Section: Ophthalmology

Original Research Article

TRIMESTER-SPECIFIC CHANGES IN INTRAOCULAR PRESSURE DURING PREGNANCY: A PROSPECTIVE COHORT STUDY

Nikita Sharma[1], Mohd. Mehboob Alam[2], Anju Nagar[3]

[1]*Assistant Professor, Department of Ophthalmology, Jawaharlal Nehru Medical College, Aligarh Muslim University, Aligarh, Uttar Pradesh, India.*
[2]*Medical officer, Department of Ophthalmology, Pt. Deen Dayal Hospital, Aligarh, Uttar Pradesh, India.*
[3]*Consultant vitreo- Retina, Department of Ophthalmology, ASG Eye Hospital, Jabalpur, Madhya Pradesh, India.*

Received *: 10/01/2025*
Received in revised form *: 08/03/2025*
Accepted *: 24/03/2025*

Corresponding Author:
Dr. Nikita Sharma,
Assistant Professor, of Ophthalmology, Jawaharlal Nehru Medical College, Aligarh Muslim University, Aligarh, Uttar Pradesh, India.
Email: nikitashar276@gmail.com

DOI: 10.70034/ijmedph.2025.2.260

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2025; 15 (2); 1443-1447

ABSTRACT

Background: Intraocular pressure (IOP) is an important ocular parameter that is influenced by various physiological changes during pregnancy. Pregnancy-induced hormonal fluctuations, particularly the elevation of estradiol and progesterone, may alter IOP dynamics. While studies have observed changes in IOP during pregnancy, there is limited data regarding trimester-specific IOP alterations and their correlation with maternal factors such as age, body mass index (BMI), blood pressure, and serum estradiol levels. This study aims to investigate IOP changes across pregnancy trimesters and their associations with maternal characteristics.

Materials and Methods: This prospective cohort study was conducted on 82 pregnant women, with measurements taken in the first, second, and third trimesters. IOP was measured in both eyes using a non-contact tonometer. Maternal factors such as age, BMI, systolic and diastolic blood pressure (SBP, DBP), serum estradiol levels, and gestational age were recorded. A control group of 82 non-pregnant women was also included for comparison. Pearson's correlation coefficient was used to assess relationships between IOP and maternal factors, and comparisons between trimesters were made using paired t-tests.

Results: Significant reductions in IOP were observed across pregnancy trimesters, with mean IOP decreasing from 15.7 ± 2.2 mmHg in the first trimester to 14.3 ± 2.0 mmHg in the second trimester, and further to 13.7 ± 2.0 mmHg in the third trimester ($p < 0.001$ for all comparisons). The control group had higher IOP values (15.9 ± 2.3 mmHg). Pearson's correlation revealed a significant negative correlation between IOP and gestational age ($r = -0.451$, $p < 0.001$) and serum estradiol levels ($r = -0.553$, $p < 0.001$), while systolic ($r = 0.322$, $p = 0.029$) and diastolic blood pressure ($r = 0.369$, $p = 0.031$) showed moderate positive correlations with IOP. No significant correlations were found with BMI and age.

Conclusion: This study demonstrates a significant reduction in IOP as pregnancy progresses, with estradiol and gestational age being negatively correlated with IOP. Blood pressure is positively correlated with IOP during pregnancy. These findings emphasize the need for monitoring IOP in pregnant women, especially those with hypertension or preeclampsia. Further research is warranted to explore the long-term ocular effects of pregnancy-induced changes in IOP.

Keywords: Intraocular Pressure, Pregnancy, Estradiol, Trimester, Glaucoma.

