Macular and Peripapillary Choroidal Thickness Measured by Enhanced Depth Imaging Optical Coherence Tomography in Chinese Pregnant Women and Healthy No-Pregnant Women

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Research Article

Keywords: Macular Choroidal thickness, Peripapillary choroidal thickness, Retinal nerve fiber layer, Enhanced depth imaging optical coherence tomography, Pregnancy.

Posted Date: December 20th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1127595/v1

Abstract

Purpose: To evaluate macular, peripapillary choroidal thickness and retinal nerve fiber layer (RNFL) thickness in different trimesters and compare the measurements with those of healthy non-pregnant women.

Methods: A prospective comparative study included 45 healthy pregnant women in first trimester, 90 women in second, 45 women in third trimesters and 45 healthy no-pregnant women as the control group. Macular choroidal thickness was measured at the subfoveal, 1mm temporal and 1mm nasal to the fovea using enhanced depth imaging optical coherence tomography (EDI-OCT). Peripapillary choroidal thickness and RNFL thickness parameters were automatically calculated by the Spectralis OCT. These parameters were analyzed among groups.

Results: The subfoveal, temporal and nasal choroidal thickness were all significantly thicker in second trimesters, comparing with those parameters in first, third trimesters and the control group (all $P<0.05$). The peripapillary choroidal thickness was significantly increased at temporal, nasal, nasal inferior, temporal inferior and global positions during pregnancy among the 4 groups (all $P<0.05$). The RNFL thickness was also significantly increased in pregnant women at nasal superior and nasal inferior quadrants.

Conclusions: Our results suggested that macular choroidal thickening appeared in second trimester. And peripapillary choroidal thickness and RNFL thickness also became thickening in pregnant women comparing with no-pregnant women as a whole.

Introduction

Pregnancy is a natural state that causes physiologically changes nearly all organs. These are associated with vascular, immunologic, metabolic, and hormonal systems changes [1]. Eye is one of the most important organs affected by these changes during pregnancy. It is reported that many ocular changes occur during pregnancy such as increases in corneal thickness and corneal curvature and decreases in corneal sensitivity and intraocular pressure [2]. Furthermore, pathological changes also have been reported during pregnancy including central serous chorioretinopathy (CSC), for which pregnancy especially pre-eclampsia is considered a risk factor [3]. The increased incidence of CSC is due to the hyperpermeability of choroid vessels during pregnancy [4].

Choroid plays a vital role in eye for the physiological and pathological functions, which is extremely sensitive to fluctuation of blood pressure [5]. During pregnancy, systemic vascular resistance decreases and hemodynamic changes affect blood pressure. Therefore, choroidal thickness makes corresponding changes as hemodynamic alterations. In addition, it is reported that the incidence of preeclampsia in all pregnant women is about 5%-7% [6]. The ocular symptoms of preeclampsia include retinopathy, optic neuropathy, retinal edema and so on. The damage to optic nerves also can lead to visual loss. Consequently, it is unclear the effect of pregnancy on retinal nerve fiber layer (RNFL) thickness at present. With developing technology, enhanced depth imaging optical coherence tomography (EDI-OCT), as a

noninvasive, rapid and high-resolution diagnostic method, is widely used for evaluating choroidal anatomy at recent studies [7].

Gokta S, et al [5]. showed that choroidal thickness increased during pregnancy in the second trimester. Dadaci, et al. obtained healthy pregnant women in the first trimesters and third trimesters. In their research, the choroidal thickness significantly

decreased in the third trimesters [8]. However, other study reported that no significant statistical differences were found for choroidal thickness between the pregnant and non-pregnant women at any of the measurement points [9]. Nowadays, there was few study about the change of peripapillary choroidal thickness for pregnant women. In addition, Arab, et al. reported that mean peripapillary RNFL thickness decreased significantly after pregnancy no mater in preeclampsia, eclampsia, or healthy pregnant women groups [10]. Another study showed average of RNFL thickness was significantly thicker in healthy pregnant group than healthy non-pregnant group [6]. However, in Tok, et al. Study, the mean RNFL thickness was similar in both preeclampsia and healthy pregnant women [11]. So the relationship between the change for choroidal thickness, peripapillary choroidal thickness, RNFL thickness and pregnancy were still unclear at present.

The aims of our study were to observe and compare macular choroidal thickness, peripapillary choroidal thickness and RNFL thickness in pregnant women and no-pregnant women. Furthermore, to analyzed the correlation among these parameters.

Methods

This study conformed to the tenets of the Declaration of Helsinki, and approved by the Ethics Committee of the people's hospital of Zhuji [NO. 2020(0015)]. All participants signed an informed consent form regarding to participate in the present study. This prospective study was performed at the people's hospital of Zhuji from January 2020 to December 2020.

