SPEECH AND SWALLOWING FUNCTION AFTER RECONSTRUCTION WITH A RADIAL FOREARM FREE FLAP OR A PECTORALIS MAJOR FLAP FOR TONGUE CANCER

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Background and Purpose: The tongue plays a more significant role in English than in Mandarin, both in apical-palatal consonant production and tense-lax distinction. Theoretically, the same surgical intervention may produce a less significant impact on postoperative Mandarin production. The impact of tongue reconstruction on Mandarin articulation has not been reported. This study compared the tongue function outcome obtained using two methods of tongue reconstruction, radial forearm free flap transfer and pectoralis major flap transfer.

Methods: Twenty-five patients with carcinoma of the tongue underwent tumor resection. The surgical defects were reconstructed using a pectoralis major flap in six patients and a radial forearm flap in 19 patients. Swallowing and speech function were evaluated 6 months to 5 years after the reconstruction. Speech intelligibility and a Mandarin articulation test were used to evaluate the articulation proficiency before and after surgery. Clinical evaluation of deglutition included a questionnaire on dietary habits and a swallowing rating of 1 to 7.

Results: Clinical evaluation showed that patients with free flap reconstruction had more intelligible speech (p = 0.014) even after total glossectomy. Assessment of data obtained by clinical questionnaire showed no significant difference between the two groups in swallowing function. Motility due to flap pliability increased speech intelligibility but had little effect on swallowing function.

Conclusion: Our results suggest that radial forearm flap transfer is better than pectoralis major flap transfer in preserving speech function and that there is no significant difference between the two methods of reconstruction in their impact on swallowing function.

Carcinoma of the tongue is the most common oral cavity cancer in Taiwan. It has been reported that nearly 27 out of each million residents in Taiwan develop carcinoma of the tongue each year [1]. Treatment includes radiation therapy or combined surgery and radiotherapy depending on the size of the tumor, the extent of tumor infiltration, and the physician’s preference [2–4]. The range of surgical options available for reconstruction of the surgical defect resulting from resection of tumor in patients with carcinoma of the tongue has changed markedly over the past decade. For example, in 1994, Urken and Biller designed a bilobed sensate radial forearm flap to preserve tongue motility [5]. Although the management of segmental mandibular defects has been the focus of much attention over the past several decades, it is the soft-tissue reconstruction of the oral cavity, and in particular the tongue, that is the most critical factor in achieving a successfully functional result. The tongue uniquely serves a multitude of varied functions, including...
articulation, mastication, deglutition, and taste. A number of recent studies have attempted to define a battery of functional tests to assess the rehabilitative outcome following surgery in the oral cancer patient [6, 7]. After reconstructive surgery, the tongue should be evaluated as a single organ even though it serves different functions, and may have been reconstructed by different methods leaving surgical defects of different sizes. Although the mobile tongue and tongue base serve different purposes in speech and deglutition, they coordinate with each other, especially after surgery, and so should be evaluated together. This study evaluated the articulation and swallowing function outcomes in 25 patients with carcinoma of the tongue base or mobile tongue who underwent 25 to 100% full-thickness resection, and compared the functional results between patients who underwent pectoralis major flap and radial forearm flap reconstructions.

**Patients and Methods**

Between July 1992 and July 1999, 33 consecutive patients (28 males, 5 females) with tongue cancer underwent tongue resection and reconstruction using a pectoralis major flap, free radial forearm flap transfer, or primary closure. None of these patients underwent segmental mandibulectomy. Patients were assigned to undergo a procedure based on the size of the defect and the physician's preference. Seven patients required marginal resection of the mandible, which did not influence the structural continuity of the mandible, and 20 patients underwent a median or paramedian mandibulectomy to expose the floor of the mouth. No patients required a laryngectomy due to the effects of tumor invasion. Partial laryngoplasty was performed in all five patients who underwent total glossectomy. Concomitant neck dissection was carried out in every patient undergoing flap reconstruction. Thirty-two patients were previously untreated, one patient with recurrent tumor received combined therapy with chemotherapy, and partial glossectomy. Preference for this method, however, was challenged by an increase in the use of microsurgical transfer of a free radial forearm flap for intraoral reconstruction. The radial forearm flap and its use in intraoral reconstruction have been previously described [5, 7]. In this study, there was no attempt to repair the hypoglossal nerve defects associated with tumor resection.

