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Correlation of Duplex Colour Doppler of extra cranial carotid arteries and MR angiogram

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INTRODUCTION

Stroke is a significant health problem that ranks in the top four causes of death in most countries and is responsible for a large proportion of the burden of neurologic disorders affecting about 0.2 – 2.5 per 1000 per year. More often disabling than fatal, stroke results in enormous costs measured in both healthcare & productivity.

According to WHO, the term "stroke" is defined as rapidly developing clinical symptoms and/or signs of loss of focal and, at times, global cerebral functions lasting for more than 24 hours or leading to death due to vascular origin cause.

Stroke is also classified by type of underlying disorder, either infarction or haemorrhage.

Causes of Ischemic Stroke are as follows:

1. Atherosclerosis

2. Embolism from heart

    -Atrial fibrillation

    -Mitral stenosis

    -Prosthetic heart valve

    -Cardiomyopathy

    -Acute myocardial infarction

    -Bacterial endocarditis

3. Hypertensive arteriolar sclerosis – Lipohyalinosis

4. Dissection

-Carotid artery

-Vertebral artery

5. Pre-thrombotic states

6. Vasospasm

-Subarachnoid haemorrhage

-Idiopathic

7. Venous

-Dehydration

Approximately 75% of all strokes are ischemic in origin. Four-fifths of these are caused by atherosclerosis, and about one-fifth of cases are thromboembolism from the heart. Cerebral ischemia is caused by a reduced blood flow lasting for several seconds or minutes. If the discontinuance of blood flow persists for more than 5 minutes, infarction of brain tissue results.

Atherosclerotic Infarction:

Atherosclerosis is a disease of large and medium-sized muscular arteries. The primary lesion – the atheroma or fibro-fatty plaque- consists of raised focal plaques within the intima with a core of lipids (mainly cholesterol, usually complexed to protein and cholesterol esters) and a covering fibrinouscap.The intimal plaques that protrude into the lumen weaken underlying media and undergo a series of complications such as haemorrhage, ulceration, and calcification. As the plaque increases in size, it progressively encroaches upon the lumen of the artery and subjacent media. Consequently, atheroma compromises arterial blood flow. It is a progressive disease process that generally begins in childhood and has clinical manifestations in middle or late adulthood.

Risk factors for carotid disease are: age, cigarette smoking, alcohol consumption, hyperlipidaemia, hypercholesteremia, hypertension, diabetes mellitus, obesity, type A personality, insufficient physical exercise, newer risk factor like homocysteine and lipoprotein (a), etc., contributes to the development of plaque formation and subsequent narrowing of the lumen of the vessels. In addition,the degree of stenosis in symptomatic carotid artery disease is highly correlated to the risk of cerebral infarction. [1-3] Therefore, appropriate evaluation of carotid artery disease via different imaging techniques is of utmost importance.

Carotid duplex ultrasound (CDUS) is a non-invasive, safe, and relatively inexpensive technique for evaluating the carotid arteries. CDUS uses B-mode ultrasound imaging and a Doppler ultrasound to detect focal increases in blood flow velocity indicative of high-grade carotid stenosis. CDUS is less precise in determining stenosis of less than 50% and the accuracy of CDUS primarily relies upon the experience and expertise of the ultra-sonographer. The complex assessment of critical CAS attributable to low intrastenotical velocities with frequency-based sonography was improved using the power mode.[4] Different methods have been described to estimate the degree of CAS with CDUS.[1, 4,5,6]

MR Angiography, especially the three-dimensional time-of-flight technique, is useful as a non-invasive diagnostic tool for evaluating suspected extra cranial and intracranial steno-occlusive disease. Our purpose is to assess the location and distribution of severe atherosclerotic stenosis in Indian patients by using MR angiography.

Time-of-flight angiography, phase-contrast angiography, and contrast-enhanced angiography are the standard MR angiography techniques. Time-of-flight (TOF) angiography is based on the flow-related enhancement of unsaturated spins entering in an imaging slice which gives more signals than surrounding stationary reels. This enhancement results from the inflow of unsaturated (completely relaxed) spin into a slice plane or imaging volume between RF excitations. Static spins within the imaging volume will undergo incomplete T1 relaxation between RF excitations resulting in less signal following the next RF pulse when compared to inflowing, completely relaxed spins in flowing blood. The distance that the unsaturated blood can extend into an imaging volume and, therefore, the degree of enhancement is proportional to the TR and the velocity of the blood. The use of gradient motion nulling (flow compensation) improves the flow-related enhancement in gradient-echo sequences. In this way, multiple thin imaging slices are obtained with a flow-compensated gradient-echo sequence in 2-D TOF. This imaging is combined with a reconstruction technique-maximum intensity projection (MIP) to acquire a 3-D image of the vessels analogous to conventional angiography.

With 3-D TOF, a volume of images is obtained simultaneously by phase-encoding in the slice-select direction. An angiographic appearance can be generated using MIP, as is done with 2-D TOF. In addition, several 3-D TOF volumes can be combined to visualize longer segments of vessels. 3-D TOF angiography will allow more excellent spatial resolution in the slice-select direction than 2-D TOF; however, with thick volumes and slow-flowing blood, loss of signal is seen with the 3-D TOF method.

Cerebral angiography is the gold standard for the evaluation of carotid arteries. However, the disadvantage of angiography includes its invasive nature, high cost, atheroembolic or thromboembolic processes resulting from intra-arterial catheter manipulation, puncture site hematoma formation, and adverse reactions to contrast medium. In addition, in a recent review of prospective studies, the risk of neurologic complications with cerebral angiography was approximately 4%, and severe neurologic complications or death was around 1% (range 0-5.7%).The advantages of intra-arterial digital subtraction angiography (DSA) include a reduced dose of contrast, smaller catheters, and shortened procedure length. Despite the lower spatial resolution, DSA has primarily replaced conventional angiography.

The European Carotid Surgery Trial (ECST) and the North American Symptomatic Carotid Endarterectomy Trial (NASCET) have shown the benefit of carotid endarterectomy over current best medical care for patients with high-grade stenosis of the symptomatic internal carotid artery. After carotid endarterectomy, the risk of disabling stroke or death is reduced by about 75% in such patients. However, this benefit exists only if the risk of stroke or death during investigation and operation is low. If this risk exceeds 10%, the value of surgery is marginal.

Adequately displaying the carotid artery and accurately defining any stenosis present plays a vital part in managing patients with presumed ischaemic events in the carotid artery territory. The two techniques routinely employed for this purpose are duplex ultrasound examination and x-ray contrast angiography. Whereas some centers routinely perform carotid endarterectomy based on results from a duplex ultrasound alone, most surgeons require angiographic demonstration of the carotid bifurcation, by either conventional cerebral angiography or intra-arterial digital subtraction angiography, before proceeding to operate. Unfortunately, for this group of patients, these invasive techniques risk causing stroke of between 1% and 4%. This risk seems to be greater for patients with an appreciable atherosclerotic narrowing of the carotid artery. Additionally, the dangers of angiography should be added to those of operation when considering patients for endarterectomy. Therefore, while striving to reduce surgical risks, every effort must also be made to minimize the dangers of angiography during the preoperative assessment of these patients. Magnetic resonance angiography is a new technique that can produce angiograms noninvasively.

In this study, we set out to measure the level of agreement between magnetic resonance angiography and duplex ultrasound in determining the degree of internal carotid artery stenosis at or around the carotid bifurcation.

AIMS AND OBJECTIVES

- To evaluate extra cranial carotid artery disease by Duplex Colour Doppler and MR angiogram in patients with stroke.
- To find the correlation between findings of Duplex Colour Doppler and MR angiogram for extra cranial carotid pathology.

REVIEW OF LITERATURE

According to American Stroke Association (ASA), the risk for recurrent stroke is as high as 40% in TIA and stroke survivors, making stroke a significant public health concern. Many large-scale, well-controlled clinical trials – e.g., North American Symptomatic Carotid Endarterectomy Trial (NASCET), European Carotid Surgery Trial (ECST), have shown that the risk of such events in symptomatic and asymptomatic individuals can be significantly reduced by carotid endarterectomy. Still, the benefit of surgery is contingent on the specific documentation of severe occlusive vascular disease by imaging studies. Thus, MRA has emerged as a handy tool for imaging vascular occlusion.

Mahesh R. Patel et al. (1995)[7] compared three-dimensional time-of-flight (TOF) MRA, two-dimensional TOF MRA, and DU in 176 carotid arteries with CA as the standard of comparison. They concluded that 3-D TOF MRA is the most accurate non-invasive test. In addition, the combined use of MRA and DU increases the accuracy and obviates the need for CA in most patients.

Hon-Man Liu et al. (1996) [8] examined 108 symptomatic patients with cerebrovascular diseases using three-dimensional time-of-flight magnetic resonance angiography (MRA) as a screening tool. Cardio embolic disease and cerebral haemorrhage cases were omitted. The degrees of stenosis of carotid arteries and their major intracranial tributaries were reported. They were classified as non-significant stenosis (0% to 49%), significant stenosis (50% to 99%), and total occlusion. The study concluded that MRA might be a good screening tool for steno-occlusive cerebrovascular disease.

CM Anderson et al. (1992) [9] performed a study on 61 patients evaluating their carotid arteries using magnetic resonance angiography (MRA) with duplex Doppler ultrasound (DUS) and x-ray angiography (XRA). Additionally, they compared the results of the above modalities. The internal and external carotids were graded by normal, mild, moderate, critical stenosis, or complete occlusion, for both ICA & ECA spearman rank correlations were 0.69 (MRA and US), 0.73 (XRA and US), and 0.85 (MRA and XRA). The correlation for ICA origins, were 0.82 (XRA and US), 0.85 (MRA and US), and 0.94 (MRA and XRA). Seven discrepancies in internal carotid interpretation larger than one grade resulted from US errors, three from MRA, and one from XRA. For example, XRA missed a 2-cm partially thrombosed aneurysm, but the US and MRA detected it. Out of 16 possible ulcers on XRA, MRA caught 11. The US failed to detect any of these ulcers. The study concluded that MRA and XRA are similar in the assessment of carotid bifurcation stenosis. Moreover, it suggested that MRA can be used to evaluate equivocal findings of the US and can replace XRA as the pre-surgical modality of diagnosis.

Suzie M. et al. (2001) [10] evaluated Ultrasonography (US) and magnetic resonance (MR) angiography in the differentiation between occlusion and near occlusion of the internal carotid artery (ICA). It involved 274 patients, of which 55 underwent catheter angiography. Out of the 37 total occlusions detected on CA, US depicted all (100%), and MR angiography showed 34 (92%). Out of 21 near occlusions on CA, MR angiography depicted all (100%), and US showed 18 (95% CI: 0.64, 0.97). They concluded that the US is the initial imaging examination, and MR Angiography can confirm the occlusion diagnosed on US imaging. No further evaluation is necessary. Catheter angiography remains beneficial for vessels with diffuse non-focal narrowing.

RL MittlJr et al. (1994) [11] compared the two-dimensional time of flight magnetic resonance angiography (MRA) and duplex Ultrasonography with arteriography for the detection of 70% to 99% stenosis at the carotid artery bifurcation. They found that the sensitivity and specificity of MRA and duplex Ultrasonography are similar for distinguishing surgical and non-surgical degrees of carotid bifurcation stenosis. Thus, they concluded that MRA has some advantages that may make it the screening test of choice. However, concordant MRA and duplex Ultrasonography for the surgical disease does not necessarily obviate the need for catheter arteriography.

DaeChulSuh et al. (2003) [12] retrospectively reviewed the cerebral angiographic findings in 268 patients with one or more severe atherosclerotic stenosis (≥70%). The analysis focused on the location of the stenosis, the anterior and posterior circulations, and the multiplicity of the lesions. They concluded that intracranial atherosclerotic stenosis was more common than extra cranial lesions. Furthermore, signal and severe stenosis have an increasing tendency toward intracranial involvement.

Patel SG1, Collie DA et al.(2002) [13] conducted a study in patients with symptomatic tight carotid stenosis for evaluation of the accuracy of CT angiography (CTA), TOF MR angiography (MRA), and color Doppler ultrasound (DUS). Additionally, they compared the findings with digital subtraction angiography (DSA) and estimated the effect of replacing DSA with non-invasive tests on the outcome, inter-observer variability, and patient preference. Patients referred from a neurovascular clinic were initially evaluated with DUS by the operator blind to symptoms. Patients with tight carotid stenosis on the symptomatic side were scheduled for DSA and underwent CTA and MRA during admission. Two experienced radiologists, blind to the data, independently read the films of DSA, CTA, and MRA. Of the 67 patients involved in the study, 34 were evaluated with all four imaging modalities. In about 80% of patients, a good correlation was noted between DSA and non-invasive tests, i.e., CTA, MRA, and DUS. Among these three, DUS agrees most closely with DSA(sensitivity 0.85, specificity 0.71) in assessing the degree of carotid stenosis. CTA underestimated (sensitivity 0.65, specificity 1.0) and MRA overestimated (sensitivity 1.0, specificity 0.57) the carotid stenosis compared with DSA. The study also revealed that misdiagnosis is very low(6%) when two of the three non-invasive tests were used in combination and performing the third test if there is disagreement in the findings. Patients preferred CTA over MRA and DSA. They concluded that the accuracy in diagnosing symptomatic carotid stenosis is similar for all three non-invasive tests; however, no technique can replace DSA. Combining two non-invasive techniques and adding a third test in case of the non-agreement was more accurate, resulting in few diagnostic errors.

Nederkoorn et al. (2003) [14] compared DUS and MRA with DSA in carotid artery stenosis by systematically reviewing published studies retrieved through PUBMED from bibliographies of review papers. The medical literature was examined for studies that met the following selection criteria:

1. The study published between 1994 and 2001
2. The study used MRA and/or DUS for assessing the severity of carotid artery stenosis
3. DSA was conducted as the standard of reference
4. For at least one definition of carotid disease (degree of stenosis), the absolute numbers of true positives, true negatives, false positives, and false-negative were either available or derivable.

Sixty-three publications were included in the analysis, which showed the pooled sensitivity and specificity of MRA for diagnosing 70-99% stenosis vs. <70% stenosis were 95% (95% CI, 92 to 97) and 90% (95% CI, 86 to 93) respectively. For DUS for the same diagnosis, pooled sensitivity was 86% (95% CI, 84 to 89), and the pooled specificity was 87% (95% CI, 84 to 90). MRA revealed 98% sensitivity (95% CI, 94 to 100) and 100% specificity (95% CI, 99 to 100) for detecting occlusion. Similarly, DUS showed 96% sensitivity (95% CI, 94 to 98) and 100% specificity (95% CI, 99 to 100) for detecting occlusion. Based on the multivariable summary receiver-operating characteristic curve (ROC) for 70-99% stenosis, the study also concluded that the performance of MRA was predicted by the type of MRA scanner, and the performance of DUS was predicted by the presence of verification bias. There was no heterogeneity in MRA performance for estimating occlusion. However, verification bias and type of DUS scanner were explanatory variables for DUS in diagnosing occlusion. Finally, the conclusion was, MRA had better discriminatory power than DUS while evaluating 70% to 99% stenosis, and both the tests are reasonably accurate in detecting occlusion.

Back MR1, Wilson JS et al.(2001) [15] evaluated and compared the role of Magnetic resonance angiography (MRA) and duplex ultrasound scan for characterizing the severity of the carotid disease. Forty patients undergoing carotid endarterectomies from 1996 to 1998 were imaged with a duplex ultrasound scan; MRA (2-D neck and 3-D intracranial, TOF technique); and bi-planar, digital subtraction cerebral arteriography. One reader blindly reviewed the studies using established threshold velocity criteria for the duplex scan. For MRA and CA, the North American Symptomatic Carotid Endarterectomy Trial method was used to assess the ICA diameter reduction. Accordingly, disease was classified into following categories- < 50%, 50%-74%, 75%-99% stenosis, and occlusion. The findings of MRA and duplex ultrasound scans were compared with CA. For MRA, Sensitivity, specificity, positive predictive value, and negative predictive value for detection of > 50% ICA stenosis were 100%, 96%, 98%, and 100% respectively; similarly, for detection of > 75% ICA stenosis values were 100%, 77%, 76%, and 100% respectively. For duplex ultrasound scan, Sensitivity, specificity, positive predictive value, and negative predictive value for detection of > 50% ICA stenosis were 100%, 72%, 88%, and 100% respectively; similarly, for detection of > 75% ICA stenosis values were 90%, 74%, 72%, and 91% respectively. Both MRA and duplex ultrasound scans accurately differentiated all cases of > 95% stenosis from occlusion. In all cases of CA-defined 75% to 99% stenosis, short-length ICA flow gaps were present on MRA. In patients with 50% to 74% stenosis, short-length ICA flow gaps were present in one-half cases on MRA. Additionally, mean angiographic stenosis was significantly greater in these patients when a flow gap was present on MRA (64% +/- 6%) versus no flow gap (57% +/- 7%). In 73% of cases, an agreement was noted among duplex ultrasound scans, MRA, and CA. Of the 24% conflicting results between MRA and duplex ultrasound scan, in all cases, MRA correctly predicted disease severity, and inaccurate duplex ultrasound scan results were due to overestimation in 83% of cases. After duplex ultrasound scan and MRA, only one patient (2%) CA findings altered the operative plan. The study concluded that MRA could accurately categorize the severity of the carotid occlusive disease. Duplex ultrasound scan facilitates patient selection for carotid endarterectomy; however, adjunct use of MRA improves diagnostic accuracy for > 75% stenosis.

