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MAGNETIC RESONANCE ANGIOGRAPHY (MRA) AND CORRELATION WITH COLOR DOPPLER ULTRASOUND (CDUS) IN EVALUATION OF THE CAROTID BULB AND PROXIMAL INTERNAL CAROTID ARTERY.

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ABSTRACT

Background: The aim of the study is to compare the magnetic resonance angiography (MRA) with color Doppler ultrasound (CDUS) for evaluation of the carotid bulb and proximal internal carotid artery. **Material & Methods:** The carotid arteries of 60 patients were studied using MRA &CDUS. All of the patients underwent both the investigations. MRA done with time-of-flight sequence and 3D- reconstruction. Carotid bulb and proximal internal carotid arteries were graded as normal, mild, moderate, or severe stenotic. **Results:** There was significant difference in the results of MRA as compared to CDUS in mild to moderate stenosis and it proved relatively more accurate in the diagnosis of severe stenosis. MRA had few false positives for complete occlusions and more false negatives in partial occlusion of the carotid arteries. In few cases MRA overestimated stenosis and in many cases underestimated the stenosis. **Conclusions**: MRA has advantages which may make it the screening test of choice. It can be done with MRI brain, can assess distal ICA and intracranial vessels but the sensitivity and specificity of MRA as compared to duplex ultrasonography is significantly lower for mild to moderate stenosis (non-surgical) however, in case of severe stenosis (surgical), it is having good sensitivity and specificity, almost equal to color doppler study. This preliminary study suggests that concordant CDUS may be used to clarify equivocal findings of MRA.

Key words: Arteries, carotid; Arteries, stenosis and occlusion; Magnetic resonance angiography (MRA); Ultrasound, Doppler

INTRODUCTION:

The magnetic resonance angiography (MRA) for carotid arteries is being done frequently to assess stenosis in the stroke patients. Because of, rapid and laminar blood flow in the normal carotid artery is well suited to MRA, particularly by the so called time-of-flight (TOF) principle imaging **(1)** (also called "flow-related enhancement" or simply "inflow"). MR imaging coils used for the neck which have adequate sensitivity for permitting visualization of relatively small vessels and high-resolution images. The interpretatin of carotid MR angiograms has improved dramatically over the past decade **(2)** Due to implementation of small voxel volumes and very short echo times to minimize turbulent flow signal loss **(3)**. In its 3D feature, a slab of data is developed that offers very high resolution and sensitivity to flow in all direction, but reflects poor contrast in the slow velocity situations. This output is the result of saturation of blood as it moves through the slab. Grayscale and Doppler ultrasound are applied for the evaluation of extra cranial branches of carotid arteries. The combination of these two ultrasound methods are known as CDUS.

Grayscale USG permits the evaluation of morphology with evaluation of atherosclerotic changes of vessel wall. It also make possible the measurement of intima-media complex thickness, by which we detect preclinical atherosclerosis and also assessing the risk stratification. We also avoid the issue of 3D TOF angiography versus 2D by taking both sequences and taking advantage of the benefits of both methods. MRA is compared in order to assess the agreement among these modalities in the evaluation of the carotid bifurcation and proximal internal carotid artery.

MATERIAL & METHODS:

The study is prospective study in the Radiology department of the Pacific Medical College & Hospital, bhilo ka bedla, Udaipur. The prior approval from ethical committee was taken.

Total 60 Patients were included in the study, which comes in the department for the evaluation of the stroke from October 2016 to May 2018.

Patient Population:

Out of total sixty patients, forty one patients were male and nineteen patients were female with age ranges from 45 years to 85 years with a high clinical risk for stroke were detect by color doppler and MRA. The stenosis in MR angiography and colour doppler study was assessed by three different radiologist randomly and all three radiologist were blind reader & they independently measured stenosis on MRA and DUS in 240 vessels (120 carotid bulbs and 120 internal carotid arteries) from 60 patients.

3DTOF-MRA Studies

MRA exams were performed on a 1.5-T essenza (Siemens AG) MRI machine using 16 channels transmit-receive head coil. 24 transverse sequential 3D TOF slices were taken using fast low-angle shot (FLASH) and slice thickness of 1.5 mm, 40/10/25° TR/ TE/8 and acquisition time of approximately 5.0 min, with velocity recompense in the slice and with a coronal saturation band over the dural venous sinuses of the occipital region and frequency encoding direction to eliminate jugular vein signals.

