COMPARATIVE EVALUATION OF DUPLEX SCAN AND TIME OF FLIGHT MAGNETIC RESONANCE ANGIOGRAPHY FOR EXTRACRANIAL CAROTID ARTERY STENOSIS IN ANTERIOR CIRCULATION ISCHEMIC STROKE PATIENTS

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ABSTRACT

Background: Duplex scanning is now the most widely used method of assessing anomalies in carotid arteries. Carotid disease is more accurately assessed by adding color coding, and test sensitivity is 100%. Duplex scan results are dependent on the operator's accuracy. However, literature data is scarce in the Indian context.

Aim: The present study aimed to comparatively assess Duplex scan and Time-of-Flight Magnetic Resonance Angiography for extracranial carotid artery stenosis in anterior circulation ischemic stroke.

Methods: The study assessed 134 subjects from both genders who presented to the Institute with Anterior circulation ischemic stroke. Demographic data were gathered for all the subjects, followed by CCA, BULB, and ICA Doppler findings and MRA (TOF) of CCA, BULB, and ICA, and MRA(TOF) of CCA. The data gathered were statistically analyzed.

Results: Doppler findings of CCA showed abnormal findings in 8.2% of patients. Doppler findings of BULB showed abnormal findings in 27.6% of patients Doppler findings of ICA showed abnormal findings in 39.6% of patients with Right >70 severe in 7.5% (n=10) subjects, Left 0-30 mild I in 5.2% (n=7) subjects, and Right 50-69 moderate in 3.7% (n=5) study subjects respectively. For the distribution of study subjects based on MRA (TOF) of CCA, BULB, and ICA, MRA(TOF) of CCA showed abnormal findings in 8.2% of patients MRA (TOF)-BULB showed abnormal findings in 17.2% patients MRA(TOF) of ICA showed abnormal findings in 38.1% patients with Right >70 severe in 7.5% (n=10) subjects.

Conclusions: The present study concludes that TOF-MRA is a better imaging modality compared to DUS in terms of sensitivity of detection and accurately quantifying severe degrees of carotid stenosis (70% to 99% stenosis). The TOF-MRA and DUS are equally effective in detecting carotid occlusions.

Keywords: Duplex scan, magnetic resonance angiography, extracranial carotid artery stenosis, ischemic stroke

INTRODUCTION

Stroke is a rapidly developed clinical sign of focal disturbance of cerebral function for >24 hours or causing death with no other cause than vascular origin. Cerebral function disturbance was caused by three morphological anomalies including rupture, occlusion, or stenosis of arteries. Neurological deficit/brain dysfunction is seen as symptoms related to the site and extent of the involved area including sensory impairment, nerve paresis, speech disturbance, multiple paralysis, monoplegia, paraplegia, hemiplegia, and/or coma where hemiplegia is seen in 90% subjects.[1]

Stroke comprises various syndromes of varying treatment, prognosis, epidemiology, and etiologies as ischemic stroke or hemorrhagic stroke. Cerebrovascular diseases are the leading cause of death and morbidity globally majorly in subjects aged <70 years from developing nations including India. The majority of survivors depend on others for continuous life support. Stroke prevalence is lesser in India, however, it is considered to increase with increasing life expectancy. In Indians, stroke is attributed to arteriopathies from CNS infections, peripartum ischemic strokes, and rheumatic heart diseases.[2]

Stroke is strictly diagnosed from imaging of cerebral and precerebral vasculature and specific pathogenesis. Major imaging modalities used are DSA Doppler ultrasound, CT angiography, MR angiography, and Doppler ultrasound. Assessing the thickness of intima-media is a measurable index of atherosclerosis where <1mm thickness is taken as normal. MRI is another non-invasive modality used for imaging blood vessels.[3]

TOF-MRA (time of flight-MRA) is another imaging modality from increased contrast between stationary tissue and blood vessels where vessels are seen as bright. MOTSA (multiple overlapping thin slab acquisitions) combined 2D coverage with 3D high resolution where image volume is divided into multiple thin overlapping slabs during acquisition which are then combined to form a single volume of data. Duplex scanning is now the most widely used method of assessing anomalies in carotid arteries. Carotid disease is more accurately assessed by adding color coding and test sensitivity is 100%. Duplex scan results are dependent on operator concerning accuracy. However, literature data is scarce in the Indian context.[4]

The present study as aimed to comparatively assess Duplex scan and Time of Flight Magnetic Resonance Angiography for extracranial carotid artery stenosis in anterior circulation ischemic stroke.