Swallowing and speech function were evaluated 6 months to 5 years postoperatively in 25 patients who underwent pectoralis major flap or radial forearm free flap reconstruction. Six pedicled flaps and 19 free flaps were used to reconstruct tongue defects of varying sizes in these patients. Pectoralis major flaps were used in one patient who underwent total glossectomy, four patients who underwent hemiglossectomy (both the tongue base and mobile tongue), and one patient undergoing partial glossectomy. Free flaps were used in two patients who underwent total glossectomy, 14 patients who underwent hemiglossectomy, and three patients who underwent partial glossectomy (1 tongue base, 2 mobile tongues). The remaining eight patients, who underwent surgical repair by primary closure, had persistent disease or died from intercurrent diseases and were excluded from this study.

**Surgical technique**

Small resections of mobile tongue (classified as "one-quarter glossectomy" in Urken et al's scheme) [6] may be primarily closed. When the defect extends to the floor of the mouth, however, primary closure leads to tethering of the tongue. Because split-thickness skin is unreliable for reconstruction, we used a forearm flap or a pectoralis major flap to provide the bulk of the tongue as well as lining for the oral cavity. In this study, when both the tongue base and mobile tongue were involved, resection was classified as hemiglossectomy unless the defect was smaller than 3 cm and readily yielded to primary closure without significant disturbance in function. Defects of the tongue base are difficult to manage by tongue flap resection, and can lead to great disturbances in tongue shape, volume, position, mobility, and ultimately function. For patients undergoing resection of the entire tongue or those who were left with a nonfunctional residual remnant, the tongue base was always resected down to the hyoid bone, including the hypoglossal nerve and lingual artery, as well as varying portions of the vallecula and pharyngeal wall. Partial laryngoplasty ensured protection against aspiration.

Initially, surgeons used the pectoralis major flap because of its simplicity in design, ease of dissection, and high reliability, especially when bulk is beneficial, such as after subtotal or total glossectomy. Preference for this method, however, was challenged by an increase in the use of microsurgical transfer of a free radial forearm flap for intraoral reconstruction. The radial forearm flap and its use in intraoral reconstruction have been previously described [5, 7]. In this study, there was no attempt to repair the hypoglossal nerve defects associated with tumor resection.

Clinical evaluation of deglutition employed a questionnaire on dietary habits and a swallowing rating of 1 to 7 [8]. Swallowing ability was rated as follows: 7 = no complaints; 6 = minimal complaints, able to swallow a bolus without difficulty; 5 = minimal complaints, able to swallow without a bolus (dry swallowing) without difficulty; 4 = moderate complaints, difficulty swallowing a bolus; 3 = moderate complaints, difficulty dry swallowing; 2 = severe complaints, difficulty swallowing a bolus and dry swallowing; and 1 = severe complaints, unable to swallow. The consistency of food in the Chinese diet is similar to that in the Western diet: liquid, semiliquid (noodle), and solid (rice).
One experienced speech pathologist, one head and neck surgeon, and patients’ spouses performed a perceptual analysis of the patients’ speech. The evaluated functions included speech intelligibility and Chinese articulation.

Intelligibility was determined by the speech pathologist, who reviewed and graded a tape of the patient’s speech on a scale of 1 to 7, and by the interview of the patient’s spouse. Intelligibility was rated as follows: 7 = no sound errors noticed in continuous speech and speech can easily be understood; 6 = sound errors occasionally noticed in continuous speech but speech is always understandable; 5 = speech is intelligible, although noticeably in error, and understandable only after listening twice; 4 = speech is intelligible with careful listening and only understandable after listening more than three times; 3 = speech intelligibility is difficult and understandable only after listening more than three times and observing body language; 2 = speech is usually unintelligible and communication is only by body language and guessing; and 1 = speech is completely unintelligible and communication is very limited.

In contrast to Western studies that used IPA (international phonetic alphabet) phonemes, Chinese consonant phonemes were used to test patients’ articulation, since the consonants are the carrier of intelligibility (Table 1) [9]. Each patient was asked to repeat the pronunciation of the examiner with various Chinese consonant phonemes. Articulation proficiency was classified as correct or distorted pronunciation. The statistical significance of differences between the two groups was determined using Student’s t-test and Fisher’s exact test.

