Original article

Acoustic analysis of voice in post-tonsillectomy patients

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Abstract

Introduction: Tonsillectomy is a common surgical procedure performed in otolaryngology setting worldwide. It is a procedure to remove the palatine tonsils, which are one of the major structures in the oropharynx which constitute part of the vocal tract. The study aimed to determine acoustic changes in post-tonsillectomy patients. ***Methodology:*** Voice sampling was collected using Praat software before and after operation, which was one day before operation and within 2-3 weeks after the operation respectively. Acoustic parameters including fundamental frequency, jitter, shimmer, harmonic to noise ratio and first formant frequency were analyzed by using paired t-test. ***Results:*** A total of 27 participants that underwent tonsillectomy or adenotonsillectomy were involved in this study. The age range of participants was 3-56 years old. The mean age of study was 18.57. There was no significant difference for all the acoustic parameters between pre-tonsillectomy and post tonsillectomy. However, there were noticeable voice changes through auditory as perceived by participants or caregiver. ***Conclusion****:* Although patient and care givers do notice a significant voice changes, but objectively this finding is not reveals during objective voice assessment.

Keywords: Tonsil; Tonsillectomy; Voice

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Introduction

Vocal tract is a closed tube resonator. The vocal tract involves the pharynx, supraglottic larynx, tongue, soft palate, hard palate, oral cavity, lips, and nasal cavity. Paranasal sinuses could also play in a role in shaping the sound quality produced at the level of the vocal cords by acting as a resonator[1]. Minor alterations in the configuration of these structures of vocal tract may produce substantial changes in voice quality[2,3]. Hypernasality often related to cleft palate, submucosal cleft palate or tonsillar hypertrophy that that hinders velopharyngeal closure. However, hyponasal speech is common as well in the case where both the tonsils and adenoid tissue are enlarged.

Besides, mild edema from an upper respiratory tract infection, pharyngeal scarring or muscle tension changes will produce more or less obvious sound alterations in vocal tract[1]. The enlarged tonsils have been implicated in disturbances to oral and nasal resonance and on articulation. An enlarged tonsil can protrude in a number of different directions causing different effects on the velopharyngeal closure with resultant hypernasality, whereas tonsils that enlarged medially can cause the so-called "cul-de-sac" resonance, producing a hollow muffled sound.

Moreover, in order to produce distinguishable voice sounds for example vowel sounds, the vocal mechanism must control the resonances of the vocal tract which produce the characteristics of vocal formants. If the vocal tract is considered to be a cavity

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resonator, then it can be seen that the position of the tongue, the area of opening of the mouth, and any changes which affect the volume of the cavity will retune the resonance. Hence, the vocal tract acts as a resonator with frequencies which can be modulated by the articulators, forming the vocal formants which make vowel sounds recognizable. Meanwhile, tonsils strategically located at the pharynx, are a part of vocal tract as well. This indicates its vital role in speech production as vocal tract is the resonance closed tube that produces distinguishable sounds especially in vowel.

One of the indications for tonsillectomy is obstructive symptoms and voice change is not an indication. Nevertheless, removing the tonsil tissue might change the voice as the volume and shape of the vocal tract is changed. Hence, the postulations of voice change need to be further investigate. This is much more concerned issue among professional voice users such as singers or choir members as they put the priority on their voice to earn a living.

Currently, there is no study on the acoustic parameter of tonsillectomy patients in South East Asia (SEA) region. It is noted that adenotonsillectomy is the most common surgical procedure in the specialty of otorhinolaryngology. Therefore, the outcome of this study will help us understand better on the effect of tonsillectomy on the voice changes by analyzing the acoustic parameter.

Methodology

Study design

This was a cross-sectional study. All the participants who underwent tonsillectomy with or without adenoidectomy were recruited from Otorhinolaryngology-Head and Neck Surgery (ORL-HNS) of the Hospital Universiti Sains Malaysia (Hospital USM). Pre- and post-operation voice samples were collected and compared in term of acoustic parameters.

Study participants

All the participants for tonsillectomy and adenotonsillectomy were recruited in ORL-HNS, Hospital USM. Participants who able to follow simple command will be included but presence of comorbidities such as cleft palate, Attention Deficit Hyperactive Disorder Attention Deficit Disorder and Autistic Spectrum Disorder will be excluded.

