Cardiopulmonary bypass circulation does not have adverse effects on ear functions: a study of otoacoustic emissions

Kardiyopulmoner bypass dolaşımı işitme fonksiyonlarını etkilemiyor: Otoakustik emisyonlarla değerlendirme

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Background: This study was performed to investigate the effects of coronary artery bypass grafting with cardiopulmonary bypass circulation on hearing and inner ear status.

Methods: The study included 42 ears of 21 patients (11 males, 10 females; mean age 61 years; range 44 to 76 years) who underwent coronary artery bypass grafting. None of the patients had a history of cerebrovascular disease such as ischemic cerebrovascular event, syncope, or hearing loss. The number of arteries bypassed ranged from 1 to 4 (mean 2.7). The patients were examined with pure tone audiometry, speech discrimination test, and tympanometry, and transiently evoked (TEOAE) and distortion product (DPOAE) otoacoustic emissions were recorded preoperatively and on the postoperative sixth day. The pure tones were obtained at the frequencies of 250, 500, 1,000, 2,000, 4,000, and 6,000 Hz.

Results: None of the patients had hearing loss or sudden deafness after surgery. Preoperative and postoperative pure tone results of the patients did not differ significantly ($p > 0.05$). The mean pre- and postoperative speech discrimination scores were 88±14% and 91±1%, respectively ($p < 0.05$). Pre- and postoperative DPOAE findings did not differ significantly ($p > 0.05$). Audiometric results showed no correlations with the number of bypassed arteries and operative variables ($p > 0.05$).

Conclusion: Our findings suggest that coronary artery bypass grafting with extracorporeal circulation does not impose a risk for hearing loss and for the functions of outer hair cells in the inner ear.

Key words: Audiometry, pure-tone; cardiopulmonary bypass/ adverse effects; hearing loss, sensorineural/etiology; otoacoustic emissions, spontaneous; postoperative complications.

Amaç: Bu çalışmada kardiyopulmoner bypass dolaşımı ile gerçekleştirilen koroner bypass cerrahisinin işitme ve iç kulak üzerine etkileri incelendi.

Çalışma planı: Koroner arter bypass cerrahisi uygulanan 21 hastanın (11 erkek, 10 kadın, ort. yaş 61; dağılım 44-76) 42 kulağında ameliyat öncesi ve sonrasında odyometrik değerlendirme yapıldı. Ameliyat öncesinde hiçbir hastada iskemik serebrovasküler olay gibi serebrovasküler hastalık, senkop ve işitme kaybı yoktu. Bypass yapılan ortalama arter sayısı 2.7 (dağılım 1-4) idi. Hastalar ameliyat öncesinde ve cerrahiden altı gün sonra, saf ses odyometrisi, konuşmayı ayırt etme testi, timpanometri, geçici uyarılmış (TEOAE) ve distorsiyon ürünü (DPOAE) otoakustik emisyonlarla değerlendirildi. Saf ses odyometride işitme eşikleri 250, 500, 1000, 2000, 4000 ve 6000 Hz frekanslarda ölçüldü.

Bulgular: Hiçbir hastada cerrahi sonrası işitme kaybı ve ani sağırlık gelişmedi. Hastaların ameliyat öncesi ve sonrası saf ses odyometri sonuçları arasında anlamlı fark yoktu ($p > 0.05$). Konuşmayı ayırt etme skorları ameliyat öncesi ve sonrasında sırasıyla %88±14 ve %91±1 bulundu ($p < 0.05$). Ameliyat öncesi ve sonrası DPOAE sonuçları anlamlı farklılık göstermedi ($p > 0.05$). Hastaların işitme bulguları ile bypass yapılan arter sayısı ve diğer ameliyat değişkenleri arasında anlamlı ilişki bulunmadı ($p > 0.05$).

Sonuç: Bulgularımız, ekstrakorporeal dolaşım desteğinde yapılan koroner bypass cerrahisinin işitme ve iç kulağın dış tüylü hücrelerinin fonksiyonu üzerinde olumsuz etki yapmadığını göstermektedir.

Anahtar sözcükler: Odyometri, saf ses; kardiyopulmoner bypass/ yan etki; işitme kaybı, sensorinöral/etyoloji; otoakustik emisyon, spontan; ameliyat sonrası komplikasyon.

