Journal of Case Reports and Scientific Images

E-ISSN: 2708-0064
P-ISSN: 2708-0056
IJCRS 2022; 4(1): 03-08
www.allcasereports.com
Received: 04-11-2021
Accepted: 09-12-2021

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Correlation of ratio of peak systolic velocity of internal carotid artery and common carotid artery in detection of carotid artery stenosis July 2018 to July 2019

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DOI: https://doi.org/10.22271/27080056.2022.v4.i1a.42

Abstract

Introduction: Doppler Sonography has become an accepted method for clinical detection and evaluation of cervical carotid occlusive disease. One of the most important parameters used in doppler assessment of carotid stenosis is the peak Doppler shift frequency occurring during systole. However, relatively little data is available to indicate how precisely peak systolic frequency correlates with luminal narrowing and how peak systolic frequency measurements made with frequency spectrum analysis should be used clinically in gauging stenotic lesions.

Aim: To assess the ratio between peak systolic velocity of internal and common carotid arteries and its significance in prediction of carotid artery stenosis.

Materials and Methods: This is a cross-sectional analytical study performed on patients who are referred to department of Radiodiagnosis, Sree Mookambika Institute of Medical Sciences (SMIMS), Kulasekharam for carotid artery ultrasonography colour doppler evaluation.

Conclusion: Doppler Sonography plays an important role in the early detection and management of carotid artery stenosis disease. The increased ratio of peak systolic velocity of internal and external carotid arteries is correlating with the detection of carotid artery stenosis, thereby improving sensitivity and specificity.

Keywords: Doppler sonography, ultrasound, peak systolic velocity, internal carotid artery, common carotid artery, external carotid artery, carotid stenosis

Introduction

Doppler ultrasonography is widely regarded as the preferred noninvasive modality for measuring carotid stenosis because it is safe, reliable, and inexpensive. Some reports have suggested that duplex ultrasonographic measurements may be even more reflective of the actual stenotic lesion as measured directly from explanted specimens than arteriography. Because the stroke rate of diagnostic cerebral angiography can be as high as 1.2%, it is advantageous that the study to screen patients for carotid lesions be noninvasive. Duplex ultrasonography can be used as a screening test to select patients for angiography; however, recent reports have supported the use of duplex ultrasonography as the sole modality for characterizing carotid lesions before endarterectomy.

Aim

The aim of the study is to assess the ratio between peak systolic velocity of internal and common carotid arteries and its significance in prediction of carotid artery stenosis.

Objectives

- To evaluate for the presence of carotid artery stenosis.
- To determine the ratio of peak systolic velocity of internal and common carotid arteries.
- To assess the correlation between the ratio of peak systolic velocity of internal and common carotid artery and prediction of carotid artery stenosis.

Materials and Methods

Study Design: This is a cross sectional study.
Study Period: July 2018 – July 2019 (1 year).

This is a cross-sectional analytical study performed on patients who are referred to Department of Radiodiagnosis, Sree Mookambika Institute of Medical Sciences (SMIMS), Kulasekharam for carotid artery ultrasonography colour doppler evaluation. From July 2018 – July 2019, 123 patients underwent carotid artery colour doppler evaluation.
All patients are provided with informed consent and the study protocol was approved by the institutional ethical committee.

Patient position
The patient was made to lie down in the supine with the head slightly hyperextended and rotated 45° away from the side being examined.

Transducer
Higher-frequency linear transducers (7 MHz) are ideal for assessment of the intima-media thickness and plaque morphology.

Imaging
Gray scale imaging of the carotid vessels were done. The extent, location, and characteristics of atherosclerotic plaque in the common carotid artery (CCA) and internal carotid artery (ICA) were documented with gray-scale imaging. The percentage of stenosis were obtained using diameter or area method.
Color Doppler imaging was performed to detect areas of abnormal blood flow that require Doppler spectral analysis.
Pulsed wave (PW) Doppler spectral analysis should be performed, and the velocity of blood flow in the mid-CCA and proximal ICA as well as proximal to, at, and immediately distal to the diseased areas should be measured [1]. Evaluation of the external carotid artery (ECA) was performed, as it is a source of bruit and differences in the Doppler appearance of the ECA and ICA improve observer confidence that the bifurcation vessels have been correctly identified.
Color and PW Doppler imaging of both vertebral arteries should also be performed to rule out the presence of a subclavian steal.
From the spectral tracing obtained at level of CCA and ICA, the ratio of PSV of ICA/CCA obtained and assessed for abnormality. This was then correlated with the PSV ratios for further data collection on to the master chart.

