



Comparison of the findings of gray scale sonography, colour Doppler and CT angiography in evaluation of Extracranial Carotid vascular stenosis

Authors

**Dr Arnav Shandil¹, Dr Nikita Verma², Dr Dinesh Sood³, Dr Narvir S.Chauhan⁴,
Dr Amit Bhardwaj⁵, Dr Raman Chauhan⁶, Dr Ambuj Shandil⁷**

¹MD Radiodiagnosis, Civil hospital Theog, Shimla, H.P. (India)

²Senior Resident, Deptt. of Radiodiagnosis, Pgimer Chandigarh, (India)

³Prof and HOD Department of Radiodiagnosis, Dr. RPGMC Kangra at Tanda, H.P (India)

⁴Associate Professor Department of Radiodiagnosis, Dr. RPGMC Kangra at Tanda , H.P (India)

⁵Profesor, Department of Neurology Dr. RPGMC Kangra at Tanda H.P (India)

⁶Astt.Prof, Department of Community Medicine, Dr. RPGMC Kangra at Tanda H.P (India)

⁷MD, Civil hospital Theog, Shimla, H.P.(India)

Department of Radiodiagnosis, Dr. RPGMC Kangra at Tanda

Corresponding Author

Dr Ambuj Shandil

Civil Hospital Theog, Shimla, H.P. (India)

Abstract

Background and Objectives: *Cerebrovascular disease with stroke in particular is one of the most important causes of death and the greatest cause of disability all over the world. Stenosis degree is considered the leading parameter in the choice of therapeutic options but factors other than the degree of stenosis are also important in assessing whether a carotid lesion will remain clinically silent. Ulcerated plaques are associated with a higher risk of embolism and occlusion, producing ischemic neurologic events.*

The purpose of this study was to evaluate the diagnostic efficacy of multidetector row CT angiography (MDCTA) and US-ECD in the evaluation of carotid plaque complicated by ulceration with MDCT being taken as reference standard

Methods: *Total of 30 patients with symptoms pertaining to cerebrovascular disease were selected over a period of one year and plaque ulceration was evaluated and compared by both Doppler ultrasound and CT angiography.*

Results: *We concluded that CDUS is inferior w.r.t CTA to assess plaque morphology and especially in identification of ulceration. This can be ascribed, in part, to the fact that acoustic shadowing from calcification obscures ulcers, and the sonography probe may not be parallel to the axis of the vessel in the region of the ulceration. Sonography is limited by its accuracy and reproducibility, especially when the lesion is calcified. The recent development of 3D US and the use of CEUS may help improve the detection of carotid ulceration.*

Keywords: *Plaque ulceration, carotid vascular disease, cerebrovascular disease, Doppler ultrasound, CT angiography.*

Introduction

Cerebrovascular disease with stroke in particular is one of the most important causes of death and the greatest cause of disability all over the world. Approximately 20-30% of all the infarcts can be related to carotid artery stenosis^{1,2}. Lesions of the extra-cranial carotid arteries, particularly the internal carotid artery near the bifurcation, are implicated in majority of cases of cerebrovascular disorders and are the major single etiological factor for stroke as opposed to intracranial occlusive diseases and cardio embolisation³. This location is readily amenable to examination by sonography as well as surgical intervention.

The evaluation of carotid vascular disease and stenosis has been plagued by a plethora of studies. The 3 major studies- North American Symptomatic Carotid Endarterectomy Trial (NASCET)⁴ and The European Symptomatic Carotid Trial (ESCT)⁵ and Asymptomatic Carotid Atherosclerosis Group (ACAS)⁶ have provided cut-off values for the degree of stenosis indicating possible benefits of carotid endarterectomy (CEA). In particular the NASCET proved the benefits of CEA in patients with symptomatic high-grade (70–99%) stenosis. Overall, the prevalence of significant (>50%) stenotic disease in symptomatic patients is stated as being in the range of 18%–20%^{7,8}.

Potential of MDCT in evaluation of carotid plaques has been well documented, with the advantage of being fast and having a high temporal and spatial resolution. This technique is considered by many authors as a reference standard in diagnosing the pathology of carotid artery like grading of internal carotid artery stenosis and occlusion, convincingly showing the distal flow in apparent totally occluded vessel, diagnosing tandem lesions and studying intracranial circulation in the shortest time. The limitations include ionising radiation dose and ballooning artefacts of heavy circulation.

