Defence Science Journal, Vol 46, No. 4, October 1996, pp 237-242


*SHORT COMMUNICATION*

# Experience of 3D TOF Magnetic Resonance Angiography in India

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**ABSTRACT**

The morbidity and discomfort following catheter insertion and contrast medium injection during invasive angiogram led to the use of an alternative noninvasive angiographic technique. This article reviews the initial results and application of three-dimensional time of flight (3D TOF) single volume MR imaging of the blood vessels of the head and neck regions. By using the 3D TOF single volume technique, the MR angiograms were acquired in 10 min and portrayed blood flow in all major arteries and veins. Arterlovenous malformations, aneurysms, obstructed cerebral vessels and the patency of a highly stenotic internal carotid artery were demonstrated.

## 1. INTRODUCTION

While the invasive contrast cerebral angiography has been set up as the standard for diagnosing and for therapeutic manipulation of different cerebrovascular diseases, the effort was to find out an alternative, efficient, reliable noninvasive, and safe procedure which can provide same or better diagnostic and morphologic information about the cerebral vessels[1]. The invasive angiogram is risky and at times it results in morbid conditions like death of the patient. While the effort was on to find out an alternative procedure, it was found that the time of flight phenomenon of flow related enhancement produces a contrast between blood and stationary tissue. This is possible only when the partially saturated spins within the imaging slices are replaced by inflowing unsaturated or fully magnetised spins. The signals from the stationary material are suppressed; whereas the signals from the fully relaxed inflowing spins remain high, if the TR is short in comparison with the longitudinal relaxation rate (T1). Thus the bright vessels seen with flow related enhancement are due to the relative attenuation of the stationary tissue and not due to the intrinsic quality of the inflowing spins. Three dimensional time of flight TOF MRA can be done by using either a single volume technique or a multiple volume technique using MIP (maximum intensity projection) reconstruction procedure. The other well-known white blood MRA techniques are: sequential 2D slice technique and phase contrast MRA technique[2,3].

The single volume three-dimensional Fourier transformation (3DFT) technique has demonstrated rapid and reliable visualisation of the intracranial circulation in many of these applications, including noninvasive evaluation of many vascular abnormalities such as aneurysms, arteriovenous malformations, vascular occlusion and venous thrombosis, etc[3,4]. However, the effect of progressive saturation of inflowing spins presents a major limitation to this method, limiting the visualisation of venous anatomy, slow flow lesions and the distal vasculature in thick imaging volumes[5].

## 2. MATERIALS & METHOD

The patients of different cerebrovascular diseases like Moyamoya disease, arteriovenous malformations,

Received 08 May 1995, revised 08 August 1996

intracranial aneurysms, angiomas, hemangiomas, etc were evaluated using noninvasive 3D TOF MRA. The results thus obtained were compared with the routine invasive conventional contrast angiography.

All studies were performed on a standard superconducting 1.5 T whole body MR system (Siemens, Magnetom) with a linearly polarised head coil. Initially, routine T1, T2 and proton-weighted images were obtained. Following this, 3D TOF MR angiography was obtained by single volume technique by using gradient FLASH (fast low angle shot) or FISP (fast imaging with steady precession) sequences. The images were obtained in the sagittal, axial and coronal planes, separately. The parameters used were:

(a) TR/TE 400/15 ms,

(b) Flip angle $15^{0}$,

(c) Slice thickness 1 mm,

(d) Field of view (FOV) 300 mm,

(e) Matrix size 256 × 256,

(f) Number of excitation 1, and

(g) Number of images obtained 64.

Following the acquisition of partition angio images, the maximum intensity projection calculation of these partition images was done. The calculated angio images were displayed on a 2D console. During the interpretation of the angio images, all the T1 and T2 weighted spin echo images and the partition angio images were also considered and the results thus obtained were then compared with the routine invasive angiograms. The study of the routine spin echo images and the partition angio images together is very important because often the interpretation of MR angio images alone may be misleading specially in the case of measuring vessel lumen size.

