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Evaluation Of Carotid Artery Abnormalities By Duplex Doppler Sonography In Clinically Diagnosed Glaucoma Patients Compared With Age Matched Controls.

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ABSTRACT

Background

Glaucoma is a chronic, progressive optic neuropathy caused by multi-factorial aetiology which leads to damage of the optic nerve & produces visual field damage resulting in a characteristic appearance of the optic disc. The overall prevalence of glaucoma in Asia has been found to be in between 2.1% to 5%. The average age of all patients with glaucoma is between 56.05 years to 57.83 years. The fact that the retro bulbar circulation originates from internal carotid arteries which are directly accessible to ultrasound study through grey scale, colour Doppler flow imaging (CDI) & spectral Doppler imaging gives us a potential tool for the evaluation of early changes in vascular flow related to glaucoma. The present study aims to evaluate the carotid artery abnormalities by sonography in glaucoma patients & age matched controls.

Methods

A hospital based case control study, was conducted in the department of Radio-diagnosis, M.G.M Medical College and M.Y Hospital and associated hospitals, Indore, Madhya Pradesh India, November 2022 to November 2023. A total of 95 glaucomatous eyes were included as study groups & 95 age matched non-glaucomatous eyes were included in the control groups. Patients with increased IOP with or without visual field defects were referred to the department of radiodiagnosis for the evaluation of the hemodynamics of the retro orbital & carotid vessels were recruited in the study. All examinations of carotid artery color doppler and orbital artery color doppler were performed using a high frequency linear-array transducer (7-13 MHz) that provides high resolution image.

Results

Among the all patients, 31.5% were belongs to 7th decade of life, with a male predominance (54%). Diminishing of vision was the most common clinical finding. 7.36% of the patients in our study group had hemodynamically significant (>50%) ICA stenosis compared to 1.05% of the patients in control group as per consensus criteria, significant correlation was observed between degrees of carotid artery stenosis with CRA PSV (p value-0.021), CRA EDV (p value-0.034) & CRA RI (0.038). and significant correlation was observed between degrees of carotid artery stenosis with PCA PSV (p value-0.015) & PCA EDV (0.031) & PCA RI (p value- 0.039).

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Conclusion
This study reveals that Doppler ultrasound of the carotid artery is a non-invasive way to evaluate blood flow in the main vessels supplying blood to the eyes and brain. Parameters such as peak systolic velocity (PSV), end-diastolic velocity (EDV), and resistive index (RI) are measured to gain insights into potential changes in blood flow associated with glaucoma. The research emphasizes the presence of vascular dysfunction in glaucoma & a strong link between glaucoma and impaired carotid artery blood flow.

Keywords- ***Glaucoma; Carotid artery; Peak systolic velocity (PSV); End-diastolic velocity (EDV); and Resistive index (RI)***

BACKGROUND

Glaucoma is a chronic, progressive optic neuropathy caused by multi-factorial aetiology which leads to damage of the optic nerve & produces visual field damage resulting in a characteristic appearance of the optic disc and a specific pattern of irreversible visual field defects that are associated frequently but not invariably with raised intra-ocular pressure (1).

All over the world glaucoma is the second leading cause of blindness & the most common cause of the irreversible loss of vision (2). It accounts for 12.3% of global blindness. Global prevalence of glaucoma is about 2% of those >40 years & 10% of those > 80 years of age. The overall prevalence of glaucoma in Asia has been found to be in between 2.1% to 5%. The average age of all patients with glaucoma is between 56.05 years to 57.83 years. Glaucoma is the 3rd most common aetiology (behind refractive errors and cataracts) and the leading cause of irreversible blindness in India. The blindness due to glaucoma in India is about 12.8% of all cause blindness. It is estimated that nearly 90% of the cases of glaucoma are undiagnosed in India (2)(3)(4).

As ophthalmic artery originates from internal carotid artery any atherosclerotic changes affecting the later may result in marked stenotic lumen of ophthalmic artery lumen at its origin, consequently reduced ocular blood flow may result due to systemic hemodynamic changes. Under such conditions, ophthalmic artery stenosis is the primary cause of the reduction of ocular blood perfusion (5)(6)(7).

In patients with complete internal carotid artery occlusion, chronic progressive ocular ischemia leads to neovascular glaucoma(7) (8).

