Audiology

An evaluation of the effects of hypertension during pregnancy on postpartum hearing as measured by transient-evoked otoacoustic emissions

Valutazione degli effetti dell'ipertensione gestazionale sulla funzionalità uditiva nel post partum mediante otoemissioni acustiche evocate transitorie

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SUMMARY

The aim of this study was to compare the ratio of hearing loss evaluated with transient evoked otoacoustic emission (TEOAEs) testing in normal and hypertensive pregnant women during the first week after delivery. This was a prospective, case-control study. The hypertensive pregnancy group included 96 women with gestational hypertension preeclampsia, eclampsia, or HELLP syndrome, while the normal pregnancy group included age-matched 107 women with normal pregnancy. Postpartum first week, pure tone hearing threshold levels of all women were measured at 0.25, 1, 2, 4 and 6 kHz. TEOAEs testing results were also recorded. All subjects also underwent a detailed ear noise and throat examination. Hearing loss with TEOAE during the first postpartum week was detected in seven (7.3%) women in the hypertensive pregnancy group and in three (2.8%) women in normal pregnancy group. Mean hearing thresholds and individual thresholds at each of the examined frequencies (0.25-6 kHz) were similar in the two groups. Bone and air conduction pure tone average and TEOAE results were not statistically significantly different in the hypertensive pregnancy and normal pregnancy groups. Lastly, the ratios of hearing loss with TEOAE were significantly higher in women with HELLP syndrome compared to women with severe and mild preeclampsia.

KEY WORDS: Gestational hypertension • Preeclampsia • Eclampsia • HELLP syndrome • Hearing impairment • Otoacoustic Emission

RIASSUNTO

L'obiettivo di questo studio è stato quello di confrontare l'entità della perdita uditiva tra un gruppo di gestanti normotese ed uno di donne in attesa ipertese, mediante la registrazione delle otoemissioni acustiche evocate transitorie (TEOAEs) nella prima settimana del periodo post-partum. Trattasi di uno studio caso-controllo di tipo prospettico. Nel gruppo delle gestanti ipertese sono state incluse 96 pazienti affette da ipertensione gestazionale, preeclampsia, eclampsia o sindrome HELLP, mentre nel gruppo delle gestanti normotese sono state incluse 107 pazienti di pari età con gravidanza normodecorsa. Nella prima settimana post-partum la soglia audiometrica tonale per le frequenze di 0.25, 1, 2, 4 e 6 kHz, è stata misurata in tutte le pazienti ed analogamente sono state registrate le TEOAEs. Tutte le pazienti inoltre sono state sottoposte ad accurata visita otorinolaringoiatrica. Nel nostro studio una perdita uditiva, misurata mediante TEOAEs nei primi 7 giorni post-partum, è stata riscontrata in 7 donne del gruppo delle pazienti ipertese, ed in 3 di quelle appartenenti al gruppo delle pazienti con gravidanza normodecorsa. I valori medi di soglia uditiva e quelli relativi ad ogni singola frequenza testata (0.25-6 kHz), sono stati simili nei due gruppi. I risultati audiometrico-tonali e TEOAEs, non hanno mostrato differenze statisticamente significative tra i gruppi di pazienti normotese ed affette da ipertensione gestazionale. L'entità della perdita uditiva, misurata mediante TEOAEs, è risultata significativamente più elevata nelle pazienti affette da sindrome HELLP, rispetto a quelle affette da preeclampsia di grado moderato o severo.

PAROLE CHIAVE: *Ipertensione gestazionale • Preeclampsia • Sindrome di HELLP • Eclampsia • Perdita uditiva • Otoemissioni acustiche*

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Introduction

Otoacoustic emissions (OAEs) are low-level sounds that are produced in the cochlea and propagated back through the middle ear into the external ear canal where they can be recorded using sensitive miniature microphone systems [1]. OAE is natural by-product of normal auditory physiology. OAEs are mixtures of emissions arising by two fundamentally different mechanisms; non-linear distortion induced by cochlear traveling waves, and linear reflections of those waves from preexisting micromechanical impedance perturbations. These mechanistic differences have been used to construct a new taxonomy for OAEs that identifies OAEs based on their mechanisms of generation rather than on details of their measurement.

