Summary: The aim of this study was to evaluate changes in acoustic features of speech after tonsillectomy and to establish concepts of patient management and rational therapeutic approach. Before and 1 month after surgery, phonetically balanced sentences and sustained vowels \( a, e, i \) were carried out and digitalized with Multi-Dimensional Voice Program (Kay Elemetrics, Lincoln Park, NJ) in all the patients, as an evaluation of nasal resonance, speech articulation, and voice handicap index (VHI). These parameters were estimated: average of fundamental frequency, Jitter percent, Shimmer, noise-to-harmonics ratio, voice turbulence index, soft phonation index, degree of voiceless, degree of voice breaks, and peak amplitude variation. Our data showed that 1 month after tonsillectomy, improvements in all the acoustic parameters, a subjective decrease of hypernasality, and an improvement of speech articulation and VHI were achieved. These data suggest the reduction of the nasal resonance and highlight the role of tonsillectomy in the improvement of voice and speech quality. Furthermore, tonsillectomy should be performed before consideration of pharyngeal flap surgery. Our results highlight that objective evaluation of speech and voice helps the specialist to improve patient management and avoid unnecessary and dangerous surgical procedures.


INTRODUCTION

Present at birth, the tonsils increase in size until 4 years of age.\(^1\) Involution begins just before puberty, with relative tonsil size being variable from person to person. In normal adults, the tonsils are not visible within the oropharyngeal airway because they are anterior to the fauces, the back of which forms the anterior boundary of the pharynx. When the tonsils intrude into the pharyngeal airway, they will alter the characteristics of speech.\(^5\)

Until now, the role of the tonsil has been regarded as solely immunologic: it is hypothesized that their position at the entrance of the respiratory and alimentary tract facilitates their functional role in the defense against pathogens.\(^3\)

There has been little interest in the role of tonsils in speech and voice, although the negative impact of enlarged tonsils vocal communication and nasooral resonance is well recognized. Enlarged tonsils with posterior placement of the upper poles into the oropharyngeal and nasopharyngeal airway, interposed between the velum and posterior pharyngeal wall, have been shown to cause hypernasal speech with incomplete velopharyngeal closure.\(^2\)

Unfortunately, otolaryngologists who have no formal training in speech or resonance disorders may not be able to qualitative analyze different speech characteristics in patients with enlarged tonsils; therefore, they primarily use endoscopy for diagnosis.

Although tonsillectomy is therapeutic for chronic tonsillitis, this procedure has the potential to affect speech and vocal quality by altering the resonant characteristics of vocal tract and speech articulation.\(^5\)

Until now, the effects of tonsillectomy on speech have been unclear, as has the appropriate choice of speech analysis methods. There are several quantitative studies on the effects of tonsillectomy on speech, but these studies mainly concentrate on the fundamental frequency (F0), with opposite results.\(^5\)–\(^7\)

The aim of this study was to evaluate changes in acoustic feature of speech and voice after tonsillectomy in adults, using the Multi-Dimensional Voice Program (MDVP) in conjunction with other tests, and to establish new concepts of management and a rational therapeutic approach.

METHODS

Forty male adults, ranging in age from 18 to 60 years (mean age, 37.4), were recruited from the ENT Department of the University of Genoa (Italy), between June 2006 and January 2007, for this nonrandomized study. All the patients underwent tonsillectomy and were operated by the same team of surgeons. Excluded from the study were patients with craniofacial anomalies, neurological problems, patients younger than 18 years, and those without tonsillar hypertrophy (enlarged tonsils) shown in the preoperative nasopharyngoscopy.

As a control group, 40 healthy male adults aged between 18 and 60 years (mean age, 38.2), without enlarged tonsils and with a normal oral resonance, were identified.

A signed informed consent was obtained from all study subjects.

Before and 1 month after surgery, for testing nasality the mirror-fogging test from Glatzol, the Gutzmann tests, and a nasality severity index were performed: the tests were scored by a certified speech pathologist (M.G.S.) experienced in resonance disorder assessment.\(^8\)\(^,\)\(^9\)

In the mirror-fogging test, the nasalization was assessed by evaluating the degree of condensation (0: no condensation; 4: severe condensation) on a cold mirror held 0.5 cm under the nose during phonation (subjects were asked to sustain the vowels \( a \) and \( i \), and the consonant \( m \)).\(^8\)