The parameters of the imaging is given in the table below.

Gray scale	Colour doppler	Map: A	Spectral doppler	Map: C
VF: 10-5	P- 100%	5.3 MHz	55 Db	Gate size: 2mm.
30dB	MI: 1.17 to 1.22	O Db	5.3 MHz	Sweep: 2
8.0MHz	Flow rate: Medium.	PRF: 3900 HZ	PRF: 4300Hz	Angle: 60deegre Acquired at 15 flims/sec.

Optimal Scanning Techniques and Doppler Settings
Sample Volume Box and Angle Correction
The US machine calculates the velocity from the doppler shift frequency reflected from red blood cells within the sample volume box. The optimal position of the sample volume box in a normal artery is in the mid lumen parallel to the vessel wall, whereas in a diseased vessel it should be aligned parallel to the direction of blood flow. In the absence of plaque disease, the sample volume box should not be placed on the sharp curves of a tortuous artery, as this may result in a falsely high velocity reading. If the sample volume box is located too close to the vessel wall, artificial spectral broadening is inevitable.

Doppler Angle
The angle affects the detected Doppler frequencies. At a Doppler angle of 0°, the maximum doppler shift will be achieved since the cosine of 0° is 1. Conversely, no Doppler shift (no flow) will be recorded if the Doppler angle is 90° since the cosine of 90° is 0. The orientation of the carotid arteries may vary from one patient to another; therefore, the operator is required to align the Doppler angle parallel to the vector of blood flow by applying the angle correction or angling the transducer.
The Doppler angle should not exceed 60°, as measurements are likely to be inaccurate. Our preferred angle of incidence is 45° [3]. Consistent use of a matching Doppler angle of incidence for velocity measurements in the CCA and ICA reduces errors in velocity measurements.

Spectral Broadening
Spectral broadening results from turbulence in the blood flow. Spurious spectral broadening can result from a large Doppler angle, a large sample volume box (3.5 mm), a sample volume box located close to the vessel wall, or a high PW doppler gain setting. The size of the sample volume box (also known as the gate) is normally kept between 2 and 3 mm. If the gate is too small (1.5 mm), the Doppler signal may be missed. Increasing the gate is helpful in searching for trickle flow or trying to obtain a Doppler signal behind a shadowing calcified plaque.

Color Doppler Parameters
Color is a display of the reflected Doppler frequencies from red blood cells.

Color Doppler Sampling Window
The color doppler sampling window (also known as the color box) is positioned over the artery to be in interrogated. The size of the color Doppler sampling window is adjusted to include all regions of interest. Adjustment of the angle of incidence can be achieved by changing pre-set color box angles from left to center or right, as well as angling the transducer to ensure that the Doppler angle of incidence is less than 60° to the direction of blood flow.

Color Velocity Scale Control
The color velocity scale is the most important parameter of the carotid US color Doppler setup. The color velocity scale is an operator-defined range of velocities that requires adjustment, analogous to the window width and level of a gray-scale image. It is not synonymous with the pulse repetition frequency (PRF), but the PRF is related to the velocity scale setting, so that increasing the velocity scale increases the PRF and vice versa [2, 4, 5, 6].
The image frame rate may appear slow if a very low color velocity scale is applied, since the PRF decreases and the time between transmit pulses in a pulse packet increases [2].

If the velocity of blood flow exceeds 1⁄2 the PRF (Nyquist limit), then the direction and velocity are inaccurately displayed and flow appears to change direction (aliasing). Aliasing can be advantageously used to demonstrate high or low flow and turbulence. If the color velocity scale is set below the mean velocity of blood flow, aliasing throughout the vessel lumen makes it impossible to identify the high-velocity turbulent color jet associated with a tight stenosis. Conversely, if the color velocity scale is set significantly higher than the mean velocity of blood flow, aliasing may disappear, resulting in a missed stenosis. In a near occlusion, blood flow velocity may be slower than the usual color velocity scale range thresholds, resulting in a false-positive appearance of an occlusion. In this setting, the area of interest should be re-evaluated by using very low color velocity settings (15 cm/sec) to enhance detection of trickle flow in a near occlusion. If this setting does not reveal detectable flow, contrast material–enhanced imaging (computed tomographic [CT] angiography, gadolinium-enhanced magnetic resonance [MR] angiography or conventional angiography) may be required to differentiate near occlusion from total occlusion. 7, 8.

