# ROLE OF ULTRASOUND DOPPLER,MAGNETIC RESONANCE ANGIOGRAPHY COMPARED WITH DIGITAL SUBTRACTION ANGIOGRAPHY IN CASES OF CAROTID ARTERY STENOSIS.

**Radiology**

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## ABSTRACT

**Background and purpose:-**In past few decades it has been observed that there is continous rise in cases of stroke, majority of strokesare associated with carotid stenosis in patients specially in elderly age group or having various risk factors such as smoking, hypertension, diabetes mellitus and dyslipidemia. Due to technological development in various non invasive modalities requires assesment of reliability, sensitivity, specificity and accuracy in comparisionwith DSA. Early detection of stenosis and grading may help physician for planning further treatment and management and hence decrease in mortality and morbidity to the patients. We evaluated role of Doppler USG, MRA in comparision with DSA for detection of carotid artery stenosis.

**Material and methods:-**In our prospective study of 50 patients wereassessed of all age groups in male and female. We compared all risk factors associated with stenosis and grading of stenosis with USG Doppler, MRA and DSA was done. PSV and ICA/CCA ratios were obtained for all cases which showed to have linear relation with degree of stenosis.

**Results:-** Overall sensitivity, specificity and diagnostic accuracy of USG was 91.49%,93.34%, 93% while MRA showed sensitivity, specificity and diagnostic accuracy of 95.12%, 94.34%, 98% respectively. DSA had sensitivity, specificity and diagnostic accuracy of 100%. Combined Sensitivity, specificity, diagnostic accuracy of both MRA and USG Doppler was 97%, 95% and 96% respectively.

**Conclusion:-**USG and MRA combined gives near equal sensitivity in detection of lesion and lesion characterisation becomes modaliy of diagnosis and DSA remain gold standard for diagnosis in cases of dilemma and therapeutic approach.

## KEYWORDS:

**Introduction :**

In past few decades it was observed there is continuous rise in cases of stroke which in turn again causes increase in mortality and morbidity. Carotid artery stenosis has direct relation with occurence of stroke specially in elderly age group or having various risk factors such as smoking, hypertension, diabetes mellitus and dyslipidemia[1] [2].

Stroke associated with extracranial carotid atherosclerotic disease could occur via several mechanisms:

- Atheroembolism of cholesterol crystals or other debris.
- Artery to artery embolism of thrombus.
- Structural disintegration of the wall (dissection)
- Acute thrombotic occlusion.
- Reduced cerebral perfusion with plaque growth [3].

Early detection of carotid artery stenosis and its severity grading helps physicians for decision making in management which is of further help to reduce morbidity and mortality to the patients.

For about 50 years DSA remain gold standard for diagnosis and treatment of this patients. With evolution of technology in the field of USG and MRI/MRA and their increase in sensitivity and specificity of detection of stenosis their non invasiveness, radiation free, cheap and high availability had made them better choice for diagnosis and treatment planning. DSA remain gold standard of reference today also where USG and MRA fails to diagnose or in cases of dilemma but being invasive modality it is reserved for therapeutic approach. [4] [5] [6].

With the expanding spectrum of management of patients with carotid artery stenosis, the main purpose of radiologists should be:-[7] [8]

(1) To confirm the presence and grading of carotid artery stenosis with various available standard methods.

(2) To determine the level ,extent and location(intra v/s extracranial involvement) of the stenosis ,

(3) To identify the specific cause and to characterise the lesion, and

(4) To look for associated ischemic changes in brain.

(5) To low the economic burden on patient and to diagnose the pathology with limited use of imaging modalities.

Till date various studies had been conducted out of which North American Society of Carotid Endarterectomy Trails has got important role due to its better effective grading system; studies concluded there is linear relation between degree of stenosis and raised PSV and ICA/CCA PSV ratio. It also stated that DSA had role in significant carotid stenosis while very less role stenosis less than <30%. [1] [9] [10] [11]

The main aim of our study is to compare the diagnostic performance of DUS, MRA in comparision to DSA in carotid artery stenosis.

