EFFECT OF HYPOTHERMIC TECHNIQUES ON COCHLEAR FUNCTION

Mona M. El Ganzoury[1], Terez B. Kamel[1], Lobna H.Khalil[2], Ahmed M. Seliem[1]

[1] Department of Pediatrics, Ain Shams University, Cairo, Egypt
[2] Department of Audiology, Ain Shams University, Cairo, Egypt

Corresponding author: Dr. Lobna Hamed Khalil, Ain Shams University Specialized Hospital, Audiology Unit, El-Khalifa El-Maammoun St. Post Code 11588, Cairo, Egypt, Phone: +202 22709207, +2 0195041332, Fax: +202 22709207, e-mail: hamedlobna@yahoo.com

Abstract

Background: Mild to moderate hypothermia are the basis of neuroprotective strategies during cardiopulmonary bypass operations. Mild hypothermia has a protective role on the cochlea and could prevent its damage during long lasting operations. However, deep hypothermia may result in cochlear cells injury. This research aims to assess the effect of different hypothermic techniques on cochlear functions in children after open heart surgery.

Material and methods: Forty children with various acyanotic heart diseases who underwent open heart surgery were included in this study. They were subdivided into two groups; Group I: twenty patients who were subjected to mild hypothermic technique (33° to 37°C), Group II: twenty patients who were subjected to moderate hypothermic technique (28° to 32°C). Audiological assessment included basic evaluation and otoacoustic emissions testing.

Results: All patients had normal hearing. Both study groups had Distortion product otoacoustic emissions (DPOAEs) amplitude >3 dB SPL at all frequencies. However, group II showed lower amplitude at all frequencies with statistically significant difference at high frequencies (4.416–8.837 KHz) compared to group I ($P<0.01$). TEOAEs showed partial pass in three patients of group I (15%) and in 15 patients of group II (75%). Moreover, Group II showed statistical significant reduction in the overall TEOAEs amplitude as well as at high frequencies (2–4 KHz) ($P<0.01$).

Conclusions: Patients exposed to moderate hypothermic technique had subtle cochlear dysfunction. Care should be taken for choice of moderate hypothermic technique in open heart surgeries for children at risk for sensorineural hearing loss.

Key words: hypothermia • cardiopulmonary bypass • children • cochlear dysfunction • otoacoustic emissions

Background

The risk of sensorineural hearing loss after surgical procedures, including extra-corporeal circulation and hypothermia, is estimated to be 0.14% in the literature, a rate six times greater than the risk incurred in by the population in general [1]. In cardiopulmonary bypass most patients are subjected to one of two techniques regarding body temperature either mild (normothermic) technique in which body temperature ranges from 32° to 37°C or moderate hypothermic technique in which body temperature ranges from 28° to 32°C [2]. Few studies revealed that mild hypothermia has a protective role on the cochlea and could prevent its damage during long lasting operations performed in extracorporeal circulation [3]. However, extracorporeal circulation with deep hypothermia may result in cochlear cells injury [4]. So this research aimed to assess the effect of different hypothermic techniques on cochlear functions in children after open heart surgery using otoacoustic emissions.

Material and methods

Forty children with various acyanotic heart diseases who underwent open heart surgery were enrolled in this study on the fifth to seventh day post operatively. They were subdivided in two groups; Group I: twenty patients (11 males and 9 females), their age mean was 7.55 (±4.41) years, they were subjected to mild hypothermic technique (33° to 37°C) and Group II: twenty children (12 males and 8 females), their age mean was 7.75 (±4.41) years, they were subjected to moderate hypothermic technique (28° to 32°C). A verbal uniform consent was obtained from all studied children's parents. The Pediatric Department Board ethically approved the study.

Patients who had history of recurrent otitis media, family history of deafness or those who showed abnormal tympanometry were excluded from the study.

Otoscopic examination then pure tone and speech audiometry were performed by using Madsen Electronic audiometer, model Orbiter 922 in a sound treated room. The pure-tone thresholds were detected for each octave frequency between 0.250 and 8.0 kHz. Immittancemetry including tympanometry and acoustic reflex threshold testing using Grason Stadler impedance meter model GSI 33 was performed. Transient Evoked otoacoustic emissions (TEOAEs) were obtained by using Smart Intelligent OAEs

Table 1. Comparison between the DPOAES response levels at different frequencies in both groups.