The MIP calculation was done at every $15^{0}$ interval. At least five to six angiogram images were obtained. Total examination time was 10 min (approximately).

Besides 15 normal healthy volunteers, a total of 100 patients of different age groups and both sexes were studied. Clinical evaluation and routine investigations (like blood and urine examinations) were done. Plain X-ray of skull, CT scan examination of the head, conventional contrast angiography (in few cases digital subtraction angiography) were done. Out of total 100 patients, 27 patients were suffering from arteriovenous malformations, 31 patients from aneurysms, 15 patients from ischaemic infarcts, 13 patients from subarachnoid haemorrhage, 2 patients from vein of Galen aneurysm, 5 patients from venous angiomas, 6 patients from capillary angiomas, and 1 patient from neck hemangiomas. Almost all the patients, except 12 patients of high risk group, underwent conventional invasive angiography as well as MR angiography. These patients had strong family history of hypertension, immunological disorders, etc and were clinically asymptomatic. Out of 100 patients, 45 underwent contrast enhanced MR angiography. Wherever slow flow was suspected or both conventional and noncontrast MR angiography results were confusing and indecisive, the contrast enhanced MR angioghraphy was performed.

Large vessel definition was determined by examination of the supraclinoid carotid bifurcation, primary bifurcation of the middle cerebral artery and anterior limb of the carotid siphon for evidence of signal loss from motion-induced dephasing (flow voids). Small vessel resolution was evaluated by inspection of the corticle vascular branches in the anterior, middle and posterior cerebral artery distributions and by visualisation of the ophthalmic, posterior communicating and superior cerebellar arteries. Note was made of the technique revealing the largest number of the uninterrupted opercular branches of the middle cerebral artery and longest segment of the posterior temporal, parietooccipital and calcarine branches of the posterior cerebral artery in each volunteer and the patient. The venous system was evaluated through examination of the internal cerebral veins and the straight, sphenoparietal and transverse venous sinuses.

## 3. RESULTS & DISCUSSIONS

MR angiography was found to be complementary in the diagnosis of many pathological conditions, anatomical abnormalities and screening of the high risk group of patients (who may often harbour small intracranial vascular aneurysms but clinically remain asymptomatic). In the case of normal healthy volunteers, the MR angiogram in all three planes could delineate well the common carotid artery and its branches (external and internal carotid arteries), the

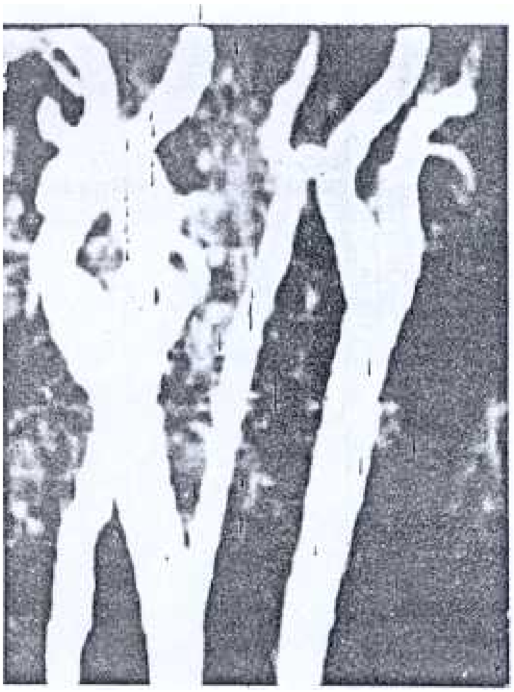

**Figure 1a. MR angiogram of a normal healthy volunteer in the coronal plane showing the carotid artery and its branches.**