In the Gutzmann test, subjects were asked to produce a series of \( a \) and \( i \) sounds alternately with the nares held open and closed (a change in vowel quality when the subject produced the vowels with the nares closed was indicative of hypernasality,
in which case a score of 1 was assigned; absence of change was assigned a score of 0.\textsuperscript{8}

For the nasality severity index, a nominal scale with five categories was used (0: normal resonance; 1: mild hypernasal; 2: moderate; 3: severe; 4: very severe).\textsuperscript{9}

Before and 1 month after surgery, the voice handicap index (VHI) was performed. The VHI is a validated questionnaire measuring psychosocial handicapping effects of voice disorders (translated and validated in Italian).\textsuperscript{10} The VHI consists of 30 statements on voice-related aspects in daily life, with 5 response levels, scored 0–4 (0: good; 4: very bad). Summarizing the scores on the 30 statements leads to a total VHI score, ranging from 0 to 120. A higher score corresponds to a worse voice-related functional status.\textsuperscript{11}

To evaluate articulation, the speech samples were elicited by means of the picture-naming test, described in Van Borsel’s study, before and 1 month after surgery.\textsuperscript{12} This test requires subjects to name black-and-white drawings of common objects and actions and elicit a speech sample containing instance of all Italian simple speech sounds and most clusters in all possible syllable combinations. The speech sample gathered consisted of 120 different words from which consonant production was compared with target productions and analyzed for errors at the segmental level.

Phonetically balanced sentences and sustained vowels a, e, i were carried out and digitalized with MDVP (Kay Elemetrics) in all the adults, before and 1 month after surgery. Recordings were made in a quiet room using a microphone at a constant mouth-to-microphone distance (10 cm). The vocal samples had intensity between 55 and 65 dB and duration of at least 5 seconds. The oronasal sentences correspond to the English “Rainbow” passage, the oral sentences are similar to the “Zoo” passage, and the ratio of nasal consonants to the total number of consonants in the nasal text is 50.4% (55/109).\textsuperscript{8,13} The sentences were done by a certified speech pathologist (M.G.S.). The specific sentences are presented in the Appendix. Patients were asked to repeat the same passages sentence by sentence.

The MDVP system computes a set of 33 acoustic voice parameters in about 16 seconds and provides flexible routines for graphical representation of the results. Also, a user-upgradeable voice database allows automatic comparison of the current results with different nosological groups.

The following parameters were estimated: average F0; Jitter percent (Jitt); Shimmer; noise-to-harmonics ratio (NHR); voice turbulence index (VTI); soft phonation index (SPI); degree of voiceless (DUV); degree of voice breaks (DVB), and peak amplitude variation (vAm).

Perturbation measures (Jitt, Shimmer, NHR, VTI, SPI, DUV, DVB, and vAm) were obtained from the sustained vowels, whereas F0 was extracted from both balanced sentences and sustained vowels.

The results were statistically evaluated by comparing mean values of each preoperative and postoperative parameter, in the “surgery” group, using the unpaired $t$ test. Probability values below 0.05 were regarded as significant; the results were reviewed and approved by the Institutional Review Board of the University of Genoa, Italy.

**RESULTS**

Our data showed an improvement in all tested parameters 1 month after tonsillectomy: the analysis of F0, Jitt, Shimmer, NHR, VTI, SPI, DUV, DVB, and vAm showed a significant postoperative ($P < 0.05$) decrease; comparison with healthy adults highlighted a significant ($P < 0.05$) postoperative normalization of F0, Jitt, NHR, VTI, DUV, DVB, and vAm (Tables 1 and 2).

F0 data showed a postoperative normalization in both the speech and vocal samples: in the speech samples, the postoperative mean value fell from 148 to 124 Hz, whereas in the healthy adults the mean value was 132 Hz (vocal results are reported in the Tables 1 and 2).

Subjective decrease of hypernasality was noted in all the patients at their postoperative clinical controls (1 month after tonsillectomy): the mirror-fogging test presented a postoperative mean assessment of 1.6 (decreased from the preoperative mean value of 3.3), the Gutzmann test values fell from 1 before the treatment to 0 after it, and the mean value on the nasality severity index fell from 3.6 to 0.5. VHI had a postoperative mean value of 22 (decreased from the preoperative mean value of 98).

The results of the phonetic analysis showed that all the patients were capable of producing all Italian vowels and consonants preoperatively and postoperatively. Before surgery, the phonetic analysis comparing consonant productions to target productions at the segmental level revealed difficulties in the articulation of several consonants: data are presented in Table 3.

One month after surgery no patients presented articulation difficulties.

