ARAŞTIRMA MAKALESİ/ORIGINAL RESEARCH

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Investigation of Changes in Visual Functions and Fundus in Coronary Artery Bypass Grafting Operations with Cardiopulmonary Bypass

Kardiyopulmoner Baypas ile Yapılan Koroner Arter Baypas Greft Operasyonlarında Görme Fonksiyonu ve Göz Dibi Değişikliklerinin Incelenmesi

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ABSTRACT

Introduction: The effects of cardiopulmonary bypass(CPB) on visual functions was sought by comparison of visual examinationsin the preoperative and early postoperative periods of isolated coronary artery bypass grafting(CABG) operations with CPB.

Methods: Twenty consequent patients (16 males, 4 females; average age 58.75±7.88 years; range 45-69 years) operated for isolated CABG with CPB at the same centre by the same team were enrolled. All patient data were recorded prospectively. The patients were compared regarding vision defects, retinal vascular and other structural changes by examination of vision, fundus examination for retinal pathologies and retinal photography to verify retinal structural changes in preoperative and postoperative periods. The findings on the last preoperative and seventh postoperative days were analyzed.

Results: Between the preoperative and postoperative examinations, visual acuity of the left eye (p=0.042), intraocular pressure of the right eye (p=0.008) and intraocular pressure of the left eye (p=0.004) were found statistically significantly higher. Intraocular pressure showed correlation with aortic cross clamp and intubation duration, which was not accepted as clinically significant. No structural defects were detected by biomicroscope. The findings of direct examination of fundus photographed preoperatively, remained unchanged postoperatively. No differences could be detected regarding arterial and venous structures, optic papilla, macula, and peripheral retinal structure between the preoperative and postoperative periods.

Discussion and Conclusion: Maintaining careful cannulation and proper management of CPB in coordination with anaesthesiologist, CABG operations can be performed safely with CPB, since no undesired effects on preoperative and postoperative direct fundusexaminations, retinal morphology, visual functions and consequently on cerebral functions in part were detected.

Keywords: coronary artery bypass grafting surgery, cardiopulmonary bypass, visual function

ÖZ

Giriş ve Amaç: Kardiyopulmoner baypas(KPB) kullanılarak izole koroner arter baypas greftleme(KABG) ameliyatı uygulanan hastaların, preoperatif ve postoperatif erken dönemdeki göz anatomileri ve görme fonksiyonları karşılaştırılarak KPB'ın görme fonksiyonu üzerine etkilerinin araştırılması amaçlanmıştır.

Yöntem ve Gereçler: Çalışmaya, Haziran 2008–Mart 2009 tarihleri arasında aynı merkez ve cerrahi ekip tarafından KPB ile izole KABG ameliyatı uygulanan ardışık 20 hasta (16 erkek, 4 kadın; ortalama yaş 58.75±7.88 yıl; dağılım 45-69 yıl) alındı. Hastaların tüm verileri prospektif olarak kaydedildi. Preoperatif ve postoperatif dönemde görme muayenesi, retinal patolojileri değerlendirmekamacıyla göz dibi bakısı ve retinal yapısal değişimleri verifiye etmek amacıyla retinal fotograflama yapılarak, muhtemel görmekusurları, retinal vasküler ve diğer yapısal değişiklikler karşılaştırıldı. Hastaların operasyondan bir gün önce ve 7 gün sonra yapılan göz bulguları analiz edildi.

Bulgular: Preoperatif ve postoperatif muayeneler arasında sol göz görme keskinliği(p=0.042), sağ göz intraoküler basıncı(p=0.008) ve sol göz intraoküler basıncı (p=0.004) anlamlı olarak daha yüksek tespit edildi. İntraoküler basınç ile kros klemp ve entübasyon süreleri arasında korelasyon saptanmış olmasına rağmen klinik olarak anlamlı bulunmadı. Çalışma hastalarında preoperatif ve postoperatif muayenelerinde biomikroskop ile herhangi bir yapısal bozukluk saptanmadı. Preoperatif fotoğraflanmış olan göz dibi incelemesinde saptanan bulgularla, postoperatif görüntüler arasında fark saptanmadı. Göz dibi muayenelerinde arteryel ve venöz yapılarda, optik papillada, makulada ve yapısal olarak periferik retinada preoperatif ve postoperatif muayeneler arasında farklılık bulunmadı.