MATERIALS AND METHODS

The present comparative clinical hospital-based, cross-sectional study aimed to comparatively assess Duplex scan and Time of Flight Magnetic Resonance Angiography for extracranial carotid artery stenosis in anterior circulation ischemic stroke. The study subjects were from the Department of Radiodiagnosis of the Institute. Verbal and written informed consent were taken from all the subjects before study participation.

The study assessed subjects from both genders who presented to the Institute with Anterior circulation ischemic stroke. The sample size for the study was assessed concerning the previous study by Ojha PT et al in 2020.[5] Overall, the proportion of patients with ischemic stroke was higher than those with hemorrhagic stroke (9.5%). Formula: $n = z\alpha 2 * pq / d2$ Where n is the required sample size. Z α is the standard normal deviation, which is equal to 1.96 at a 95% confidence interval. p is the prevalence in the population of the factor under study. q = 100-p d = Absolute precision taken as 5% p = 9.5% q

= 90.5% n = number of samples is to be studied n = zα2 * pq / d2 = (1.96) 2 * 9.5* 90.5 / (5)2 = 3302.81/25 = 134.

The inclusion criteria for the study were subjects with ischemic stroke in the anterior circulation of the brain as confirmed by undergoing MRI Brain (Stroke protocol) with 3D TOF MR Angiography and subjects that were willing to participate in the present study. The exclusion criteria for the study were subjects having a stroke due to cerebral hemorrhage, due to head injury, claustrophobic, pacemaker, ferromagnetic intra-cerebral aneurysm clips, metallic implants, uncooperative subjects, severely-ill subjects, and subjects that did not give consent for study participation.

For Doppler examination of the carotid artery, a Toshiba XARIO200 machine with a 6-12 MHz linear array High Definition [HD] probe was used. No pre-examination preparation of the patient was needed. Carotid arteries were examined with patient lying in the supine position with an extended neck. The examiner was seated on the right side of the patient. The neck was examined by tilting and rotating the head away from the examiner. Carotid arteries were examined in longitudinal and transverse axes. Transverse and longitudinal axis views of carotid arteries were obtained from an anterior, lateral, or posterolateral approach.

Consent from the patients was taken. A survey of the entire cervical carotid arteries in longitudinal and transverse positions was done by placing the transducer over the anterolateral aspect of the neck. The common carotid artery was identified(lies with the IJV) at the clavicle, and the transducer moved cephalic along the artery until the common carotid artery was bifurcated. The internal and external carotid arteries were identified. The vertebral artery was examined by placing the transducer over the lateral aspect of the neck and it lies in the foramen transversarium. The waveforms were taken along the longitudinal axis of the artery. Intima media thickness was measured. The location of plaque and major points of obstruction were noted during survey examinations. Each abnormal area was examined carefully for the extent of plaque formation, plaque morphology and degree of luminal narrowing was noted. A detailed examination of atheromatous lesions was conducted.

When the longitudinal examination was completed, the carotid and vertebral arteries were studied from a transverse position beginning from the clavicle moving cephalad. The data gathered from the color Doppler examination consisted of – Peak Systolic velocity of the common carotid artery (CCA); Peak systolic velocity of the internal carotid artery (ICA); Velocity ratios between CCA and ICA; Plaque characteristics as seen in grey scale imaging; and the presence of Spectral broadening.

