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Correlation of magnetic resonance angiography and transcranial doppler ultrasound in acute stroke patients

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Abstract

The incidence of cerebrovascular diseases increases with age, and the number of strokes is projected to increase as the elderly population grows. Most cerebrovascular diseases are manifest by the abrupt onset of a focal neurologic deficit. Computed Tomography images identify or exclude hemorrhage as the cause of stroke, and they identify extra-parenchymal hemorrhages, neoplasms, abscesses, and other conditions masquerading as stroke. Non-contrast CT brain is the 1st imaging investigation usually performed in acute stroke patients.

Magnetic Resonance Imaging (MRI) reliably documents the extent and location of infarction in all areas of the brain, including the posterior fossa and cortical surface. It also identifies intracranial hemorrhage and other abnormalities but is less sensitive than CT for detecting acute blood. Diffusion-weighted imaging is more sensitive for early brain infarction than standard MR sequences or CT, as is fluid-attenuated inversion recovery (FLAIR) imaging. Using IV administration of gadolinium contrast, MR perfusion studies can be performed. Thus it is evident that both TCD and MRA are promising modalities in the evaluation of acute stroke. This dissertation aims to compare and correlate the findings of MRA and TCD and their advantages and disadvantages in the practical hospital set-up.

Total 50 patients – 30 Male and 20 Females – with a clinical diagnosis of stroke (Acute or Chronic) were evaluated with MRI and MR Angiography and Transcranial Doppler(TCD) with TCD being performed prior to MRI/MRA in all patients. Time interval between these two examinations was 2 to 8 hours.

Out of 50 patients studied, 10 patients were excluded due to inadequate insonation windows. Of the 40 patients, 24 patients showed abnormality on MRA. Of the MRA abnormal 24 patients, 20 were abnormal on TCD (True positive on TCD), while 4 were normal on TCD (False negative on TCD). Also of the 16 MRA normal patients, 9 were normal on TCD (True negative) while 7 were abnormal on TCD (False positive). Analysis of above findings revealed, Sensitivity 83.33 %, Specificity 56.25%, Positive predictive value 74.07 %, Negative predictive value 69.23 % for TCD compared to MRA in Assessment of the Anterior circulation.

Keywords: Transcranial Doppler; Stroke; Cerebrovascular Accident; Magnetic Resonance Imaging

1. Introduction

Cerebrovascular diseases include some of the most common and devastating disorders: ischemic stroke, hemorrhagic stroke, and cerebrovascular anomalies such as intracranial aneurysms and arterio-venous malformations (AVMs. The incidence of cerebrovascular diseases increases with age, and the number of strokes is projected to increase as the

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elderly population grows. Most cerebrovascular diseases are manifest by the abrupt onset of a focal neurologic deficit. A stroke, or cerebrovascular accident, is defined by this abrupt onset of a neurologic deficit that is attributable to a focal vascular cause. Thus, the definition of stroke is clinical, and laboratory studies including brain imaging are used to support the diagnosis.[1]

Computed Tomography images identify or exclude hemorrhage as the cause of stroke, and they identify extra-parenchymal hemorrhages, neoplasms, abscesses, and other conditions masquerading as stroke. Non-contrast CT brain is the 1st imaging investigation usually performed in acute stroke patients.

Magnetic Resonance Imaging (MRI) reliably documents the extent and location of infarction in all areas of the brain, including the posterior fossa and cortical surface. It also identifies intracranial hemorrhage and other abnormalities but is less sensitive than CT for detecting acute blood. Diffusion-weighted imaging is more sensitive for early brain infarction than standard MR sequences or CT, as is fluid-attenuated inversion recovery (FLAIR) imaging. Using IV administration of gadolinium contrast, MR perfusion studies can be performed.