Tartışma ve Sonuç: Preoperatif ve postoperatif direkt fundus incelemesi, retinal morfoloji ve görme fonksiyonu, buna bağlı olarak dakısmen serebral fonksiyonlar üzerine olumsuz etkisi saptanmayan KPB ile yapılan KABG cerrahisi, dikkatli ve özenli kanülasyon, cerrahi ve anestezi birimleri ile koordinasyon içinde doğru pompa idaresi ile güvenle yapılabilir.

Anahtar Kelimeler: koroner arter baypas grefti cerrahisi, kardiyopulmoner baypas, görme fonksiyonu

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INTRODUCTION

Cardiovascular disease is the main reason of morbidity and mortality in western and developing countries (1). Recently, coronary artery bypass grafting (CABG) operation, which is performed for surgical treatment of coronary artery disease with success not only worldwide but also in our country, took its place in the literature as the most performed cardiac surgical practice (2). Although the operative mortality of CABG is 2-3% approximately, morbidity due to neurological and neurophysiological complications is relatively higher (3). Neurological injury is a well-known sequela following cardiac surgery with cardiopulmonary bypass (CPB) and it is an important reason of morbidity and mortality (4). Despite the significant effort made to understand the relative contribution of many perioperative factors regarding the occurrence of neurological complications following CPB, evaluating the contribution of each of the potentially responsible factors such as embolization, hypoperfusion, hypoxemia, hypotension, arrhythmia, coagulopathies, dehydration, and inflammation is difficult (5). Even though numerous mechanisms may be blamed related to CPB owing to its structure and function, one of the most important reasons of neurological complications depending on CPB is the air or particle embolization from any stage of the CPB circuit (6). Whatever the source is, the arterial occlusion caused byembolization may result in target organ injury and undesired results may occur temporarily or permanently (7). The incidence of major neurologic events like stroke, unconsciousness and diffuse encephalopathy is 2-5%, where the incidence of minor events such as nystagmus, decreased coordination, hyporeflexia and sensorial anomalies is between 20-25% (8).

Eye is located as an appendage of the brain due to the special anatomical structure of its retinal layer for function of vision (9). Some of the retinal pathologies affecting the visual function are directly related to cerebral pathologies; therefore, some of the cerebral pathologies may result in findings which bring out the retinal pathologies (10). Loss of vision related to postoperative ischemia arises from the lesions of the visual pathway caused by insufficient oxygen supply to the tissues due to many reasons (11). Loss of vision (acuity or field) secondary to ischaemic optical neuropathy (ION) is a rare but devastating complication of cardiac surgery with CPB (4). While the incidence of postoperative loss of vision among all types of operations differs between 0.1-0.002 %, cardiac surgery related ION was reported to be limited to a few patient-case reports (12). Myers et al reported 37 patients withloss of vision due to anterior ION secondary to retinal artery occlusion or cerebral ischemia following vertebra surgery (13). In another study, postoperative low haemoglobin concentration, history of severe clinical vascular disease and coronary angiography performed in the last 48 hours prior to operation were shown tobe related to blindness following CPB in patients with ION (14). In a prospective study including 312 patients who were operated for CABG, whose bedside ophthalmologic evaluation was done preoperatively and postoperatively, 25.6% of the patients were reported to develop neuroophtalmological complications, of whom 17.3% had areas of retinal infarction, 2.6% had retinal embolism, 2.6% had defects in field of vision, 4.5% had decrease in visual acuity and 1.3% developed Horner's syndrome (15).

Ischaemic optical neuropathy is defined as a defect of the optic nerve which usually results in permanent loss of vision. The pathophysiology of this disease is variable, and it isconsidered not only as a haemorrhagic but also as a neurological complication of CABG operations. In this study, it is aimed to compare the preoperative and early postoperative anatomical structures of the eyes and visual functions of the patients operated for isolated CABG with CPB, to understand the pathophysiology and risk factors of ION more clearly and search for

the effects of CPB on visual functions.

MATERIAL AND METHODS

A total of 20 patients with an age of 45 to 70 years, who were diagnosed with coronary artery disease by cardiac catheterization (≥%75 stenosis in one or more coronary arteries), who had normal carotid arteries by colour Doppler ultrasonography and were operated for isolated CABG with CPB in the same centre by the same team between June 2008 and March 2009, were enrolled in the study. All the patients were interned one day prior to operation and all their preoperative examinations were done. The patients were transferred to the same eye clinic preoperatively and on the seventh postoperative day under the supervision of a doctor, where their examination of eye and vision were done firstly, and fundus examination by ophthalmoscope and retinal photographic imaging was performed following pupillary dilatation secondly, all by the same ophthalmologist. These findings were recorded. The demographic data (age, gender), presence of comorbidities (smoking, diabetes mellitus, hypertension, hyperlipidaemia, left ventricle ejection fraction), preoperative medications (acetylsalicylic acid, metoprolol, antihyperlipidemic and antihypertensive drugs, oral nitrates etc.), preoperative and postoperative laboratory parameters, operation information, number of grafts used, durations of CPB and aortic cross clamp, intubation duration, amount of drainage, amount of blood products used, length of stay in the intensive care unit and hospital were recorded.

