

单眼低度近视儿童双眼黄斑区视网膜和脉络膜血流密度分析

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摘要 **目的** 使用眼底相干光层析血管成像术 (OCTA) 测量单眼低度近视儿童双眼黄斑区视网膜、脉络膜血流密度, 并探讨其临床意义。**方法** 采用横断面研究, 收集2022年6月至2023年2月大连市第三人民医院眼科门诊就诊的8~14岁单眼低度近视儿童45例 (90眼) 临床资料。经1%环喷托酯睫状肌麻痹后验光, 将等效球镜度 (SE) $-3.00\text{ D} \sim -0.50\text{ D}$ 纳入近视眼组, $\text{SE} + 0.25\text{ D} \sim +2.00\text{ D}$ 纳入非近视眼组。使用IOL Master 500测量眼轴 (AL)、平均角膜曲率半径 (CR), 计算轴率比 (AL/CR)。使用海德堡SD-OCT进行黄斑区水平线性扫描并获取中心凹下脉络膜厚度 (SFCT) 值。使用OCTA模块获取 $3\text{ mm} \times 3\text{ mm}$ 的视网膜脉络膜血流图像, 通过Image J图形处理软件获取浅层视网膜血管丛 (SCP) 血流密度、深层视网膜血管丛 (DCP) 血流密度、脉络膜毛细血管层 (CC) 血流密度及中心凹无血管区 (FAZ) 面积。采用Pearson相关分析各血流指标与年龄、AL、CR、AL/CR、SFCT的相关性。**结果** 近视眼组SE和SFCT均小于未近视眼组, 而AL和AL/CR均大于未近视眼组, 差异均有统计学意义 (均 $P < 0.05$)。近视眼组DCP血流密度小于非近视眼组, 差异有统计学意义 ($P < 0.01$); 其他血流指标2组比较无统计学差异 (均 $P > 0.05$)。Pearson相关分析结果显示, 近视眼组SCP、DCP血流密度与SE呈正相关 (r 分别为0.611、0.731, 均 $P < 0.05$); 与AL呈负相关 (r 分别为-0.568、-0.712, 均 $P < 0.05$); 与AL/CR呈负相关 (r 分别为-0.557、-0.564, 均 $P < 0.05$)。非近视眼组SCP、DCP血流密度与AL/CR呈负相关 (r 分别为-0.615、-0.656, 均 $P < 0.05$)。2组CC血流密度、FAZ面积与年龄、SE、AL、CR、AL/CR、SFCT无相关性 (均 $P > 0.05$)。**结论** 单眼低度近视儿童近视眼与非近视眼比较, DCP血流密度降低; 近视眼视网膜血流密度与SE、AL、AL/CR相关, 非近视眼视网膜血流密度仅与AL/CR相关。

关键词 单眼低度近视; 相干光层析血管成像术; 视网膜; 脉络膜; 血流密度

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Analysis of retinal and choroidal blood flow density in the macular areas of both eyes of children with mild monocular myopia

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Abstract **Objective** To assess retinal and choroidal blood flow density in the macular regions of children diagnosed with unilateral low myopia using optical coherence tomography angiography (OCTA). This study aimed to investigate the clinical significance of these measurements. **Methods** A cross-sectional study was conducted on 90 eyes of 45 children with monocular myopia and adolescents aged 8 to 14 years who visited the outpatient department of the Ophthalmology of Dalian Third People's Hospital between June 2022 and February 2023. Optometry was performed after a 1% cyclopentolate cycloplegic muscle paralysis. Eyes with spherical equivalent (SE) -3.00 D to -0.50 D were included in the myopia group, whereas those with $\text{SE} -0.25\text{ D}$ to $+2.00\text{ D}$ were placed in the non-myopia group. The Master system was used to measure axial length (AL) and corneal curvature radius (CR), and to calculate AL/CR. Heidelberg spectral-domain optical coherence tomography (SD-OCT) was used to perform horizontal linear scanning of the macular area to obtain subfoveal choroidal thickness (SFCT). The OCTA module was used to obtain $3\text{ mm} \times 3\text{ mm}$ choroidal blood flow images, which were imported into ImageJ graphics processing software to obtain the blood flow densities of the superficial choroidal plexus (SCP), deep choroidal plexus (DCP), choroidal capillary (CC), and foveal avascular zone (FAZ). Pearson's correlation was used to examine the correlations between each blood