Study procedure

Written research proposal was approved by the USM Research Ethics Committee (Human). Participants were recruited during admission for tonsillectomy. The participants selected for the study were subjected to a complete ear, nose and throat examination. Researcher briefed the study objective and rationale of the study based on study information sheet and seeks for participant's signed informed consent.

Participants were then invited to a quiet room with ambient noise less than 50 dB[4]. Proforma included demographic data and indications for tonsillectomy or adenotonsillectomy for each participant was charted. An omnidirectional microphone was used to collect the voice sample. Mouth-to-microphone distance was 5 cm. A straw measuring 5 cm was strategically positioned to maintain the necessary mouth-to-microphone distance. Microphone was placed at 45^0-90^0 from mouth axis in order to reduce aerodynamic noise from the mouth in collecting voice sample.

Microphone was connected to laptop using MIC input jack. Microphone was positioned using microphone stand in order to get a stable voice sample. Voice sampling was collected by using Praat software Version 5.3.32 in a personal laptop with a sampling rate of 44,100Hz (Paul Boersma and David Weenink, Phonetic Sciences Department, University of Amsterdam, Amsterdam, The Netherlands). Pre-operation voice sampling was collected on the day of admission which was one day before operation. Post-operation voice sampling was collected at 2-3 weeks after operation. Participant's information and voice sampling were confidential and only used for research purposes.

Praat software was calibrated for each participant and ambient noise was measured using sound level meter. The ambient noise was less than 50 dB based on reading on sound level meter[4], before the voice sample collection started.

Each participant was seated in upright position. Participants were asked to produce and sustain vowel /a/ at a comfortable pitch and loudness level for a minimum 6 seconds. Periodic continuous sounds such as vowels are well suited for comparative analysis of the function of the vocal tract resonator, as with vowel articulation the tract can generally be modeled as a single tube chamber[5]. Although acoustic analysis to running speech for voice evaluation would be desirable as running speech is the natural context for voice usage. However, running speech is intrinsically non-stationary and this makes many acoustic parameters difficult to use. Noise and perturbation measures rely on the assumption that the processed signals are stationary[6-8].

The researcher demonstrated the procedure and the participant was given practice trials until he or she

showed a good understanding of the task. After that, 3 productions were recorded and 3 seconds segment from the middle portion of the voice sample was used for subsequent analysis. The decision to take this mid-segment was to avoid inadvertently recording of any of the initializing segments of the formant values at the onset of vowel.

The same procedure was conducted after operation during the second meeting with participants. However, during the second meeting, participant was asked to describe his/her voice quality. The participants were also asked, whether they perceived any change in their voices postoperatively. The question was directed to caregiver if the participant was in the pediatric age range.

After the voice sampling recording, researcher clicked and shown the graph to the participant as a visual feedback for the auditory stimuli recorded. Next, researcher provided the acoustic analysis of voice parameters to the participant. From the voice report, researcher jotted down the mean pitch, jitter (local), shimmer (local) and mean harmonic-to-noise ratio (HNR).

Next, data was entered into SPSS software version 19 (SPSS Inc, Chicago, IL) for data analysis and hypothesis testing. The fundamental frequency, jitter, shimmer, harmonic-to-noise ratio and first formant frequency were compared between pre-operation and post-operation. Paired t-test was performed for hypothesis testing of normal distribution. Meanwhile, Wilcoxon-Signed-Rank Test was used for hypothesis testing of non-normal distribution.

Results

A total of 27 participants were recruited in this study. 14 were male and 13 were female. The 27 participants were made up of 11 children and 16 adults. The mean age for this study was 18.57. The age range was in between 3 to 58 years old (Table 1). 11 patients underwent only tonsillectomy and the rest 16 together with adenoidectomy.

Table 1: Age distribution

Age range (years old)	n (%)
0-9	8 (29.6)
10-19	8 (29.6)
20-29	5 (18.5)
30-39	5 (18.5)
40-49	0 (0.0)
50-59	1 (3.8)
Total	**27 (100.0)**

In this study, duration between pre-tonsillectomy and post-tonsillectomy voice samples collection was planned within 10 to 21 days, during the patients' visit to the clinic post operatively.

