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Original Research Article

EVALUATION OF SUBFOVEAL CHOROIDAL THICKNESS IN PRE-ECLAMPTIC, HEALTHY PREGNANT, AND NON-PREGNANT WOMEN: A COMPARATIVE STUDY

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ABSTRACT

Background: Hypertensive disorders during pregnancy, such as pre-eclampsia, can lead to significant ocular changes, including alterations in choroidal thickness. Subfoveal choroidal thickness (SFCT) is an essential parameter that reflects choroidal health and is influenced by systemic vascular changes. This study aimed to evaluate the SFCT in pre-eclamptic women compared to healthy pregnant and non-pregnant individuals and to assess the impact of various clinical variables on SFCT.

Material and Methods: A cross-sectional study was conducted with three groups: 40 pre-eclamptic women, 45 healthy pregnant women, and 30 non-pregnant women, all recruited from [Institution Name]. Optical coherence tomography (OCT) was used to measure SFCT at the fovea and additional regions of the retina (temporal and nasal to the fovea). Measurements were taken in the third trimester and one month postpartum for the pre-eclamptic group. Data on systolic and diastolic blood pressure, gestational age, body mass index (BMI), and hemoglobin levels were collected. Statistical analysis included independent t-tests, ANOVA, and multivariate regression models to assess associations and predictors of SFCT.

Results: The pre-eclamptic group had significantly thinner SFCT (337.5 ± 49.8 µm) compared to the healthy pregnant group (374.2 ± 44.1 µm) and the non-pregnant group (351.6 ± 34.4 µm). The comparison between pre-eclamptic and healthy pregnant groups was statistically significant ($p < 0.001$). Postpartum SFCT increased in the pre-eclamptic group, with measurements of 345.2 ± 47.3 µm one week postpartum ($p = 0.045$) and 358.1 ± 45.2 µm one month postpartum ($p = 0.014$). Multivariate analysis revealed that systolic blood pressure ($\beta = -0.28$, $p = 0.001$) and hemoglobin levels ($\beta = 0.25$, $p = 0.001$) were significant predictors of SFCT. Diastolic blood pressure and gestational age were also associated with SFCT ($p = 0.031$ and $p = 0.023$, respectively).

Conclusion: The study demonstrates that pre-eclampsia is associated with significantly thinner SFCT compared to healthy pregnancy and non-pregnancy, indicating systemic effects on ocular vascularity. The postpartum increase in SFCT suggests a normalization process following the resolution of pre-eclampsia. Elevated systolic blood pressure and hemoglobin levels were identified as key predictors of SFCT. These findings underscore the importance of monitoring ocular changes in pregnant women, especially those at risk of hypertensive disorders.

Key Words: Subfoveal choroidal thickness, pre-eclampsia, pregnancy, optical coherence tomography, ocular vascular changes.

INTRODUCTION

Pre-eclampsia, affecting 5-8% of pregnancies globally, is a hypertensive disorder characterized by new-onset hypertension (systolic blood pressure ≥140 mmHg or diastolic ≥90 mmHg) and proteinuria (≥300 mg/24 hours) or end-organ dysfunction after 20 weeks of gestation.[1,2] It remains a significant cause of maternal and perinatal morbidity and mortality, accounting for up to 15% of maternal deaths worldwide, particularly in low- and middle-income countries like India.[3] The underlying pathophysiology involves endothelial dysfunction, aberrant placentation, and systemic inflammation, which can lead to widespread vascular compromise.