In a normal carotid US examination, the color velocity scale should be set between 30 and 40cm/sec (mean velocity). In a diseased artery, however, the color velocity scale should be shifted up or down according to the mean velocity of blood flow to demonstrate aliasing only in systole.

Color Gain Control

The color gain should be set so that color just reaches the intimal surface of the vessel. If the color gain setting is too low, trickle flow may go undetected. If a high color gain setting is applied, "bleeding" of the color into the wall and surrounding tissues may limit visualization of the plaque surface and may result in misalignment of the angle correction with the direction of blood flow during a PW Doppler examination.

Results

A total of 123 participants were included in this study. Among them, 88 (71.5%) were males and 35 (28.5%) were females. The mean age of the study population was 56.72 years with a standard deviation of 9.31 years.

Peak systolic velocity of right internal and common carotid arteries

The peak systolic velocity of right internal carotid artery has a mean of 67.72 (24.57). The peak systolic velocity of right common carotid artery has a mean of 60.53 (17.83). These values are represented in table 1.

Table 1: Peak systolic velocity (PSV) of right internal and common carotid arteries (n = 123)

S. No	Descriptive statistics	PSV right internal carotid artery	PSV right common carotid artery
1	Mean	67.72	60.53
2	Standard deviation	24.57	17.83
3	Minimum	26.60	20.50
4	Maximum	200.00	150.90

The ratio of the peak systolic velocity of the right internal carotid artery and common carotid artery has a mean of 1.19 with a standard deviation of 0.56. The distribution of the ratio of peak systolic velocity of the right internal carotid artery and common carotid artery is shown in the figure 1.

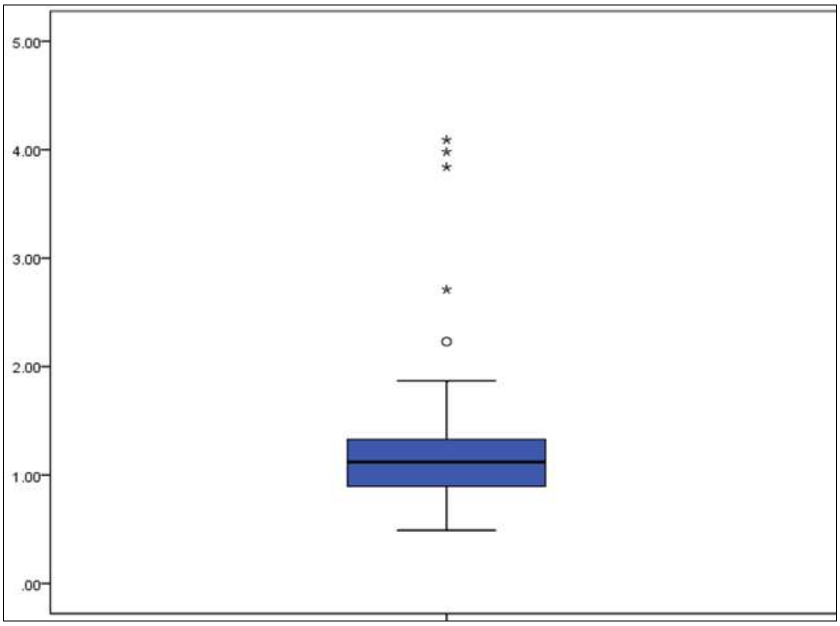

Fig 1: Box plot showing the distribution of the ratio of the peak systolic velocity of the right internal carotid artery and common carotid artery

Peak systolic velocity of left internal and common carotid arteries

The peak systolic velocity of left internal carotid artery has a mean of 71.08 (29.77). The peak systolic velocity of left common carotid artery has a mean of 72.84 (27.58). These values are represented in table 2.

Table 2: Peak systolic velocity (PSV) of left internal and common carotid arteries (n = 123)

S. No	Descriptive statistics	PSV left internal carotid artery	PSV left common carotid artery
1	Mean	71.08	72.84
2	Standard deviation	29.77	27.58
3	Minimum	34.90	20.00
4	Maximum	272.00	301.90

The ratio of the peak systolic velocity of the left internal carotid artery and common carotid artery has a mean of 1.04 with a standard deviation of 0.46. The distribution of the ratio of peak systolic velocity of the left internal carotid artery and common carotid artery is shown in the figure 2.