Honish C1 et al. (2005) [16]performed a 5-year retrospective analysis of 140 carotid arteries from patients with carotid US and DSA and possibly MR Angiography for comparing the reliability of ultrasound measurements of carotid stenosis with MRA and DSA. US parameters such as peak systolic velocity (PSV), end-diastolic velocity (EDV), and ICA/CCA peak systolic velocity ratio were recorded. The NASCET technique was used for measuring stenosis on MRA and DSA. Statistical analysis included ROC curves and Kappa computation. For stenosis > 70% at PSV > 173 cm/s, sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), kappa and weighted kappa were 0.87, 0.80, 0.70, 0.93, 0.64 and 0.71 respectively. MRA kappa was 0.78, (sensitivity 0.75, specificity 1.0, PPV 1.0, NPV 0.85). It concluded that US parameters should be validated in each center. At best, the US can only approximate the accuracy of DSA, probably due to its inherent limitations. MR Angiography has a perfect specificity and PPV, but it needs standardization. Simultaneous use of MRA and US for screening increases sensitivity to over 0.9 without compromising specificity in >70% stenosis.

Johnson MB 1 et al. (2000)[17] compared Doppler ultrasound, MR angiography (TOF and contrast MRA), and conventional catheter angiography in the evaluation of carotid stenosis in forty patients. The ultrasound and MR angiography results were compared with CA using parameters such as kappa, sensitivity, and specificity (with confidence intervals). Using NASCET criteria, CA revealed 20 mild (26%), 12 moderate (15%), 34 severe stenoses (44%) and 12 ICA occlusions (15%). US showed 95% specificity and 65% sensitivity for detecting surgically manageable cases, while MRA had specificities varying from 95-100% and sensitivities varying from 82-100%. All MR techniques were found to show excellent agreement with catheter angiography concluding it more reliable than Doppler ultrasound in determining surgical lesions and analogous to catheter angiography.

Krappel (2002) [18] et al. examined the quality and usefulness of TOF MR-angiography and Doppler sonography, respectively, in evaluating the extra-cranial arteries before cervical spine operations. Among twenty patients examined, only one case where the results were incompatible with a complete occlusion diagnosed sonographically was assessed as severe stenosis on MRA. Thus, he concluded that TOF-MRA could replace the Doppler examination in the preoperative assessment of the carotids.

Pfister et al. (2009)[19] performed a prospective study involving 25 patients (age 54-88 yrs.) with neurological deficits and ICA stenosis. These patients underwent pre-surgical ultrasound examination using Colour Coded Duplex Sonography (CCDS), 3D CCDS, 3D power Doppler, 3D B-flow, contrast-enhanced 3D B-flow, and CTA/MRA. An experienced examiner performed contrast-enhanced 3D B-flow ultrasound after bolus injection of 2.4 ml Sonovuei.v. Each patient also underwent CTA (Sensation 16, Siemens) or MRA (1.5 T, Symphony Siemens) as a reference method for evaluating ICA stenosis. Two observers independently assessed and interpreted all images. A 10%-scale from 50% to 99% was used for assessment of the extent of stenosis. Spearman

Correlation and Wilcoxon Signed Rank Test with a significance threshold of $p<0.05$ were performed for statistical analysis. During surgery and CTA/MRA, the ICA stenosis ranged from 60% to 99% (mean 80%). With paired Wilcoxon test, non-significant differences were found for 3D B-flow with and without contrast medium ($p<0.05$). Spearman correlation coefficient for correlation with a surgical evaluation regarding the extent of ICA stenosis was o.77 for B-scan, 0.84 for 3D Power Doppler, 0.90 for 3D CCDS, 0.91 for B-flow, and 0.93 for contrast-enhanced 3D B-flow. Contrast-enhanced flow detection of 3D B-flow proved helpful in cases of circular calcifications. The study concluded that in correlation with surgery and CTA/MRA, an accurate evaluation of the extent and morphology of ICA stenosis using 3D B-flow, with and without contrast medium, is reasonable.

Netuka et al. (2016)[20]compared histological evaluation carotid artery stenosis with non-invasive imaging techniques. CT angiography (CTA), Digital subtraction angiography (DSA), Doppler ultrasonography (DUS), and MR angiography (MRA) were conducted for assessment of ICA stenosis. Additionally, atherosclerotic plaque specimens were histologically processed, and slides were prepared for scanning maximal stenosis and measuring the whole plaque's diameter and minimum diameter. These measurements were compared with preoperative imaging findings, and correlation coefficients were computed for clinically significant stenosis groups (<50 %, 50-69 %, ≥70 %). A significant correlation was seen between histological and imaging findings for each diagnostic procedure, with the most significant correlation coefficient for CTA. In 152 patients undergoing CTA and histological measurements, CTA underestimated histological measurement by 11.9 % as per NASCET methodology and 2.4% based on ECST methodology. In 138 patients undergoing DSA and histological measurements, DSA underestimated histological evaluation by 12.2% (NASCET) and 7% (ECST). In 107 patients undergoing MRA and histological measurements, MRA underestimated histological evaluation by o.6% (NASCET) and overestimated by 2.6% (ECST). In 88 patients undergoing DUS and histological measurements, DUS overestimated histological evaluation by 1.8%.

Long A1, Lepoutre A et al. (2002)[21] systematically reviewed the literature (five databases, 1990 to February 2001) to examine the evaluation of ICA stenosis by duplex ultrasonography, MR- and CT-angiography. Each of these imaging modalities was compared with DSA, and sensitivity, specificity was calculated. Regardless of technique, sensitivity exceeded 80% and specificity 90% in over two-thirds of the methodologically studies. Levels of reproducibility were the main drawback of duplex ultrasonography. When the results of duplex and MR-angiography agree, the combination use of these two techniques provides a better diagnosis than either technique taken alone. They concluded that all three techniques appear suitable for measuring stenosis of the proximal internal carotid compared to DSA.

IMAGING ASSESSMENT OF CAROTID ATHEROSCLEROSIS

Duplex Ultrasound in carotid stenosis-

Duplex ultrasound has become the screening and diagnostic imaging modality of choice in carotid occlusive disease mainly because of its low cost, accuracy, and non-invasiveness. Early studies have arrived at velocity criteria for diagnosing and classification of carotid disease, and the most widely used in the 1980s and 1990s have been those developed by Strandness and Zweibel[22-24]. Historically, patients with carotid artery disease are divided into two groups: symptomatic and asymptomatic. The symptomatic group of patients typically has had a neurologic event (stroke, transient ischemic attack, or amaurosisfugax) secondary to cerebral ischemia. It is likely due to embolization of atherosclerotic plaque originating at the carotid bifurcation. The North American Symptomatic Carotid Endarterectomy Trial [2] and the European Symptomatic Carotid Trial [25] involved these symptomatic patients. The asymptomatic group includes patients without a history of a neurologic event. The Asymptomatic Carotid Artery Study [26] involved asymptomatic patients having clinical markers for atherosclerosis.

The prevalence of significant (50%) stenotic disease in symptomatic patients is stated as being in the range of 18%–20% [27, 28], while in asymptomatic patients referred for carotid imaging is 14% [29]. Doppler US is the most common initial imaging examination conducted worldwide to aid in diagnosing carotid disease. The number of Doppler ultrasounds performed annually for diagnosis is substantial due to the high prevalence of carotid artery disease[30]. In addition, approximately 80% of patients in the United States undergo carotid endarterectomy after a US examination as the only preoperative imaging study. Therefore, the findings of the US examination must be accurate and consistent.

Considerable gains have been made in the quality of US examinations of the carotid arteries over the past 2 decades. The technology has experienced tremendous advances in equipment, ranging from continued improvements in grey-scale resolution to landmark advances in Doppler methods, including color Doppler imaging. The imaging community has gained expertise in the performance of carotid US and interpretation of the results through the widespread use of technology, research, and continuing medical education. In addition, various accrediting bodies have been established by groups such as the Intersocietal Commission for Accreditation of Vascular Laboratories, the American Institute of Ultrasound in Medicine, and the American College of Radiology to improve and standardize the quality of vascular US examinations.

Magnetic Resonance Imaging (MRI) -

For identifying vulnerable plaques, MRI is valuable in accurately assessing plaque size and composition. A prospective study by Takaya et al. involved 154 asymptomatic patients with carotid stenosis diagnosed on ultrasound. A baseline MRI was also performed to evaluate plaque characteristics such as thin or ruptured fibrous cap, hemorrhage within the plaque, larger lipid-rich necrotic core, and larger maximum wall thickness. The patients were followed for 38.2 months for subsequent cerebrovascular events [31]. Even though this was a small study, it set the basis for more extensive research to determine the role of MRI in recognizing high-risk atherosclerotic plaques causing neurologic events. Despite the advantage of MRI in avoiding ionizing radiation, the disadvantages of this imaging modality include longer scanning time, producing motion artifacts. Additionally, the risk of gadolinium-induced nephrogenic systemic fibrosis in patients with end-stage renal disease (prevalence 3%) [32]restricts its usefulness to few patients.

Histopathology -

Recent advances in imaging modalities are enabling a more thorough evaluation of carotid plaque characteristics. Many studies are trying to correlate the findings on imaging with histology evaluation of atherosclerotic plaques. One such study by the Committee on Vascular Lesions of the Council on Arteriosclerosis defines and classifies advanced types of atherosclerotic lesions based on histology [33]. It also attempted to associate the imaging characteristics of lesions with histological types. This correlation of images to ex vivo plaque is helping advance the understanding of plaque morphology and vulnerability.

Imaging modalities in Identifying the Vulnerable Plaque-

The carotid artery stenosis is noninvasively diagnosed with different imaging techniques like duplex ultrasound, CT-angiography, or MR-angiography. However, despite large trials and refinement of criteria, stenosis alone cannot predict the high-risk asymptomatic plaques likely to cause neurologic symptoms. Currently, data garnered from various imaging modalities have been studied to help identify these high-risk plaques. The recent development of B-mode ultrasound has improved the ability of duplex scanning to estimate the severity of stenosis and the characteristics of plaque morphology. These characteristics include echolucency, calcification, hemorrhage within the plaque, and other features like plaque volume, surface irregularity, fibrous cap thickness, and the size and location of the necrotic core. This evaluation of plaque peculiarities via ultrasound is important for the stratification of high-risk patients[34, 35].

Echolucency/Grey Scale Median-

Carotid atherosclerosis with echoleucent plaque is highly associated with the occurrence of cerebrovascular events[36, 37]. There is a direct correlation between the plaque's echoleucency on ultrasound with the episodes of TIA or stroke in the future. However, as evaluation plaque echolucency was subjective and qualitative, it was difficult to correlate and credit risk [38-41]. Echolucency has been further defined and quantified using the method of image normalization and measurement of the greyscale median (GSM), a computer-quantified measure of echolucency[42-44]. Multiple studies have shown an association between low GSM and plaque instability [45-47].

Calcification-

Calcification is a comparatively common structural feature of the atherosclerotic plaque and is heightened with advanced age, chronic renal failure, diabetes, and inflammation [48]. Compared to non-calcified plaques, calcified atherosclerotic plaques are less prone to disrupt and result in symptoms [49]. This implies that calcification imparts structural stability to the fibrous cap [50]. A study of patients with carotid artery disease found that the incidence of cerebrovascular events was fewer in patients with calcified carotid plaques than in those with noncalcified plaques [51]. A study by Grogan et al. revealed that symptomatic plaques are more echolucent and less calcified on B-mode ultrasound than asymptomatic plaques [52]. Calcification, however, is not a standard feature of the aging process but a dynamic process in the progression of atherosclerosis [53, 54]. It results from a complicated interplay between inflammatory cytokines and the activation of bone-building cells [55]. The presence and extent of carotid plaque calcification can be precisely quantified with a CT scan and is inversely related to plaque macrophage infiltration and symptomatic outcome [56]. In vivo quantitative assessment of carotid plaque, calcification may help identify asymptomatic patients with vulnerable carotid plaques at higher risk for development of cerebrovascular events and benefit from carotid interventions.

Intraplaque Hemorrhage-

Intraplaque hemorrhage is a plaque characteristic that was thought to correlate with symptoms of carotid artery disease. The American Heart Association Type VI plaque is a complicated plaque characterized by surface irregularity, intraplaque hemorrhage, or thrombus. Although there is controversy over whether intraplaque hemorrhage alone is a predictor of future ischemic events, it is a marker of plaque inflammation and instability. A study by Hatsukami et al. involved 43 symptomatic and asymptomatic patients undergoing carotid endarterectomy for highly stenotic lesions and compared histologic findings to preoperative images [40]. This study failed to show an association between symptoms of the patients and the presence or volume of hemorrhage within the plaque. Moreover, it did not correlate symptoms with calcification, fibrous intimal tissue, lipid core, or necrotic core. These findings show a limited use for intraplaque hemorrhage alone as a surrogate for plaque vulnerability. On the contrary, other studies utilizing either ultrasonography or MRI to detect intraplaque hemorrhage have shown intraplaque bleeding as a plaque characteristic of cerebrovascular events [57, 58].

METHODOLOGY

i) Study site:

The study was conducted at MRI and Ultrasound department, Holy Spirit Hospital, Andheri (E), Mumbai.

ii) Study population:

Involved patients of all ages referred for MRA and Doppler to evaluate cerebrovascular pathology (symptoms as headache, giddiness, focal neurodeficit).

iii) Study design:

Analytic type of Observational study

iv) Sample size:

As per the previous year's record of the hospital, on average, every month, positive MRA study reported were found to be

$X1=3$ to $X2=4$ cases.

As data collection duration is 20 months, the expected sample size will be:

$$\frac{20(X1)+20(X2)}{2} + \frac{(20x3)+(20x4)}{2} = 70$$

v) Time frame to address the study:

24 months (November 2014 to November 2016)

We completed data collection in 20 months and statistical analysis of data in four months.

vi) Inclusion criteria:

Patients of all age groups with cerebrovascular pathology (symptoms- headaches, giddiness, and focal neurodeficit).

vii) Exclusion criteria:

1. Patients who refuse to undergo MRI
2. Contraindications to MRI such as any metallic implants
3. Patients who have claustrophobia or anxiety disorders exacerbated by MRI
4. Allergy to jelly used for the ultrasound

A total of 73 patients of all age and sex groups with h/o focal neurological deficit with suspected stroke underwent an MR angiography study by using a 3-D time of flight technique on a 1.5T machine with a standard head coil. Images were acquired in the axial planes through three-dimensional acquisition, gradient-echo technique with spoiling and flow compensation. The angiography findings were categorized as an ipsilateral or contralateral side with results that were ≥ 50% were recorded as significant stenosis. The stenosis measurements were computed directly on the maximum intensity projection views of MRAs.The findings were recorded as follows

(1) Normal or clinically non-significant stenosis (i.e., < 50% stenosis)

(2) Clinically significant stenosis (i.e., ≥ 50% stenosis) on the ipsilateral side and contralateral side.

B-mode ultrasound imaging and Doppler ultrasound were used to detect focal increases in blood flow velocity diagnosing carotid stenosis. Characterization of plaque and stenosis is done according to NASCET criteria. The narrowest ICA diameter at the site of maximum stenosis in each segment of the artery was measured and the difference is divided by the original diameter.

On greyscale imaging, plaque characterization is as follow-

Type 1- Hypoechoic plaque with thin echogenic rim

Type 2- Echogenic plaque having >50% hypoechoic areas

Type 3- Echogenic plaque having <50% hypoechoic area

Type 4- Uniformly echogenic plaque

Colour Doppler criteria for evaluation of carotid artery atherosclerotic disease-

ICA Stenosis: NASCET Criteria

ICA Stenosis (%)	ICA PSV (cm/sec)	ICA EDV (cm/sec)	PSV Ratio: ICA/CCA
Normal	<125	<40	<2.0
<50%	<125	<40	<2.0
50-69%	125-230	40-100	2.0-4.0
>70%	>230	>100	>4.0
Near occlusion	Variable	Variable	Variable
Total occlusion	Undetectable	Undetectable	Not applicable

Reference: Grant EG et al, Radiology 2003; 229: 340-346

Pre Procedure Workup of patients:

The general parameters like the age and sex of the patient were recorded. Patient history was taken to see for predisposing factors like diabetes and hypertension. After obtaining a detailed history, patients, underwent a thorough clinical and neurological examination. A CT scan / MRI of the brain was done in all patients to rule out the hemorrhagic cause of stroke.

Equipment facilities:

- 1.5 TESLA GE SIGNA EXCITE HD MRI.