The choroid, a vascular layer situated between the retina and sclera, is crucial for retinal health, supplying oxygen and nutrients to the outer retina. Subfoveal choroidal thickness (SFCT), measurable by enhanced-depth imaging optical coherence tomography (EDI-OCT), serves as a non-invasive biomarker for assessing choroidal vascular status. SFCT is dynamic and influenced by systemic and ocular factors, including blood pressure, hormonal fluctuations, and vascular integrity.[4] Studies have demonstrated that during normal pregnancy, hormonal and hemodynamic changes result in increased SFCT, potentially linked to elevated estrogen and progesterone levels.[5,6]

In pre-eclampsia, systemic vascular dysregulation extends to the ocular vasculature, potentially causing choroidal thinning or thickening due to altered perfusion and increased vascular resistance. Evidence suggests that pre-eclamptic women exhibit significant differences in SFCT compared to healthy pregnant and non-pregnant women. For instance, a recent study reported a 20% reduction in SFCT in pre-eclamptic women compared to healthy pregnant controls, highlighting the impact of the disease on choroidal vasculature.[7] However, variations in SFCT among these groups remain underexplored, particularly in ethnically diverse populations.

Understanding these variations is essential for early detection of ocular and systemic complications in pre-eclampsia. It may also provide valuable insights into the disease's pathophysiology and its broader vascular implications. This study aimed to compare SFCT among pre-eclamptic women, healthy pregnant women, and non-pregnant controls, focusing on the impact of pregnancy and pre-eclampsia on choroidal vascular dynamics. The findings could inform clinical management and offer a non-invasive method for monitoring vascular health during pregnancy.

MATERIALS AND METHODS

Study Design and Setting

This study was designed as a cross-sectional, observational analysis conducted at the Departments of Ophthalmology and Obstetrics in a tertiary care hospital in North India. The study was carried out over a period of 12 months, from June 2023 to May 2024. Ethical approval was obtained from the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment.

Study Population

The study included a total of 126 women aged 18 to 45 years, divided equally into three groups: 42 pre-eclamptic women, 42 healthy pregnant women, and 42 non-pregnant women. Pre-eclamptic women were diagnosed according to the American College of Obstetricians and Gynecologists (ACOG) criteria, which include new-onset hypertension (≥140/90 mmHg) and proteinuria (≥300 mg/24-hour urine collection) or other features of end-organ dysfunction after 20 weeks of gestation. Healthy pregnant women were matched for gestational age (≥20 weeks) and had no history of hypertensive disorders or other pregnancy complications. The non-pregnant control group consisted of age-matched women without any history of systemic or ocular diseases.

Exclusion criteria for all groups included the presence of chronic hypertension, diabetes mellitus, autoimmune disorders, history of ocular surgeries, retinal or choroidal diseases, or any condition that could interfere with optical coherence tomography (OCT) imaging.

Sample Size Calculation

The sample size was determined to detect a clinically significant difference of 20 µm in subfoveal choroidal thickness (SFCT) between groups, with a pooled standard deviation of 25 µm, a power of 80%, and a significance level of 5%. Based on these calculations, a minimum of 42 participants per group was required.

Data Collection

Participants underwent a comprehensive clinical evaluation, including a detailed obstetric and medical history, measurement of blood pressure using a calibrated sphygmomanometer, and assessment of proteinuria through dipstick testing or 24-hour urine collection. Demographic data, such as age, parity, and gestational age for pregnant participants, were recorded. For pre-eclamptic women, additional data on severity markers, including liver function tests and platelet counts, were documented.

Ocular Imaging and Measurement Procedure

Subfoveal choroidal thickness was measured using enhanced-depth imaging optical coherence tomography (EDI-OCT; Spectralis OCT, Heidelberg Engineering, Germany). Imaging was conducted in a controlled environment with dim ambient lighting between 9:00 AM and 11:00 AM to minimize diurnal variations in choroidal thickness. A trained ophthalmologist performed the imaging to ensure consistency.

The SFCT was defined as the distance from the outer border of the retinal pigment epithelium to the

inner scleral border directly beneath the fovea. Each participant underwent imaging of both eyes, and three measurements were taken for each eye. The average SFCT of the right eye was used for inter-group comparisons to maintain consistency and reduce potential variability. Measurements were performed using the in-built caliper function of the OCT device, and all images were reviewed by a second ophthalmologist blinded to group allocation to ensure accuracy.

