

Decrease in middle ear resonance frequency during pregnancy

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Abstract

Many physiological changes occur during pregnancy. The aim of the study was to reveal whether there is a change in middle ear resonance frequency during pregnancy. A prospective case-control study was designed at a tertiary referral center. The study included 46 pregnant women at the third trimester (27-40 weeks) and 43 nonpregnant voluntary women. All the study subjects underwent pure-tone audiometry and multifrequency tympanometry. Pure-tone hearing levels at frequencies of 250 to 8000 Hz and resonance frequency values were compared between pregnant and nonpregnant women. Impact of age, side of the tested ear, and weight gained in pregnancy on resonance frequency were evaluated. Air conduction threshold values at frequencies of 250 Hz and 500 Hz were significantly higher in pregnant women than in the control group ($P < 0.001$). Middle ear resonance frequency values of both ears in pregnant women were found to be significantly lower than those in control group ($P < 0.001$). There was no statistically significant relation of middle ear resonance frequency values to age or side of the tested ear in both groups ($P > 0.05$). A negative correlation between weight gained in pregnancy and middle ear resonance fre-

quency values was determined for the left ear (correlation coefficient for left ears: -0.348 , $P = 0.018$). The results of this study suggest that resonance frequency may be decreased during the pregnancy. More comprehensive studies in which many pregnant women followed regularly before and after pregnancy are needed to have more certain links.

Introduction

Hormonal system of women is unique due to the changes observed in pregnancy, menstrual cycle and menopause period. During a normal pregnancy period, in order to meet the needs of fetus and placenta that grow rapidly, a lot of certain alterations occur in metabolic, cardiovascular, hematologic, respiration, urinary, gastro-intestinal and endocrine system.¹ These alterations help women to be protected against some risks in pregnancy and during birth and enable fetal development.² Weight gain is the most noticeable physiologic alteration in pregnancy, especially during the third trimester. As a result of hormonal alterations and weight gain, fluid increases in the intercellular space and edema is formed.

The middle ear is a system that turns acoustic energy into mechanical energy. Tympanometry measures the middle ear function objectively by using 226 Hz probe-tone. Multifrequency tympanometry (MFT) is a method providing the analysis of tympanogram obtained over different probe tones in the range of 200 Hz and 2000 Hz.³ Resonance frequency is the main parameter of MFT. Resonance frequency is the frequency that the resistance is lowest and the middle ear system vibration is highest. High-frequency probe tones are quite valued to determine pathology changing stiffness effect of the middle ear system. Thus, research has been focused on the role of MFT in the differential diagnosis of various middle ear pathologies.⁴

A few studies have been reported in regard to hearing function in pregnancy. Investigators have shown reversible sensorineural hearing loss at low frequencies during pregnancy.^{5,6} However, there is a lack of data to reveal the mechanisms causing hearing loss in pregnant women. There might be a link between the alterations in pregnancy and middle ear acoustic features. In other words, weight gain and edema during pregnancy might affect the acoustic impedance of the middle ear. However, to best of our knowledge, there has been no study using MFT to evaluate the middle ear resonance frequency in pregnant women yet. The objective of this study is to reveal whether there is a link between the alterations in pregnancy and middle ear resonance frequency.

Materials and Methods

This study was approved by local Institutional Review Board and Ethics Committee (Project no: KA13/159). Sampling extent was calculated by statistical pre-assessment applied before the study. The study

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included 46 (92 ears) pregnant women at the third trimester (27-40 weeks) on follow up of Gynecology and Obstetrics Department. The control group consisted of 43 (86 ears) voluntary subjects. All the study subjects provided written informed consent.

Following criteria was followed to have the subjects be enrolled in the study: i) age range of the subjects from 20 to 40 years; ii) no use of medications or hormones that may affect the test results in controls; iii) one has not exposed any otorhinolaryngologic disorders affecting hearing thresholds permanently before; iv) no external auditory canal and tympanic membrane pathology to be detected in otoscopic examination; v) in audiometric evaluation, hearing thresholds are to be ≤ 15 dB at speech frequencies (500, 1000, 2000 Hz), with no air-bone gap; vi) middle ear pressure between -50 and $+50$ daPa, compliance between 0.39 and 1.30 cc, and presence of acoustic reflexes in impedancemeter screening.