  Configuration: NV ARRAY

  IGC #: 14661

  GE #: 2383613-3/M1085PA

  Cable S/N: 38716

Date: 11-19-03

- PHILIPS IU 22

Transducer: L9-3

Frequency range- 9 to 3 MHertz

Effective aperture length- 38 mm

Scanning parameters:

The slice thickness and imaging parameters for the sequences will be as follows and is subject to variation per individual case:

Patient Preparation	Extra cranial MRA
Plane	Axial
Mode	3D
Pulse sequence	TOF SPGR
Imaging Options	Fast
# of Echoes	1
TE	6.9
TR	30
Flip Angle	20
Bandwidth	20.83
Freq.	256
Phase	160
FOV	20

Slice Thickness	2.6
Spacing	1.3
Scan Time	5.27 Min

ix) Statistical methods:

Windows 8.0 (SPSS, Chicago, IL) and Excel 2000 (Microsoft, Redmond, WA) with SPSS were used for statistical analysis. Co-relation between the modalities was analyzed after appropriate coding by using spearmen co-relation co-efficient. P-value of < 0.05 was taken as significant.

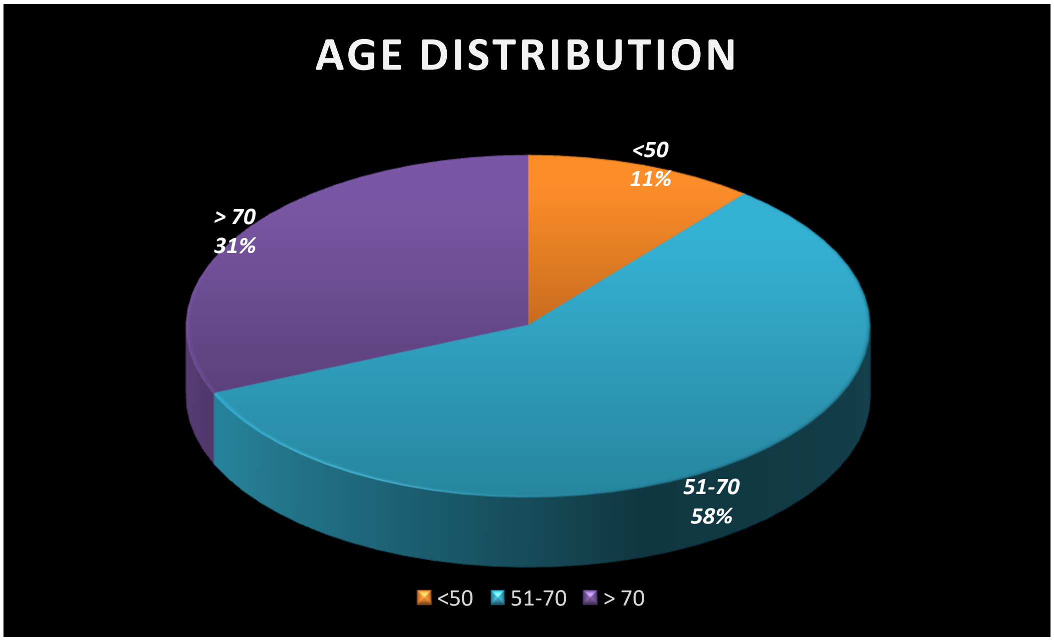
OBSERVATIONS AND RESULTS

This study includes 73 cases of stroke from November 2014 to November 2016. The study was carried out prospectively in the Department of Radio diagnosis in our institute. The following observations were made.

Table 1 - Age wise distribution of patients in present study.

Age group (years)	N	%
<50	8	11%
51-70	42	58%
> 70	23	31%

Total	73	100.0%



Out of the total 73 patients included in the study, a maximum of 42 (58%) were in the age group of 51-70 years. 23 (31%) patients were in the>70 years, age group. Minimum patients, i.e., 8 (11%), were over the age group of <50. Thus, the mean age of the study population was 59.5 (range 30-89 years).

Table 2 - Sex wise distribution of patients in present study.

Gender	N	%
Female	26	35.6%
Male	47	64.4%
Total	73	100.0%

Out of the 73 patients studied, 47 (64.4%) were male, and 26 (35.6%) were female.

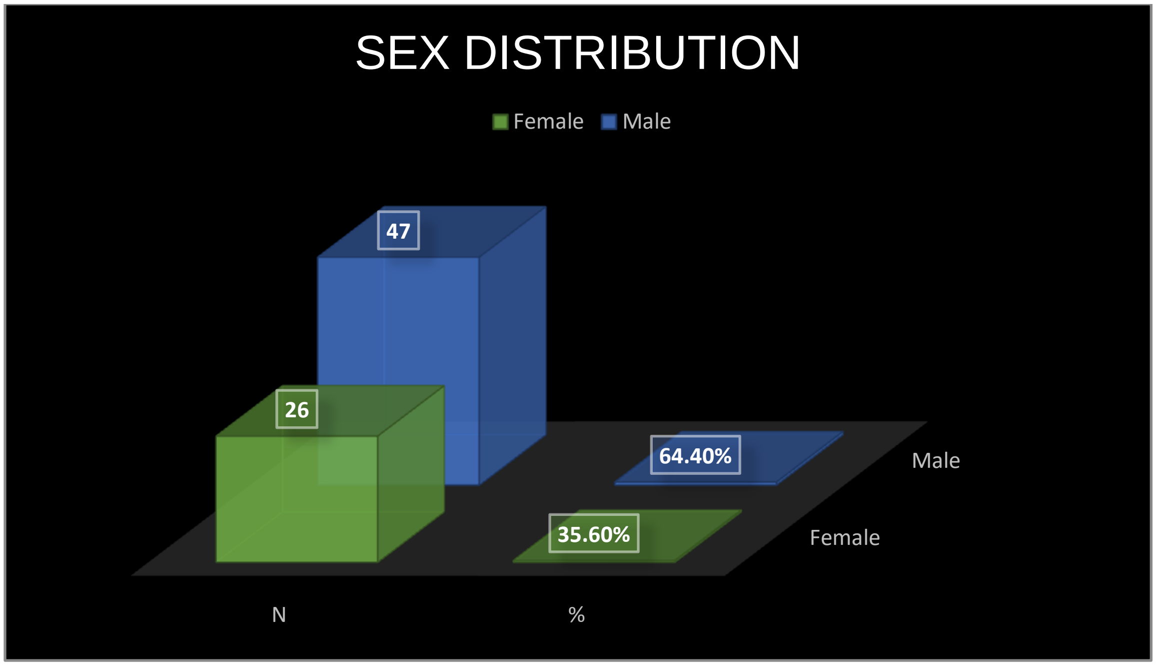
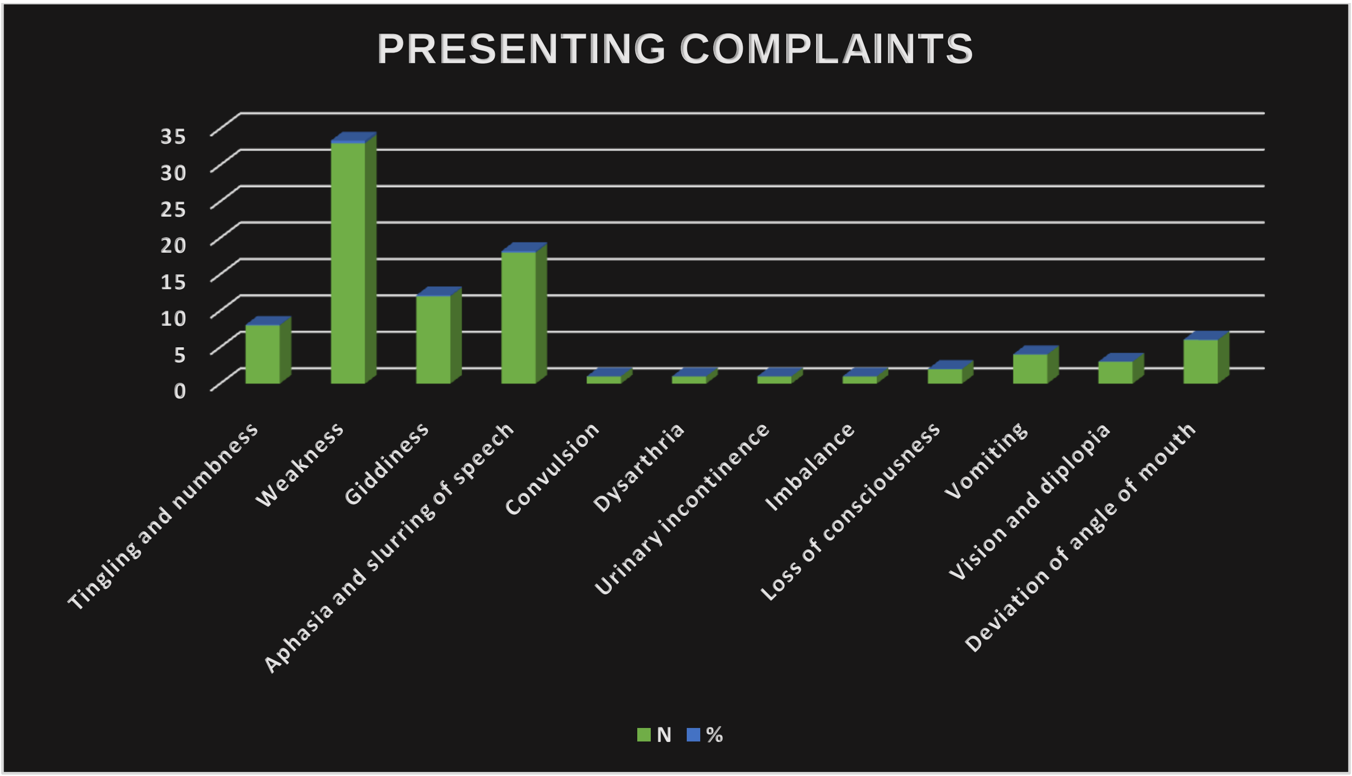


Table 3 - Clinical symptoms wise distribution of patient at presentation.

Presenting Complaints	N	%
Tingling and numbness	8	8.9%
Weakness	33	36.7%
Giddiness	12	13.3%
Aphasia and slurring of speech	18	20%
Convulsion	1	1.1%
Dysarthria	1	1.1%
Urinary incontinence	1	1.1%
Imbalance	1	1.1%
Loss of consciousness	2	2.2%
Vomiting	4	4.4%
Vision and diplopia	3	3.3%
Deviation of angle of mouth	6	6.6%



Out of the 73 patients seen in this study, the most typical presenting symptom in patients with cerebral infarction was hemiparesis (36.7%). Eighteen patients (20%) presented with aphasia or slurring in speech, while 12 patients (13.3%) presented with giddiness, 8 (8.9%) patients presented with tingling /numbness, 6 (6.6%) presented with a deviation of angle of the mouth and four patients presented with Vomiting. Other presenting symptoms like Convulsion, Dysarthria, Urinary incontinence, imbalance, vision, and diplopia as seen in 1.1-3.3 %. Most of the patients presented with a combination of symptoms.

Table 4–Association with Diabetes

Diabetes Mellitus	N	%
Present	38	52.1%
Absent	35	47.9%
Total	73	100%

This table shows that diabetes is associated with an increased frequency of stenosis.

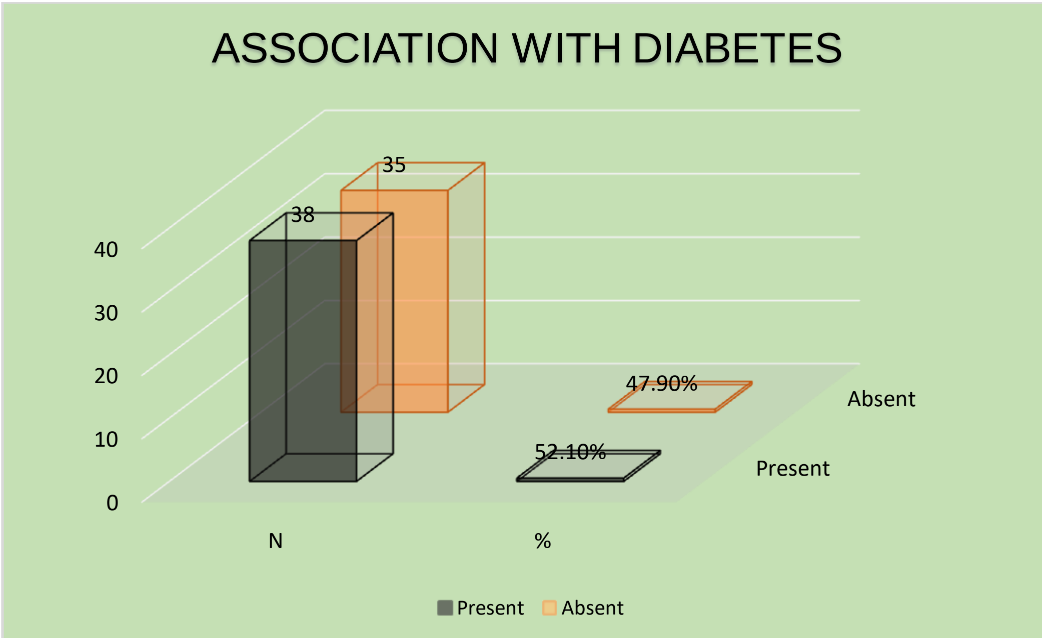


Table 5–Association with Hypertension

Hypertension	N	%
Present	43	58.9%
Absent	30	41.1%
Total	73	100%

This table shows that hypertension is associated with an increased frequency of stenosis.

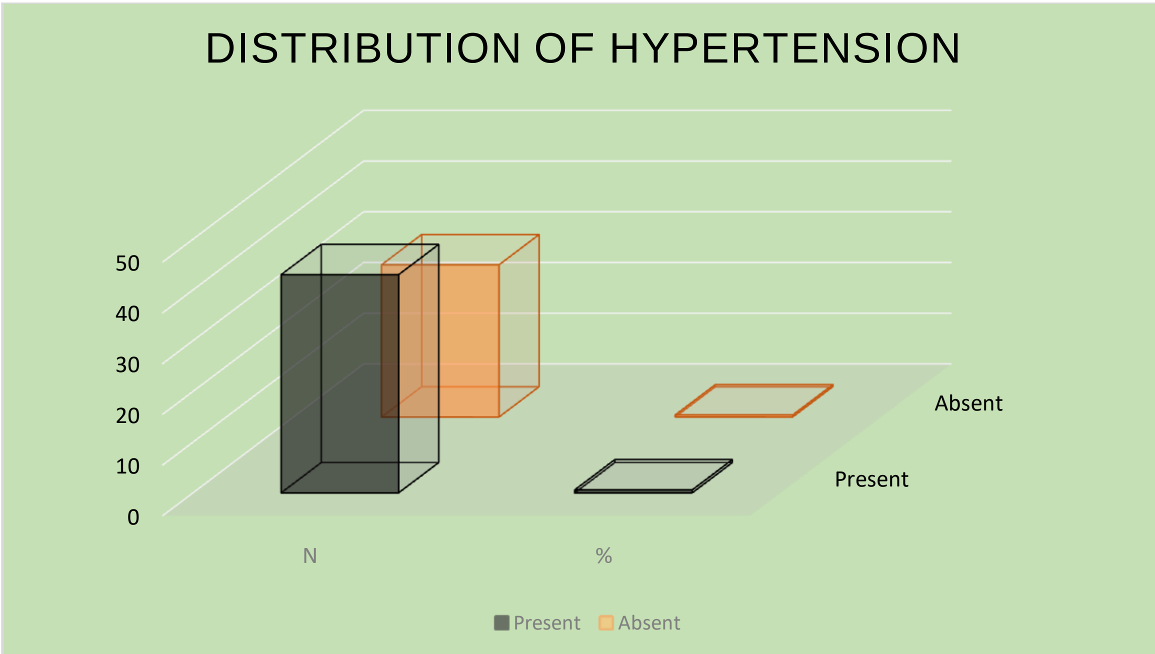


Table 6 – Frequency distribution of lesions on MRA on the ipsilateral side

Finding on MRA	N	%
Normal	31	42.6%
<50 % Stenosis	24	32.9%
>50 % Stenosis	18	24.7%
Total	73	100%

Among the 73 patients included in this study, 24 (32.9%) patients with stroke had <50% stenosis in ICA on the ipsilateral side, and 18 (24.7%) had >50% stenosis in ICA on the ipsilateral side on MRA.