A total of 180 healthy pregnant women and 45 non-pregnant women at the reproductive age were investigated. This study was conducted with 4 groups: the first trimester was defined as gestational age less than 13 weeks (n=45), the second trimester from 14 weeks to 28weeks (n=90) and the third trimester over 28weeks (n=45) [12]. The control group was consisted of healthy no-pregnant women (n=45) .

The inclusion criteria were healthy pregnant women without system diseases, healthy no-pregnant women, whose age between 20 to 45 years old and axial length (AL) between 21 to 26mm. Exclusion criteria included high introcular pressure (>21mmHg), systemic diseases or ocular diseases that might affect retinal or choroidal thickness(such as diabetes mellitus, high blood pressure, glaucoma, uveitis and choroidal diseases) [5].

All participants received a comprehensive ocular examination, including best-corrected visual acuity (BCVA), slit-lamp examination, intraocular pressure (IOP) measurement, AL measurement and dilated funduscopy. Noncontact tonometer (TX-20P, Canon Tokyo Japan) and noncontact optical biometer (IOL

Master, Carl zeiss Germany) were used for measure IOP and AL. Choroidal thickness were measured by EDI-OCT using spectral domain OCT after pupil dilation (Spectralis OCT; Heidelberg Engineering, Heidelberg, Germany) that encompassed the macular and optic nerve. Choroidal thickness referred to the areal from the outer surface of the retinal pigment epithelium to the chorioscleral interface. Macular choroidal thickness were measured at the fovea and at position 1 mm temporal and nasal to the fovea (Figure 1). Only the horizontal scan through the center of the macular was selected for further analysis. Peripapillary choroidal thickness was manual measured by Herdelberg Engineering software. Firstly, the inner boundary of RNFL was adjusted to the outer lay of RNFL hyperreflection, then the outer boundary of RNFL was adjusted to the chorioscleral interface, the distance between the inner and outer boundary of RNFL was peripapillary choroidal thickness(Figure2) [13]. The peripapillary choroidal thickness and RNFL thickness parameters were automatically calculated by the SD-OCT and divided into seven sections: temporal quadrant, temporal superior quadrant, nasal superior quadrant, nasal quadrant, nasal inferior quadrant, temporal inferior quadrant, and global thickness [14]. Central macular thickness (CMT) was measured, which defined as the distance between the internal limiting membrane (ILM) and the surface of retinal pigment epithelium (RPE) at the fovea. Average of three consecutive CMT measurements was used for analysis. All OCT scans were completed in the morning (8:00am to 12:00pm) to avoid diurnal variations of choroidal thickness [2]. All measurements were performed by an experienced ophthamologist. Only right eye was selected for further analysis.

Statistical analysis was performed using SPSS version 22 (IBM Corp., Armonk, NY, USA). All data are expressed as the mean ± standard deviation. Comparisons between the pregnant and non-pregnant women were performed using the Student's *t* test. One-way analysis of variance (ANOVA) was used to determine the significance of differences among the four groups. The association among macular choroidal thickness, peripapillary choroidal thickness, peripapillary RNFL thickness and CMT were assessed using Pearson's correlation coefficient tests. A *P* value of 0.05 was considered significant.

Results

Demographics and clinical features

One hundred eighty eyes of 180 healthy pregnant women and 45 eyes of 45 age-matched healthy no-pregnant women were included. The mean gestational age was 11.47±1.32, 23.69±3.81 and 31.13±2.46weeks in first, second, and third trimester, respectively. The mean age, AL, IOP and CMT of the 4 groups did not differ significantly. The demographic and clinical characteristics of the participants were summarized in Table 1.

Table 1
Demographic and clinical characteristics for pregnant and control groups

Characteristics	first trimester (n=45)	second trimester (n=45)	third trimester (n=45)	control group (n=45)	F	P
GA(weeks)	11.47±1.32	23.69±3.84	31.13±2.46	/		
Age(years)	29.18±3.96	29.69±4.61	30.18±3.71	30.64±6.64	0.76	0.52
AL(mm)	24.07±1.02	24.04±0.88	24.13±1.06	24.40±1.02	0.99	0.40
IOP(mmHg)	13.00±2.07	12.35±2.41	12.77±1.92	13.02±2.66	0.83	0.48
CMT	206.31±18.29	203.40±10.21	202.56±11.16	203.42±14.37	0.63	0.60

Values are presented as the mean±standard deviation. GA: gestational age. AL: axial length. IOP: intraocular pressure. CMT: central macular thickness.

Macular choroidal thickness

There were statistically significant differences in subfoveal (t=2.09, P=0.04) and nasal positions (t=2.53, P=0.01) between healthy pregnant women and no-pregnant women. However, no significant difference was seen in temporal position (t=1.71, P=0.09).