Carotid duplex sonography (CDUS) is a non-invasive means by which to estimate the degree of cervical carotid stenosis and is often the initial screening method of choice for carotid pathology prior to evaluation by MDCT owing to its low cost, high accuracy easy availability, absence of ionising radiation and lack of contrast nephrotoxicity. It also is helpful in defining the normal and mild stenosis group who would need no aggressive treatment. Disadvantages being that it is often operator dependent and is inaccurate in defining the extremely narrowed lumen group separate from total occlusion and can even miss the tandem plaques.

In low-income and middle income countries like India, cerebrovascular diseases are steadily increasing, with the poor are now becoming increasingly affected by stroke, because of both changing population exposures to risk factors and most tragically, non-affordability for the high cost of stroke care.

Material and Methods

This was a prospective observational study for a period of one year from Jan 2016- Jan 2017. Consisting of total of 30 patients or the patients with symptoms pertaining to cerebrovascular disease Duplex sonography and CTA were done. The data so obtained was analysed and the findings of gray scale ultrasonography and Doppler ultrasonography parameters with CT angiographic findings was compared for stenosis. Doppler measurements was obtained in the stenotic portion of the carotid lumen and parameters measured included:- Peak systolic velocity (PSV), Peak end diastolic velocity (EDV), Systolic and diastolic ratios (table1)

Table 1: Diagnostic Criteria for Carotid Ultrasound Examinations⁹

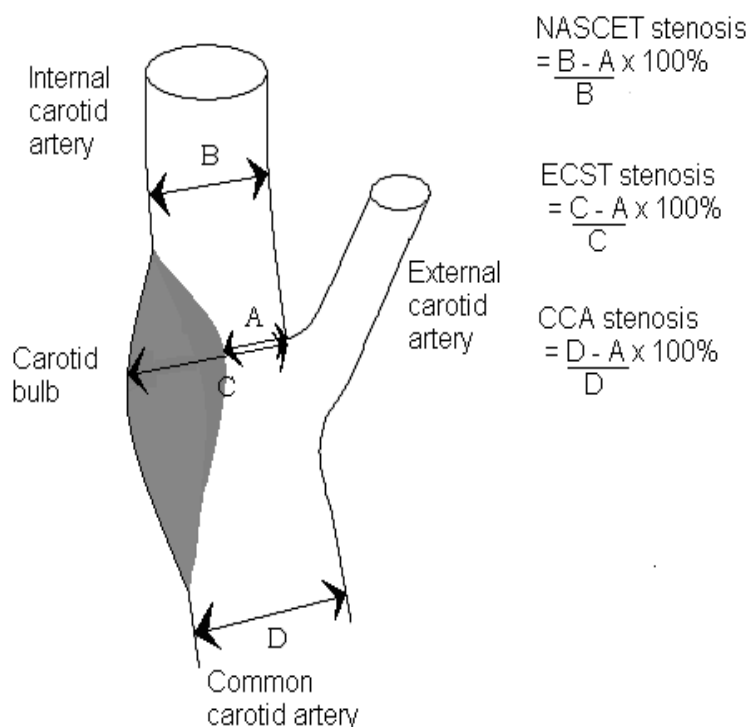
	ICA PSV	PLAQUE	ICA/CCA PSV RATIO	ICA EDV
Normal	<125 cm/sec	none	<2.0	<40 cm/sec
<50%	<125 cm/sec	<50% diameter reduction	<2.0	<40 cm/sec
50% - 69%	125-230 cm/sec	≥50% diameter reduction	2.0-4.0	40-100 cm/sec
≥ 70% to near occlusion	>230 cm/sec	≥50% diameter reduction	>4.0	>100 cm/sec
Near occlusion	low	Visible	Variable	Variable
Total occlusion	undetectable	Visible, no detectable lumen	Not applicable	Not applicable

ICA- internal carotid artery; CCA - Common Carotid Artery; PSV- Peak Systolic velocity; EDV- End Diastolic Velocity

Measurements to quantify the degree of stenosis were made by selection of a plane perpendicular

to the lumen centre line using the NASCET criteria.(figure.1)

Figure 1 Showing various methods of measuring the stenosis in carotid arteries



For quantifying the degree of stenosis our criteria derived to correspond to the NASCET angiographic determinations for stenosis as the ECST method for grading carotid artery stenosis tends to give a more severe assessment of narrowing than the NASCET technique.