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flow parameter and age, AL, CR, AL/CR, and SFCT. **Results** The SE and SFCT of the myopia group were smaller ($P < 0.05$) than those of the non-myopia group, whereas the AL and AL/CR were significantly larger ($P < 0.05$) than those of the non-myopia group. The DCP blood flow density in the myopia group was significantly lower than that in the non-myopia group ($P < 0.01$). There was no statistically significant difference between the residual blood flow parameters of the myopia and non-myopia groups ($P > 0.05$). The Pearson's correlation analysis indicated that the SCP and DCP blood flow densities in the myopia group were positively correlated with SE ($r = 0.611, 0.731, P < 0.05$), negatively correlated with AL ($r = -0.568, -0.712, P < 0.05$), and negatively correlated with AL/CR ($r = -0.557, -0.564, P < 0.05$). The SCP and DCP blood flow densities were negatively correlated with AL/CR in the non-myopia group ($r = -0.615, -0.656, P < 0.05$). The CC density and FAZ area in the two groups did not correlate with age, SE, AL, CR, AL/CR, or SFCT ($P > 0.05$). **Conclusion** Compared to non-myopic eyes, the eyes of children with mild monocular myopia had lower DCP blood flow density. Moreover, retinal blood flow density in myopic eyes was correlated with SE, AL, and AL/CR, whereas retinal blood flow density in non-myopic eyes was only correlated with AL/CR.

Keywords mild monocular myopia; optical coherence tomography angiography; retina; choroid; blood flow density

近视是最常见的眼部疾病,发病率逐年升高。研究^[1]显示,2050年,全球预计约49.8%人口罹患近视。5~18岁青少年屈光参差发病率为1.6%~10.3%,随着年龄增加发病率与严重程度也随之增高^[2]。随着城市化进程加快、教育程度加强与户外活动的减少,近视出现低龄化、高度化趋势。高度近视与白内障、脉络膜视网膜萎缩、黄斑裂孔、视网膜劈裂、后巩膜葡萄肿等眼部并发症密切相关,而这些并发症的产生与视网膜血管形态变化密切相关^[3-4]。研究^[5]表明,高度近视黄斑区血流密度下降,且与眼轴具有一定的相关性。可见视网膜、脉络膜的血流变化在近视的发生发展中起到重要作用。眼底相干光层析血管成像术(optical coherence tomography angiography, OCTA)是一种新型的眼底血流检查技术,具有无创、快速、重复性好等特点,广泛应用于青光眼、黄斑变性、糖尿病视网膜病变、马凡综合征等眼部疾病的诊断与发病机制研究^[6-7]。既往多是针对儿童双眼近视血流变化进行的研究,针对单眼低度近视儿童双眼眼底血流差异的研究鲜有报道。本研究利用OCTA分析单眼低度近视儿童双眼黄斑区视网膜、脉络膜血流指标的差异,并进一步探讨其临床意义,旨在为明确近视的发生和发展机制以及防控策略提供参考依据。

1 材料与方法

1.1 临床资料及分组

本研究为横断面研究。收集2022年6月至2023年2月大连市第三人民医院眼科门诊就诊的单眼低度近视儿童的临床资料。纳入标准:(1)年龄8~14岁;

(2)屈光间质透明;(3)患者经1%环喷托酯睫状肌麻痹验光后,一眼为等效球镜度(spherical equivalent, SE)-3.00 D~-0.50 D;另一眼为SE-0.25 D~<+2.00 D;(3)矫正视力 ≥ 0.8 。排除标准:(1)眼部外伤及手术史;(2)患有活动性眼病;(3)曾使用低浓度阿托品、角膜塑形镜、多焦软性隐形眼镜、功能性框架眼睛等近视防控手段。共纳入45例(90眼),平均年龄(12.21 ± 2.11)岁,男21例,女24例。根据屈光状态分为近视眼组(45眼)与非近视眼组(45眼)。本研究获得大连市第三人民医院伦理委员会批准(批准号:2021-037-001),所有患者及监护人均签署知情同意书。