As commonly measured in the clinic, distortion-product and other evoked OAEs comprise a mixture of emissions produced by both mechanisms [2]. Measurement of OAEs is a rapid, reproducible and objective method of evaluating hearing, and a non-invasive measurement of cochlear function. The clinical utility of OAEs has been extensively described in both normally hearing subjects and those with sensori-neural hearing loss [3]. The primary clinical applications of these emissions appear to be in neonatal screening and ototoxic monitoring [4]. Audiologic examinations suggest that sudden deafness, tinnitus and impairment of sound localization are usually due to dysfunction of the cochlea resulting from ischaemia to the inner ear and central auditory pathways [5]. Moreover, anatomo-pathologic changes such as thromboembolic events or vessel constriction in pathologic findings of the inner ear are identical and responsible for the ischaemia, but ischemic focuses can also damage auditory pathways and centres [6 7].

Cochlear microcirculatory disorders associated with impaired local oxygenation have been considered to be a major pathogenetic factor in hearing impairment, and most therapeutic strategies are aimed at improving cochlear blood flow and oxygenation [8]. Preeclampsia is a common disorder that is a consequence of vasospasm, endothelial dysfunction and ischaemia [9]. Preeclampsia, which effects microcirculation and a possible immunologic pathogenesis, can potentially induce damage to the inner ear and result in sensory neural hearing loss [10]. Significant differences between healthy pregnant women and preeclamptic women have been found for the impairment of TEOAE, and these findings suggest a possible effect of preeclampsia on the inner ear, at least temporarily. The aim of the present study was to compare the rates of hearing loss with TEOAEs in pregnant women with various types of hypertensive disorders as gestational hypertension, superimposed preeclampsia, mild or severe preeclampsia, eclampsia and HELLP syndrome compared to normal pregnant women during the postpartum period.

Materials and methods

Study group and design

This prospective case-control study was performed at Cumhuriyet University Hospital from June 2008 to May 2009. This study was included 96 women (hypertensive pregnancy group) with gestational hypertension (16 women, 16.7%), superimposed preeclampsia (4 women, 4.2%), mild preeclampsia (28 women, 29.2%), severe preeclampsia (24 women, 25.0%), eclampsia (10 women, 10.4%) or HELLP syndrome (14 women, 14.6%), and 107 women matched for gestational week (normal pregnancy group) with normal pregnancy. All patients were informed of the audiometric testing and examination process, informed consent was obtained from each participants and full medical history was obtained. Gestational hypertension was defined by the presence of a maternal blood pressure above 140/90 mmHg after 20 weeks of gestation. Preeclampsia was defined by the presence of a maternal blood pressure above 140/90 mmHg after 20 weeks of gestation and proteinuria of at least 300 mg/24 hour. Eclampsia was defined by the presence of tonic-clonic convulsions in preeclampsia. HELLP syndrome was defined by hemolysis, elevated liver enzyme levels and a low platelet count in pregnant woman. Exclusion criteria were history of ear surgery, acute or chronic otitis media, history of tympanic membrane perforation, ear or head trauma, upper respiratory tract infection at examination, intake of ototoxic drugs or employment in a noisy environment. One hundred and seven women matched for gestational age with a normal pregnancy were recruited as controls from the obstetric ward and followed at the inpatient clinic of Cumhuriyet University Hospital. The controls were pregnant women who were followed at the Obstetrics service of our hospital from the first trimester and who completed the pregnancy without complications. All subjects in the study underwent a detailed ear nose and throat (ENT) examination (otoscopic, pure tone audiometry (0.25 - 4.0 kHz), and TEOAE (1.5-4 kHz) tests) by the same investigator (EA). In order to ensure that the test results were not influenced by conditions such as wax or occlusion/obstruction/collapse of the external auditory canal, an otoscopic investigation was carried out prior to testing.