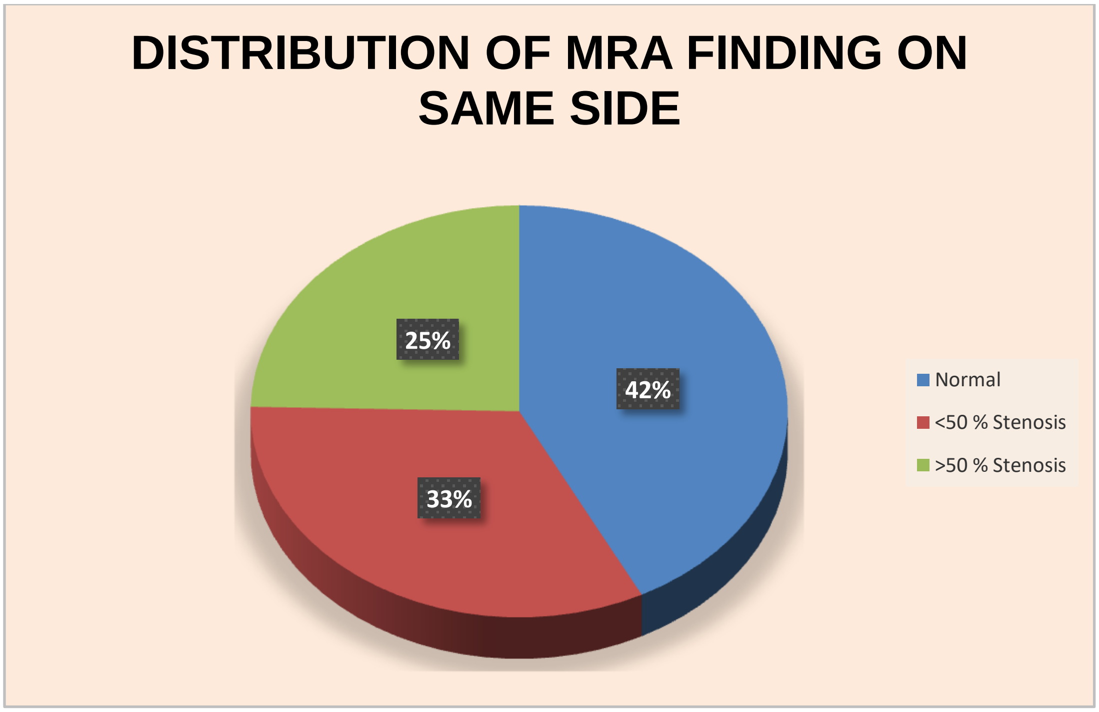


Table 7– Frequency distribution of various lesions on MRA on the C/L side

Finding on MRA	N	%
Normal	48	65.8%
<50 % Stenosis	19	26.0%
>50 % Stenosis	6	8.2%
Total	73	100%

Among the 73 patients included in this study, 19 (26%) patients with stroke had <50% stenosis in ICA on the contralateral side, and 6 (8.2%) had >50% stenosis in ICA on the contralateral side on MRA.

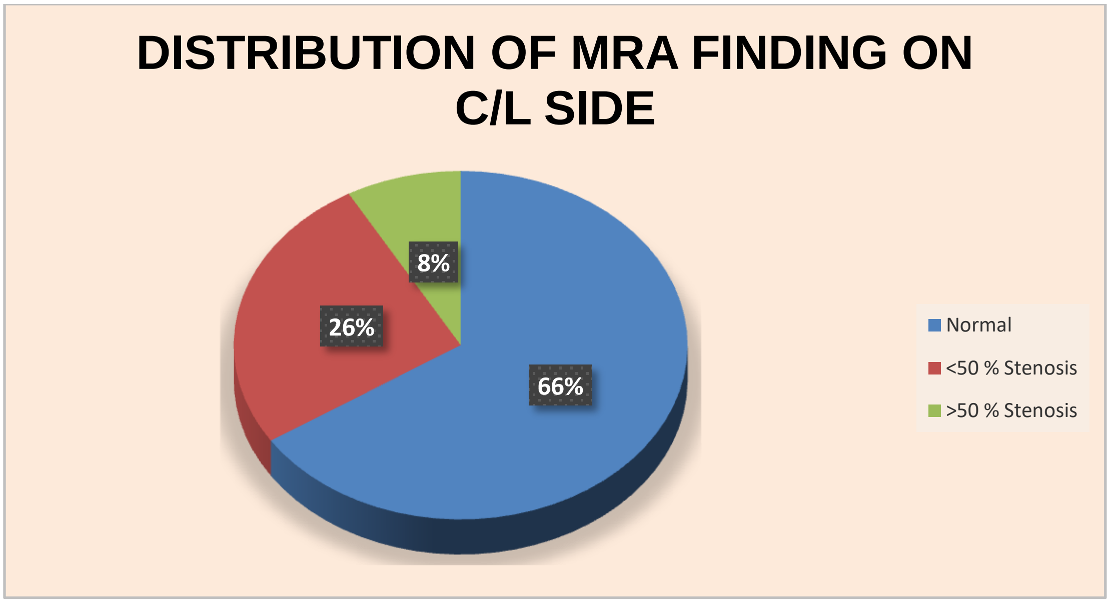


Table 8 – Frequency distribution of morphology of plaque on Doppler on theipsilateral side

Finding on Doppler	N	%
Normal	28	38.4%
Echoleucent plaque	27	37%
Calcified plaque	18	24.6%
Total	73	100%

On Doppler greyscale imaging, 27 (37%) had echoleucent plaque in ICA on the ipsilateral side, and 18 (24.6%) patients had a calcified plaque in ICA on the ipsilateral side**.**

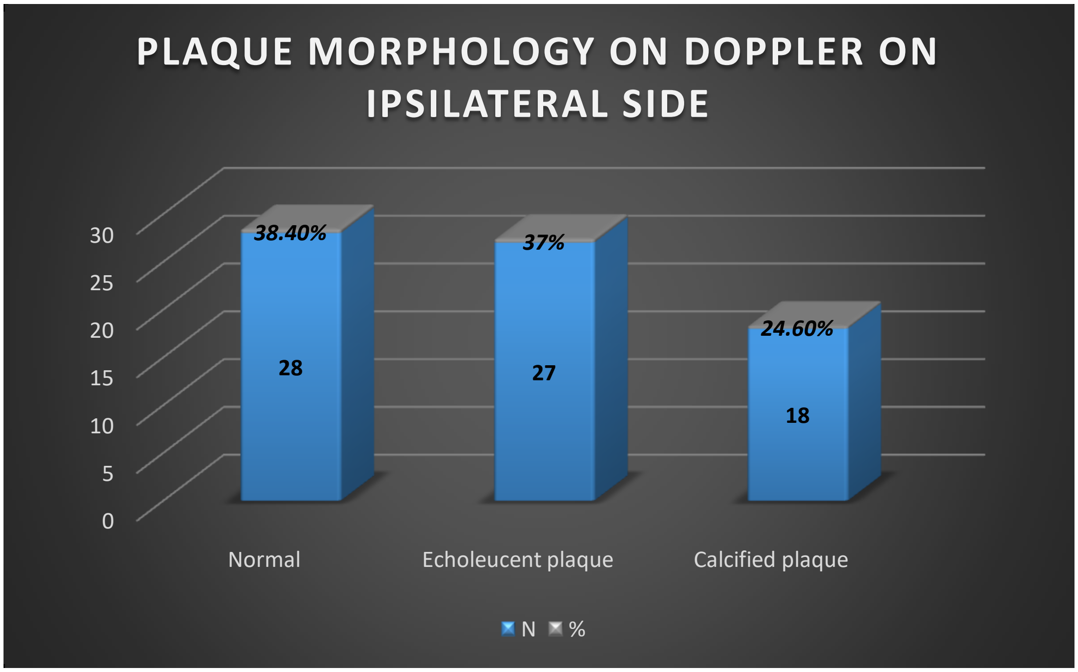


Table 9 – Frequency distribution of morphology of plaque on Doppler on the C/L side

Finding on Doppler	N	%
Normal	30	41.1%
Echoleucent plaque	28	38.4%
Calcified plaque	15	20.5%
Total	73	100%

On Doppler greyscale imaging, 28 (38.4%) had echoleucent plaque in ICA on the contralateral side, and 15 (20.5%) patients had a calcified plaque in ICA on the contralateral side.

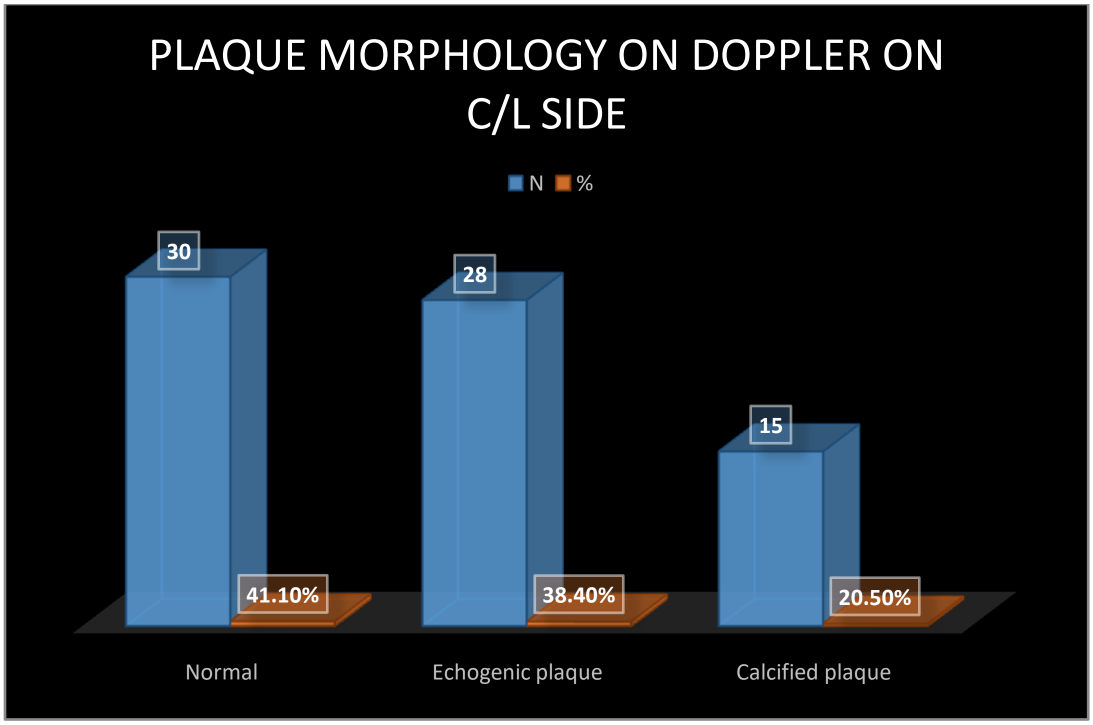


Table 10 – Frequency distribution of plaque on Doppler on the ipsilateral side

Finding on Doppler	N	%
Normal	28	38.3%
<50%	24	32.9%
50-69%	9	12.3%
>70 %	2	2.7%
Near complete occlusion	5	6.8%
Total occlusion	5	6.8%
Total	73	100%

Of 73 patients on Doppler imaging, 24 (32.9%) had <50% stenosis in ICA on the same side. 9(12.3%) had 50-69 % stenosis while 2 (2.7%) had >70% stenosis in

ICA on same side. 5(6.8%) patients had near-complete occlusion of same side ICA, and 5 (6.8%) patients had total occlusion of same side ICA.

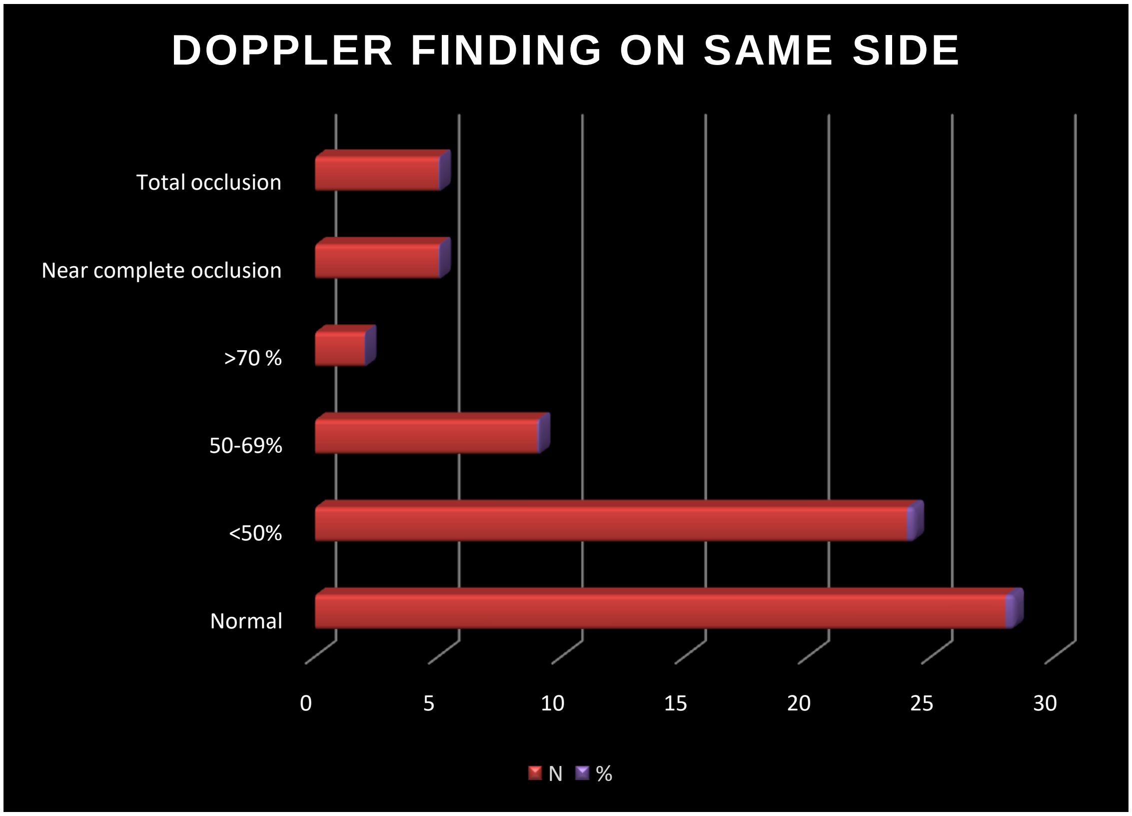
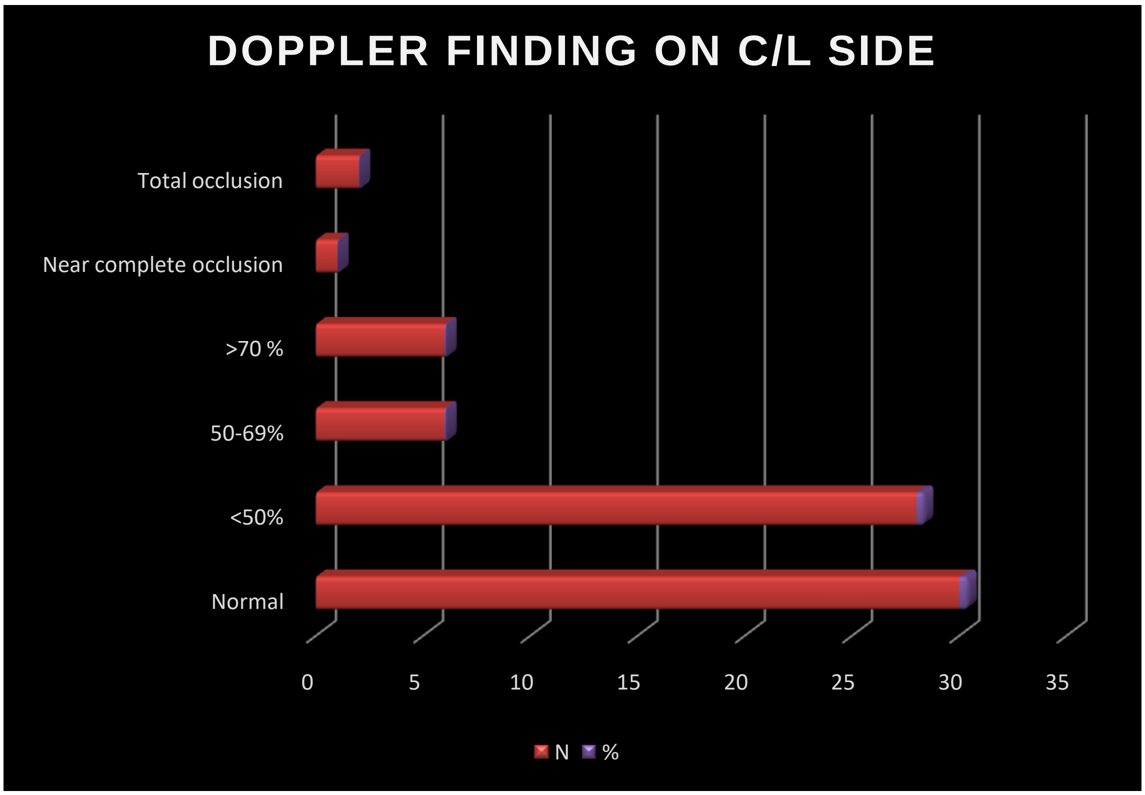


Table 11 – Frequency distribution of plaque on Doppler on the C/L side

Finding on Doppler	N	%
Normal	30	41.2%
<50%	28	38.3%
50-69%	6	8.2%
>70 %	6	8.2%
Near complete occlusion	1	1.4%
Total occlusion	2	2.7 %

Total	73	100%

Of 73 patients on Doppler imaging, 28 (38.3%) had <50% stenosis in ICA on the contralateral side. 6(8.2%) had 50-69 % stenosis while 6 (8.2%) had >70% stenosis in ICA on contralateral side. 1(1.4%) patients had near-complete occlusion of contralateral side ICA, and 2 (2.7%) patients had total occlusion of contralateral side ICA.