1.2 检查方法

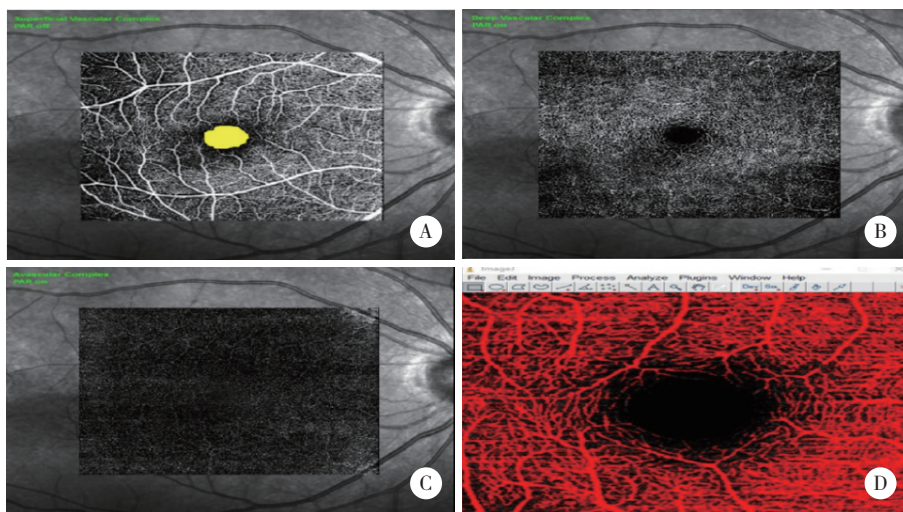
1.2.1 常规检查:对入组患者进行双眼裸眼视力、最佳矫正远视力(corrected distance visual acuity, CDVA)、裂隙灯显微镜检查,1%环喷托酯进行睫状肌麻痹后使用自动电脑验光仪验光,IOL Master 500(德国蔡司公司)测量眼轴(axial length, AL)及平均角膜曲率半径(corneal curvature radius, CR),计算轴率比(AL/CR)。

1.2.2 黄斑区脉络膜、视网膜血流密度测量

使用SD-OCT(德国海德堡公司)获取黄斑区水平线性扫描及3 mm × 3 mm血流图像。中央凹下脉络膜厚度(subfoveal choroidal thickness, SFCT)计算为中央凹处视网膜色素上皮层外界与脉络膜外层的垂直距离。OCTA图像使用10° × 10°角度扫描,包括512个A扫描和512个B扫描。扫描过程使用TruTrack眼动跟踪系统减少伪影的产生。Spectralis软件将血流密度图自动分割为视网膜浅层血流图

像(内界膜到内丛状层上17 μm)、视网膜深层血流图像(内界膜到外丛状层下17 μm)以及脉络膜毛细血管血流图像(图1A~1C)。将获取的图像导入Image J图像处理软件,创建出二值化血管图像,血流密度为选定区域内毛细血管面积与总面积比值,进而获得视网膜浅层毛细血管丛(superficial capillary ple-

xus,SCP)血流密度、视网膜深层毛细血管丛(deep capillary plexus,DCP)血流密度、脉络膜毛细血管丛(choriocapillaris,CC)血流密度(图1D)。使用Image J图像处理软件设定比例尺,手动描绘黄斑中央凹无血管区边界,计算中央凹无血管区(foveal avascular zone,FAZ)面积(图1A)。



A,SCP,foveal avascular zone is shown as a yellow zone;B,DCP;C,CC;D Image J analysis of SCP.

图1 OCTA获取黄斑区毛细血管分层图像与Image J分析视网膜SCP血流密度

Fig.1 OCTA acquisition of macular capillary stratification images and Image J analysis of SCP blood flow density

1.3 统计学分析

采用SPSS 26.0软件进行统计学分析。计量资料采用 $\bar{x} \pm s$ 表示,2组比较采用独立样本t检验。血流参数与年龄、AL、CR、AL/CR、SFCT的相关性采用Pearson相关性分析。 $P < 0.05$ 为差异有统计学意义。

2 结果

2.1 2组患者一般临床指标比较

结果显示,近视眼组SE、SFCT小于未近视眼组,

AL、AL/CR大于未近视眼组,差异均有统计学意义(均 $P < 0.05$)。而2组CDVA、CR比较差异无统计学意义(均 $P > 0.05$),见表1。

2.2 2组黄斑区视网膜、脉络膜血流指标比较

结果显示,近视眼组DCP血流密度小于非近视眼组,差异有统计学意义($P < 0.01$),而SCP、CC血流密度和FAZ面积2组比较差异均无统计学意义(均 $P > 0.05$)。见表2。