All the findings were recorded in the report. The ICA is considered normal when ICA PSV is less than 125 cm/sec and no plaque or intimal thickening is visible sonographically. Additional criteria include ICA/CCA PSV ratio < 2.0 and ICA EDV < 40 cm/sec. A 50%–69% ICA stenosis is diagnosed when ICA PSV is 125–230 cm/sec and plaque is visible sonographically. Additional criteria include an ICA/CCA PSV ratio of 2.0–4.0 and an ICA EDV of 40–100 cm/sec. A >70% ICA stenosis but less than near occlusion of the ICA is diagnosed when the ICA PSV is greater than 230 cm/sec and visible plaque and luminal narrowing are seen at grayscale and color Doppler US. Additional criteria include ICA/CCA PSV ratio 4 and ICA EDV 100 cm/sec. The higher the Doppler parameter lies above the threshold of 230 cm/sec, the greater the likelihood of severe disease. In cases of near occlusion of the ICA, the velocity parameters may not apply, since velocities may be high, low, or undetectable. This diagnosis is established primarily by demonstrating a markedly narrowed lumen at color or power Doppler US. Total occlusion of the ICA should be suspected when there is no detectable patent lumen at gray-scale US and no flow with spectral, power, and color Doppler US.

Magnetic resonance (MR) angiography, computed tomographic (CT) angiography, or conventional angiography may be used for confirmation in this setting.[6]

In clinical practice worldwide, several established measurement methods are used to quantify the severity of internal carotid artery (ICA) stenosis before revascularization including The North American Symptomatic Carotid Endarterectomy Trial (NASCET), European Carotid Surgery Trial (ECST) method, common carotid (CC) method. All these methods have similar prognostic value, and as such, are acceptable means of risk stratification For the North American Symptomatic Carotid Endarterectomy Trial (NASCET) method, stenosis was classified as mild (0% to 49%), moderate (50% to 69%), severe (70% to 99%), or complete occlusion.[7]

In Magnetic Resonance Angiography, detailed history was recorded for all the subjects, and subjects were asked to wear cotton dresses were screened for any metal, and were asked to remove any metal. IV access in the arm was established to inject contrast material. 3D TOF – MR Angiography was performed on a WIPRO GE OPTIMA 360 1.5 Tesla MR system. The following imaging parameters were used: repetition time/echo 23/7.0, flip angle 25°, slice thickness 0.7mm, number of slice44/slab, number of slabs 4, slice overlap 25%, flow direction feet to head with 40mm saturation at the head end, field of view 180x158 and 256 matrix size. Reconstructions are done using 3D maximum intensity projection (MIP) and volume rendering techniques (VRT).

Resuscitation apparatus and emergency drugs were kept ready. TOF – MRA findings were recorded in all patients as per the proforma, under the following headings:- 1) Common carotid artery 2) Internal carotid artery 3) ACA:- A1 A2 A3 4) Anterior communicating artery 5) MCA:- M1 M2 M3 M4 6) Posterior communicating artery 7) PCA:- P1 P2 P3 P4 8) Vertebral artery 9) Basilar artery

Data entry was done using M.S. Excel and statistically analyzed using Statistical Package for social sciences (SPSS Version 16) for M.S. Windows. Descriptive statistical analysis was carried out to explore the distribution of several categorical and quantitative variables. Categorical variables were summarized with n (%), while quantitative variables were summarized by mean ± S.D. All results were presented in tabular form and are also shown graphically using a bar diagram or pie diagram as appropriate.

RESULTS

The present comparative clinical hospital-based, cross-sectional study aimed to comparatively assess Duplex scan and Time of Flight Magnetic Resonance Angiography for extracranial carotid artery stenosis in anterior circulation ischemic stroke. The study assessed 134 subjects from both genders who presented to the Institute with Anterior circulation ischemic stroke. The mean age of the study subjects was 64.29±11.06 years. The majority of the study subjects were in the age range of 66-75 years with 33.6% (n=45) subjects followed by 32.1% (n=43) subjects from 56-65 years, and 11.2% (n=15) subjects from 46-55 subjects respectively. There were 70.9% (n=95) males and 29.1% (n=39) females in the present study. Ischemic infarct clinical history was positive in all 100% (n=134) study subjects. Both left, and right side was affected in 14.2% (n=19), 35.8% (n=48), and 50% (n=67) study subjects respectively (Table 1).

