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Effect of articulatory rehabilitation after oral cancer surgery on higher brain activation

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Abstract. The present study aimed to verify the importance of postoperative articulatory rehabilitation in patients with oral cancer and to clarify the neurological changes underlying articulatory functional recovery. A longitudinal assessment of oral function and accompanying brain activity was performed using non-invasive functional magnetic resonance imaging (fMRI). We assessed 13 patients with cancers of the tongue and oral floor before and after ablative surgery. Articulatory function was assessed preoperatively and postoperatively using a conversation intelligibility test and the Assessment of Motor Speech for Dysarthria test. Patients also performed a verbal task during fMRI scans. The assessments were then repeated after the patients had undergone 4–6 months of articulatory rehabilitation therapy. Compared to pretreatment levels, articulatory rehabilitation resulted in a significant increase in activation in the supplementary motor cortex, thalamus, and cingulate cortex. The present study offers a quantitative assessment of the effects of speech rehabilitation by investigating changes in brain activation sites.

Key words: articulatory rehabilitation; functional magnetic resonance imaging; oral cancer surgery.

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Malignant neoplasms, or cancers, are the leading cause of death worldwide. Although head and neck cancers account for only a small proportion of all cancers, the proportion of oral cancers among head and neck cancer cases is high, at 59%,[1–4] and is increasing. Chemotherapy, radiotherapy, and surgery are the current treatments generally used for oral cancer.

Surgical treatment results in deformation or defects in the tongue, jaw, and surrounding tissues, which may lead to chewing and swallowing dysfunction and articulatory impairment,[5] whereas functional impairments are arguably less severe following chemotherapy or radiotherapy. However, chemotherapy, radiation therapy, and chemoradiotherapy often result in adverse effects such as dysphagia and masticatory disorders due to mucositis and pharyngitis, as well as myelosuppression, nausea, vomiting, and functional impairments. Nevertheless, surgical treatment can also result in deglutition disorders, masticatory disorders, and dysarthria, similar to those observed after chemoradiotherapy, because it causes deformations and defects in the tongue, mandible, and surrounding tissues.

Oral functions are extremely important for dietary intake and swallowing, as well as for daily activities such as communication. For oral cancer patients, articulatory function deteriorates even if reconstructive surgery is performed following tumour resection. The accompanying decrease in conversation intelligibility has a great effect on the quality of life, regardless of age.[6]

Postoperative articulatory impairment varies considerably depending on the extent, type, and size of the resected tumour. Regarding the advantages of articulatory rehabilitation, although several studies have been conducted using evaluations based on articulatory tests, only a few studies have used objective evaluations based on a clear understanding of how the extent of the resection and the differences in reconstruction methods have influenced the development of articulatory disorders after surgery. Extensive research has been conducted using articulation testing to assess the effectiveness of articulatory rehabilitation, although studies on the relationship between postoperative articulatory impairment and the extent of the resection and the method of reconstruction are limited.[7] Because awareness is growing regarding the importance of rehabilitation in the field of oral surgery,[8–10] additional reliable methods for the evaluation of articulatory function are needed in daily clinical practice; therefore, we conducted this research, focusing on functional magnetic resonance imaging (fMRI).

In recent years, neuroimaging techniques such as fMRI, magnetoencephalography (MEG), near-infrared spectroscopy (NIRS), and positron emission tomography (PET) have shown considerable advancements, and studies have utilized these techniques in the areas of rehabilitation and neuroscience. Research using fMRI to assess the recovery of brain function in patients with brain damage has been reported[11,12]; it has been shown that the recovery of motor function following brain damage caused by stroke is related to functional and structural reconstruction of the motor cortex and related areas based on brain plasticity.[13] The usefulness of fMRI has been described extensively.