The pregnant women were further divided into three subgroups according to the GA. There were statistically significant difference among the 4 groups in subfoveal, temporal and nasal positions (all P<0.05)(Table 2).

Table 2
Macular choroidal thickness for each group.

Location	first trimester (n=45)	second trimester (n=90)	third trimester (n=45)	control group (n=45)	F	P*
Subfoveal(mm)	268.87±44.35	308.98±52.83	272.64±65.16	267.47±86.73	7.27	<0.001
Temporal(mm)	277.69±52.35	307.82±56.66	280.44±75.12	272.27±76.85	4.31	0.01
Nasal(mm)	243.78±36.26	283.44±54.25	251.53±65.98	238.44±89.07	7.32	<0.001

Values are presented as the mean±SD. *means ANOVA test.

Peripapillary choroidal thickness

For the mean peripapillary choroidal thickness, there were statistically significant difference at temporal quadrant (T, t=2.05, P=0.04), nasal quadrant (N, t=2.23, P=0.03), nasal inferior quadrant (NI, t=2.21, P=0.03), temporal inferior quadrant (TI, t=2.44, P=0.02) and global quadrant (G, t=2.17, P=0.03) between

pregnant women and no-pregnant women. However, no significant differences were found at temporal superior (TS, t=0.55, P=0.58) and nasal superior positions (NS, t=1.06, P=0.29).

In addition, peripapillary choroidal thickness was further compared among the 4 groups. We noticed that there were also statistical differences among the groups at T, N, NI, TI and G positions (all P<0.05) (Table 3).

Table 3
Peripapillary choroidal thickness for each group

location	first trimester (n=45)	second trimester (n=90)	third trimester (n=45)	control group (n=45)	F	P*
T	172.44±47.30	188.09±44.81	173.53±40.24	163.80±63.39	2.86	0.04
TS	189.20±49.55	203.20±39.18	197.36±36.55	194.09±57.91	1.07	0.36
NS	195.33±48.39	207.60±43.70	201.11±43.05	194.49±58.89	1.06	0.37
N	188.36±52.96	202.91±50.23	191.44±45.77	176.11±55.72	2.89	0.04
NI	163.27±54.84	177.67±44.73	166.24±42.16	150.64±57.93	3.15	0.03
TI	160.47±53.31	171.69±45.51	154.42±40.89	144.62±57.14	3.40	0.02
G	178.47±46.71	192.84±39.94	181.22±37.48	170.35±54.28	2.91	0.04

Values are presented as the mean±SD. *means ANOVA test. T-temporal, TS- temporal superior, NS-nasal superior, N-nasal, NI-nasal inferior, TI-temporal inferior; G-global.

Peripapillary RNFL thickness

In pregnant women, the peripapillary RNFL thickness was thicker only at the NS (t=2.81, P=0.01) and NI quadrants (t=3.27, P<0.05) comparing with no-pregnant women. Meanwhile, there were same significant differences of peripapillary RNFL thickness among 4 subgroups at NS and NI quadrants (Table4) .

Table 4
Mean peripapillary RNFL thickness among subgroups

location	first trimester (n=45)	second trimester (n=90)	third trimester (n=45)	Control group (n=45)	F	*P**
T	92.69±16.27	93.56±16.81	94.44±20.32	92.24±18.89	0.14	0.94
TS	143.64±29.28	150.73±22.30	148.33±25.26	141.29±21.07	1.88	0.13
NS	111.31±29.34	115.13±20.59	111.64±29.17	100.29±28.47	3.32	0.02
N	66.67±16.41	67.62±13.74	65.22±17.12	62.47±22.23	0.98	0.40
NI	118.73±29.97	122.44±26.08	123.73±26.06	106.53±28.31	4.04	0.01
TI	158.93±24.94	160.47±32.58	165.20±30.72	158.67±23.77	0.49	0.69
G	106.47±10.90	107.09±11.96	107.93±12.80	104.16±10.09	0.92	0.43

Values are presented as the mean±SD. *means ANOVA test. T-temporal, TS- temporal superior, NS-nasal superior, N-nasal, NI-nasal inferior, TI-temporal inferior; G-global.

Correlations analysis

The subfoveal, temporal and nasal choroidal thickness all had significant positive correlations with peripapillary choroidal thickness at any positions(all $P<0.05$). Besides, the subfovea choroidal thickness had significant positive correlations with temporal choroidal thickness ($P<0.05$) and nasal choroidal thickness($P<0.05$). And the temporal choroidal thickness had significant positive correlations with nasal choroidal thickness($P<0.05$) (Table 5). No significant correlations was found between the subfoveal, temporal, nasal choroidal thickness and CMT(all $P>0.05$).