DISCUSSION

In patients with high-grade (>70%) carotid artery stenosis, advantages of carotid endarterectomy have already been established in many large randomized studies [59-61]. Identifying these patients has reinforced the demand for reliable and exact diagnostic tools to assess the degree of carotid artery stenosis. In the past, DSA has been considered the single most accurate test for preoperative evaluation of stenosis. However, the incidence rate of intervention-related stroke ranges from 0.5% to 1.0% [62-64]. Therefore, Non-invasive imaging tools like MR angiography and duplex ultrasound have been considered potential replacements for DSA [65-72]. The problems with these imaging modalities are less accuracy and reliability, which can result in inappropriate treatment.

An accurate distinction between complete occlusion of the internal carotid artery (ICA) from near-complete occlusion is often difficult. This analysis, however, is crucial because of the significant implications in therapeutic management and clinical outcome. As long as the ICA lumen is patent, symptomatic patients are at high risk for embolic stroke. The risk of embolic stroke and the benefit of surgery stratify according to the degree of stenosis [73, 74]. With 90%–94% stenosis, the risk of stroke at one year in medically treated patients was 35%, and that in patients who underwent carotid endarterectomy (CEA) was 8.7% [75]. Although there is little available literature regarding the risk of stroke in patients with near occlusion (lesions with stenosis greater than 94%), the North American Symptomatic Carotid Endarterectomy Trial, or NASCET, reported that the risk decreases but remains significant at 11.1% per year. It approximates the stroke risk of patients having 70%– 89% ICA stenosis [75]. Thus, patients with complete ICA occlusion are at minimal risk for embolic phenomena. The continued symptoms experienced by these patients may be associated with hemispheric hypo perfusion, in which medical therapy is usually maximized. Therefore, these patients are generally not treated surgically with CEA.

This study includes a prospective and direct comparison of MR angiography and duplex sonography to evaluate stenosis of the carotid bifurcation in symptomatic patients. This study's purpose was to systematically review the contemporary literature and compare the diagnostic performance of MRA and duplex Doppler. In addition, we aimed to increase precision by combining published studies. Moreover, we attempted to determine variables that might explain part of the difference in outcome across studies.

The present study includes 73 patients with a history of stroke. MRA and Duplex for extra cranial carotid artery were performed for all patients. Findings of different lesions were then studied.

1) SEX AND MEAN AGE:

In our study, out of the total 73 patients included, a maximum of 42 (58%) were in the age group 51-70 years, followed by >70 years age group, which included 23 (31%). Minimum patients, i.e., 8 (11%), were over the age group of <50. Thus, the mean age of the study population was 59.5 (range 30-89 years). Out of the 73 patients studied, 47 (64.4%) were male, and 26 (35.6%) were female.

Sex distribution comparison in our study and other studies

	GR Young et al	**MR Patel et al**	**Borisch et al**	**Our study**
Male	49/70 (70%)	58/88 (65.9%)	32/39 (82.1%)	47/73 (64.4%)

Female	21/70 (30%)	30/88 (34.1%)	7/39 (17.9%)	26/73 (35.6%)
Mean Age (yrs.)	62	70	67.4	59.5

In a study conducted by Borisch et al. [76], out of 39 patients, 7(17.9%) were women, and 32(82.1%) were men with a mean age of (41–80 years)
67.4. GR Young et al. [68] studied 70 patients; the distribution of male patients was 70% while females were 30%. MR Patel et al. [7] studied 88 patients, out of which 65.9% were male and 34.1% were female

Concerning clinical symptoms, the most common clinical presentation in our study was weakness seen in 33 (36.7%) patients, followed by aphasia seen in 18 (20%) patients, and almost all patients presented with a combination of symptoms. In his study, young et al. [68] reported the most common presentation was a recent, non-disabling stroke or transient ischemic attack in the carotid artery territory in all cases. Out of 70 patients, there were 26 patients with stroke (37%), 36 with a transient ischemic attack (51%), and 8 (11%) with both stroke and transient ischemic attack. This difference maybe because of the dedicated study of carotid territory ischemia. In our study, the percentage of tingling numbness (8.9%) is low because of all patients with acute infarct symptoms, including speech difficulty, giddiness, and visual abnormalities.

In our study, out of 73 patients, 38(52.1%) had diabetes mellitus, and 43(58.9%) had hypertension.MR Patel et al. [7], in his study, reported risk factors for atherosclerotic disease are hypercholesterolemia (47%), hypertension (73%), diabetes mellitus (35%), and smoking (64%).

In our study, out of 73 patients, 27 (37%) patients had echoleucent plaque in ipsilateral ICA, and 28 (38.4%) patients had echoleucent plaque in contralateral

ICA. Calcified plaque is noted in 18 (24.6%) patients in the ipsilateral ICA and 15 (20.5%) patients in the C/L ICA. Marie Louise et al. [77], in her study, reported objectively measured echoleucent carotid plaques compared with echo rich plaques predict a 3.1-fold risk of ipsilateral ischemic strokes (equivalent to 17% absolute risk increase) in previously symptomatic but not in previously asymptomatic patients.

Correlation of MRA and Colour Doppler-

For Ipsilateral side-

Ipsilateral Side			
Doppler	**MRA**		**Total**
	Normal	**Occlusion**	
Normal	17	11	28
	54.8%	26.2%	38.4%
Occlusion	14	31	45
	45.2%	73.8%	61.6%
Total	31	42	73
	100.0%	100.0%	100.0%
Kapp Statistic - 0.265; p<0.05 (Agreement-65.7%)			

On comparing the MRA and Doppler findings on the ipsilateral side, we observed that out of 42 cases showing occlusion on MRA, 31 (73.8%) were also showing occlusion on Doppler, while out of 31 patients showing normal results on MRA, 17 (54.8%) were also normal on Doppler. The agreement between the two modalities for the ipsilateral side was 65.7% (kappa value-0.265;$p<0.05$).

For Contralateral side-

C/L Side			
Doppler	**MRA**		**Total**
	Normal	**Occlusion**	
Normal	24	6	30
	50.0%	24.0%	41.1%
Occlusion	24	19	43
	50.0%	76.0%	58.9%
Total	48	25	73
	100.0%	100.0%	100.0%
Kapp Statistic - 0.244; p<0.05 (Agreement-58.9%)			

On comparing the MRA and Doppler findings on the contralateral side, we observed that out of 25 cases showing occlusion on MRA, 19 (76.0%) were also showing occlusion on Doppler, while out of 48 patients showing normal results on MRA, 24(50.0%) were also normal on Doppler. The agreement between the two modalities for the contralateral side was 58.9% (kappa value-0.244;p<0.05).

Ipsilateral **Side**				
Doppler	**MRA**			**Total**
	Normal	**<50%**	**>50%**	
Normal	16	8	4	28
	51.6%	33.3%	22.2%	38.4%
<50%	13	9	2	24
	41.9%	37.5%	11.1%	32.9%
>50%	2	7	12	21
	6.5%	29.2%	66.7%	28.8%

Total	31	24	18	73
	100.0%	100.0%	100.0%	100.0%
Kapp Statistic - 0.25; p<0.05 (Agreement-50.6%)				

On comparing the MRA and Doppler findings on the ipsilateral side, we observed that out of 18 cases showing >50 % stenosis on MRA, 12 (66.7%) subjects showed >50 % stenosis on Doppler. Out of 24 patients showing <50 % stenosis on MRA, 9 (37.5%) were also showing <50 % stenosis on Doppler. And out of 31 cases showing normal results on MRA, 16(51.6%) were also normal on Doppler. The agreement between the two modalities for the ipsilateral side was 50.6% (kappa value-0.25; p<0.05).

C/L Side				
	MRA			**Total**
	Normal	**<50%**	**>50%**	
Normal	25	5	0	30
	52.1%	26.3%	0.0%	41.1%
<50%	18	10	0	28
	37.5%	52.6%	0.0%	38.4%
>50%	5	4	6	15
	10.4%	21.1%	100.0%	20.5%
Total	48	19	6	73
	100.0%	100.0%	100.0%	100.0%
Kapp Statistic - 0.262; p<0.05 (Agreement-56.16%)				

On comparing the MRA and Doppler findings on the contralateral side, we observed that out of 6 cases showing >50 % stenosis on MRA, all 6 (100%) were also showing >50 % stenosis on Doppler. Out of 19 patients showing <50 % stenosis on MRA, 10 (52.6%) were also showing <50 % stenosis on Doppler. And out of 48 cases showing normal results on MRA, 25(52.1%) were also normal on Doppler. The agreement between the two modalities for the contralateral side was 56.1% (kappa value-0.262; $p<0.05$).

CONCLUSION

- In our study of 73 patients with acute infarct, we tried to evaluate the role of MRA and Colour Doppler to evaluate carotid artery pathology.
- A majority of the patients were males in their fifth to seventh decades of life.

- Hypertension and diabetes mellitus are risk factors for carotid artery atherosclerotic pathology.
- The most typical presenting symptom in patients with stroke was weakness followed by speech abnormality.
- There is more likelihood of developing stroke with ipsilateralecholeucent plaque in ICA than with calcified plaque.
- Echoleucent plaques in contralateral ICA are more commonly associated with stroke than calcified plaque.
- Doppler and MRA are non-invasive, safe, and relatively inexpensive techniques and are the techniques of choice for evaluating carotid pathology.
- Doppler ultrasound helps us to characterize the plaque causing stenosis in carotid arteries.
- Good correlation is noted between MRA and Colour Doppler in evaluating carotid artery pathology on the ipsilateral and contralateral side in patients with stroke.

SUMMARY

The study aims to estimate and correlate the role of Color Doppler and MRA in patients of Cerebrovascular accidents. All 73 patients with a definitive history of acute infarct were studied,

- Out of the total 73 patients included, a maximum of 42 (58%) were in the age group of 51-70 years followed by >70 years age group which included 23 (31%). Minimum patients, i.e., 8 (11%), were over the age group of <50. The mean age was 59.5 (range 30-89 years).
- Out of the 73 patients studied, 47 (64.4%) were male, and 26 (35.6%) were female patients.
- Out of 73 patients, 52% were Diabetic, and 59% were Hypertensive, suggesting a stronger association of hypertension with atherosclerotic pathology of carotid arteries.

MRA in the evaluation of carotid artery pathology-

- Out of a total of 73 patients with stroke, 75% of patients had either normal or non-significant (<50%) stenosis on the same side Internal Carotid Artery on MRA, While 25 % of patients had significant stenosis on the same side Internal Carotid Artery.
- Out of a total of 73 patients with stroke, 92% patients had either normal or non-significant (<50%) stenosis on the contralateral side Internal Carotid Artery on MRA, While 8 % of patients had significant stenosis on the contralateral side Internal Carotid Artery.

Ultrasound in the evaluation of carotid artery pathology-

- Out of a total of 73 patients with stroke, On Doppler greyscale imaging, 27 (37%) had echoleucent plaque in ICA on the ipsilateral side, and 18 (24.6%) patients had a calcified plaque in ICA on the ipsilateral side.
- Out of a total of 73 patients with stroke, 28 (38.4%) had echoleucent plaque in ICA on the contralateral side, and 15 (20.5%) patients had a calcified plaque in ICA on the contralateral side on Greyscale ultrasound imaging.
- On color Doppler imaging, 38.3% of patients had normal ipsilateral side Internal Carotid Artery results. 6.8% of patients reveal total and near-total

occlusion of ipsilateral side Internal Carotid Artery. 32.9% patients had <50% stenosis, 12.3 % patients had 50-69% stenosis and 2.7 % patients had >70% stenosis of ipsilateral side Internal Carotid Artery.

- On color Doppler imaging, 41.2 patients had normal results in contralateral side Internal Carotid Artery. 2.7 % and 1.4% of patients reveal total and near-total occlusion of contralateral side Internal Carotid Artery respectively. 38.3% patients had <50% stenosis, 8.2 % patients had 50-69% stenosis and 8.2 % patients had >70% stenosis of contralateral side Internal Carotid Artery.

Correlation between MRA and Color Doppler-

- On comparing the MRA and Doppler findings on the ipsilateral side, we observed that out of 18 cases showing >50 % stenosis on MRA, 12 (66.7%) were also showing >50 % stenosis on Doppler. Out of 24 cases showing <50 % stenosis on MRA, 9 (37.5%) showed <50 % stenosis on Doppler. And out of 31 cases showing normal results on MRA, 16(51.6%) were also normal on Doppler. The agreement between the two modalities for the ipsilateral side was 50.6% (kappa value-0.25;p<0.05)
- On comparing the MRA and Doppler findings on the contralateral side, we observed that out of 6 cases showing >50 % stenosis on MRA, all 6 (100%) were also showing >50 % stenosis on Doppler. Out of 19 cases showing <50 % stenosis on MRA, 10 (52.6%) showed <50 % stenosis on Doppler. And out of 48 cases showing normal results on MRA, 25(52.1%) were also normal on Doppler. The agreement between the two modalities for the contralateral side was 56.1% (kappa value-0.262;p<0.05)

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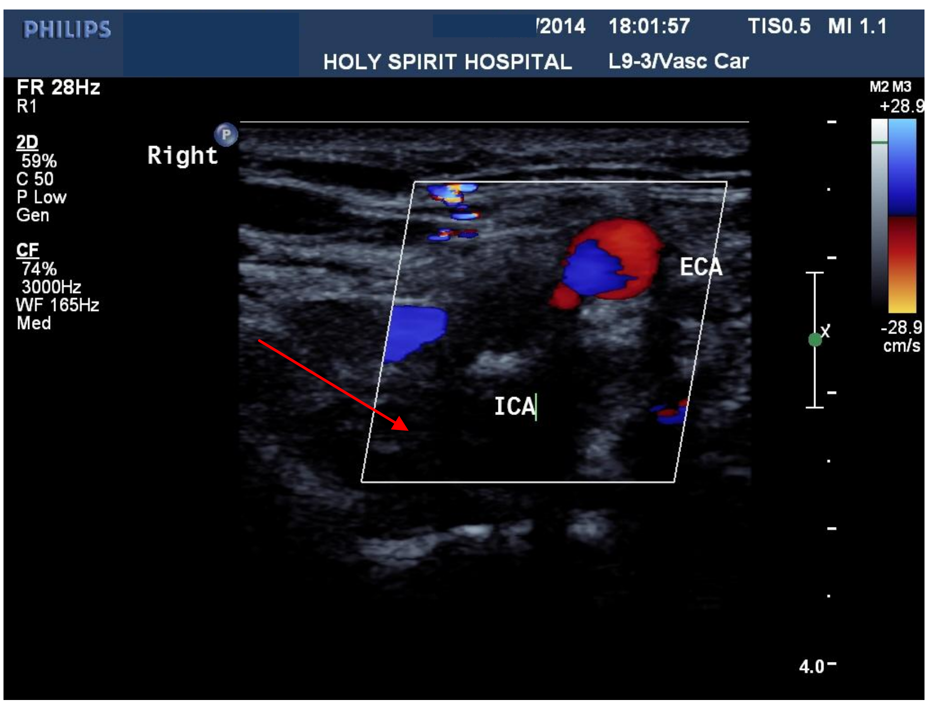
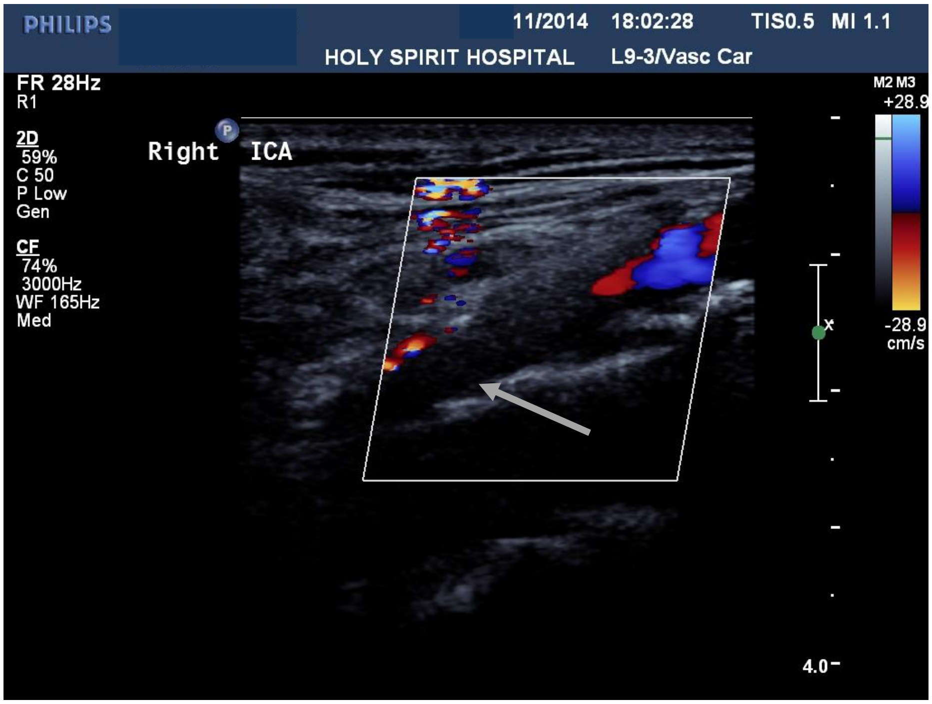
ANNEXURE -1 PHOTOGRAPHS

