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Effect of delivery mode on objective and subjective aspects of voice

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Abstract. – OBJECTIVE: This study aimed to compare the effect of delivery on both objective and subjective parameters of voice.

PATIENTS AND METHODS: This is a prospective parallel-group randomized controlled trial. 105 women grouped in two; vaginal delivery (NG) and cesarean group (CG). The fundamental frequency (F0), jitter, shimmer, noise-to-harmonics ratio (NHR), number of voice breaks (VBn) and percentage of voice breaks (VB%) were determined in acoustic analysis. Voice Handicap Index 30 (VHI) was used for subjective analysis.

RESULTS: In NG, a significant decrease in jit%, shim% and VB% was observed (p <.05). In CG, all parameters including F0 showed a significant decrease in early postpartum period (p <.05). CG had more significant improvement in F 0, jit%, shim%, shimdB, VB%, VBn according to test statistics values. VHI scores increased in both NG and CG.

CONCLUSIONS: The change of objective parameters was more significant in CG. Vaginal delivery may cause vocal trauma which results in deterioration in objective acoustic measures as well as decrease in subjective voice quality.

Key Words:
Labor, Cesarean delivery, Voice, Voice quality, Speech acoustics.

Introduction

Pregnant women can experience physiological, psychological, anatomic, and metabolic changes. Anatomy, physiology, and psychology of pregnant women undergo profound changes during prepartum, intrapartum, and postpartum period[1]. Voice is a sensitive signal reflecting functions of the respiratory, endocrine, gastrointestinal, and nervous systems. Especially in the last trimester decreased respiratory reserve and gastroesophageal reflux can disorder voice quality[2]. Additionally, an increase in levels of sex hormones causes Reinke's edema (vocal cord swelling) and mucosal congestion in the larynx. Psychological and emotional factors can contribute to the change in objective acoustic parameters and subjective self-assessment tools[3]. After parturition estrogen, progesterone, and cortisol hormone levels dramatically decrease, and vocal fold edema resolves[4]. Previously, the decrease in average voice pitch, pitch range, and pitch variability after giving birth was demonstrated[5]. The fundamental frequency (F0) of the human voice varies considerably according to sex hormone levels[5]. Like F0 the change of other acoustic parameters could be expected. The normal vaginal delivery itself is a process, which forces pregnant women to make intensive use of their voice. Therefore, it is noteworthy to question whether the mode of delivery has an effect on voice quality.

Several studies[6-8] about vocal changes during pregnancy have been published. However, we could not find any study, which compares both objective and subjective aspects of vocal changes in the prepartum and postpartum periods in the same patient population. This study compared the influence of delivery modes on objective and subjective parameters of voice quality in pregnant women. The secondary aim was to assess acoustic measures and patient-reported outcomes in the prepartum and postpartum periods.

Patients and Methods

Patients

A total of 105 patients who underwent normal vaginal delivery or cesarean section in a tertiary referral center were enrolled in this study. Age, weight gain during pregnancy, mode of delivery (normal/cesarean section), and anesthesia method (general/spinal) in patients who underwent cesar-

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ean section were noted. Patients were evaluated into two main groups: normal vaginal delivery (NG) and cesarean section group (CG). All included subjects had no history of smoking, voice disease, voice surgery, or previous head, and neck surgery. Women with active upper respiratory tract infection, a history of rheumatologic disorders, endocrinologic problems, and polycystic ovary were excluded. Participation was voluntary so the participants who did not return surveys and who did not properly answer the questions were excluded from the study. Informed consent was obtained from all of the participants. This study was approved by the institutional ethical board (No: 66) and was conducted following the Declaration of Helsinki and its later amendments.

The pain was assessed by using a 0-10 numeric pain intensity scale. Before discharging the patients, they were asked to evaluate the pain during labor based on pain scores from 0 to 10 (0: no pain, 10: worst possible pain).

Prepartum and Postpartum Assessment of Voice

Acoustic sampling was performed before and after labor. Prepartum assessments were performed during the last control visits of the patients 1 week before the labor. Postpartum assessments were performed at least 24 hours later after the labor before discharging the patient from the hospital. All samples were recorded in a soundproof room in the audiology department. Praat (Paul Boersma and David Weenink, Phonetic Sciences, University of Amsterdam, Amsterdam, The Netherlands, version 6.0.21; http://www.praat.org/), was used for digital voice recordings. The microphone (Audio-Technica AT2010; Audio Technica, Machida, Tokyo, Japan) was located 10 cm from the patient's mouth while they pronounced the sustained vowel ''a'' at a comfortable intensity and pitch levels for 5 s. The sampling frequency was 44.1 Hz at 16 bits. A middle stationary segment with a length of 2.5 sec was chosen for acoustic analysis. Investigated acoustic parameters were as follows; fundamental frequency (F_0), jitter percent (jit%), shimmer percentage (shim%), shimmer amplitude (shimdB), noise-to-harmonic ratio (NHR) number of vocal breaks (VBn), and percentage of vocal breaks (VB%).

