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Perfusion published online 4 April 2014
DOI: 10.1177/0267659114529324

Original Paper

Perfusion

Perfusion
1–7

DOI: 10.1177/0267659114529324
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Choroidal changes after cardiopulmonary bypass

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Abstract

Aim: Choroid, which is the vascular tissue responsible for blood supply to the outer parts of the retina, might be affected by hemodynamic events. We aimed to reveal choroidal thickness and ocular pulse amplitude changes after cardiopulmonary bypass in which gross hemodynamic alterations occur.

Methods: Forty-two eyes of 42 patients who underwent heart surgery with cardiopulmonary bypass were examined in this prospective, cross-sectional case series. The spectral domain optical coherence tomography (Spectralis, Heidelberg, Germany) was used to analyze sub-foveal choroidal thickness. The ocular pulse amplitude, the surrogate of gross choroidal blood flow, was measured with the Pascal dynamic contour tonometer (Pascal DCT, Swiss Microtechnology AG, Port, Switzerland).. The intraocular pressure was also measured with this tonometer. The examinations were performed pre-operatively and post-operatively at the first week and first month.

Results: The mean age of the patients was 58.8 ± 12.4 years. The mean sub-foveal choroidal thickness and ocular pulse amplitude values did not change statistically significantly after the operations at the follow-up visits ($p>0.05$). Also, there were no important correlations between cardiopulmonary bypass time and mean sub-foveal choroidal thickness and ocular pulse amplitude changes at the post-operative first week ($p>0.05$). The intraocular pressure values were decreased markedly at the control visits ($p<0.05$).

Conclusions: Sub-foveal choroidal thickness and ocular pulse amplitude are unchanged, while intraocular pressure decreases one week and one month after cardiopulmonary bypass.

Keywords

cardiopulmonary bypass; choroidal thickness; ocular pulse amplitude; heart surgery; intraocular pressure

Introduction

The cardiopulmonary bypass (CPB) procedure is a surgical technique that allows extracorporeal circulation and eliminates the difficulty of operating on the beating heart. Significant alterations in hemodynamics could affect end organs during CPB. Visual disturbances and ocular vascular disorders are not rare after CPB during heart surgery.[1,2] The main pathogeneses are considered to be ocular ischemia, microembolism and hypoperfusion.[3,4]

Vision problems after CPB addresses retinal and optic nerve blood flow disturbances.[4] Although the choroid is very important for the blood supply of the outer retinal layers, there is a gap about the impact of CPB on choroid in the literature. This situation might be due to the difficulties of imaging the choroid. However, a novel technique, enhanced depth imaging optical coherence tomography (EDI OCT), enables satisfactory visualization of the choroid.

Most of the blood flow in the eye is within the choroidal circulation.[5] Since multiple organ dysfunctions, including the eye, after CPB are still a significant clinical problem due to ischemia and microembolism, we hypothesized that the choroid might be affected after

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CPB. Our aim was to demonstrate sub-foveal choroidal thickness and ocular pulse amplitude alterations after the extracorporeal circulation procedure in routine on-pump cardiovascular operations in order to evaluate the perfusion and autoregulatory status of the choroid.

Materials and Methods

In this prospective case series, a total of 42 patients who underwent heart surgery with CPB were recruited. This study was conducted in accordance with the ethical standards of the Declaration of Helsinki and was approved by the Institutional Ethical Committee.

Study population

The types of heart operations that were performed during CPB were as follows: combined coronary artery bypass grafting surgery (CABGS) and valve repair (11 patients), CABGS only (18 patients), heart valve repair only (11 patients) and atrial septal defect repair (2 patients). All of the subjects underwent an ophthalmic examination, including visual acuity assessment (Snellen chart), biomicroscopy, indirect retinoscopy, ocular pulse amplitude (OPA), intraocular pressure (IOP) and OCT measurements. Exclusion criteria were any ocular surgery other than uneventful phacoemulsification and any ocular disease other than age-related cataract or mild refractive errors. Some possible factors that might affect choroidal thickness measurements, such as smoking cigarette, drinking coffee and the instillation of mydriatic eye drops were avoided for at least one day before the ocular examinations.

