RESEARCH ARTICLE

Changes in the distributions of fluorine-18-labelled fluoro-2-deoxy-D-glucose accumulation into tongue-related muscles after dissection in patients with tongue cancer

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Objectives: To elucidate the changes in the distributions of fluorine-18-labelled fluoro-2-deoxy-D-glucose (¹⁸F-FDG) accumulation in the tongue muscles of patients following four kinds of surgical operations for tongue cancers.

Methods: The changes in the distributions of ¹⁸F-FDG accumulations in the tongue muscles on positron emission tomography (PET)-CT, in association with imaging findings on CT and MRI, were retrospectively analyzed before and after four kinds of surgical operations for 50 patients with tongue cancers.

Results: ¹⁸F-FDG-PET-positive areas appeared at the back of the intrinsic muscles of the tongue after invasive surgery for tongue cancers despite the absence of abnormal findings on CT and MRI. A correlation between the standardized uptake value maximum of ¹⁸F-FDG in the intrinsic muscles and the degree of invasiveness of the surgical procedures for tongue cancers ($r = 0.539$, $p < 0.01$) was found.

Conclusions: It is important to pay attention to the changes in ¹⁸F-FDG distributions in the intrinsic muscles of the tongue before and after invasive surgery despite the absence of abnormal findings on CT and MRI when evaluating the tongue on ¹⁸F-FDG-PET.

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Table 1 Data summary in 50 patients with tongue cancers

Site of primary cancers (numbers)	SUVmax of primary cancers (mean $\pm$ SD)	Age (years) (mean $\pm$ SD)	Male/female (numbers)	Pathological diagnosis (numbers)
Tongue (50)	1.50–22.70 (9.71 $\pm$ 5.80)	35–86 (62.92 $\pm$ 13.30)	35/15	Squamous-cell carcinoma (48) Spindle-cell carcinoma (1) Cystadenocarcinoma (1)

SUVmax, standardized uptake value with the highest point of fluorine-18-labelled fluoro-2-deoxy-D-glucose; SD, standard deviation.

Introduction

Treatment for patients with tongue cancers commonly involves surgical dissection, radiotherapy (RT) and chemotherapy.¹ It is very difficult to evaluate tongue cancer recurrence on CT and MRI after surgical dissection because of the anatomical and histological damage.² Therefore, positron emission tomography (PET) using fluorine-18-labelled fluoro-2-deoxy-D-glucose (^{18}F -FDG) could be clinically applied for the evaluation of patients with tongue cancers, and its usefulness has been clearly evaluated.³

However, false-positive ^{18}F -FDG-PET accumulations in the tongue after RT for tongue cancer have been reported.⁴ In a recent report, we also clarified the alterations of ^{18}F -FDG accumulation into adjacent remaining muscles in patients after neck dissection (ND) for oral cancers despite the absence of changes in them on MRI and CT examinations.⁵ Therefore, it is important to understand the possible alterations of the distributions of ^{18}F -FDG-PET accumulation after treatment for tongue cancers.

To the best of our knowledge, there have been no reports on the alterations of ^{18}F -FDG distributions before and after surgery for tongue cancers with various kinds of surgical procedures. In the present study, whether the distributions of ^{18}F -FDG accumulation before and after surgery for tongue cancers were different after four kinds of surgical procedures was evaluated.

Methods and materials

50 consecutive patients (35 males, 15 females; mean age $\pm$ standard deviation 62.92 $\pm$ 13.30 years, range 35–86 years) with tongue cancers were retrospectively evaluated at the Kyushu Dental University Hospital, Kitakyushu, Japan, between 2005 and 2014 in the present study (Table 1). No

recurrences were detected in the present study. All 50 patients were Japanese and underwent CT, MRI and ^{18}F -FDG-PET-CT both before and after surgery for tongue cancers. CT, MRI and ^{18}F -FDG-PET-CT examinations were each performed twice, within 1 month before and then within 1 month after surgery. CT, MRI and ^{18}F -FDG-PET-CT examinations were each then performed in all 50 patients at least 6 months after surgery because post-operative inflammation had almost disappeared by then. Approval of the present study was obtained from the institutional review board at the Kyushu Dental University (No. 12–13).