Patients who described visual function defi ciency clinically in the preoperative period, who already had vision defects or history of diagno sis of retinopathy, who had carotid stenosis detected by Doppler ultrasonography, peripheral arterial disease, cardiac valvular disease, congenital heart disease, left ventricular systolic function defect (ejection fraction≤%25), heart failure, acute coronary syndrome, cerebrovascular disease; patients with<45 years and>70 years of age; patients with hepatic or renal failure, endocrinological disorders (hypothyroidism, hyperthyroidism), systemic inflammatory diseases, haematological diseases; patients with low haemoglobin(Hb) levels (≤10 g/dl); patients cannulated from femoral artery due to the ascending aorta calcification; patients who had an acute myocardial infarction and percutaneous coronary intervention in the last 30 days prior to operation, emergency operations, patients who were reoperated due to hemodynamic instability or bleeding, patients who required intra-aortic balloon pump, patients with a diagnosis of active or chronic autoimmune diseases, patients who were operated on beating heart or redo CABG were excluded from the study.

Both eyes were examined preoperatively and on the seventh postoperative day on both eyes in terms of visual acuity, intraocular pressures, measurements of refraction deficiencies by autorefractometry and measurements of keratometry; optic disc structure, arterial and venous structural disorders and other retinal pathologies as fundus examination parameters, and all of these were recorded. The retinal images were obtained and recorded by digital camera and stored in the form of jpeg into computer environment following digital magnification. The preoperative and postoperative retinal images were compared in terms of retinal anatomy, vascular wall changes, arteriosclerotic changes, arteriovenous compression, soft exudates, hard exudates, microaneurysms, neovascularization, retinal haemorrhage, vascular occlusion, optic disc edema, optic nerve damage, embolism (gas embolism, platelet embolism, Hollenhorst plaque, calcium plaque, Roth spot, lipid embolism etc.) and findings related to di- abetic changes by an ophthalmologist unaware of the patient data. For both eyes, correlation between intraocular pressure changes and preoperative LVEF, durations of aortic cross clamp and CPB, Hct difference between the preoperative and postoperative periods and duration of intubation were sought.

Written informed consent form was obtained from all the patients included in the study. This study complied with the Declaration of Helsinki and was carried out following approval of the Education Planning Committee of Istanbul Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital.

Premedication and anaesthetic technique were standardized. All patients received 0.5 mg oral alprazolam on the night before surgery and 5 mg intramuscular midazolam was administered 30 minutes prior to operation. Monitorization was made continuously by 5-channel ECG, invasive arterial pressure, and central venous pressure monitorizations. Anaesthetic induction was made with 10 mcg/kg fentanyl citrate, 0.1 mg/kg midazolam and 0.6 mg/kg rocuronium bromide was given for muscular relaxation. Anaesthetic maintenance was done with midazolam (0.03 mg/kg) and rocuronium bromide (0.15 mg/kg).

All the patients were operated under general anaesthesia with standard median sternotomy. Left internal mammarian artery was harvested and saphenous vein grafts were prepared if required. Pericardium was opened and examined; when no adhesions were seen, allthe patients were administered intravenous systemic Heparin (300-400 IU/kg) maintaining an "activated clotting time" (ACT) >450 seconds. Finding an appropriate cite by palpation, arterial cannulation was made on theascending aorta and two-stage venous cannulation was made on the right atrial appendage and CPB was initiated. ACT was checked in every 30 minutes and additional heparinization was made for maintenance. Roller pump (Cobe Cox III, Lakewood, Co 80215, USA) and membrane oxygenators (Medtronic Trillium, Affinity Nt 541t, Minneapolis, USA) were used. Antegrade hypothermic and hyperkalemic blood cardioplegia was applied to all patients. Surgery was performed under moderate systemic hypothermia (28-30ºC). Cardiopulmonary bypass flow was maintained 2.2-2.5 l/min/m^2, mean perfusion pressure was maintained between 50 and 80 mmHg, haematocrit level was maintained between 20 to 25 percent during CPB. For the coronary bypass operations, the left internal mammary artery (LIMA) was preferred for the arterial graft for left anterior descending artery (LAD) revascularization, whereas saphenous venous grafts were used for the other vessels. Distal and proximal anastomoses were done during aortic cross clamp. A single mediastinal drain was used in all patients; if the thorax cavity was opened, an additional drain was inserted.