INTRODUCTION

Pregnancy is a dynamic physiological state characterized by systemic hormonal, vascular, and metabolic changes, which influence multiple organ systems, including the ocular system. One critical parameter affected during pregnancy is intraocular pressure (IOP), which is closely associated with the risk and progression of ocular conditions such as glaucoma.[1] Understanding the variations in IOP during different trimesters of pregnancy is crucial for managing ocular health, especially in pregnant individuals with pre-existing eye diseases.[2]

Studies have consistently reported a reduction in IOP during pregnancy, with the changes most notable in the second and third trimesters.[3,4] For instance, an average decrease in IOP ranging from 1.5 to 3.0 mmHg during pregnancy compared to non-pregnant controls, with the lowest values observed in the third trimester.[4] This decline is primarily attributed to hormonal influences, particularly elevated levels of progesterone, relaxin, and estrogen, which enhance aqueous humor outflow and reduce episcleral venous pressure. Progesterone, for example, has been shown to relax ciliary muscle tone, thereby increasing uveoscleral outflow.[5]

Systemic changes also play a role in reducing IOP during pregnancy. The increased cardiac output and decreased systemic vascular resistance observed in pregnancy contribute to reduced episcleral venous pressure, an essential factor in maintaining lower IOP.[6] Additionally, pregnancy-induced corneal biomechanical changes, such as increased elasticity and reduced rigidity, may further influence IOP readings.[7] These physiological alterations are generally reversible postpartum, with IOP levels returning to pre-pregnancy values within weeks after delivery.[8]

The implications of these changes extend beyond physiological adaptation. For instance, women with glaucoma may experience fluctuations in disease progression during pregnancy, necessitating modifications in their treatment plans.[5] In India found that nearly one fourth of women with pre-existing glaucoma required changes in medication due to concerns about fetal safety and pregnancy-induced IOP variations [9]. On the other hand, the natural decline in IOP during pregnancy may offer transient protective effects against glaucomatous progression.[7]

Despite these findings, data on trimester-specific IOP changes remain sparse, particularly in populations with diverse genetic and environmental factors.[9] Studies specific to Indian populations, for example, are limited, even though genetic predisposition and unique environmental factors may influence ocular physiology differently.[10]

This study aimed to evaluate the changes in intraocular pressure across the three trimesters of pregnancy, providing critical insights into the trimester-specific dynamics of IOP. The findings will contribute to a better understanding of ocular physiological adaptations during pregnancy and offer guidance for the clinical management of pregnant individuals with or at risk of ocular disorders.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Department of Ophthalmology at a tertiary care hospital, for a period of 2 years from June 2022 to May 2024. The study focused on evaluating changes in intraocular pressure (IOP) among pregnant women during different trimesters of pregnancy. The study also included a control group of non-pregnant women matched for age and body mass index (BMI) to provide a baseline for comparison.

Study Population

The study enrolled pregnant women in first trimester (≤12 weeks) aged 20–40 years with confirmed singleton pregnancies attending the antenatal clinic and ophthalmology outpatient department and were also followed in second trimester (13–26 weeks), and third trimester (≥27 weeks). Additionally, a control group of healthy, non-pregnant women with regular menstrual cycles was included. Participants with a history of glaucoma, previous ocular surgery, systemic diseases such as diabetes or hypertension, thyroid dysfunction, or the use of medications known to affect IOP were excluded. Recruitment was done consecutively to minimize selection bias.

Sample Size

The sample size was calculated using a formula for detecting differences in means, assuming a clinically significant difference of 2 mmHg in IOP across trimesters, a standard deviation of 2.5 mmHg, a significance level of 0.05, and 80% power.[11] A minimum of 78 pregnant women, and the control group, was required. To account for potential dropouts, the final sample size was adjusted to 82 participants per group. So, a total of 164 participants were enrolled in the study.

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee. All participants provided written informed consent before enrollment. The study adhered to the principles of the Declaration of Helsinki, ensuring participant confidentiality and the voluntary nature of participation.

Data Collection

Demographic and clinical data, including age, BMI, gestational age, and medical history, were recorded during the initial visit. IOP was measured using a Goldmann applanation tonometer, which is widely regarded as the gold standard for IOP measurement. All measurements were taken in a controlled clinical environment to ensure consistency and reliability.

Measurements were performed in both eyes between 9:00 AM and 11:00 AM to minimize the effects of diurnal variation. For each eye, three consecutive IOP readings were obtained, and the average value was recorded. Calibration of the tonometer was performed daily before data collection. All measurements were conducted by a single trained ophthalmologist to eliminate inter-observer variability.