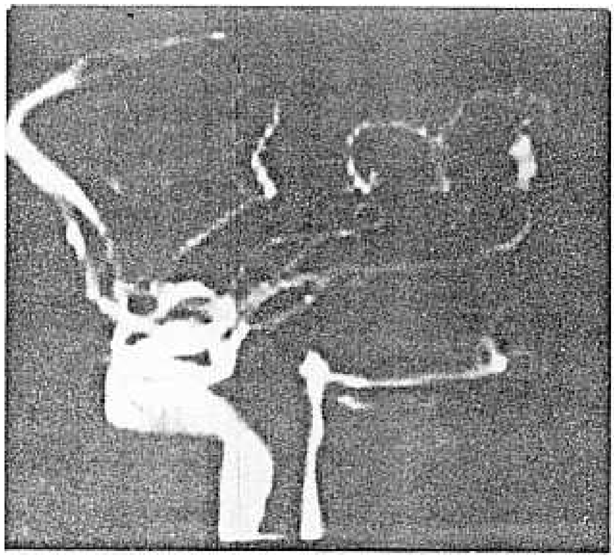

**Figure 1c. MR angiogram of a normal healthy volunteer in the sagital plane showing the anterior cerebral artery and middle cerebral artery with their cortical branches.**

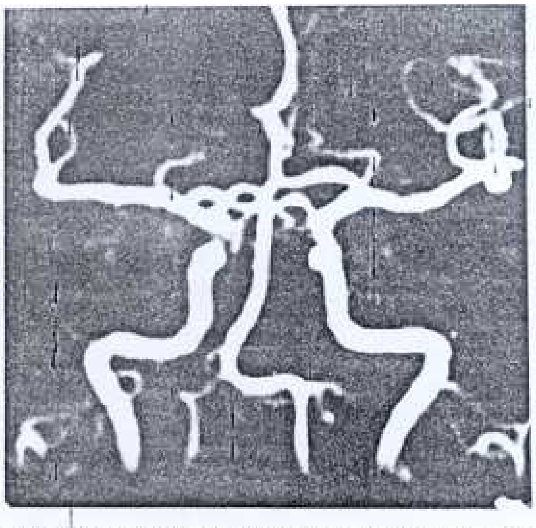

**Figure 1b. MR angiogram of a normal healthy volunteer in the coronal plane.**

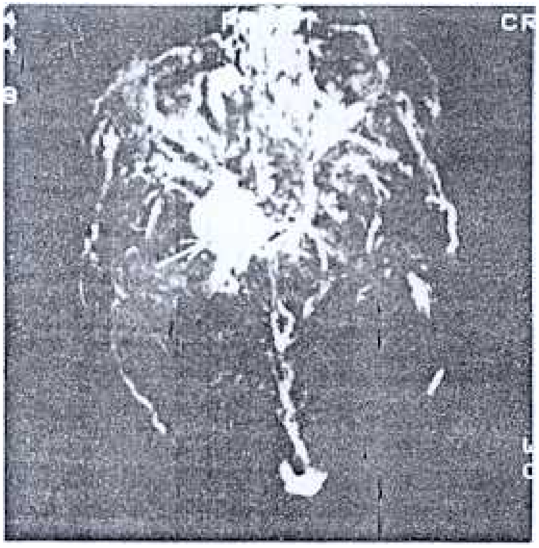

**Figure 2a. MR angiogram in axial plane shows internal carotid artery aneurysm.**

vertebral artery, the basilar artery, anterior cerebral artery, middle cerebral artery, posterior cerebral artery and their branches (Fig. 1). The MR angiogram was found to be a reliable diagnostic technique in the evaluation of arterial occlusive disease in the young individuals[6]. We studied a group of four patients of Moyamoya disease confirmed by routine conventional angiogram and contrast CT examination of the head. These patients were subjected to 3D TOF MR angiogram. The results were very encouraging. The block at supraclinoid portion of both carotids were found to be 7/8, basal cerebral moyamoya vessels (MMVs) were visualised in three patients. Periorbital external carotid collaterals were shown in two out of four cases. Leptomeningeal collaterals were visualised in two out of four cases.