MRA is an attracting modality for evaluation of vascular diseases. Vessel accessibility is not a problem as with ultrasonography. Patients are spared the discomfort of and potential risks of adverse reactions from injection of contrast material needed for conventional X-ray angiography. MRA often demonstrates flow gaps with turbulence, high grade stenosis, near-occlusion as well as occlusion. MRA cannot reliably identify reversed flow direction in the carotid or vertebro-basilar arteries unless special sequences are applied. MR angiography may be useful as a screening investigation to identify patients who should have conventional angiography or who might benefit from medical thrombolytic intervention[2].

Transcranial ultrasound can rapidly and non-invasively image blood flow in the major basal intracranial arteries. Its accuracy makes it acceptable for use in screening for hemodynamically significant intracranial stenosis or vessel occlusions. Although it has a relatively limited field of view and is not technically feasible in approximately 10% of cases, the information obtained is becoming increasingly relevant to therapeutic decision-making in the prevention and management of stroke. Transcranial Doppler ultrasound(TCD) or Transcranial colour-coded duplex(TCCD) have the advantages of being inexpensive, portable and non-invasive and requiring minimal patient cooperation; however,TCD has not been widely accepted for use in acute stroke. The major criticism of TCD is the belief that TCD is too operator dependent to be applied to acute stroke decision-making.

Thus it is evident that both TCD and MRA are promising modalities in the evaluation of acute stroke. This dissertation aims to compare and correlate the findings of MRA and TCD and their advantages and disadvantages in the practical hospital set-up.

2. Material and methods

This study has been performed from October 2010 to August 2012. A synopsis was submitted to the Ethical approval committee and the study was started after the approval was received.

Total 50 patients – 30 Male and 20 Females – with a clinical diagnosis of stroke (Acute or Chronic) were evaluated with MRI and MR Angiography and Transcranial Doppler(TCD) with TCD being performed prior to MRI/MRA in all patients. Time interval between these two examinations was 2 to 8 hours.

Patient having contraindication to MR Examination (Cardiac pacemaker, Cochlear implants, Claustrophobia) and those denying consent were excluded from the study.

2.1. MRI and MR Angiography Technique

MR machine used for this study was

- 3.0 tesla GE – Signa machine.
- Coil : Standard Head and Neck Angiography coil.
- Basic Parameters : FOV = 200mm, Matrix = 256 x 224,

A special stroke protocol was used which always included the following sequences :

- Axial Diffusion Weighted Image (DWI) at b-value of 600 and 1000. Corresponding Apparent Diffusion co-efficient (ADC) maps were generated from these two sequences by the DWI software.
- Axial T2 FLAIR sequence.
- Axial 2-slab 3D-Time of Flight (TOF) Brain Angiography : extending from base of skull up to just above the corpus callosum, so as to include Circle of Willis, anterior and posterior circulation arteries and their major branches.
- Axial 3D-TOF Neck Angiography including the origin of both Common carotid arteries up to the entry of Internal carotid artery (ICA) into the carotid canal.
- When possible (co-operative patient) additional sequences were obtained including : T1 Axial, GRE Axial, T2 Propellor Axial, T1 Sagittal and T2 Coronal.
- The acquired data was examined on the MR console or GE Advantage Workstation with angiography interpretation done by correlating with source angiography images, 3D vessel representation and Maximum intensity projections. With the help of software the adjoining overlapping soft tissue was cut-off by a "Cutting" tool, for better viewing of vessels in 3D representation.

2.1.1. Interpretation

- Acute or Chronic infarcts were diagnosed based on imaging features on DWI/ADC and T2 FLAIR images and other sequences.
- In patients with haemorrhage the stage of haemorrhage was assessed by comparison with appearance on T1 Axial images and confirmed by blooming on GRE axial images.
- Patients in which a complete MR examination (MRI+MRA) was not possible were excluded from the study.
- Adverse effects: No adverse effects were noted in any patient during or immediately after the MR examination was completed.

2.2. Trans-Cranial Doppler (TCD) technique

2.2.1. TCD Machine

RMS-SPECTRA-102 Series, Transcranial Doppler Diagnostic and Monitoring System.