**Results :** In our presented prospective study of 50 patients there were total 28 male(56%) and 22 patients (44%) females, showing male preponderance. Youngest patient in our study was 8 years male suffering moyamoya disease and eldest one was 80 years male suffering near total occlusion of right carotid artery. Most common symptom of presentation was weakness followed by blurring of vision.Various risk factors were evaluated out of which hypertension (44%), diabetes melitus(26%), dyslipidemia (24%) and other risk factors include smoking, cardiac history and obesity had strong correlation with stenosis. Most common age group of presentation in our study was 61-70yrs (17 patients) and 51-60yrs (14 patients).Right side was most commonly affected with patients of > 60% stenosis which were 23 in number. All patients were subjected to CT for primary evaluation out of 50, 27 were normal;18 presented with infarct and 5 had infarct with hemorrhage showing positive correlation with patients having significant stenosis(23 patients).

USG has effectively detected 43 true positive cases whereas MRA detected 47. In mild ( <49% ) stenosis(total 10 patients) USG accurately detected total 9 pathologies and MRA detected 8. USG had better results for detecting mild stenosis with sensitivity and specificity of 100% & 97.56 respectively. In moderate ( 50-69% ) stenosis(total 22 patients USG accurately diagnosed 20 pathologies and MRA detected in 21 patients. MRA overestimated diagnosis in 3 cases in patients with moderate stenosis. For severe stenosis (70-89% total 8

patients) USG detected 6 cases and overestimated stenosis in 1 patient while MRA diagnosed stenosis accurately in all patients thus suggesting MRA is better modality in high grade stenosis. In near total to complete stenosis group (total 10 patients)Doppler detected pathology in 8 patient and overestimated degree of stenosis in 2 cases of near total occlusion as complete stenosis. MRA effectively detected stenosis in all cases as were confirmed on DSA. Collaterals were seen in 4 patients in those with severe stenosis (10 patients) 1 at CCA and 3 at ICA; USG failed to diagnose collaterals in all cases while MRA was efficient enough to detect in all cases. In our study Peak Systolic velocity and ICA:CCA PSV ratio showed direct linear correlation with degree of stenosis which correlated to NASCET criteria of carotid artery stenosis.

**Discussion :**

In our prospective study of two years conducted at AVBR sawangi (meghe) wardha, effect from June 2015 to June 2017. We included total 50 patients suspected as case of carotid artery stenosis and referred to our department for USG/MRA and DSA. Youngest patient in our study was 8 years male suffering from moyamoyadisease and eldest one was 80 years male suffering near total occlusion .

In our study there were 28 male (56%) and 22 females (44%) showing male preponderancethis result are consistent with study conducted by North American Symptomatic Carotid Endarterectomy Trial (NASCET) studies, where NASCET had 72% male and 28% female patients (12). Grarg S et al (1) ,samrin et al (2) and Takahashi et al (13) showed same results. Garg S et al in their study explained its cause probably due to protective effect of hormones in females (1).

Maximum number of patients were seen in 51-60 (28%) and 61-70(34%) age group consist of total 31 patients (62%) which suggest increase in number of carotid artery stenosis with increase in age(table 3). Garg S et al (1) in there study observed mean age of 60 +- 15 years ; samrin et al (2) has shown maximum number of patients in age group of 51-69 age group. Sanjeev Sehrawat et al(9), Hupp et al (14) and Horner et al (15) showed same results in their study.

In our study various risk factors like hypertension(44%), diabetes mellitus(26%) , dyslipidemia(24%) and smoking(14%) had major relation with carotid artery stenosis. Same concordance were seen by samrin et al(2) ; and Garg S et al (1)and who conducted their study on large group of population in 1043 patients showing significant relation. Various other studies like De Angelis M et al (16); Polak JF et al(17); Shetty S et al(18) and Nambakam et al(19) also claimed similar results. In patients with carotid artery stenosis, Carotid artery on right side was more commonly involved accounting for 22 patients (44%) followed by bilateral(32%) and left sided(24%) involvement which correlated with studies done by Garg S (1) and Samrin et al(2). Similar studies of commonly right sided involvement was given by Singh AS et al and Schulte-Altedorneburg G et al.