**Results**

Complications of surgery included orocutaneous fistula in seven cases (three with pedicled flap, four with free flap), infection in three cases, and flap skin loss in five cases. The fistula healed with local wound care in five cases and closure with a pectoralis major flap was performed in two patients. Four patients died of persistent disease. The entire forearm skin graft was lost due to infection in one patient who required a second skin-grafting procedure.

**Speech**

After hemiglossectomy and pectoralis major flap transfer, intelligibility fell to grade 6 in one patient, 5 in one patient, and 4 in two patients (Table 2). The average grade was 4.75. After total glossectomy, the pectoralis major flap transfer did not restore the speech of any patient (all remained in grade 1). In patients who underwent radial forearm flap transfer, the intelligibility grade after hemiglossectomy was 7 in 10 patients, 6 in one, 5 in two, and 3 in one. The average postoperative grade was 6.36, which was significantly better than 4.75 for pectoralis major flap transfers (p = 0.014). Even after total glossectomy, patients undergoing radial forearm flap transfer had more understandable speech (grade 2 in one patient, grade 3 in another patient) than those undergoing pectoralis major flap transfer (all remained in grade 1).

As shown in Table 3, after pectoralis major flap transfer, patients developed obvious handicaps in the production of apical-alveolar stop consonants and lingua-velar consonants. Compared with pectoralis major flap transfer, the production of all consonants in Table 3 was improved in patients who underwent free flap reconstruction, although this difference was not significant between the two groups. Neither of these transfers significantly restored lingua-velar contact. The consonants /g/, /k/, and /h/ were perceived as distorted but intelligible. Bilabial and labio-dental consonants were less affected by the surgical intervention.

**Swallowing**

In patients undergoing total glossectomy, a liquid diet was necessary postoperatively no matter which type of flap was used (Table 2). In patients undergoing hemiglossectomy, pectoralis major flap transfer helped one patient to eat a regular diet (grade 6) and one to eat a semiliquid diet (grade 5). Average swallowing function fell to 5.0 because two patients developed orocutaneous fistulae, which affected their swallowing ability (both grade 4). The fourth patient (secondary reconstruction), whose preoperative diet was limited to liquids, was able to eat noodles after surgery (grade 5). Among patients who underwent hemiglossectomy, radial forearm flap helped 10 patients to eat a regular diet (grade 6) and one patient to eat a semiliquid diet (grade 5). Average swallowing function fell to 5.43.

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**Table 1.** Comparison between Chinese consonant phonemes and phonemes of the international phonetic alphabet

<table>
<thead>
<tr>
<th>Place/manner</th>
<th>Interdental</th>
<th>Stop</th>
<th>Affricate</th>
<th>Nasals</th>
<th>Fricatives</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>P</td>
<td>t</td>
<td>s</td>
<td>ts</td>
<td>t’ h</td>
</tr>
<tr>
<td>Apical-alveolar</td>
<td>t’</td>
<td></td>
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<tr>
<td>Apical-palatal</td>
<td>s</td>
<td>t’</td>
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<td></td>
</tr>
<tr>
<td>Laminal-palatal</td>
<td>s</td>
<td>t’</td>
<td></td>
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<tr>
<td>Lingua-velar</td>
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Apical = tongue tip; laminal = dorsal surface of tongue.
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Table 2. Intelligibility test and swallowing test results according to type of reconstruction and primary extent of surgery

<table>
<thead>
<tr>
<th>Reconstruction</th>
<th>Primary extent</th>
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<tbody>
<tr>
<td></td>
<td>Tongue base*</td>
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<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>PMF</td>
<td>1</td>
</tr>
<tr>
<td>RFF</td>
<td>1</td>
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<tr>
<td>One-tailed t-test p value</td>
<td>-</td>
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</table>

Numbers in parentheses represent the swallowing test score. *Sample too small for statistical testing; †swallowing score given for patients with orocutaneous fistulae only after these were closed by spontaneous healing or secondary reconstruction. SD = standard deviation; PMF = pectoralis major flap; RFF = radial forearm flap.