Glaucomatous axonal loss takes many years before the noticeable alterations in the visual field. Once the alterations occur, visual field loss is irreversible; therefore, early diagnosis of glaucoma is critical for preventing progressive vision loss .

The fact that the retro bulbar circulation originates from internal carotid arteries which are directly accessible to ultrasound study through grey scale, colour Doppler flow imaging (CDI) & spectral Doppler imaging gives us a potential tool for the evaluation of early changes in vascular flow related to glaucoma (6).

Use of carotid circulation with sonographic parameters as a tool for early diagnosis of glaucoma and progression has not been systematically studied and only few studies have been done where glaucoma suspects were included in the study. By evaluation of hemodynamic characteristic and correlation of retro bulbar blood flow with carotid arterial circulation in

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glaucoma patients, early therapeutic intervention will slow the onset and progression of irreversible glaucoma(6) (7).

The present study aims to evaluate the carotid artery abnormalities by sonography in glaucoma patients & age matched controls.

METHODS

A time bound, hospital based case control study, was conducted in the department of Radio-diagnosis, M.G.M Medical College and M.Y Hospital and associated hospitals, Indore, Madhya Pradesh, India after receiving approval from Institutional Scientific and Ethical Committee. The period of the Study was from November 2022 to November 2023.A total of 95 glaucomatous eyes were included as study groups & 95 age matched non-glaucomatous eyes were included in the control groups. All patients in study group & control group were evaluated for carotid artery & retro-orbital. vascular circulation abnormalities.

Patients with increased IOP with or without visual field defects were referred to the department of radiodiagnosis for the evaluation of the hemodynamics of the retro orbital & carotid vessels. All ultrasound examinations were performed using a high frequency linear-array transducer (7-13 MHz) that provides high resolution image. Spectral Doppler sonography of bilateral carotid arterial system for peak systolic velocity, end diastolic velocity were done to determine quantification of carotid circulation hemodynamics. B mode evaluates the characterisation of the plaques & also measures intima media thickness, an increase in which is generally considered as marker of atherosclerosis. Orbital scan perform in grey scale to obtain an overview of orbit anatomy amd Colour flow imaging is then used to identify the major vessels in the orbit & to assess the vascularity of any detected pathology. The standard examination takes about 10- 15 minutes per eye.

Pulsed Doppler spectral waveforms are then obtained. The peak systolic velocity (PSV) & end diastolic velocity (EDV) values are obtained by taking the velocity reading at the peak of the spectral wave pattern and that at the wave trough, respectively. (14) (15 (16). The peak systolic (PSV) and end-diastolic (EDV) velocities are measured in the ophthalmic artery, central retinal artery, and in the posterior ciliary arteries. The measurements to calculate vascular resistance (expressed by the resistivity index and pulsatile index) using the following formula:

Resistivity index = (PSV-EDV)/PSV.