The 50 patients were retrospectively divided into 4 groups according to the 4 kinds of surgical procedures for tongue cancers that they underwent. The procedures were marginal dissection alone (MD; 15 patients), MD including tissue flap reconstruction (7 patients); hemiglossectomy (HMGS; 20 patients) including tissue flap reconstruction; and subtotal glossectomy (STGS; 8 patients) (Table 2). Each group was further subdivided by the presence or absence of RT (Table 2).

All patients fasted for at least 4 h prior to intravenous administration of 0.1 mCi (3.7 MBq) kg^{-1} body weight of ^{18}F -FDG. The examination with ^{18}F -FDG was performed with a PET-CT in-line system (Discovery ST Elite; GE Medical Systems, Waukesha, WI). 1 h after ^{18}F -FDG injection, each patient underwent a single integrated PET-CT examination. Patients were instructed not to chew or talk during the study. Prior to scanning, all patients had to remove objects such as removable dental bridgework and dentures from their mouth. The patients were positioned in the head-first, supine position. They were instructed to perform breath-holding during CT acquisition, which was performed first from the head to the pelvic floor. In PET-CT imaging, the following parameters for the CT scan were used: 140 kV, 60–160 mA (two-dimensional auto mA), 0.6 s per tube rotation, slice thickness of 4.25 mm, helical pitch of 1.5:1 and table speed of 22.50 mm/rotation; coverage was 824.5–1096.5 mm, and acquisition time was 22.8–30.0 s. Immediately following the CT scan, a PET scan was acquired from the pelvic floor to the head. The PET camera (Discovery ST Elite) had 18 rings of 336 detectors and simultaneously produced 35 slices, 4.34-mm thick, along a 152-mm axial field of view, with 3-slice overlap at the borders of the field of view. The transaxial resolution was 4.8 mm (full width at half-maximum) at 1 cm radius from the centre, and

Table 2 Surgical methods and use of radiotherapy for tongue cancers

Surgical methods for tongue cancers	Numbers	Presence of RT
MD	15	1
MDF	7	1
HMGS	20	5
STGS	8	5
Total	50	12

HMGS, hemiglossectomy including tissue flap reconstruction; MD, marginal dissection alone; MDF, marginal dissection including tissue flap reconstruction; RT, radiotherapy; STGS, subtotal glossectomy including tissue flap reconstruction.

Table 3 Fluorine-18-labelled fluoro-2-deoxy-D-glucose (^{18}F -FDG) accumulations in the intrinsic muscles of the tongue of patients with tongue cancers before and after surgery

Areas surgical methods	SUVmax (mean $\pm$ SD)			
	MD	MDF	HMGS	STGS
Anterior areas in intrinsic muscles of tongues before surgery	2.09–4.76 (3.18 $\pm$ 0.68)	2.22–5.89 (4.12 $\pm$ 1.09)	1.60–6.50 (3.41 $\pm$ 0.78)	2.09–3.76 (4.33 $\pm$ 0.88)
Anterior areas in intrinsic muscles of tongues after surgery	2.65–5.35 (3.53 $\pm$ 0.88)	2.50–4.00 (3.36 $\pm$ 1.09)	1.18–8.30 (3.44 $\pm$ 0.98)	
Others in intrinsic muscles of tongues before surgery except anterior areas	1.11–2.29 (1.57 $\pm$ 0.31)	1.13–2.46 (1.69 $\pm$ 0.34)	0.91–2.86 (1.53 $\pm$ 0.28)	1.08–1.98 (1.41 $\pm$ 0.48)
Others in intrinsic muscles of tongues after surgery except anterior areas	1.24–2.06 (1.67 $\pm$ 0.38)	0.99–2.99 (1.90 $\pm$ 0.44)	1.16–6.98 (2.88 $\pm$ 0.58)	1.90–4.72 (3.65 $\pm$ 0.45)

HMGS, hemiglossectomy including tissue flap reconstruction; MD, marginal dissection; MDF, marginal dissection including tissue flap reconstruction; SD, standard deviation; STGS, subtotal glossectomy including tissue flap reconstruction; SUVmax, standardized uptake value with the highest point of fluorine-18-labelled fluoro-2-deoxy-D-glucose.

the sensitivity of the device was 1.3 counts per second per megabecquerel with a two-dimensional acquisition time of 2 min, resulting in a total scanning time of 18–24 min for each scan.