Open heart surgery (OHS) is frequently performed, and the incidence of severe hearing loss following OHS is reported as 0.1%.[1,2] There is debate on the impact of coronary artery bypass grafting (CABG) on inner ear functions, and microemboli, perfusion failure, and ototoxicity are considered to be the most likely causes of hearing impairment. The effect of OHS on hearing remains controversial; while some studies report hearing loss,[3,4] some report that there is no significant change in hearing following OHS.[5]

Otoacoustic emissions (OAE) are acoustical signals, which occur spontaneously as narrow band tonal signals or after stimulation of the ear. This is an objective and noninvasive method to test functional status of the inner ear. Otoacoustic emissions can even show subtle changes in the inner ear functions before they become clinically evident. Both TEOAEs (transiently evoked OAE) and DPOAEs (distortion product OAE) are produced by active micromechanisms of the outer hair cells (OHCs) of the organ of Corti. The DPOAE, which is a consequence of normal nonlinear processes in the cochlea, has gained popularity as a clinical test for hearing screening, research and diagnostic purposes.[6-8]

This study was performed to examine the effects of CABG on hearing and inner ear status. This is the first study to assess the effects of CABG on OAE, as well.

PATIENTS AND METHODS

Twenty-six consecutive patients who had CABG with cardiopulmonary bypass between January and July 2004 were examined. None of the patients had a history of cerebrovascular disease such as ischemic cerebrovascular event, syncope, or hearing loss. Physical and neurological examinations were normal in the entire group. No murmur was reported on carotid artery auscultation.

Informed consent was obtained from all the patients. Pre- and postoperative audiologic assessments were performed by the same audiologist and otolaryngologist. While preoperative audiologic assessments included all the patients, postoperative assessment, which was performed on day 6, could be performed only in 21 patients. Five patients who were not available for postoperative assessment were excluded. Therefore, 42 ears of 21 patients (11 males, 10 females; mean age 61 years; range 44 to 76 years) were included in the analyses.

Audiologic evaluation

Pure tone audiometry and speech discrimination tests were performed using an AC40 clinical audiometer (Interacoustics, Assens, Denmark). Tympanometry and TEOAE and DPOAE testing were performed. The pure tones were obtained at the frequencies of 250, 500, 1,000, 2,000, 4,000, and 6,000 Hz.

The TEOAEs and DPOAEs were recorded consecutively and analyzed with the use of the ILO-96 cochlear emission analyzer (Otodynamics, London, United Kingdom). The TEOAEs were evoked by clicks of 80 μsec duration, with a click rate of 50/sec. The stimulus level in the outer ear was 80±3 dB per sound pressure level. The post-stimulus time ranged from 2 to 20 msec. A total of 260 stimuli were averaged above the noise rejection level of 47 dB. Stimuli were presented nonlinearly, in that every three click stimuli were followed by an inverted stimulus that was three times greater in amplitude. The TEOAE response level was set as at least 3 dB of the level of the noise floor.

DPOAEs were measured using fixed intensity of the primary tones and data were recorded for frequency regions ranging from 1 to 6.3 kHz. Distortion product amplitudes were plotted as a function of f2 frequency. The ratio of the two primary tones (f2/f1) was 1.22. Stimulus levels were 65 dB and 55 dB for f1 and f2 frequencies, respectively. Distortion products obtained at 2f1-f2 exceeding the background noise by at least 3 dB were considered present.

Operation

Anesthesia was induced with 0.50 μg/kg of remifentanil, 0.10 mg/kg of midazolam, 3.00 mg/kg of thiopental, and 0.90 mg/kg of rocuronium, and was maintained with 0.25-0.50 μg/kg/hour of remifentanil and 3.00-6.00 mg/kg/hour of propofol infusion. After standard sternotomy, an ascending aortic cannula and two-stage venous cannula were placed, extracorporeal oxygenation was maintained by a membrane oxygenator (D 708 Simplex III, Dideco, Mirandola, Italy). Ringer lactate (1500 ml) was used as the prime solution. Anticoagulation was maintained with heparin (3.0 mg/kg) and activated clotting time was kept between 400 and 500 sec. Body temperature was reduced to 28-32 °C to achieve mild hypothermia. At the early stage after the operation, respiration was maintained with a volume-controlled respirator (T-Bird VELA, Model: 1618602, Serial No: AET01172, Viasys Healthcare, Conshohocken, PA, USA). The patients were extubated after recovery from general anesthesia and initiation of normal breathing. No ototoxic drug was used during the perioperative period.

Statistical analysis

Preoperative and postoperative audiometric findings were compared using the paired t-test. Comparisons between different groups were made with the Kruskall-Wallis test. Correlations were assessed with the Spearman's test.