It had 2 types of Pencil probes attached to it:

2MHz Pulsed Wave：

- Depth: 5 – 134 mm
- Maximum blood flow velocity:500cm/s
- Flow velocity precision: +/-5%
- GATE: 4-20 mm

4MHz Continuous Wave：

- Maximum blood flow velocity:500cm/s
- Flow velocity precision: +/-5%

Both these probes were Dual channel probes capable of being used for : Routine diagnostics, M-Mode, HITS (High Intensity Transient Signals / Micro-embolic signals) and Monitoring.

2.2.2. Insonation Protocol

A thorough insonation was performed as fast as possible by using the following insonation windows,

- Trans-temporal Insonation: Bilateral, for assessment of Bilateral Anterior, Middle and Posterior cerebral arteries.
- Trans-foraminal / Sub-Occipital Insonation: For assessment of bilateral Vertebral arteries and basilar arteries.

Trans-orbital Window (Bilateral ophthalmic arteries, Bilateral carotid siphon), and Submandibular window (Extracranial Internal carotid artery) though used were not routinely performed.

2.2.3. Interpretation

The Mean flow velocity was the most important criteria used, with other findings used as supportive evidence. The detailed interpretation criteria are discussed in "Review of Literature" section.

3. Results

A total of 50 patients were studied, and were divided into age groups of < 30 years, 31-40, 41-50, 51-60, 61-70, 71-80 and 81-90. In our study the least age was 27 years and the highest age was 85 years. The highest numbers of patients were in the age group of 61-70 years (17 patients), (34 % of the entire study group). Least number of patients was in the age group < 30 years (1 patient). The second largest group was of age 51-60 years comprising of 11 patients (22 % of the study group).

In our study out of 50 patients, 30 patients (60 %) were male and 20 (40 %) were females.

A risk factor survey for associated diseases in our study revealed that 21 patients (42 %)were suffering from Diabetes mellitus, 26 patients(52 %) were suffering from hypertension and 9(18 %) patients were suffering from Ischemic heart disease. 20 patients(40%) were found to be suffering from 2 out of these 3 diseases while there were 3 patients(6 %) suffering from all the three diseases.

The most common mode of presentation was hemiparesis / hemiplegia (27 patients) followed by slurred speech(14 patients). These features mostly correspond to a event of acute stroke, which was the predominant group in our study. Only 4 patients presented with features of old cerebrovascular accident.

Table 1 MRI Findings: Etiology

MRI Abnormality	Number of patients	% of Study Group
Acute Infarct – With obvious abnormality in a major artery.	Without secondary haemorrhage = 27	54%
	With secondary haemorrhage = 5	10%
Acute infarct – without obvious arterial abnormality.	6	12%
Hypertensive intraparenchymal bleed	3	6%
Cerebral venous sinus thrombosis with venous infarct.	3	6%
Old ischemic stroke	4	8%
Lacunar infarct	2	4%

The 50 patients in our study showed a wide range of abnormalities on MRI study. All these patients presented with features of stroke, emphasizing that a number of different pathologies are included in the etio-pathogenesis of stroke. The largest group was that of Acute infarct – with a demonstrable abnormality in the arteries forming the Circle of Willis on conventional MR sequences as well as MR Angiography – which was subsequently performed in all of these patients. Of the 32 patients in this group (64 % of total study group) 27 patients did not show secondary haemorrhage within these acute infarcts, while 5 patients revealed secondary hemorrhagic transformation. The second largest group was that of patients with acute infarct without any obvious arterial abnormality visible. This group had 6 patients (12 % of total study group), none of which showed hemorrhagic transformation. The patients in this group had acute infarcts larger in size that could not be classified as Lacunar infarcts and hence they were included in a separate group. Next in descending order of patients were the groups of Hypertensive bleed (3 patients – 6 % of study group) and Cerebral venous sinus thrombosis with hemorrhagic venous infarct (3 patients – 6% of study group) and Lacunar infarcts (2 patients – 4% of study group). Patients with imaging features of old ischemic infarcts with gliosis were included as a separate group and this group had 4 patients.(8 % of study group).

