood flow are possible, in addition to imaging the flowing blood. The method is based on phase movement effect that is on differences of spin movements in terms of number and direction that are reported in time and space. Blood flow is not uniform and flow velocity will be different on section, being higher in the middle of the vessel and lower adjacent to its walls. A movement of different precession of spins is produced with a different Larmor frequency that is a dephasing between them. Spins moving within a magnetic gradient field accumulate phase, which is proportional to velocity.

By manipulation of the amplitude and duration of the bipolar magnetic gradient, the examination can be tailored to particular flow velocities. Giant aneurysms, subject to slow and turbulent flow, are particularly suitable for this technique. It is important to ensure that the correct velocity encoding (Venc, measured in cm/s), is chosen.

„Black Blood” or „Dark Blood” Angiography is an alternative approach is to depict the vessel lumen itself by enhancing the signal void created by flowing protons. This renders the vessel black in contrast to the surrounding stationary tissue. Instead of the maximum intensity projection (MIP) method used in bright blood techniques, black blood requires a minimum intensity projection (MINIP) which is designed to depict only those pixels at least 2 standard deviations (SD) below background intensity. Its advantage over bright blood techniques is that signal loss due to turbulence, which would otherwise cause image degradation, contributes to the desired signal void. Black blood images have found an application in the extracranial carotid vessels, but are problematic in the intracranial circulation because of the intimate relationship of the internal carotid artery to the skull base. Bone produces a signal void and is therefore difficult to differentiate from the signal void produced from flowing blood.

Like TOF, the black blood technique is relatively insensitive to slow flow. Its niche within the head probably lies in the demonstration of those vessels surrounded by soft tissue such as the middle or anterior cerebral arteries.

Resolution can be improved with the use of a surface coil.

Besides these native sequences a new vascular imaging method was developed CE-MRA („contrast enhanced MR Angiography”) that is obtained by intravenously injecting a paramagnetic contrast agent Magnevist (Acidum Gadopenteticum), Gadovist (Gadobutrolum) or Omniscan (Gadodiamidum) type (it contains Gadolinium) in 1 ml/kg body -dosage. Recently - Vasovist (Gadovist Veset Trisodium) - a new contrast agent was approved, which is an

Fig. 4 Aneurysm of Basilar Artery on MRI
albumin-targeted intravascular contrast agent that does not contain Gadolinium chelates.

After filling up the vascular lumen the signal from the examined segment is noticed. 3D-FLASH sequences are used to acquire fast images in real time. Intravascular blood loaded with paramagnetic contrast agent has a lower relaxation time than the surrounding tissues and it will be visualized with a distinct T1 hypersignal. CE-MRA creates the angiographic effect to selectively shorten the T1 of blood and thereby cause the vessels to appear bright on T1 weighted images.

The sequences best suited to this imaging are fast 3D gradient echo sequences, with short TR (< = 5 msec) and short TE (1-2 msec). Given that echo time is very short, the gradients are not flow compensated.

To remove the signal of venous flow it is required to optimally correlate Magnevist injection and signal acquisition and this can be done by 2 methods.

The first is bolus test that consists of MR signals acquisition from the examined vascular segment with a fast sequence after injecting a bolus of 1-2 ml Magnevist and setting the optimal delay time.

By serial MRA the signals are acquired from the very moment when a bolus of Magnevist followed by serum is injected by an injectomat, the procedure being repeated for several times (fig. 5).

CE-MRA visualizes vascular lumen (similar to DSA) unlike in TOF-MRA or PC-MRA that visualize intravascular flow. CE-MRA has found a wide acceptance in the clinical routine, caused by the advantages in investigating the areas with physiologic turbulent blood flow (infracavernous part of ICA – Internal Cerebral Artery) or pathologic turbulent blood flow (stenosis, thrombosed aneurysms).

Advantages of CE-MRA are the possibility of inplane imaging of the blood vessels, which allows examining large parts in a short time and high resolution scans of different types of cerebral lesions. 3D-MRA can be acquired in any plane with no use of ionizing radiation, with slices at high resolution in axial, coronal (frontal) or sagittal plane and even oblique sections could be done as well.

