EVALUATION OF ELECTRO-ACOUSTIC PARAMETERS OF THE VOICE PRE AND POST ADENO-TONSILLECTOMY IN CHILDREN

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SOMMARIO

Il vocal tract, l'insieme delle cavità situate al di sopra del piano glottico, serve ad arricchire il tono fondamentale laringeo (F0), prodotto dalla vibrazione della mucosa delle corde vocali, di un insieme di suoni multipli dello stesso: le armoniche. Gruppi di armoniche con maggiore contenuto energetico rappresentano le formanti vocaliche. Esse sono in numero variabile ma le più significative sono le prime tre (F1, F2, F3). Modificazioni anatomiche del vocal tract determinano una alterazione dei valori formantici. L'intervento di adeno-tonsillectomia dovrebbe teoricamente comportare un cambiamento delle formanti. Scopo del nostro lavoro è stato quello di verificare il reale impatto che l'intervento di adeno-tonsillectomia determina sul prodotto vocale ed in particolare sui parametri elettroacustici della voce. Il nostro campione è costituito da 28 bambini di età compresa tra 5 e 14 aa di cui 13 maschi e 15 femmine con un'età media di 8,6 aa. Tutti i soggetti sono stati sottoposti ad una registrazione delle cinque vocali della lingua italiana /a/, /e/, /i/, /o/, /u/ prima e trenta giorni dopo l'intervento di adeno-tonsillectomia e ad una valutazione psicopercettiva della voce mediante la scala GIRBAS.

I campioni vocali sono stati analizzati mediante l'utilizzo di due software di analisi vocale:il WinPitch e lo SpeechViewer IBM. In particolare sono stati valutati i valori della frequenza fondamentale F0, e delle prime tre formanti (F1, F2, F3). I risultati ottenuti hanno evidenziato l'assenza di alterazioni a carico della F0, per la F1 un lieve aumento per la vocale /o/, per la F2 un moderato incremento per la /o/ e lieve per /a/ ed /i/, per la F3 moderati incrementi per tutte le vocali tranne che per la /a/. L'analisi statistica condotta con il T-test ed il Mann Witney test ha evidenziato l'assenza di qualunque significatività delle variazioni riscontrate. I nostri risultati sono in linea con quelli presentati da altri autori per cui è ragionevole concludere che l'intervento di adeno-tonsillectomia non comporta modificazioni dei parametri elettroacustici della voce, e la valutazione clinica del prodotto vocale mediante l'utilizzazione della scala GIRBAS rappresenti un test valido per la monitorizzazione della voce. D'altra parte le piccole modificazioni riscontrate, seppure di nessun significato, statistico impongono una maggiore attenzione nei soggetti professionisti della voce che si sottopongano ad intervento di adeno-tonsillectomia.

SUMMARY

The vocal tract, that is all cavities placed above the glottis, is meant to enrich the larynx fundamental frequency (F0), produced by the vibration of the vocal folds, through a series of accessory sounds multiples of the fundamental tone: the harmonics. Groups of harmonics with an energetic enrichment from the supraglottals resounding form the vowel formants. These are variable in number but the most important ones are F1, F2, F3, that is the first, the second and the third of the formants. Anatomical changes of the vocal tract produce a modification of the formants values. Therefore, adeno-tonsillectomy might change the formants. The aim of this study was to evaluate the real impact that adeno-

tonsillectomy determines on the vocal performance and, also, on the electro- acoustic parameters of the voice. The sample we utilized consists in 28 children aged between 5 and 14, of whom 13 males and 15 females (the average is 8,6 years). All patients underwent the registration of the five Italian vowels /a/, /e/, /i/, /o/, /u/ before and 30 days after the adeno-tonsillectomy and a psycho-perceptive evaluation of the voice by using GIRBAS scale. Vocal samples were analyzed by two software of vocal analysis: the WinPitch and the Speech Viewer IBM. Specifically, we evaluated the values of the fundamental frequency (F0) and of the first three formants (F1, F2, F3).