Cardiopulmonary bypass technique

In all cases, the CPB procedure involved a hollow-fiber membrane oxygenator, a coronary artery bypass machine, a 40 µm arterial line filter, systemic hypothermia down to 30-32°C, pulsatile flow of 2.4 L/min/m^2 during aortic cross-clamping and continued flow after the removal of the cross-clamp, with a mean arterial pressure of 50-60 mmHg. Myocardial protection was maintained by intermittent antegrade cold blood cardioplegia (4:1 blood to crystalloid ratio). Heparin was given to maintain the activated clotting time between 450-480 seconds and was neutralized by protamine at the end of CPB.

Ocular examination techniques

The measurements were performed before the surgery and at the first week and the first month after surgery. One of the eyes of each subject was selected randomly and included for the study. The selected eye was the same for all three measurements. Choroidal thickness measurements were done with spectral-domain OCT (Spectralis, Heidelberg, Germany). Spectral-domain OCT is a non-invasive, non-contact, transpupillary imaging device for investigating retinal and choroidal structures. This OCT provides 40,000 A scans/second, with an axial resolution of 7 µm and transversal resolution of 14 µm by using a 870-nm wavelength superluminescent diode. The sub-foveal choroidal thickness (SFCT) was measured from the outer part of the hyper-reflective line, corresponding to the retina pigment epithelium to the inner surface of the sclera. The ocular pulse amplitude (OPA) and intraocular pressure (IOP) measurements were done with the Pascal dynamic contour tonometer This non-invasive, contact device is attached to a slit-lamp biomicroscope and it has a 7-mm tip diameter and a 1.2-mm pressure sensor diameter. The OPA is accepted as the difference between systolic and diastolic values of the pulsatile IOP. Only quality 1 and 2 measurements were taken into consideration for OPA measurements.

Statistical analysis

The SPSS 17.0 software for Windows (SPSS Inc., Chicago, IL, USA) was used to analyze outcomes. 'P' values lower than 0.05 were considered to be statistically significant. The paired samples t-test was used for comparison of the OPA, IOP and SFCT values before and after CPB. For sub-group analysis (CABGS only, valve repair only and combined CABGS-valve repair), the Wilcoxon signed rank test was used. The Bonferroni correction is also taken into consideration for the sub-group analysis. Pearson's correlation analysis was used to detect correlations between OPA, IOP, SFCT changes and CPB periods (total CPB time and aortic cross-clamp time).

Results

The mean age of the patients was 58.8 ± 12.4 (range: 26–79) years. Thirty-four patients were male (81%) and 8 patients were female (19%). Table 1 shows the mean SFCT, OPA and IOP values before and after heart surgery. The mean SFCT and OPA values did not change statistically significantly after the operations at any of the follow-up visits, but the mean IOP value was markedly decreased after CPB. In none of the patients did we encountered vision loss, anterior chamber changes or retinal problems.

Figure 1 shows the EDI OCT of the choroid of a patient in the follow-up visits. Figure 2 shows the box-plot graphic of CABGS only patients for OPA, IOP and SFCT parameters. The decrease in IOP at the first month visit is

Table 1. The SFCT, OPA and IOP values before and after cardiopulmonary bypass are shown.

	Pre-operation	1st week	1st month
SFCT *(μm)*	255.5 ± 69.4	253.9 ± 72.4 *(p=0.92)*	258.3 ± 80.8 *(p=0.77)*
OPA *(mmHg)*	2.12 ± 0.89	2.16 ± 0.91 *(p=0.80)*	1.98 ± 0.94 *(p=0.12)*
IOP *(mmHg)*	16.8 ± 2.3	15.8 ± 2.7 *(p=0.005)*	15.4 ± 2.6 *(p=0.007)*

(SFCT: sub-foveal choroidal thickness, OPA: ocular pulse amplitude, IOP: intraocular pressure).