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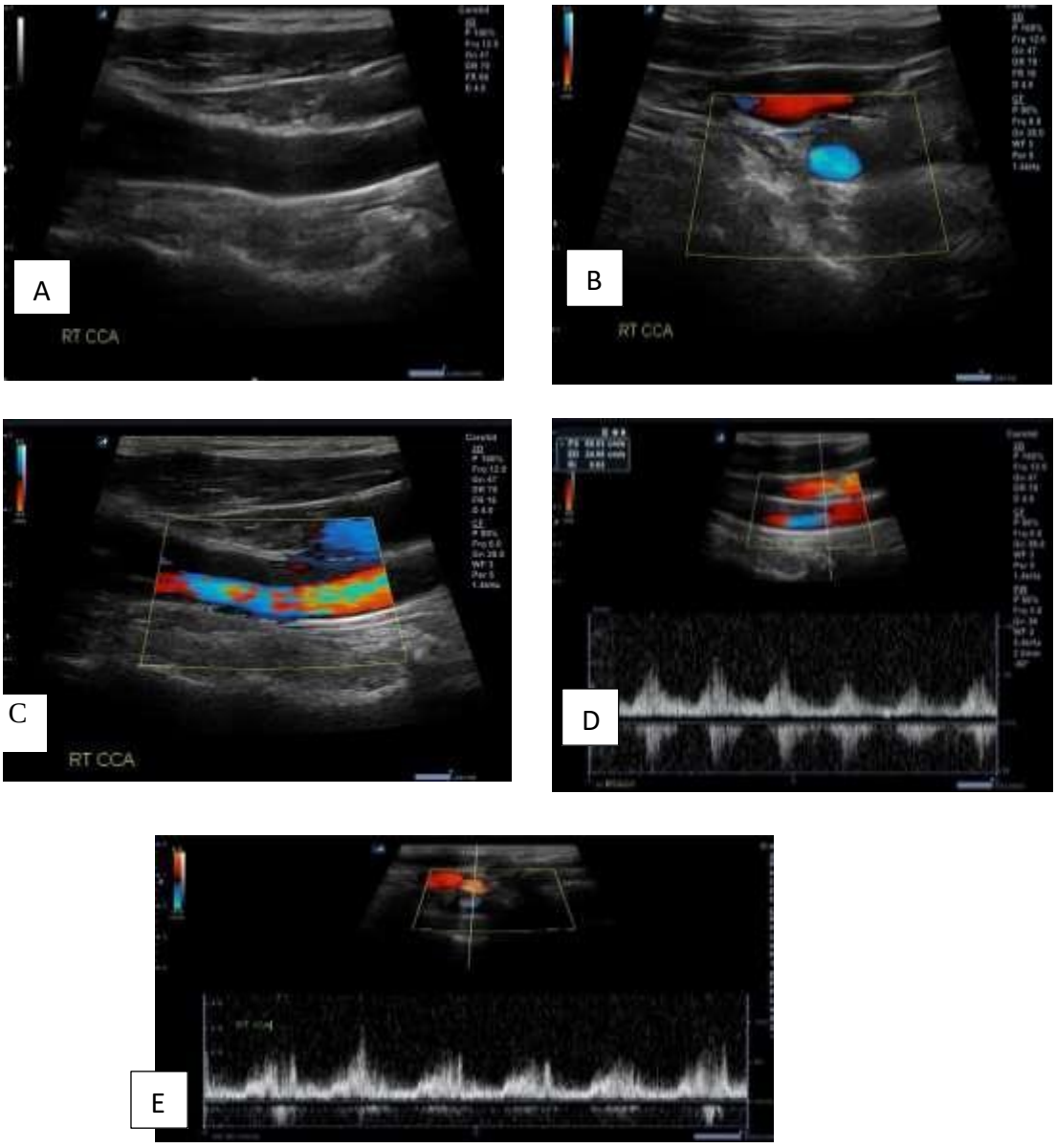
Figure 1



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Figures **(A), (B),(C), (D) (E)** is showing carotid plaque in Right CCA on B Mode study and Figure **(B), (C)** showing Right CCA plaque on color Doppler with stenosis <50%.
Right ICA PSV was 55 cm/sec and PSV ICA/CCA ratio was 0.9. Figure **(D)** & **(E).**

