The Short Term Effects of Cardiopulmonary Bypass Surgery on Choroidal, Macular and Retinal Nerve Fiber Layer Thickness

Kardiopulmoner Bypass Cerrahisinin Koroid, Makula ve Retina Sinir Lifi Tabakası Kalınlığına Kısa Dönemdeki Etkisi

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ÖZ

Amaç: Bu çalışmada kardiopulmoner bypass (KPB) cerrahisi sonrasında koroid, makula ve retina sinir lifi tabakasındaki (RSLT) değişiklikleri araştırmayı amaçladık.

Gereç-Yöntem: KPB yöntemi ile kalp cerrahisi geçiren 31 hasta çalışmaya dahil edildi. Her hastaya tam oftalmolojik muayene yapıldı. Koroid, makula ve RSLT kalınlıkları spektral-domain optik koherans tomografi yardımıyla ölçüldü.

Bulgular: Hastaların ortalama yaşı 60.77±8.8 yıl idi. Subfoveal, temporal ve nazal bölgelerde ölçülen koroid kalınlığındaki değişim anlamlı değildi (p>0.05). Ameliyat öncesi ve sonrası ölçümler karşılaştırıldığında makula ve RSLT kalınlıklarında da istatistiksel farklılık izlenmedi (p>0.05).

Sonuç: Koroid, makula ve RSLT kalınlığı KPB cerrahisi sonrası 1. ayda değişmemektedir.
Anahtar Sözcükler: kardiopulmoner bypass, koroid kalınlığı, makula kalınlığı, optik koherans tomografi, retina sinir lifi tabakası kalınlığı.

ABSTRACT

Purpose: We aimed to evaluate the changes in choroidal, macular and retinal nerve fiber layer (RNFL) thickness after cardiopulmonary bypass (CPB) surgery.

Materials-Methods: A total of 31 patients underwent heart surgery with CPB were included in this prospective case series. Each subject underwent a standard ophthalmological examination. The choroidal, macular and peripapillary RNFL thickness measurements were performed using spectral-domain optical coherence tomography.

Results: The mean age of the patients was 60.77±8.8 years. The change in choroidal thickness was not significant at subfoveal, temporal and nasal macular locations (p>0.05). There were no statistically significant differences between the pre- and postoperative period with regard to macular thickness and peripapillary RNFL thickness measurements (p>0.05).

Conclusion: Choroidal, macular and RNFL thickness remained unchanged one month after CPB surgery.

Keywords: cardiopulmonary bypass; choroidal thickness; macular thickness; optical coherence tomography; retinal nerve fiber layer thickness.

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INTRODUCTION

The cardiopulmonary bypass (CPB) procedure utilizes extracorporeal circulation that constitutes a tremendous tool for surgeon to work on non-beating heart [1]. However, during surgery gross hemodynamic changes occur from the use of the heart-lung device, the administration of heparin, the establishment of hypothermia, the decrease in hemoglobin concentration from hemodilution and from the low arterial pressure [2]. Ocular complications after CPB as a result of systemic hypotension, embolism, hypothermia and hypoperfusion are rare but may cause severe visual impairment [3]. Possible causes of vision loss following cardiac surgery include; anterior ischemic optic neuropathy, branch or central retinal artery occlusion, pituitary apoplexy and cortical blindness [4]. The retina and choroid, as a highly vascular end organ with the greatest blood flow per mm^3 in the body [5], might be more susceptible ocular structures to hemodynamic instability.

Retinal nerve fiber layer (RNFL) and macular thickness measurements provide important clinical data for understanding the disorders of posterior ocular structures and with advances in the optical coherence tomography (OCT) technology even to obtain high quality sections of macula and neuroretina has been possible [6]. Imaging of the choroid was dramatically improved with the development of spectral domain optical coherence tomography (SD-OCT) and to assess choroidal thickness by enhanced depth imaging SD-OCT provides new data about choroid for researchers [7].

We hypothesized that dramatic hemodynamic changes and deterioration in the homeostasis during CBP would immediately affect the retina and choroid as being highly vascular structures. Our aim in this study was to investigate the effects of CPB on posterior ocular structures by measuring the choroidal, macular and RNFL thicknesses.

MATERIALS AND METHODS

In this prospective case series, 31 patients who underwent CPB surgery were included in the study. All subjects were informed about the goals of the study and informed consent was obtained. This study followed the tenets of the Declaration of Helsinki and the protocol was approved by the local Ethics Committee.

Ocular Examinations

Each subject underwent a standard ophthalmological examination including best-corrected visual acuity (BCVA), slit lamp examination, Goldmann applanation tonometer, pachymetry, indirect retinoscopy and OCT screening. All measurements were performed preoperatively and at the first month after surgery. Exclusion criteria included any corneal or retinal abnormalities, optic disc disorders and cup/disc ratio abnormalities, any history of ocular surgery or ocular trauma other than uneventful phacoemulsification not within 6 months, refractive errors exceeding ±2.0 diopters.