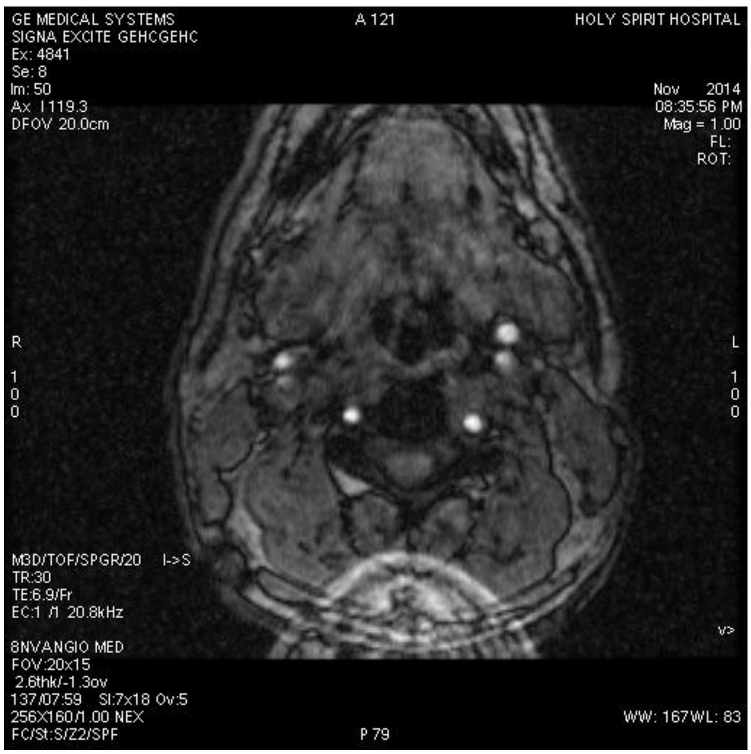
CORRELATION OF CAROTID DOPPLER AND MRA FOR COMPLETE OCCLUSION IN INTERNAL CAROTID ARTERY



Colour Doppler showing complete occlusion of the Right Internal Carotid Artery



No colour flow in the Right Internal carotid artery

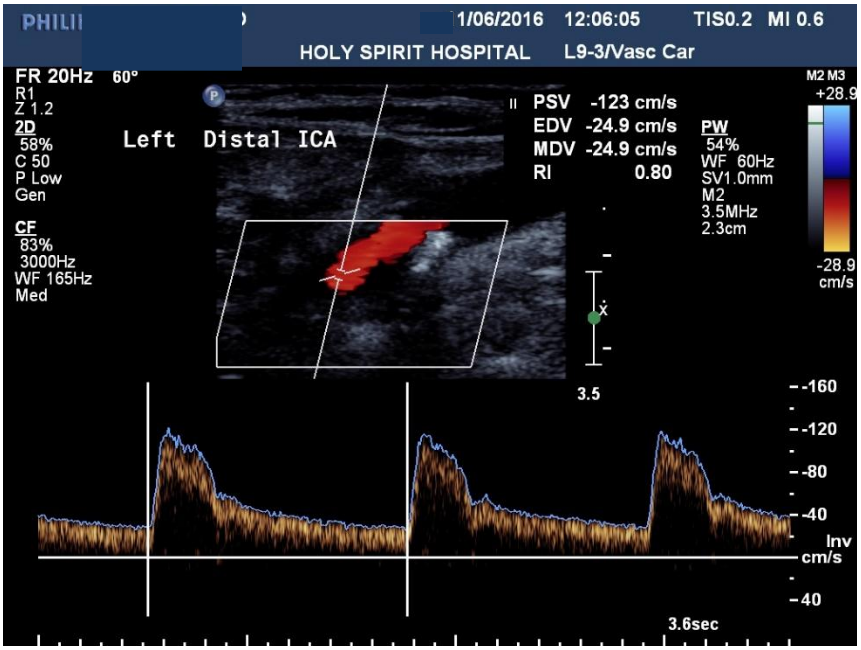


Axial MRA showing non-visualisation of the Right Internal carotid artery at origin

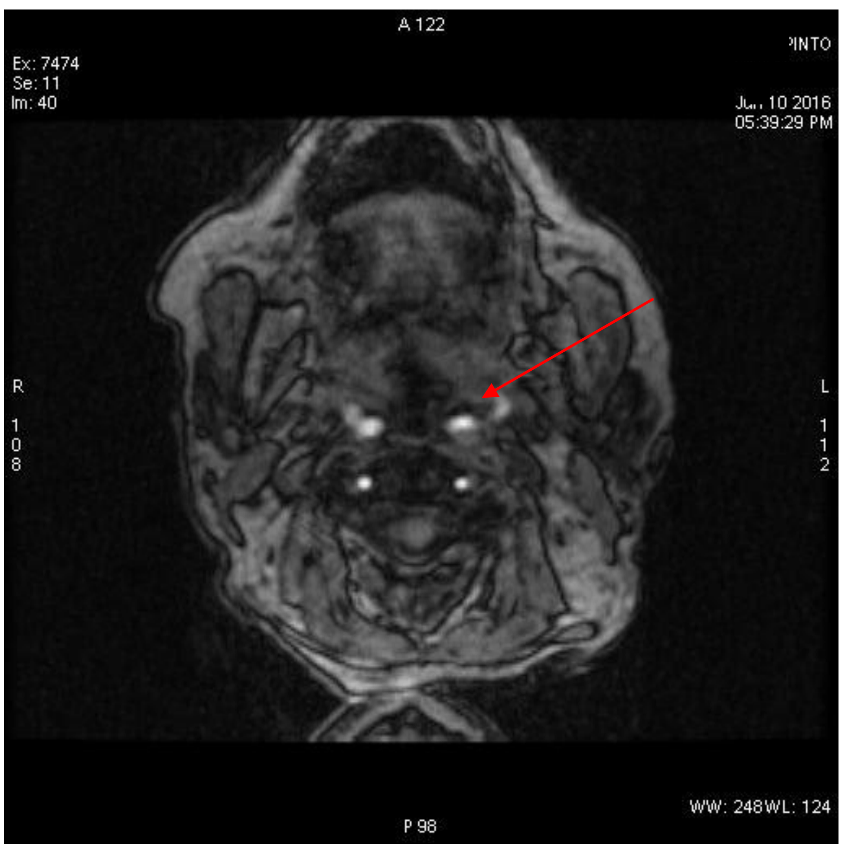
Coronal view of MRA showing non visualisation of the Right ICA

CORRELATION FOR <50% OCCLUSION

Colour Doppler showing fibro calcific plaque in proximal ICA. PSV-91.1



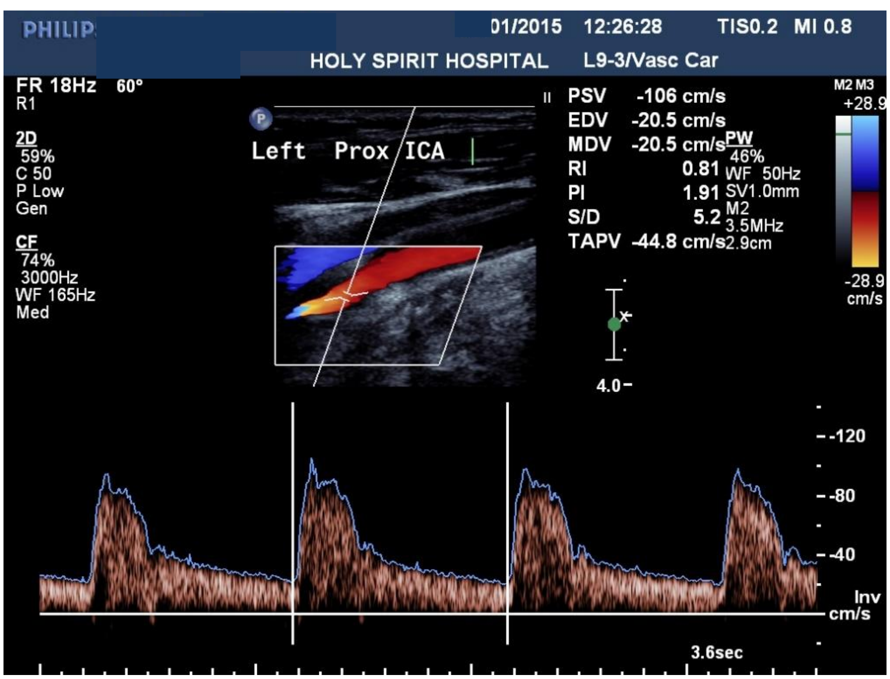
Colour Doppler showing PSV- 123 distal to plaque



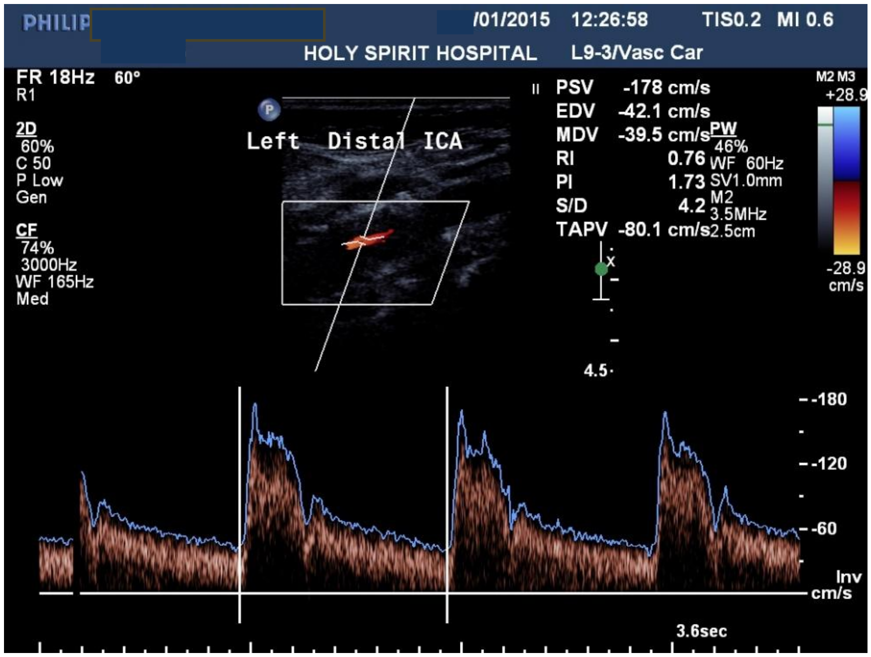
Axial MRA scans showing moderate narrowing in the Left ICA at origin

Coronal reformat images showing narrowing in the Left ICA at origin

CORRELATION FOR 50-69 % STENOSIS



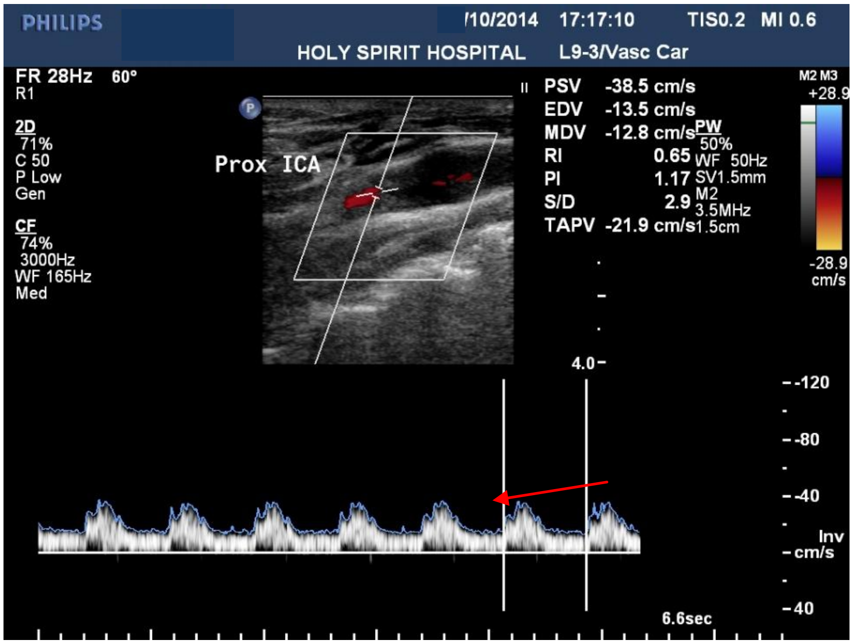
Colour Doppler showing calcified plaque in the proximal ICA. PSV-106



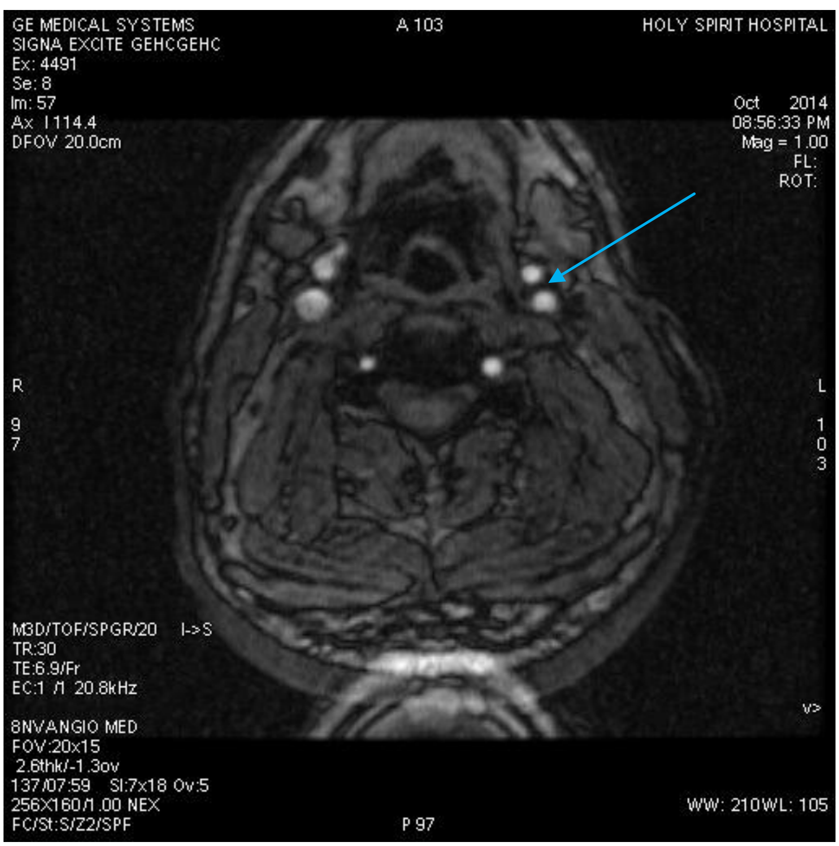
Colour Doppler showing PSV of 178 distal to the plaque.50-69% stenosis

Coronal MRA showing moderate narrowing at Left ICA origin.