Pure tone audiograms and speech tests were performed using Clinical Audiometer AC-40 (Interacoustics A/S, Assens, Denmark) in silent cabins. Tests were performed in accord with the standards of the Industrial Acoustic Company (Bronx, NY, USA). Air conduction hearing thresholds were measured using TDH 39 standard earphone between 250 and 8000 Hz frequencies. Bone conduction hearing thresholds were measured by Radioear B-71 bone vibrator between 500 and 4000 Hz frequencies.

Immittance measure of the subjects was performed using GSI TymStar Version 2 (Grason Stadler Inc., MN, USA) middle ear tympanometer. Primarily, tympanogram and static admittance were recorded using probe tone of 226 Hz. Tympanometry parameters were recorded having been changed in the rate of 200 daPa/s as air pressure is between $+200$ and -400 daPa. Probe tone of the middle ear resonance frequency was measured between 250-2000 Hz. Susceptance curve obtained after automatic frequency scanning was analyzed. Frequency - positive peak in which tympanic membrane compliance of notch peak is minimal and equal to 3 peaked tympanogram gained - was accepted as RF. In case this condition would not be available as a result of automatic frequency screening, higher and lower frequencies than this frequency determined automatically were screened over at a rate of 50 Hz up-down. Frequency at which notch and positive peak equity was determined has been accepted as RF.

Statistical analysis of the data was performed using SPSS for Windows 18 package program (SPSS Inc, Chicago, IL, USA). Student's

t test was used for the continuous variables complying with normal distribution; Mann Whitney U test was used for the continuous variables not complying with normal distribution. Pearson correlation was used for correlation analysis. Values for P values less than 0.05 were considered as statistically significant.

Results

Totally 89 women were included in the study. The mean ages were 30.9 ± 3.9 and 29.5 ± 5.3 years in the pregnant women and controls, respectively. There was no statistically difference between groups in terms of average age (Student's *t* test, $P=0.265$). Gestational week varied from 27 to 39 [mean \pm standard deviation (SD) = 32 ± 3 weeks]. Weight gained in pregnancy was 6 to 20 kg (mean \pm SD = 11.5 ± 2.9 kg).

Table 1 shows the pure-tone hearing levels at frequencies of 250 to 8000 Hz. Air conduction threshold values at frequencies of 250 Hz and 500 Hz were significantly higher in the pregnant women than in the control group for both right and left ears ($P < 0.001$).

Middle ear resonance frequency values of both ears in pregnant women were found to be significantly lower than those in control group ($P < 0.001$) (Table 2). There was no statistically significant relation of middle ear resonance frequency values to age or side of the tested ear in both groups ($P > 0.05$). A significant negative correlation (Pearson analysis, correlation coefficient for right and left ears: -0.219 ; -0.348 , respectively) between weight gained in pregnancy and middle ear resonance frequency values was determined for the left ear ($P=0.018$).

Discussion

Pregnancy is a complex period that directly or indirectly alters a lot of body compartments and functions from the beginning until the birth. Undoubtedly, hearing functions undergo several changes in this period. There are some studies that focus on hearing function during pregnancy in the literature. However, no study evaluating the middle ear resonance frequency during pregnancy could be found, which might be related to hearing levels. In our study, for the first time, we showed that

Table 1. Comparison of pure-tone hearing levels between pregnant women and controls.

Frequency	Right ear (median, dB)			Left ear (median, dB)		
	Pregnant women	Controls	P value	Pregnant women	Controls	P value
250 Hz	15	10	$<0.001^*$	15	10	$<0.001^*$
500 Hz	15	10	$<0.001^*$	15	10	$<0.001^*$
1000 Hz	5	5	0.829*	5	5	0.2*
2000 Hz	5	5	0.229*	5	5	0.203°
4000 Hz	5	5	0.385*	0	5	0.301*
6000 Hz	10	10	0.102*	5	10	0.372°
8000 Hz	5	5	0.578°	5	10	0.624°

*Student's *t* test; °Mann Whitney U test.

Table 2. Comparison of middle ear resonance frequency between pregnant women and controls.

Feature	Group	N	Mean	Standard deviation	Median	P value*
Right ear RF	Control	43	998.8	104.9	1000	<0.001
	Pregnant women	46	754.4	139.8	750	
Left ear RF	Control	43	1037.2	123.0	1000	<0.001
	Pregnant women	46	790.2	139.3	750	

*Student's *t* test.

RF is decreased in addition to decreased hearing levels at low frequencies during third trimester of pregnancy.