The data we obtained revealed the absence of variations for F0, a moderate increase of /o/ for F1, the same moderate increase of /o/ and a minor increase of /a/ and /i/ for F2, finally, a moderate increase of all vowels except /a/ for F3. T-test and Mann Witney statistical analysis have attributed no significance to these variations. Our results are in line with those carried-out by other authors, therefore we can conclude that adeno-tonsillectomy cannot modify the electro-acoustic parameters of the voice and that only the psycho-perceptiveness evaluation of the voice by GIRBAS scale represents a valid test for its evaluation. On the other hand, although the observed little modifications do not have a statistical importance, they ask for particular care to the voice of professional people (i.e. singers, actors etc.) that want to undergo to the adeno-tonsillectomy.

1. INTRODUCTION

The vocal tract, beginning at the glottis and extending to the lips, is considered to be the acoustic resonator of the voice. It is a very complex anatomical tract in which the fundamental tone, generated by the vibrations of the vocal folds is enriched, by a series of accessory sounds that are multiples of the fundamental tone: harmonics.

Groups of them acquire an energetic enrichment from the supraglottic resounding and form the vowel formants.

For this reason the vocal tract may be assimilated to the sound box of a musical instrument. The difference between a musical instrument and the human voice consists in the fact that our vocal apparatus is susceptible to huge changes and therefore any change in its structure may cause different kinds of voice modifications (Ferrero F., Genre A., Boe L. J., Contini M., 1979).

Adeno-tonsillar hypertrophy determines tightening of the vocal tract because of the total or partial isolation of the oro-nasal cavity. Consequently, this modifies the voice reducing rhino-pharyngeal and oro-pharyngeal spaces. Studies on the true impact that adeno-tonsillectomy has on the vocal production are very few (Chuma et al., 1999; Ilk et al., 2002; Saida H., Hirose H., 1996; Neri et al., 2002).

Chuma et al. (1999) have not encountered substantial vocal modifications following adeno-tonsillectomy with the exception of the second vowel formant F2 for the /i/ and /a/ which increase in tone and the first vowel formant F1 for the /o/ which appears to be reduced following surgery.

Ilk et al (2002) have found changes in vowel formant F3 for the /o/ which tends to reduce either for adequate hearing feed-back or for the changes following surgery. Saida et al (1996) did not find any variation in F0, F1, F2 following surgery but only a little decrease of F3. Neri et al (2002) have found statistical significant variations of the F1 for the vowels /a/, /o/, /u/, and less significance for /i/ and /e/. F2 was statistically increased for /e/ and /u/ and less for /i/. Finally they noted, three months after the surgery, significant decrease of F3 in relation to an improvement of the orbicular muscle tone of the lips and therefore in consequence of the recovery of the nasal airways.

The aim of this study was to evaluate if there exist any alterations of the electro-acoustic parameters following adeno-tonsillectomy verifying:

- if and how the values of the fundamental tone (F0) and vowel formants (F1, F2, F3) of speech could modify, in relation to the changes of the vocal tract resonance;
- if there is any use of electro-acoustic evaluation of the voice versus psycho-perceptive and therefore clinical assessment.

2. MATERIALS AND METHODS

A total of 28 patients were investigated between the age of 5 and 14 of whom 13 males and 15 females (mean age 8.6 years). The subjects were mixed with the patients who were being treated in the ENT Clinic (in the last two years) at the University of Catanzaro and who were subjected to adeno-tonsillectomy according to the normal clinic protocol.

Everyone underwent an objective ENT exam using the flexible or rigid 2.7 mm Explorent paediatric fiberendoscope .

In all the patients, the following conditions were found: nasal obstruction, breathing obstruction during sleep, recurrent inflammation, nasal language, breath control through the mouth due to the lacking of a better breath control following repeated cycles of medical therapy.

All patients affected by head, facial and hearing malformations are not included in this study. Due to the difficulty in adequate recording, patient below the age of 5 were excluded. None of the patients underwent speech therapy prior to surgery. All patients underwent an evaluation of their voice using GIRBAS method, a reliable and trustworthy instrument with a rapid perceptual analysis of the speech production. The GIRBAS scale, which was proposed by Hirano (1981), integrated by Dejonckere (1998) and recommended by European Laryngologicalical Society (2001) is a perceptual evaluation that refers to the ability of the clinic, independent of the acoustic measurement. For each parameter a point system is used, score from 0 to 3, where 0 represents normal condition, while 1, 2, 3 correspond to the grades: light, moderate and heavy.