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Figure 2

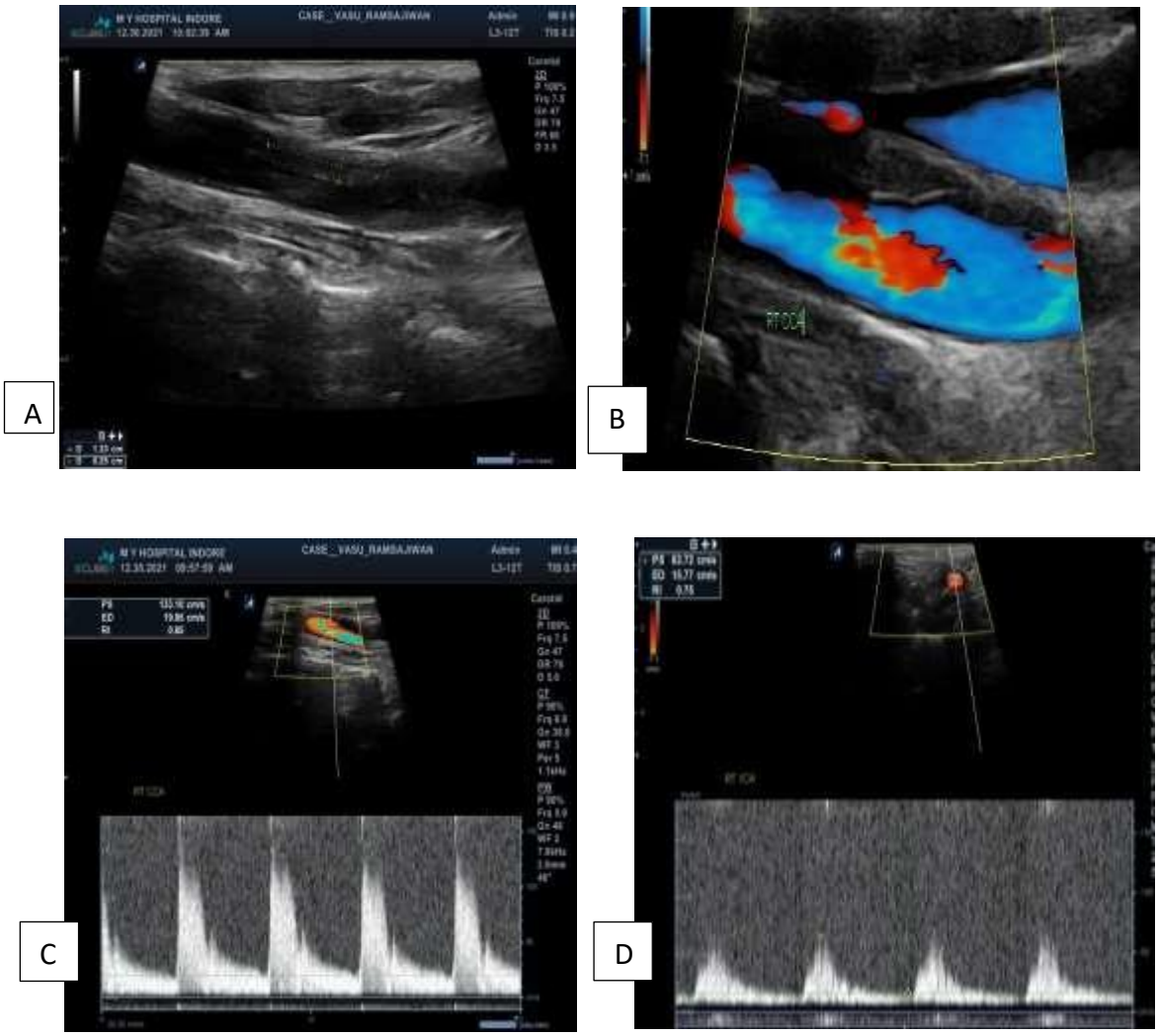

Figure- **(A), (B),(C), and (D)** showing carotid plaque in Right CCA on B Mode and color Doppler respectively with stenosis <50%.
Right ICA PSV was 63 cm/sec & PSV ICA/CCA ratio was 0.47 (Figure **C, D**)