Applying the transverse slices to locate the bifurcations, 2 sagittal 3D TOF slabs were used, one placed on each bifurcation, using the procedure described by Masaryk et al **(9)**. Fast imaging with steady state precession (FISP) was carried out with 70/7-8/20-30° TR/ TE/8, a matrix of 256 X 256, field of view (FOV) of 220 mm, 32 partitions per slab, acquisition time of 9.6 min, and velocity compensation in frequency and slab selection directions. The prolong repetition time provides very little saturation of blood over imaging volume. A coronal saturation band was used over the occipital area. In few cases, a second coronal saturation band was used anteriorly to carotid to remove any artefact from tongue motion and jaw motion. A transverse 3D TOF slab was then implemented. The slab was placed at the bifurcation when a lesion away from the bifurcation was not detected on the sagittal acquisition, if detected the slab was placed at center of the lesion (FISP, 50/ 7/25° TR/ TE/8, matrix = 192 X 256, 64 partition, superior transverse saturation band, FOV = 210, time = 10.3 min). Maximum intensity projections (MIPs)10 applied, which was calculated easily and permits the inspection of angiograms and execution of additional sequences, if necessary, before the patient left the study. The projections were photographed and with the individual slices from transverse acquisition and the bifurcations from the sagittal 3D acquisition.

CDUS Studies

The 7.5-12 MHz linear transducer on GE-E8 ultra sound machine was used for Color flow Doppler imaging. Carotid arteries were examined thoroughly in transverse and longitudinal planes. Spectral analysis was performed on areas of flow abnormality or if none existed, at the region of the maximum velocity of the CCA, ICA, and ECA. Peak systolic velocities and end diastolic velocities were noted. Doppler ultrasound detects the focal increased in blood flow velocity at rate of >150 cm/sec which indicates of high grade carotid stenosis**.(13,14,15)** The peak systolic velocity is the most commonly applied to detect the severity of the stenosis, but the spectral configuration and end diastolic velocity provide additional information.**(12)** This may improve the efficiency of the procedure, but it has not been shown any improvement in accuracy as an adjunct to CDUS.**(13,15,17,18)**

Assignment of Stenosis Grade

Diameter percent stenosis grades are denoted in Table1. MRA stenosis grades were defined by evaluating the observed width of stenotic vessel with width of closest normal portion of proximal and distally vessel. The orientation that established the greatest stenosis was selected. When the stenosis reached over a long segment so that there was no immediately adjacent normal segment for evaluation, the normal diameter was measured by reference of the contralateral side or by calculating the stenosis by measurement of residual lumen & vessel size if able to detect plaques of muscular wall of the vessel directly **(11)**. Doppler study and MRA images were read in blinded fashion by three radiologists individually and randomly. The radiologists had two or more years' experience in MRA, and were experianced with common artifacts such as saturation, flow separation, turbulence, and MIP effects. In the study, only the proximal 4cm of the ICA was included & stenosis at other sites was ignored so that correlation could be made with CDUS as distal ICA is not well assessed by CDUS. Doppler cross-sectional diameter stenosis was assigned by area of residual lumen divided by area of vessel & supplemented by the measured velocities according to the algorithm recommended by Bluth et al **(12)**.

RESULTS:

In our study, we observe that there was significant difference in the results of MRA as compare with CDUS in mild to moderate stenosis and relatively less difference in the results for severe stenosis. In our opinion few important reasons were playing important role for this difference, first of them was high observer difference in MRA probably due to very similar signal intensity of soft plaque with surrounding tissue and flow related artifacts at bulb, so the plaques sometimes under reported or sometimes over reported. Second, in Positive remodeling cases when plaque is identified on Doppler but sometimes no obvious difference in the lumen diameter as compare to distal and proximal vessel diameter so reported false negative on MRA and third reason was MRA stenosis measurement done by proximal and distal vessel diameter but at the level of bulb region it is difficult to compare the lumen from proximal and distal as it is already the widest part.

In some other studies reported that sensitivity and specificity for 3D TOF MRA for predicting 50-99% angiographic stenosis varied between 73-100% and 59-99%, respectively.**(10, 27-31)**

Compared to CDUS, MRA is not cost-effective and time consuming. It is not commonly accessible than CDUS and difficult to be performed if the patient is critically ill, unable to lie supine or has claustrophobia, a pacemaker or ferromagnetic implants.[10] In most of the series, up to 17% of MRA studies are unfinished because the patient could not bear the study or could not lie still enough to produce an image of adequate quality for interpretation. **(32)**

The evaluation of the carotid arteries by Carotid duplex ultrasound is a better approach though it is a safe, non-invasive, and relatively economic technique.

CDUS is 91-94% sensitive and 85-99% specific in noticing a symptomatic stenosis of the internal carotid artery.**(9,10,11)** While restricted, CDUS has usefulness in gaining clear evidence about plaque composition. Intraplaque hemorrhage, which may amplified the risk of embolism and effect on prognosis, can be imagined on high resolution B-mode.**(8,9,10,11,16,17)** Moneta and colleagues stated that the ratio of ICA peak systolic velocity to the common carotid artery velocity precisely estimated a high grade stenosis amenable to surgery.**(18)** Using available facts and receiver operator characteristic analysis, test criteria can be established that get the most out of patient outcome for a precise clinical situation.**(19,20)**

CDUS is more specific in defining stenosis of less than 50 percent, but this infrequently effects on its clinical usefulness. **(9,10)**.