Table 2 MRI Findings: Vascular territories and Hemorrhage

	Anterior Circulation	**Posterior Circulation**
Hemorrhage	10(20%)	1(2%)
Non-hemorrhagic Infarct	31(62%)	8(16%)

Though Table 1 gives us a good depiction of various aetiological factors leading to stroke stroke, Table 2 helps in the clinical setting by explaining the vascular territory (Anterior or Posterior) thus may suggest correlation with clinical features and whether the pathology is purely ischemic or hemorrhagic, thus determining treatment strategies, whether to thrombolyse or not. Of the 50 patients we studied 41 patients (82% of study gorup) had anterior circulation stroke out of which 31 patients (62 % of study group) had infarcts while 10 patients (20 % of study group) had haemorrhage. Of the 9 patients with Posterior circulation strokes(18 % of study group), 8 patients(16% of study group) had infarct while 1 patient (2 % of study group) had haemorrhage.

Out of total 50 patients, 14 showed a Normal MR Angiography. These included patients with stroke caused by pathology other than stenosis / occlusion of major intracranial arteries including Hypertensive bleed, Cerebral venous sinus thrombosis, Lacunar infarcts etc. Ther rest of 36 patients showed obvious stenosis / occlusion of some major intracranial artery. This category of patients has been further divided into the following groups based on the artery affected.

Extracranial stenosis and occlusion is seen in only one patient each.In comparison, Intracranial arterial abnormalities are much more commonly found in our study, stenosis occuring in 24 patients (48%), while occlusion seen in 12 patients(24%).