The subjects chosen were in a normal condition (0 points). They were subjected to a voice recording test one day before surgery and 30 days after, when the recovery was complete. In each phase the patient was invited to pronounce the vowels /a/, /e/, /i/, /o/, /u/ prolonged for 5-6 seconds.

A microphone (Model TM 333, a unidirectional dynamic type, TEV Co Taejon) was used placed at a standard distance of about 20 cm from the mouth in a silent surrounding, respecting the procedures recommended by the European Society of Laryngology.

The voice samples at each stage were made digitally, using a PC that analyzed the data using two different software: Win Pitch and Speech Viewer III.

Win Pitch is a vocal spectrograph programme. It is a non invasive method and able to analyze the psycho-acoustic parameter of the voice (Fig. 1)

Based on the harmonic structure and the location of the aperiodic sign within the spectre we can distinguish the various grades of alteration from the vocal product (classified from Yanagihara, 1967). In a scale from 1 to 4, where 4 indicates maximum grade of alteration, the use of this programme allows us to obtain the values of the parameter F0.

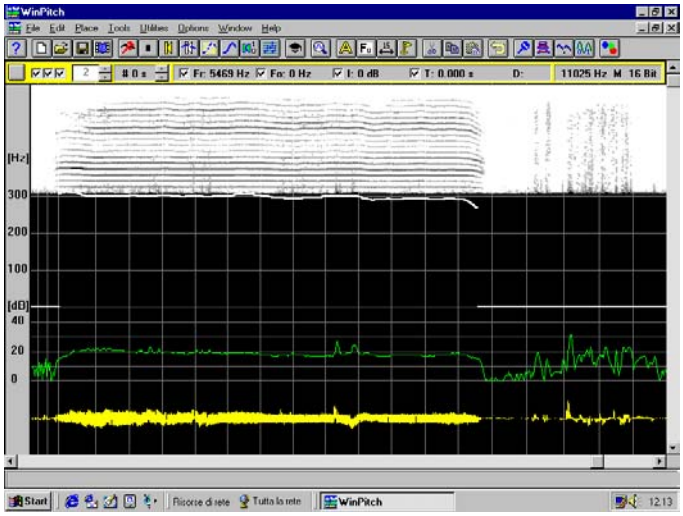

Fig. 1 An example of the spectrogram as appears with Win –Pitch software.

The F0 or the fundamental frequency, that corresponds to the number of vocal folds vibrations per second, depends on the anatomical and physiological characteristics of the individual and to his particular vocal tract. It is directly linked to the vocal folds and therefore to their length, mass and tension.

With the use of Speech Viewer III it is possible to calculate the values of other acoustic parameters, which are the object of our work: the vowel formants.

These are groups of harmonics with a greater content of energy and a multiple of the basic frequency. The formants reflect the characteristics of the resonance through the upper laryngeal vocal tract, associated with the articulation of the tongue with the other articulated structures which are both fixed and moveable and reflect in their value the deadening sound and energy absorbed by the vocal tract during each production of every vowel.

The formant F1, between 250 and 1050 Hz, depending on the vowel pronounced, is created in the oral cavity and is directly correlated with the major or minor opening of the mouth and the relationship the tongue encounters with the mandibular arch. The formant F2 is between 600 and 3200 Hz and is originated by the position of the tongue. The formant F3 is between 2400 and 3750 Hz and is causes by the movement of the orbicular muscle of the lips. (Fig. 2)