No patient experienced side effects.

**DISCUSSION**

Because the normal resonance of speech relies on an unobstructed nasopharyngeal passage, any barrier, such as hypertrophied tonsils, causes change in resonance and thus speech quality. Very little has been published with regard to the role that tonsils play in either normal or disordered speech; although some authors report that hypertrophic tonsils could alter oropharyngeal resonance characteristics, but the specifics of how tonsils impair speech are first reported in our study.\textsuperscript{4,14,15}

Examination of postoperative data reveals that certain speech parameters are modified by tonsillectomy. Furthermore, preoperative tonsil size is directly related to the degree of audible changes in speech characteristics after tonsillectomy.\textsuperscript{4}

In our patients, enlarged tonsils were found to be in the nasopharynx and interposed between the velum and posterior pharyngeal wall. These large masses are known to obstruct sound transmission into both the oral and nasal cavities, causing an increase in nasal resonance: in several patients, speech became hypernasal when the tonsils became hypertrophic.\textsuperscript{4}

Hypertrophic tonsils in the oropharynx that extend upward into the nasopharynx cause velopharyngeal insufficiency, impending full palatal movement.\textsuperscript{4}

Many otolaryngologists and speech pathologists believe that tonsils and adenoids should never be removed in patients with hypernasal speech as adenotonsillectomy in patients with pre-
existing velopharyngeal insufficiency is often observed to exacerbate hypernasality. Our study shows that this concern is unfounded, thus hypernasal speech is indeed not a contraindication for tonsillectomy.

With the understanding that closure of the nasopharynx is velar-adenoïdal, tonsillectomy would not be expected to cause hypernasality, a hypothesis confirmed by our data.

Patients with hypernasality are often referred for pharyngeal flap surgery, a risky procedure, which in patients with tonsillar hypertrophy can be fatal (obstructive sleep apnea is a well-recognized complication of pharyngeal flap surgery). Enlarged tonsils can result in an anterior tongue base position and a long soft palate. Furthermore, when the tonsils prolapse posteriorly during speech, they prevent the palate from fully approximating the posterior pharyngeal wall. For these reasons, our data indicate that tonsillectomy should be recommended before the more dangerous pharyngeal flap surgery.

The MDVP is a powerful software tool for quantitative acoustic assessment of voice quality; it is capable of calculating 33 parameters from a single vocalization. These acoustic analyses, which provide an extensive representation of vocal function, cannot be obtained from airway resistance or perceptual measures alone. Therefore, the precise knowledge of changes in these tested parameters provides a comprehensive and thus superior depiction of vocal function and aids in providing more objective predictions of the effects of surgery. According with other authors, articulation problems may affect acoustic properties of vocal fold: for this reason, we consider important the analysis of the different acoustic measures (F0, Jitt, Shimmer, NHR, VTI, SPI, DUV, DVB, and vAm) in patients with enlarged tonsils.

In our experience F0, Jitt, Shimmer, NHR, VTI, SPI, DUV, DVB, and vAm are the parameters that give the most objective information about the presence of vocal modification; a multiple regression analysis of these eight acoustic measures may provide a quick and relatively sensitive method that may be clinically useful in measuring change of vocal quality.

F0 is indicative of the vocal fold vibratory rate and reflects resonance characteristics, of the supralaryngeal vocal tract, related to tongue articulation and placement. F0 showed significant change postoperatively, both in the vocal and speech samples. This observation indicates that tonsillectomy, although a procedure that does not affect the larynx, changes the structure of the vocal tract and thus the resonance of speech production (lowering the pitch of the voice often decreases the resonance and consequently can decrease the nasal resonance values), and is thus a surgery capable of improving speech quality.

Jitt and Shimmer reflect the grade of hoarseness and roughness of the speech spectrum: their postoperative normalization and improvement highlight improvement of the vocal quality, with the absence of a slight grade of hoarseness and roughness in the voices (Table 2).

The postoperative normalization of F0, Jitt, Shimmer, and vAm shows the regularization of loudness.