TEOAE was performed in all cases. TEOAE testing and analysis was conducted with a commercial device (Maico, ERO Scan Analyzer, GmbH Salzufer, 13/14, 10587, Berlin GE) which had been calibrated before the study. Disposable ear tips were used to cover the probe and seal them snugly in the ear canal during testing. When the test was complete, the results were displayed on the screen as "PASS" when there was a TEOAE response, and "REFER" when there was no response to a stimulus. When a "REFER" result was obtained, the screening test was repeated. The click stimulus was in the 0.7-4 kHz frequency range at an intensity of 83 dB/SPL (± 3 dB). The test was

recorded in both ears during each session. The results were presented in dB as an average for band range 1.5-4 kHz, even for pre-defined frequencies of the TEOAE spectrum, namely 1.5, 2, 2.5, 3, 3.5 and 4 kHz. A mean TEOAE amplitude below 6 dB at band range 1.5-4 kHz was considered as lack of otoacoustic emission.

Conventional pure-tone audiometry using a clinical audiometer (Interacoustics Clinical Audiometer, AC 40, Assen, Denmark) was performed to measure hearing thresholds in dB HL at 0.25, 0.5, 1, 2, 4, and 6 kHz in 61 (67.8%) women in the hypertensive pregnancy group, and in 29 (32.2%) in the normal pregnancy group. In addition, hearing thresholds were also measured at 0.5, 1, 2, and 4 kHz using bone-conduction methods. Subjects were tested by the same investigator (EA) at the Ear, Nose, and Throat Clinic during the first week after their neonates were delivered either naturally or by Caesarean section.

Ethical considerations

The Human Ethics Committee of Cumhuriyet University approved the study in accordance with the declaration of Helsinki.

Statistical methods

In both the hypertensive and normal pregnancy groups, past medical and family history and TEOAE results were analyzed using the chi-square test, while the influence of subject age, gravidity, parity, maternal weight, arterial blood pressure levels, haemoglobin, haematocrit and platelet values on the results were assessed using the Student's t-test. The ratio of hearing loss with TEOAE in the women with HELLP syndrome, mild preeclampsia, severe preeclampsia, gestational hypertension and eclampsia of the hypertensive pregnancy group were compared with Fisher's exact test. Pure tone hearing thresholds and pure tone average levels results were analyzed using the multiple ANOVA test. A p value < 0.05 was considered statistically significant.

Results

Overall, 203 subjects were enrolled in this prospective case-control study which included 96 women with gestational hypertension, preeclampsia, eclampsia, or HELLP syndrome in the hypertensive pregnancy group, and 107 women matched for gestational age with a normal pregnancy.

The mean ages for the hypertensive and normal pregnancy groups were comparable (28.5 ± 6.8 [range = 17-44] *vs*. 28.3 ± 6.6 [range = 18-44], respectively). As indicated in Table I, there were no differences between the ratios of gravidity or parity in the two study groups, but a statistically significant difference ($p < 0.005$) was noted for the gestational age in the two groups. The mean gestational ages were 35.1 ± 4.1 years in the hypertensive pregnancy group and 38.5 ± 7.8 years in the normal pregnancy group. Mean body weight was also significantly different ($t = 2.05$, $p < 0.005$) between the hypertensive pregnancy and normal pregnancy groups, which were 79.6 ± 16.7 and 73.3 ± 12.8 kg, respectively.

Table I. Age, gestational age, gravidity and parity of the hypertensive and normal pregnancy groups.