The peripapillary choroidal, macular and RNFL thickness measurements were performed with Cirrus HD spectral domain OCT (Carl Zeiss Meditec, Dublin, CA) by the same masked technician. The average and four (temporal, nasal, inferior and superior) quadrant peripapillary RNFL thickness were obtained with the 200x200 cube scan protocol along a circle with a diameter of 3.45 mm around the center of the disc. Signal strengths >7 were included in the study. The choroid was independently measured manually by the same blinded observer (MK) from the external part of the outer highly reflective layer to the sclerochoroidal interface under the foveal center and at three different points 500 µm apart, starting from the foveal centre, in the nasal (Nasal CT; 0.5, 1, and 1.5 mm from the fovea) and temporal (Temporal CT; 0.5, 1, and 1.5 mm from the fovea) directions.

Cardiac Surgery Technique

All of the patients included in this study were administered coronary artery bypass grafting. All patients underwent surgery with the help of CPB that was established with an aortic cannula and a single venous cannula. The CPB circuits essentially used membrane oxygenators equipped with arterial filters. The systemic temperature was lowered to 30-32C. Pulsatile flow of 2.4 L/min/m2 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 and retrograde cold blood cardioplegia. Heparin was given to maintain the activated clotting time between 450-480 seconds and was neutralized by protamine at the end of CPB.

Statistical Analysis

Data analysis was performed by using SPSS for Windows, version 23 (IBM Corp., Armonk, NY, USA). Whether the distribution of continuous variables were normally or not was determined by Kolmogorov Smirnov test and this test yielded normal distribution for all groups ($p>0.05$). Continuous variables were shown as mean ± standard deviation (SD). The mean difference between pre- and postoperative values was compared by using paired *t* test. A p value less than 0.05 was considered statistically significant.

RESULTS

The mean age of the patients was 60.77±8.8 ranging from 46 to 77 years. Twenty four patients were male (77.5%) and 7 patients were female (22.5%). Preoperative demographics of all patients are seen at Table 1. Any retinal problem or vision loss observed in none of the patients at the postoperative visit.

Table 1. *Demographic characteristics of all patients.*

Variables	**n=31**
Age (years)	60.77±8.8
Sex	24 male, 7 female
IOP (mmHg)	14.74±1.8
BCVA (Snellen)	0.92±0.04
CCT (µm)	545.2±32.1

IOP: Intraocular pressure, BCVA: Best corrected visual acuity, CCT: central corneal thickness

The mean subfoveal choroidal thickness of both eyes at pre- and postoperative period listed in Table 2. No statistically significant difference observed in regard to choroidal thickness values at all examined points (p>0.05).

Table 2. *Mean choroidal thickness of all examined points*

Variables (µ)	**Preoperative**	**Postoperative**	**P value**
SFCT			
Right	284.19±57.09	277.32±64.9	0.43
Left	282.23±68.74	290.58±64.12	0.30
N_1			
Right	262.35±53.55	269.68±63.66	0.39
Left	250.55±61.07	255.65±62.27	0.50
N_2			
Right	235.90±57.67	235.61±62.07	0.97
Left	233.03±67.15	233.94±66.61	0.92
N_3			
Right	202.65±58.57	203,97±48.44	0.86
Left	196.03±54.49	196.87±65.90	0.93
T_1			
Right	280.29±50.06	279.71±71.54	0.94
Left	272.35±72.33	278.55±72.79	0.53
T_2			
Right	294.52±65.90	280.94±79.90	0.17
Left	262.06±72.77	281.58±80.01	0.11
T_3			
Right	296.94±65.66	290.13±75.79	0.45
Left	267.55±74.78	268.65±75.00	0.92

SFCT :Subfoveal choroidal thickness, N: nasal, T: temporal.

Macular thickness values at pre- and postoperative visit are shown in Table 3. There was no significant difference between these two visits in terms of central macular thickness (p>0.05).

The mean preoperative RNFL thickness of right and left eyes were 92.23±13.52 µm and 94.90±11.38 µm, respectively. The mean postoperative RNFL thickness of right and left eyes were 99.61±35.33 µm and 95.71 ±19.73 µm, respectively. Quadrantal peripapillary RNFL thickness (superior, nasal, inferior and temporal) measurements are shown in Table 4. There were no significant differences between pre- and postoperative period in regard to both mean and quadrantal peripapillary RNFL thickness values (p>0.05).

