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. OAEs are natural by-products 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. 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. The primary pathogenetic factor in hearing impairment, and most significant differences produced by both mechanisms. 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. The primary pathogenetic factor in hearing impairment, and most significant differences produced by both mechanisms. 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. The primary pathogenetic factor in hearing impairment, and most significant differences produced by both mechanisms. 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. The primary pathogenetic factor in hearing impairment, and most significant differences produced by both mechanisms. 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.
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.

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 preeclamp sia, severe preeclampsia, gestational hypertension and eclampsia in the hypertensive pregnancy group, these were governed with a normal pregnancy.

| Table I. Age, gestational age, gravidity and parity of the hypertensive and normal pregnancy groups. |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Hypertensive pregnancy (n = 96) | Normal pregnancy (n = 107) | p value |
| Age | 28.5 ± 6.8 | 28.3 ± 6.6 | 0.198 |
| Gestational age | 35.1 ± 4.1 | 38.5 ± 7.8 | 0.014 |
| Gravidity | 2.9 ± 2.5 | 2.9 ± 1.8 | 0.708 |
| Parity | 1.4 ± 1.9 | 1.5 ± 1.3 | 0.480 |

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

| 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 | 0.001 |
| MxTAd (mmHg) | 104.3 ± 19.7 | 80.8 ± 12.3 | 0.001 |
| MnTAs (mmHg) | 125.7 ± 17 | 100 ± 9.9 | 0.001 |
| MnTAd (mmHg) | 79.7 ± 14.2 | 62.7 ± 7.5 | 0.001 |
| Hb (gr/dl) | 12.8 ± 1.8 | 12.1 ± 1.3 | 0.014 |
| Hct (%) | 37.6 ± 5.2 | 35.9 ± 3.6 | 0.079 |
| Platelets (1000/mm³) | 201.8 ± 57.9 | 221.5 ± 68.1 | 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.

| 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 ± 10.8                     |
|                | AC (dB) 10.7 ± 7.9 | 11.7 ± 11.8                     |
|                | 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                     |
|                | AC (dB) 11.6 ± 7.7 | 18.8 ± 16.3                     |
| 6 kHz          | Right ear AC (dB) 17.9 ± 11.6 | 15.4 ± 9.9                     |

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. Hypertension is a common vascular disease that can cause structural changes in blood vessels, heart and circulatory system pathology. 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. 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. \cite{11,18,20}. Friedland et al. \cite{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. \cite{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. Przewoźni et al. \cite{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. \cite{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. \cite{21-23} Thus, preeclampsia may cause hearing loss. Bakhshae et al. \cite{23} found a significant difference 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 toxemia may be seen in the hearing of mothers. Bakhshae et al. \cite{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. \cite{10} The present study is the first to show that pregnancy toxemia 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 Bakhshae et al. \cite{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 Bakhshae et al. \cite{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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