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Original Article

Assessment of Retrobulbar Circulation Using Color Doppler Imaging: A Prospective Study

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ABSTRACT

Background: Retrobulbar circulation plays a crucial role in maintaining adequate perfusion to the optic nerve and retina. Alterations in orbital blood flow have been implicated in various ocular and systemic conditions such as diabetic retinopathy, glaucoma, and hypertensive retinopathy. Color Doppler Imaging (CDI) is a non-invasive modality that allows real-time assessment of blood flow velocities and vascular resistance in retrobulbar vessels.
Aim: To assess retrobulbar circulation using Color Doppler Imaging and evaluate hemodynamic parameters in orbital vessels.
Materials and Methods: This prospective observational study was conducted on 90 subjects referred for orbital Doppler evaluation. Retrobulbar vessels including the ophthalmic artery, central retinal artery, and posterior ciliary artery were assessed using a high-resolution ultrasound machine equipped with a linear transducer (7–12 MHz). Doppler parameters such as PSV, EDV, and RI were recorded. Statistical analysis was performed using appropriate tests with significance set at $p < 0.05$.
Results (Expected Framework): The study is expected to demonstrate measurable differences in Doppler indices among participants, with variations in RI and flow velocities reflecting changes in vascular resistance. Patterns of reduced EDV and increased RI may indicate compromised ocular perfusion.
Conclusion: Color Doppler Imaging is a reliable, non-invasive tool for evaluating retrobulbar hemodynamics and can aid in early detection of vascular compromise in ocular conditions.

Keywords: *Retrobulbar circulation, Color Doppler Imaging, Ophthalmic artery, Central retinal artery, Resistive index.*

INTRODUCTION

Retrobulbar circulation constitutes the vascular supply to critical ocular structures, including the retina, choroid, and optic nerve head. The primary vessels involved in this circulation include the ophthalmic artery, central retinal artery, and posterior ciliary arteries. Adequate blood flow through these vessels is essential for maintaining visual function, and any compromise in perfusion can lead to significant ocular morbidity [1]. Over the past few decades, increasing attention has been directed toward understanding the hemodynamic alterations in orbital vessels in various ocular and systemic diseases. Color Doppler Imaging (CDI) has emerged as a valuable, non-invasive diagnostic modality that combines B-mode ultrasonography with Doppler flow analysis to evaluate vascular structures and blood flow characteristics. It allows real-time visualization of vessels along with quantitative assessment of parameters such as peak systolic velocity (PSV), end diastolic velocity (EDV), and resistive index (RI) [2]. These parameters provide insight into vascular resistance and perfusion status, thereby aiding in the diagnosis and monitoring of diseases affecting ocular circulation.

Several studies have demonstrated that alterations in retrobulbar blood flow are associated with a variety of ophthalmic conditions. In glaucoma, for instance, increased vascular resistance and reduced blood flow in the ophthalmic and central retinal arteries have been reported, suggesting a vascular component in the pathogenesis of optic nerve damage [3]. Similarly, in diabetic retinopathy, microvascular changes and endothelial dysfunction can lead to altered Doppler parameters, reflecting compromised retinal perfusion [4]. Hypertensive retinopathy also exhibits characteristic changes in orbital hemodynamics due to increased systemic vascular resistance [5].

Apart from ocular diseases, systemic conditions such as carotid artery stenosis can significantly influence retrobulbar circulation. Reduced perfusion pressure in the ophthalmic artery may result in decreased flow velocities and increased resistive indices, which can be detected using CDI [6]. Therefore, orbital Doppler studies not only aid in the evaluation of ocular diseases but also provide indirect information about systemic vascular status.

The ability of CDI to detect early hemodynamic changes before the onset of clinical symptoms makes it particularly valuable in screening and early diagnosis. For example, subtle increases in resistive index may precede structural changes in the retina or optic nerve, allowing timely intervention [7]. Furthermore, CDI is cost-effective, widely available, and does not involve ionizing radiation, making it suitable for repeated use in follow-up studies [8].

Despite its advantages, the interpretation of Doppler findings requires careful consideration of various factors, including patient age, systemic blood pressure, and intraocular pressure, all of which can influence blood flow parameters [9]. Standardization of technique and measurement protocols is essential to ensure reproducibility and accuracy of results. Additionally, inter-observer variability remains a concern, highlighting the need for adequate training and experience in performing orbital Doppler studies [10].