The Voice Handicap Index (VHI) was developed by Jacobson et al that consists of 30 items with a five-point Likert-type scale manner for each item (from 0 = never to 4 = always)[9]. Patients with severe voice problems would gain higher total VHI scores, of which the highest score can be 120. It is a valid and reliable instrument for assessing the self-perception of patients' voice problems, and it has been translated and validated into Turkish by Kılıç et al[10]. VHI is a well-accepted measure and it has been widely used in the evaluation of outcomes of treatments at clinics and in research.

Statistical Analysis

Statistical data processing and visualization were performed by using R Project software[11]. Parametric tests were used when the variables were normally distributed according to the Kolmogorov-Smirnoff and Shapiro-Wilk tests. Non-parametric tests were preferred when the sample size was <30 and the variables were not normally distributed. When exploring the relationship between continuous variables, and the paired samples *t*-test and independent samples *t*-tests were employed. Continuous and categorical data were presented as mean (±standard deviation) and n (%), respectively. Correlation tests were performed to investigate the relationship between continuous variables. The level of significance was set at $p<.05$.

Results

Patient Characteristics

Thirty-seven patients underwent normal vaginal delivery (NG) and 68 patients underwent cesarean section (CG). The age gained weight during pregnancy and pain assessment results are listed in Table I. No significant difference was found in mean weight gain however, the patients

Table I. Demographic and clinical characteristics of patients.

	Vaginal delivery (NG)	Cesarean group (CG)	p*
Age	26.5 (4.7)	29.7 (6.0)	.003
Weight gain (kg)	5.3 (2.4)	5.8 (2.3)	.281
Pain Score	13.8 (5.6)	9.9 (6.5)	.003

Abbreviations: n, number; %, percentage; SD, Standard Deviation (*Independent samples *t*- test).

in the CG group were older than those in the NG. Additionally, the mean pain score was higher in NG than in group CG. There was no significant correlation between the pain scores and postpartum acoustic parameters. Also, neither age nor weight gain and postpartum acoustic parameters were significantly correlated (Pearson's correlation test; $p > .05$).

Comparison of Voice Outcomes Between the Normal Vaginal Delivery and Cesarean section Groups

The prepartum and postpartum data of acoustic examinations of both groups are shown in Table II. In NG, statistical analyses showed a significant decrease (increase in voice quality) in jit%, shim%, and VB%. For F0, shim%, shimdB, NHR, and VBn improvements were noticed but the difference was not statistically significant (paired-samples *t*-test; $p > .05$).

In CG, all parameters including F0 showed a significant decrease which indicates an improvement in acoustic parameters in the early postpartum period. We also analyzed the mean differences (MD) and test statistics (t) values in the pre and postpartum period. Based on F_0; CG had a greater change (MD=17.9; t:3.5) than NG (MD= 4.4; t:0.4). CG also had a more significant improvement in jit%, shim%, shimdB, NHR, VB%, and VBn based on *t* values. Mean postpartum F_0 was 228.6 (42.3) in NG and 209.6 (33.8) in CG (independent samples *t*-test; *p*:0.013). There were no significant differences in any other postpartum acoustic parameters between the two groups. In CG, we compared the results of patients who received general or spinal anesthesia. Except for jit% there were no significant differences in the acoustic outcomes between the two groups according to anesthesia types ($p > .05$) Mean jit% was higher in patients who received spinal anesthesia (1.83) than in general anesthesia (1.47) (*p*:0.005).

In NG, mean VHI scores increased from 5.0 to 9.1 whereas CG mean VHI scores increased from 4.9 to 10.3 (paired-samples *t*-test; $p < .001$). The increment of VHI scores was higher in CG than in NG (t: -8.2 and -3.9 respectively). The prepartum and postpartum VHI scores are summarized in Table III. Results of the most important parameter of acoustic analysis F0 and VHI scores in NG and CG are demonstrated in Figures 1 and 2 respectively.

Discussion

During pregnancy anatomical, physiological, and psychological alterations may affect voice quality. The gradual enlargement of the uterus leads to changes in the location of the diaphragm and reduces the respiratory capacity. Respiratory functions such as functional residual capacity, expiratory reserve volume, and residual volume are decreased during pregnancy and at term[12,13]. Progressively increased sex steroid levels throughout

Table II. Acoustic analysis results according to the mode of delivery.