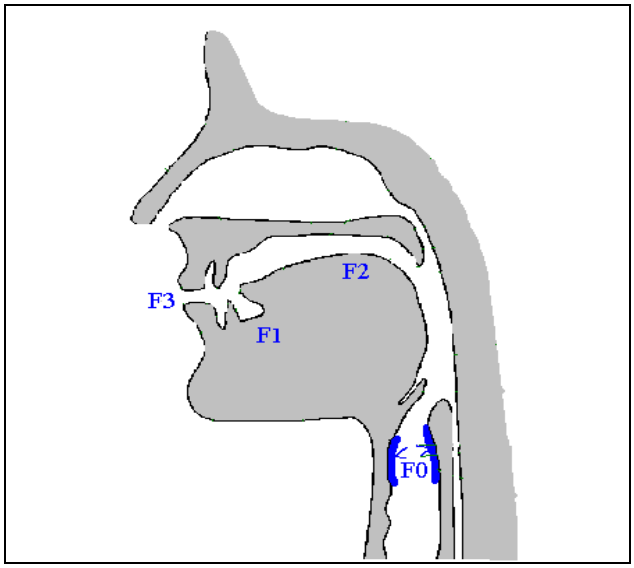

Fig. 2: Side of production of the fundamental frequency (F0) and vowel formants (F1, F2, F3) in the vocal tract.

In the spectrogram these are identified by a series of peaks that are shown on a long frequency field (Fig. 3). It is their different disposition on these frequencies that allows to distinguish one vowel sound from another.

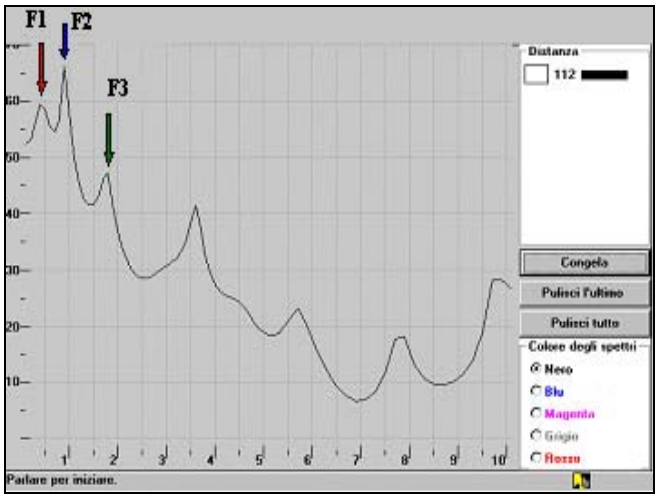

Fig. 3: An example of the vowel formants (F1, F2, F3) view with speech viewer software.

The registered spectres have been suspended in about three seconds from the beginning of the phonation, which is the time considered to be perfect and also more manageable.

Statistical analysis was performed using Mann-Witney unpaired tests to assess pre and post-surgical changes in speech rating data and Paired t-test for dependent means to value pre and post-operative significant variations in vowel formant structure.

3. RESULTS

The quantitative analysis of the voice has been derived from the values obtained for the fundamental frequency (F0) and for the formants F1, F2, and F3. Those were drawn from the registration in the period immediately preceding surgery and 30 days after.

Regarding the calculation of the formant values, an inclusive media of the singular parameter F1, F2 and F3 (all subjects of whom were included in the registration of the vowel /a/, /e/, /i/, /o/, /u/) during the period of examination have been made. In particular the mean values of F0, F1, F2 and F3 derived from the recording of the vowels are indicated in Table I.

Vowel	F0 pre	F0 post	F1 pre	F1 post	F2 pre	F2 post	F3 pre	F3 post
/a/	288	278	415	430	1184	1254	2219	2242
/e/	276	288	395	400	995	1000	2322	2461
/i/	298	286	380	380	1268	1338	2809	2995
/o/	291	296	525	608	1139	1273	2532	2652
/u/	294	284	409	448	852	920	2739	2830

Tab. I: Mean values obtained for the fundamental frequency (F0) and for the formants (F1-F2-F3) regarding all patients for each vowel.

The results obtained from t-test and Mann-Witney test revealed no significant changes in vowel structure for all of the vowels (Tab. II).