On assessing the distribution of study subjects based on CCA, BULB, and ICA Doppler findings, Doppler findings of CCA showed abnormal findings in 8.2% patients with Right 0-30 mild I in 2.2% (n=3) subjects, left 0-30, mild I and Right mild 2, left mild 1 in 1.5% (n=2) each, and Left >70 severe, Right 31-49 mild 2, Right >70 severe, and Right and left mild 1 in 0.7% (n=1) study subjects respectively. Doppler findings of BULB showed abnormal findings in 27.6% of patients with Left 0-

30 mild I and Right 0-30 mild I in 4.5% (n=6) subjects and Left 31-49 mild 2, Right 31-49 mild 2, and Right and left mild 1 in 3.7% (n=5) subjects each. Doppler findings of ICA showed abnormal findings in 39.6% of patients with Right >70 severe in 7.5% (n=10) subjects, Left 0-30 mild I in 5.2% (n=7) subjects, and Right 50-69 moderate in 3.7% (n=5) study subjects respectively (Table 2).

For the distribution of study subjects based on MRA (TOF) of CCA, BULB, and ICA, MRA(TOF) of CCA showed abnormal findings in 8.2% of patients where Right 31-49 mild 2 was seen in 2.2% (n=3) subjects, Left 0-30 mild I and Right 0-30 mild I in 1.5% (n=2) study subjects, and Left 31-49 mild 2, Left >70 severe, Right >70 severe and Left mild 2, right mild 1 in 0.7% (n=1) study subjects respectively. MRA (TOF)-BULB showed abnormal findings in 17.2% of patients with Right 0-30 mild I in 3% (n=4) subjects, left 31-49 mild 2, Left 50-69 moderate, and Right 31-49 mild 2 in 2.2% (n=3) subjects each, and Left 0-30 mild I, Right 50-69 moderate, and Right and left mild 1 in 1.5% (n=2) study subjects each. MRA(TOF) of ICA showed abnormal findings in 38.1% of patients with Right >70 severe in 7.5% (n=10) subjects, right 50-69 moderate in 3.7% (n=5) subjects, and Left 0-30 mild I, Left >70 severe, Right 0-30 mild I, and Left mild 2, right mild 1 in 3% (n=4) subjects respectively (Table 3).

DISCUSSION

The study assessed 134 subjects from both genders who presented to the Institute with Anterior circulation ischemic stroke. The mean age of the study subjects was 64.29±11.06 years. The majority of the study subjects were in the age range of 66-75 years with 33.6% (n=45) subjects followed by 32.1% (n=43) subjects from 56-65 years, and 11.2% (n=15) subjects from 46-55 subjects respectively. There were 70.9% (n=95) males and 29.1% (n=39) females in the present study. Ischemic infarct clinical history was positive in all 100% (n=134) study subjects. Both left, and right side was affected in 14.2% (n=19), 35.8% (n=48), and 50% (n=67) study subjects respectively. These results were consistent with the studies of Vudumala P et al[8] where authors reported the majority of subjects aged 61-70 and 51-60 years with 37.5% and 30% subjects and right and left side affected were reported 50% and 35.8% study subjects and with Kusumlatha P et al[9] where authors assessed 83.3% males and 16.7% females in their study. These results also correlated with Young GR et al[10] where 37% (n=26) of subjects with stroke were reported by authors.