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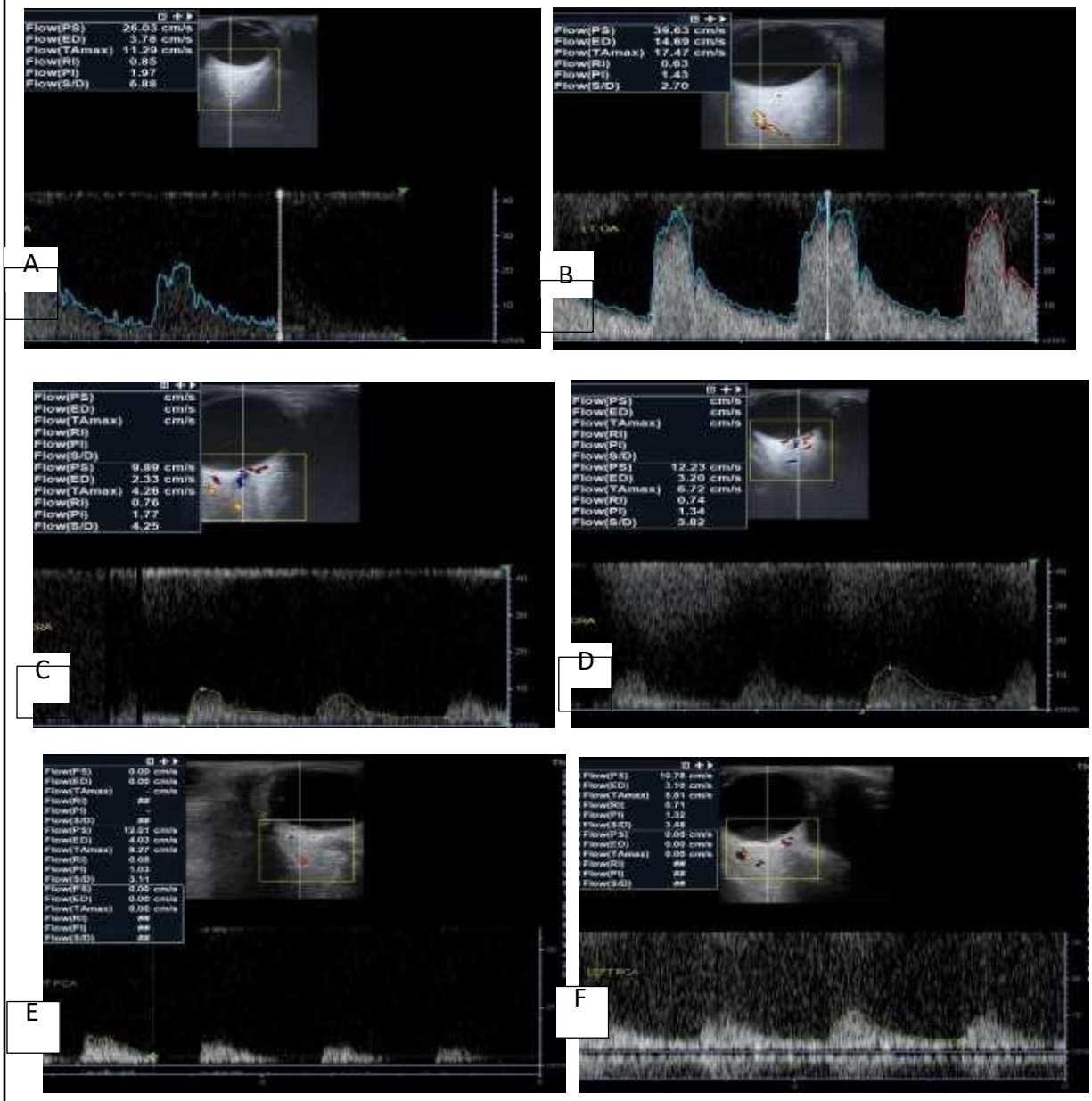
Figure 3



Spectral Doppler shows **(A)** Right OA PSV-26.0cm/sec, EDV-3.7cm/sec, RI-0.85. **(B)**Left OA PSV-39.6cm/sec, EDV-14.6cm/sec, RI-0.63**(C**)Right CRA PSV-12.2cm/sec, EDV-3.2cm/sec,RI-0.74 **(D)** Left CRA PSV-9.8cm/sec. EDV-2.3 cm/sec, RI-0.76 **(E)** Right PCA PSV-12.5 cm/sec, EDV-4.0 cm/sec,RI-0.68 **(F)** Left PCA PSV-10.7 cm/sec, EDV-3.1 cm/sec,RI-0.71.

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RESULTS

More than one third of patients (31.6%) patients enrolled in our study were of age group between 61-70 years of age with group 51-60 year of age being second most populated group. There were 43 (45%) females and 52 (55%) males and in this study, showing a male predominance.
In our study, diminishing of vision was the most common finding in 55 % of patients followed by headache and ocular pain.

In our study, On duplex Doppler examination 7.36% of the patients in our study group had hemodynamically significant (>50%) ICA stenosis compared to 1.05% of the patients in control group as per consensus criteria.
Mean PSV in ophthalmic artery in our study group in patients with no ICA stenosis was 26.64±10.54 mmHg whereas mean EDV was 7.25±6.96mm Hg & the mean RI value was 0.89±0.15. No statistical significant correlation was observed between different grades of carotid stenosis with ophthalmic artery PSV(p value-0.533),EDV(p value-0.469), & RI (p value-0.99).
Mean PSV in central retinal artery in our study group in patients with no ICA stenosis was 12.6±4.1 mmHg whereas mean EDV was 4.2±1.5mm Hg & the mean RI value was 0.66±0.15. Statistically significant correlation was observed between degrees of carotid artery stenosis with CRA PSV (p value-0.021), CRA EDV (p value-0.034) & CRA RI (0.038).

