Speech Intelligibility After Glossectomy and Speech Rehabilitation

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Background: Oral tumor resections cause articulation deficiencies, depending on the site, extent of resection, type of reconstruction, and tongue stump mobility.

Objectives: To evaluate the speech intelligibility of patients undergoing total, subtotal, or partial glossectomy, before and after speech therapy.

Patients and Methods: Twenty-seven patients (24 men and 3 women), aged 34 to 77 years (mean age, 56.5 years), underwent glossectomy. Tumor stages were T1 in 3 patients, T2 in 4, T3 in 8, T4 in 11, and TX in 1; node stages, N0 in 15 patients, N1 in 5, N2a-c in 6, and N3 in 1. No patient had metastases (M0). Patients were divided into 3 groups by extent of tongue resection, ie, total (group 1; n=6), subtotal (group 2; n=9), and partial (group 3; n=12). Different phonological tasks were recorded and analyzed by 3 experienced judges, including sustained 7 oral vowels, vowel in a syllable, and the sequence vowel-consonant-vowel (VCV). The intelligibility of spontaneous speech (sequence story) was scored from 1 to 4 in consensus. All patients underwent a therapeutic program to activate articulatory adaptations, compensations, and maximization of the remaining structures for 3 to 6 months. The tasks were recorded after speech therapy. To compare mean changes, analyses of variance and Wilcoxon tests were used.

Results: Patients of groups 1 and 2 significantly improved their speech intelligibility (P<.05). Group 1 improved vowels, VCV, and spontaneous speech; group 2, syllable, VCV, and spontaneous speech. Group 3 demonstrated better intelligibility in the pretherapy phase, but the improvement after therapy was not significant.

Conclusions: Speech therapy was effective in improving speech intelligibility of patients undergoing glossectomy, even after major resection. Different pretherapy ability between groups was seen, with improvement of speech intelligibility in groups 1 and 2. The improvement of speech intelligibility in group 3 was not statistically significant, possibly because of the small and heterogeneous sample.

PATIENTS AND METHODS

The sample was composed of 27 patients (24 men and 3 women) aged 34 to 79 years (median age, 56.3 years), who were treated at the Departments of Head and Neck Surgery and Otorhinolaryngology and of Speech, Voice, and Swallowing Rehabilitation at the Centro de Tratamento e Pesquisa Hospital do Câncer A. C. Camargo, São Paulo, Brazil, from June 18, 1997, through November 22, 1999. The tumor stages were: T1 in 3 patients, T2 in 4, T3 in 8, T4 in 11, and TX in 1. Node stages were N0 in 15 patients, N1 in 5, N2a-c in 6, and N3 in 1. Metastasis stage was M0 in all 27 patients. Tumor histological findings included squamous cell carcinoma in 26 patients and adenoid cyst carcinoma in 1 patient. Tongue resection (glossectomy) was associated with the site and extension of the lesion. Resection for T1, T2, and some T3 tumors was classified as partial glossectomy or hemiglossectomy (group 3, n = 12 [10 with floor of mouth]); resections including all of the tongue but preserving the base, as subtotal glossectomy (group 2, n = 9 [all including floor of mouth]); and larger resections, as total glossectomy (group 1, n = 6 [4 with floor of mouth]). Pectoralis major myocutaneous flap for reconstruction was used in 15 patients; microsurgical transplanted, in 3; tongue flap, in 6; and primary closure, in 3. All but 2 patients underwent radiation therapy (preoperative in 3 and postoperative in 22) (Table 1). The postoperative radiation therapy started from 6 to 10 weeks after the procedure (median, 8 weeks). The first recording and the speech rehabilitation program started from 2 to 8 weeks postoperatively (median, 5 weeks). Eighteen patients started the rehabilitation program simultaneously with postoperative radiotherapy, and 4 patients started after irradiation therapy.

By the time they started speech therapy, 4 patients were maintained with a nasogastric feeding tube, 10 were using mixed feeding (oral and nasogastric), and the remaining 13 patients were receiving only oral feeding (for groups 1 and 2, liquid, thick liquid, and paste; for group 3, all consistencies). All patients underwent speech, voice, and swallowing therapy for 3 to 6 months.