Acquisition and Post processing Technique of MRA Images

First the volume to examine is chosen („slab”), which is centred on the part of cerebral vessels under investigation: cervical (the junction of the carotid artery) or intracranial (Willis polygon). The volume to examine is set on 2 pilot images: sagittal and coronal, with a thickness of 32-90 mm. At TOF sequence, in order to use „inflow” effect, we position the volume to investigate in a plane onto the blood flow direction of cerebral arteries.

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Fig.5 Anterior Communicant Artery (ACoA) Aneurysm.
5a: TOF MIP MRA images

5b: MRI T2FLAIR

5c: TOF VRT images in the same patient

5d: CE-MRA VRT images in the same patient
Then the volume to examine is divided into a great number of partitions, sections of 0.8 – 1.5 mm thick (thinner sections are required for 3D-TOF). Spatial resolution of voxel is 0.9x0.9x0.9 mm when a matrix of 256/256 is used. 3

In order to selectively visualise the cerebral arterial system one should suppress/avoid venous flow signal.

After that the signals acquisition is being made and the angiotomograms are obtained as axial sections on which the structures with flow hipersignal are visualised. Then these images are postprocessed with the maximum intensity projection (MIP) algorithm by which we extract hyper-intense voxels out from the 2- or 3-dimensional data set and IRM projection angiogram is done. All 4 cerebral magistrals with their branches are visualised on the same image so they are unselective and non-dynamic. VRT (Volume Rendering Technique) could be used too, for a better exposure of vessels. By computer post processing these images could be virtually rotated towards any axis and could be enlarged to closely examine the vessels from different angles. 3

Selective images of Carotideal, Vertebrabasilar system or images of one single cerebral artery could be acquired by positioning specifically presaturation volumes along the vessels axis that should not be visualised as hyper-intense.

By applying selective presaturation volumes one could check the existence and calibres of different arterial segments of Willis polygon when detecting aneurysms that should be planned for surgery (fig. 6).

This technique continuously develops and acquires faster sequences and the spatial resolution improves as well, the best results are obtained with Black Blood FSE-MRI technique in association with 3D-TOF and 3D FISP Multislab TOF-MRA and 3D FLASH CE-VRT.

The sensitivity of MRA in the detection of cerebral aneurysms was 86% for aneurysms larger than 3 mm in size (similar to that of Arteriography), though sensitivity rates of 95 % were reported in other cases. 4

16% cerebral aneurysms detected by MR were false positive. 5

In 2001 MRA was thought to be useful as screening test in patients with high risks of cerebral aneurysms. 6

In 2002 a study was performed to evaluate the diagnostic accuracy of 3D-TOF MRA for cerebral aneurysms. 3D-TOF MRA was performed in 82 patients with 133 cerebral aneurysms. Each patient underwent rotational DSA and then the results were interpreted and compared. 3D-TOF-MRA was performed on 1.5 Tesla system and the results were interpreted by 4 readers of different experiences. One hundred five (79%) of all 133 aneurysms were detected with MRA by a neuroradiologist, 100 (75%) were detected by an experienced neurosurgeon, 84 (63%) were detected by a general radiologist, and 80 (60%) were detected by a resident neuroradiologist. Detection was less accurate for aneurysms under 3.0mm in size and for those that were located at the region of the ACoA and ACA. 29 false-positive aneurysms were encountered by a neuroradiologist, 19 by a neurosurgeon, 31 were encountered by a radiologist, and 30 were encountered by a resident neuroradiologist. The majority of false-positive aneurysms were located in the ICA (fig.7). 7

CONCLUSIONS

It is concluded that after implementing this new examination technique in Neurosurgery Clinic from Timișoara the number of patients that underwent cerebral MRA continuously grew between 2001 and

![Fig. 6 MRA - a bilobed aneurysm of ACoA:](image)
2008 and since 2006 MRA became first-choice diagnostic method for cerebral aneurysms, at present only special cases require complementary examinations (if there are contraindications for MRA).

This trend is shown in Table 1.