Although sound originates at the laryngeal level, there are significant alterations and enhancement of the vocal output as a result of the transfer function in the supraglottic cavities. Large tonsillar tissue has a damping effect during the transfer

### TABLE 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimal Value</th>
<th>Maximum Value</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0 (Hz)</td>
<td>102</td>
<td>185</td>
<td>164</td>
</tr>
<tr>
<td>Jitt (%)</td>
<td>0.44</td>
<td>1.34</td>
<td>0.85</td>
</tr>
<tr>
<td>Shimmer (%)</td>
<td>1.81</td>
<td>4.17</td>
<td>2.54</td>
</tr>
<tr>
<td>NHR</td>
<td>0.13</td>
<td>0.16</td>
<td>0.15</td>
</tr>
<tr>
<td>VTI</td>
<td>0.02</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>SPI</td>
<td>4.17</td>
<td>20.57</td>
<td>15.47</td>
</tr>
<tr>
<td>DUV (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DVB (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>vAm (%)</td>
<td>4.34</td>
<td>21.61</td>
<td>9.01</td>
</tr>
</tbody>
</table>

### TABLE 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimal Value</th>
<th>Maximum Value</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0 (Hz)</td>
<td>150</td>
<td>265</td>
<td>195</td>
</tr>
<tr>
<td>Jitt (%)</td>
<td>0.29</td>
<td>2.98</td>
<td>1.22</td>
</tr>
<tr>
<td>Shimmer (%)</td>
<td>1.60</td>
<td>8.88</td>
<td>5.01</td>
</tr>
<tr>
<td>NHR</td>
<td>0.07</td>
<td>0.63</td>
<td>0.30</td>
</tr>
<tr>
<td>VTI</td>
<td>0.01</td>
<td>0.87</td>
<td>0.25</td>
</tr>
<tr>
<td>SPI</td>
<td>1.01</td>
<td>45.88</td>
<td>21.89</td>
</tr>
<tr>
<td>DUV (%)</td>
<td>0</td>
<td>2.70</td>
<td>0</td>
</tr>
<tr>
<td>DVB (%)</td>
<td>0</td>
<td>3.88</td>
<td>0</td>
</tr>
<tr>
<td>vAm (%)</td>
<td>14.07</td>
<td>44.23</td>
<td>19.46</td>
</tr>
</tbody>
</table>

P < 0.05 represents the significant statistical analysis by comparing mean values of each preoperative and postoperative parameters.
function, causing a reduction in quality and precision of the output. These damped effects influence noise; NHR measures the aperiodic noise present in the analyzed signal, whereas VTI is the ratio of spectral inharmonic energy to spectral harmonic energy. In patients with enlarged tonsils, the tonsillar tissue may cause important turbulent air passage, through the vocal resonator, and produces an augmentation of vocal tract inertia and resistance that can interfere with a speaker’s ability to produce a regular voice. The augmentation of inertance causes skewing of the glottal flow, whereas a higher resistance produces a nonlinear pressure-flow relation in the glottis, resulting from air leakage through the glottis during phonation, caused by an incomplete closure of the glottis. NHR and VTI postoperative normalization represents an altered dynamic in the structures of the resonator, which implies postoperative changes of vocal tract structures and a greater acoustical quality of the voice, with less nasalized vowels.

The postoperative values of Jitt, VTI, SPI, DUV, and DVB highlight the regularization of the supraglottic flow with the reduction of vocal tract inertia and resistance, resulting in less laryngeal adductory force necessary for phonation (Table 2).

Studies regarding articulation and deglutition suggest risk of articulation difficulties (more or less temporary) in patients with enlarged tonsils. When the tonsils occupy the pharyngeal airway, to maximize the oral airway, dropping of the mandible and tongue is frequently seen in patients as a compensatory mechanism. It is known that hypertrophied tonsils may alter facial growth by contributing to tongue and mandibular displacement. Patients with enlarged tonsils have a retroclined lower incisors, protruded upper incisive, and a shorter lower dental arch; furthermore, they have retrognathic, posteriorly inclined mandibles, an anterior tongue base position, enlarged anterior facial height, and enlarged skeletal open bite.

These abnormalities, often present in patients with enlarged tonsils, account for the observed preoperative articulation errors of several sounds: the shorter lower dental arch causes the distortions of the r, s, l, d, n, and t sounds produced by the tongue tip between the incisors and of f and v sounds from bilabial production (Table 3).

The preoperative articulation of sch lacking sufficient frication is due to the presence of the tonsils preventing sufficient narrowing of the vocal tract.

The preoperative occurrence of devoicing, correlating to a reduction in vocal fold vibrations from h, d, g, and z sound production, highlights that abnormally high resistance in the vocal tract causes incomplete closure of the glottis (Table 3).

Our data indicate that tonsils may alter the dimensions of the pharyngeal orifice and interfere with sound transmission, and therefore should be removed as the first surgical option. Tonsillectomy should be the first surgical consideration when those speech abnormalities shown to be resolved in this study are present.