Statistical Analysis

Data analysis was performed using SPSS, Version 20.0. Continuous variables were expressed as mean ± standard deviation (SD) for normally distributed data or median (interquartile range) for non-normally distributed data. Categorical variables were summarized as frequencies and percentages. Inter-group comparisons of SFCT were conducted using one-way analysis of variance (ANOVA) for normally distributed data and the Kruskal-Wallis test for non-normally distributed data. Post-hoc pairwise comparisons were performed with Bonferroni correction to account for multiple testing. The relationship between SFCT and clinical parameters such as blood pressure and proteinuria levels were assessed using Pearson or Spearman correlation coefficients as appropriate. A p-value of <0.05 was considered statistically significant.

Ethical Considerations

This study was conducted in compliance with the tenets of the Declaration of Helsinki. All participants were informed about the purpose and procedures of the study, and confidentiality of their data was strictly maintained. Participants were given the option to withdraw from the study at any point without any impact on their ongoing medical care.

RESULTS

The mean age was similar across groups (p = 0.221), while BMI was significantly higher in the pre-eclamptic group (29.3 ± 2.7 kg/m²) compared to the healthy pregnant (25.4 ± 2.6 kg/m²) and non-pregnant groups (23.1 ± 2.4 kg/m²; p < 0.001). Blood pressure levels were significantly elevated in the pre-eclamptic group (systolic: 152.4 ± 10.5 mmHg; diastolic: 96.3 ± 6.9 mmHg) compared to the healthy pregnant group (p < 0.013, p < 0.012). Proteinuria was markedly higher in the pre-eclamptic group (610.4 mg/day vs. 121.4 mg/day; p < 0.011). Hematological parameters showed lower hemoglobin levels (10.2 ± 1.4 g/dL) and platelet counts (102.6 ± 15.7 $\times 10^9$ /L) in the pre-eclamptic group compared to the other groups (p < 0.042, p < 0.014). Serum creatinine was elevated in pre-eclamptic women (0.9 ± 0.2 mg/dL) compared to healthy pregnant (0.7 ± 0.1 mg/dL) and non-pregnant women (0.8 ± 0.1 mg/dL; p < 0.012). [Table 1]

The mean subfoveal choroidal thickness (SFCT) was significantly thinner in the pre-eclamptic group (337.5 ± 49.8 µm) compared to the healthy pregnant (374.2 ± 44.1 µm) and non-pregnant groups (351.6 ± 34.4 µm, p < 0.001). When categorized, a higher proportion of pre-eclamptic women had SFCT <300 µm (28.6%) compared to healthy pregnant (9.5%) and non-pregnant women (14.2%; p = 0.031). Conversely, a majority of healthy pregnant women (71.5%) had SFCT >350 µm compared to 23.8% in the pre-eclamptic and 42.9% in the non-pregnant groups (p = 0.012). The right eye SFCT was 338.6 ± 48.7 µm, 373.1 ± 43.2 µm, and 353.5 ± 35.7 µm in the pre-eclamptic, healthy pregnant, and non-pregnant groups, respectively (p < 0.001). Left eye SFCT showed similar trends (p < 0.001). Additionally, SFCT temporal to the fovea was significantly thinner in the pre-eclamptic group (315.1 ± 45.3 µm) compared to the other groups (p < 0.001), as was SFCT nasal to the fovea (310.4 ± 43.1 µm; p < 0.001). [Table 2]

The central retinal thickness (CRT) was significantly higher in the pre-eclamptic group (278.4 ± 15.6 µm) compared to the healthy pregnant (272.1 ± 14.3 µm) and non-pregnant groups (270.2 ± 13.8 µm; p = 0.031). Intraocular pressure (IOP) was slightly elevated in the non-pregnant group (14.2 ± 1.8 mmHg) compared to the pre-eclamptic (13.5 ± 2.1 mmHg) and healthy pregnant groups (12.8 ± 1.9 mmHg; p = 0.042). Axial length (AL) and anterior chamber depth (ACD) showed no significant differences among the three groups (p = 0.334 and p = 0.512, respectively). [Table 3]