For Doppler versus MRA (TOF) in study subjects, DOPPLER VERSUS MRA (TOF) In this study, out of 134 patients, • Doppler CCA and MRA CCA showed stenosis in 11 patients Doppler BULB showed stenosis in 37 patients; MRA BULB showed stenosis in 23 patients. • Doppler ICA showed stenosis in 53 patients; MRA ICA showed stenosis in 51 patients Erickson SJ et al[11] analyzed 49 patients of stroke with color Doppler and MRA and found ultrasound measurement of stenosis is most accurate at less than 40% diameter stenosis. In Reddy A et al51doppler showed abnormalities in the Bulb in 7 patients [14%], whereas in MRA it was in 5 patients [10%]. This was consistent with Nederkoorn PJ et al[12] authors reported that MRA had a better discriminatory power compared with DUS in diagnosing 70% to 99% stenosis and is a sensitive and specific test compared with DSA in the evaluation of carotid artery stenosis. For detecting occlusion, both DUS and MRA are very accurate. For the diagnosis of 70% to 99% versus <70 stenoses, MRA had a pooled sensitivity of 95% (95% CI, 92 to 97) and a pooled specificity of 90% (95% CI, 86 to 93). These numbers were 86% (95% CI, 84 to 89) and 87% (95% CI, 84 to 90) for DUS, respectively. For recognizing occlusion, MRA yielded a sensitivity of 98% (95% CI, 94 to 100) and a specificity of 100% (95% CI, 99 to 100), and DUS had a sensitivity of 96% (95% CI, 94 to 98) and a specificity of 100% (95% CI, 99 to 100).

Turnipseed WD et al[13] studied that for high-grade stenosis and occlusions, MRA was 91% accurate, while duplex imaging was 86% accurate when compared with conventional angiography. This study suggests that the combined use of MRA and duplex imaging is accurate for the detection of high-grade carotid stenoses. When MRA and duplex ultrasound tests are used in combination to evaluate patients with symptoms, there is an excellent correlation between severe carotid stenosis (70% to 99%) and complete arterial occlusions as documented by x-ray angiography (XRA). The major problem in correlating non-invasive tests with XRA is that it is difficult to distinguish borderline moderate stenoses precisely (60% to 69%) from borderline severe stenoses (70% to 80%). The gold standard of XRA tends to under read severity of stenoses and MRA tends to over read severity of stenosis. Duplex imaging is often helpful in clarifying grades of stenosis when results of XRA and carotid MRA do not coincide.

Back MR et al[14] studied that for detection of > 75% stenosis sensitivity was 100% for MRA and 90% for Doppler. Discordance between MRA and Doppler was obtained as Doppler over-estimated severity while MRA correctly predicted disease severity in all cases. CEMRA had better discriminatory power. Wardlaw JM et al [15] concluded that a comparison of Doppler with MRA TOF shows anomalies in the bulb in 12 patients (30%) and TOF MRA confirms the same cases. They found that MRA is inaccurate in assessing 50-70% stenosis because of its false positives due to overestimation of the stenosis.

CONCLUSIONS

The present study, considering its limitations, concludes that TOF-MRA is a better imaging modality compared to DUS in terms of sensitivity of detection and accurately quantifying severe degrees of carotid stenosis (70% to 99% stenosis). The TOF-MRA and DUS are equally effective in detecting carotid occlusions. For milder degrees of stenosis duplex ultrasound scores over TOF-MRA in terms of sensitivity of detection, as well as having the added advantage of characterizing the plaque morphology. In cases of carotid occlusion TOF MRA fails to delineate the exact superior extent of the occlusion as it is flow flow-dependent technique, whereas DUS shows the exact length of the occluded segment which might prove beneficial in planning interventions.

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TABLES

S. No	Characteristics	Number (n=134)	Percentage (%)
1.	**Mean age (years)**	64.29±11.06	
2.	**Age range (years)**		
a)	36-45	13	9.7
b)	46-55	15	11.2
c)	56-65	43	32.1
d)	66-75	45	33.6
e)	>76	18	13.4
3.	**Gender**		

a)	Males	95	70.9
b)	Females	39	29.1
4.	**Ischemic infarct clinical history**	134	100
5.	**Side affected**		
a)	Both	19	14.2
b)	Left	48	35.8
c)	Right	67	50