All patients were transferred to intensive care unit intubated postoperatively. They were extubated following onset of spontaneous bre athing and normalization of orientation and cooperation if the hemodynamic and respiratory functions were appropriate. If there wasno contraindication, 50 mg/day of metoprolol was started orally to all patients following the first postoperative day.

Statistical Analysis

Statistical analysis was performed using the SPSS Windows version 15.0 (SPSS Inc, Chicago, IL, USA). Among the data measured, those showing normal distribution were expressed as mean±standard deviation; those not showing normal distribution were expressed as median (minimum-maximum). The data obtained by counting were given as percentages (%). Among the data measured, the normality of distribution was evaluated by histogram or Kolmogorov-Smirnov test, thehomogeneity of distribution was evaluated by 'Levene's test for equality of variance'. Paired samples T test was used for statistical comparison between preoperative and postoperative eye examinations. Pearson correlation coefficient was used in case of normal distribution of data and Spearman Rank correlation coefficient was preferred in case of unnormal distribution The statistical significance of the

difference between the groups was evaluated with One-Way ANOVA, Tukey HSD test and Paired samples test according to the data distribution. Statistical significance was accepted as $p<0.05$.

RESULTS

The demographic characteristics and clinical data of the patients were summarized in **Table 1**. Among the patients enrolled in the study, 90% (n=18) had acetylsalicylic acid, (ASA), 55% (n=11) had metoprolol, 40% (n=8) had antihyperlipidemic, 35% (n=7) had oral nitrate, 55% (n=11) had antihypertensive drug therapies.

Ninety-five percent (n=19) of the patients had left anterior descending artery (LAD), 65% (n=13) had diagonal artery (Dg), 50% (n=10) had circumflex artery (Cx), %5 (n=1) had left main coronary artery (LMCA) and 55% (n=11) had right coronary artery (RCA) critical lesions with coronary angiography.

Table 1: **Demographic Characteristics of Study Patients**

Patient's Characteristics	**Preoperative Patients (n = 20)**
Age (years) (mean ± standard deviation)	58.75 ± 7.88
Male (%)	16 (80 %)
Female (%)	4 (20 %)
BMI (Kg/m^2) (mean ± standard deviation)	26.9 ± 2.9
Hypertension (%)	15 (75 %)
Diabetes mellitus (%)	10 (50 %)
Smoking (%)	16 (80 %)
Hyperlipidaemia (%)	11 (55 %)
Ejection fraction (%) (mean ± standard deviation)	53.3 ± 8.5

BMI: Body mass index

The preoperative and early postoperative blood analysis and haematological parameters of the patients summarized in **Table 2**. The average systolic arterial pressures measured with invasive monitorization in the operating theat- re during anaesthesia induction were 119.5 ± 8.9 mmHg (min-max; 110-140). Among the patients, 5% (n=1) had one, 45% had (n=9) two, 30% had (n=6) three, 20% had (n=4) four grafts bypassed. The average aortic cross clamp and cardiopulmonary bypass durations of the patients were 74.9 ± 25.8 minutes (min-max; 20-127) and 99.4±31.4 minutes (min-max; 35-173), respectively. The average arterial pressures maintained during CPB were 74.8 ± 5.5 (min-max; 70-85) mmHg. The average Hct values obtained during anaesthesia induction, during CPB and at the end of the operation were 33.6 ± 3.1 % (min-max; 30-43), 23.3 ± 3.0% (min-max; 20-30) and 26.7 ± 2.7% (min-max; 21-32), respectively. The average number of erythrocyte suspensions transfused regarding the Hct value during CPB was 0.8 units (max: 2); each of the patients were given one unit of fresh frozen plasma at the end of the operation. The average perioperative liquid

Table 2: Preoperative and Postoperative Blood Results and Haematological Parameters of Patients