Subjective perception of voice changes

It is always important to take into consideration of patient's perception of the problem, this is much more concerned when comes to voice issue. How the patient perceived him/her voice before and after the operation and is there any voice changes noted by the patients or caregiver of the patient (for pediatric). Voice changes were noted by 12 participants subjectively while 15 participants did not perceive any voice changes through auditory.

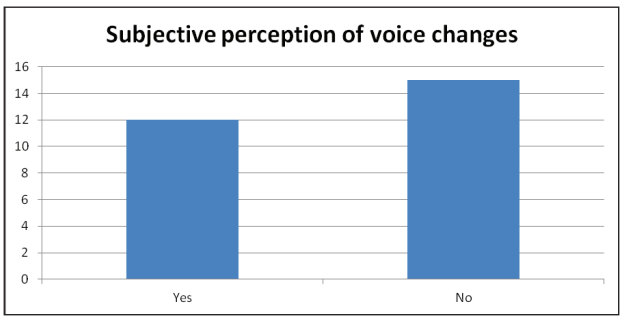

Figure 1: Subjective perception of voice changes

b) Objective evaluation of voice changes

Fundamental frequency (F_0) between pre- and post-tonsillectomy

A paired t-test was conducted to determine the mean difference of fundamental frequency between pre-tonsillectomy and post-tonsillectomy (Table 2). The p-value is 0.604. There is no significant difference on fundamental frequency between pre-tonsillectomy and post-tonsillectomy.

Frequency perturbation (jitter) between pre- and post-tonsillectomy

A paired t-test was conducted to determine the mean difference of frequency perturbation (jitter) between pre-tonsillectomy and post-tonsillectomy (Table 2). The p-value is 0.906. There is no significant difference on frequency perturbation (jitter) between pre-tonsillectomy and post-tonsillectomy.

Amplitude perturbation (shimmer) between pre- and post-tonsillectomy

A paired t-test was conducted to determine the mean difference of amplitude perturbation (shimmer) between pre-tonsillectomy and post-tonsillectomy (Table 2). The p-value is 0.675. There is no significant difference on amplitude perturbation (shimmer) between pre-tonsillectomy and post-tonsillectomy.

Harmonic-to-noise ratio (HNR) between pre- and post-tonsillectomy

A paired t-test was conducted to determine the mean difference of harmonic-to-noise ratio (HNR) between pre-tonsillectomy and post-tonsillectomy (Table 2). The p-value is 0.686. There is no significant difference on harmonic-to-noise ratio (HNR) between pre-tonsillectomy and post-tonsillectomy.

First formant frequency (F_1) between pre- and post-tonsillectomy

A paired t-test was conducted to determine the mean difference of first formant frequency (F_1) between pre-tonsillectomy and post-tonsillectomy (Table 2). The p-value is 0.538. There is no significant difference on first formant frequency (F_1) between pre-tonsillectomy and post-tonsillectomy.

Table 2: Paired t-test of the objective variables

Variable	Mean (SD)		Mean difference	t-stats (df)	p-value
	Pre-tonsillectomy	Post-tonsillectomy			
Fundamental Frequency (F_0)	233.02 (67.56)	230.586 (67.962)	2.433	0.525 (26)	0.604
Frequency perturbation (Jitter)	0.477 (0.278)	0.484 (0.243)	0.007	-0.119 (26)	0.906
Amplitude perturbation (Shimmer)	4.178 (2.642)	4.412 (2.304)	-0.233	-0.425 (26)	0.675
Harmonic-to-noise ratio (HNR)	17.532 (4.773)	17.177 (4.132)	0.355	0.409 (26)	0.686
First formant frequency (F_1)	861.05(182.53)	843.91 (200.07)	17.140	0.625 (26)	0.538

p-value significant if <0.05

Discussion

There were 27 participants involved in this study. Our data showed that there is no significant difference for the acoustic parameters tested including fundamental frequency, jitter, shimmer, harmonic-to-noise ratio and first formant frequency in term of mean difference between pre-tonsillectomy and post-tonsillectomy (p=0.604, 0.906, 0.675, 0.686, 0.538 respectively).