	Hypertensive pregnancy (n = 96)	Normal pregnancy (n = 107)
Age	28.5 ± 6.8	28.3 ± 6.6
Gestational age	35.1 ± 4.1*	38.5 ± 7.8
Gravidity	2.9 ± 2.5	2.9 ± 1.8
Parity	1.4 ± 1.9	1.5 ± 1.3

** (p < 0.005), hypertensive pregnancy* vs. *normal pregnancy. Data are expressed as mean ± SD.*

Although not significant, a past medical history of hypertension was reported for six women (17.1%) in the hypertensive pregnancy group and in 10 subjects (9.5%) in the normal pregnancy group. Additionally, a family history of hypertension was noted for 14 (40%) women in the hypertensive pregnancy group and in 29 (27.6%) individuals in the normal pregnancy group. As seen in Table II, a statistically significant difference was observed for the mean maximum and minimum diastolic and systolic arterial blood pressure levels. In addition, while haemoglobin values were different between the two groups, there were no significant differences in either haematocrit or platelet values.

The findings in Table III indicate that the degree of hearing loss between the two groups was comparable ($p > 0.05$). In addition, there were no substantial differences in TEOAE findings between the hypertensive pregnancy [abnormal n = 7 (7.3%)] and normal pregnancy [abnormal n = 3 (2.8%)] groups. Considering the ratios of hearing loss with TEOAE of women with HELLP syndrome, mild preeclampsia, severe preeclampsia, gestational hypertension and eclampsia in the hypertensive pregnancy group, these were

Table II. Haemoglobin, haematocrit, platelet values, and diastolic and systolic arterial blood pressure in the two groups.

	Hypertensive pregnancy (n = 96)	Normal pregnancy (n = 107)	p value
MxTAs (mmHg)	161.7 ± 22.4	129.4 ± 19.6	p = 0.001
MxTAd (mmHg)	104.3 ± 19.7	80.8 ± 12.3	p = 0.001
MnTAs (mmHg)	125.7 ± 17	100 ± 9.9	p = 0.001
MnTAd (mmHg)	79.7 ± 14.2	62.7 ± 7.5	p = 0.001
Hb (gr/dl)	12.8 ± 1.8	12.1 ± 1.3	p = 0.014
Hct (%)	37.6 ± 5.2	35.9 ± 3.6	p = 0.079
Platelets (1000/mm^3)	201.8 ± 57.9	221.5 ± 68.1	p = 0.128

MxTAs: Maximum systolic arterial blood pressure; MxTAd: Maximum diastolic arterial blood pressure; MnTAs: Minimum systolic arterial blood pressure; MnTAd: Minimum diastolic arterial blood pressure; Hb: Haemoglobin; Hct: Haematocrit; Plt: Platelets. Data are expressed as mean ± SD.

significantly higher in women with HELLP syndrome compared to those with severe and mild preeclampsia ($p < 0.05$). Clinical characteristics and the number of women identified with hearing loss in the hypertensive pregnancy group are shown in Table IV.

Pure-tone hearing thresholds (HTLs) were essentially identical for both air and bone conduction audiometry, and audiometry results were recorded for both ears of 90 (44.3%) women [61 (67.8%) in the hypertensive pregnancy group; 29 (32.2%) in the normal pregnancy group]. Mean HTLs at each of the examined frequencies were directly compared between two groups.

As shown in Table V, there were no statistically or clinically significant differences between the two ears when mean pure-tone hearing thresholds (HTLs) were compared for each subject. Women in both groups were compared with bone and air conduction pure tone average, but no statistically significant differences were found between groups.

Table III. Pure -tone hearing thresholds for [air conduction (AC) and bone conduction (BC)] the hypertensive and normal pregnancy groups.