The CT data were back projected to the workstation; the images were degraded from a 512×512 matrix to a 128×128 matrix to correspond with the PET images, and they were also forward projected. The resulting

Figure 1 Fluorine-18-labelled fluoro-2-deoxy-D-glucose positron emission tomography CT (^{18}F -FDG-PET-CT), CT and MRI findings of a 72-year-old male before and 13 months after MD for SCC in the right side of the tongue. (a) ^{18}F -FDG-PET-CT demonstrates increased uptake in the anterior of the intrinsic muscles of the tongue before surgery (arrow). (b) Axial CT image with a soft-tissue window shows no density changes of the anterior of the intrinsic muscles of the tongue that coincide with the ^{18}F -FDG-PET-positive areas before surgery (arrow). (c) Short inversion-time inversion recovery (STIR) images show no signal changes of the anterior of the intrinsic muscles of the tongue that coincide with the ^{18}F -FDG-PET-positive areas before surgery (arrow). (d) ^{18}F -FDG-PET-CT demonstrates increased uptake in the anterior of the intrinsic muscles of the tongue (arrow) but not at the back after surgery. (e) Axial CT image with a soft-tissue window shows no density changes of the anterior of the intrinsic muscles of the tongue that coincide with ^{18}F -FDG-PET-positive areas after surgery (arrow). (f) STIR images show no signal changes of the anterior of the intrinsic muscles of the tongue that coincide with the ^{18}F -FDG-PET-positive area after surgery (arrow).

Table 4 Differences in the rates of patients with fluorine-18-labelled fluoro-2-deoxy-D-glucose (^{18}F -FDG) accumulation and the extent of ^{18}F -FDG accumulation in four tongue-related muscles among four surgical methods before and after treatments

Muscles	Surgical methods	Number of patients with ^{18}F -FDG accumulation into muscles (%)		SUVmax (mean $\pm$ SD)	
		Before	After	Before	After
Mylohyoid	MD	0/15 (0)	0/15 (0)	1.01–2.07 (1.49 $\pm$ 0.29)	1.15–1.76 (1.37 $\pm$ 0.20)
	MDF	0/7 (0)	0/7 (0)	1.18–1.54 (1.35 $\pm$ 0.14)	1.02–1.39 (1.21 $\pm$ 0.13)
	HMGS	0/20 (0)	3/20 (15.0)	0.88–1.65 (1.35 $\pm$ 0.23)	1.10–3.87 (1.83 $\pm$ 0.70)
	STGS	0/8 (0)	1/8 (12.5)	0.85–1.77 (1.38 $\pm$ 0.27)	1.50–3.08 (1.83 $\pm$ 0.52)
Genioglossus	MD	0/15 (0)	0/15 (0)	0.91–1.76 (1.28 $\pm$ 0.23)	0.99–1.89 (1.39 $\pm$ 0.25)
	MDF	0/7 (0)	0/7 (0)	0.84–1.37 (1.18 $\pm$ 0.17)	1.14–1.37 (1.23 $\pm$ 0.09)
	HMGS	1/20 (5.0)	1/20 (5.0)	0.99–2.50 (1.51 $\pm$ 0.29)	1.18–2.85 (1.64 $\pm$ 0.40)
	STGS	0/8 (0)	1/8 (12.5)	1.20–1.50 (1.36 $\pm$ 0.15)	1.50–3.70 (1.97 $\pm$ 0.74)
Geniohyoid	MD	0/15 (0)	0/15 (0)	0.95–1.56 (1.16 $\pm$ 0.17)	0.94–1.46 (1.16 $\pm$ 0.15)
	MDF	0/7 (0)	0/7 (0)	0.76–1.43 (1.12 $\pm$ 0.25)	0.73–2.01 (1.23 $\pm$ 0.41)
	HMGS	0/20 (0)	1/20 (5.0)	0.96–1.41 (1.16 $\pm$ 0.14)	1.10–3.90 (1.54 $\pm$ 0.64)
	STGS	0/8 (0)	1/8 (12.5)	1.00–1.50 (1.24 $\pm$ 0.20)	1.35–3.26 (1.80 $\pm$ 0.65)
Hyoglossus	MD	1/15 (6.7)	0/15 (0)	1.06–2.26 (1.49 $\pm$ 0.28)	1.22–2.15 (1.54 $\pm$ 0.27)
	MDF	0/7 (0)	0/7 (0)	1.23–1.54 (1.42 $\pm$ 0.13)	1.19–1.60 (1.41 $\pm$ 0.15)
	HMGS	0/20 (0)	2/20 (10.0)	1.06–2.16 (1.44 $\pm$ 0.25)	1.14–2.64 (1.79 $\pm$ 0.41)
	STGS	0/8 (0)	1/8 (12.5)	1.14–1.53 (1.40 $\pm$ 0.14)	1.50–3.44 (1.90 $\pm$ 0.69)