Several studies that have evaluated changes in acoustic parameters and formant frequencies after tonsillectomy with or without adenoidectomy found no changes postoperatively. Chuma *et al* reported that tonsillectomy had only minor quantitative and qualitative effects on various acoustic parameters[9]. Tolga et al reported statistically insignificant changes in females post-operatively[10]. In general, it was reported statistically significant changes only found in male pediatric age[3,10].

Tonsillectomy and adenoidectomy do not directly affect the larynx and therefore should not influence the rate at which vocal folds open and close during sustained phonation. The surgical procedure of tonsillectomy does not involve laryngeal tissue, so voice characteristics remain relatively stable[11].

For fundamental frequency, a slight change in the vowel /a/ was observed. However, this change was not consistent and not statistically significant (in some cases a slight increase, while in others a slight decrease was observed after the operation). The F_0 histogram was found to be very sharp, suggesting no substantial changes post-operatively. Although jitter variation is random in nature, jitter values obtained from the same speaker, before and after the operation were consistent and within a certain range (0.01 < Jitt or jitt< 0.84). This result is consistent with no changes in the pitch (fundamental frequency).

Shimmer values were random in nature as well. The shimmer values obtained from the same speaker fluctuated when parameter extraction was conducted more than once before the operation. By considering the position of participants consistent (participants were asked to maintain upright sitting position) during the voice sample collection, the position of tonsils changed relative to the movement of jaw and

tongue while producing target stimulus. As shimmer measures of amplitude perturbation, the amplitudes of individual harmonics are determined by both the source amplitudes (larynx) and filter functions (vocal tract). The amplitude might be altered in relative to the obstructive mass in the oropharyngeal cavity and result in the fluctuating shimmer values observation in the same speaker. The configuration between the obstructive mass to the tongue and jaw opening probably contributes to this observation. The true difference in oropharyngeal dimensions may be directly affecting the voice quality and vocal tract resonance overall. It is probably a combination of change in mouth opening and the resultant change in the jaw position that also contribute to this observation[12].

Based on the previous studies done by other researcher, HNR values were consistently decreased one week after the operation suggesting a less buzzy speech quality. However, it tended to increase for some patients 4 weeks after the operation, suggesting replacement of a soft tissue with the tonsils[13]. In this study, the HNR values were decreased generally. However, the finding was not statistically significant. It is suggesting the duration for post-operative voice sample collection was within 2 to 3 weeks time. Therefore, it is difficult to analyze further postoperatively.

Comparison between objective and subjective findings

Changes in the structure of the vocal tract after an operation are assumed to cause changes in the speech characteristics of the individuals[13]. Examination of the time-course changes after tonsillectomy revealed that acoustic parameters were noted to not cause significant differences on the study samples.

Through the objective analysis, it was noted there was no voice changes between pre- and post-tonsillectomy. However, based on the data analysis for the part of subjective perception of voice by participants or caregivers (in the case of pediatric participants), there were near to half (n=12/27) of the participants or caregivers of participants reported on the voice changes perceived auditorily after operation. They were 3 parents reported on the voice changes on the first few days of post-tonsillectomy. Thereafter, the voice quality seems to get back to the original which was before the operation. It is interesting to note that all changes in the acoustic parameters tended to recover. It is suggesting an involvement of auditory feedback and/or replacement of a new soft tissue with the tonsils. Extirpation of soft tissue from the oropharynx altered the anatomy of supralaryngeal acoustic transmission pathway and the acoustic measures related to vocal tract resonances[14].

Patient's perception of voice is an important treatment outcome measure, especially in the case of benign disease where the greatest impact is on the quality of life. Hence, they should be advised of potential voice changes, especially professional voice users who may be particular sensitive to changes in resonant characteristics. However, study done by Behrman et. al., one fifth of the patients perceived their voices to be improved after surgery and none thought that the voice to be worse. Therefore, it is concluded that patients are unlikely to perceive a change in voice as a result of surgery, but in those cases where a difference is perceived, it is likely to be a positive change[15].

Conclusion

There is no significant difference in all the acoustic parameters tested. In other words, there is no voice change in the pre- and post-tonsillectomy patients based on the objective finding. However, it was noted there is noticeable voice changes through auditory as perceived by some of the participants or caregivers of participants.

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