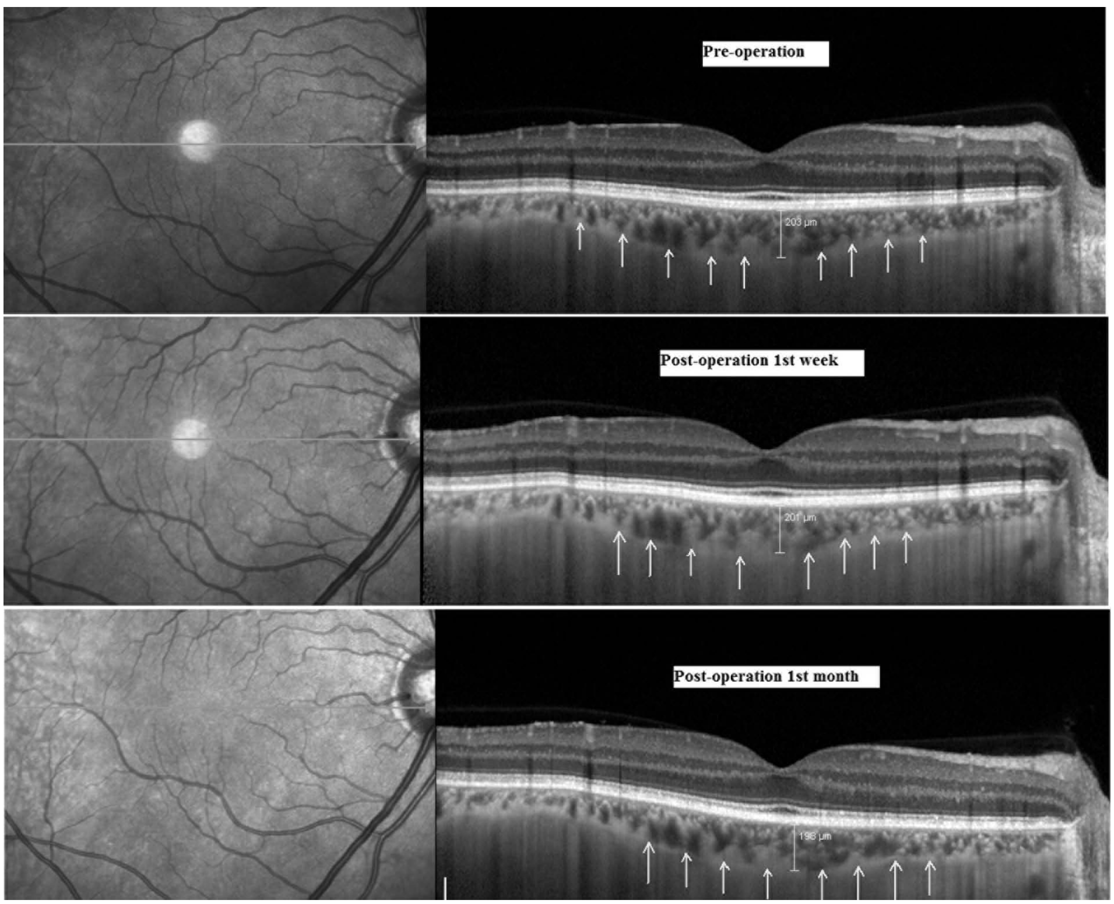

Figure 1. The enhanced depth OCT imaging of the choroid of a patient in the follow-up visit (The white arrows show the outer border of the choroid).

statistically significant, as is shown in Figure 2 (p=0.02). Figure 3 shows the box-plot graphic of combined CABGS and valve repair patients for OPA, IOP and SFCT parameters. There were no significant alterations in the studied parameters. Figure 4 shows the box-plot graphic of valve repair only patients for OPA, IOP and SFCT parameters. The increase in SFCT at the first-week visit is statistically significant, as is shown in Figure 4 (p=0.01).

The mean CPB time was 137.6 ± 36.7 minutes and the mean aortic cross-clamp time (ischemic time of the myocardium) was 85.7 ± 33.9 minutes. When we analyzed the correlations of CPB time and aortic cross-clamp time with the changes of SFCT, OPA and IOP at the first-week visit, these periods were not correlated significantly with the changes of the studied parameters (Table 2).