In our study the MRA having 70 – 80 % accuracy in mild to moderate stenosis and around 85 % accuracy in sever stenosis as compare with CDUS.

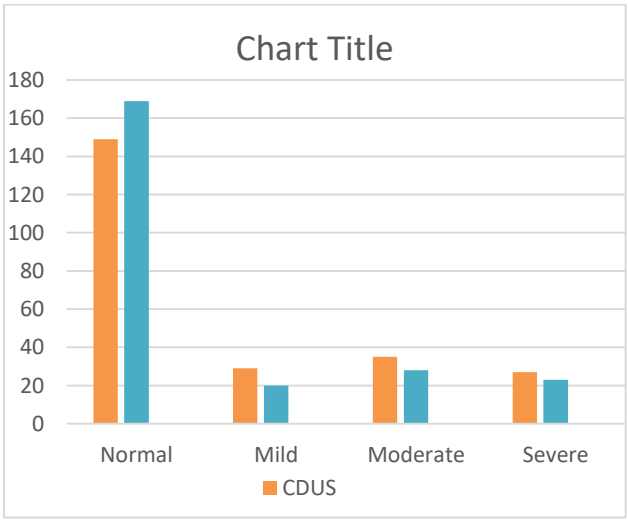
Table1:

SEVERITY	Stenosis Percentage
Mild	15-35%
Moderate	35-65%
Severe	65-95%

Table 2:

Degree of stenosis	CDUS	3D-TOF MRA
Normal	**149**	**169**
Mild	**29**	**20**
Moderate	**35**	**28**
Severe	**27**	**23**
Total	**240**	**240**

Graph 1:



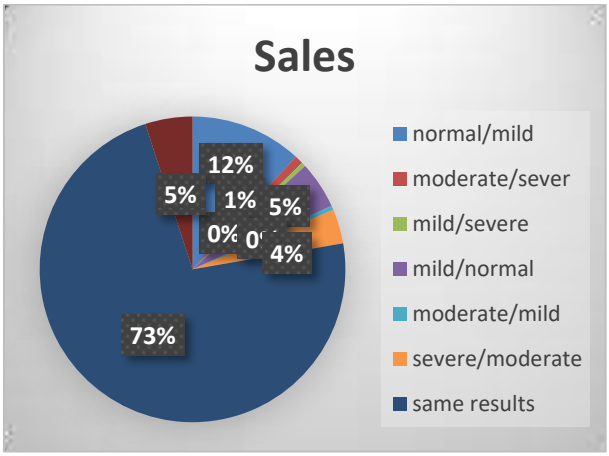


Table 3:

Patients having a same result		180
3D-TOF MRA	**CDUS**	**Patients having a different result**
Normal	**Mild stenosis**	**26**
Mild	**moderate**	**11**
Moderate	**Severe**	**2**
Mild	**severe**	**1**
Mild	**Normal**	**11**
Moderate	**Mild**	**1**
Severe	**Moderate**	**8**

DISCUSSION:

Out study, have found that 3D TOF magnetic resonance angiography in screening and grading carotid stenosis in the patients of stroke having good and similar results when the stenosis was severe but in case of mild and moderate stenosis, it proves less sensitive and specific as compared to CDUS. In our opinion, as the two methods provide complementary data, they should be used in combination as a diagnostic tool for assessment of stenosis. For the surface plaque assessment, CDUS is superior to 3D TOF MRA. The continuing technological developments and the so many studies indicating diagnostic consistency and diagnostic relationship of these two non-invasive methods lead us MRA is good for the screening purpose to just rule out occlusion or severe stenosis for characterization of plaque and final labeling of mild, moderate and severe stenosis must undergo Doppler evaluation.

The patients with carotid ischemic symptoms commonly do not have much severe carotid stenosis so that not required stenting. The DSA is gold standard for strok patients but not reasonable in every patient of stroke. So being as invasive and relatively more risky procedure, the MR angiography along with color Doppler study provides a better diagnostic tool.**(25, 26)** Therefore; patients are commonly selected for angiography preferring one of the noninvasive tests.

When, MR angiography is supplemented with CDUS have better sensitivity & specificity then MRA alone which proved less specific in the characterization of normal, mild and moderate stenotic plaques and almost equivocal sensitive and specific in the characterization of severe stenosis.