Pregnant women were evaluated during routine antenatal visits, with measurements taken once in each trimester. Non-pregnant controls were assessed during a single visit. Gestational age was confirmed using ultrasonography and the last menstrual period.

Statistical Analysis

Data were entered into a spreadsheet and analyzed using SPSS software 20.0. Continuous variables, such as IOP and BMI, were expressed as mean ± standard deviation, while categorical variables, such as demographic characteristics, were summarized as frequencies and percentages. A one-way analysis of variance (ANOVA) was used to compare mean IOP across the trimesters and the control group, followed by Tukey's post-hoc test for pairwise comparisons. The correlation between IOP and gestational age, BMI, and other clinical variables was assessed using Pearson's correlation coefficient. Statistical significance was set at $p < 0.05$.

RESULTS

The study included 164 participants: 82 pregnant women followed through the first, second, and third trimesters, and 82 age- and BMI-matched non-pregnant women as controls. The mean age was similar across groups, with the majority of participants in their mid-to-late twenties. BMI increased progressively across trimesters, and parity distribution in the first trimester was nearly equal (51.2% primiparous). Blood pressure showed a significant decline during pregnancy, with systolic and diastolic values decreasing progressively across trimesters compared to the control group ($p = 0.034$ and $p = 0.022$, respectively). Hemoglobin levels also exhibited a significant reduction, dropping from 11.8 ± 0.8 g/dL in the first trimester to 11.3 ± 1.0 g/dL in the third trimester, compared to 12.1 ± 0.8 g/dL in controls ($p = 0.041$). Serum estradiol levels rose markedly during pregnancy, with a significant increase from 436.8 ± 62.3 pg/mL in the first trimester to 3763.2 ± 190.2 pg/mL in the third trimester, significantly higher than the control group's levels of 85.9 ± 15.6 pg/mL ($p < 0.001$) (Table 1).

Table 1: Demographic and Clinical Characteristics of Participants across Different Trimesters and Control Group

Characteristic	First Trimester (n=82)	Second Trimester (n=82)	Third Trimester (n=82)	Control Group (n=82)	p-value
	Frequency (%)/Mean ± SD				
Age (years)	27.8 ± 3.4	27.8 ± 3.4	27.8 ± 3.4	27.6 ± 3.5	0.871
Body Mass Index (BMI, kg/m²)	23.1 ± 2.8	24.3 ± 2.9	24.4 ± 3.0	22.0 ± 2.9	0.734
Parity					
Primi	42 (51.2)	-	-	-	-
Multi	40 (48.8)	-	-	-	-
Systolic Blood Pressure (mmHg)	112.4 ± 7.1	110.2 ± 6.8	109.6 ± 7.0	114.0 ± 6.9	0.034
Diastolic Blood Pressure (mmHg)	72.8 ± 5.4	70.4 ± 6.1	69.8 ± 6.0	74.2 ± 5.8	0.022
Hemoglobin (g/dL)	11.8 ± 0.8	11.6 ± 0.9	11.3 ± 1.0	12.1 ± 0.8	0.041
Serum Estradiol Levels (pg/mL)	436.8 ± 62.3	1321.4 ± 155.8	3763.2 ± 190.2	85.9 ± 15.6	<0.001

In this study, intraocular pressure (IOP) measurements revealed significant changes across the trimesters compared to the control group. The mean IOP in the right eye decreased progressively from 15.8 ± 2.3 mmHg in the first trimester to 13.8 ± 2.0 mmHg in the third trimester, with the control group showing a higher mean of 16.0 ± 2.4 mmHg ($p < 0.001$). A similar trend was observed in the left eye, with a decrease from 15.6 ± 2.2 mmHg in the first trimester to 13.6 ± 2.1 mmHg in the third trimester, compared to 15.9 ± 2.3 mmHg in the control group ($p < 0.001$). The combined IOP values also showed a significant reduction across trimesters, from 15.7 ± 2.2 mmHg in the first trimester to 13.7 ± 2.0 mmHg in the third trimester, with the control group showing a higher value of 15.9 ± 2.3 mmHg ($p < 0.001$). The incidence of IOP > 21 mmHg was lower in the pregnant groups (2.4% in the first trimester) compared to the control group (4.9%) ($p = 0.036$) (Table 2).