Observations and Results

Total of 180 arteries (60 CCA+ 60 ICA+ 60 ECA) were analyzed in the course of study comprising of extra-cranial vessels on both sides of neck. Estimation of the degree of ICA stenosis on DUS was done according to the PSV. On CTA the estimation of the degree of stenosis was estimated

on axial images according to NASCET - criteria. The degree of ICA stenosis was expressed in percent. The severity of stenosis was classified into mild stenosis (<50%), moderate stenosis (50 - 69%) and severe stenosis (≥ 70 %).

All statistical analysis was done in SPSS 21. The interpretation of the kappa coefficient and ICC was done according to the one proposed by Landis and Kock¹⁰.

**Comparative Analysis of Stenosis in CDUS with CT Angiography
Common Carotid artery (table 2)**

		Stenosis By CTA				Total
		1-49%	50-69%	Severe Stenosis	Total Occlusion	
Stenosis by CDUS	1-49%	44	0	0	0	44
	50-69%	2	6	2	0	10
	Severe stenosis	0	0	0	2	2
	Total occlusion	0	0	0	4	4
Total		46	6	2	6	60

Table 2- Comparison of the degree of CCA stenosis with CT angiography and colour Doppler US.

- We observed that in Common carotid arteries, for grading of normal to mild stenosis there was perfect concordance between CDUS and CTA with Concordance rate of 100%. Indicating almost perfect agreement
- For moderate stenosis (50 -69%) concordance of 60 % was seen .If only luminal morphology

was used to grade stenosis in both CTA and CDUS concordance reaches 80% for detection of moderate stenosis

- Mismatched scans were mainly seen when colour Doppler US showed moderate degrees of stenosis (66.7% of all non concordant scans) (table 3)
- The observed agreement for grading of stenosis for CCA was substantial with kappa value of 0.76.

Table 3 Correlation of results of CT angiography and Doppler in grading degree of stenosis in mismatch group

		Stenosis By CT Angiography				
		Direct Correlation	Overestimated by one category	Overestimated by two categories	Underestimated by one category	Overestimated by two categories
Colour Doppler-US (%)	50-69%	6	2	0	2	0
	70 - 100%	0	2	0	0	0
Total occlusion		4	0	0	2	0

B. Internal Carotid artery

- Similarly in case of internal carotid arteries we found that all the 34 normal to mildly stenosed arteries showed a concordance of 100%
- For moderate stenosis, out of total of 6 arteries, 4 were correctly identified on CTA with a concordance rate of 67%.
- In grading severe stenosis concordance rate was 75%

- Completely occluded arteries showed a concordance of (100%)
- In the mismatch group(6 arteries) grading of stenosis was one category higher in 4 arteries (66.7% of non concordant scans) and two category higher in 2(33.3% of non concordant scans) arteries. (table 4)

The agreement for grading of stenosis was observed to be excellent with kappa value of 0.83

Table 4 Correlation of results of CT angiography and Doppler in grading degree of stenosis in mismatch group

		Stenosis By CT Angiography				
		Direct Correlation	Overestimated by one category	Overestimated by two categories	Underestimated by one category	Overestimated by two categories
Colour Doppler-US (%)	50-69%	4	2	0	2	0
	70 - 100%	6	0	2	0	0
Near total		0	2	0	0	0
Total occlusion		10	0	0	2	0

C. Total (CCA+ICA)

On comparing the correlation between the degree of stenosis in both ICA and CCA we found that

- All the 78 arteries showing grade 1 stenosis were correctly identified on CTA indicating perfect agreement (concordance 100%)
- For moderate stenosis concordance rate was 62%. If we further use only the degree of luminal narrowing to grade the stenosis the rate increased to 75%