Blood results and haematological parameters	Preoperative data of study patients (n = 20) (mean ± standard deviation)	Postoperative data of study patients (n = 20) (mean ± standard deviation)
Haemoglobin (mg/dl)	13.3 ± 1.6	9.1 ± 1.2
Haematocrit (%)	40.4 ± 3.2	28.6 ± 1.6
Uric Acid (mg/dl)	5.8 ± 1.3	6.3 ± 1.4
Creatinine (mg/dl)	1.12 ± 0.31	0.97 ± 0.29
Urea (mg/dl)	22.1 ± 4.5	17.1 ± 3.4
Fasting Blood Glucose (mg/dl)	115.2 ± 26.3	132.1 ± 62.5
HbA_{1c} (%)	6.3 ± 1.5	6.1 ± 1.2
LDL-cholesterol (mg/dl)	134.7 ± 44.2	121.9 ± 31.5
Cholesterol (mg/dl)	192.8 ± 32.5	174.6 ± 41.9
Platelet count ($x10^3/\mu L$)	219.9 ± 62.4	265.1 ± 60.9
CRP (mg/L)	0.99 ± 0.54	28.91 ± 5.58
Triglyceride (mg/dl)	173.9 ± 94.9	165.7 ± 75.1

HbA1c: Glicolysed Haemogobin
LDL: Low Density Lipoprotein
CRP: C-reactive protein

balance of the patients was +205 ml (ranging from -800 to +800 ml). In the postoperative intensive care unit, the average intubation duration of the patients was 9.35 ± 4.49 (min-max; 6-22) hours, drainage was 650 ± 205 ml (min-max; 250-1050) and Hct level was 28.6 ± 1.6% (min-max; 26-32). 20% (n=4) of the patients were given low-dose inotropic support. Apartfrom two patients transferred to the inpatient clinic on the second and fourth postoperative days due to late extubation and agitation, all thepatients left the intensive care unit on the first postoperative day. Atrial fibrillation occurred in one (5%) patient and agitation in two (10%) in the inpatient clinic follow-up. None of the patients had any neurological deficit or loss of vision.

The findings of physical examination of the eye preoperatively and on 7th postoperative day were summarized in **Table 3**. Among the preoperative and postoperative examinations, left eye visual acuity (p=0.042), right eye intraocular pressure (p=0.008) and left eye intraocular pressure (p=0.004) in the postoperative period were found statistically significantly higher. There was not any

Table 3: Comparison of Preoperative and Postoperative Findings of Visual Examinations

Findings	Preoperative values (n = 20)	Postoperative values (n = 20)	p value
	mean ± standard deviation	mean ± standard deviation	
VA right	8.90±1.02	9.10±0.91	0.163*
VA left	8.71±1.55	8.92±1.20	0.042*
To right	13.25±1.71	13.75±2.04	0.008 *
To left	14.01±1.17	14.81±1.79	0.004 *
ORM right	0.52±0.67	0,54±0,68	0.123*
ORM left	0.46±0.57	0.48±0.55	0.163*
KRM right horizontal	43.03±1.45	43.01±1.47	0.163*
KRM right vertical	43.08±1.39	42.96±1.10	0.086*
KRM left horizontal	42.70±1.44	42.70±1.37	0.987**
KRM left vertical	43.12±1.59	43.05±1.44	0.055*

*Paired Samples T test
VA: Visual acuity
ORM: Autorefractometry
To: Intraocular pressure
KRM: Keratometry

statistically significant correlation between duration of intubation, CPB and aortic cross clamp and postoperative intraocular pressures of the left and right eyes. There were no structural defects detected among the study population with preoperative examination by biomicroscope (**Figure 1**). This didnot change in the postoperative period either (**Figure 2**). Using direct photography of the fundus preoperatively, 30% (n=6) of the patients had retinal hard exudates, 20% (n=4) had soft exudates, %10 (n=2) had arteriovenous compression and venous ectasia in a single eye due to arterial compression, 15% (n=3) had retinal haemorrhage of small diameter. However, there were no differences compared to the postoperative fundus photographs. No differences were found between the preoperative and postoperative examinations of the superior nasal, inferior temporal and inferior nasal arterial and venous structures, optic papilla, macula, and structural peripheral retina.