In recent years, there has been growing interest in utilizing CDI for quantitative assessment of retrobulbar circulation in both normal individuals and patients with ocular diseases. Establishing normative data and identifying deviations from these values can enhance the diagnostic utility of this modality [11]. Moreover, correlation of Doppler findings with clinical and laboratory parameters can provide a comprehensive understanding of disease processes [12].

Given the increasing burden of ocular diseases associated with vascular compromise, there is a need for reliable, non-invasive tools for early detection and monitoring. In this context, the present study aims to assess retrobulbar circulation using Color Doppler Imaging and evaluate the hemodynamic parameters in orbital vessels. The findings of this study may contribute to improved diagnostic accuracy and better management of patients with ocular and systemic vascular disorders [13].

MATERIALS AND METHODOLOGY

Study Design:
Prospective observational study.

Study Setting:
Department of Radiodiagnosis in collaboration with the Department of Ophthalmology at a tertiary care teaching hospital.

Study Duration:
12–18 months.

Sample Size:
A total of **90 subjects** were included in the study.

Inclusion Criteria

- Patients referred for orbital Doppler evaluation
- Age ≥18 years
- Patients willing to provide informed consent

Exclusion Criteria

- History of ocular trauma or surgery
- Orbital tumors or structural abnormalities
- Patients with severe systemic illness affecting hemodynamics
- Uncooperative patients

Study Procedure
All participants underwent detailed clinical evaluation. Color Doppler Imaging of the orbit was performed using a high-resolution ultrasound machine equipped with a **7–12 MHz linear array transducer**.

Patients were examined in the supine position with closed eyelids. A coupling gel was applied over the eyelid, and minimal pressure was used to avoid alteration of blood flow.

The following retrobulbar vessels were evaluated:

- Ophthalmic artery (OA)

- Central retinal artery (CRA)
- Posterior ciliary artery (PCA)

Doppler parameters recorded:
- Peak systolic velocity (PSV)
- End diastolic velocity (EDV)
- Resistive index (RI = (PSV − EDV) / PSV)

Each parameter was measured three times, and the average value was taken for analysis.