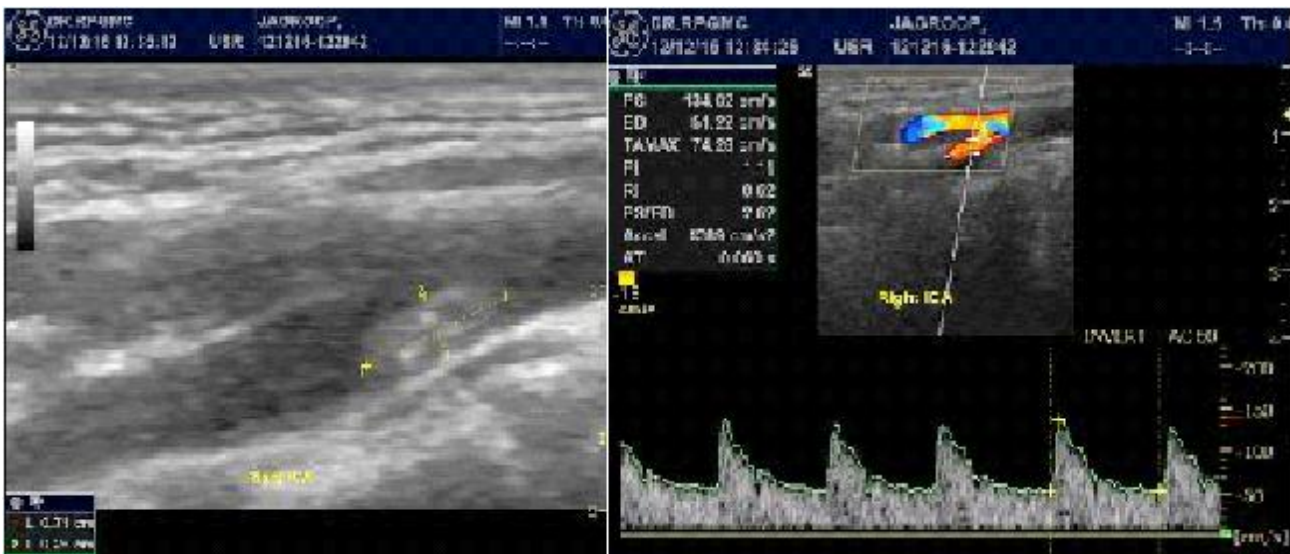
- For grading of severe stenosis the concordance rate was 75%
- Out of 20 arteries showing complete occlusion , concordance rate of 80% was observed and if we include near total and total occlusion as a single category the concordance rate increases to 90% (Table 5)
- Overall agreement between CDUS and CTA in grading of stenosis was found to be Excellent with kappa value of 0.81

Table 5 Comparison of the degree of carotid stenosis with CT angiography and colour Doppler US.

		CCA+ICA_grade				Total
		<50%	51- 69%	70- 99%	100%	
CCD+ICD_grade	<50%	78	0	0	0	78
	51 -69%	2	10	4	0	16
	70 -99%	0	0	6	2	8
	Near total Occlusion	0	0	0	4	4
	100%	0	0	0	14	14
Total		80	10	10	20	120

Illustrated Cases

Case 1 Showing Moderate stenosis: A 60 year old hypertensive male came to our department with complaints of Transient loss of vision right eye.

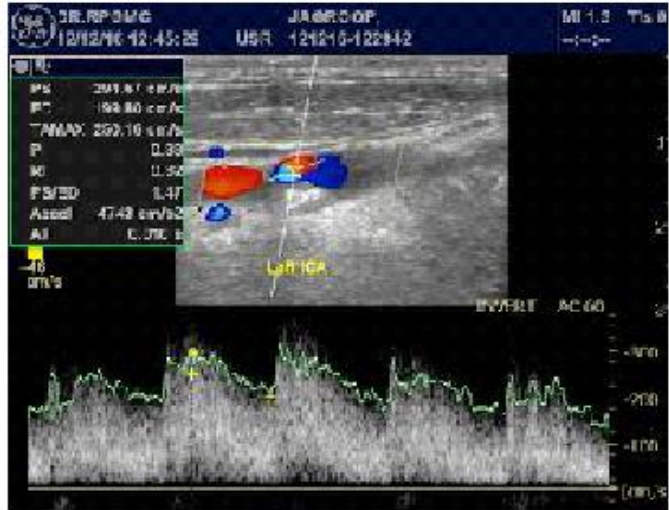


(a)

(b)