Table 5
Correlation between macular choroidal thickness and peripapillary choroidal thickness in pregnant women

peripapillary choroidal thickness	Macular choroidal thickness					
	subfovea		temporal		nasal	
	r	*P*	*r*	*P*	*r*	*P*
N	0.338	<0.001	0.306	<0.001	0.330	<0.001
NS	0.322	<0.001	0.276	0.001	0.327	<0.001
TS	0.380	<0.001	0.310	0.001	0.390	<0.001
T	0.457	<0.001	0.349	<0.001	0.499	<0.001
TI	0.428	<0.001	0.326	<0.001	0.479	<0.001
NI	0.330	<0.001	0.287	0.001	0.373	<0.001
G	0.426	<0.001	0.351	<0.001	0.454	<0.001
temporal	0.806	<0.001	-	-	0.739	<0.001
nasal	0.901	<0.001	0.739	<0.001	-	-

In addition, we found the subfoveal, temporal and nasal choroidal thickness had positive correlation with peripapillary RNFL thickness at N (r=0.349, P<0.001; r=0.310, P<0.001; r=0.353, P<0.001, respectively) and NS quadrants (r=0.271, P<0.001; r=0.233, P<0.001; r=0.244, P<0.001, respectively). The subfoveal and nasal choroidal thickness had negative correlation with peripapillary RNFL thickness at T (r=-0.244, P=0.001; r=-0.159, P=0.033, respectively) and TI quadrants (r=-0.215, P=0.004; r=-0.232, P=0.001, respectively). The temporal choroidal thickness had negative correlation with peripapillary RNFL thickness at TI quadrants (r=-0.254, P=0.001) (Table 6).

Table 6
Correlation between macular choroidal thickness and peripapillary RNFL thickness in pregnant women

peripapillary RNFL thickness	macular choroidal thickness					
	subfovea		temporal		nasal	
	r	*P*	*r*	*P*	*r*	*P*
N	0.349	<0.001	0.310	<0.001	0.353	<0.001
NS	0.271	<0.001	0.233	0.002	0.244	<0.001
TS	-0.011	0.887	0.037	0.625	-0.009	0.899
T	-0.244	0.001	-0.142	0.057	-0.159	0.033
TI	-0.215	0.004	-0.254	0.001	-0.232	0.002
NI	0.205	0.006	0.106	0.155	0.175	0.018
G	0.024	0.748	0.012	0.876	0.029	0.702

Discussion

By comparing 180 healthy pregnant women in different trimesters with 45 healthy no-pregnant women in our study, we detected macular choroidal thickness increased during pregnancy. It was consisted with previous reports [4]. Kara, et al. study showed that subfoveal choroidal thickness increased in pregnant women compared with age-matched no-pregnant women [4]. However, Azuma et al. and Rothwell et al. had demonstrated that there was no significant difference in macular choroidal thickness between healthy pregnant and non-pregnant women [15, 16]. Only the pregnant women in the first or third trimester were enrolled in their study might attribute to this contradictory results. As distinct from these studies, we enrolled the pregnant women in each trimesters and performed macular choroidal thickness examination via EDI-OCT.

Our research also found that the most obvious increase of choroidal thickness appeared in the second trimester. It was consisted with GoktaS, et al. report that choroidal thickening could occur at the regions subfoveal, temporal, and nasal to the fovea in the second trimester [5]. Additionally, one study suggested the subfoveal and parafoveal chorodial thickness also increased significantly in second trimester in comparison to the first or third trimester [17]. And, a study conducted by Dadaci, et al. revealed choroidal thickness significantly decreased in the last trimester compared to the first trimester [8]. We considered that blood volume gradually increased at the beginning of pregnancy and a rapid increase occurred in second trimester, after then, slowly increased. Besides, vascular resistance progressively decreased from the fifth week of the gestation that caused blood pressure reduced [5]. The most obvious change of blood volume and vascular resistance occurred in the middle of pregnancy. Therefore, it might be the reason for the increase of choroidal thickness in the second trimester. Pregnancy was been considered a risk factor for CSC that commonly developed in the third trimester. Tan, et al. observed that choroidal thickness increased

significantly in patients with acute CSC [18]. We speculated the increased choroidal thickness observed in the second trimester might be the stimulative factor underlying development of CSC in the third trimester.