Discussion

The mobile tongue is responsible for oral manipulation of food for the swallow and the basal tongue is responsible for the oral initiation of the swallow. Thus, every effort should be made to reconstruct the oral cavity to permit as much range and coordination of tongue motion as possible. Freedlander et al assessed 12 patients with tongue carcinoma, and found no differences in patients’ assessment of the functional outcome of pedicled-flap versus free-flap reconstruction [10]. In that report, only the multiple sites of oral cavity involvement were noted, and no data on objective functional analysis, tumor size, or surgical defect were reported. In our series, the size of the surgical defect determined the consistency of the diet no matter what type of reconstructive flap was used, and the orocutaneous fistulae further significantly affected future outcome. McConnel et al showed that the tongue provides the major driving force for swallowing liquid.
The residual tongue can influence either the free or pedicled flap to approximate the palate and pharyngeal wall. Therefore, as more residual tongue is preserved, oral manipulation and swallowing improve. In this study, patients who underwent total glossectomy could only consume a liquid diet, while patients who underwent hemiglossectomy or partial glossectomy (without complications) could eat regular or semiliquid diets. Thus, although the bulkiness and contour of the flap are important, the functional amount of the residual tongue plays a more significant role in swallowing function. There is a lack of data regarding what critical volume of the tongue base is needed to achieve contact with the pharyngeal wall to cause the epiglottis to prolapse over the endolarynx and to generate sufficient driving force on the bolus to propel it through the pharynx. In addition, the spontaneous healing of an oro-cutaneous fistula may cause shrinkage and inferior displacement of the flap, limiting the final bulkiness and motility of the residual tongue. In this study, the tongue base excursion was significantly limited, especially after healing of a fistula. Our results demonstrate that the volume of the residual tongue base and absence of tethering from severe scars play a major role in the process of deglutition.

The intrinsic muscles provide the tongue with a unique and almost limitless array of voluntary and involuntary movements. These muscles work with extrinsic muscles in a concerted fashion to not only change the position of the tongue within the oral cavity, but also to alter its shape. In this study, the articulation test demonstrated the importance of this sophisticated functioning of the tongue. A variety of contacts between the tongue and teeth, alveolar, and palate produce various kinds of stop, affricate, nasal, and fricative consonants. Using the thin, supple tissue of a radial forearm flap allows the residual tongue to maintain its characteristics of mobility and pliability, which facilitates articulation and improves intelligibility ratings. Several studies have demonstrated that lesions in the anterior oral cavity are likely to cause significant problems with speech and tongue motility [12]. Posterior cavity lesions are more likely to result in significant problems with deglutition. In this study, patients with pliable free flap reconstruction had a higher intelligibility rating than those with pedicled flap reconstruction, especially patients who underwent hemiglossectomy. Even the two patients who underwent total glossectomy in the free flap group had better speech intelligibility than those in the pedicled flap group. However, all patients in the hemiglossectomy group demonstrated various difficulties with velar stop consonants no matter which type of flap was used. This might have been due to surgical damage to tongue elevators, i.e., the styloglossus or the palatoglossus. The distortion of apical-alveolar stop consonants could be detected in all patients in the hemiglossectomy group, especially among those who underwent pectoralis major flap transfer. Tethering and adynamia of the tongue tip resulting from the procedure might have been responsible for these effects. Although the implications of this study are limited by the small number of subjects, a trend was found that the amount of the residual tongue plays an important role in swallowing and the motility of the reconstructed tongue plays an important role in speech.

The tense-lax distinction between vowel pairs is often used to describe differences in voice quality mainly found in some Germanic languages, particularly English, North German, and Dutch ([I:, y, u, e, a:] are characterized as tense and [I, y, u, e, a] as lax) [13]. The terminology tense-lax has also been applied to vocalic opposition found in a number of Asiatic languages, but not in Mandarin [9]. Various studies have shown, however, that this opposition is based on a difference between an expanded pharynx (with advanced tongue root and lowered larynx) and a constricted pharynx [14-17]. The protrusion of the tongue root can enlarge the resonant space and produce tenser vowel sounds. These findings suggest that the oral tongue plays a more significant role in English than in Mandarin and may explain why relatively less deterioration of articulation affecting speech intelligibility occurs in Mandarin speakers than in English speakers after the same surgical intervention. Furthermore, there are no uvula consonants in Mandarin phonemes [9], although these can be heard in English phonemes such as /N/ and /R/. Neither of the reconstructive methods used in this study improved the intelligibility of lingua-velar consonants. Theoretically, the production of intelligible consonants should be influenced to a greater extent among English speakers than Mandarin speakers when tongue surgery involves the styloglossus or palatoglossal fold. All of these differences remain to be determined.

References

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