Mean PSV in posterior ciliary artery in our study group in patients with no ICA stenosis was 16.7±5.4 mmHg whereas mean EDV was 5.4±1.4mm Hg & the mean RI value was 0.67±0.15. Statistically significant correlation was observed between degrees of carotid artery stenosis with PCA PSV (p value-0.015) & PCA EDV (0.031) & PCA RI (p value- 0.039).

Table 1 : Distribution of patients on the basis of age among study group & control group.

Table no.-1

Age Group (Years)	Study Group	Percentage (%)	Control group	Percentage (%)
21-30	4	4.22	4	4.21
31-40	6	6.32	6	6.32
41-50	19	20.0	19	20.00
51-60	27	28.42	27	28.42
61-70	30	31.58	30	31.58
71-80	9	9.47	9	9.47
Total	95	100.00	95	100

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Table 2: Distribution of cases in study group & control group on the basis of coexisting co-morbidities among in glaucoma cases & control group
Table no.-2

Risk factors	Study Group	Percentage (%)	Control Group	Percentage (%)
Nil risk factors	35	36.84	71	74.74
Systemic hypertension only	35	36.84	14	14.74
Diabetes only	15	15.79	6	6.32
Diabetes + Hypertension	10	10.53	4	4.21
TOTAL	95	100	95	100

Table 3: Distribution of glaucoma patients in study group according to their presenting symptom.

Clinical features	Study Group	Percentage (%)
Headache	18	18.95
Ocular pain	13	13.68
Halos around light	4	4.21
Redness	0	0.00
Nausea	0	0.00
Diminishing of vision	55	57.89
Eye discharge	5	5.26
Total	95	100.00

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Table no4.- Correlation of vascular hemodynamic parameters of ophthalmic artery with different degrees of carotid stenosis.

Table no.- 4

Table.4

INDICATORS	DEGREES OF CAROTID STENOSIS								
	NO STENOSIS (NUMBERO F CASES=78)		<50% (NUMBERO F CASES=11)		50-70% (NUMBERO F CASES=3)		70%-100% (NUMBERO F CASES=3)		P VALUE
	VALUES	SD	VALUES	SD	VALUES	SD	VALUES	SD	VALUES
OPHTHALMIC ARTERY PEAK SYSTOLIC VELOCITY(OA PSV)	26.64	±10.54	31.23	±17	26.17	±2.56	22.06	±8.8	0.533
OPHTHALMIC ARTERY END DIASTOLIC VELOCITY(OA EDV)	7.25	±6.96	4.88	±2.05	4.22	±0.88	3.63	±2.3	0.469
OPHTHALMIC ARTERY RESISTIVE INDEX(OA RI)	0.89	±0.15	0.83	±0.12	0.82	±0.049	0.88	±0.04	0.99
P VALUES WERE CALCULATED USING ONE WAY ANALYSIS OF VARIANCE									

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Correlation of vascular hemodynamic parameters of central retinal artery with different degrees of carotid stenosis.

Table. 5

INDICATORS	DEGREES OF CAROTID STENOSIS								
	NO STENOSIS (NUMBERO F CASES=78)		<50% (NUMBERO F CASES=11)		50-69% (NUMBERO F CASES=3)		70%-100% (NUMBERO F CASES=3)		P VALUE
	VALUES	SD	VALUES	SD	VALUES	SD	VALUES	SD	VALUES
CENTRAL RETINAL ARTERY PEAK SYSTOLIC VELOCITY(CRA PSV)	12.6	±4.1	12.1	±2.8	10.8	±2.7	9.1	±2.2	0.021
CENTRAL RETINAL ARTERYARTERY END DIASTOLIC VELOCITY(CRA EDV)	4.2	±1.5	4.1	±1.5	3.6	±1.4	2.8	±0.8	0.034
CENTRAL RETINAL ARTERY RESISTIVE INDEX(CRA RI)	0.66	±0.15	0.66	±0.16	0.68	±0.16	0.7	±0.17	0.038
P VALUES WERE CALCULATED USING ONE WAY ANALYSIS OF VARIANCE									

Correlation of vascular hemodynamic parameters of posterior ciliary artery with different degrees of carotid stenosis.