All patients speak Portuguese and were able to read the speech samples and to sign the informed consent. The perceptual evaluation of speech protocol is often used in the clinical routine of the speech pathologist and includes how the speakers use their voice and speech in relation to vocal quality, pitch, loudness, articulation, and speech rate and intelligibility. The perceptual evaluation of speech focuses on the criteria of the intelligibility of the vowel, isolated or in a standard sentence; the vowel-consonant-vowel articulatory sequence (VCV); and spontaneous speech. The recording protocol consisted of the following:

1. Sustained 7-vowel oral emission consisting of /a/, /e/, /i/, /o/, /u/, and /l/;
2. Standard sentence with 7 oral vowels within a consonant/vowel syllabic context, with the voiceless plosive phoneme /p/ within the standard sentence “Digo /p ... para ele”;
3. VCV articulatory sentence using apa, ata, aka, ada, aga, ama, ana, anha, afa, asa, ava, aza, aja, ala, ara, and arra (19 consonants), also within the standard sentence “Digo ... / para ele”; and
4. Spontaneous speech, ie, story in sequence of its visual presentation on cards.

The speech samples were recorded with 5-second gaps between the emissions, inside rooms with acoustic treatment and with the patient standing up. The emissions were captured by a professional unidirectional microphone (Leson, Manaus, Brazil) kept 15 cm from the patient's mouth and recorded using a digital recorder (model MDS 303; Sony, Tokyo, Japan) and a mini-disk (Sony). The recording order was random to avoid vocal fatigue at the end of the emission, and mainly to avoid the predictability of the usual sequence of the presentation.

RESULTS

The results obtained after judgment by 3 trained listeners were described according to the speech tasks among the 3 groups of patients before and after speech therapy.

The improvement in the mean intelligibility of vowel (vowel understanding) was significant only in group 1. Before therapy, the mean score was 11.83; after, it was 15.83 (P = .048). Speech impairment after major glossectomy was severe, and the patients benefited from speech therapy, but for the others, the results were not significant (Table 3).

The improvement of mean intelligibility of vowel in a syllable (vowel-in-syllable understanding) was significant for group 2. Before therapy, the mean score was 14.44; after therapy, it was 18.77 (P = .04). Speech impairment to syllable was moderate to severe in the pretherapy phase in groups 1 and 2, and the mean intelligibility scores were 12.66 and 14.44, respectively. Speech was improved in both groups, but it was significant just for group 2. For group 3, there was no significant difference (Table 3).

The improvement of mean intelligibility for VCV was significant for groups 1 and 2. Before and after therapy, the mean intelligibility scores for group 1 were 20.00 and 29.50, respectively (P = .04); for group 2, they were 26.22...
In the pretherapy phase, patients underwent evaluation according to tongue mobility, the presence of lingual-palatal contact, and the presence of teeth and/or prostheses. In group 3 patients, anteroposterior tongue movement was observed in 11 patients, tip-of-tongue elevation in 7, midtongue elevation in 7, and back-tongue elevation in 8. Four patients had no tongue contact with the palate. Lingual-palatal contact was observed on the left side of the tongue in 2 patients, right side of the tongue in 3, tip-of-tongue in 2, midtongue in 4, and back-tongue in 7. We observed 22 toothless patients, 2 with complete dentition, and 3 with partial prostheses (Table 2).

For all patients, 16 therapy sessions were proposed. The average number of sessions was 10 for group 1, 12 for group 2, and 10 for group 3.

The speech sample was analyzed by 3 speech therapists (E.C.A., N.M.S.M., and A.P.B.B.) experienced in the treatment of patients undergoing oral cavity resection. The evaluation board was oriented to register individually what they heard between the alternatives. The recordings of the speech activities of each patient before and after speech therapy were presented randomly, so that the listeners did not know what part of the therapeutic process the patients were in.

Each listener gave a score for each speech task, ie, for vowel from 0 to 7, for syllable from 0 to 7, and for VCV from 0 to 19, according to the number of understandable answers. The total score was the sum of the listener's score for vowel from 0 to 21, for syllable from 0 to 21, and for VCV from 0 to 57.

In the story in sequence, speech intelligibility was evaluated by the listeners, the final score was established after a discussion carried by the group, and a consensus score was then concluded, based on the following criteria (adapted from McConnel et al18):

1. **Intelligible** indicates clear, with no difficulty whatsoever understanding the speech;
2. **Partially intelligible**, some difficulty understanding part of the sentence, but no loss in understanding the story;
3. **Intelligible with attention**, much difficulty understanding part of the sentence, with loss in comprehension of the story; and
4. **Unintelligible**, impossible to understand the sentence and all of the story.