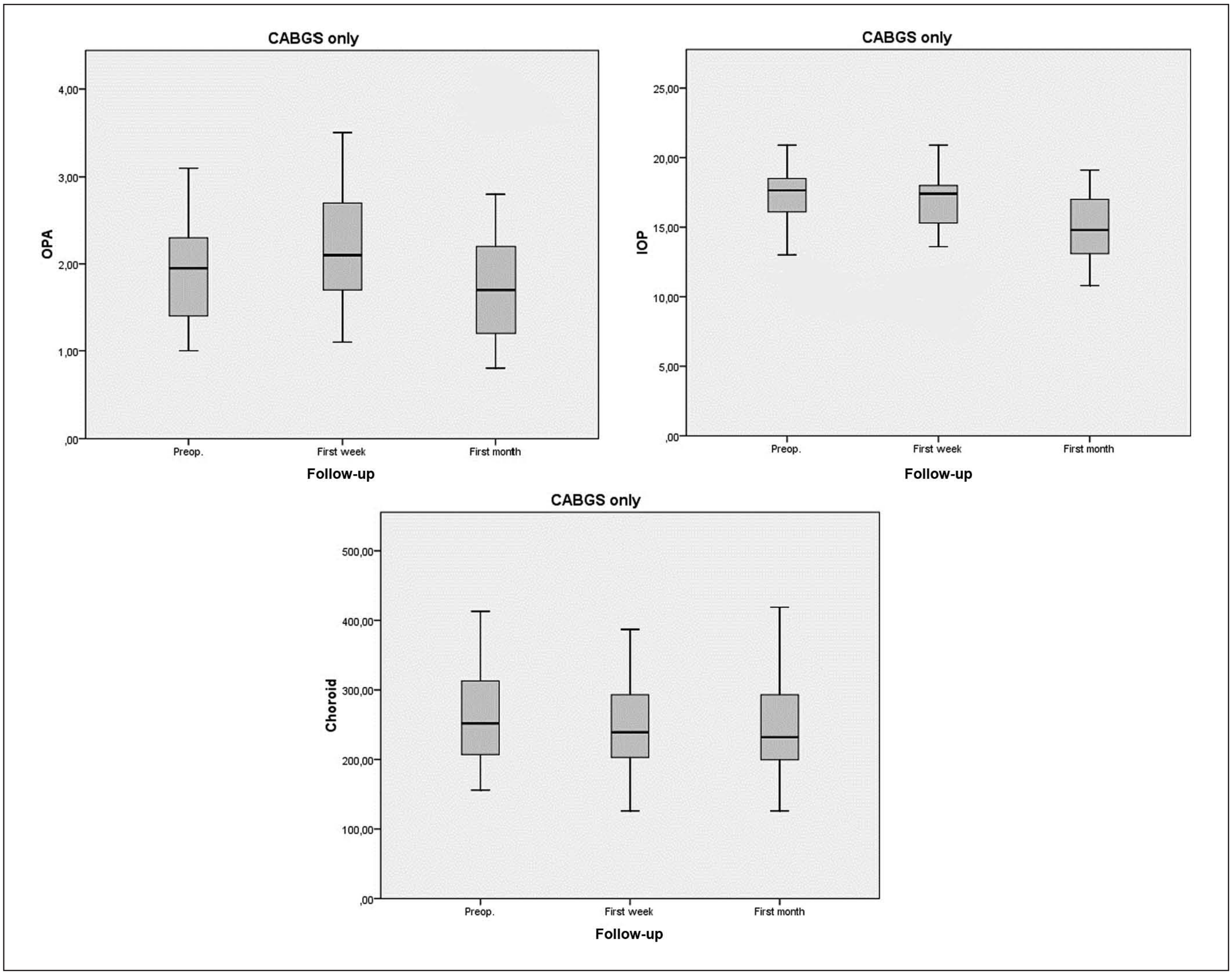

Figure 2. The box-plot graphic of CABGS only patients for OPA, IOP and SFCT parameters (CABGS: coronary artery bypass grafting surgery; OPA: ocular pulse amplitude; IOP: intraocular pressure; SFCT: sub-foveal choroidal thickness).