2.3 近视眼组黄斑区血流指标与年龄、SE、AL、CR、

表1 2组患者一般临床指标比较 ($\bar{x} \pm s$)

Tab.1 Comparison of general clinical data between the two groups ($\bar{x} \pm s$)

Group	CDVA (log MAR)	SE (D)	AL (mm)	CR (mm)	AL/CR	SFCT (μm)
Myopic	-0.013 ± 0.01	-1.80 ± 0.72	24.47 ± 0.93	7.82 ± 0.25	3.13 ± 0.05	222.1 ± 34.6
Non-myopic	-0.011 ± 0.01	0.03 ± 0.02	23.71 ± 0.90	7.82 ± 0.26	3.03 ± 0.05	250.7 ± 31.8
t	-0.475	-9.208	2.254	0.022	0.730	-2.361
P	0.638	<0.001	0.032	0.983	<0.001	0.025

CDVA, corrected distance visual acuity; SE, spherical equivalent; AL, axial length; CR, corneal curvature radius; SFCT, subfoveal choroidal thickness.

表2 2组黄斑区视网膜、脉络膜血流参数比较

Tab.2 Comparison of retinal and choroidal blood flow parameters in the macular regions of the two groups

Group	SCP blood flow density (%)	DCP blood flow density (%)	CC blood flow density (%)	FAZ area (mm ²)
Myopic	29.81 ± 5.95	20.79 ± 4.79	24.97 ± 3.08	0.23 ± 0.08
Non-myopic	32.17 ± 6.08	24.59 ± 4.43	26.13 ± 3.29	0.25 ± 0.10
<i>t</i>	-1.904	-3.921	-1.730	-1.079
<i>P</i>	0.060	<0.001	0.087	0.283

SCP, superficial capillary plexus; DCP, deep capillary plexus; CC, choriocapillaris; FAZ, foveal avascular zone.

AL/CR、SFCT的相关性分析

结果显示,近视眼组SCP血流密度与SE呈正相关($r = 0.611, P = 0.016$);与AL、AL/CR呈负相关(r 分别为-0.568、-0.557,均 $P < 0.05$);而与年龄、CR、SFCT不相关(均 $P > 0.05$)。DCP血流密度与SE呈正

相关($r = 0.731, P < 0.01$);与AL、AL/CR呈负相关(r 分别为-0.712、-0.564,均 $P < 0.05$);而与年龄、CR、SFCT无相关性(均 $P > 0.05$)。CC血流密度、FAZ面积与年龄、SE、AL、CR、AL/CR、SFCT均不相关(均 $P > 0.05$),见表3。

表3 近视眼组黄斑区血流参数与年龄、SE、AL、CR、AL/CR、SFCT的相关性分析

Tab.3 Correlation analysis of macular blood flow parameters with age, SE, AL, CR, AL/CR, and SFCT in the myopic group

Parameters	Age	SE	AL	CR	AL/CR	SFCT
SCP blood flow density						
<i>r</i>	0.347	0.611	-0.568	-0.417	-0.557	-0.059
<i>P</i>	0.206	0.016	0.027	0.122	0.031	0.833
DCP blood flow density						
<i>r</i>	-0.004	0.731	-0.712	-0.584	-0.564	0.048
<i>P</i>	0.987	<0.001	<0.001	0.078	0.028	0.876
CC blood flow density						
<i>r</i>	0.078	0.160	-0.123	-0.119	-0.058	-0.003
<i>P</i>	-0.783	0.568	0.662	0.673	0.836	0.991
FAZ area						
<i>r</i>	-0.497	-0.046	-0.201	-0.318	0.174	0.193
<i>P</i>	0.059	0.871	0.473	0.249	0.535	0.491

SCP, superficial capillary plexus; DCP, deep capillary plexus; CC, choriocapillaris; FAZ, foveal avascular zone; SE, spherical equivalent; AL, axial length; CR, corneal curvature radius; SFCT, subfoveal choroidal thickness.