The therapeutic program aimed at maximizing the residual tongue tissue movements, developing adaptation and articulatory compensations, and modifying negative compensations. The therapy was planned and followed these steps: differentiation of isolated vowels and vowels with bilabial phonemes; phonemic review to maximize adaptation and compensatory movements (articulatory contacts and/or mobility of remaining structures) to reduce distortion and substitute articulation; modification of suprasegmentary functions pause (distinctive value), duration, intensity, and intonation (ascendent and descendent curves, high and low pitch); reduction of speech rate (words per minute); pneumophonic-articulatory coordination; speech and saliva coordination; overarticulation exercises; yawning and chewing; and support of auditory feedback.

To compare the mean total score for vowel, syllable, and VCV, a 2-factor analysis of variance was used, with surgery as the independent factor and time (before or after the speech therapy) as repeated measure. The Tukey multiple comparison procedure (Honestly Significant Difference Tukey test) was used. The Wilcoxon test was used to compare the mean score for spontaneous speech analysis (story in sequence) with a score of 1 to 4. The differences were considered significant at P<.05. The mean (x̄) and confidence interval (CI) were represented by Figures 1, 2, and 3. The following formula was used to determine CIs:

CI 95% (x̄) = ̄± 1.96

and 36.66, respectively (P = .003). For group 3, there was no significant difference (Table 3).

The results for spontaneous speech, using a score of 1 to 4, demonstrated improvement of mean perceptual score for groups 1 (3.33 to 2.50; P = .06), 2 (2.78 to 1.65; P = .01), and 3 (1.42 to 1.25, P = .16) for nearly intelligible speech. The improvement was significant only for groups 1 and 2 (Table 4).

The clinical rehabilitation improved speech and swallowing of the patients. By the end of the rehabilitation program (average length of therapy, 3 months), 25 patients were receiving only oral feeding. Two patients continued to receive nasogastric feeding. One of these was patient 1 in group 1, aged 75 years, who eventually underwent a gastrostomy. The other, patient 13 in group 2, had an aggressive cervical recurrence and was unable to swallow.

**COMMENT**

Oral cancer and its treatment—surgery, radiation therapy, and/or chemotherapy—affect the stomatognathic and respiratory systems and can result in voice, speech, and swallowing impairment.27,28 Restoration of communication skills to maximal efficiency has been a priority for the speech pathologist. Restoration of speech intelligibility depended, of course, on the restoration of the tract’s structure and function. Surgery and prosthesis were the possible approaches to this task.

Several studies have reported on the intelligibility characteristics of patients undergoing partial and total glossectomy. Unfortunately, many studies have described only 1 or 2 patients.12,14,20,28

In our study, 27 patients had mild to severe impairment of speech intelligibility before therapy. The sample was heterogeneous according to the extent of surgery (total or partial resection of the tongue and floor of mouth), reconstruction, radiation therapy, tongue mobility, and lingual-palatal contact and the presence of teeth and prostheses. All patients continued the rehabilitation during the radiation therapy to maximize the mobility of the remaining structures. During the study, pectoralis major myocutaneous flap was our first choice for reconstruction after major resections. At that time, routine free flaps
were not available in our institution. The 3 patients who underwent this kind of reconstruction were young, communicative, actively working patients. The patients improved their speech, independent of the type of reconstruction. The small sample size does not permit assessment of the effect of this variable on the speech intelligibility results.

The objectives and techniques during speech therapy were based on the literature, according to Skelly et al and Gillis and Leonard. Speech characteristics should be defined, taking into consideration the listener’s perception, on all the segmental and suprasegmental variables of speech. Perceptual analysis reflected the acceptability of the functional and social role of communication.

The patients might be unable to shape the vocal tract for the vowel sound in the usual manner. Vowels are sounds produced with laryngeal vibration and an open vocal tract that is shaped to produce particular patterns of resonance. Before therapy, group 1 demonstrated unintelligible emission, vocalic confusion, and accumulated saliva in the mouth. The lips and mandibular movements were maximized, and suprasegmental factors were emphasized. The results were significant (median improvement, 11.83 to 15.83). Group 2 had a stump tongue to help vocal tract modifications before therapy, and the mean values of intelligibility were better than those of group 1 (median, 15.88). Group 2 patients improved intelligibility through the therapeutic exercises (median improvement, 15.88 to 17.00), but it was not significant, probably because of the small sample size and better speech in pretherapy.