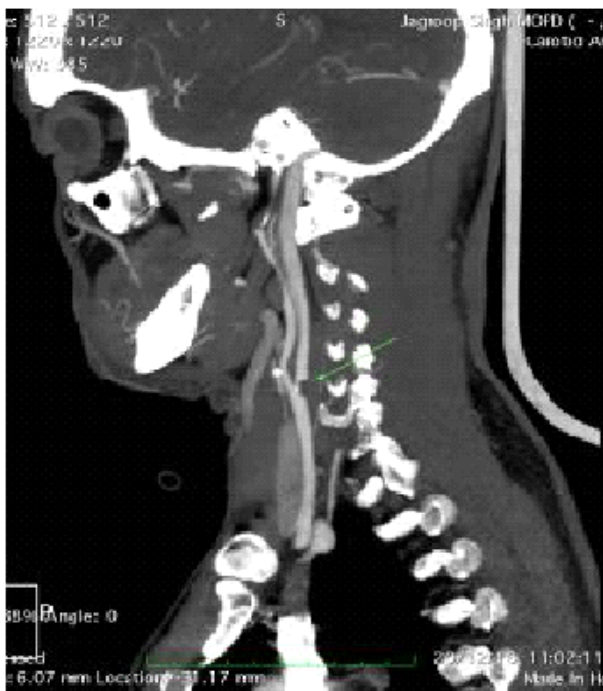


(c)

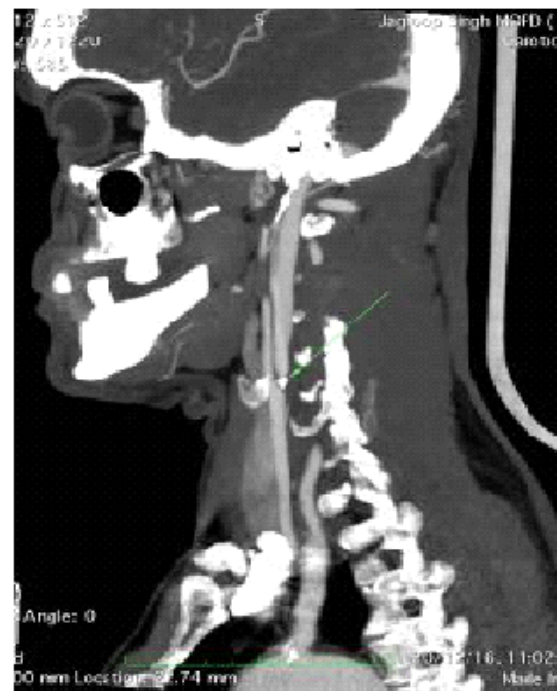


(d)

Images Case : Coronal oblique gray scale and corresponding colour doppler pulse waveform images (a and b) of right ICA shows an echogenic plaque with foci of calcification measuring 0.7 by 0.2 cms (a) at right proximal ICA showing PSV of 134 cm/s (b) suggestive of mild stenosis. Oblique coronal gray scale and colour doppler pulse waveform images (c and d) of left ICA shows a calcified plaque at left proximal ICA measuring 0.6 by 0.4 cm (c) causing severe stenosis of left ICA with PSV of 294 cm/s (d).



(a)



(b)

Images Case: Right and left sagittal (a ,b) MIP images of the same patient shows a softplaque (green arrow) in right proximal ICA (a) causing its moderate stenosis and a calcified plaque (green arrow) in left proximal ICA (b) causing its severe stenosis .

Discussion

Cerebrovascular disease or stroke is becoming a significant health problem and is on a rise with stroke in fact, when considered separately from other cardiovascular diseases, ranks third among

all causes of severe disability and death after heart disease and cancer. Atherosclerotic narrowing at the carotid bifurcation¹¹ is often the inciting factor for ischemic cerebrovascular events

The role of vascular surgeon in the evaluation and treatment of patients with chronic arterial occlusive disease is evolving rapidly. The results of two landmark trials:- NASCET and the ECST - have shown carotid artery endarterectomy to yield a considerable benefit in patients with 70–99% stenosis and a small benefit in patients with 50–69% stenosis. In these studies, angiography was the gold standard technique used to quantify the carotid artery stenosis degree.

Angiography provides detailed information of the location and extent of the lesions and serves as roadmap for the surgeon or interventional radiologist, but with an increased risk of thromboembolic events and a marked financial cost besides being an invasive procedure associated with patient discomfort. Consequently, non-invasive techniques such as US-ECD, and MDCTA are now employed to quantify carotid artery stenosis¹².