The consequences of speech disorders are potentially devastating to a patient’s quality of life, other studies have shown that patients with speech disorders are often stereotyped as less intelligent, less pleasant, and less attractive than people with normal speech; such perceptions can seriously affect the social life and self-esteem of these patients. The VHI shows that the relationship between self-assessment of voice quality and scores is clear and statistically significant, in subjects with and without vocal complaints; the worse the self-assessment of the voice, the lower the VHI score. Our results indicate that patients with enlarged tonsils encounter the same degree of problems in daily life as other voice-impaired patients, and therefore require the maximum level of attention and care.

The postoperative normalization of nasalance highlights the absence of nasal air escape during speech and the important role of enlarged tonsil in velopharyngeal closure.

For all these reasons, an objective speech analysis in all patients affected by tonsillar hypertrophy should be performed.

| TABLE 3. Articulation Outcome (%) Before (T 1) and 1 Month After Tonsillectomy (T 2) |
|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| Articulation Outcome (%) (T 1) | Comments | Articulation Outcome (%) (T 2) |
| /r/ | 87.5 (35/40) deviations | Production of a rolled sound without sufficient trill | 100 normal (40/40) |
| | 62.5 (25/40) derhotacized /r/ | Production of the /r/ with the tongue tip between the incisors | |
| | 12.5 (5/40) dentalized /r/ | |
| | 12.5 (5/40) devoiced /r/ | |
| /s/ | 45 (18/40) deviations | Production of the /s/ sound without sufficient frication | 100 normal (40/40) |
| | 30 (12/40) sigmatismus simplex | Production of the /s/ with the tongue tip between the incisors | |
| | 15 (6/40) sigmatismus dentalis | |
| /f/ /v/ | 10 (4/40) bilabial production | |
| /l/ /d/ /n /t/ | 40 (16/40) dentalization | Production of several alveolar sounds with the tongue tip between the incisor | 100 normal (40/40) |
| /sch/ | 37.5 (15/40) articulation without sufficient frication | |
| Devoicing | 17.5 (7/40) devoicing of /b/ | 100 normal (40/40) |
| | 42.5 (17/40) devoicing of /d/ | |
| | 35 (14/40) devoicing of /g/ | |
| | 37.5 (15/40) devoicing of /z/ | |
CONCLUSIONS
Our study shows that in selected cases, such as enlarged palatine tonsils, the decision to perform tonsillectomy depends on its potential effect on speech and velopharyngeal function. A complete therapeutic approach to patients affected by tonsillar hypertrophy should also consider significant speech abnormalities as criteria for perform tonsillectomy: our results indicate that an objective evaluation of speech and voice helps the specialist in the management of the patients and avoids incorrect and potentially dangerous procedures.

REFERENCES

Appendix. Balanced sentences
The oronasal sentences below contain a mixture of nasal and non-nasal sounds in the approximate proportion found in everyday Italian speech (11.6% nasal consonants). The nasal sentences below exclude nasal consonants and are designed to detect hypernasality. The nasal sentences are loaded with nasal consonants and are designed to detect hyponasality.

All the adults were instructed to repeat each passage with a comfortable vocal pitch and loudness. If a subject made an error, the passage was repeated.

Oronasal sentences
Si presumo che in caso di omonimia gli interessati producano la documentazione necessaria a disambiguare la situazione.

Il colloquio di lavoro al quale mi sono recato ieri non credo che porterà significativi sviluppi alla mia carriera lavorativa.

Oral sentences
La strada è stata asfaltata ieri dagli operai dopo quel periodo così protetto di pioggia e forti acquazzoni.

Se corri veloce alla chiesa che è di lato alla piazza puoi vedere la sorella di Dario che oggi si sposa.

Vorrei ripetere il viaggio che ho fatto a febbraio sulla costa cosi’ protratto di piogge e forti acquazzoni.

La strada è stata asfaltata ieri dagli operai dopo quel periodo così protetto di pioggia e forti acquazzoni.

Il colloquio di lavoro al quale mi sono recato ieri non credo che porterà significativi sviluppi alla mia carriera lavorativa.

Nasal sentences
Mi sembra di mentire mutando sempre la mia impressione in merito al mantenimento di Manuela con il mansionario di smis-tare le missive importanti.

Nino Musante è un importante componente della Commissione impegnata al mantenimento del monumento di marmo messo nel Museo di Musica di Milano.