As we all known, there were no literature about peripapillary choroidal thickness of pregnant women. Previous studies on peripapillary choroidal thickness only been reported in some systemic diseases. Vural, et al [19] found that inferior and nasal peripapillary choroidal thicknesses decreased in patients with vitamin D deficiency. In their study, they thought that a decrease in vitamin D activity in the eye could cause vascular endothelial dysfunction and resulted in choroidal thinning. Patients with multiple sclerosis (MS) showed peripapillary choroidal thinning when compared with healthy subjects in all zones around the optic disc [20]. They considered the decrease of peripapillary choroidal thickness might be secondary to a reduction in blood flow subsequent to RNFL atrophy in MS patients. Therefore, changes in choroidal blood volume might resulted in the dysfunction of photoreceptors and peripapillary choroidal status was important due to the role of choroidal vascularity in the anterior optic nerve [21]. In our study, peripapillary choroidal thickness was thicker in pregnant women with significance for temporal, nasal, nasal inferior, temporal inferior and global quadrant measurement. This result had not been reported before and the significance of this finding has yet to be determined. The precise mechanism for increased peripapillary choroidal thickness at most zones during pregnancy in our study was still unclear nowadays.

The RNFL was the inner retinal layer formed of axons from the retinal ganglion cells, and was the only central nervous system structure which was visible on fundoscopic examination as axons converge in the optic disc [11]. Therefore, it could discover axonal damage and reflected neuroprotection and neurodegeneration. In our study, we found the peripapillary RNFL thickness was thicker at the NS and NI quadrants in normal pregnant women. Tok, et al investigated the effects of severe preeclampsia on RNFL and they found no significant difference between preeclampsia and healthy pregnant women during the pregnancy [11]. In contrast to their study, Neudorfer's study showed that the RNFL thickness increase in pre-eclamptic patients with abnormal retinal findings compared to the pre-eclamptic patients without abnormal retinal findings [22]. However, there was no control group included healthy pregnant women in their study. At present, we could not find any literature on RNFL measurement in health pregnant women. As we all known, the structures of RNFL not only composed of ganglion cells axons, but also glial and vascular components [23]. Therefore, we could only speculate a thicker RNFL in pregnant women compared to no-pregnant women might caused by pregnant-related vasodilatation. It was reported that the RNFL thickenss also could thicker in preeclampsia because of retinal edema secondary to cerebral edema [22]. Therefore, the change of RNFL thickness might reflect subclinical involvement of the central nervous system in their disease,especially for preeclampsia women. Further studies were needed to investigate this possibility in depth.

Previous researches observed the relationship between choroidal thickness and refractive error, intraocular pressure or axial length and so on [9]. Our study found the subfoveal, temporal and nasal choroidal thickness were all positively correlated with peripapillary choroidal thickness. The subfoveal choroidal thickness was also positively correlated with temporal and nasal choroidal thickness. Additionally, the subfoveal, temporal and nasal choroidal thickness all had positive correlation with peripapillary RNFL

thickness at N and NS quadrants. No correlations with subfoveal or peripapillary choroidal thickness were found for CMT. Our results had not been reported before, which indicated that choroid as a whole appeared a tendency of elevation in thickness no matter on macular or optic disk during pregnancy. During pregnancy, vascular resistance decreased due to hormonal change and resulted in reduced blood pressure. The reduction of blood pressure and systemic vascular resistance might explain the increase of the whole choroidal thickness. In addition, one study reported ocular blood flow would increase during pregnancy caused by vasodilation due to estrogen change [5]. Therefore, we considered that these factors would affect both macular and peripapillary choroidal thickness and the choroidal thickness elevation presented a positive correlation between macular and optic disk.

One of our limitations of our study was that we did not evaluate the same pregnant woman from the first trimester to postpartum. A longitudinal study of choroidal thickness could been conducted in further study. Another limitation of our study was that patients of preeclampsia were not enrolled in our study. The change of peripapillary choroidal thickness in preeclampsia was still unknown.

Conclusions

Our study shows macular choroidal thickness increased during pregnancy and most obviously increased in second trimester. It implies to us that we need pay more attention to the ocular change of pregnant women in the second trimester. And peripapillary choroidal thickness and RNFL thickness also become thicker in pregnancy women simultaneously. We think our results provide valuable information in regard to interpreting pregnancy associated ocular disorders and constitute the basis for future studies.

Declarations

Acknowledgments

No application.

Funding

This work was supported by The Medical and Health Science and Technology Plan of Zhejiang Province (2021RC163).

Confict of interest

There are no ethical/legal conflicts involved in the article. All authors have read and approved the content, and agree to submit it for consideration for publication in your journal.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Haishuang Lin, Huanjie Fang, Mengting Ruan and Jiawei Zhao. The first draft

of the manuscript was written by Hanfei Wu and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethical approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the people's hospital of Zhuji [NO.2020(0015)]. We affirmed that our participants provided informed consent for publication of the images in Figure 1a, 1b and Figure 2.

Consent to participate

Informed consent was obtained from all individual participants included in this study. The participants provided their written informed consent to participate in this study.