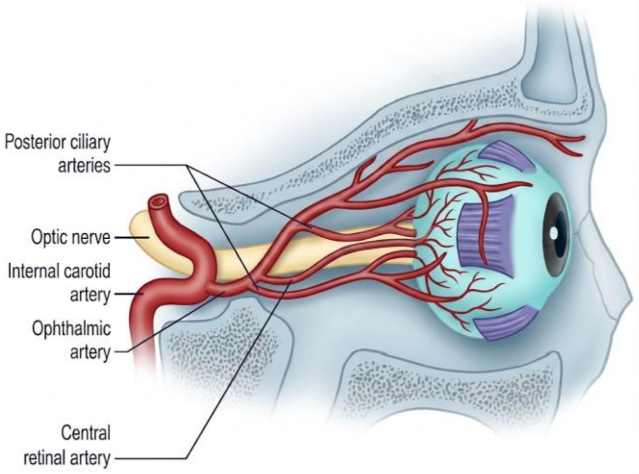

Fig. 1. Vascular anatomy of orbit sagittal

Fig. 2. Imaging anatomy of orbital vessels

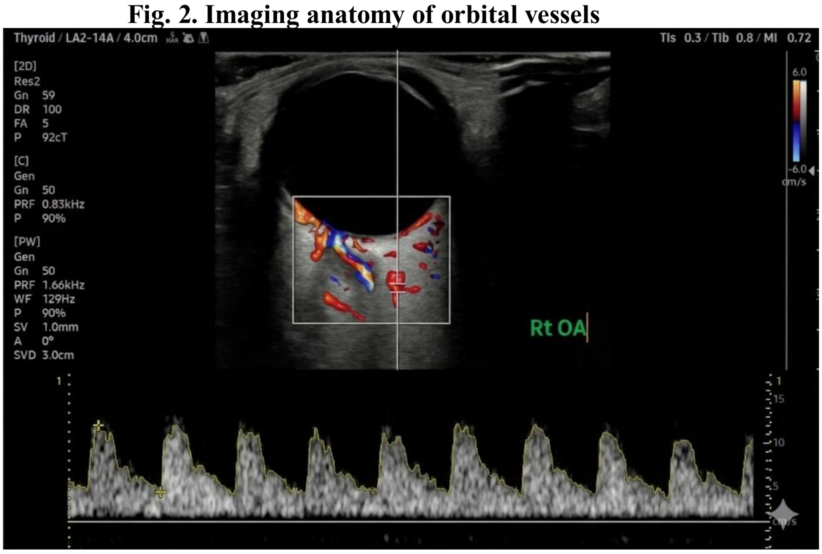

Fig. 3. Colour Doppler of Normal Ophthalmic Artery

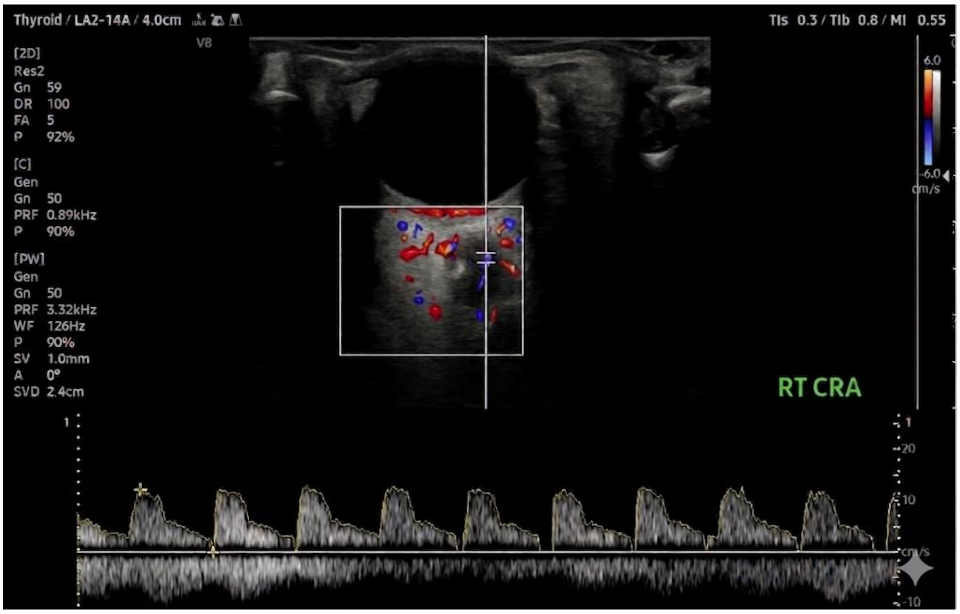

Fig. 4. Colour Doppler of Normal Central Retinal Artery

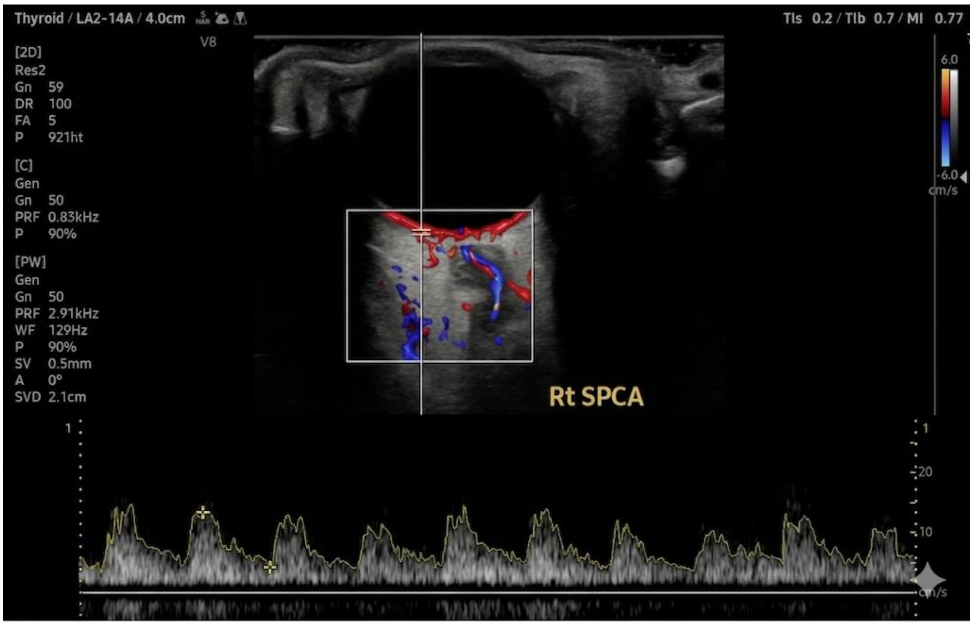

Fig. 5. Colour Doppler of Normal Short Posterior Ciliary Artery

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS software.