2.4 非近视眼组黄斑区血流指标与年龄、SE、AL、CR、AL/CR、SFCT的相关性分析

结果显示,非近视眼组SCP、DCP血流密度与AL/CR呈负相关(r 分别为-0.615、-0.656,均 $P < 0.05$),而与年龄、SE、AL、CR、SFCT不相关(均 $P > 0.05$)。非近视眼组CC血流密度、FAZ面积与年龄、SE、AL、CR、AL/CR、SFCT均不相关(均 $P > 0.05$)。见表4。

3 讨论

轴性近视的特点是随着近视的发展眼轴拉长,

牵拉视网膜导致视网膜变薄,从而影响视网膜的血流灌注^[8]。眼底视网膜、脉络膜微循环系统为视网膜组织提供氧气与营养物质,眼底血流灌注的改变可能是近视发生发展的危险因素。OCTA可以定量分析视网膜各层显微结构及眼底毛细血管密度,广泛应用于视网膜微血管疾病的研究与临床诊断^[9]。

本研究对单眼低度近视儿童的双眼黄斑区视网膜、脉络膜血流密度及脉络膜厚度进行分析,并探讨黄斑区血流参数与年龄、SE、AL、CR、AL/CR、SFCT的相关性。结果显示,与非近视眼组比较,近视

表4 非近视组黄斑区血流指标与年龄、SE、AL、CR、AL/CR、SFCT的相关性分析

Tab.4 Correlation analysis of macular blood flow parameters with age, SE, AL, CR, AL/CR, and SFCT in the non-myopic group

Parameters	Age	SE	AL	CR	AL/CR	SFCT
SCP blood flow density						
<i>r</i>	0.435	0.206	-0.311	-0.075	-0.615	-0.194
<i>P</i>	0.105	0.462	0.260	0.791	0.015	0.488
DCP blood flow density						
<i>r</i>	0.142	0.385	-0.514	-0.296	-0.656	-0.262
<i>P</i>	0.613	0.157	0.051	0.284	0.008	0.346
CC blood flow density						
<i>r</i>	0.438	0.090	0.322	0.318	0.118	-0.126
<i>P</i>	0.102	0.750	0.241	0.249	0.765	0.654
FAZ area						
<i>r</i>	-0.385	0.041	-0.124	-0.228	0.181	0.337
<i>P</i>	0.158	0.886	0.660	0.413	0.519	0.219

Abbreviations as in Tab. 3.

眼组SFCT变薄($P < 0.05$),然而2组CC血流密度比较却没有统计学差异($P > 0.05$),这与以往研究^[10-11]结果一致。几项针对儿童和青少年的前瞻性研究^[12-14]表明,随着近视程度加深,脉络膜会逐渐变薄,脉络膜厚度变化在近视发展中起着重要作用。脉络膜是高度血管化组织,由毛细血管层、中血管层与大血管层组成。近视眼脉络膜变薄主要发生在中血管层与大血管层^[15]。READ等^[16]发现,当屈光参差超过1.50 D时,高度近视眼的脉络膜毛细血管密度低于低度近视眼。结合本研究结果,说明在近视早期,脉络膜毛细血管密度并不随着脉络膜厚度降低而减小。

本研究发现近视眼组DCP血流密度小于非近视眼组($P < 0.05$),而2组SCP比较无统计学差异($P > 0.05$),与LIN等^[17]研究结果一致。另外研究结果显示,近视眼组SCP与AL呈中等强度负相关,而DCP与AL呈强负相关,与以往研究^[18-19]结果一致。分析原因可能与SCP比较,DCP毛细血管直径更小,更容易受到近视眼轴拉长所导致的机械应力破坏^[20-21]。同时也有研究^[19,22]显示,DCP损伤后较难修复,因此近视眼DCP血流密度显著下降。

目前,关于近视眼视网膜血流密度降低的确切机制尚未明确,主要有以下几种理论:(1)轴性近视眼轴拉长对视网膜血管产生机械应力,导致部分血管受损,血管密度下降,从而降低视网膜营养与氧

供给^[23];(2)眼轴增加牵拉视网膜,使视网膜变薄,视神经节细胞密度降低。此时视网膜对于氧气与营养物质的需求减少,导致该区域血管密度代偿性降低^[23-24];(3)血管内皮生长因子(vascular endothelial growth factor, VEGF)由视网膜血管内皮细胞与色素上皮细胞产生,在血管的形成中发挥重要作用^[25]。近视眼眼轴拉长、视网膜变薄后,视网膜血管内皮细胞与色素上皮细胞发生变性,导致VEGF分泌减少,从而导致视网膜血管密度降低^[26];(4)眼轴增加导致视网膜总面积增加,因此神经节细胞与视网膜血管密度同比降低。二者达到供需平衡时,视网膜血管密度不会因为神经节细胞的代谢需求发生改变^[27-28]。