RESULTS

The number of arteries bypassed ranged from 1 to 4 (mean 2.7). The mean hospital stay was 7 days (range 6

Table 1. Frequency-specific pure tone audiometry results (mean dB±SD)

	Frequency (Hz)					
	250	500	1,000	2,000	4,000	6,000
Preoperative	25±11	20±9	18±10	21±15	37±23	49±25
Postoperative	25±14	19±10	17±7	19±12	37±22	48±23

to 8 days). Ejection fraction of the patients ranged from 40% to 67% (mean 55.6%). Cross-clamp time ranged from 36 to 71 minutes (mean 52 min) and cardiopulmonary bypass time ranged from 55 to 155 minutes (mean 83 min). No correlations were found between operative variables and postoperative hearing results ($p>0.05$). There was also no relationship between the number of bypassed arteries and audiometric results ($p>0.05$).

Preoperative and postoperative pure tone results of the patients did not differ significantly ($p>0.05$; Table 1). Pre- and postoperative speech discrimination scores of the patients were 88±14% and 91±1%, respectively ($p<0.05$). None of the patients had hearing loss or sudden deafness after surgery.

Pre- and postoperative DPOAE findings did not differ significantly ($p>0.05$; Table 2).

DISCUSSION

Extracorporeal circulation is an essential part of the OHS procedure. However, this procedure may lead to some complications in the nervous system due to reperfusion injury or extracorporeal circulation. It was reported that significant neurological injury was observed in 2-5% of patients, while mild cognitive dysfunction was seen in 70% of patients.[9,10] The incidence of severe hearing loss following OHS was reported as 0.1% and this condition was attributed to the impact of OHS on inner ear functions.[1]

There are several mechanisms that may be associated with the occurrence of hearing loss after OHS. Shapiro et al.[11] reported that the presence of basilar artery atherosclerosis, prolonged pump time, and perfusion failure might be the most likely etiology of hearing loss. Walsted et al.[12] reported on four patients who developed profound sensorineural hearing loss following cardiac surgery with extracorporeal circulation, suggesting the possible role of microembolisms leading to the occlu-

sion of the cochlear branch of the internal auditory artery. The type of the operation may also affect cerebral circulation. This is particularly true in some OHSs like valvular replacement and left ventricular aneurysm operations in which air embolism or emboli from atheromatous plaques may cause cerebrovascular events. In our series, the absence of postoperative hearing loss may be attributed to the absence of valvular replacement operations or patients with severe atherosclerosis.

Phillipps et al.[13] showed that patients undergoing CABG had statistically significant threshold shifts compared to controls, with four of 20 patients (5 ears) having developed statistically significant high-frequency hearing loss which was associated with age, minimum temperature and minimum blood pressure during the operation, and the duration of bypass. Low arterial blood pressure during or after CABG may affect cerebral hemodynamics and may result in hearing loss. None of the patients in our study had low cardiac output that could give rise to hearing impairment.

Despite the above-mentioned studies, a prospective study performed in 181 volunteers undergoing aortocoronary bypass surgery found no causal relationship between hearing loss and OHS and concluded that hearing loss occurring following OHS might be associated with ototoxic therapy.[14] On the other hand, hearing loss was also reported in three cases undergoing general surgery under general anesthesia without extracorporeal circulation and the authors proposed that microemboli or cochlear membrane breaks with perilymph fistulas due to increased middle ear pressure might be possible causes of sudden sensorineural hearing loss.[15] Bilateral hearing loss was also reported after a minor abdominal operation under general anesthesia.[16]

Hearing loss is less prevalent than neurological complications after cardiac surgery, suggesting the role of some factors other than extracorporeal circulation. It is of note that previous studies on hearing status after OHS

Table 2. Amplitudes recorded on DPOAE testing (mean dB±SD)

	f2 frequencies on DPOAE testing (kHz)					
	1	2	3	4	5	6
Preoperative	3.8±4.7	3.5±4.4	1.8±3.8	2.5±4	1.4±3.3	0.5±2.3
Postoperative	6.1±6.6	3.8±4.3	3.3±8.6	1.8±3.1	1.4±3.7	0.3±1.1

DPOAE: Distortion product otoacoustic emission.

were performed using conventional audiologic methods where subjective factors may not have been eliminated. However, OAE testing is objective and the use of OAE testing before and after OHS in larger series may provide more accurate information on the incidence and cause of hearing loss.

In our study, pure tone audiometry results and hearing thresholds of the patients did not change significantly after OHS. In addition, there was no significant change in the DPOAEs of the patients. The DPOAEs show outer hair cell status in the inner ear. In case of any detrimental effect on inner ear functions, a decrease is observed in their amplitudes even in the absence of a clinically evident threshold shift on pure tone audiometry. Thus, the absence of a DPOAE abnormality strongly suggests that CABG alone does not affect inner ear functions.

In conclusion, hearing loss, if any, occurring after CABG is probably due to the effects of general anesthesia rather than extracorporeal circulation and OHS. Our findings suggest that extracorporeal circulation does not impose a risk for hearing loss as well as for the functions of outer hair cells in the inner ear.

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