The most common site of involvement in our study was carotid bulb seen in 18 patients(36%) followed by ICA in 17 patients (34%) & is similar to study done by Sethi et al (20) who found that the carotid bifurcation was commonly involved bythe atherosclerotic plaque followed by ICA and intracranial portions of ICA. In their study, 50% plaques were located at bifurcation, 19.4% in internal carotid arteries and 30.6% in the common carotid arteries. Similar results were also observed in a study byRajagopal et al (21). Plaques are more common at bifurcation due to transient reversal of flow, flow separation and eddy formation in these areas. Samrin et al (2) in their 50 patients found carotid bulb involvement in 19 cases while they found common carotid artery as second most common site of involvement. The second most common site of involvement minor variation found in our study and Samrin et al study might be due to subject variability. Contrary to our findings, Rajesh M and coworkers(22)observed common carotid artery as the most common site of plaque in TIA patients (50%), this difference from our study can be due to different study population.

All 50 patients underwent CT for clinical management; out of total patients 18 patients found to have infarct , 5 patients had infarct with hemorrhagic transformation and other 27 patients were normal. In our study 22 patients presented with hypertension and 23 patients showed significant stenosis >60% and hence showing direct relation between stroke, hypertension and stenosis. Study conducted by Lawes et al.(23) in 1,88,000 patients with hypertension out of which 68000 had stroke events.Ina study conducted by fernandes et al;(24) shown to have

similar results.

In the literature of ultrasound, different authors say that amongst the 3 major Doppler parameters i.e PSV, EDV, PSV ratio(ICA:CCA); PSV ratio is the most accurate predictor of clinically significant ICA stenosis. Because a ratio compensates for the patient to patient physiological variability and also compensate for instrument variability hence PSV ratio has been considered best for assessing stenosis. (24)(25).

In our study PSV and ICA/CCA PSV ratio were assessed (table 1)in correlation with degree of stenosis showing direct relationship between increased PSV and ratio with increasing severity of stenosis. In total 10 patients (20%) with < 49% stenosis of PSV<125 cm/sec and <2 ratio of ICA/CCA PSV.

**Table 1:** ICA:CCA PSV ratio compared with degree of stenosis.

| Psv ratio | % Stenosis | No. of Patients |
|---|---|---|
| <2.0 | <49 | 10 |
| 2.0-4.0 | 50-69 | 22 |
| >4.0 | >70 | 8 |
| Variable | Near occlusion | 7 |
| NA | Total occlusion | 3 |
| Total(N) | | 50 |

For 50-69% stenosis there were total 22 patients i.e 44% of total patients; PSV was in range of 125-230 cm/sec&ratio of ICA/CCA PSV between 2-4. There were total 8 patients i.e 16 % of total in >70% stenosis group in whom PSV was >230 cm/sec and ICA/CCA PSV ratio of > 4. In patients who had near total occlusion or complete occlusion there was low and undetectable flow respectively. Our study is in concordance with Garg S (1) ,sehrawat et al (9); Jahromi, Afshin S. et al (10) and Tahmasebpour HR. et al(26)who observed direct relation between high degree of stenosis and raised PSV.

Findings of carotid artery for overall and individual categorised percentage stenosis(<49%, 50-69% ,70-89%, near total and complete occlusion)(table 2) was observed for USG and MRA in turn compared with DSA. In our study we observed that in group < 49 % stenosis (total patient 10/50) USG showed better estimation of stenosis with sensitivity(100%) & diagnostic accuracy (98%) this result is in concordance with David netuka et al. (27); reddy a et al (28)& Erickson S.J, Mewissen M.W et al (29) the later analyzed 49 patients with various Doppler velocity parameters for carotid artery stenosis in correlation with angiography. They found that B-mode measurement of diameter stenosis is most accurate at less than 40% diameter stenosis. David netuka et al in their study of 103 patients observed that USG is better modality for estimation of <49% stenosis whereas, MRA underestimated the degree of stenosis in this category.