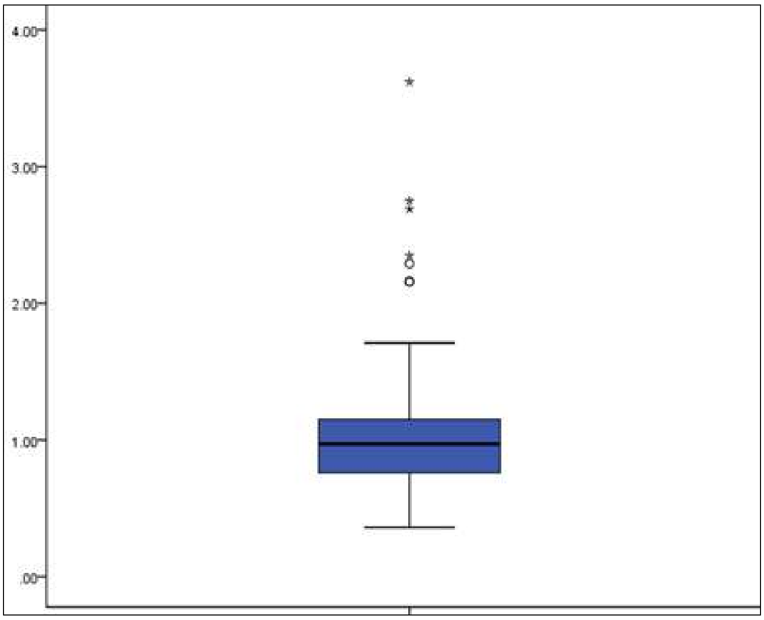

Fig 2: Box plot showing the distribution of the ratio of the peak systolic velocity of the left internal carotid artery and common carotid artery

Carotid stenosis

In the right side, carotid stenosis was present in 31 (25.2%) study participants. Among them, majority had stenosis between 20-40%. The severity of right side carotid stenosis is given in the table 3.

Table 3: Distribution of study participants according to severity of right side carotid stenosis (n = 123)

S. No	Severity of stenosis	Number	Percentage
1	Absent	92	74.8
2	< 20%	3	2.4
3	20 - 40%	14	11.3
4	40 - 60%	9	7.4
5	60 - 80%	5	4.1

In the left side, carotid stenosis was present in 29 (23.6%) of the study participants. Among them, majority had stenosis between 20-40%. The severity of right side carotid stenosis is given in the table 4.

Table 4: Distribution of study participants according to severity of left side carotid stenosis (n = 123)

S. No	Severity of stenosis	Number	Percentage
1	Absent	94	76.4
2	< 20%	3	2.4
3	20 - 40%	13	10.6
4	40 - 60%	6	4.9
5	60 - 80%	7	5.7

The distribution of study participants according to the severity of carotid stenosis is represented in the figure 3.

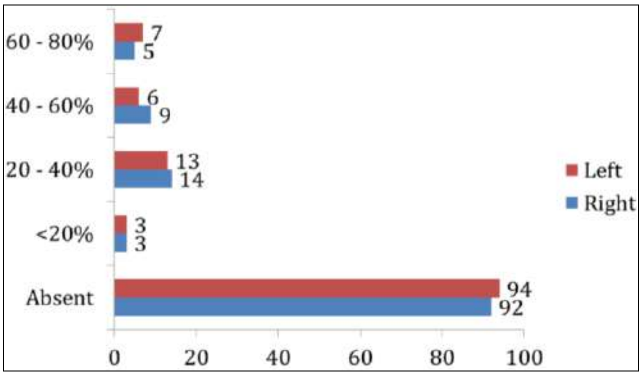

Fig 3: Bar diagram showing severity of carotid artery stenosis in the study population (n = 123)

Correlation between ratio of PSV of internal and common carotid arteries and severity of stenosis

There is strong correlation between the ratio of peak systolic velocity of right internal and common carotid artery and severity of carotid artery stenosis. The Pearson's correlation co-efficient between these two was found to be 0.46 with a p value of 0.00. The relation between these two variables is represented in the figure 4.