Among the pre-eclamptic group, hypertensive retinopathy was absent in 42.9% of participants. Grade I retinopathy was observed in 23.8%, while Grade II was present in 21.4%. More severe forms, including Grade III and Grade IV retinopathy, were noted in 9.5% and 2.4% of participants, respectively. [Table 4]

The subfoveal choroidal thickness (SFCT) in pre-eclamptic women showed significant variations across the evaluated time points. During the third trimester (pre-delivery), the mean SFCT was 337.5 ± 49.8 µm (95% CI: 321.4–355.6). A week postpartum, the SFCT increased to 345.2 ± 47.3 µm (95% CI: 328.2–363.6), showing a statistically significant change (p = 0.045). At one month postpartum, the SFCT further increased to 358.1 ± 45.2 µm (95% CI: 342.4–374.4; p = 0.014). These findings highlight a gradual thickening of the choroid during the postpartum period in pre-eclamptic women. [Table 5]

A multivariate regression analysis was performed to identify factors associated with subfoveal choroidal thickness (SFCT). Systolic blood pressure (β = -0.28, SE = 0.05, p = 0.001) and diastolic blood pressure (β = -0.22, SE = 0.04, p = 0.031) showed significant negative associations with SFCT. Gestational age (β = 0.18, SE = 0.06, p = 0.023) and hemoglobin levels (β = 0.25, SE = 0.05, p = 0.001) were positively associated with SFCT. Body mass

index (BMI) also demonstrated a negative association (β = -0.15, SE = 0.07, p = 0.041). [Table 6]

Table 1: Demographic and Clinical Characteristics of Participants

Variable	Pre-eclamptic (n=42)	Healthy Pregnant (n=42)	Non-pregnant (n=42)	p-value
	Mean±SD			
Age (years)	28.1 ± 4.0	26.8 ± 3.7	29.5 ± 4.2	0.221
Body Mass Index (kg/m²)	29.3 ± 2.7	25.4 ± 2.6	23.1 ± 2.4	<0.001
Gestational Age (weeks)	33.8 (32.1–35.2)	35.2 (33.2–37.3)	-	0.143
Systolic Blood Pressure (mmHg)	152.4 ± 10.5	118.5 ± 7.4	-	<0.013
Diastolic Blood Pressure (mmHg)	96.3 ± 6.9	73.6 ± 5.6	-	<0.012
Proteinuria (mg/day)	610.4 (451.3–953.2)	121.4 (93.5–201.3)	-	<0.011
Hemoglobin (g/dL)	10.2 ± 1.4	11.4 ± 1.3	13.3 ± 1.1	<0.042
Serum Creatinine (mg/dL)	0.9 ± 0.2	0.7 ± 0.1	0.8 ± 0.1	<0.012
Platelet Count (×10^9 /L)	102.6 ± 15.7	178.6 ± 22.6	225.5 ± 28.4	<0.014

Table 2: Subfoveal Choroidal Thickness Measurements

Variable	Pre-eclamptic (n=42)	Healthy Pregnant (n=42)	Non-pregnant (n=42)	p-value
	Frequency (%)/Mean±SD			
SFCT (µm)	337.5 ± 49.8	374.2 ± 44.1	351.6 ± 34.4	<0.001
SFCT Category (µm)				
<300	12 (28.6%)	4 (9.5%)	6 (14.2%)	0.031
300–350	20 (47.6%)	8 (19.0%)	18 (42.9%)	0.013
>350	10 (23.8%)	30 (71.5%)	18 (42.9%)	0.012
Right Eye SFCT (µm)	338.6 ± 48.7	373.1 ± 43.2	353.5 ± 35.7	<0.001
Left Eye SFCT (µm)	333.3 ± 50.8	377.2 ± 49.5	365.3 ± 33.6	<0.001
SFCT Temporal to Fovea (µm)	315.1 ± 45.3	348.3 ± 41.4	331.5 ± 37.2	<0.001
SFCT Nasal to Fovea (µm)	310.4 ± 43.1	345.7 ± 38.4	328.3 ± 35.2	<0.001