HMGS, hemiglossectomy including tissue flap reconstruction; MD, marginal dissection; MDF, marginal dissection including tissue flap reconstruction; SD, standard deviation; STGS, subtotal glossectomy including tissue flap reconstruction; SUVmax, standardized uptake value with the highest point of ^{18}F -FDG.

sinograms were filtered with a 6.00-mm post filter or a 4.30-mm loop filter, exponentiated and entered as attenuation correction factors into the PET image reconstruction with 2 iterations and 21 subsets. On the other hand, all PET studies were iteratively reconstructed with no attenuation correction.

MR images were acquired using a 1.5-T full-body MR system (EXCELART Vantage™ Powered by Atlas; Toshiba, Tokyo, Japan) with a circular polarized neck coil to visualize the level of the maxilla and mandible. MR images were obtained using the following four sequences: (1) short inversion-time inversion recovery (STIR); (2) fast spin echo T_1 weighted images; and (3) fast spin echo T_1 weighted images with contrast-medium enhancement. Enhanced-CT was performed with an Aquilion™ machine (Toshiba) after the patient received an intravenous dose of 50 ml of iohexol (300 mgI ml⁻¹, Omnipaque™ 300; Daiichi Pharmaceutical Co. Ltd., Tokyo, Japan) at the start of scanning and an additional 50-ml intravenous infusion during scanning to allow better visualization of the vascular structures. Scanning was performed in the axial plane without angulation, in 5-mm-thick contiguous sections from the cavernous sinuses to the thoracic inlet. Images were photographed using standard algorithms and soft-tissue windows.

The PET-CT, MR and CT images were independently assessed by two expert radiologists (SK and HK).

All PET images were analyzed on a personal computer-based, digital viewing system (GE view, Dornstadt, Germany) to choose transverse slices for comparison and to adapt the level of the greyscale in the images. The extents of ^{18}F -FDG accumulations were judged by the standardized uptake value of the highest point (SUVmax) within the regions of interest for the

muscles of the tongue, including the mylohyoid, genioglossus, geniohyoid and hyoglossus muscles, before and after surgeries in the patients with tongue cancers. In the 50 patients with tongue cancers, the SUVmax values of ^{18}F -FDG accumulations in the muscles of the tongue, including the mylohyoid, genioglossus, geniohyoid muscles and hyoglossus muscles, were evaluated. A value of 2.5 was selected as the cut-off SUVmax, because the extent of ^{18}F -FDG accumulation into malignant tumours was commonly >2.5 .^{6–8} In the respective areas, the precise SUVmax of ^{18}F -FDG was measured on PET-CT images.

The SUVmax values of ^{18}F -FDG in the respective muscles mentioned above were compared among the four groups using analysis of variance (Kruskal–Wallis test). In patients with tongue cancers, the correlations between surgical removal and the SUVmax of ^{18}F -FDG in the related remaining intrinsic muscles were analyzed using Spearman's correlation coefficient. In the respective groups, the change of SUVmax by RT was evaluated using the Mann–Whitney U test based on the presence or absence of RT. p -values <0.05 were considered to indicate a significant difference. Correlations from the Spearman analysis were classified into five grades: very weak, 0.00 to ± 0.20 ; weak, ± 0.20 to ± 0.40 ; moderate, ± 0.40 to ± 0.70 ; strong, ± 0.70 to ± 0.90 ; and very strong, ± 0.90 to ± 1.00 .