In second group of 50-69% (total Patient 22/50) MRA showed low specificity(88.89%) due to overestimation of stenosis in 2 patients which are seen as flow voids and is the drawback of TOF sequence and results were confirmed by DSA. similar findings were seen in study done by David netuka, et al (27), reddy a et al (28) and Claudia Fellner et al (30). Claudia Fellner et al found that MRA is inaccurate in assessing 50-70% stenosis because of its false positive results due to overestimation ofstenosis.Davidnetuka et al in their study of 103 patients also concluded that MRA overestimated moderate stenosis. JM Serfaty, P Chirossel, JM Chevallier, et al(31)also found that MRA is inaccurate in assessing 50-70% stenosis because of its false positives due to overestimation of the stenosis.
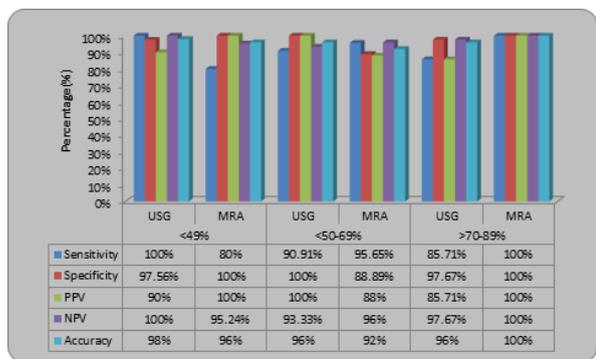
In third group of 70-89 % stenosis (total patients 8/50) MRA showed sensitivity, specificity,diagnostic accuracy of 100% &detected all patients while USG underestimated stenosis in 1 patient with low sensitivity 85.71%, specificity 97.67 and diagnostic accuracy of 96% as compared to MRA. In the fourth group>89% stenosis of near total and complete occlusion (total patients 10/50); USG overestimated degree of stenosis in 1 patient showing sensitivity 88.89%, specificity 97.56% and diagnostic accuracy of 96 % where as MRA detected all patients with sensitivity, specificity and diagnostic accuracy of 100%; similar results were observed by Paul J.Nederkoorn, et l (7) who also found that MRA has better discriminatory power compared with duplex ultrasonography in detecting 70-89% stenosis and near total to complete stenosis. Similar findings were seen in study done by

davidnetuka et al(27)reddy A et al (28), Claudia Fellner et al;(30)& Michael R Jaff et al (32). E. Johansson and A.J. Fox (33), Utter GH et al(34) and Chen cj et al (35); the later in their study found that patients in near total occlusion are candidate for surgical intervention while patient of total occlusion are not which were accurately diagnosed by MRA.Davidnetuka et al(27) in their study of 103 patients found that USG overestimated high grade stenosis as a complete occlusion due to lower sensitivity of low flow detection.

In our study of 50 patients there were total 10 patients in group of near total and complete occlusion out which 4 patients had collateral 3 at ICA and 1 at CCA which were effectively detected by both MRA and DSA while USG failed to locate collaterals in all cases. Our study results are similar to study done by reddy a et al 28);Helene Zachrisson et al (36); Henderson RD, Eliasziw M, Fox AJ, et al(104); Liebeskind DS(37); van Laar PJ, Hendrikse J, Klijn CJ, et al(38); Lim CC, Petersen ET, Ng I, et al(39) and van Osch MJ, Hendrikse J, Golay X, et al(40).

**Table 2 & its Graph :-** Sensitivity, Specificity, and Positive and Negative predictive values forultrasound (US) and magnetic resonance angiography (MRA) at different cut off points, assuming the results of digital subtraction angiography (DSA) to represent the true situation.

| Compa rision | USG | | | | | MRA | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sensiti vity(%) | Speci ficity(%) | PPV(%) | NPV(%) | Diagnos tic accurac y(%) | Sensit ivity(%) | Specifi city(%) | PPV(%) | NPV(%) | Diag nosti |
| For <49% stenosi s | 100 | 97.56 | 90 | 100 | 98 | 80 | 100 | 100 | 95.24 | 96 |
| For 50-69% stenosi s | 90.91 | 100 | 100 | 93.33 | 96 | 95.65 | 88.89 | 88 | 96 | 92 |
| For <70-89% stenosi s | 85.71 | 97.67 | 85.71 | 97.67 | 96 | 100 | 100 | 100 | 100 | 100 |
| For occlus ion | 88.89 | 97.56 | 88.89 | 97.56 | 96 | 100 | 100 | 100 | 100 | 100 |