Colour doppler ultrasound techniques are safe and relatively easy to perform, but when compared with digital subtraction angiography, they demonstrate lower sensitivity (65–87%) and specificity (71–91%) for detection of carotid artery stenoses. Power doppler and contrast enhancement are improvements, but ultrasound still may not be able to reliably differentiate high-grade carotid artery stenosis from occlusion, a critical factor in surgical and non-surgical decision making.

In addition, potential limitations of CDUS are: the presence of heavy calcifications, difficulties in the evaluation of the carotid bifurcation when it is located higher than normal and inability to exclude the presence of lesions involving either the origin of the supra-aortic vessels or the intracranial circulation for non-surgical decision-making.

Nowadays MDCTA reaches excellent sensitivity for stenosis between 70% and 99%. The purpose of our study was grading and comparison of degree of stenosis, between the CDUS and CTA. Keeping with the present trend of opting for non-invasive diagnostic modalities, we have attempted

to study, evaluate and correlate the findings of Doppler scanning, with MDCT Angiography with MDCT angiography being the reference standard. In our study, the mean age of 59.1±14 years (Mean± SD), which is less when compared with the similar studies^{13,14}. This could be attributable to the impact of modern and ultra modern lifestyle which should be of alarming concern to us. Males were more affected than females (4:1) which is similar to that seen in various other studies^{14,15} which could be due to reluctance of the part of females to seek medical attention and more importantly due to low prevalence of smoking culture among females

Hypertension was found to be the most common single risk factor in our study present in 5 patients (16.7%) which is similar to different studies^{16,17,18}. followed by diabetes in 3(10%) and smoking in 1(3%). Presence of more than one risk factor had an additive effect in the development of cerebrovascular disease which is further verified by the work of Papademetriou V et al¹⁹. Stroke and TIA constituted the predominant presenting feature in our study which is well in conformity with various other studies^{13,20}

We included all the normal arteries and mildly stenosed arteries under one category as grading them into separate category is unlikely to affect the prognosis and management of patients. Also ECA were excluded during our data compilation due to extremely low incidence of pathology in them and also due to the fact that the presence of plaques/stenosis in ECA is unlikely to affect the symptomatology, management and prognosis of these patients. For normal or mildly stenosed arteries (<50%) we found concordance rate of 100% in identifying normal or mildly stenosed vessels between the two modalities. For moderately stenosed arteries (50-69%) concordance rate was 62% showing fair agreement. If we use only the amount of luminal occlusion as a grading criteria for stenosis the concordance further increases to 75%. For severely stenosed ICA's, The concordance rate between CDUS and CTA was 75%, Overall

concordances rate for detecting severe stenosis in carotid arteries was 60%

This variation in our study could be attributed to numerous factors; like technical limitations associated with ultrasound equipment having susceptibility for misidentifying the artefacts for stenosis coupled with observer variability. Unfavourable patient morphology like short neck, obesity, higher location of CCA bifurcation probably led to overestimation of the degree of stenosis in the patients by CDUS. Other factors which can limit the doppler assessment of extra cranial carotids are presence of oedema and post-radiotherapy scarring, or poor visualisation of distal part of ICA due to poor accessibility. There was poor agreement between these two modalities in identifying near total occlusion.

Arteries identified as occluded on CDUS were also found to be occluded on CTA showing 100% concordance. The overall kappa value for grading of stenosis in our study was 0.81, indicating excellent agreement between these two imaging modalities. Individual kappa values for grading of stenosis in CCA were 0.76 for ICA was 0.83 which indicates good agreement between these modalities in grading of stenosis which is slightly less when compared to study done by Kasim Abul-Kasim²⁰ and Sameh Abd El Raouf et al¹⁵ who observed the kappa values of 0.92 and 0.9306 respectively. However the overall result is comparable to our study. In a different study by Giuseppe Di Gioia et al²¹ found out that DUS - PSV could identify patients with stenosis $\geq 70\%$ at MDCTA which can be compared to our study.

Conclusion

We hence conclude that the result of CDUS are comparable to CTA in grading of carotid artery stenosis showing almost perfect agreement in cases of mild stenosis and thrombosed arteries with poor correlation seen in differentiating near total from total occlusion which can be of importance in patient management hence, recommend that CDUS should be used as initial screening method for evaluation followed by a

more definitive CTA if significant stenosis is seen on CDUS (before any intervention) preferably within one month of CDUS examination as long latency between the examinations can change the morphology of plaque and grading of stenosis which can impact intervention and treatment outcomes.

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