Haupage et al.[14] used fMRI to assess the brain activation areas involved in postoperative changes in tongue movement and deglutition function in six tongue cancer patients. In these six patients, the brain activation regions at 6 months after surgery more closely resembled those of nine healthy individuals compared to the measurements taken in these six patients before surgery. Mosier et al.[15] performed imaging analysis of tongue movements while swallowing saliva using fMRI in four tongue cancer patients who had been treated with partial tongue resection and primary plicature at 6 months after surgery; these data were subsequently compared with those obtained for eight healthy subjects. Their findings showed that strong activation of the parietal lobes and the cerebellum and changes in the brain cortex after partial tongue resection reflected adaptations in the biomechanics of tongue movements during swallowing. Their results indicated that, although the extent of resection affects tongue movement during deglutition, perception is unaffected. Both these studies compared healthy individuals with the postoperative conditions of tongue cancer patients, and the fMRI tasks included tongue tapping and saliva deglutition. Because the number of participants was small (i.e., $n < 10$), an individual assessment rather than a population-level analysis was conducted.

We believe that accurately assessing postoperative articulatory function in oral cancer patients requires evaluation of tongue movement as well as actual articulation, in addition to a comparison of the patient articulatory status before and after surgery and after articulatory rehabilitation. Conducting a population analysis may also be useful for verifying the relationship between brain activity and speech. Performing a population analysis of articulatory issues before surgery would greatly facilitate the identification of sites that are commonly activated in healthy subjects, and may play a major role in the creation of a database of fMRI experiments involving articulation. In addition, the creation of such a database may lead to new discoveries. Finally, performing a population analysis may identify common properties of the group, which would facilitate the characterization of individual differences within this group.

Thus, we employed non-invasive fMRI to examine brain activity during articulatory rehabilitation of oral cancer patients in order to establish the role of postoperative articulatory rehabilitation. The present study also aimed to improve and objectively assess the motivation of oral cancer patients to undergo articulatory rehabilitation based on patient feedback, which may facilitate the development of guidelines for rehabilitating postoperative oral cancer patients.

Materials and methods

Patients

The participants were recruited from patients who were examined and given a definitive diagnosis of tongue and oral floor cancer at our hospital. The patients included in this study required ablative surgery, had no history of psychiatric or neurological disease, and provided written consent after receiving a full explanation of the intent of the study. To avoid age- or sex-related biases in the data, we recruited patients of both sexes and across a broad range of ages. The study was approved by the institutional research ethics committee.

We examined 13 patients with cancer of the tongue and oral floor, including eight men and five women with a mean age of 65.8 years (range 41–82 years). The primary site was the tongue in nine cases and the oral floor in four. The resections were partial glossectomy ($n = 5$), hemiglossectomy ($n = 3$), subtotal glossectomy ($n = 1$), and resection of the tongue and oral floor ($n = 4$). The TNM classification was T1 in one case, T2 in six cases, T3 in three cases, and T4 in three cases. Disease was classified as stage I in one case, stage II in five cases, stage III in two cases, and stage IV in five cases (Table 1).

Experimental procedures

The experimental procedures included a series of preoperative and postoperative examinations. Before surgery, each participant was examined in the rehabilitation department of our hospital, and articulation was assessed by a qualified speech therapist using the conversation intelligibility test[16] and the Assessment of Motor Speech for Dysarthria (AMSD) test.[17] The conversation intelligibility test (Table 2) is used widely to evaluate articulatory function in oral cancer patients.

Conversation intelligibility, which refers to the ease with which a person's speech can be understood, is the most important indicator of communicative competence in oral communication. Kawaguchi et al.[18] evaluated the communication skills of 59 postoperative lingual cancer patients based on intelligibility and showed that patients with speech clarity of 80% or higher had no trouble in their daily conversations, whereas those with speech clarity of 40% or lower experienced difficulties in their daily conversations. The test is an effective method of objectively evaluating the severity of articulatory impairment in oral and oropharyngeal cancer patients.[19] Postoperative speech status was also assessed using the conversation intelligibility test, which has been used widely in Japan to assess speech impairment in postoperative oral cancer patients.[20]

The AMSD (Tables 3 and 4) is a test that evaluates speech impairments resulting