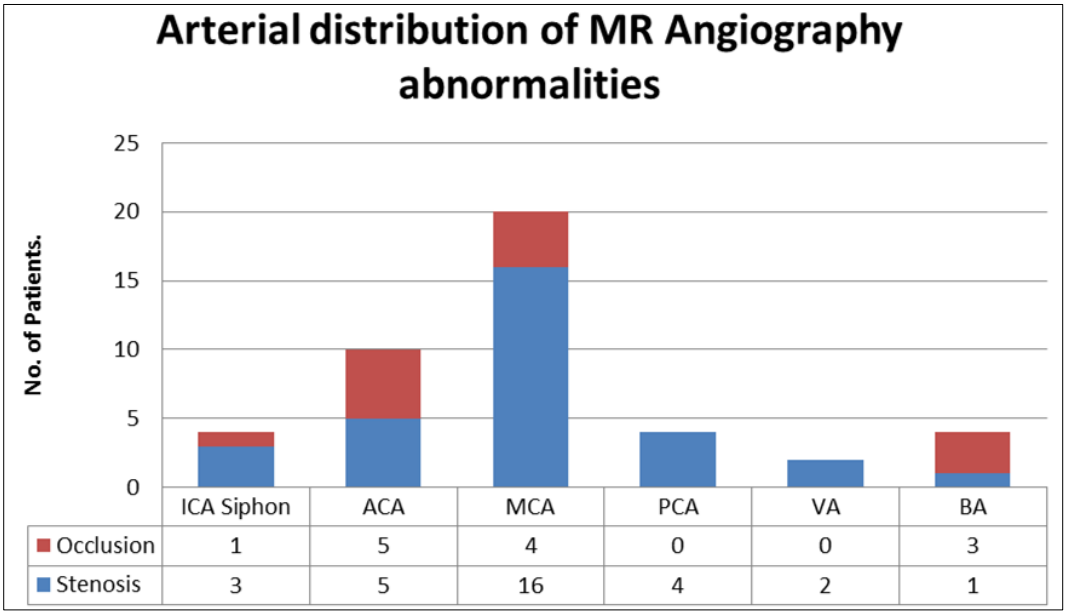

Figure 1 Arterial distribution of MR angiography abnormalities

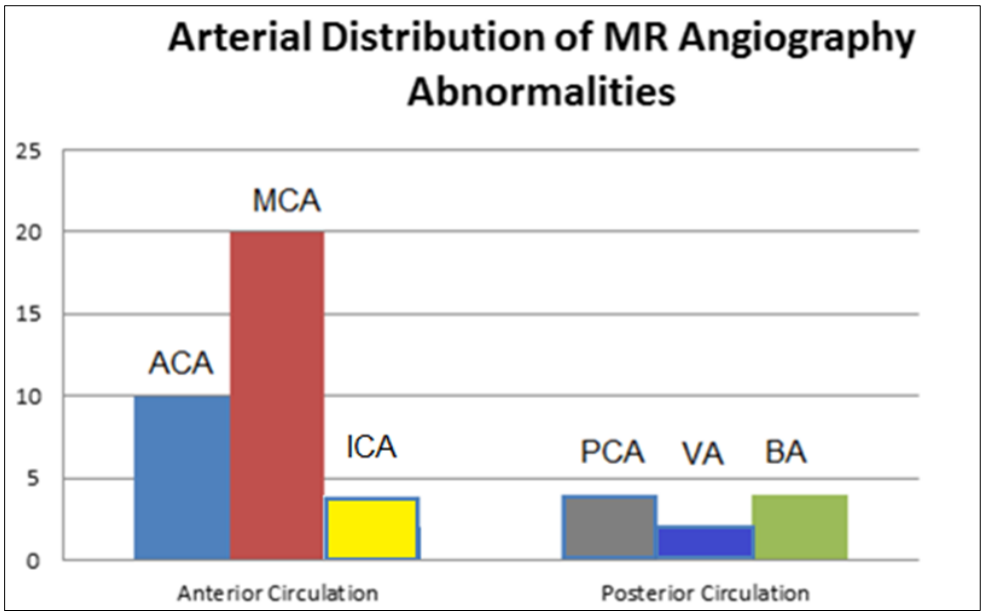

Figure 2 Arterial distribution of MR angiography abnormalities

The total numbers of abnormalities on MR Angiography are 44, while clinically, the total number of abnormal patients was 36. This is because few patients showed abnormalities in more than one arteries and each of these arteries was counted as positive separately. Vertebral artery showed only two abnormalities (Both stenosis). In our study Anterior circulation abnormalities were found in 34 arteries and posterior circulation abnormalities were found in 10 arteries.

Of the patients that we studied, TCD was not possible in 10 patients (20%) because the insonation windows were inadequate. We defined inadequate windows as when significant hemodynamic information was not available on TCD scanning. When flow signals of the major branches – ACA, MCA, PCA – were not found even after prolonged scanning from a particular trans-temporal window, it was said to be unavailable. Due to difficulties in insonation of posterior circulation and the variable course of arteries, when flow signals from none of the 3 vessels i;e 2 vertebral arteries and Basilar artery were found the window was considered inadequate. When flow signals from even a single vessel could be found, the findings were included in analysis. In few patients with inadequate temporal insonation windows, all of the posterior circulation artery waveforms were obtained. Though these posterior fossa findings may have been included in the assessment of TCD and MRA for the posterior circulation alone, such patients were excluded from the final analysis for overall intracranial circulation..

The maximum number of patients with inadequate insonation windows were in the age group 71 – 80 years (6 patients = 12 % of total sample size). The two adjoining age groups 61 – 70 years and 81 – 90 years had 2 such patients each. None of the patient aged less than 60 years had inadequate insonation windows. The correlation between age and Inadequate windows was tested statistically by by using Fisher's exact test and the p-value was very low (< 0.001). As the p-value is < 0.05, therefore there appears to be a statistically significant association between increasing age and insonation window inadequacy.

In our study, out of 30 male patients, 4 had inadequate windows(15.35 % of males, 8% of total sample size). Among 20 female patients, inadequate window was found in 6 patients (30% of females and 12% of total sample size).

Thus it was seen that greater % of patients in the female group had inadequate windows of insonation than those in the male group. This was further evaluated for statistical significance by using the Fisher's exact test, and we got a p-value of 0.17. As this p-value was > 0.05 therefore, we concluded that there is no statistically significant association between gender of patient and inadequacy of window.