Correlation for Non-significant stenosis

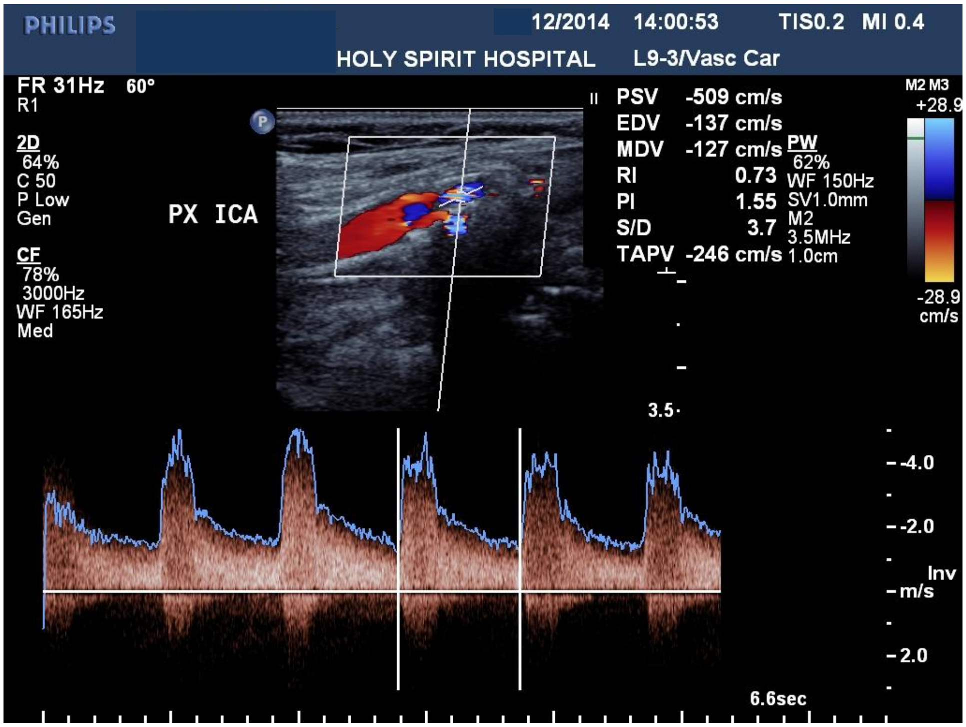


Colour Doppler showing an echogenic plaque not causing significant stenosis

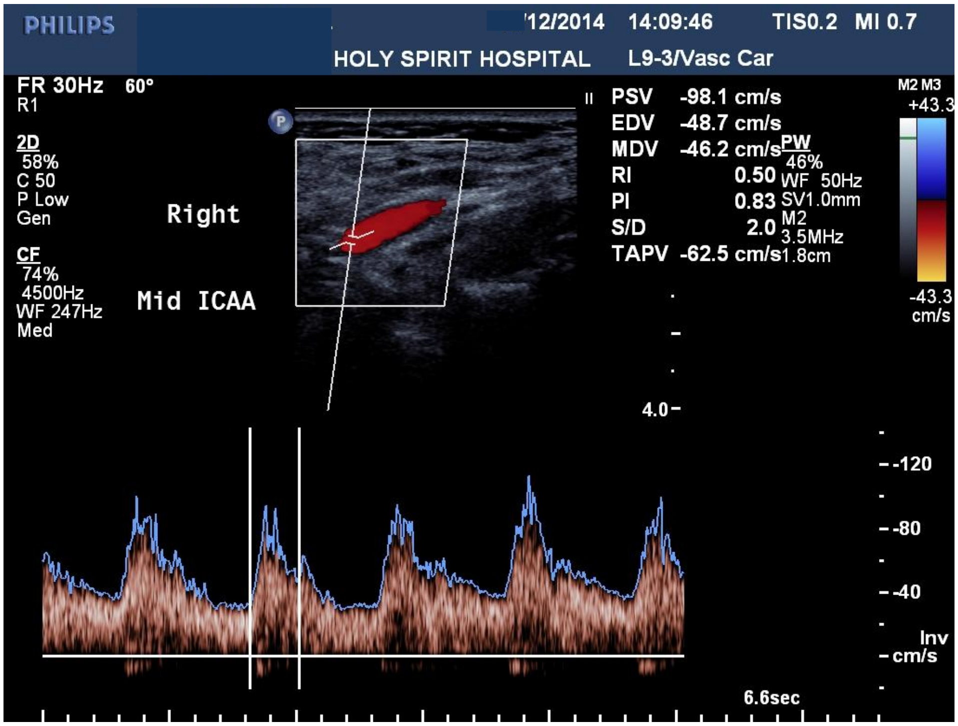


Axial MRA Image revealing moderate narrowing in left ICA.

CORRELATION OF >90% OCCLUSION



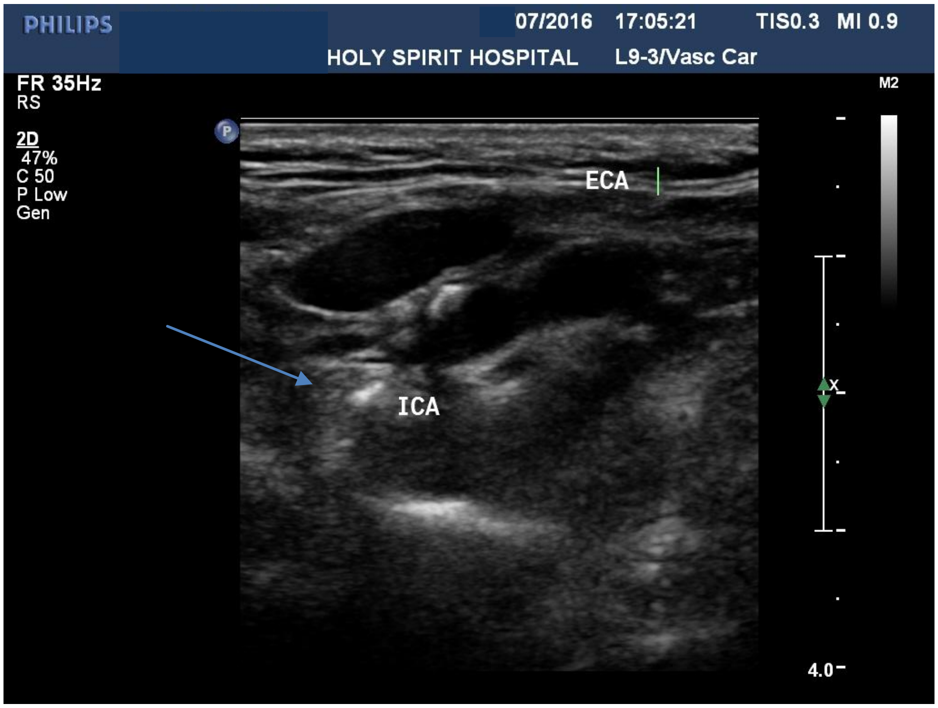
Colour Doppler showing PSV >425 in proximal ICA



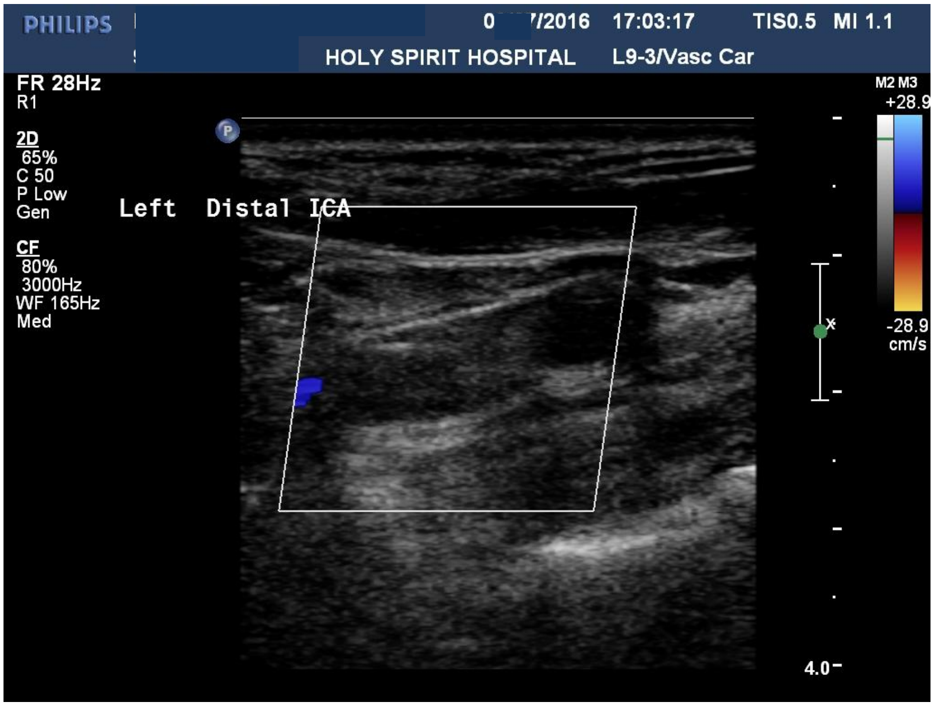
PSV OF 98.1 in mid ICA

Coronal MRA image showing severe narrowing in proximal ICA

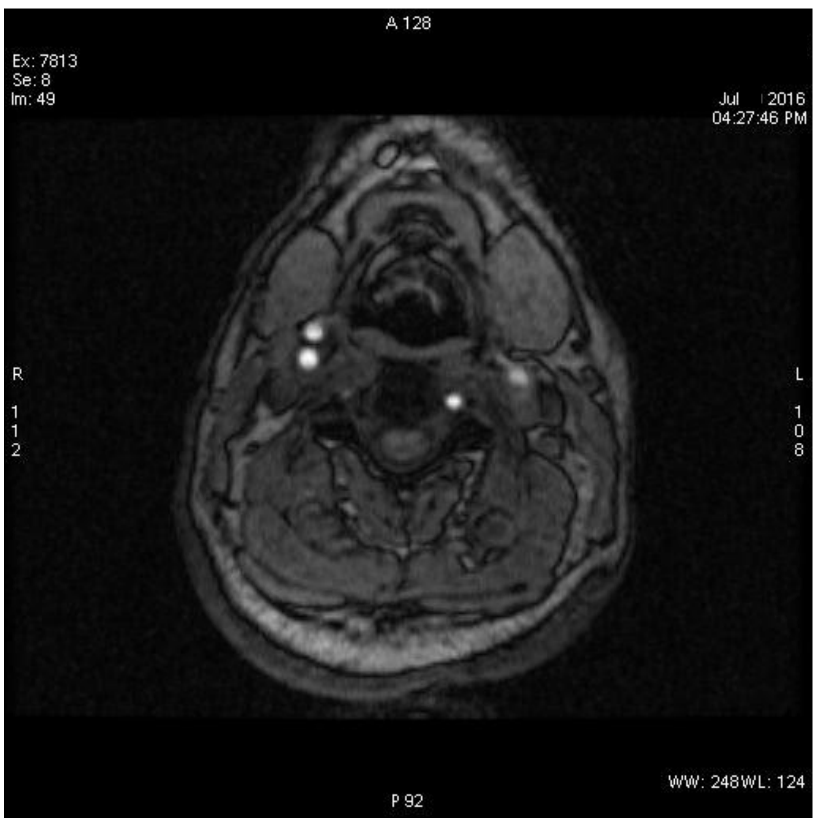
CORRELATION FOR COMPLETE STENOSIS



Calcified plaque at the origin of Left ICA



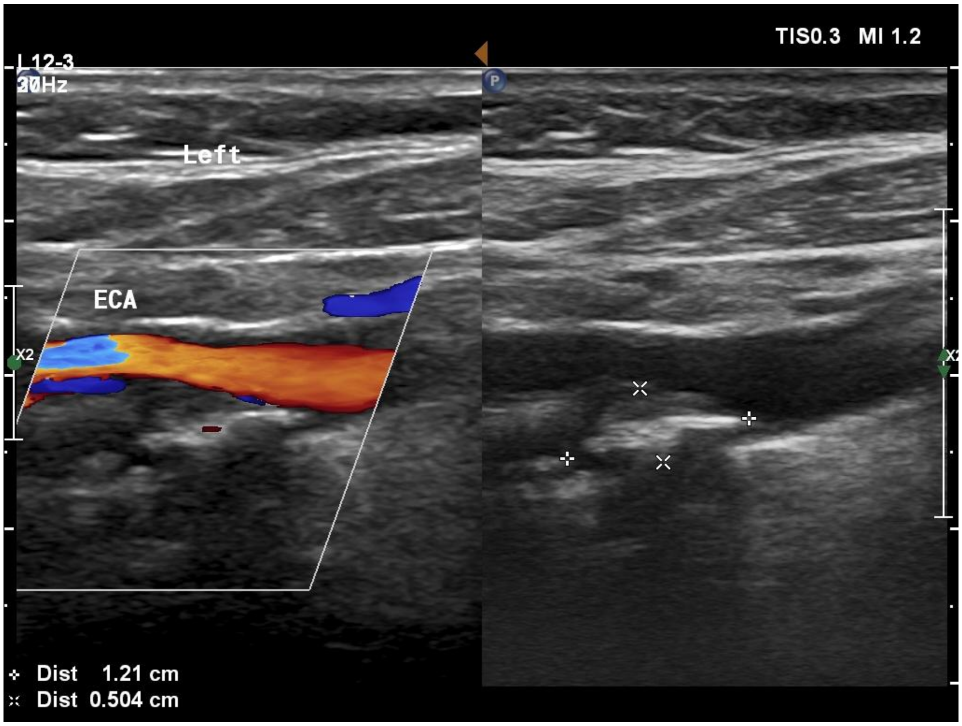
Doppler image showing Thrombosis of left Distal ICA with no colour flow



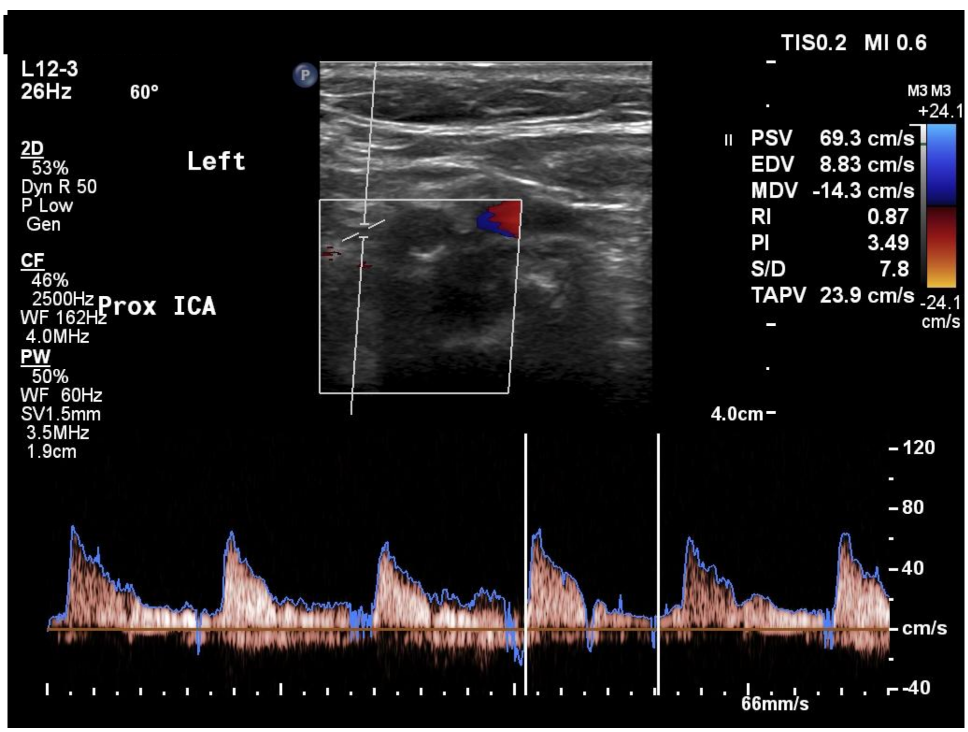
Axial MRA showing Normal Right ICA with non-visualisation of Left ICA suggestive of complete thrombosis