Vowel a		
	T-test	Mann Witney test
F0	0,106	>0,10
F1	0,8917	>0,10
F2	0,791	>0,10
F3	0,8965	>0,10
Vowel e		
	T-test	Mann Witney test
F0	0,396	>0,10
F1	0,4657	>0,10
F2	0,7762	>0,10
F3	0,2883	>0,10
Vowel i		

	T-test	Mann Witney test
F0	0,0382	>0,10
F1	1,000	>0,10
F2	0,7486	>0,10
F3	0,5086	>0,10
Vowel o		
	T-test	Mann Witney test
F0	1,000	>0,10
F1	0,6163	>0,10
F2	0,5185	>0,10
F3	0,6400	>0,10
Vowel u		
	T-test	Mann Witney test
F0	0,5830	>0,10
F1	0,7007	>0,10
F2	0,7846	>0,10
F3	0,5316	>0,10

Tab. II: Statistical analysis performed to assess pre and postoperative vowels changes.

4. DISCUSSION

According to the results we have drawn some considerations about the modifications of the acoustic parameters of the voice following adeno-tonsillectomy that allows an enlargement of the oro-rhino-pharynx cavities.

By definition, the acoustic resonance is the enrichment of the fundamental tone (F0) from the larynx with a series of accessory sounds, the so called harmonics, produced by the multiples of the fundamental frequency, that are moved by supralaryngeal cavity.

In particular, the electro-acoustic study of the vocal resonance is done using some parameters including the study of formants. These are harmonic groups with major energy peaking in a different way and with a special location for each vowel which are also at the base of the differential and therefore the recognition of such. The most important are the first two F1 and F2, while F3, F4 and F5 have a minor importance.

The analysis of the results of component F1 and F2 have shown no variation of F1 with the exception of a moderate elevation for /o/ and the modification of the values of F2. Still a slight increase for /o/ and an even more modest one for the vowels /a/ and /i/, while there was no change in the remaining vowels 30 days after surgery in respect to the initial values

(prior surgery). Such change however, that is statistically evaluated by t-test and Mann Witney test, have not revealed any significance. On the other side, we can say that modifications most consistently verified for the vowel /o/ (increase of F1 and F2) even if without significant statistics, do not determine any change in the difference of the interformantic F2-F1 and this parameter is known to be the most significant data for the vocal perception more than absolute value of the single vowel formant.

In regards to the parameter F3, there have been increases for all vowels with the exception of /a/ but here also the statistic analysis have not revealed great significance.

Our data are in line with what can be found in literature (2, 3, 4, 5) where only small post-surgery initial variations of these parameters (F1 and F2) have been kept in a variable period of time (from 90-120 days).

Return to normality has been attributed to an acoustic feed-back from the patient, the acoustic memory and more to the post surgical reparation of the tonsil fossae. Given the lack of statistical significance of the changes in F0 and in vowel formants F1, F2 and F3, we can conclude that psycho-perceptive analysis of the voice, using GIRBAS scale, allows by itself, to express an exact evaluation of the acoustic modification parameters of the voice after adeno-tonsillectomy. Not with standing this, we maintain that the minor differences we have already noted and they were also pointed out by various authors, should be taken into careful account whenever this surgical operation is proposed to professionals of the voice (actors, singers).

5. CONCLUSION

This study started with the intention to evaluate the real impact of adeno-tonsillectomy on the acoustic characteristics and perception of the voice.

From the analysis of the results, it is evident that the values of F0 result unchanged after surgery, as F0 reflects the condition of the vocal folds, which are not involved in the surgery.

For vowel formants however, multiple modifications have appeared although statistical analysis has revealed not significant; particularly there was no modification of the parameter F1 of all the vowels with the exception of /o/, moderate increase of F2 in the vowel /o/ and minimal in the vowel /a/ and /i/, whereas in the remaining vowels this parameter was not modified. The evaluation of the interformant difference F2-F1 does not undergo substantial modification and this parameter is regarded as the most important for the vocal perception, more than the single values.

Moreover, the results have shown that F3 increased in all the vowels with the exception of /a/ but it is also true that the importance of this at the end of the vocal perception it is absolutely minimal and in time tends to become normal.

Our results are therefore in line with those carried out from other authors and we can conclude that given the low evidence of modifications shown by the instrumental analysis, only the psico-perceptiveness of the voice carried out by speech therapists could be useful to show the possible initial changes in the voice characteristics.

Furthermore, these changes that are almost always minimal, allow the patient to undergo the adeno-tonsillectomy in absolute tranquillity, especially when we consider the voice professionals (singers, actors) who are particularly careful to minimal changes of their voice.

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