The phonological tasks were inserted in standard sentences to extend the linguistic clues for the speaker and the interlocutor. The emission of the vowel inserted in the syllable was coarticulated with the phoneme /p/, because of the integrity of the structures involved in their emission (bilabial). (When emitting the phoneme /p/, there is obstruction of the aerial current by the lips and the abrupt release.) The result was significant in group 2, because some facilitators could be described, such as the presence of teeth or prosthesis, improving the direction and pressure of the airflow to produce bilabial phonemes. The justification was not applicable for group 1.

Table 1. Patient Groups According to Treatment

<table>
<thead>
<tr>
<th>Resection (Group No.), Patient No.</th>
<th>Surgery (Resection)</th>
<th>Neck Dissection</th>
<th>Reconstruction</th>
<th>Radiation Therapy*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Total</td>
<td>No</td>
<td>Bilateral</td>
<td>Pectoralis†</td>
</tr>
<tr>
<td>2</td>
<td>Total</td>
<td>Yes</td>
<td>Bilateral</td>
<td>Pectoralis†</td>
</tr>
<tr>
<td>3</td>
<td>Total</td>
<td>Yes sectional</td>
<td>Bilateral</td>
<td>Pectoralis† and plate</td>
</tr>
<tr>
<td>4</td>
<td>Total</td>
<td>Yes</td>
<td>Bilateral</td>
<td>Pectoralis†</td>
</tr>
<tr>
<td>5</td>
<td>Total</td>
<td>Yes</td>
<td>Bilateral</td>
<td>Pectoralis†</td>
</tr>
<tr>
<td>6</td>
<td>Total</td>
<td>No</td>
<td>Bilateral</td>
<td>Pectoralis†</td>
</tr>
</tbody>
</table>

Subtotal (2)

| 7                                  | Subtotal            | Yes sectional  | Bilateral      | Pectoralis† and plate |
| 8                                  | Subtotal            | Yes             | Bilateral      | Pectoralis† and plate |
| 9                                  | Subtotal            | Yes sectional  | Bilateral      | Pectoralis† and plate |
| 10                                 | Subtotal            | Yes             | Bilateral      | Pectoralis†       |
| 11                                 | Subtotal            | Yes             | Bilateral      | Pectoralis†       |
| 12                                 | Subtotal            | Yes sectional  | Bilateral      | Pectoralis† and plate |
| 13                                 | Subtotal            | Yes sectional  | Bilateral      | Pectoralis† and plate |
| 14                                 | Subtotal            | Yes marginal   | Bilateral      | Pectoralis†       |
| 15                                 | Subtotal            | Yes sectional  | Bilateral      | Pectoralis† and rib |

Partial (3)

| 16                                 | Partial             | No              | ...            | ...               |
| 17                                 | Partial             | No              | Unilateral     | ...               |
| 18                                 | Partial             | Yes             | Bilateral Tongue flap | Post 6100 |
| 19                                 | Partial             | Yes             | Unilateral Tongue flap | Post 5940 |
| 20                                 | Partial             | Yes marginal   | Bilateral Tongue flap | ...     |
| 21                                 | Partial             | Yes marginal   | Bilateral Tongue flap | Post 6400 |
| 22                                 | Partial             | Yes             | Unilateral Tongue flap | Post 6100 |
| 23                                 | Hemif                | Yes             | Unilateral Tongue flap | Post 6000 |
| 24                                 | Hemif                | Yes marginal   | Bilateral Lateral of arm§ | Post 6000 |
| 25                                 | Hemif                | Yes             | Unilateral Pectoralis† and | Post 6500 |
| 26                                 | Hemif                | Yes sectional  | Bilateral Pectoralis† and plate | Post 6000 |
| 27                                 | Partial[¶]          | Yes marginal   | Bilateral Tongue flap | Post 6100 |

*Pre indicates before speech therapy; post, after speech therapy; and ellipses, not none. To convert rad to gray, multiply by 0.01.
†Indicates pectoralis major myocutaneous flap.
‡Indicates gracilis microsurgical transplant.
§Indicates lateral arm microsurgical transplant.
¶Indicates presence of tongue contact with palate.
#Indicates presence of tongue mobility.
\Indicates sternodeidomastoid myocutaneous flap.
The anterior large flap in the oral cavity results in a better oral phase of swallowing and speech (anterior phonemes), according to Conley and Sachs and Robertson. In patient 2 (group 1), we observed a pectoralis major myocutaneous flap contacting the hard palate, thereby improving the speech.