References

1. Ulusoy DM, Duru N, Ataş M et al (2015) Measurement of choroidal thickness and macular thickness during and after pregnancy. Int J Ophthalmol 8:321–325. https://doi.org/10.3980/j.issn.2222-3959.2015.02.19
2. Benfica CZ, Zanella T, Farias LB et al (2018) Comparative analysis of choroidal thickness in third trimester pregnant women. Int J Retina Vitreous 4:6. https://doi.org/10.1186/s40942-018-0108-0
3. Kim JW, Park MH, Kim YJ et al (2016) Comparison of subfoveal choroidal thickness in healthy pregnancy and pre-eclampsia. Eye (Lond) 30:349–354. https://doi.org/10.1038/eye.2015.215
4. Kara N, Sayin N, Pirhan D et al (2014) Evaluation of subfoveal choroidal thickness in pregnant women using enhanced depth imaging optical coherence tomography. Curr Eye Res 39:642–647. https://doi.org/10.3109/02713683.2013.855236
5. Goktas S, Basaran A, Sakarya Y et al (2014) Measurement of choroid thickness in pregnant women using enhanced depth imaging optical coherence tomography. Arq Bras Oftalmol 77:148–151. https://doi.org/10.5935/0004-2749.20140038
6. Ataş M, Açmaz G, Aksoy H et al (2014) Evaluation of the macula, retinal nerve fiber layer and choroid in preeclampsia, healthy pregnant and healthy non-pregnant women using spectral-domain optical coherence tomography. Hypertens Pregnancy 33:299–310. https://doi.org/10.3109/10641955.2013.877924
7. Zhang J, Wang H, Yu Q et al (2017) Enhanced Depth Imaging Optical Coherence Tomography: A New Way Measuring Choroidal Thickness in Pregnant Women. *J Ophthalmol* 2017:8296574. https://doi.org/10.1155/2017/8296574
8. Dadaci Z, Alptekin H, Acir NO et al (2015) Changes in choroidal thickness during pregnancy detected by enhanced depth imaging optical coherence tomography. Br J Ophthalmol 99:1255–1259. https://doi.org/10.1136/bjophthalmol-2014-306343
9. Takahashi J, Kado M, Mizumoto K et al (2013) Choroidal thickness in pregnant women measured by enhanced depth imaging optical coherence tomography.*Jpn Ophthalmol*57:435–439.

https://doi.org/10.1007/s10384-013-0265-5

10. Arab M, Entezari M, Ghamary H et al (2018) Peripapillary retinal nerve fiber layer thickness in preeclampsia and eclampsia.*Int Ophthalmol*38:2289–2294. https://doi.org/10.1007/s10792-017-0718-9
11. Tok A, Beyoğlu A (2020) Antenatal and postpartum comparison of. HD-OCT findings of macula, retinal nerve fiber layer, ganglion cell density between severe preeclampsia patients and healthy pregnant woman.*Hypertens Pregnancy*39:252–259. https://doi.org/10.1080/10641955.2020.1758938
12. Wu HF, Ruan XC, Zhao JW et al (2020)Comparison of choroid thickness in healthy pregnant women and non-pregant women.*Chin J Ocul Fundus Dis*36:620–624. https://doi.org/10.3760/cma.j.cn511434-20190916-00289
13. Wu XS, Chen RR, Zhao SX et al (2016) Repeatability and reproducibility of manual measurements to peripapillary choroidal thickness in healthy children using enhanced depth imaging OCT. Chin J Exp Ophthalmol 34:1107–1111. https://doi.org/10.3760 /cma.j.issn.2095-0160.2016.12.012
14. Acmaz G, Atas M, Gulhan A et al (2015) Assessment of Macular Peripapillary Nerve Fiber Layer and Choroidal Thickness Changes in Pregnant Women with Gestational Diabetes Mellitus, Healthy Pregnant Women, and Healthy Non-Pregnant Women. Med Sci Monit 21:1759–1764. https://doi.org/10.12659/MSM.893221
15. Azuma K, Okubo A, Suzuki T et al (2021) Assessment of the choroidal structure in pregnant women in the first trimester. Sci Rep 11:4629. https://doi.org/10.1038/s41598-021-84204-x
16. Rothwell RT, Meira DM, Oliveira MA et al (2015) Evaluation of Choroidal Thickness and Volume during the Third Trimester of Pregnancy using Enhanced Depth Imaging Optical Coherence Tomography: A Pilot Study. J Clin Diagn Res 9:NC08–NC11. https://doi.org/10.7860/JCDR/2015/12888.6402
17. De A, Mazumdar R (2016)TO ANALYSE THE CHOROIDAL THICKNESS IN DIFFERENT TRIMESTER OF UNCOMPLICATED PREGNANCY BY ENHANCED DEPTH IMAGING OPTICAL COHERENCETOMOGRAPHY. *Journal of Evolution of Medical and Dental Sciences*5:6005–6008. https://doi.org/10.14260/jemds/2016/1355
18. Tan CS, Cheong KX, Sadda SR (2013) Change in subfoveal choroidal thickness in central serous chorioretinopathy.*Eye (Lond)*27(10):1221–1222. DOI: 10.1038/eye.2013.164
19. Vural E, Hazar L, Çağlayan M et al (2021) Peripapillary choroidal thickness in patients with vitamin D deficiency.*Eur J Ophthalmol*31:578–583. https://doi.org/10.1177/1120672120902025
20. Garcia-Martin E, Jarauta L, Pablo LE et al (2019) Changes in peripapillary choroidal thickness in patients with multiple sclerosis.*Acta Ophthalmol*97:e77-e83. https://doi.org/10.1111/aos.13807
21. Huang W, Wang W, Zhou M et al (2013) Peripapillary choroidal thickness in healthy Chinese subjects.*BMC Ophthalmol*13:23. https://doi.org/10.1186/1471-2415-13-23
22. Neudorfer M, Spierer O, Goder M et al (2014)The prevalence of retinal and optical coherence tomography findings in preeclampticwomen. *Retina*34:1376–1383. https://doi.org/10.1097/IAE.0000000000000085