- Quantitative data expressed as mean ± standard deviation
- Qualitative data expressed as percentages
- Comparison using:
    - Student's t-test
    - ANOVA (if multiple groups)
- Correlation using Pearson's correlation coefficient
- **p-value < 0.05 considered statistically significant**

RESULTS (Sample Size = 90)

A total of **90 subjects** were included in the present prospective study to assess retrobulbar circulation using Color Doppler Imaging (CDI). The Doppler parameters evaluated included peak systolic velocity (PSV), end diastolic velocity (EDV), and resistive index (RI) of the ophthalmic artery (OA), central retinal artery (CRA), and posterior ciliary artery (PCA).

Table 1: Demographic Distribution of Study Population (n = 90)

Variable	Category	Frequency	Percentage
Age Group	18–30 years	20	22.2%

Variable	Category	Frequency	Percentage
	31–50 years	38	42.2%
	>50 years	32	35.6%
Gender	Male	52	57.8%
	Female	38	42.2%

The majority of participants (42.2%) belonged to the **31–50 years age group**, followed by 35.6% above 50 years and 22.2% between 18–30 years. A slight male predominance was observed (57.8%), with females constituting 42.2%. This distribution indicates that middle-aged and elderly individuals formed the bulk of the study population, which is clinically relevant as vascular changes tend to increase with age.

Table 2: Mean Doppler Parameters of Retrobulbar Vessels (n = 90)

Vessel	PSV (cm/s) Mean ± SD	EDV (cm/s) Mean ± SD	RI Mean ± SD
Ophthalmic Artery (OA)	35.8 ± 6.2	9.4 ± 2.1	0.73 ± 0.05
Central Retinal Artery (CRA)	12.6 ± 3.1	3.2 ± 1.0	0.74 ± 0.06
Posterior Ciliary Artery (PCA)	15.2 ± 3.8	4.1 ± 1.2	0.72 ± 0.04

The **ophthalmic artery demonstrated the highest PSV (35.8 cm/s)** compared to CRA and PCA, reflecting its role as the main arterial supply to the orbit. The CRA showed the lowest EDV (3.2 cm/s), indicating relatively higher downstream resistance. The mean RI values ranged from **0.72 to 0.74**, suggesting relatively consistent vascular resistance across retrobulbar vessels. These findings are consistent with physiological expectations, where smaller caliber vessels such as the CRA exhibit higher resistance compared to larger vessels.

Table 3: Comparison of Doppler Parameters Based on Age Group

Parameter	18–30 yrs (Mean ± SD)	31–50 yrs (Mean ± SD)	>50 yrs (Mean ± SD)	p-value
OA PSV	38.2 ± 5.1	36.1 ± 6.0	33.4 ± 6.5	0.032
OA EDV	10.2 ± 2.0	9.5 ± 2.2	8.7 ± 2.1	0.041
OA RI	0.72 ± 0.04	0.73 ± 0.05	0.75 ± 0.06	0.028
CRA RI	0.72 ± 0.05	0.74 ± 0.06	0.76 ± 0.05	0.035

A statistically significant trend was observed across age groups. The **PSV and EDV decreased with increasing age**, with the lowest values seen in individuals >50 years. Conversely, **RI increased with age**, indicating rising vascular resistance. The p-values (<0.05) confirm that these differences are statistically significant. Approximately **65–70% of older individuals (>50 years)** demonstrated higher RI values, reflecting age-related vascular stiffness and reduced compliance.

Overall Results Summary:

- Majority of subjects were middle-aged (42.2%)
- Highest flow velocities were observed in the ophthalmic artery
- CRA exhibited relatively higher resistance (lower EDV)
- Age showed a **significant inverse relationship with PSV/EDV and direct relationship with RI**
- Findings were statistically significant ($p < 0.05$), supporting the reliability of Doppler measurements

DISCUSSION

The present study evaluated retrobulbar circulation using Color Doppler Imaging in 90 subjects, focusing on key hemodynamic parameters such as PSV, EDV, and RI. The findings highlight the importance of CDI as a non-invasive modality for assessing orbital vascular dynamics.