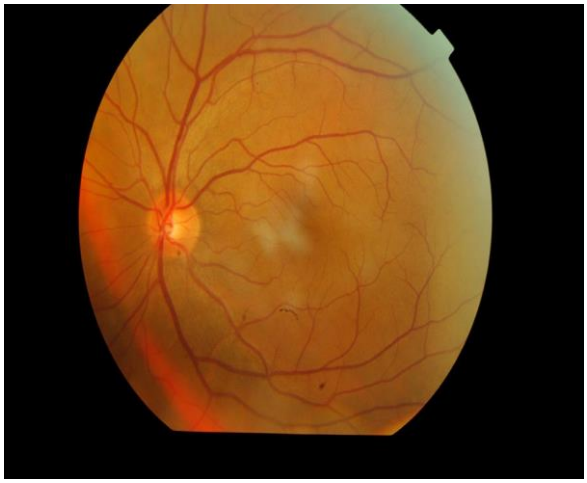

Figure-1: Preoperative image sample of the fundus

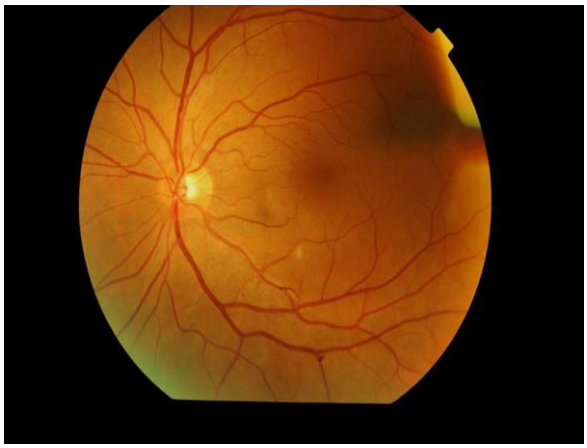

Figure-2: Postoperative image sample of the fundus

DISCUSSION

In this study, we investigated whether CPB affected the visual functions or not, by comparing the eye anatomy and visual functions of the patients in the preoperative and early postoperative periods of isolated CABG withCPB. Thus, any undesired effect of isolated CABG with CPB was not detected by findings of examination of vision and fundus directly, in terms of retinal morphology and visual functions, and partially on cerebral functions as related.

Coronary artery bypass grafting operations have been performed safely and successfully in our country as well as the whole World (16). Despite the advancements in surgical technique, anaesthetic management and supportive medical therapies, major adverse renal, cardiac, and cerebral events are ongoing threatsfollowing cardiac surgery (17). Coronary artery bypass grafting operation is a lifesaving and life quality enhancing procedure; however, cerebral complications are responsible for most of thereasons for morbidity and mortality following cardiac surgery (18). Brain injury following cardiac surgery may be presented either as a definite neurological complication or a neuropsychological dysfunction undetectable under normal conditions (5). Depending on the definition of the occurred deficiency, the incidence of neurological complications following CABGwas reported to vary between 0.4 to 80% (19). The mechanisms for these neurological and neurophysiological complications have not been well understood yet; factors such as micro- or macro embolism, low mean arterial pressure, advanced age, history of neurological or psychiatric disease, increased duration of CPB and operation, type of oxygenator system and CPB type as pulsatile or nonpulsatile may result in differences regarding cerebral perfusion during and following CABG (20). Neurological complications following CABG operations are matters of concern due to their effects on length of hospital stay, mortality, healthcare expenses and quality of life (21).

Since introduced in 1953 by John H. Gibbon, CPB has been used to support cardiac surgery (22). Not only that evolution and clinical use of CPB and modern myocardial protection methods made countless cardiac operations possible which cannot be performed either, but also these techniques are in relation with many complications and pathophysiological processes which involve almost all the patients operated (21). Blindness, which is a rare entity following cardiac surgery with CPB, is not an event completely understood. It may be caused by ischemic optical neuropathy (ION) which may lead to loss of visual acuity and field of

vision; however, cortical mechanisms are also a probability for loss of vision (4). In a review of 5.6 million patients from National Inpatient Sample the visual loss ratio after cardiac surgery was 8.64/10.000 (23).) Ischemia related visual loss following surgery originates from lesions of visual pathway, which cause inability to supply oxygen to the tissues for many reasons (24). In a study, perioperative ION was detected in 17 (0.06%) of 27,915 patients operated for CABG (4). ION is the most frequent reason of perioperative visual loss; Kalyani *et al.* found that, 11 patients (0.113%) had perioperative optic neuropathy out of 9701 surgery patients operated for CABG (25).

Although a small probability, one of the etiologic factors for ION is embolism; however, proving the relationship between embolism and ION is difficult (26). Horton reported two patients with cilioretinal arterial embolism (27). Short posterior ciliary arteries provide blood supply to both the optic disc and the cilioretinal artery; therefore, embolization of the cilioretinal artery is theoretically possible to result in ION by affecting the optic disc (28). In another study, three patients who developed ION, two operated for CABG and one with cardiac catheterization, significant retinal embolism was detected (29). Portnoy et al showed choroidal perfusion loss, related ION, and retinal embolism in a patient by fluorescein angiography (30). In a prospective study including 421 patients operated for CABG, infarctions of the retina were detected in 5 patients and the optic nerve infarctions in 2 (31). Likewise, in another study, retinal embolism was shown with fundus fluorescein angiography (FFA) and evidence of microvascular occlusion were found in all patients with pathologic FFA; although, the reasons for occlusion could not be found, the possible reasons were mentioned as vascular spasm, gas micro-bubbles or particle embolism with platelet-fibrin micro-aggregates (26). In our study, FFA which was planned to be performed when clinically required was not needed, since evidence of embolism was not detected both with clinical findings and retinal images.