Table 2: Intraocular Pressure (IOP) in Different Trimesters of Pregnancy and Control Group

Intraocular pressure (IOP)	First Trimester (n=82)	Second Trimester (n=82)	Third Trimester (n=82)	Control Group (n=82)	p-value
	Frequency (%)/Mean ± SD				
Right Eye (mmHg)	15.8 ± 2.3	14.4 ± 2.1	13.8 ± 2.0	16.0 ± 2.4	<0.001
Left Eye (mmHg)	15.6 ± 2.2	14.2 ± 2.0	13.6 ± 2.1	15.9 ± 2.3	<0.001
Combined (mmHg)	15.7 ± 2.2	14.3 ± 2.0	13.7 ± 2.0	15.9 ± 2.3	<0.001
IOP > 21 mmHg	2 (2.4)	0 (0.0)	0 (0.0)	4 (4.9)	0.036

The comparison of intraocular pressure (IOP) across trimesters revealed significant reductions. From the first to the second trimester, the mean decrease in IOP was -1.3 mmHg (±0.6), with a 95% confidence interval of [-1.5, -1.1], and this change was statistically significant (p < 0.001). A further reduction of -0.6 mmHg (±0.4) was observed from the second to the third trimester, with a 95% confidence interval of [-0.7, -0.5] (p < 0.001). The cumulative decrease from the first to the third trimester was -2.7 mmHg (±0.8), with a 95% confidence interval of [-2.3, -1.7], which was also statistically significant (p < 0.001) (Table 3).

Table 3: Comparison of Intraocular Pressure (IOP) Across Different Trimesters of Pregnancy

Trimester Comparison	IOP Change (mmHg)			p-value
	Mean	SD	95% CI	
First to Second Trimester	-1.3	±0.6	[-1.5, -1.1]	<0.001
Second to Third Trimester	-0.6	±0.4	[-0.7, -0.5]	<0.001
First to Third Trimester	-2.7	±0.8	[-2.3, -1.7]	<0.001

A significant negative correlation was observed between intraocular pressure (IOP) and gestational age (r = -0.451, p < 0.001), indicating that IOP tends to decrease as pregnancy progresses. Serum estradiol levels also showed a significant negative correlation with IOP (r = -0.553, p < 0.001), suggesting that higher estradiol levels may be associated with lower IOP. Systolic and diastolic blood pressures had weak but statistically significant positive correlations with IOP (r = 0.322, p = 0.029; r = 0.369, p = 0.031, respectively), implying that higher blood pressure may be associated with increased IOP. Body mass index (BMI) and age did not show significant correlations with IOP (r = 0.157, p = 0.186; r = 0.184, p = 0.298, respectively), suggesting that these factors may have a minimal impact on IOP in this population (Table 4).

Table 4: Correlation Between Intraocular Pressure (IOP) and Clinical Variables

Variable	Pearson's Correlation Coefficient (r)	p-value
Gestational Age (weeks)	-0.451	<0.001
Body Mass Index (kg/m^2)	0.157	0.186
Age (years)	0.184	0.298
Systolic Blood Pressure (mmHg)	0.322	0.029
Diastolic Blood Pressure (mmHg)	0.369	0.031
Serum Estradiol Levels (pg/mL)	-0.553	<0.001

DISCUSSION

This study aimed to investigate the changes in intraocular pressure (IOP) across the trimesters of pregnancy, comparing it with a control group of non-pregnant women, and to explore potential correlations with various maternal factors. The findings revealed a significant decline in IOP as pregnancy advanced, with the mean IOP decreasing from 15.7 ± 2.2 mmHg in the first trimester to 14.3 ± 2.0 mmHg in the second trimester and 13.7 ± 2.0 mmHg in the third trimester (p < 0.001). These results are consistent with previous studies by Paramjyothi et al., and Sundaram et al., who reported a progressive reduction in IOP during pregnancy.[12,13] This decrease in IOP is likely a result of hormonal changes, particularly elevated levels of estradiol and progesterone during pregnancy, which are known to affect the dynamics of aqueous humor production and drainage.[14]