Frequency (kHz)			Hypertensive pregnancy HTLs in dB (n = 96)	Normal pregnancy HTLs in dB (n)
0.25 kHz	Right ear	AC (dB)	16.2 ± 10.9	18.6 ± 16.1
	Left ear	AC (dB)	13.4 ± 7.2	18.4 ± 20.3
0.5 kHz	Right ear	BC (dB)	12.3 ± 7.9	12.2 ± 8.5
		AC (dB)	13.1 ± 10	15.2 ± 15.2
	Left ear	BC (dB)	10.8 ± 6.8	11.2 ± 11.9
		AC (dB)	10.90 ± 7.1	13.6 ± 20.2
1 kHz	Right ear	BC (dB)	9.9 ± 7.4	10.5 ± 6.7
		AC (dB)	9.91 ± 7.44	13.3 ± 12.6
	Left ear	BC (dB)	8.7 ± 6.7	9.7 ± 11.2
		AC (dB)	8.9 ± 6.8	11.9 ± 19.6
2 kHz	Right ear	BC (dB)	10.9 ± 8	11. ± 7.8
		AC (dB)	10.7 ± 7.9	11.7 ± 10.8
	Left ear	BC (dB)	9.3 ± 6.9	9.5 ± 11.2
		AC (dB)	9.3 ± 6.8	11 ± 19.3
4 kHz	Right ear	BC (dB	13.2 ± 8.8	13.3 ± 9.6
		AC (dB)	13.7 ± 11	14 ± 11.7
	Left ear	BC (dB	11.6 ± 7.3	11.9 ± 11.7
		AC (dB)	12.3 ± 8.1	13.5 ± 19.4
6 kHz	Right ear	AC (dB)	17.9 ± 11.6	18.8 ± 16.3
	Left ear	AC (dB)	15.4 ± 9.9	15.9 ± 19.9

There were statistically significantly differences between groups (F = 0.78, p = 0.701). (dB): decibels; (HTLs): hearing thresholds; (kHz): kilohertz; (SD): standard deviation. Data are expressed as mean ± SD.

Table IV. Clinical and hearing loss data with TEOAE in the hypertensive pregnancy group.

	Patients (n = 96) [n (%)]	Hearing loss (n = 7) [n (%)]
Gestational hypertension	16 (16.7%)	1 (14.3%)
Superimposed preeclampsia	4 (4.2%)	0
Mild preeclampsia	28 (29.2%)	1 (14.3%)
Severe preeclampsia	24 (25.0%)	0
Eclampsia	10 (10.4%)	1 (14.3%)
HELLP syndrome	14 (14.6%)*	4 (57.1%)

** $p < 0.05$ vs. mild and severe preeclampsia subgroups.*

Table V. Pure tone average levels in the hypertensive and normal pregnancy groups.

	Hypertensive Pregnancy (n = 96)	Normal Pregnancy (n = 107)	p
Left ear AC	9.7 ± 6.4	12.3 ± 19.4	NS
Left ear BC	9.5 ± 6.2	10.2 ± 11.1	NS
Right ear AC	11.6 ± 7.7	12.7 ± 12.4	NS
Right ear BC	11 ± 7.9	10.4 ± 6.7	NS

There were no statistically significantly differences between groups (F = 1.32, p = 0.268, p > 0.05). air conduction (AC) and bone conduction (BC). Data are expressed as mean ± SD. NS: not significant.

Discussion

According to our findings, hypertension in pregnancy may not cause hearing impairment in the postpartum period, but it may be associated with hearing loss in women with HELLP syndrome. No clinically significant differences were found when comparing mean pure-tone hearing thresholds (HTLs) between the hypertensive pregnancy and normal pregnancy groups.