Discussion

Our results show that sub-foveal choroidal thickness and ocular pulse amplitude do not change after CPB. Also, CPB time is not associated with early post-operative SFCT and OPA alterations. Additionally, we found that intraocular pressure decreased significantly after CPB. Since OPA and IOP are usually well correlated, the difference between their changes after CPB indicates some other mechanisms.

Significant alterations in hemodynamics and homeostasis occur during and after CPB due to extracorporeal circulation, the administration of heparin, the establishment of hypothermia, the decrease in hemoglobin concentration from hemodilution and from the low arterial pressure.[4,6] The eye, as an end organ, might be affected by the resultant ischemia, hypoperfusion and bolism.[4,7] Nevertheless, we found that CPB did not have an important impact on SFCT and OPA, indicating the choroid has effective hemodynamic autoregulation mechanisms. In general, the risk of embolism is greater in valve repair operations, but combined valve repair and CABGS patients also carry similar risks for embolism. The significant SFCT increase in the valve repair only group when compared with the combined surgery group might have occurred due to the low number of participants in the sub-groups.

In this study, the mean IOP decreased significantly at the post-operative first-week and first-month visits. Its reason might be diuretic and antihypertensive drug usage after CPB or ischemia of ciliary bodies. It has been shown that IOP rises during CPB and stays high for several days post-operatively.[8–10] Deutch and Lewis[9] reported that the mean IOP returns to baseline by the third post-operative day after CPB. On the other hand, Hayashi et al.[11] found that IOP values during CPB were significantly decreased compared with baseline values and returned to baseline levels at the