Frequency	0.783 KHz	1.165 KHz	1.560 KHz	2.211 KHz	3.125 KHz	4.416 KHz	6.250 KHz	8.837 KHz
Group I Mean SD	12.38 6.94	17.35 9.169	23.08 9.65	23.40 9.78	21.10 9.78	18.85 6.225	27.75 9.89	28.95 12.02
Group II Mean SD	7.10 8.39	11.95 8.803	19.58 8.76	21.45 9.592	18.68 9.00	14.20 8.30	19.75 9.85	15.85 10.32
P value	**0.01****	**0.01***	**0.09**	**0.37**	**0.25**	**0.00****	**0.00****	**0.00****

* High statistically significant; ** very high statistically significant.

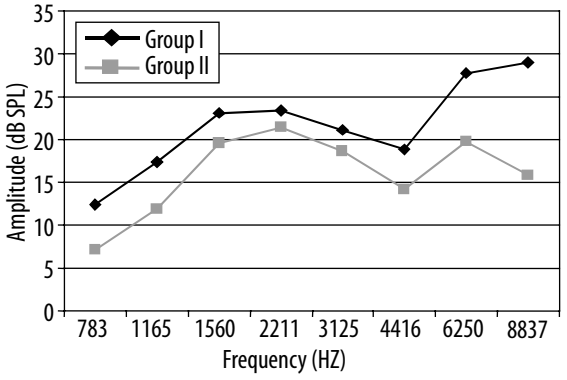

Figure 1. DPOAES amplitude levels at different frequencies in both groups. Group I: normothermic ; Group II: hypothermic.

analyzer, version 3.02. Subjects were resting in a sound treated room. A probe fitted to the tested ear delivered acoustic stimuli at an average of 80 dBSPL and responses (echo levels) were recorded at 5 frequency bands over a range of 1 to 4.0 kHz. The results of TEOAEs were interpreted according to Maxon et al. [5] into one of three categories. Pass: the response was 3 dB or above signal-to-noise ratio (SNR ≥3 dB) in all test frequency bands, Partial pass: the response was present in at least one of the test frequency bands but not in all frequency bands and Fail: No response is present in any of the test frequency bands.

For DPOAEs testing, two primary frequencies, f1 and f2 were presented simultaneously with f2/f1 equaling 1.22. Eight points per octave were measured and plotted as function of f2 ranging from 0.5 to 8.0 kHz. Primary tone level combinations L1/L2=75/65 dBSPL. DPOAEs measurement at 2f1/f2 were considered present when the emission amplitude at all individual frequencies was at least 3 dB higher than its associated noise amplitude (SNR ≥3 dB).

Statistical analysis

the data analyzed using IBM computer SPSS (Statistical Program for Social Science) version 15 as follows: quantitative variables as range, mean and standard deviation (SD). Student "t" test was used for two independent means with normal distribution while comparison between two independent groups for non-parametric data was by using Wilcoxon Rank Sum test. P<0.05 was considered a significant.

Results

Forty children with various acyanotic heart diseases who underwent open heart surgery were enrolled in this study. Twenty-one patients (70%) had weight below 5th centile and 17 patients (56.7%) had height below 5th centile The cardiopulmonary bypass surgery with extracorporeal circulation lasted no more than two hours

These children were subdivided into two groups age and gender matched; Group I: twenty patients who were subjected to mild hypothermic technique (33° to 37° C), they were 11 males and 9 females, their age mean was 7.55 (±4.41) years, and Group II: 20 children who were subjected to moderate hypothermic technique (28° to 32°C), they were 12 males and 8 females with a mean age of 7.75 (±4.41) years.

All children had normal hearing sensitivity as revealed by pure tone and speech audiometry with no statistical difference between two groups. All children had type (A) tympanograms indicating normal middle ear pressure.

All the children had DPOAEs amplitude >3 dB at all frequencies. However, group II (hypothermic group) showed a very highly significant reduced amplitude levels at high frequencies (4.416–8.837 kHz) (P<0.01) (Table 1, Figure 1).