23. Smith C, Vianna J, Chauhan B (2017) Assessing retinal ganglion cell damage. *Eye* 31.:209–217. https://doi.org/10.1038/eye.2016.295

Figures

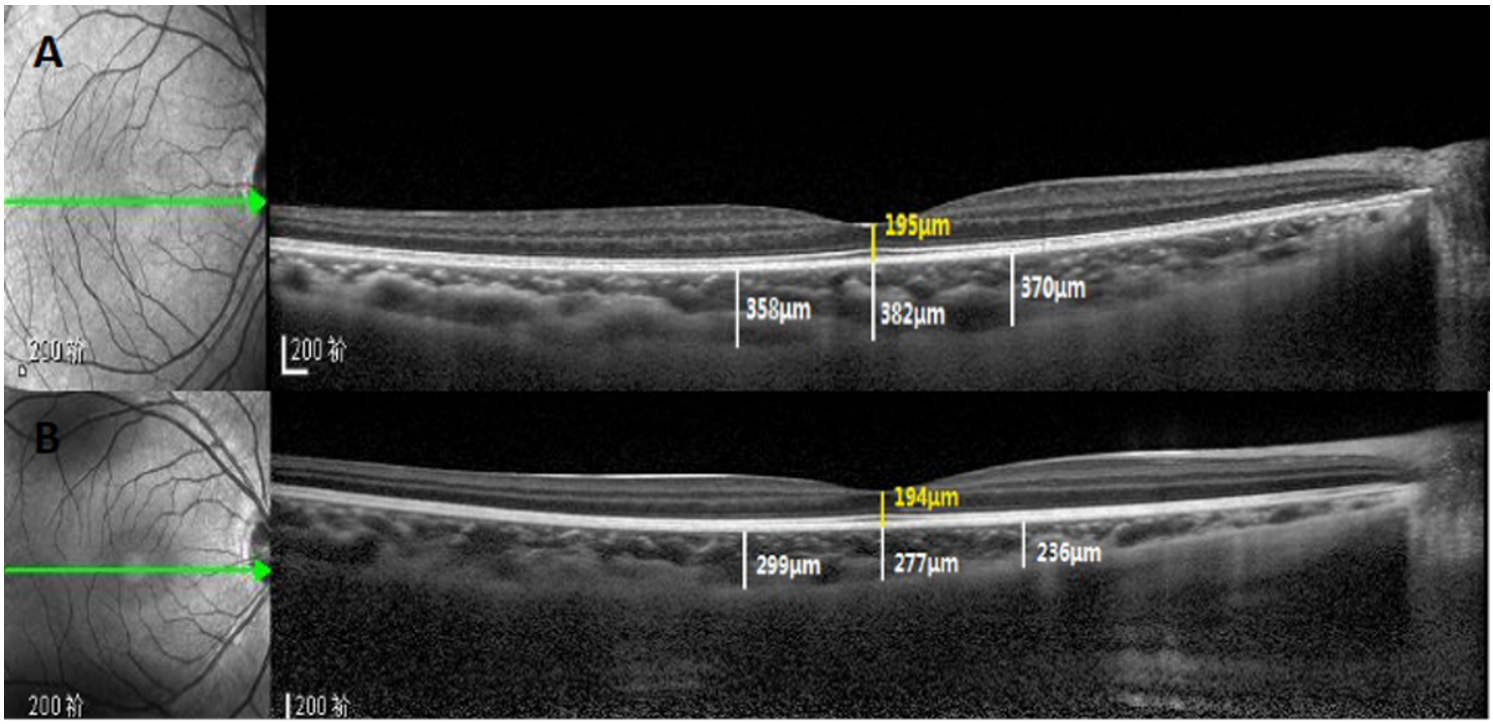

Figure 1

(A) Optical coherence tomography image from second trimester.The choroidal thickness was measured from the retinal pigment epithelium to the inner surface of the sclera at the subfovea(382um), 1 mm temporal(358um), and 1 mm nasal to the fovea(370um). (B) Optical coherence tomography image from a no-pregnant woman.