In VCV, we observed the vocal tract constricted (constriction and occlusion) by high air pressure, and this sequence was coarticulated with the vowel /a/ and produced into a connected speech (standard sentence). The central vowel had been related to the vowel that caused the least confusion of intelligibility to the listeners. The tongue was an important articulator for 14 phonemes (anterior-dental, alveolar and palatal, and posterior-velar). Therapeutic training consisted of constricting the vocal tract in a similar manner, by holding the teeth or lips together, lips and gum together, or lips, buccinator, and gum or teeth together to produce anterior phonemes, and by moving other structures (palatal, pharyngeal, and laryngeal) to produce posterior phonemes. Leonard et al. reported that anterior resections alter consonant production because of constriction and occlusion of the vocal tract, and that posterior resections alter vowel production.

It was important to add modifications of airflow and air pressure like those of original sound, and then to produce an acoustic signal that a listener perceives as the phoneme. The suprasegmentary factors (duration, pause,
intelligibility, and speech rate) helped the emission and influenced the listener’s perception. Articulatory adaptations and compensations with the remaining structures in isolation, or together, were described in the literature, ie, lips, buccinator, mandible, palate, uvula, pharynx, and larynx, for restoration of speech intelligibility of patients undergoing glossectomy.11,10,22 An improvement of intelligibility (significant difference) was observed for groups 1 and 2 (major resections). This is in disagreement with the findings of Leonard et al,13 who reported worse speech in patients undergoing subtotal compared with total glossectomy because of the resections of adjacent structures. The speech results of patients undergoing glossectomy differ between studies, as do the methods used for analysis. Most studies involved small samples undergoing evaluation.

Group 3 had a tongue stump and learned to use their residual tongue mass to its maximum potential. Even with 50% loss of tongue mass, vowel and consonant articulation was very good. We observed tongue mobility and lingual-palatal contact, thereby reducing the substitution and articulatory distortions during therapeutic program. The auditory feedback, again, was important to produce nearly normal sounds. This group had mild impairment and we observed improvement of intelligibility, but it was not significant. Heller et al14 described normal speech after 6 or 8 months of speech therapy in patients undergoing partial glossectomy.

In connected speech, the listener hears contextual cues afforded by other intact speech sounds. In connected speech, other cues (eg, intonation, pause, reduced speech rate, saliva control, and air pressure) could also be imposed on a phrase or sentence and could influence the listener’s perception. It was more a functional task that checked overall intelligibility and demanded a quick ability to produce many kinds of sounds. The spontaneous speech was considered intelligible with attention for group 1, and no patients were considered unintelligible. These were significant improvements after major surgery (total and subtotal). The speech of group 3 patients was considered nearly intelligible. Some data reported better results in connected speech or sentence emission than in monosyllables in patients undergoing glossectomy.10,11 Similar data described improvement of speech intelligibility for patients undergoing partial glossectomy (6%-24%) and after the therapy (24%-46%). For patients undergoing total glossectomy, speech intelligibility ranged from 0% to 8% at admission and from 18% to 42% after therapy.12

The role of the speech pathologist is to determine the way the patients can be rehabilitated by using available structures. The patients can learn to achieve new speech sound targets that approximate the acoustic characteristics of the original so closely that the listener will perceive them as the original. The following 3 strategies were valuable during speech therapy: the reduction of speech rate, temporal modifications (pause and duration) of emission, and auditory feedback to maintain acoustic characteristics of sound, in concordance with previously published data.9,11,14

Different abilities between groups before therapy were seen, ie, the improvement of intelligibility of speech in groups 1 and 2 was statistically significant, and the improvement of speech intelligibility in group 3 was not, possibly because of the small sample. Speech therapy effectively improved speech intelligibility of patients undergoing glossectomy, even those undergoing a major resection. The major goal of speech rehabilitation is the functional use of oral communication.

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