Out of 50 patients we studied TCD findings were obtained in a total of 40 patients. In rest 10 patients, TCD was not possible due to inadequate insonation windows. Of these 40 patients 16 patients showed abnormal MCA on MR Angiography. According to Table 9, the number of abnormal MCA findings on MR Angiography was 20, but because 4 out of these 20 patients were those with inadequate insonation windows, these 4 patients were excluded from the comparative analysis of the two modalities. Of the MRA abnormal 16 patients, 13 were abnormal on TCD(True positive

on TCD), while 3 were normal on TCD(False negative on TCD). Also of the 24 MRA normal patients, 12 were normal on TCD (True negative on TCD) while 12 were abnormal on TCD(False positive). The analysis of the above findings revealed the following findings for TCD compared MRA : Sensitivity 81.25 %, Specificity 50%, Positive predictive value 52.00%, Negative predictive value 80.00 % Of the 13 True positive patients in TCD, 8 patients showed elevated velocities (MFV > 80 cm/sec), while 5 patients showed extremely low velocities (Dampened velocities, dampened waveform, slow systolic acceleration, slow diastolic decceleration). This finding of elevated / dampened velocities has further evaluated later by correlating them with the grade of stenosis found in MRA. Of the 3 False negative patients on TCD one patient (Case No 30), had a complete occlusion on right ICA, MCA and ACA as well as infarcts in R-MCA territory on MRI/MRA. On TCD examination we found that the anterior circulation arteries (ACA, MCA and ICA siphon) showed normal flow. Further assessment of this patient with Carotid Doppler, DSA could not be performed as this patient succumbed soon after MRI/MRA. The possible explanations for this mismatch could be

- Since TCD was performed before MRA, the thrombosis of R-ICA,ACA and MCA might have developed in the interval period .
- Faulty technique of TCD – Sampling of deep meningeal vessels misinterpreted as that of ACA and MCA, incorrect angle of insonation.
- Technical factors

Thus though these False positives reduce the accuracy of TCD, they give us additional information about cerebral hemodynamics in stroke patients that is not demonstrated by MRA. A way of minimizing these False positives will be to increase the threshold cut-off to > 100 cm/ sec from the current 80cm / sec so that the patients with flow diversion causing only slight velocity elevation are still considered as normal.

Out of 50 patients we studied TCD findings in PCA were obtained in a total of 40 patients.. Of these 40 patients 4 patients showed abnormal PCA on MR Angiography. Of the MRA abnormal 4 patients, all four showed positive findings on TCD(True positive on TCD). Also of the 36 MRA normal patients, 16 were normal on TCD(True negative on TCD) while 20 were positive on TCD(False positive on TCD). The analysis of the above findings revealed the following findings for TCD compared to MRA : Sensitivity 100 %, Specificity 44.44%, Positive predictive value 16.67 %, Negative predictive value 100 %.

Out of 50 patients studied, 10 patients were excluded due to inadequate insonation windows. Of the 40 patients, 24 patients showed abnormality on MRA. Of the MRA abnormal 24 patients, 20 were abnormal on TCD (True positive on TCD), while 4 were normal on TCD (False negative on TCD). Also of the 16 MRA normal patients, 9 were normal on TCD (True negative) while 7 were abnormal on TCD (False positive). Analysis of above findings revealed, Sensitivity 83.33 %, Specificity 56.25%, Positive predictive value 74.07 %, Negative predictive value 69.23 % for TCD compared to MRA in Assessment of the Anterior circulation.

4. Discussion

Both Transcranial Doppler and Magnetic Resonance Angiography are non-invasive modalities to assess the intracranial circulation. Of the various indications, stroke is a peculiarly important indication for vascular assessment because it is a dynamic evolving process and the vascular status of a patient often determines the therapeutic decisions made.

4.1. Age Distribution of patients

The highest number of patients were in the age group of 61-70 years (17 patients), constituting 34 % of the entire study group. The least number of patients was in the age group < 30 years (1 patient – 2% of study group). The second largest group was that of age 51-60 years comprising of 11 patients, 22 % of the study group. Thus the prevalence of stroke in our study was more in elderly patients, typically > 50 years, and was less in the young age groups. The age group below 50 years of age contributed 22 % patients to the study, while the remaining 78 % patients were above the age of 50 years.