	Vaginal delivery (NG)				Cesarean group (CG)			
	Mean (SD)	MD	*t*	*p**	Mean (SD)	MD	*t*	*p**
preF0	232.9 (40.5)	4.4	0.4	.650	227.5 (37.6)	17.9	3.5	<.001
postF0	228.6 (42.3)				209.6 (33.8)			
preJitter (%)	3.9 (1.9)	2.5	7.3	<.001	4.1 (1.9)	2.5	10.9	<.001
postJitter (%)	1.5 (0.5)				1.6 (0.5)			
preShimer (%)	14.3 (5.4)	2.2	2.4	.023	13.9 (5.0)	1.9	2.6	.011
postShimer (%)	12.1 (5.3)				11.9 (4.8)			
preShimer (dB)	1.5 (0.2)	0.1	1.8	.083	1.5 (0.2)	0.8	2.1	.044
postShimmer(dB)	1.4 (0.1)				1.4 (0.3)			
preNHR	0.25 (0.21)	-0.02	-1.2	.226	0.15 (0.16)	-0.01	-0.5	.616
postNHR	0.28 (0.28)				0.17 (0.16)			
preVoice Break (n)	1.2 (2.5)	0.6	1.4	.153	1.5 (2.5)	0.9	2.9	.004
postVoice Break (n)	0.6 (1.3)				0.5 (1.0)			
preVoice Break (%)	2.9 (5.9)	2.0	2.4	.020	3.9 (5.0)	2.8	4.3	<.001
postVoice Break (%)	0.9 (1.6)				1.2 (2.0)			

Mean acoustic analysis results according to labor method. Bold prints indicate a more significant difference before and after labor according to test statistic (*t*-value). (*Paired samples *t*-test). Abbreviations: n, number; %, percentage; SD, Standard Deviation; MD, Mean Difference; *t*, Test Statistics; F0, Fundemantal Frequency; dB, decibel; NHR, Noise to harmonic ratio.

Table III. Mean voice handicap Index scores according to the mode of delivery.

	Vaginal delivery (NG)				Cesarean group (CG)			
	Mean (SD)	MD	*t*	*p**	Mean (SD)	MD	*t*	*p**
preVHI postVHI	5.0 9.1	-4.0	-3.9	<.001	4.9 (5.2) 10.3 (7.0)	-5.4	**-8.2**	<.001

Mean VHI scores according to labor method. Bold prints indicate a more significant difference before and after labor according to *t* value. (*Paired samples *t*-test). Abbreviations: n, number; %, percentage; SD, Standard Deviation; MD, Mean Difference; *t,* Test Statistics; VHI, Voice Handicap Index.

pregnancy are thought to be a major hormonal factor in respiratory changes. Because of increased estrogen and progesterone levels, respiratory mucosa becomes vascular, edematous, and friable. These morphological changes are termed "laryngopathia gravidarum"[14].

During labor, because of increased muscular work, pain, anxiety, and hyperventilation respiratory alterations rapidly occurred and the above-mentioned mucosal changes can be aggravated. Pushing efforts can also exacerbate mucosal edema and vocal trauma during normal vaginal delivery. This can be the reason for decreased VHI results and deteriorated acoustic parameters in women undergone normal vaginal delivery. In our study women undergone cesarean section (CG) presented better voice outcomes than women undergone normal labor (NG). Pushing efforts and pain during normal labor can lead to vocal straining and tiredness. Since the duration of labor is long in normal vaginal delivery, the time span of vocal overuse is also extended. If all cesarean section operations were performed under general anesthesia, these results might be different. Intubation trauma can diminish acoustic parameters; however, in our study group general anesthesia did not yield worse results than spinal anesthesia in terms of voice quality.

The pitch of a normal voice depends on the fundamental frequency (F0) and is related to the length, tension, stiffness and vibration frequency of the vocal folds. F0 is the main parameter of the acoustic analysis and it is primarily determined by the elasticity, tension, and mass of the vocal folds. Jitter and shimmer are two common measures of perturbation and NHR represents the ratio of non-periodic components to periodic components of voice. In other words, jitter and shimmer and increment in NHR represent the irregularity of voice. Elevation in subglottic pressure, edema, and loss of elasticity of vocal cords increase F0[15]. In terms of postpartum values, NG had higher F0 (higher pitch) than in CG. During the early postpartum period CG demonstrated a greater decrease in F0 than in NG. This finding can be interpreted as normal vaginal delivery and it provokes more vocal strain than cesarean section. Painful and active labor can exacerbate

Figure 1. Preterm and post-term fundamental frequency (F0) and Voice Handicap Index (VHI) scores in the normal vaginal delivery group. Boxes indicate the first and third quartiles, and median observations denote by a line in each box. Mean values are demonstrated by an "+" in the boxes. Whisker caps indicate the minimum and maximum values.