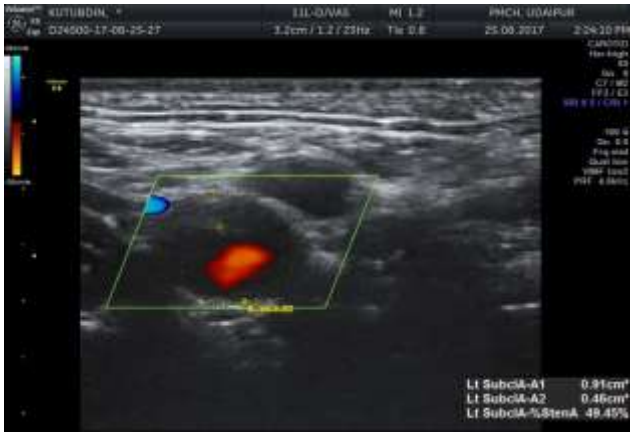
The previous studies have reported the sensitivity and specificity of both CDUS and MRA evidently to angiography in the finding of surgical disease.**(23,26,29,30)** Some researcher have stated that the combine use of ultrasound and MRA is not only economical, [32] but results in an overall error rate that is comparable to the inter-observer reliability when two radiologists are presented with the same conventional angiogram revealing carotid artery disease. **(33)**

When alone color doppler ultrasound is taken as screening for stenosis it can give better result than MRA at carotid bulb and proximal ICA but as distal ICA and intracranial ICA cannot be assessed by it, so cannot be taken as single screening test. When MRA taken as single screening test, it proves less sensitive and specific in the grading of the mild & moderate stenosis and normal cases in our study so we recommend the combination of carotid ultrasound and MRA to obviate the need for conventional angiography in the every patient with stroke for pre surgical assessment of patients with carotid artery disease and use should be limited in high grade stenotic patients after screening with MR angiography & CDUS requires stent or surgery for the treatment.

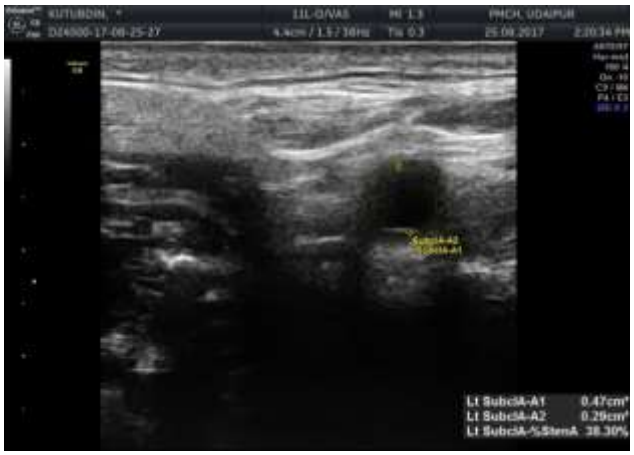
CONCLUSION:

MRA having some advantages, like it can be done with MRI brain, can assess distal ICA and intracranial vessels that make it screening test of choice but our study shows that the sensitivity and specificity of MRA as compared to duplex ultrasonography is significantly lower for mild to moderate stenosis (non-surgical) however, in case of severe stenosis (surgical), it is having good sensitivity and specificity, almost equal to color doppler study. This preliminary study suggests that concordant CDUS may be used to clarify equivocal findings of MRA.

Figures:

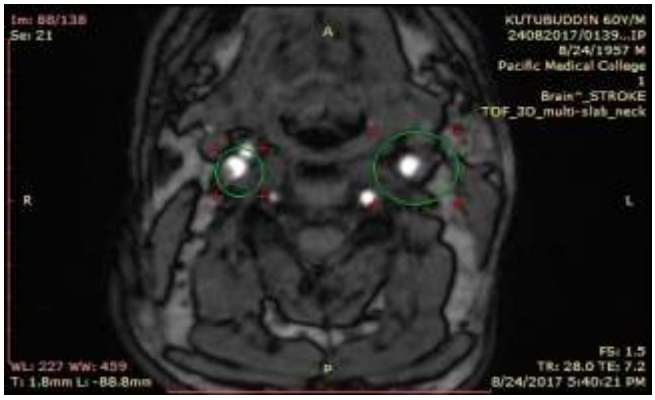


(a)



(b)

Fig1: CDUS image (a) shows around 45-55% of stenosis in the left common carotid bulb region and image (b) shows around 30-40% stenosis in right common carotid bulb, so categories into moderate stenosis on left side and mild stenosis on right side.



(c)

(d)

Fig 2: MRA TOF image (c) in axial sections showing mild eccentric narrowing at bilateral common carotid bulb region marked by circle. 3D- reconstructed TOF image (d) in coronal plane showing mild stenosis at both common carotid and proximal ICA region by visual comparing with proximal and distal diameter.

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