Some form of hearing loss is the most common sensory disorder in the United States, affecting more than 36 million people, 80% of which are irreversible. There are many factors that cause hearing loss in adults, such as exposure to intense and/or continuous noise, inhalation of toxic substances, ingestion of ototoxic drugs, metabolic and circulatory alterations, infections, different types of injuries and genetic inheritance [11 12]. Hypertension is a common vascular disease that can cause structural changes in blood vessels, heart and circulatory system pathology [13]. Arterial hypertension is a risk factor for hearing loss. Various studies have been carried out in this regard, some of which have indicated that hypertension may be a risk factor for hearing loss [14-17]. Arterial hypertension may directly affect hearing in a number of ways. High pressure in the vascular system may cause inner ear haemorrhage, which may cause progressive or sudden hearing loss. When blood viscosity is increased, the capillary blood flow and oxygen load are reduced which causes tissue hypoxia, thus causing hearing deficits and hearing loss in

hypertensive patients. Moreover, arterial hypertension may cause ionic changes in cell potentials, thus causing hearing loss [11 18-20]. Friedland et al. [14] showed that low-frequency hearing loss is associated with underlying cardiovascular disease, and as audiogram patterns correlate strongly with peripheral arterial disease it may represent a screening test. Agrawal et al. [15] compared the effects of cardiovascular risk factors and noise exposure on frequency-specific audiometric thresholds among US adults, and those representing cardiovascular disease were associated with both high- and low-frequency hearing loss. Przewoźny et al. [16] investigated risk factors of sensorineural hearing loss in patients with early stages of ischaemic stroke, and showed the highest risk of hearing loss in the group of ischaemic stroke patients occurred for older individuals, particularly men with tinnitus, lacunaria stroke, multiple, bilateral ischaemic focuses and arterial hypertension. Ni et al. [17] investigated the relationship between hearing loss, blood pressure and arterial compliance of female workers exposed to occupational noise in a textile mill, and found that those with low artery compliance or with high blood pressure may suffering from hearing loss.

The pathogenesis of preeclampsia is complex and incompletely understood, although it may be associated with maternal multiorgan failure, coagulopathy, maternal and foetal death and vasospasm, microthrombus and ischaemia in the peripheral tissue [21-23]. Thus, preeclampsia may cause hearing loss. Bakhshaee et al. [23] found a significant difference in TEOAEs of neonates from healthy mothers compared to those from hypertensive pregnancies in the first exam. At follow-up tests two and four weeks later, TEOAEs did not show any significant differences. Therefore, it seems that preeclampsia might have some transient effects on hearing. Also, this possible transient effect of pregnancy toxaemia may be seen in the hearing of mothers. Bakhshaee et al. [10] reported that damage to the inner ear hair cells during preeclampsia was possible. In the same study, they evaluated hearing in 37 preeclamptic and 38 healthy women with TEOAE and found significant differences between the two groups. These findings indicate the possible effect of preeclampsia on the inner ear, at least temporarily [10]. The present study is the first to show that pregnancy toxaemia may have effects on hearing. Seven (7.3%) women with hypertension and three (2.8%) healthy women with TEOAE disturbances consistent with hearing impairment were noted in the postpartum period, although there was not a statistically significant difference between the two groups.

Each of the two studies by Bakhshaee et al. [10 23] suggest that preeclampsia may have some temporary effects on hearing in both newborns and mothers. However, our results do not support the results of Bakhshaee et al. [10].

Consequently, we found no significant difference between hypertensive and healthy pregnant women in terms of hearing evaluation. Damage to the inner ear hair cells consequent to hypertension during pregnancy is possible, but results of our study suggest that ischaemia of the inner ear caused by vasospasm and microthrombus by hypertension during pregnancy does not result in hearing impairment in the postpartum period.

Undoubtedly, the aetiology of hearing impairment is multifactorial, and environmental, genetic and individual differences may be important in the development of the hearing loss. There are, however, some limitations of our study; a relatively small number of women were evaluated, subjects with more than one disease causing hypertension in pregnancy were included in the study, and the study was performed in a single centre.

Conclusions

Hearing loss may develop during the early postpartum period in women with HELLP syndrome, but other variants of hypertensive disorders in pregnancy do not impair hearing function. Further studies are needed to assess the effect of subtypes of hypertensive pregnancy disorders on hearing impairment after delivery.

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