In a study done to observe audiological alterations in 20 pregnant women and 18 control subjects, Sennaroglu *et al.*⁵ reported a significant difference in pure tone hearing thresholds of pregnant women and control group at 125, 250 and 500 Hz. This difference continued in each of three trimesters when analyzed by separating pregnancy period into three trimesters. Kenny *et al.*⁷ reported that reversible, unilateral, sensorineural hearing loss at low frequencies was observed despite being rare in pregnancy. The authors considered that the reason of reversible sensorineural hearing loss seen in pregnant women was the result of the mechanical pressure growth over the hairy cells in inner ear and alterations in tissues. According to these authors, hearing thresholds were increased to normal levels after pregnancy with the removal of mechanical pressure. In the study of Karan *et al.*,⁶ it is stated that although pregnancy does not have a certain effect at high frequencies, it results in hearing loss at low frequencies and this loss increases from the first trimester of pregnancy to the last trimester of it. Lavy⁸ also reported the patients exposed to sudden sensorineural hearing loss in the pregnancy period. In consistent with above mentioned studies, pure tone hearing thresholds values at 250 Hz and 500 Hz in both ears of the pregnant women were found higher than control group in our study. In a recent study, on the other hand, a relation of obesity with hearing loss at the high frequencies was determined.⁹ According to this finding, weight increase during pregnancy does not seem to be directly related to the hearing loss in low frequencies. Instead, odema may be the main factor for the decrease of hearing levels at low frequencies.

A deterioration affecting the low-frequency hearing levels in the pregnant reminds the similar type of hearing loss in Ménière's disease. Especially at the early period of Ménière's disease, with the increase in endolymphatic fluid as a result of apical area exposure, hearing loss is quite clear in low frequencies. To support the impact of endolymphatic fluid pressure on the middle ear dynamics, MFT is a subject that has been studied before in Ménière's disease. Bianchedi *et al.*¹⁰ analyzed Ménière's patients with immittanceometry using 220 Hz and 678 Hz probe tone. RF values were measured over 678 Hz in 70% of cases with Ménière's disease. In the preliminary study of Franco-Vidal *et al.*,¹¹ RF level in the symptomatic ears of 40 patients with Ménière's was measured as 752 Hz while this level was 820 Hz in asymptomatic ears. Sugasawa *et al.*¹² confirmed the previous results in their study conducted on Ménière's disease patients. Although endolymphatic fluid increase is not at pathological level during pregnancy, a similar mechanism that occurred in Ménière's disease can also be mentioned in pregnant women.

In our study, RF values lower than normal level was determined in both ears of pregnant women, and this condition was found to be statistically significant. This finding suggests that alterations occurred in the body of pregnant women affect ear tissues. In detail, middle ear mucosal edema may lead to changes in RF. The other possible factors are changes in ligamentous attachments or ossicular joint laxity. As we know, stapes fixation leads to increase in RF, whereas ossicular discontinuity leads to decrease in RF. However, these mentioned pathologies are associated with conductive-type hearing loss. There was no air-bone gap in any study subject in our study. In addition, RF level attained with MFT was lower although classical tympanometry values were attained at normal values. It means that classical tympanometry remains insufficient to analyze the dynamics of the middle ear in certain conditions. In the light of all these findings, we speculate that pressure increase in the inner ear, affecting oval window and causing alterations in the middle ear impedance, could cause decrease in static compliance values of pregnant women. On the other hand, we are aware of this speculation requires further research.

A negative link between the values of middle ear RF and weight gained in pregnancy was determined; however, this link was statistical-

ly significant only for the left ear. The reason why there is a statistically significant negative link only for the left ear must be revealed by the studies having more facts. A negative link between gestational age and middle ear RF levels in both ears of the pregnant was determined. However, this link failed to reach a statistical significance.

It is obvious that pregnancy affects not only a lot of mechanisms in the body, but also affects the tissues in the organ of hearing. However, this is a population-based study including limited number of subjects. The other limitation is to evaluate the pregnant women only during third trimester. From this point, further research investigating the impact of weight gain and edema during pregnancy on middle ear acoustic features should be designed.

Conclusions

Resonance frequency of middle ear was found to be low during third trimester of the pregnancy in the present study. Together with decreased hearing levels at low frequencies, low RF indicates that the acoustic immittance of the middle ear changes during the pregnancy. More comprehensive studies in which many pregnant women followed regularly before and after pregnancy are needed to analyze the mechanisms to be able to have more certain links.

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