综上所述,单眼低度近视儿童的近视眼相比非近视眼DCP血流密度降低,其中近视眼视网膜血流密度与近视发展呈负相关,非近视眼视网膜血流密度仅与AL/CR呈负相关。本研究为横断面研究,样本量较少,且集中黄斑区3 mm × 3 mm范围眼底血流变化,未来尚需前瞻性、大样本研究,同时进一步检验儿童眼底不同区域,不同层次视网膜、脉络膜血流减少与近视发生发展的因果关系。

参考文献:

- [1] BRIEN A, HOLDEN, PHD D, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050 [J].

- Ophthalmology, 2016, 123 (5) : 1036-1042. DOI: 10.1016/j.ophtha.2016.01.006.
- [2] 李盼, 张学辉, 艾欣, 等. 不同程度屈光参差的单眼近视儿童配戴角膜塑形镜后近视进展对比[J]. 国际眼科杂志, 2022, 22 (9) : 1528-1532. DOI: 10.3980/j.issn.1672-5123.2022.9.21.
- [3] ŽIVKOVIĆ MAJA LJ, LAZAR L, MARKO Z, et al. The influence of myopia on the foveal avascular zone and density of blood vessels of the macula—an OCTA study [J]. Medicina, 2023, 59 (3) : 452.
- [4] IKUNO Y. Overview of the complications of high myopia [J]. Retina, 2017, 37 (12) : 2347-2351. DOI: 10.1097/iae.0000000000001489.
- [5] SHI Y, YE LY, CHEN QY, et al. Macular vessel density changes in young adults with high myopia: a longitudinal study [J]. Front Med (Lausanne), 2021, 8: 648644. DOI: 10.3389/fmed.2021.648644.
- [6] DIAO K, HUANG XM, YAO MY, et al. Inter-examiner and intra-examiner reliability of optical coherence tomography angiography in vascular density measurement of retinal and choriocapillaris plexuses in healthy children aged 6-15 years [J]. Front Med (Lausanne), 2023, 10: 1161942. DOI: 10.3389/fmed.2023.1161942.
- [7] 中华医学会眼科学分会眼底病学组, 中国医师协会眼科医师分会眼底病专业委员会. 我国眼底相干光层析血管成像术的操作和阅片规范(2017年)[J]. 中华眼科杂志, 2017, 53 (10) : 729-734. DOI: 10.3760/cma.j.issn.0412-4081.2017.10.003
- [8] SAMPSON DM, GONG PJ, AN D, et al. Axial length variation impacts on superficial retinal vessel density and foveal avascular zone area measurements using optical coherence tomography angiography [J]. Invest Ophthalmol Vis Sci, 2017, 58 (7) : 3065. DOI: 10.1167/iops.17-21551.
- [9] XIONG F, MAO T, WANG JC, et al. Superficial retinal vessel density and foveal avascular zone in myopic anisometropia: an OCTA-based study in young Chinese children [J]. Biomed Res Int, 2022, 2022: 1-9. DOI: 10.1155/2022/1229009.
- [10] YAZDANI N, EHSAEI A, HOSEINI-YAZDI H, et al. Wide-field choroidal thickness and vascularity index in myopes and emmetropes [J]. Ophthalmic Physiologic Optic, 2021, 41 (6) : 1308-1319. DOI: 10.1111/opo.12875.
- [11] 丁香英, 鲁元媛, 赵芳坤, 等. 青少年低中度近视患者配戴角膜塑形镜前后黄斑部脉络膜厚度的变化[J]. 中国医科大学学报, 2019, 48 (9) : 822-827. DOI: 10.12007/j.issn.0258-4646.2019.09.012.
- [12] JIN PY, ZOU HD, XU X, et al. Longitudinal changes in choroidal and retinal thicknesses in children with myopic shift [J]. Retina, 2019, 39 (6) : 1091-1099. DOI: 10.1097/iae.0000000000002090.
- [13] XIONG SY, HE XG, ZHANG B, et al. Changes in choroidal thickness varied by age and refraction in children and adolescents: a 1-year longitudinal study [J]. Am J Ophthalmol, 2020, 213: 46-56. DOI: 10.1016/j.ajo.2020.01.003.
- [14] DEVARAJAN K, SIM R, CHUA J, et al. Optical coherence tomography angiography for the assessment of choroidal vasculature in high myopia [J]. Br J Ophthalmol, 2020, 104 (7) : 917-923. DOI: 10.1136/bjophthalmol-2019-314769.