Stroke increases with age: individual Indian studies have estimated that the prevalence rates increases from 21/100,000 for the 20-40 age group to 625/100,000 in the 60+ year age group[86]. Similarly, the incidence rates increase from 27-34/100,000 in the 35-44 age group to 822-1116/100,000 in the 75+ age group. However in India, the prevalence of stroke in younger individuals is high (18-32% of all stoke cases) compared with high-income countries. In another study in India during the study period, 2002–2004, reliable information was available in 2162 acute stroke

cases (CT confirmed). It was evident that the incidence of stroke was rising with advancing age – the maximum being in the age bands of 41-70 years[3].

60 % patients of in our study were males while 40 % were females. According to Sethi *et al*[4] men are more likely to have a stroke than women: the male/female sex ratio for India is 7:1. This may be due to differences in risk factors such as smoking and drinking which are more prevalent among men in India compared with women.

In another study in 2010, Ashu Aggarwal et al[5] concluded that men's stroke incidence rates are 1.25 times greater than women's. The difference in incidence rates between the sexes is somewhat larger at younger ages but non-existent at older ages.

A risk factor survey for associated diseases in our study revealed that 21 patients (42 %) were suffering from Diabetes mellitus, 26 patients(52 %) were suffering from hypertension and 9(18 %) patients were suffering from Ischemic heart disease. 20 patients(40%) were found to be suffering from 2 out of these 3 diseases while there were 3 patients(6 %) suffering from all the three diseases.

Victor and Adams[6] states that several factors are known to increase the liability to stroke, most important of these are hypertension, heart disease, atrial fibrillation, diabetes mellitus, cigarette smoking, and hyperlipidemia. A Guideline published by the American Heart Association in 2006[7] states that Non-modifiable stroke risk factors include, age, sex, low birth weight, ethnicity and genetic factors, but modifiable risk factors include smoking, hypertension, and high cholesterol.

According a study performed by Sridharan et al[8], the prevalence of various risk factors in Stroke patients in India were as follows, Diabetes 3 – 12 %, Hypertension 12 – 40 % and Heart disease 7 %. They also evaluated the prevalence of other risk factors like smoking, alcohol consumption, Obesity etc.

Of the 50 patients we studied 41 patients (82% of study group) had anterior circulation stroke out of which 31 patients (62 % of study group) had infarcts while 10 patients (20 % of study group) had haemorrhage. Of the 9 patients with Posterior circulation strokes(18 % of study group), 8 patients(16% of study group) had infarct while 1 patient (2 % of study group) had haemorrhage.

Uma Sundar and R Mehetre[10] in 2001 assessed 184 stroke patients, classified them into anterior and posterior circulation strokes and whether they were ischemic or hemorrhagic types.

Out of total 50 patients,14 (28%)showed a Normal MR Angiography. These included patients with stroke caused by pathology other than stenosis / occlusion of major intracranial arteries including Hypertensive bleed, Cerebral venous sinus thrombosis, Lacunar infarcts etc. Ther rest of 36 patients (72%) showed obvious stenosis / occlusion of some major intracranial artery.

In our study, extracranial stenosis and occlusion was seen in only one patient each. In comparison, intracranial arterial abnormalities are much more commonly found in our study, stenosis occuring in 24 patients (48%), while occlusion seen in 12 patients (24%).

J. H. Gillard *et al*[12] performed a study assessing MR Angiography findings in 30 anterior circulation stroke patients.

Of the various arteries assessed we found that Middle cerebral artery showed the maximum number of abnormalities (Total 20 patients = 16 stenosis and 4 occlusion). Next most common artery to show abnormalities on MR Angiography was anterior cerebral artery (Total 10 = 5 stenosis and 5 occlusions). In our study Anterior circulation abnormalities were found in 30 patients (60%) and posterior circulation abnormalities were found in 10 patients (20%).