Table.6

INDICATORS	DEGREES OF CAROTID STENOSIS								
	NO STENOSIS (NUMBERO F CASES=78)		<50% (NUMBERO F CASES=11)		50-69% (NUMBERO F CASES=3)		70%-100% (NUMBERO F CASES=3)		P VALUE
	VALUES	SD	VALUES	SD	VALUES	SD	VALUES	SD	VALUES
POSTERIOR CILIARY ARTERY PEAK SYSTOLIC VELOCITY(CRA PSV)	16.7	±5.4	15.4	±4.7	13.9	±4.4	12.2	±4.2	0.015
POSTERIOR CILIARY ARTERY END	5.4	±1.4	5.1	±1.3	4.3	±1.2	3.6	±1.2	0.031

DIASTOLIC VELOCITY(CRA EDV)									
POSTERIOR CILIARY ARTERY RESISTIVE INDEX(CRA RI)	0.67	±0.07	0.66	±0.07	0.69	±0.08	0.7	±0.07	0.039

DISCUSSION

The purpose of the study is to evaluate clinically diagnosed glaucoma patients for abnormalities in carotid arterial circulation with age matched controls. This haemodynamic assessment of the carotid vasculature before the onset of visual field changes helps in early detection and treatment of the disease among high risk groups results in halting the progression of the disease & irreversible damage to the retinal nerve fibres All patients with increased intra ocular pressure above 21 years of age were recruited in the study an as diagnosed by department of ophthalmology were included in the study group. Everyone underwent duplex colour Doppler sonography of carotid & orbital vasculature for the evaluation of carotid & retro orbital hemodynamics after informed and written consent.

In this study, age distribution of patients was between 21-80 years with maximum number of patients were belonging to the 7^{th} decade of life (31.5%) followed by patients in 6^{th} decade (28.4%).

In our study population, gender distribution of cases showed 54% were male and 46% were females. In our study, percentage distribution of clinical features was considered between two groups. Majority of study group patients, presented with diminishing of vision in 55(57.89 %) followed by headache in 18(18.95%), ocular pain in13(13.68%).

Mean PSV in ophthalmic artery in our study group in patients with no ICA stenosis was 26.64±10.54 mmHg, whereas mean EDV was 7.25±6.96mm Hg & the mean RI value was 0.89±0.15.

Mean PSV in central retinal artery in our study group in patients with no ICA stenosis was 12.6±4.1 mmHg, whereas mean EDV was 4.2±1.5mmHg & the mean RI value was 0.66±0.15. Statistically significant correlation was observed between degrees of carotid artery stenosis with CRA PSV (p value-0.021), CRA EDV (p value-0.034) & CRA RI (0.038).

Mean PSV in posterior ciliary artery in our study group in patients with no ICA stenosis was 16.7±5.4 mmHg whereas mean EDV was 5.4±1.4mmHg & the mean RI value was 0.67±0.15. Statistically significant correlation was observed between degrees of carotid artery stenosis with PCA PSV (p value- 0.015) & PCA EDV (0.031) & PCA RI (p value- 0.039).

There was high prevalence of carotid artery disease as evidenced by increased intima media thickness (47.37%), plaques (17.89 %) & significant stenosis (7.36%) of internal carotid arteries in glaucoma study group compared with controls in our study.

Carotid artery Doppler investigation may play an important role in early referral for screening of patients with glaucoma & prevention of disease progression before irreversible damage occurs.

CONCLUSION

In conclusion, the evaluation of carotid artery Doppler ultrasound in glaucoma patients provides valuable insights into the vascular component of the disease. The study demonstrates significant hemodynamic alterations in glaucoma patients, underscoring the role of vascular dysfunction in its pathogenesis. Importantly, carotid Doppler ultrasound emerges as a promising tool for the early diagnosis of glaucomatous changes, offering a non-invasive method to detect individuals at risk before significant optic nerve damage occurs.

The integration of carotid Doppler findings with other diagnostic modalities and the potential for personalized treatment strategies represent exciting advancements in glaucoma care. Future research, including longitudinal studies and clinical trials, will further elucidate the role of vascular health in glaucoma and potentially lead to novel therapeutic approaches. Ultimately, a comprehensive approach that addresses both IOP and vascular factors holds the promise of improving outcomes for patients with glaucoma and reducing the burden of this sight-threatening disease.

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