Results

Pathological diagnoses and the distributions of SUVmax of ^{18}F -FDG accumulations in tongue cancers

The pathological diagnoses and the distributions of the SUVmax of ^{18}F -FDG accumulations in tongue cancers

Figure 2 Fluorine-18-labelled fluoro-2-deoxy-D-glucose (^{18}F -FDG)-PET-CT and MRI findings of a 67-year-old male before and 18 months after hemiglossectomy including tissue flap reconstruction for squamous-cell carcinoma in the right side of the tongue. (a) ^{18}F -FDG-PET-CT demonstrates increased uptake in the anterior of the intrinsic muscles of the tongue (arrow) but no uptake at the back of the intrinsic muscles of the tongue before surgery. (b) Short inversion-time inversion recovery (STIR) images show no signal changes of the anterior of the intrinsic muscles of the tongue that coincide with the ^{18}F -FDG-PET-positive areas before surgery (arrow). (c) ^{18}F -FDG-PET-CT demonstrates increased uptake in the anterior of intrinsic muscles of the tongue (arrow) and appears at the back of the intrinsic muscles of the tongue (arrowhead) after surgery. (d) STIR images show no signal changes of the anterior (arrow) and the back (arrowhead) of the intrinsic muscles of the tongue that coincide with the ^{18}F -FDG-PET-positive areas after surgery.

of 50 patients are shown in Table 1. The pathological diagnosis was squamous-cell carcinoma (SCC) in 48 patients, cystadenocarcinoma in 1 patient and spindle-cell carcinoma in 1 patient. The SUVmax of ^{18}F -FDG in the primary lesions ranged from 1.50 to 22.70 (mean $\pm$ standard deviation: 9.71 ± 5.80) (Table 1).

Changes in the distributions of ^{18}F -FDG accumulation in the intrinsic muscles of patients with tongue cancers after surgery

^{18}F -FDG accumulations into the intrinsic muscles of the tongues of patients with tongue cancers before and after surgery are shown in Table 3. In all groups before surgery for tongue cancers, ^{18}F -FDG accumulated only in the anterior areas of the intrinsic muscles of the tongue but not in the mylohyoid, genioglossus, geniohyoid and hyoglossus muscles (Figure 1, Tables 3 and 4). In Groups MD (100%) and MD including tissue flap reconstruction (71.4%), no changes in ^{18}F -FDG-PET-positive areas were detected after surgery for tongue cancers in most patients (Table 3).

In Groups HMGS and STGS, however, ^{18}F -FDG-PET-positive areas changed after surgery and were detected at the back of the intrinsic muscles of the tongue in most patients but not in the mylohyoid, genioglossus, geniohyoid and hyoglossus muscles (Figures 2 and 3, Tables 3 and 4). There were no abnormal findings in ^{18}F -FDG-PET-positive areas of the back of the intrinsic muscles of the tongue on CT and MRI (Figures 2 and 3). In Group HMGS, ^{18}F -FDG accumulations remained in the anterior areas of the intrinsic muscles of the tongue after surgery.

A correlation between the surgical procedure for tongue cancer and the SUVmax of ^{18}F -FDG in the back of the intrinsic muscles of the tongue ($r = 0.539$ $p < 0.01$) was found using Spearman's correlation coefficient.

Effect of RT on the changes in the distributions of ^{18}F -FDG accumulation into the intrinsic muscles of patients with tongue cancers after surgery

The effect of RT on the changes in the distributions of ^{18}F -FDG accumulation in the intrinsic muscles of

Figure 3 Fluorine-18-labelled fluoro-2-deoxy-D-glucose (^{18}F -FDG)-PET-CT, CT and MRI findings of a 35-year-old male before and 7 months after subtotal glossectomy for squamous-cell carcinoma in the right side of the tongue. (a) ^{18}F -FDG-PET-CT demonstrates increased uptake in the anterior of the intrinsic muscles of the tongue (arrow) and in the tumour (arrowhead) before surgery. (b) Axial CT image with a soft tissue window shows no density changes of the anterior of the intrinsic muscles of the tongue that coincide with the ^{18}F -FDG-PET-positive areas before surgery (arrow). (c) Short inversion-time inversion recovery (STIR) images show no signal changes of the anterior of the intrinsic muscles of the tongue that coincide with the ^{18}F -FDG-PET-positive areas before surgery (arrow). (d) ^{18}F -FDG-PET-CT demonstrates increased uptake at the back of the intrinsic muscles of the tongue (arrow) after surgery. (e) Axial CT image with a soft tissue window shows no density changes of the back of the intrinsic muscles of the tongue that coincide with the ^{18}F -FDG-PET-positive areas after surgery (arrow). (f) STIR images show no signal changes of the back of the intrinsic muscles of the tongue that coincide with the ^{18}F -FDG-PET-positive area after surgery (arrow).

patients with tongue cancers after surgery is shown in Table 5. In each of the four groups, no significant differences in the change of SUVmax were found between the presence and absence of RT using the Mann–Whitney *U* test (Table 5).