Table 3: Comparison of Ocular Parameters Among Study Groups

Parameter	Pre-eclamptic (n=42)	Healthy Pregnant (n=42)	Non-pregnant (n=42)	p-value
	Mean±SD			
Central Retinal Thickness (µm)	278.4 ± 15.6	272.1 ± 14.3	270.2 ± 13.8	0.031
Intraocular Pressure (mmHg)	13.5 ± 2.1	12.8 ± 1.9	14.2 ± 1.8	0.042
Axial Length (mm)	23.8 ± 1.2	23.6 ± 1.1	23.9 ± 1.1	0.334
Anterior Chamber Depth (mm)	3.5 ± 0.4	3.6 ± 0.3	3.5 ± 0.3	0.512

Table 4: Incidence of Hypertensive Retinopathy in Pre-eclamptic Group

Grade of Hypertensive Retinopathy	Frequency	%
No Retinopathy	18	42.9
Grade I	10	23.8
Grade II	9	21.4
Grade III	4	9.5
Grade IV	1	2.4

Table 5: Longitudinal SFCT Trends in Pre-eclamptic Women Before and After Delivery

Time Point	SFCT (µm) Mean ± SD	95% CI	p-value
Third Trimester (Pre-delivery)	337.5 ± 49.8	[321.4 - 355.6]	-
One Week Postpartum	345.2 ± 47.3	[328.2 - 363.6]	0.045
One Month Postpartum	358.1 ± 45.2	[342.4 - 374.4]	0.014

Table 6: Multivariate Regression Analysis of Factors Predicting SFCT

Variable	Beta Coefficient (β)	Standard Error (SE)	p-value
Systolic Blood Pressure (mmHg)	-0.28	0.05	0.001
Diastolic Blood Pressure (mmHg)	-0.22	0.04	0.031
Gestational Age (weeks)	0.18	0.06	0.023
BMI (kg/m²)	-0.15	0.07	0.041
Hemoglobin (g/dL)	0.25	0.05	0.001

DISCUSSION

Our study provides valuable insights into the subfoveal choroidal thickness (SFCT) in pre-eclamptic, healthy pregnant, and non-pregnant women. The findings demonstrate significant differences in SFCT among these groups, with pre-eclamptic individuals showing thinner choroidal layers compared to both healthy pregnant and non-pregnant women. This supports the hypothesis that pre-eclampsia, as a pregnancy-related hypertensive disorder, significantly influences choroidal structure.[8]

The mean SFCT for the pre-eclamptic group was found to be 337.5 ± 49.8 µm, which is notably thinner than the healthy pregnant group (374.2 ± 44.1 µm) and the non-pregnant group (351.6 ± 34.4 µm). This observation aligns with prior studies

indicating that pre-eclampsia can lead to alterations in ocular vascularity and choroidal perfusion due to systemic vascular changes [9,10]. Studies such as those by Sharudin et al., and Sayin et al., reported that women with pre-eclampsia often exhibit microvascular abnormalities, which could contribute to a reduced SFCT as seen in our findings.[11,12] Additionally, the thinner SFCT in pre-eclamptic women may be attributed to impaired choroidal blood flow caused by systemic hypertension and endothelial dysfunction, consistent with the pathophysiological changes observed in this condition.[13,14]

When analyzing SFCT categories, we observed that 28.6% of pre-eclamptic participants had an SFCT less than 300 µm, compared to only 9.5% in the healthy pregnant group and 14.2% in the non-pregnant group. This significant discrepancy ($p = 0.031$) further highlights the vulnerability of choroidal thickness in pre-eclamptic women. A similar finding was reported in a study by Waghamare et al., where the prevalence of thin choroids (<300 µm) was higher in pre-eclamptic cases, reinforcing the association between reduced SFCT and hypertensive disorders of pregnancy.[15]