Table 1: Demographic and disease data in study subjects

S. No	**Parameters**	**Number (n=134)**	**Percentage (%)**
1.	**CCA doppler findings**		
a)	Normal	123	91.8
b)	Left 0-30 mild I	2	1.5
c)	Left >70 severe	1	0.7
d)	Right 0-30 mild I	3	2.2
e)	Right 31-49 mild 2	1	0.7
f)	Right >70 severe	1	0.7
g)	Right and left mild 1	1	0.7
h)	Right mild 2, left mild 1	2	1.5
2.	**BULB doppler findings**		
a)	Normal	97	72.4
b)	Left 0-30 mild I	6	4.5
c)	Left 31-49 mild 2	5	3.7
d)	Left >70 severe	1	0.7
e)	Right 0-30 mild I	6	4.5
f)	Right 31-49 mild 2	5	3.7
g)	Right 50-69 Moderate	2	1.5
h)	Right >70 severe	1	0.7
i)	Right and left mild 1	5	3.7
j)	Right and left mild 2	2	1.5
k)	Left mild 2, right mild 1	1	0.7
l)	Right mild 2, left mild 1	2	1.5
m)	Right mild 2, left moderate	1	0.7
3.	**ICA doppler findings**		
a)	Normal	81	60.4
b)	Left 0-30 mild I	7	5.2
c)	Left 31-49 mild 2	1	0.7
d)	Left 50-69 Moderate	2	1.5
e)	Left >70 severe	4	3
f)	Right 0-30 mild I	4	3
g)	Right 31-49 mild 2	4	3
h)	Right 50-69 Moderate	5	3.7
i)	Right >70 severe	10	7.5
j)	Right and left mild 2	3	2.2
k)	Left mild 2, right mild 1	1	0.7
l)	Right mild 2, left mild 1	2	1.5
m)	Right mild 2, left moderate	1	0.7
n)	Right moderate left severe	1	0.7
o)	Right severe left moderate	3	2.2
p)	Right and left severe	1	0.7

q)	Left severe and right mild 2	4	3

Table 2: Distribution of study subjects based on CCA, BULB, and ICA Doppler findings

S. No	**MRA (TOF)- CCA**	**Number (n=134)**	**Percentage (%)**
1.	**MRA (TOF)- CCA**		
a)	Normal	123	91.8
b)	Left 0-30 mild I	2	1.5
c)	Left 31-49 mild 2	1	0.7
d)	Left >70 severe	1	0.7
e)	Right 0-30 mild I	2	1.5
f)	Right 31-49 mild 2	3	2.2
g)	Right >70 severe	1	0.7
h)	Left mild 2, right mild 1	1	0.7
2.	**MRA (TOF)- BULB**	134	100
a)	Normal	111	82.8
b)	Left 0-30 mild I	2	1.5
c)	Left 31-49 mild 2	3	2.2
d)	Left 50-69 Moderate	3	2.2
e)	Left >70 severe	1	0.7
f)	Right 0-30 mild I	4	3
g)	Right 31-49 mild 2	3	2.2
h)	Right 50-69 Moderate	2	1.5
i)	Right >70 severe	1	0.7
j)	Right and left mild 1	2	1.5
k)	Right and left mild 2	1	0.7
l)	Right mild 2, left mild 1	1	0.7
3.	**MRA (TOF)- ICA**		
a)	Normal	83	61.9
b)	Left 0-30 mild I	4	3
c)	Left 31-49 mild 2	3	2.2
d)	Left 50-69 Moderate	3	2.2
e)	Left >70 severe	4	3
f)	Right 0-30 mild I	4	3
g)	Right 31-49 mild 2	3	2.2
h)	Right 50-69 Moderate	5	3.7
i)	Right >70 severe	10	7.5
j)	Right and left mild 2	2	1.5
k)	Left mild 2, right mild 1	4	3
l)	Right moderate left severe	1	0.7
m)	Right severe left moderate	2	1.5
n)	Right and left severe	1	0.7
o)	Left severe and right mild 2	1	0.7
p)	Right Mild 1 & Left Moderate	1	0.7
q)	Right Mild 2 & Left Severe	1	0.7
r)	Left Mild 2 & Right Severe	2	1.5

Table 3: Distribution of study subjects based on MRA (TOF) of CCA, BULB, and ICA