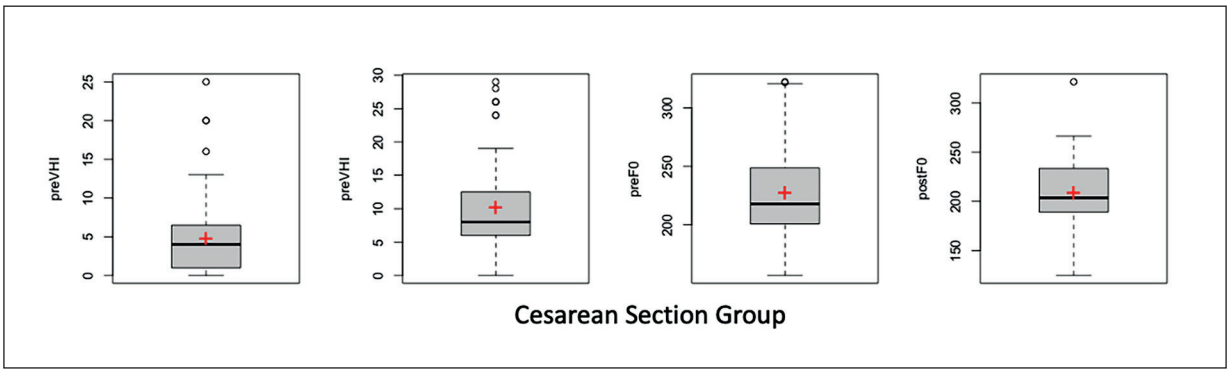

Figure 2. Preterm and post-term fundamental frequency (F0) and Voice Handicap Index (VHI) scores in the cesarean section group. Boxes indicate the first and third quartiles, and median observations denote by a line in each box. Mean values are demonstrated by an "+" in the boxes. Whisker caps indicate the minimum and maximum values.

the abovementioned changes in the respiratory system and larynx.

Although acoustic parameters showed an increase in voice quality (decrease in jit%, shim%, and VB) in both NG and CG, this increase was more significant in CG. These findings also support our hypothesis normal vaginal delivery can induce vocal overuse, thus causing a more significant decrease in voice quality than cesarean section.

In this study we observed a significant decrease (reduced irregularity of voice) in bit%, shim%, and VB% in NG. In early postpartum assessment, all acoustic parameters including F0 showed a significant decrease in CG. After delivery due to the separation of the placenta and consequential loss of progesterone production, the respiratory system quickly returns to its pre-pregnant state and mucosal edema resolves[16,17]. In addition, the decrease in intra-abdominal pressure and increased chest compliance reduce the pressure on the diaphragm. Due to these alterations tidal volume and residual volume normalizes[18]. These physiological postpartum changes explain the improvement of acoustic parameters after delivery in our study.

According to subjective assessment by VHI, both groups reported decreased voice quality. In contrast to objective findings, the increment of VHI scores was higher in CG than in NG. VHI has functional, physical, and emotional aspects and is administered by the patients themselves, regardless of the type of voice disorder. Rowland et al[19] reported that women who had a forceps-assisted vaginal delivery and unplanned cesarean section births were more likely to have post-traumatic psychological difficulties. Because VHI score affects emotional factors, this can be the reason for the discordance between objective and subjective measures. The lack of a strong correlation between objective parameters and VHI scores was previously noticed[20]. Although many studies have indicated that objective measurements are more valuable in diagnosing voice disorders, they cannot evaluate a patient's perception of his/her voice[21].

The difference between CG and NG could be an important topic, especially for pregnant voice professionals. Increased vascularity and mucosal edema can cause traumatic injury of vocal cords in female singers during pregnancy[22]. In addition to these changes, vocal straining during delivery can damage the vocal cords, which is crucial for a female opera singer. Understanding how delivery affects the voice will allow professional voices to be informed of what kind of potential change can occur and how to be careful about their voices. To prevent vocal misuse and to enhance pulmonary capacity, we should teach all patients how to perform breathing exercises, regardless of their profession.

The study's strength is the assessment of both objective and subjective measures in the prepartum and postpartum period, which was not previously published in the literature. We detected significant changes in acoustic parameters and subjective measures during the postpartum period. Additionally, this is the first report comparing the vocal outcomes of two delivery modes. The main limitation in our study was the lack of additional aerodynamic analysis such as maximum donation time and being unable to follow the same patients in the late post-term period. Longitudinal studies that follow up the same patient population should be conducted to evaluate voice changes related to the postpartum period.

Conclusions

The delivery mode significantly affects acoustic parameters and VHI scores. Normal vaginal delivery had a more prominent influence on the deterioration of acoustic parameters. In contrast, a significant decrement in subjective parameters in women undergoing cesarean section might be attributed to emotional factors. During normal vaginal delivery, vocal overuse and straining can aggravate vocal cord edema and decrease voice quality. Breathing exercises can also be helpful to prevent unnecessary vocal cord damage in pregnant women who prepare for birth.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Authors' Contribution

Ozgur Kocak patient selection, data collection, writing and submit the article; Dogan Atan; voice analysis.

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