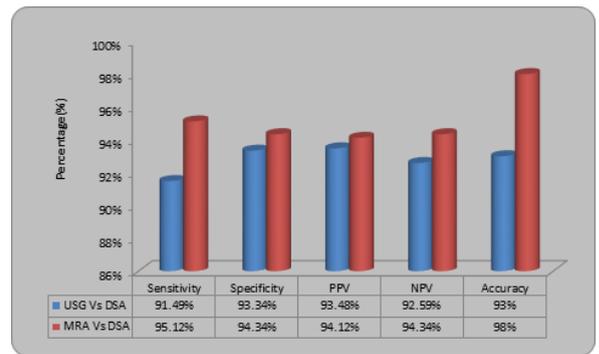| | USG | MRA | USG | MRA | USG | MRA |
|---|---|---|---|---|---|---|
| | <49% | | <50-69% | | >70-89% | |
| Sensitivity | 100% | 80% | 90.91% | 95.65% | 85.71% | 100% |
| Specificity | 97.56% | 100% | 100% | 88.89% | 97.67% | 100% |
| PPV | 90% | 100% | 100% | 88% | 85.71% | 100% |
| NPV | 100% | 95.24% | 93.33% | 96% | 97.67% | 100% |
| Accuracy | 98% | 96% | 96% | 92% | 96% | 100% |

From all the above data overall sensitivity, specificity and diagnostic accuracy of USG was 91.49%,93.34%, 93% while MRA showed sensitivity, specificity and diagnostic accuracy of 95.12%, 94.34%, 98% respectively.DSA had sensitivity, specificity and diagnostic accuracy of 100% (table 3). Combined Sensitivity, specificity, diagnostic accuracy of both MRA and USG Doppler was 97%, 95% and 96% respectively; our study is in concordance with IngithaBorisch et al (5). In their study MR angiography had a sensitivity and specificity of 94.9% and79.1%, respectively. Sensitivity and specificity of duplex sonography were 92.9% and 81.9%, respectively. Combining data from both tests revealed a sensitivity and specificity of 100% and 81.4%, respectively, for concordant results (80% of vessels).Paul J. Nederkoorn et al(7), in their study MRA and USG Doppler showed sensitivity in range of 92-100%, 84-98% and specificity of 86-100%,84-100% respectively.Combining data from both tests revealed a sensitivity and specificity of 96.3% and 80.2%,

respectively. Theodor Adla, RadkaAdlova(6), also found MR angiography had a sensitivity and specificity of 94% and 93%, respectively. Sensitivity and specificity of duplex sonography were 89% and 84.02%, respectively. Similar conclusion was cited in studies done byWutkeR(41), Alvarez-Linera J et al(42) and Remonda L et al(43).

**Table 3 & its graph :-** overall Accuracy, sensitivity, specificity, positive predictive value and negative predictive value of colour Doppler ultrasound (USG), magnetic resonance angiography ( MRA) and digital substraction angiography (DSA) for detecting stenosis. All values are indicated as percentages.

| | Accuracy | | | Sensitivity | | | Specificity | | | PPV | | | NPV | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Modality | USG | MRA | DSA | USG | MRA | DSA | USG | MRA | DSA | USG | MRA | DSA | USG | MRA | DSA |
| Stenosis | 93 | 98 | 100 | 91.49 | 95.12 | 100 | 93.34 | 94.34 | 100 | 93.48 | 94.12 | 100 | 92.59 | 94.32 | 100 |



| | Sensitivity | Specificity | PPV | NPV | Accuracy |
|---|---|---|---|---|---|
| USG Vs DSA | 91.49% | 93.34% | 93.48% | 92.59% | 93% |
| MRA Vs DSA | 95.12% | 94.34% | 94.12% | 94.34% | 98% |