The ischaemic effect on the optic nerve is classified as anterior ION (AION) and posterior ION (PION) regarding the variability of the blood supply to optic nerve. While AION results more in loss of visual field, visual acuity and swelling of the optic disc, PION results in acute loss of visual acuity and loss of visual field like AION, but without swelling of the optic disc (4). AION emerges mostly after cardiac surgery because of insufficient blood flow by short posterior ciliary arteries to retrolaminar portion of the head of the optic nerve (32). There have been many etiological theories regarding AION; the most widely accepted one among these is the interruption of the optic nerve ahead of lamina cribrosa due to lack of the oxygen supply, oxygen transfer capacity or blood flow (4). Numerous surgical interventi- ons and patient related factors have been emp- hasized which may result in decrease of blood flow through posterior ciliary arteries. Intrinsic small vessel disease due to diabetes mellitus, hypertension, prolonged hypotension periods and vasospasm induced by catecholamines or other vasoconstrictors in bloodstream are a few of these (24). Other than AION, which is due to insufficient blood flow, the incidence of spontaneous AION not caused by arteritis was found as 0.01% per year over a study population in USA (33). Risk factors for occurrence of AION apart from arteritis in non-operated population are known as high serum choles- terol, triglyceride, and glucose levels; hyper- lipidaemia, hyperfibrinogenaemia; long term smoking history; hypertension, anaemia, and diabetes (34). Shapira et al reported that significant correlation was not found between these factors and AION in 8 patients with AION among 602 operated consecutively; whereas they found that prolonged CPB duration, low haematocrit levels, higher increase in periope- rative weight and the use of epinephrin and

amrinone perioperatively were the factors related to AION (24). Mansour et al. reported that severe anaemia in patients undergoing CABG appears to be a risk factor for AION, especi- ally in diabetics, and needs prompt correction to prevent or reverse ischemic ocular events (28). It was theorized that, prolonged CPB du- rations resulted in more inflammation and increased endogenous catecholamine levels; the synergistic effect of combination of endogenous catecholamine sources, low cardiac flow and decreased haematocrit levels stimulated by exogenous vasoactive drugs and CPB led to vasoconstriction and ischemia in posterior ciliary artery circulation resulting in AION (24). The very low incidence of AION requires a long follow-up period of a very high number of patients to make it clinically detectable; however, it would not be right to accept the occurrence of acute ION in patients operated for cardiac surgery with CPB as "spontaneous". Besides, the incidence is much higher in this population than spontaneous ION. In our study, patients with high cholesterol and triglyceride levels, who have diabetes and history of smoking were also included; however, no findings could be detected in terms of changes in retinal morphology or reduction in visual function. If the number of patients enrolled in our study were to be compared with the incidence of AION, this number should have been very much higher for AION to occur in any of the study patients. Anyway, the aim of our study was not to detect a situation like AION which exists with severe clinical manifestations, but to investigate the presence of possible retinal pathologies in patients operated with CPB, even subclinically.

Perioperative optic neuropathy (PON) is a potentially devastating complication of any surgical procedure; because, if once a visual loss occurs, it rarely recovers and there is not any known treatment method for PON (25). Warner et al reported that, PON occurred in 0.0008% of the patients operated for non-cardiac surgical procedures (35). Nevertheless, Nuttall et al found that the incidence of PON was 0.06% in patients of the Mayo Clinic operated for cardiac surgery with CPB and they detected an increase in the frequency of PON from 1976 to 1994 (4). This incidence was also supported by other studies; Kalyani et al found in a comparative study with a group of PON patients and a control group matching in terms of potential risk factors such as age, gender, diabetes, hypertension, hyperlipidaemia and the type of cardiac surgery that, there was not a statistically significant difference, but suspicious data (25). Likewise, no significant relationship was found between presence of advanced age, gender, diabetes, hypertension, hyperlipidaemia, and variable postoperative examination parameters of vision, in our study.