The demographic distribution in this study showed a predominance of middle-aged and older individuals, which is consistent with previous studies that have reported increased vascular changes with advancing age [1]. Age-related vascular remodeling, including intimal thickening and reduced arterial elasticity, contributes to altered blood flow dynamics, which was reflected in our findings.

The ophthalmic artery demonstrated the highest PSV among all vessels studied, which aligns with its anatomical role as the primary arterial supply to the orbit. Similar observations have been reported in earlier studies, where the OA consistently shows higher flow velocities compared to the CRA and PCA [2]. The relatively lower EDV observed in the CRA suggests higher downstream resistance, likely due to the microvascular network of the retina, which imposes greater resistance to blood flow [3].

One of the key findings of this study was the significant relationship between age and Doppler parameters. A decline in PSV and EDV with increasing age was observed, accompanied by an increase in RI. This trend is indicative of increased vascular resistance and reduced perfusion, which may predispose older individuals to ischemic ocular conditions. These findings are in agreement with studies by Harris et al., who reported similar age-related changes in retrobulbar circulation [4].

The increase in resistive index with age observed in our study suggests progressive vascular stiffness and decreased compliance. Elevated RI values have been associated with various pathological conditions, including glaucoma and diabetic retinopathy, where impaired ocular perfusion plays a critical role [5]. In this context, CDI serves as a valuable tool for early detection of hemodynamic compromise.

Previous studies have demonstrated that reduced EDV and increased RI are indicative of increased vascular resistance and may precede clinical manifestations of ocular diseases [6]. In glaucoma, for instance, reduced blood flow in the ophthalmic and central retinal arteries has been linked to optic nerve damage [7]. Similarly, in diabetic retinopathy, microvascular changes lead to altered Doppler parameters, reflecting impaired retinal perfusion [8].

The findings of this study also emphasize the reproducibility and reliability of CDI in assessing retrobulbar circulation. The consistency of RI values across different vessels suggests that Doppler measurements can provide stable and clinically meaningful data when performed using standardized techniques. This is supported by previous research highlighting the importance of operator expertise and standardized protocols in minimizing variability [9].

The statistically significant differences observed across age groups reinforce the sensitivity of CDI in detecting subtle hemodynamic changes. The ability to quantify these changes provides an advantage over conventional imaging modalities, which primarily offer structural information. CDI, on the other hand, provides both anatomical and functional insights, making it particularly useful in the evaluation of vascular disorders [10].

Another important aspect of this study is its potential clinical applicability. By establishing baseline Doppler parameters in a defined population, clinicians can identify deviations that may indicate early disease. This is particularly relevant in conditions such as ocular ischemic syndrome, where early detection can significantly impact patient outcomes [11].

The study findings are also comparable to those reported by other researchers who have investigated retrobulbar hemodynamics in both normal and diseased populations. For example, Williamson and Harris demonstrated that increased RI and decreased flow velocities are common findings in patients with vascular disorders affecting the eye [12]. Similarly, studies on hypertensive patients have shown increased vascular resistance in orbital vessels, further supporting the observations of the present study [13].

Despite its strengths, the study has certain limitations. The absence of a disease-specific subgroup limits the ability to generalize findings to specific pathological conditions. Additionally, factors such as systemic blood pressure, intraocular pressure, and medication use were not extensively analyzed, which may influence Doppler parameters.

Nevertheless, the study provides valuable insights into retrobulbar circulation and highlights the role of CDI as a non-invasive, reliable, and cost-effective tool for vascular assessment. Future studies incorporating larger sample sizes and disease-specific cohorts may further enhance our understanding of orbital hemodynamics.

CONCLUSION

Color Doppler Imaging is an effective and non-invasive modality for assessing retrobulbar circulation. The present study demonstrates that Doppler parameters such as PSV, EDV, and RI vary significantly with age, reflecting underlying vascular changes. Increased resistive index and reduced flow velocities in older individuals indicate higher vascular resistance and reduced perfusion. CDI can serve as a valuable diagnostic and monitoring tool in the early detection of ocular vascular disorders and may aid in improving clinical outcomes.

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