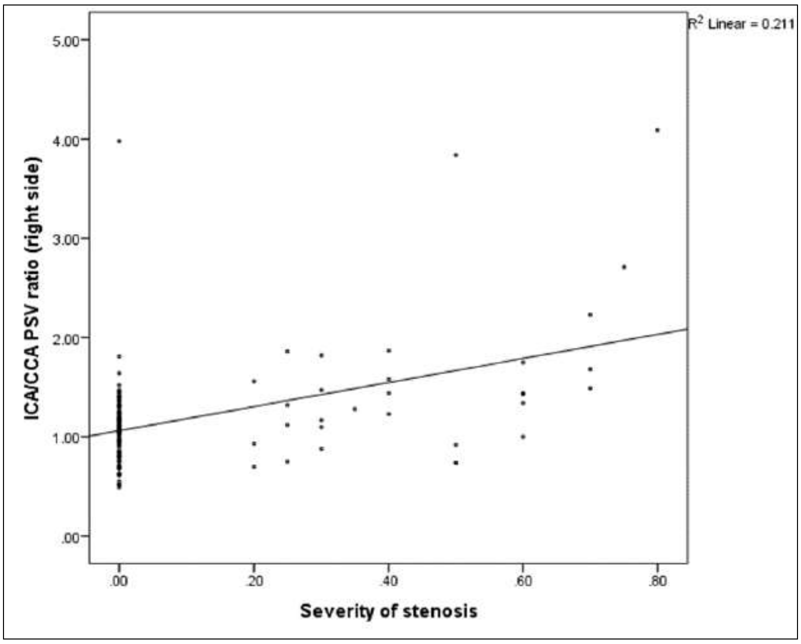

Fig 4: Scatter plot showing the correlation between the ratio of peak systolic velocity of right internal and common carotid artery and severity of carotid artery stenosis

There is strong correlation between the ratio of peak systolic velocity of left internal and common carotid artery and severity of carotid artery stenosis. The Pearson's correlation co-efficient between these two was found to be 0.56 with a p value of 0.00. The relation between these two variables is represented in the figure 5.

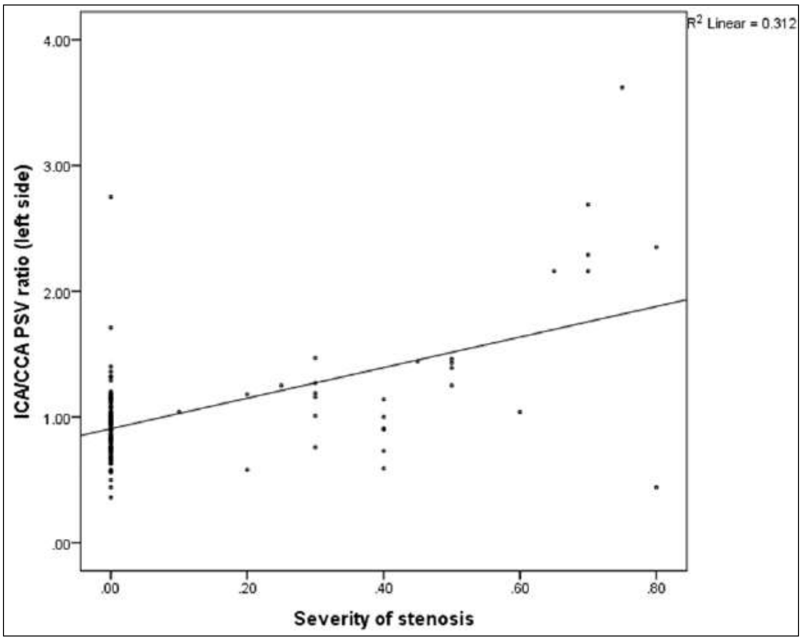

Fig 5: Scatter plot showing the correlation between the ratio of peak systolic velocity of left internal and common carotid artery and severity of carotid artery stenosis

Table 5: Mean ratio, standard deviation and range for different grades of carotid stenosis of both sides

S. No	Severity of stenosis	Total number of cases	Mean of ratio of PSV of ICA/CCA	SD	Range
1	Absent	186	1.29	0.42	0.5-2.75
2	< 20%	6	1.39	0.16	1.18-1.47
3	20 - 40%	27	0.92	0.31	0.58-1.56
4	40 - 60%	15	1.31	0.14	0.59-2.16
5	60 - 80%	12	0.98	0.54	0.44-2.69

Discussion

A total of 123 participants were included in this study. Among them, 88 (71.5%) were males and 35 (28.5%) were females. The mean age of the study population was 56.72 years with a standard deviation of 9.31 years.