Table 3. *The comparison of the macular thickness between pre- and postoperative period.*

Variables (µ)	**Preoperative**	**Postoperative**	**P value**
MT			
Right	254.68±30.08	249.42±23.89	0.17
Left	254.16±24.52	251.87±22.39	0.29

MT: Macular thickness

Table 4. *The comparison of the average and segmental RNFL thickness between pre- and postoperative period.*

Variables (µ)	**Preoperative**	**Postoperative**	**P value**
Average RNFLT			
Right	92.23±13.52	99.61±35.33	0.16
Left	94.90±11.38	95.71 ±19.73	0.79
Superior			
Right	115.03±21.79	113.10±20.66	0.53
Left	113.45±22.85	111.97±32.89	0.21
Nasal			
Right	72.03±13.65	74.52±10.52	0.19
Left	67.71±11.27	71.26±18.12	0.15
Inferior			
Right	116.26±19.27	116.82±22.01	0.72
Left	108.48±27.18	109.87±29.01	0.11
Temporal			
Right	67.26±12.52	69.52±15.97	0.39
Left	61.61±12.73	62.81±17.13	0.14

RNFLT: Retinal nerve fiber layer thickness

DISCUSSION

Our results indicate that choroidal, macular and RNFL thicknesses do not change one month after CPB surgery.

Perioperative ocular injury in cardiac surgery are rare but may cause serious and permanent visual loss. The incidence of ocular complications after cardiac surgery was reported between 0.06% and 0.113% [8]. Main reasons of cardiac surgery related vision loss are branch or central retinal occlusions and ischemic optic neuropathy. Significant hemodynamic alterations occur during CPB include gross changes in homoeostasis, hypothermia, systemic vasodilatation, decrease in hemoglobin concentration from hemodilution and various changes in metabolite concentrations [4]. During open heart surgery large numbers of micro emboli circulate in blood stream may result in retinal vascular occlusions or retinal ischemia[4].

The choroid, one of the most metabolically active tissue in the body, supplies blood to the outer one-third of the neuroretina and the retinal pigment epithelium and provides oxygen and nutrients to the fovea. Previous choroidal imaging techniques such as indocyanine green angiography and ultrasound provides limited data about choroidal circulation due to poor resolution and reproducibility [7]. With the invention of SD-OCT, documentation of the choroid dramatically improved with clear and highly reproducible choroidal images[9]. However the true correlation between choroidal measurements and in vivo choroidal function is uncertain[10], choroidal thickness is still the closest objective marker of choroidal health available with present imaging techniques[7]. The choroidal blood flow is well autoregulated by myogenic, neurogenic and metabolic factors maintaining the relative constant ocular temperature and retinal perfusion pressure[11]. The choroidal vascular beds supply nutrients to the most critical ocular parts including optic nerve and macula. Thus autoregulation is much more efficient to the choroid than retina[12]. In the present study we observed choroidal thickness did not change significantly after CPB. Similarly, Pekel et al. reported that subfoveal choroidal thickness and ocular pulse amplitude are unchanged, while intraocular pressure decreased one week and one month after CPB[13].

Optic nerve is the most vulnerable site of ischemic injury of the visual pathway and ischemic optic neuropathy is reported as one of the most common ocular complication in patients undergoing cardiac surgery with CPB [3]. Indeed, optic nerve head blood flow is autoregulated over a wide range of perfusion pressures [14]. Prolonged CPB time, anesthetic duration>6 hour, blood loss of >1000 ml and intractable hypotension may cause severe reduction in blood supply or oxygen transportation capability, exceeding the autoregulation ability limit of the vascular beds that supply blood to the optic nerve. Retinal neurodegeneration presented as thinning of the RNFL has been well-documented since the use of OCT. Because the retinal arteriole blood flow is adequately maintained by autoregulation, the relationship between retinal microvascular and microstructural changes is still controversial [15]. In the present study, we observed RNFL thickness did not change one month after CPB. Pekel et al. found peripapillary RNFL was slightly thinner in coroner artery bypass grafting (CABG) surgery patients, although the difference was not statistically significant [16]. In contrast with our results, Buyukates et al. found that, after one month from CABG surgery, the inferior quadrant peripapillary RNFL became significantly thinner than the preoperative values [17].

Our results indicate that CPB surgery does not affect the macula. We observed no statistically significant difference between pre- and postoperative period in terms of macular thickness. Similarly, Pekel et al. reported the macular thicknesses of the CABG surgery patients and control subjects were very similar[16].

Our study has a number of limitations. The study group was relatively small. It would be nice if we perform all measurements within one week postoperatively. However, all patients were sent to intensive care unit immediately after the operation and we were unable to perform OCT measurements at the very early postoperative period.

In this study, we investigated the impact of CPB on retinal and choroidal structures. In conclusion, we observed CPB did not affect the choroidal, macular and RNFL thickness at first month of the surgery.

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