Another important risk factor for PON is vascular disease. Nutall et al reported two-fold increase in PON incidence in patients with history of vascular disease (4). Besides, the difference between preoperative and the lowest postoperative haemoglobin levels were detected to be close to statistically significant limit, which was commented as a probability of a statistically significant relationship regarding the incidence of PON in a group with a greater decrease in haemoglobin levels (25). In our study, no correlation was found between the differences of preoperative haematocrit levels of the patients and not only the lowest haematocrit during CPB, but also postoperative haematocrit levels following stabilization with appropriate transfusions, and statistically significantly different preoperative and postoperative intraocular pressure values.

Cannulation and cross clamping of the aorta is the primary requirement of CPB, both of which may result in thromboembolism of retinal arteries and visual centres of the brain (35). Blauth et al showed this CPB dependent phenomenon by fluorescein retinography (36). In another study, thromboembolic particles were shown to be scattered during the initi-

ation of CPB and thromboembolism was dependent to alpha-stat or pH-stat management and the type of oxygenator during the procedure (37). The potential benefit of the procedures on beating heart in the group of patients requiring revascularization is avoidance of aortic manipulations. During the operations in our study, ascending aorta was examined by palpation to determine the segments with potential risk prior to cannulation for CPB and cannulation was tried out of these areas. Moreover, all the anastomoses were performed in a single cross-clamp period to avoid additional manipulations of the aorta, even though aortic side-clamping technique which is used frequently might have shortened the CPB duration.

More decrease in haemoglobin levels in patients requiring CPB than the "off-pump" patients is due to priming solutions for CPB circuit and probably higher dose of heparinization resulting in increased amounts of bleeding; therefore, decreased response to oxygen requirement of the retina and brain leads to potential ischaemia (5). The other potential risk factors for PON in cardiac surgery with CPB are hypotension, arrhythmia, hypocoagulability and tissue edema which are factors related to CPB in general (35). Decrease in blood flow due to mild-medium hypothermia which is frequently used in cases requiring CPB may create predisposition to ischaemia of the optic nerve. Each one centigrade decrease in temperature is known to decrease the blood flow to brain by 6-7% (38). In our study, all of the patients were cooled down to the same temperature (28ºC). Hypotension was not seen both in the perioperative and the postoperative periods and hypertension was avoided by proper medications. Also, none of our study patients developed postoperative arrhythmia.

Two different studies reported that, the factors effective on the pathogenesis of PON were hypotension, anaemia, and elevated intraocular pressure particularly during spinal surgery, and the possible reason held responsible for the increase in intraocular pressure was the length of time in prone position (39-40). This might be the reason for the single parameter which was found to be significantly different among the preoperative and postoperative examinations of the eye, other than the clinically insignificant decrease in the visual acuity of the left eye (VA-left).

Being a case-control study is an aspect of our study which makes it powerful and specific; since, most of the studies addressing the effects of CPB on visual functions discuss case and control groups consisted of different populations matched. Standardization was obtained by having the same surgery team with their own standard surgical techniques and standard postoperative approach for follow-up period by them. The same was available for the preoperative and postoperative examinations of vision and fundus, yet differences in evaluating the- se were tried to be avoided. For such a serious and rare complication like ION, not as much as 20 patients like in our study, but much more patients should be investigated; however, this might only be possible if multi-centre trials are constructed over a long period of time. Although no difference between preoperative and postoperative periods were found with direct examination methods regarding visual functions and fundus morphology, fundus imaging by another method such as FFA was required since it is not possible to visualize retinal vascular structures with a diameter smaller than 30 micrometres (26). Studies similar to ours using methods like FFA may enable detection of the effects of CPB on retina and thus, the brain.

This study had some limitations. First, this is a single centre study with a relatively small sample size. Secondly, we had no information about the changes occurred in examinations of vision or fundus after the seventh postoperative day even though this was a case control-study. Thirdly, even though no difference was shown

by direct examination of visual functions and fundus morphology between the preoperative and postoperative periods, fundus imaging by more technological methods such as FFA was not performed despite the fact that visualization of retinal vascular structures smaller than 30 micrometres was not probable by direct examination.

CONCLUSION

With direct examination of the fundus and vision, any negative effect of CABG operation with CPB was not detected on the retinal morphology and visual functions solely, and related cerebral functions in part. When evaluated in terms of visual functions, by maintaining ca reful cannulation and proper management of cardiopulmonary bypass by the surgeon in coordination with the anaesthesiologist, CPB can be used safely in CABG operations. Well-standardized, large scale with a higher number of patients or even multicentre studies using much sensitive techniques like FFA to assess possible retinal and related cerebral changes in microvascular scale may enable obtaining much significant results about this topic.

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