Coronal image showing normal Right ICA with non-visualisation of the Left ICA

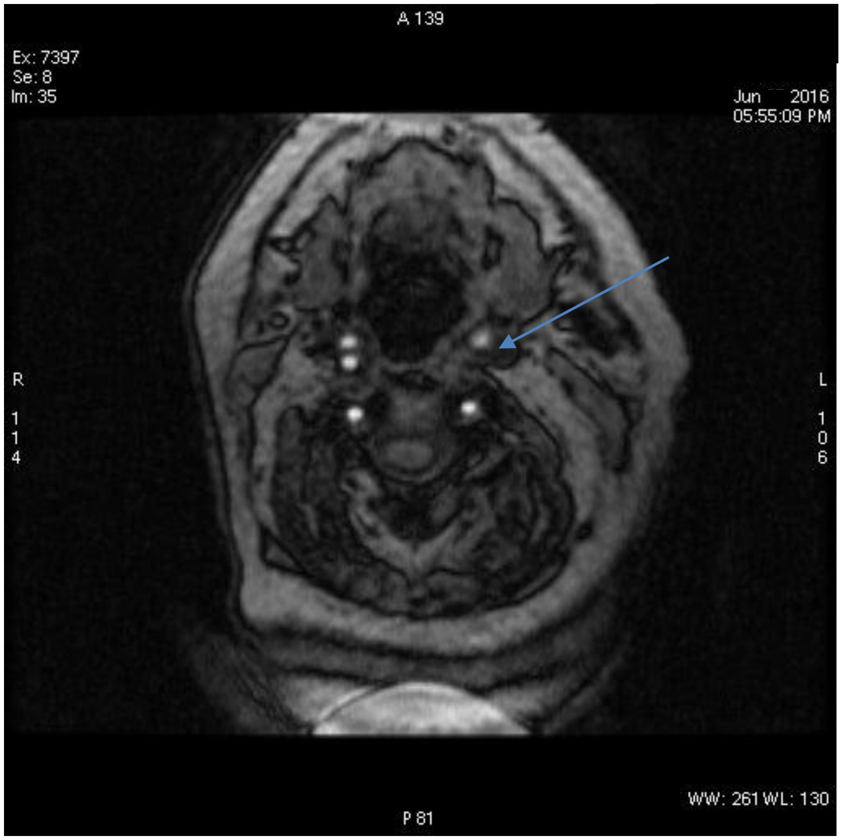
CORRELATION FOR COMPLETE OCCLUSION



Doppler showing calcified plaque in the Left carotid bulb

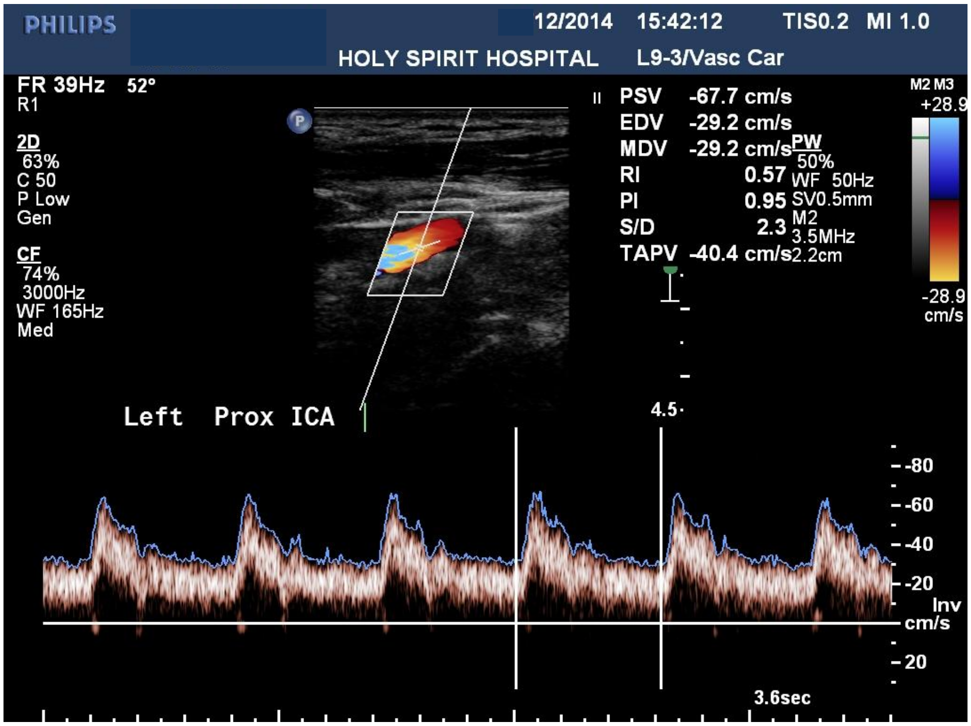


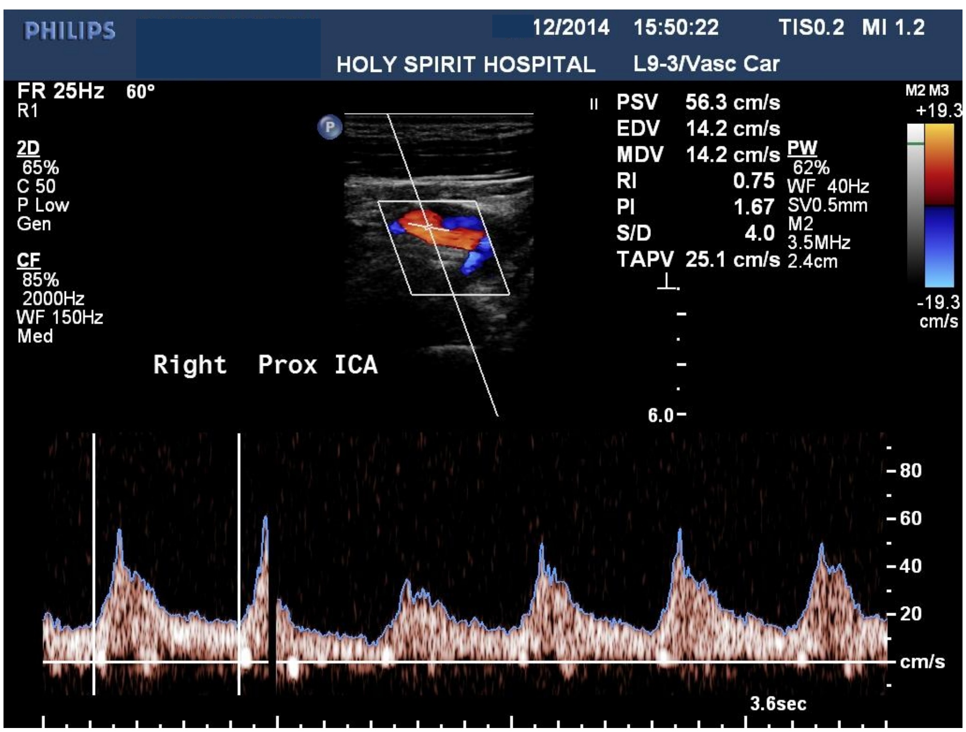
Left proximal ICA with Non visualisation of distal ICA



Axial MRA showing non-visualisation of the Left ICA

CORRELATION OF NORMAL FINDING IN MRA AND DOPPLER

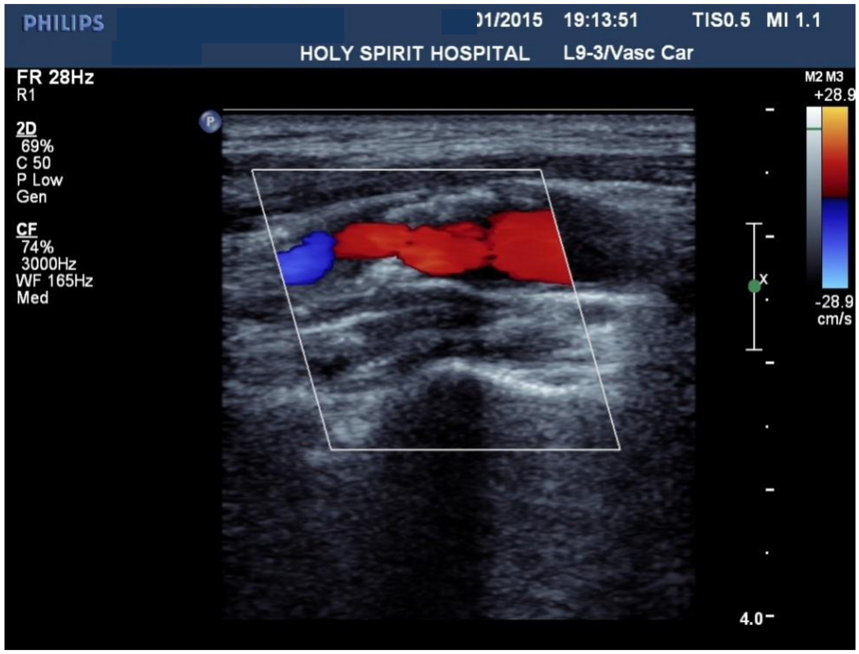




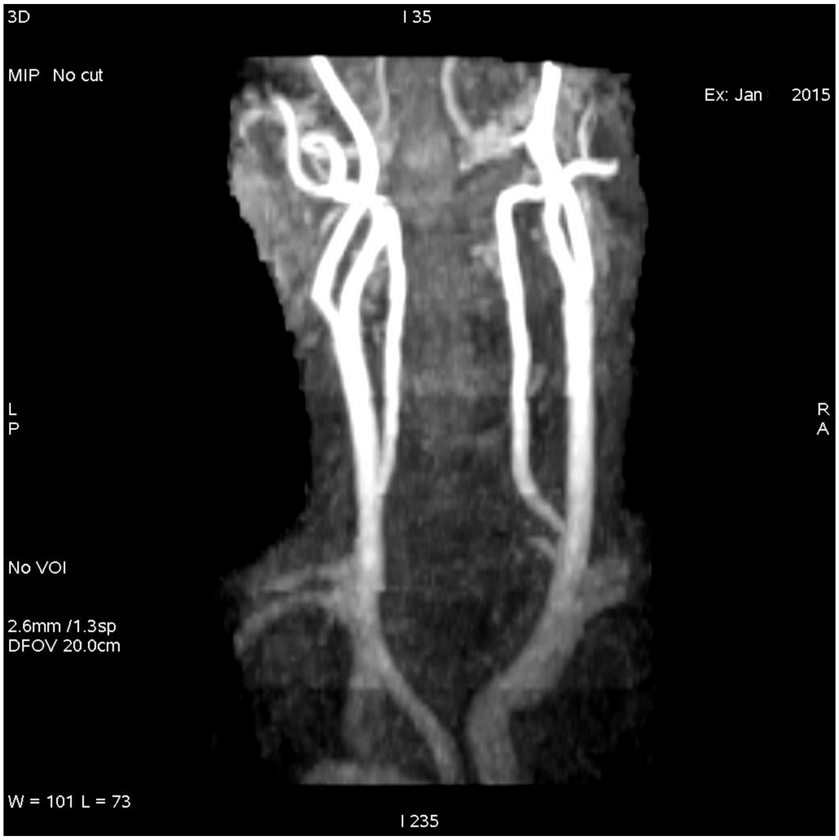
Normal Doppler study

Coronal image showing normal MRA

CORRELATION FOR <50% STENOSIS

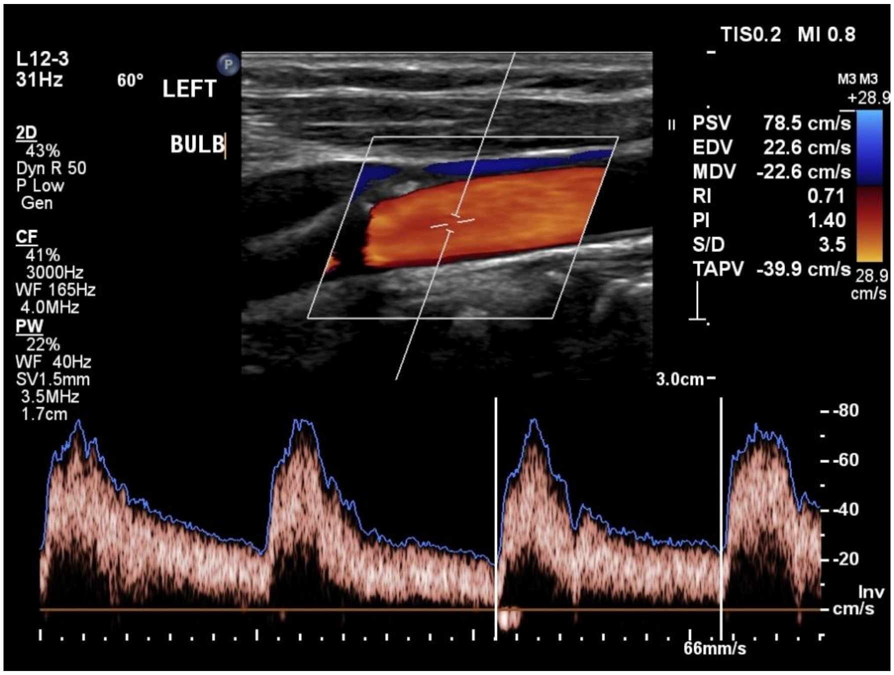


Colour Doppler showing calcified plaque causing <50% stenosis

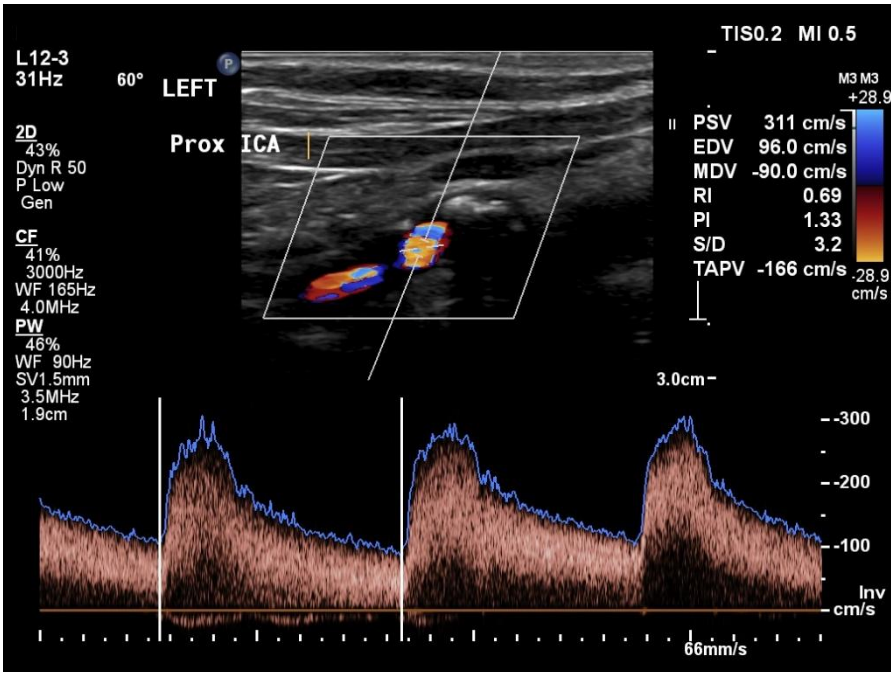


Normal MRA

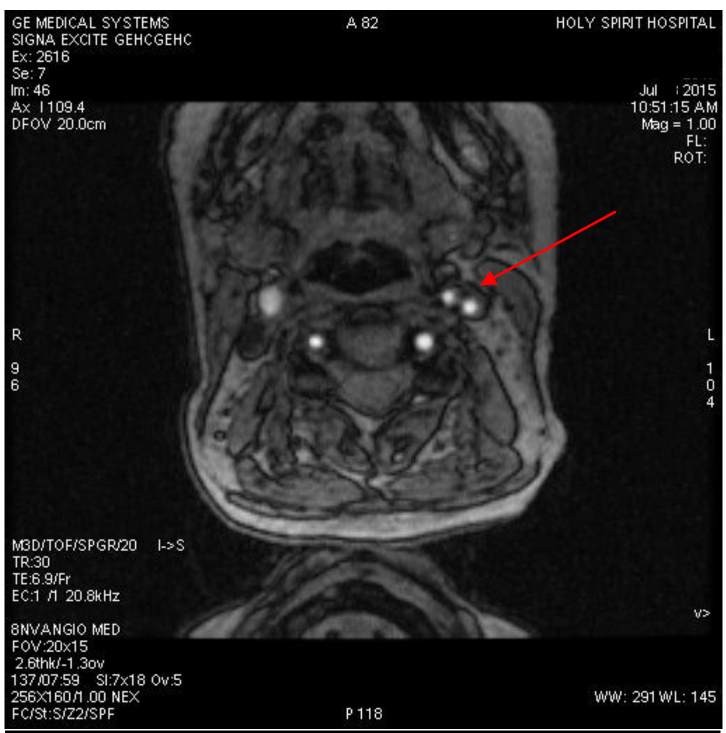
CORRELATION OF NEAR COMPLETE OCCLUSION



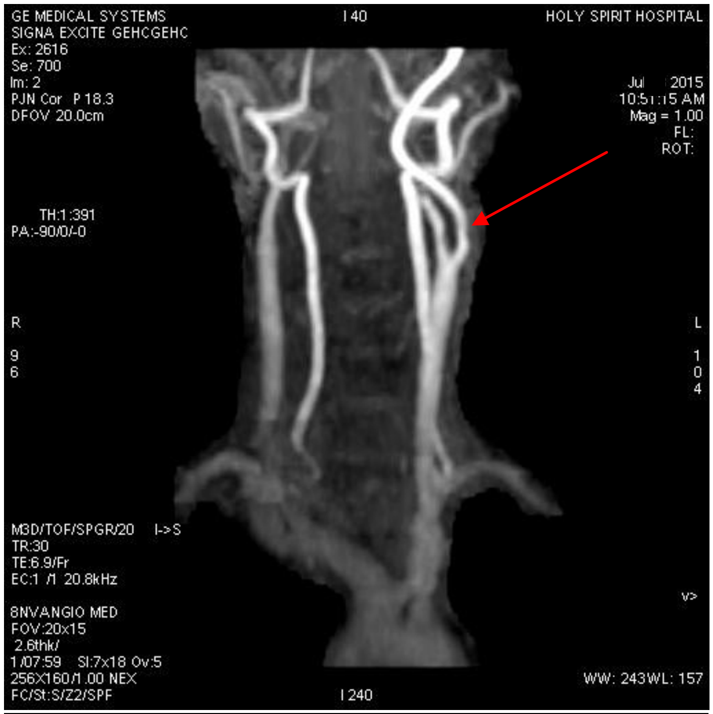
Colour Doppler showing PSV 78.5 in the Left carotid bulb



Doppler showing PSV 311 in proximal ICA suggestive of subtotal occlusion <95%



Axial MRA showing mild narrowing of the Left ICA



Coronal reformat showing mild narrowing in the Left ICA

ANNEXURE-2 PROFORMA

CASE RECORD FORM

Name: Age:

Sex:

ADDRESS:

O.P.D.NO.: I.P.O. NO/WARD NO:

DT OF ADMISSION: DATE OF DISCHARGE:

Clinical History:

Past history of:

Diabetes mellitus

Hypertension

SYSTEMIC EXAMINATION:

Respiratory system:

Cardiovascular system:

Per abdomen

CNS EXAMINATION

1. Higher functions:

Consciousness

Memory

Speech

2. Motor response:

Tone

Reflexes

3. Sensory system:

4. Power

Ultrasonography finding

Grey scale evaluation

- Echogenic plaque
- Calcified plaque

Colour Doppler evaluation

- Peak systolic velocity proximal to plaque
- Peak systolic velocity at the level of plaque
- Peak systolic velocity distal to plaque

Distribution of stenosis on Doppler

- Normal
- <50 % stenosis
- 51-69% stenosis
- >70 % stenosis but less than near complete occlusion
- Near complete occlusion

- Complete occlusion

MRA findings

- Normal
- Non-significant stenosis <50 %
- Significant stenosis >50 %

FINAL OUTCOME: **-** By correlation with findings on

a) Colour Doppler

b) MRA