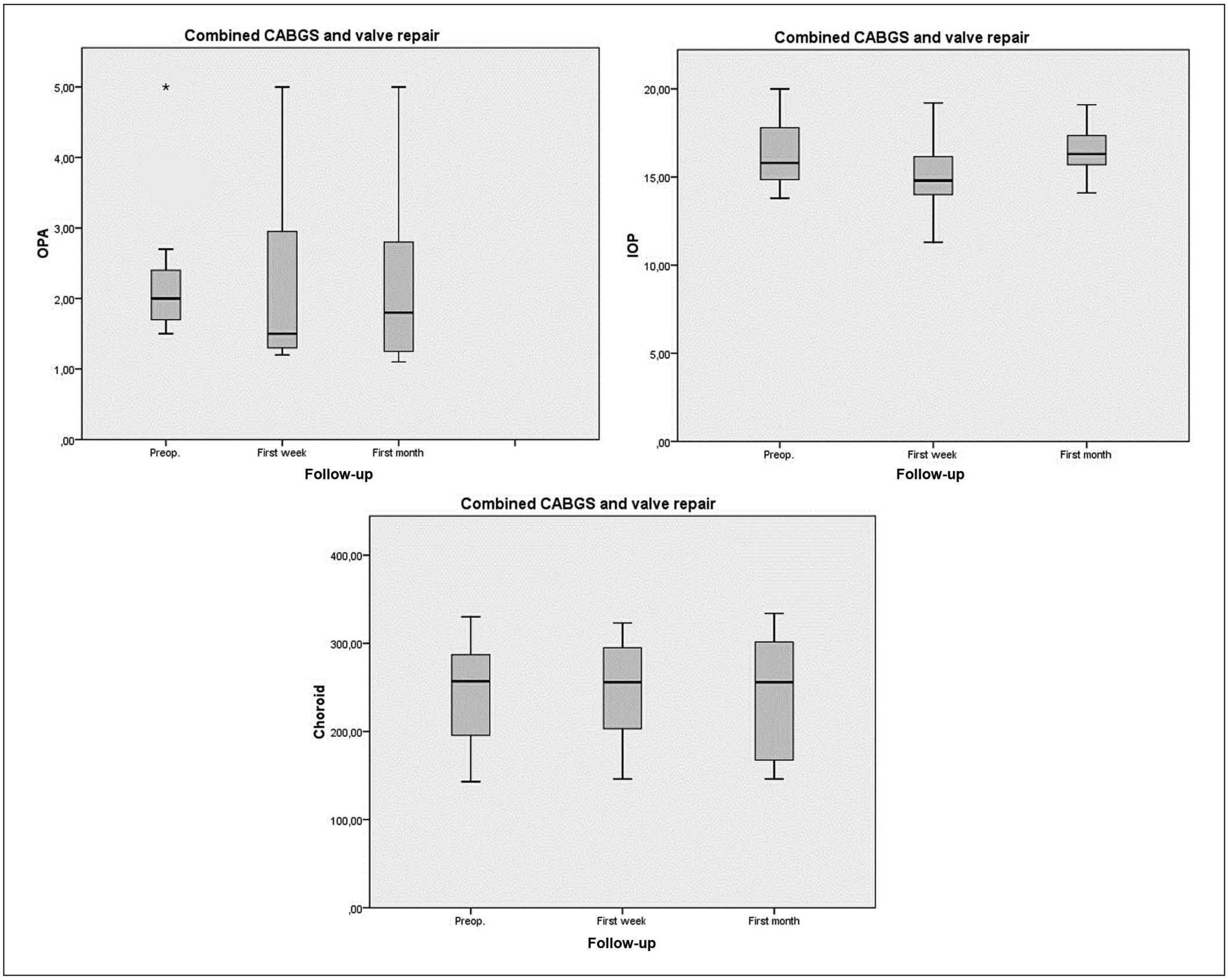

Figure 3. The box-plot graphic of combined CABGS and valve repair patients for OPA, IOP and SFCT parameters (CABGS: coronary artery bypass grafting surgery; OPA: ocular pulse amplitude; IOP: intraocular pressure; SFCT: sub-foveal choroidal thickness).

end of operation. Goto et al.[12] noted that olprinone, a cardiotonic agent, decreased IOP and increased ocular blood flow in patients after cardiac surgery with CPB.

Increased duration of CPB is strongly associated with a greater systemic inflammatory response and increased vascular resistance, thus, increased risk of ocular complications.[1] Also, it was reported that longer duration of CPB was correlated with increased embolic load.[13] Additionally, the duration of CPB was found to be longer in patients who developed ocular problems, such as anterior ischemic optic neuropathy.[1] Nenekidis et al.[14] reported that optic nerve head (ONH) blood flow was reduced during CPB and a negative association between extracorporeal circulation time and ONH blood flow occurred. However, we did not find an association between CPB time and choroidal changes in this study. The reason might be the relatively longer time interval between the operations and the ocular examinations. Another reason might be the usage of pulsatile flow rather than continuous flow during CPB.

Ocular perfusion pressure (OPP) is defined as arterial blood pressure minus IOP.[15] Many factors, such as vascular resistance, blood oxygen levels and hypothermia, might affect OPP.[16,17] It was shown that retinal blood flow remains unchanged despite large alterations in OPP[18,19]. It is obvious that autoregulation of choroidal blood flow is associated with ocular perfusion pressure. Although it is not known if gross OPP alterations can affect the choroid, our results, which might be interpreted as a decrease in OPP, do not affect SFCT and OPA to any extent.

Our study has several limitations. One of them is the inability to perform the measurements on the first postoperative day in order to see the early effects of gross hemodynamic alterations on the choroid. However, it