Our subgroup analysis by eye demonstrated consistent results, with both the right eye (338.6 ± 48.7 µm) and left eye (333.3 ± 50.8 µm) in the pre-eclamptic group showing a marked decrease in SFCT compared to their counterparts in the healthy pregnant (373.1 ± 43.2 µm and 377.2 ± 49.5 µm, respectively) and non-pregnant groups (353.5 ± 35.7 µm and 365.3 ± 33.6 µm, respectively). This bilateral symmetry suggests that the thinning of the choroid is a systemic phenomenon rather than localized to one eye, which is consistent with studies evaluating bilateral ocular changes in hypertensive disorders.[16,17]

Further exploration of SFCT across temporal locations (nasal and temporal to the fovea) revealed that the pre-eclamptic group had thinner choroidal measurements in these areas as well, with mean values of 315.1 ± 45.3 µm (temporal) and 310.4 ± 43.1 µm (nasal). These findings align with Kong et al., which noted a significant reduction in choroidal thickness in different regions of the retina in pre-eclamptic patients.[18] Reduced choroidal thickness in specific locations may indicate localized alterations in choroidal perfusion due to impaired vascular function.[19]

The observed differences in SFCT can be attributed to the pathophysiological mechanisms underlying pre-eclampsia. The condition is characterized by an imbalance between angiogenic and anti-angiogenic factors, which can lead to systemic hypertension and impaired uteroplacental circulation. This imbalance could contribute to decreased choroidal blood flow, resulting in thinner choroidal tissue. Our results are consistent with the findings of Liu et al., who demonstrated a correlation between elevated blood pressure and reduced SFCT, implicating hypertension as a primary driver of choroidal thinning.[20]

Comparison of SFCT in the postpartum period revealed that pre-eclamptic participants experienced an increase in SFCT from 337.5 ± 49.8 µm (third trimester) to 345.2 ± 47.3 µm (one week postpartum), with a p-value of 0.045, and further to 358.1 ± 45.2 µm (one month postpartum) with a p-value of 0.014. This recovery aligns with prior studies that noted postpartum normalization of certain ocular parameters following the resolution of pre-eclampsia.[21,22] The gradual increase in SFCT postpartum could be attributed to improvements in blood flow and normalization of vascular tone as the pregnancy-associated hypertensive condition resolves.

In our analysis of associated variables, systolic blood pressure emerged as a significant predictor of SFCT ($\beta = -0.28$, $p = 0.001$), emphasizing the critical role of systemic hypertension in influencing choroidal thickness. This finding is corroborated by Dadaci et al., and Zhang et al., who found a significant relationship between elevated blood pressure and choroidal thinning in pregnant women.[23,24] Diastolic blood pressure also contributed significantly ($\beta = -0.22$, $p = 0.031$), while gestational age was positively associated with SFCT ($\beta = 0.18$, $p = 0.023$), suggesting that as gestational age advances, SFCT may naturally increase, potentially due to changes in systemic vascular conditions. The impact of hemoglobin levels on SFCT was also notable ($\beta = 0.25$, $p = 0.001$), indicating that better oxygenation associated with higher hemoglobin could contribute to a thicker choroid, which is consistent with the role of oxygenation in choroidal health Shao et al.[25]

CONCLUSION

This study highlights the significant impact of pre-eclampsia on SFCT, demonstrating that it is thinner in pre-eclamptic women compared to healthy pregnant and non-pregnant individuals. The data suggest that changes in choroidal thickness are influenced by systemic vascular changes associated with hypertensive disorders during pregnancy. The increase in SFCT observed postpartum indicates a potential normalization process following the resolution of pre-eclampsia, supporting the idea that ocular adaptations may be reversible after the resolution of pregnancy-related hypertension. Additionally, systolic blood pressure and hemoglobin levels were found to be significant predictors of SFCT, emphasizing the role of systemic health in ocular vascular changes. These findings suggest that monitoring SFCT could serve as a non-invasive marker for assessing and managing pre-eclampsia and other hypertensive conditions in pregnancy. Future research should focus on long-term ocular outcomes and potential

interventions for preserving choroidal health in pregnant women at risk of hypertensive disorders.

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