Uma Sundar and R Mehetr[11] performed a study in 184 stroke patients, in which neuro-imaging was done with MR Angiography and Digital subtraction angiography.

In our study, TCD was not possible in 10 patients (20%) because the insonation windows were inadequate. This means that clinically relevant information was not available from TCD examination in 20 % patients in our study group. Various studies performed on TCD till date comment on varying failure rate of TCD owing to inadequacy of insonation windows.

That racial differences can affect the window availability with age, was stated by Aaslid et al[12]. They concluded that the failure rate in European subjects would be very low compared with that of other races

In our study, the maximum number of patients with inadequate insonation windows were in the age group 71 – 80 years (6 patients = 12 % of total sample size). The correlation between age and Inadequate windows was tested statistically by using Fisher's exact test and the p-value was very low (< 0.001). As the p-value is < 0.05, therefore there is statistically significant association between increasing age and insonation window inadequacy.

Also in different studies Bruno A et al[14] and Hasley J. H[15] determined that the detection of MCA flow signal is much more difficult in females than in males and in elderly than in younger patients.

In comparison to the above mentioned studies, in our study we found that a statistically significant association existed between the increasing age of patient and inadequacy of insonation windows. However unlike other studies we did not find a statistically significant association between gender and inadequacy of insonation windows. A possible explanation for this discrepancy may lie in the small sample size of our study. With an increase in sample size the p value (0.17 in our study) may fall below 0.05.

Of the MRA abnormal 16 patients, 13 were abnormal on TCD (True positive), while 3 were normal on TCD (False negative). Also of the 24 MRA normal patients, 13 were normal on TCD (True negative) while 12 were abnormal on TCD (False positive). The analysis of the above findings revealed the following findings for TCD compared MRA: Sensitivity 81.25 %, Specificity 50.00%, Positive predictive value 52.00%, Negative predictive value 80.00 %

Extensive review of literature shows very few studies performed till date comparing TCD with MRA. Of the few studies performed, each of them assessed various aspects of this comparison like relationship with therapeutic decision making, relation with prognosis, correlation of MRA Grade of stenosis with TCD Mean flow velocity (MFV) values.

The analysis in the present study revealed the following findings for TCD compared MRA: Sensitivity 60%, Specificity 60%, Positive predictive value 33.33%, Negative predictive value 81.82 %

Thus the overall accuracy of TCD was less for ACA than MCA. There are no studies performed that compare the accuracy of TCD with any imaging modality for evaluation of ACA. Alejandro M. Brunser[16] et al performed a study titled "Accuracy of Transcranial Doppler Compared with CT Angiography in Diagnosing Arterial Obstructions in Acute Ischemic Strokes" in which they state that ACA is an artery with the lowest sensitivity for TCD diagnosis. This statement also holds true for our study as the sensitivity we obtained was also low (60%)

5. Conclusion

In our study, we used two non-invasive modalities to assess the intracranial vasculature in stroke patients. Of these, MR Angiography was already being used frequently at our institute. Also it was studied and compared worldwide with other modalities (DSA/CTA) in various studies. TCD was a newer modality for us, with very few studies available comparing it with other modalities in setting of stroke. Hence for the purpose of our study, for statistical analysis, we assumed MR Angiography to be the Gold Standard for Intracranial vascular assessment and compared all TCD findings with it. All the observations and conclusions made so far in this study are based on the above assumption.

However MR Angiography is not the Actual Gold Standard Modality for vascular imaging. Digital subtraction angiography (DSA) has long been considered the reference standard for imaging evaluation of intracranial stenosis and occlusion.

DSA provides excellent visualization of the intracranial vasculature. However, it has several limitations including a high skill required to perform the study and the necessity for intra-arterial catheterization, which results in increased morbidity and mortality for the patient, with a 0.7% stroke risk associated with each procedure.

Given the disadvantages of DSA, 3D time-of-flight (TOF) MRA is a feasible noninvasive technique to evaluate the intracranial vasculature.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to declare.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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