Out of 31 patients of aneurysms, in 21 patients the MR angiographic results were similar to that of routine

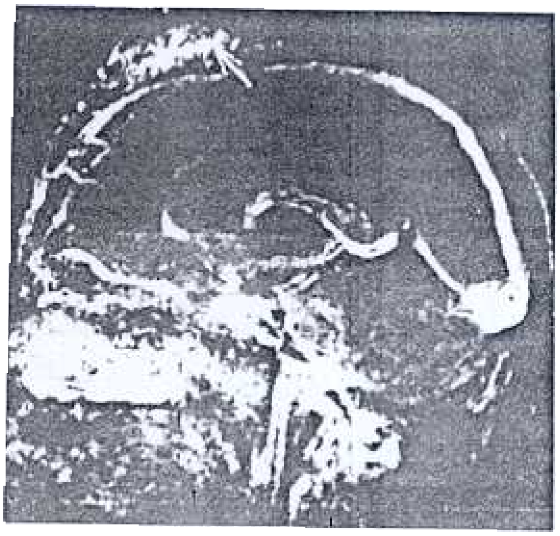

Figure 2b. MR angiogram in sagittal plane shows the cirsoid aneurysm.

Figure 4. Post-contrast MR angioram in sagittal plane shows a venous angioma.

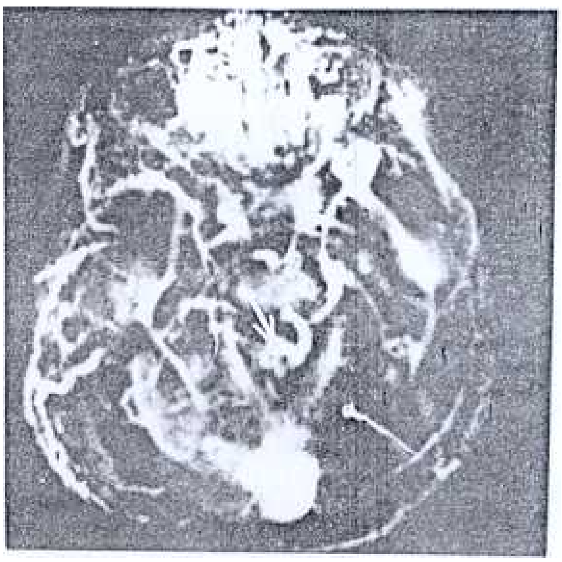

Figure 3. MR angiogram in axial plane shows the vein of Galen aneurysm malformation.

conventional contrast angiography (Fig. 2). In the remaining 10 patients, MR angiography were performed as a screening procedure, because these patients belonged to high risk group who were more prone to develop intracranial aneurysms (majority of them had family history of hypertension, few were having polycystic renal diseases and few were suffering from aortoarteritis); they were not subjected to invasive conventional angiography because they were asymptomatic. In five out of ten patients, the MR angiography were negative. In the remaining five patients MR angiography revealed the presence of small intracranial aneurysms (4-5 mm size).

In six cases, both invasive angiography and the MR angiography revealed the presence of small aneurysms (3-4 mm size). But, post-operative histopathology proved the lesions to be capillary angiomas and not aneurysms. Hence a word of caution regarding diagnosis and management could be sounded. In two children where invasive contrast angiography could not be done as the clinical condition of these patients was very unstable and the consent of the parents for invasive angiography could not be obtained, only MR angiography was performed. The MR angiography clearly demonstrated the vein of Galen aneurysmal malformation (Fig. 3). In five patients, the routine invasive contrast angiography and noncontrast MR angiography did not reveal any abnormality. But, when MR angiography was repeated after administration of I.V. Gadolinium, the results were encouraging and showed the presence of venous angiomas (Fig. 4). In 27 patients of arteriovenous malformations, the MR angiography could reveal the nidus (Fig. 5). In majority of the cases, the arterial feeders could not be defined very well. Only the major arterial feeders could be defined. In all the cases, the venous drainage could be delineated well.