The peak systolic velocity of right internal carotid artery has a mean of 67.72 with a standard deviation of 24.57. The peak systolic velocity of right common carotid artery has a mean of 60.53 with a standard deviation of 17.83. The maximum peak systolic velocity of right internal carotid artery was 200 cm/s and the minimum value recorded was 26.60 cm/s. Similarly, the maximum peak systolic velocity of right common carotid artery was 150.90 cm/s and the minimum value was 20.50 cm/s.

The ratio of the peak systolic velocity of the right internal carotid artery and common carotid artery has a mean of 1.19 with a standard deviation of 0.56.

The peak systolic velocity of left internal carotid artery has a mean of 71.08 with a standard deviation of 29.77. The peak systolic velocity of left common carotid artery has a mean of 72.84 with a standard deviation of 27.58. The maximum peak systolic velocity of left internal carotid artery was 272.00 cm/s and the minimum value recorded was 34.90 cm/s. Similarly, the maximum peak systolic velocity of left common carotid artery was 301.90 cm/s and the minimum value was 20.00 cm.

The ratio of the peak systolic velocity of the left internal carotid artery and common carotid artery has a mean of 1.04 with a standard deviation of 0.46.

In the right side, of 123 study participants, 92 people had no stenosis which is 74.8% of study population. Carotid stenosis was present in 31 (25.2%) study participants. Out of which, 3 people (2.4%) had less than 20% stenosis. 14 people (11.3%) had stenosis between 20-40%. 9 people (7.4%) had stenosis between 40-60%. Only 5 people (4.1%)) had stenosis between 60-80%.

The Pearson's correlation co-efficient between the ratio of peak systolic velocity of right internal and common carotid artery and severity of carotid artery stenosis was found to be 0.46 with a p value of 0.00 which shows a strong correlation between PSV ratio and stenosis severity.

In the left side, of 123 study participants, 94 people had no stenosis which is 76.4% of study population. Carotid stenosis was present in 29 (23.6%) study participants. Out of which, 3 people (2.4%) had less than 20% stenosis. 13 people (10.6%) had stenosis between 20-40%. 6 people (4.9%) had stenosis between 40-60%. Only 7 people (5.7%) had stenosis between 60-80%.

The Pearson's correlation co-efficient between the ratio of peak systolic velocity of left internal and common carotid artery and severity of carotid artery stenosis was found to be 0.56 with a p value of 0.00 which shows a strong correlation between PSV ratio and stenosis severity.

On combining right and left sides, 186 cases had no stenosis with 1.29 as the mean ratio of PSV of ICA/CCA, standard deviation of 0.42 and range of about 0.5 to 2.75.

6 cases had less than 20% stenosis with mean of 1.39, standard deviation of 0.16 and range of about 1.18 to 1.47. 27 cases had 20 to 40% stenosis with mean of 0.92, standard deviation of 0.31 and range of about 0.58 to 1.56. 15 cases had 40 to 60% stenosis with mean of 1.31, standard deviation of 0.14 and range of about 0.59 to 2.16. 12 cases had 60 to 80% stenosis with mean of 0.98, standard deviation of 0.54 and range of about 0.44 to 2.69.

The mean ratio of PSV of ICA/CCA of patients with less than 20% stenosis and 40-60% stenosis is higher than that of no stenosis cases which shows strong correlation. However the ratio of cases with 20-40% stenosis and 60-80% stenosis is less than that of no stenosis cases which doesn't correlate with the stenosis.

Limitations of the study

Pearson correlation coefficient shows strong positive correlation between the PSV ratio of ICA/ CCA and severity of stenosis on both sides. However, on combining the sides, the mean ratio of different grades of stenosis doesn't correlate well with the severity of stenosis. This may be due to the limited number of cases with stenosis as compared to the large number of no stenosis which may affect the overall mean. This can be overcome by doing large number of stenosis cases in the study.

Conclusion

Doppler Sonography plays an important role in the early detection and management of carotid artery stenosis disease. The increased ratio of peak systolic velocity of internal and external carotid arteries is correlating with the detection of carotid artery stenosis, thereby improving sensitivity and specificity.

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