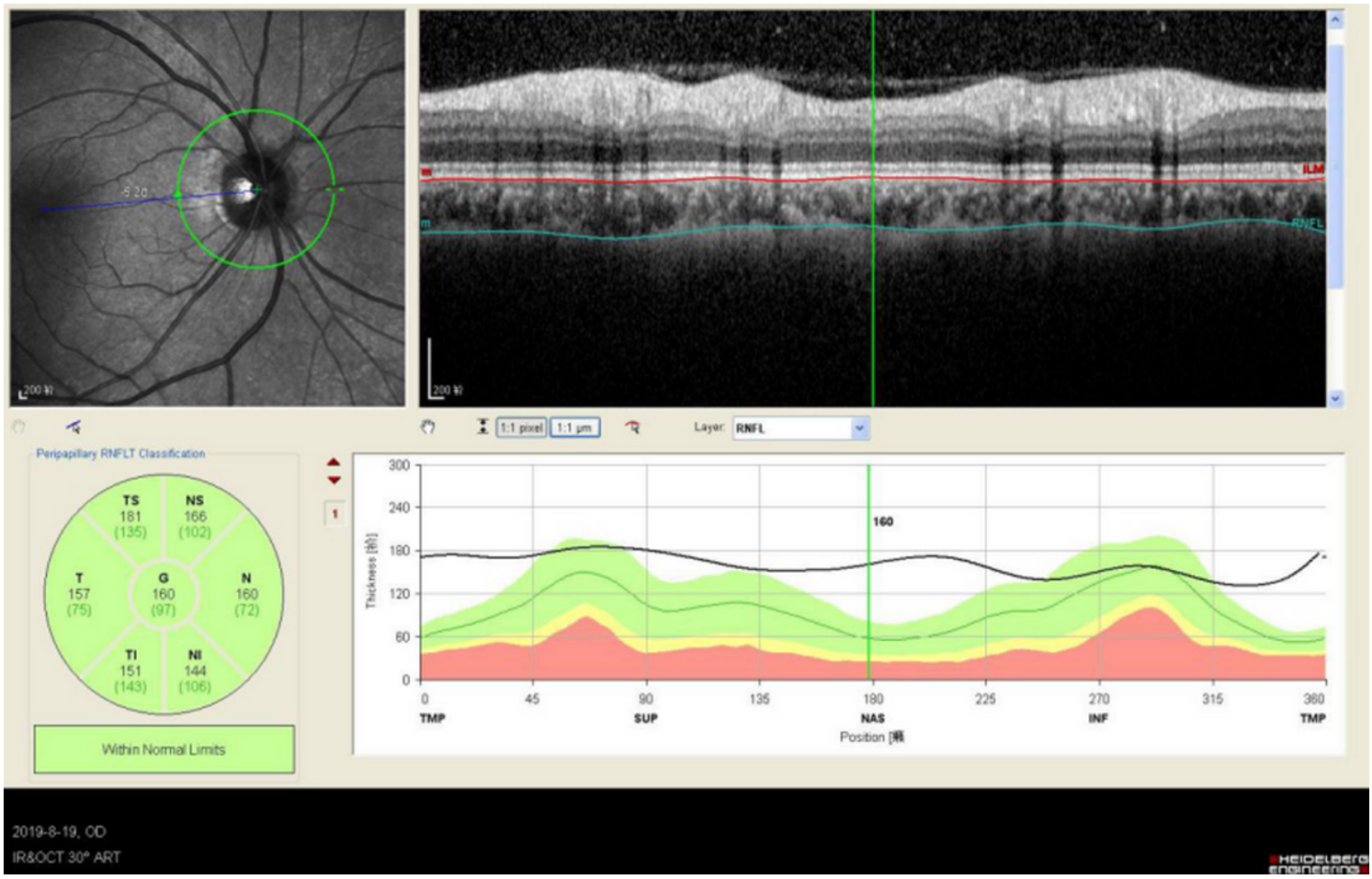

Figure 2

Representative of peripapillary choroidal thickness.T-temporal, TS- temporal superior, NS-nasal superior, N-nasal, NI-nasal inferior, TI-temporal inferior; G-global.