**Choice of Imaging Method:**
Prior to choosing imaging modality, complete clinical evaluation should be done followed by imaging evaluation. Approach for imaging mainly depends on patients health status, prior history of any implant, known carotid artery stenosis and hospital own method of approach. For better diagnosis at least evaluation with 2 modalities to be done. (32)

In our study we found combined use of USG and MRA gives sensitivity and specificity near equal to DSA in diagnosing, grading stenosis and detecting hemodynamic status and collaterals. Primary evaluation with USG to be done because of its easy avaibility, cheap, non invasive, radiation free and better sensitivity in grading stenosis showing hemodynamic status and lesion characterisation. Patients with <49% stenosis should go under follow up imaging while patients having >50 stenosis should under go MRA or CTA (for patients with metallic implant) (44) (45)

Main advantage of MRA and CTA are non invasive, multiplanner reconstruction of imaging, evaluation of both intra and extra cranial carotid artery, showing extension of plaque better sensitivity and specificity than USG Doppler in evaluation of stenosis. Also it can evaluate aorta and itsanomalies and can evaluate changes in brain parachyma in same setting.Patients poorly suited to MRA,because of claustrophobia, implanted device, or other factors,may be evaluated by CTA, whereas those with extensive calcification should undergo MRA.(46)

Conventional angiographyis usually reserved for patients when noninvasiveimagingstudies have yielded discordant results or in the case of poor quality of the noninvasive imaging.(32)

Case 1:- Case of 65 year old male presented with left sided hemiplegia. Fig a colour doppler ultrasound image shows hypoechoic thrombus in right ICA with no flow. Figure b shows undetectable PSV and abnormal waveform. Fig c 3D TOF MRA image shows non visualisation of right ICA. Fig D & E DSA images confirms the same findings of USG and MRA.

(a)          (b)

(c)          (d)          (e)
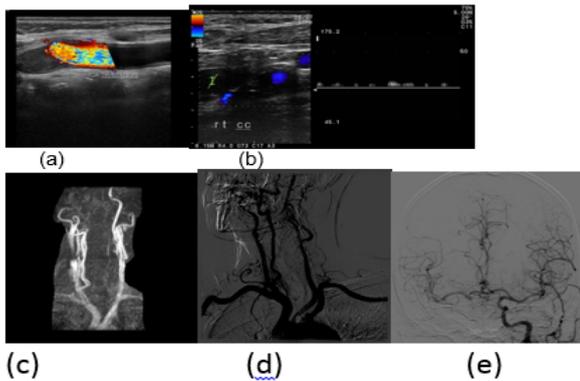
## Conclusion

Based on our study following conclusion can be drawn : USG is non invasiveradiation free modality is good screening and diagnostic capacity can demonstrate hemodynamic changes, each and every layer of vessel wall(i.e intima, media and advantitia). Accurate measurement of vessel diameter, character , extent and site of lesion can be done. USG found to have better sensitivity and specificity for lesser degree of stenosis (<49%)and hence can diagnose early lesions. MRA being non invasive, radiation free and 3D reconstruction capability becomes better modality for diagnosing both intra cranial and extra cranial arterial stenosis. Flow quantification,lesion characterisation, and collaterals can be done with high degree of confidence.MRA can detect anomalies of aortic arch, carotid anomalies, extra and intracranial arterial stenosis and associated changes in brain parenchyma respectively.MRA has better role in high degree of stenosis 70-89% and >90% stenosis and less role in lower and moderate degree of stenosis.

DSA still remain gold standard in diagnosing the degree of stenosis, and hemodynamic changes. Also it has added benefit of therapeutic approach.DSA can effectively diagnose extent, site, extra and intracranial stenosis extent of involvement and collaterals and brain perfusion.   DSA being invasive, require radiation and contrast also can not give detail about vessel wall, nature of lesion sould be reserved for in cases of dilemma.

USG and MRA combined gives near equal sensitivity in detection of lesion and lesion characterisation becomes modaliy of diagnosis and DSA remain gold standard for diagnosis in cases of dilemma and therapeutic approach.

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