TEOAEs results showed partial pass in only three patients (15%) of the (normothermic) group I and in 15 patients (75%) of the (hypothermic) group II. Moreover, group II showed a significant reduction in the overall amplitude as well as at high frequencies "2–4" kHz (P<0.01) (Table 2, Figure 2).

Discussion

In concordance with many studies, patients in the current study showed growth failure. Infants with congenital heart disease (CHD) are prone to malnutrition for several reasons including decreased energy intake, increased energy requirements or both. Severity of malnutrition ranges from mild under-nutrition to failure to thrive. This can have a notable effect on the outcome of surgery, increasing morbidity and mortality [6].

In the current study all patients had post-operatively normal hearing sensitivity. Sudden hearing loss following cardiac surgery with extracorporeal circulation was first reported by Arenberg et al. [7] in 1972. In 1980, Plasse et al.

Table 2. Comparison between the TEOAEs response levels at different frequencies in both groups.

Frequency	1 KHz	1.5 KHz	2 KHz	3 KHz	4 KHz	Overall response
Group I Mean SD	 6.62 5.79	 10.11 5.79	 12.40 12.40	 11.63 5.54	 8.04 5.171	 9.76 3.83
Group II Mean SD	 5.98 5.61	 9.06 6.56	 7.93 7.93	 8.12 5.64	 4.28 4.98	 7.07 4.43
P value	**0.62**	**0.44**	**0.00****	**0.00****	**0.00****	**0.00****

** Very high statistically significant.

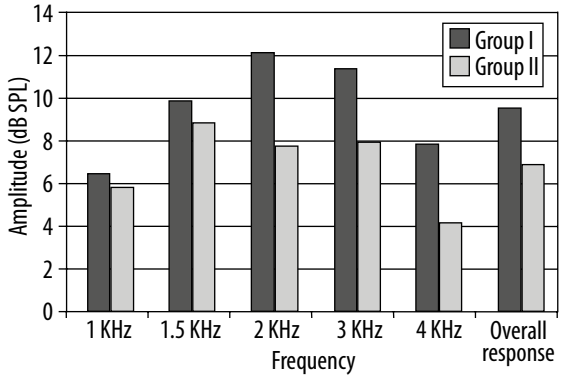

Figure 2. TEOAES amplitude levels at different frequencies and the overall response level of both groups. Group I: normothermic ; Group II: hypothermic.

[8] reported seven cases of unilateral sensorineural hearing loss (SNHL) from a total of 7,000 immediately after cardiac operations for coronary artery bypass or congenital heart disease. However, Brownson et al. [9] performed audiometry in 50 post-operative patients and found no changes in hearing.

Few researchers have studied the effects of temperature changes on cochlear function in humans using TEOAEs. Both Veuilet et al. [4] and Seifert et al. [10] reported TEOAEs alterations among the frequency components with cooling. Namyslowski et al. [3] assessed TEOAEs before and following surgery. TEOAEs showed no tendency to decrease in patients whose extracorporeal normothermia circulation time was between 1–2 hours.

More recently, using DPOAEs, Erdinc et al. [11] investigated extreme hypothermia in children undergoing congenital open heart surgery where body temperature can be lowered over a large temperature interval. Inner ear functions diminished with the increased degree of hypothermia and returned to normal with warming.

Despite all the children in this study had normal hearing sensitivity by pure tone and speech audiometry, DPOAEs of the hypothermic group II showed a highly significant reduced amplitude at high frequencies (4.416–8.837 kHz). Also TEOAEs results showed partial pass in only 15% of the normothermic group I compared to 75% of the hypothermic group II. Moreover, the hypothermic group II had a significant reduction in the overall amplitude as well as at high frequencies "2–4" kHz.

While TEOAEs have the advantage of evaluating middle-frequency (1–4 kHz), DPOAEs precisely detect cochlear dysfunction in a frequency-specific manner and measuring higher frequency ranges. OAEs significant findings among the moderate hypothermic group II might imply impairment in the activation of cochlear OHCs generating OAEs. These were evident mainly at high frequency regions of the cochlea as detected by both TEOAEs and DPOAEs. This reflects more affection of the basal turn of the cochlea other than the rest of the cochlea.