Routinely, the MR angiography is performed without the use of any contrast media. But in certain cases, specially in delineating the slow flow lesions,

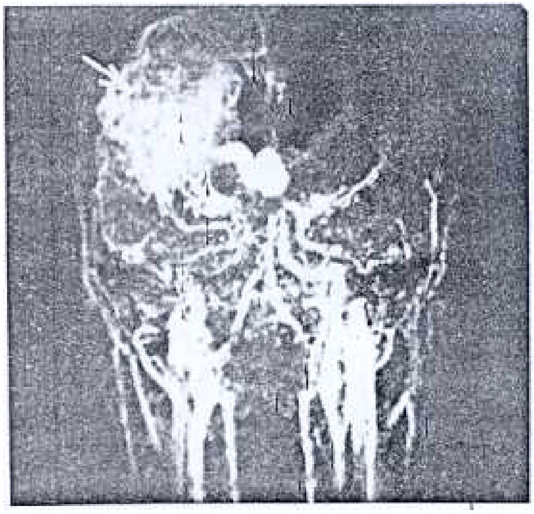

Figure 5a. MR angioram in coronal plane.

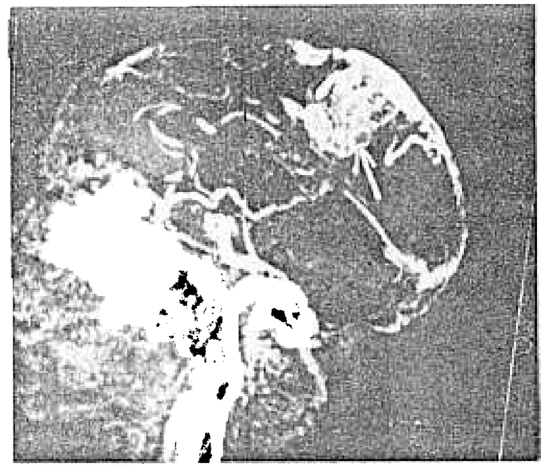

Figure 5b. MR angioram in sagittal plane shows arteriovenous malformation.

angiomatous lesions, venous obstruction, etc. the use of MR contrast media is strongly indicated. Post-contrast MR angiography only can detect properly such type of lesions[7,8,9]

In the case of children, often catheter angiography remains difficult either from technical point of view (the catheter negotiation with the cerebral vessel) or due to the refusal of the parents to give consent for the invasive angiogram. In such cases, the MR angiogram is the only procedure of choice. It is very safe and often provides the adequate diagnostic information required for the management.

The study was performed in collaboration with the different teaching medical institutes of Delhi and the Army Hospital, Delhi Cantonment. The defence personnel (Army, Air force and Navy) and their families were benefitted by this study. In most of the defence patients of cerebrovascular diseases, where the routine contrast conventional angiography could not be performed due to lack of facility, patient's age or patient's serious clinical condition, etc. the MR angiography in INMAS, Delhi, could play a significant role in the diagnosis and management.

## 4. CONCLUSION

To conclude, MR angiography can be used as a safe screening procedure for detecting small intracranial vascular aneurysms in clinically asymptomatic high risk group of patients. It can be employed on children and old age patients, where conventional angiography is unsafe and hazardous and also for periodic evaluation of the patients after radiotherapy or surgery for arteriovenous malformations. It facilitates Gadolinium-DTPA contrast enhanced MRA for the evaluation of slow flow and cryptic vascular malformations which go undetected by conventional angiography and noncontrast MRA. It can also be used for the evaluation of brain tumours.

With the introduction of new techniques like magnetisation transfer phenomenon and TONE techniques, the noninvasive MR angiography will become the diagnostic procedure of choice and the best alternative to the invasive conventional angiography.

## ACKNOWLEDGEMENTS

I am very thankful to the Department of Science & Technology, Goverment of India, for awarding me the Young Scientist Project on MRA, under which the whole study of this paper was done. Also my sincere gratitudes to Col. A. Jena, Col. R.P. Tripathi, Mr. H.S. Bist and Sub. K.D. Prasad for their immense help and cooperation.

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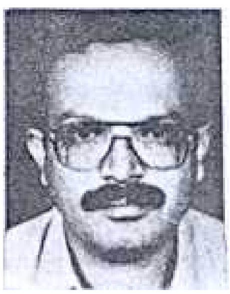

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