At the same time the number of cerebral aneurysms diagnosed with this method constantly grew (up to a maximum between 2006 and 2008) as well as the percentage of aneurysms diagnosed exclusively with MRA grew from 0% in 2001 to 90% (87-93%) between 2006 and 2008.

In 2001 all the cerebral aneurysms were diagnosed using the Arteriography and in 2008 all the cerebral aneurysms were diagnosed using MRA, associated with Angio CT in a few cases.

Over the same period of time the total number of cases with SAH continuously decreased and the diagnosis of cerebral aneurysms was more and more accurate as it is shown in Table 2. The high sensitivity of MRA in the detection of cerebral aneurysms has been reported(table 2).

MRA presents many advantages: the procedure is non-invasive and the patient is not exposed to ionizing radiation, and it could be performed even in patients allergic to iodine contrast medium material that could not undergo DSA or AngioCT. The paramagnetic agents have a beneficial safety, contrast agent Magnevist used for CE-MRA is non-allergenic, it is intravenously injected and it is not nephrotoxic. MRA is ideal for screening cerebral aneurysms because the procedure is non-invasive and it does not require arterial catheterization as classic Arteriography thus avoiding complications that could result from DSA or Percutaneous Carotideal Arteriography.

The technique produces images in section in axial, coronal or sagittal planes and oblique sections with 2D or 3D reconstructions without any ionizing radiations.

The disadvantages of MRA consist in the followings: it could not be performed in patients with cardiac...
stimulator, mechanic valvular prosthesis or other implants of ferromagnetic medical devices, bone rods, insets, screws and other complex dental works. It is difficult to perform MRA in patients with psychomotor disturbances, in comatose and claustrophobic patients because the acquisition time is longer than that of DSA and AngioCT and the patients must sit still.

MRA imaging could be affected by different factors such as size, rate, and direction of blood flow through aneurysm in relation with the magnetic field, thrombosis or intra-aneurismal calcification.

The artefacts that occur in MRA case are specific for each technique such as artefacts of movement, interpretation (false positive results due to substances that have a short T1 and mimic blood flow: fat, sub-acute haematoma, intravascular thrombosis in sub-acute stage, structures that quickly captured Gadolinium and false negative results due to stenosis, arterial occlusions or thrombosis) or flow.

It was reported low detection of small vessels and vessels with sinuous trajectory and misinterpretations due to the overlapping of vessels and malprojections.

Recent studies revealed the occurrence of Nephrogenic Systemic Fibrosis (NSF) in patients with renal pathology, after injecting contrast agents that contain Gadolinium, Omniscan type (our clinic exclusively used Magnevist). That is why Omniscan or other contrast agents that contain Gadolinium are no longer used in patients with renal pathology.

In conclusion, compared with the Arteriography, MRA can detect intra-cranial aneurysms with greater levels of

![Fig. 8. MRA of a patient with 3 cerebral aneurysms: right MCA (middle cerebral artery) bifurcation aneurysm, Basilar Top Artery aneurysm and left vertebral artery aneurysm.](image)
sensitivity and accuracy and the experience of Neurosurgery Clinic from Timișoara proves that MRA is the first-choice diagnostic method for cerebral aneurysms.

In conclusion, compared with the Arteriography, MRA can detect intracranial aneurysms with greater levels of sensitivity and accuracy and the experience of Neurosurgery Clinic from Timișoara proves that MRA is the first-choice diagnostic method for cerebral aneurysms.

In 2008, in Neurosurgery Clinic from Timișoara all the cerebral aneurysms were diagnosed using MRA, in a few cases MRA was associated with Angio CT for a more accurate diagnosis.

REFERENCES

1. Patient education: Cerebral aneurysm - Copyright 2001-2006 Stanford Hospital & Clinics. All rights reserved.
7. Okahara M, Kiyosue H, Yamashita M. Et al., Diagnostic Accuracy of Magnetic Resonance Angiography for Cerebral Aneurysms in Correlation with 3D-Digital Substraction Angiographic Images - A Study of 133 cases Stroke, 33, 1803, 2002