Recent experimental animal studies have shown ischemic induced injury after reperfusion of the inner ear. Glutamate, an excitatory neurotransmitter in the cochlea, is thought to play an important role in the pathogenesis of ischemia-induced cochlear damage. However, the role of mild hypothermia in prevention of inner ear damage have been proved by many researchers. Watanabe et al. [12] demonstrated that hearing loss and inner ear damage were completely prevented by pre-ischemic mild hypothermia. Hyodo et al. [13] considered that such protective effects were primarily through reduction of glutamate efflux. On other hand the protective role of post-ischemic mild hypothermia have been suggested through the attenuation of oxidative stress [14]. Till now, evaluation of such protective role using moderate hypothermia, have not yet been investigated.

So, in the present study such subtle cochlear dysfunction, found in group II, might be explained by mild ischemia and /or hypoperfusion injury of the inner ear that might have occurred during cardiopulmonary bypass surgery. Yet, normal hearing in both groups would reflect the protective value of using hypothermia during cardiopulmonary bypass surgery,

Conclusions

Patients exposed to moderate hypothermic technique during cardiac surgery had subtle cochlear dysfunction. Care should be taken for choice of moderate hypothermic technique in open heart surgeries for children at risk for sensorineural hearing loss.

References:

1. Borin A, Cruz OLM: Study of distortion-product otoacoustic emissions during hypothermia in humans. Rev Bras Otorrinolaringol, 2008; 74(3): 401–9
2. Harry A, Wellons JR, Zacour RK: Adult Cardiac Surgery (Part A-General Considerations) – Cardiopulmonary Bypass. In: Mastery of Cardiothoracic Surgery, Kaiser LR, Kron IL, Spray TL (eds.), Lippincott Williams & Wilkins Companies, 2007; 305–14
3. Namyslowski G, Morawski K, Urban I et al: Influence of hypothermia and extracorporeal circulation on transiently evoked otoacoustic emission (TEOAE) in children operated on for various heart defects. Otolaryngol Pol, 2003; 57(2): 263–69
4. Veuillet E, Gartner M, Champsaur G et al: Effects of hypothermia on cochlear micromechanical properties in humans. J Neurol Sci, 1997; 145(1): 69–76
5. Maxon A, White K, Vohr B, Behrans T: Using Transient Evoked Otoacoustic Emission for Neonatal Hearing Screening. Br J. Audiol, 1993; 27: 149–53
6. Varan B, Tokel K, Yilmaz G: Malnutrition and growth failure in cyanotic and acyanotic congenital heart disease with and without pulmonary hypertension. Arch Dis Child, 1999; 81: 49–52
7. Arenberg IK, Allen GW, DeBoer A: Sudden deafness imme diately following cardiopulmonary bypass. J Laryngol Otol, 1972; 86: 73–77
8. Plasse HM, Spencer FC, Mittleman M, Frost JO: Unilateral sudden loss of hearing. An unusual complication of cardiac operation. J Thorac Cardiovasc Surg, 1980; 79: 822–26
9. Brownson RJ, Stroud MH, Carver WF: Extracorporeal cardiopulmonary bypass and hearing. Arch Otolaryngol Head Neck Surg, 1971; 93: 179–82
10. Seifert E, Brand K, van de Flierdt K et al: The influence of hypothermia on outer hair cells of the cochlea and its efferents. Br J Audiol, 2001; 35: 87–98
11. Erdinc A, Güzin A, Babür et al: Effect of hypothermia on Distortion Product Otoacoustic Emission Findings in Children Undergoing Congenital Open Heart Surgery. Int Adv Otol, 2009; 5: (1)
12. Watanabe F, Koga K, Hakuba N, Gyo K: Hypothermia prevents hearing loss and progressive hair cell loss after transient cochlear ischemia in gerbils. Neuroscience, 2001; 102(3): 639–45
13. Hyodo J, Hakuba N, Koga K et al: Hypothermia reduces glutamate efflux in perilymph following transient cochlear ischemia. Neuroreport, 2001; 12: 1983–87
14. Takeda S, Hakuba N, Yoshida T et al: Postischemic mild hypothermia alleviates hearing loss because of transient ischemia. Neuroreport, 2008; 19(13): 1325–28