- [15] LIU XT, LIN ZY, WANG FF, et al. Choroidal thickness and choriocapillaris vascular density in myopic anisometropia [J]. Eye Vis, 2021, 8 (1) : 1-10. DOI: 10.1186/s40662-021-00269-9.
- [16] READ SA, ALONSO-CANEIRO D, VINCENT SJ, et al. Longitudinal changes in choroidal thickness and eye growth in childhood [J]. Invest Ophthalmol Vis Sci, 2015, 56 (5) : 3103. DOI: 10.1167/iops.15-16446.
- [17] LIN FB, ZHAO ZN, LI F, et al. Longitudinal macular retinal and choroidal microvasculature changes in high Myopia [J]. Invest Ophthalmol Vis Sci, 2021, 62 (15) : 1. DOI: 10.1167/iops.62.15.1.
- [18] LIN FB, LI F, GAO K, et al. Longitudinal changes in macular optical coherence tomography angiography metrics in primary open-angle Glaucoma with high myopia: a prospective study [J]. Invest Ophthalmol Vis Sci, 2021, 62 (1) : 30. DOI: 10.1167/iops.62.1.30.
- [19] YE J, WANG MY, SHEN MX, et al. Deep retinal capillary plexus decreasing correlated with the outer retinal layer alteration and visual acuity impairment in pathological Myopia [J]. Invest Ophthalmol Vis Sci, 2020, 61 (4) : 45. DOI: 10.1167/iops.61.4.45.
- [20] ZHENG FH, CHUA J, KE MY, et al. Quantitative OCT angiography of the retinal microvasculature and choriocapillaris in highly myopic eyes with myopic macular degeneration [J]. Br J Ophthalmol, 2022, 106 (5) : 681-688. DOI: 10.1136/bjophthalmol-2020-317632.
- [21] KUR J, NEWMAN EA, CHAN-LING T. Cellular and physiological mechanisms underlying blood flow regulation in the retina and choroid in health and disease [J]. Prog Retin Eye Res, 2012, 31 (5) : 377-406. DOI: 10.1016/j.preteyeres.2012.04.004.
- [22] BORRELLI E, SACCONI R, BRAMBATI M, et al. In vivo rotational three-dimensional OCTA analysis of microaneurysms in the human diabetic retina [J]. Sci Rep, 2019, 9 (1) : 16789. DOI: 10.1038/s41598-019-53357-1.
- [23] KHAN MH, LAM AKC, ARMITAGE JA, et al. Impact of axial eye size on retinal microvasculature density in the macular region [J]. J Clin Med, 2020, 9 (8) : 2539. DOI: 10.3390/jcm9082539.
- [24] MO J, DUAN AL, CHAN S, et al. Vascular flow density in pathological myopia: an optical coherence tomography angiography study [J]. BMJ Open, 2017, 7 (2) : e013571. DOI: 10.1136/bmjopen-2016-013571.
- [25] POURNARAS CJ, RUNGGER-BRÄNDLE E, RIVA CE, et al. Regulation of retinal blood flow in health and disease [J]. Prog Retin Eye Res, 2008, 27 (3) : 284-330. DOI: 10.1016/j.preteyeres.2008.02.002.
- [26] YANG Y, WANG JH, JIANG H, et al. Retinal microvasculature alteration in high Myopia [J]. Invest Ophthalmol Vis Sci, 2016, 57 (14) : 6020-6030. DOI: 10.1167/iops.16-19542.
- [27] AL-SHEIKH M, PHASUKKIJWATANA N, DOLZ-MARCO R, et al. Quantitative OCT angiography of the retinal microvasculature and the choriocapillaris in myopic eyes [J]. Invest Ophthalmol Vis Sci, 2017, 58 (4) : 2063-2069. DOI: 10.1167/iops.16-21289.
- [28] MILANI P, MONTESANO G, ROSSETTI L, et al. Vessel density, retinal thickness, and choriocapillaris vascular flow in myopic eyes on OCT angiography [J]. Graefes Arch Clin Exp Ophthalmol, 2018, 56 (8) : 1419-1427. DOI: 10.1007/s00417-018-4012-y.

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