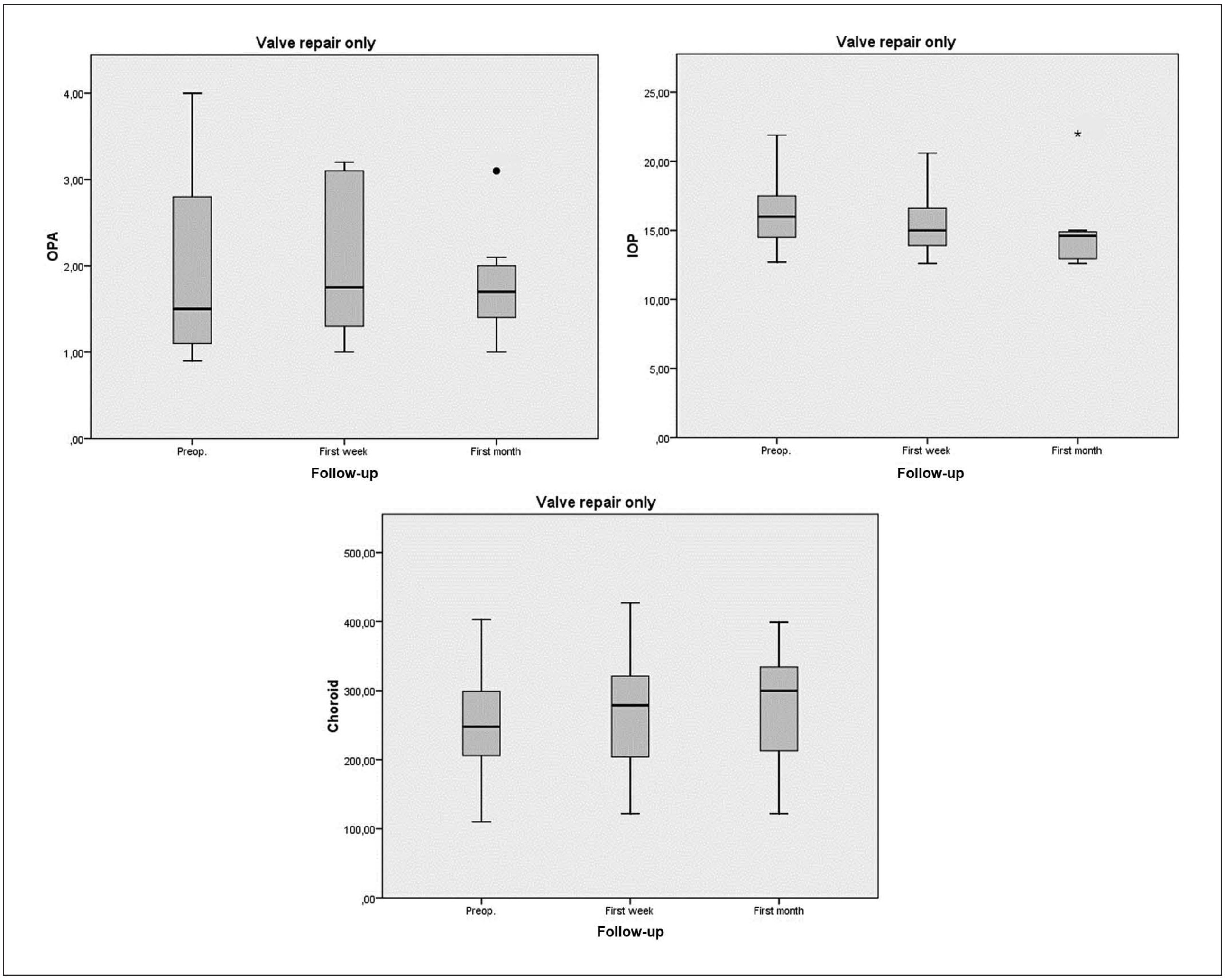

Figure 4. The box-plot graphic of valve repair only patients for OPA, IOP and SFCT parameters (OPA: ocular pulse amplitude; IOP: intraocular pressure; SFCT: sub-foveal choroidal thickness).

Table 2. The 'p' values for the correlation of OPA, SFCT and IOP changes with CPB time and ACC time at the first-week visit are shown.

	CPB time	ACC time
OPA	0.46	0.51
SFCT	0.29	0.08
IOP	0.50	0.67

(CPB: cardiopulmonary bypass; ACC: aortic cross-clamp; OPA: ocular pulse amplitude; SFCT: sub-foveal choroidal thickness; IOP: intraocular pressure).

was not possible to examine the patients via OCT and dynamic contour tonometry since they were in intensive care units. Another limitation is the lack of ocular Doppler ultrasound investigation and ocular perfusion pressure measurements that might support our findings.

In conclusion, the two choroidal parameters, SFCT and OPA, are not affected by heart surgery under CPB, while IOP decreases significantly one week and one month post-operatively. In other words, the CPB procedure does not impair the autoregulatory mechanisms of choroidal blood flow in the intermediate follow-up time. Since the factors that change SFCT and OPA are not fully understood, in general, this study also might give a little idea about the nature of these parameters.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

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