Pregnancy induces an increase in circulating estradiol levels, which plays a pivotal role in modulating ocular fluid dynamics.[15] Our study found a significant negative correlation between serum estradiol levels and IOP (r = -0.553, p < 0.001), suggesting that higher estradiol levels are associated with a reduction in IOP. This finding aligns with the work of Qin et al., who found that estradiol affects the trabecular meshwork and Schlemm's canal, leading to improved drainage of intraocular fluid and subsequent reduction in IOP.[16] Erkan Pota et al., also noted that estradiol-induced changes in the uveoscleral outflow contribute significantly to the reduction in IOP during pregnancy.[17]

Gestational age was another factor significantly correlated with IOP in this study. The negative correlation (r = -0.451, p < 0.001) between gestational age and IOP suggests that as pregnancy progresses, IOP continues to decrease, likely due to the sustained increase in estrogen and progesterone levels. This is supported by Bujor et al., who observed that with increasing gestational age, the ocular changes induced by hormonal fluctuations tend to intensify, leading to a decrease in IOP.[18] This is also consistent with the findings of Yang et al., who reported that IOP reductions were more prominent in the third trimester, possibly due to the peak levels of estradiol at that time.[19]

Conversely, in our study, systolic blood pressure (SBP) and diastolic blood pressure (DBP) exhibited moderate positive correlations with IOP (r = 0.322, p = 0.029; r = 0.369, p = 0.031, respectively). This suggests that elevated blood pressure may contribute to higher IOP, a well-established phenomenon in ophthalmology. Similar findings were observed by Nislawati et al., who demonstrated that hypertension is a significant risk factor for increased IOP.[20] The positive correlation between blood pressure and IOP in pregnancy is especially pertinent, as hypertensive disorders such as preeclampsia are common during pregnancy and are known to cause elevated IOP and increase the risk of glaucoma.[21] This highlights the need for close monitoring of blood pressure and IOP in pregnant women, particularly those with a history of hypertension or preeclampsia, to prevent long-term ocular complications.[22]

The role of body mass index (BMI) and age in influencing IOP was less pronounced in this study. BMI showed no significant correlation with IOP ($r = 0.157$, $p = 0.186$). These results suggest that other physiological factors, such as hormonal changes, might have a more pronounced effect on IOP than BMI and age during pregnancy.[23,24]

Interestingly, the incidence of elevated IOP (>21 mmHg) was observed to be higher in the first trimester (2.4%), compared to 0% in the second and third trimesters. While this suggests a transient elevation in IOP early in pregnancy, the decline in IOP in later trimesters may reflect the cumulative effects of hormonal changes that induce aqueous humor drainage and decrease fluid production. This finding supports the work of Sen et al., who observed that IOP tends to stabilize and decrease as pregnancy progresses, likely due to the peak levels of progesterone and estradiol reached in the second and third trimesters.[25]

The trimester-based comparison of IOP changes revealed a mean reduction of -1.3 mmHg from the first to the second trimester, -0.6 mmHg from the second to the third trimester, and -2.7 mmHg from the first to the third trimester ($p < 0.001$ for all comparisons). These reductions were consistent with study by Goldich et al, who reported that IOP decreases as pregnancy advances, with the greatest reduction observed from the first to the third trimester.[26] The decrease in IOP during pregnancy is thought to be mediated by hormonal changes and changes in blood pressure regulation, both of which are tightly linked to the progression of pregnancy.[26]

CONCLUSION

In conclusion, our study adds to the existing body of literature on IOP changes during pregnancy, highlighting the dynamic nature of ocular health throughout the course of gestation. The significant correlation between IOP and estradiol levels, as well as blood pressure, provides a scientific basis for understanding the ocular changes during pregnancy and their potential impact on pre-existing ocular conditions. Clinicians should be aware of these changes and consider them when managing pregnant women, particularly those with risk factors for ocular disease.

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