Discussion

In our recent study, ^{18}F -FDG-PET-positive areas appeared in the trapezius and sternocleidomastoid muscles of the sides opposite to surgery after ND for oral cancers but not without ND.⁵ In addition, there was no hypertrophy on CT and MRI in most muscles mentioned above. The results suggest that the distributions of ^{18}F -FDG-PET accumulations changed before and after the surgeries according to the surgical procedures. Moreover, false-

positive ^{18}F -FDG-PET accumulations in the tongue after RT for tongue cancers have been reported in three patients.⁴ Therefore, we hypothesized that ^{18}F -FDG-PET accumulations in the intrinsic muscles of the tongue and tongue-related muscles, such as the mylohyoid, genio-glossus, geniohyoid and hyoglossus muscles, might alter after some treatments for tongue cancer, despite normal healing. Whether ^{18}F -FDG accumulation distributions in tongue-related muscles before and after surgery for tongue cancers changed according to the four kinds of surgical procedures was evaluated in the present study.

The most interesting result in the present study was that prominent changes in the distributions of ^{18}F -FDG-PET-positive areas were visualized on PET-CT before and after surgery depending on the surgical procedures for tongue cancers. However, no abnormal findings were found in the ^{18}F -FDG-PET-positive areas

Table 5 The effect of radiotherapy on the changes in the distributions of fluorine-18-labelled fluoro-2-deoxy-D-glucose (¹⁸F-FDG) accumulation in the intrinsic muscles of patients with tongue cancers after surgery

Surgical methods	Areas	SUVmax (mean ± SD)	
		Absence of RT	Presence of RT
MD	Anterior areas	3.50 ± 0.70	4.03
	Others except anterior areas	1.66 ± 0.27	1.78
MDF	Anterior areas	3.38 ± 0.55	3.22
	Others except anterior areas	2.01 ± 0.86	1.20
HMGS	Anterior areas	3.62 ± 1.76	2.32 ± 0.95
	Others except anterior areas	3.80 ± 1.70	4.07 ± 1.38
STGS	Anterior areas	—	—
	Others except anterior areas	3.38 ± 0.11	3.79 ± 1.30

HMGS, hemiglossectomy including tissue flap reconstruction; MD, marginal dissection; MDF, marginal dissection including tissue flap reconstruction; RT, radiotherapy; SD, standard deviation; STGS, subtotal glossectomy including tissue flap reconstruction; SUVmax, standardized uptake value with the highest point of ¹⁸F-FDG.

of the back of the intrinsic muscles of the tongue on CT and MRI. Before surgery, ¹⁸F-FDG-PET-positive areas could be visualized in the anterior area of the tongue of most patients (about 80%), as in our previous study.⁶ At the same time, when the anterior area of the tongue remained after all four kinds of surgeries, ¹⁸F-FDG-PET-positive areas remained in the anterior area of the tongue. However, according to the increasing extent of excision of the tongue by HMGS and STGS, ¹⁸F-FDG-PET-positive areas that were detected at the back of the intrinsic muscles of the tongue remained after surgery despite the absence of abnormal findings on CT and MRI. The possible explanation for this is that the posterior area of the tongue plays a main and a supplemental role in tongue movement with the remaining intrinsic muscles of the tongue after surgery.⁹ The complementary roles of the intrinsic muscles of the tongue are limited for tongue movements, depending on the expansion of the area of excision of the tongue according to the surgical procedure. Therefore, the possible explanation for the present results is that changes in the distributions of ¹⁸F-FDG-PET-positive areas between before and after surgery might be due to the compensatory functions of tongue movements after the surgical procedures mentioned above. At the same time, post-operative inflammation had almost disappeared by at least 6 months after surgery. Therefore, we could understand that the distributions of ¹⁸F-FDG-PET-positive areas occurred despite the lack of abnormal findings on CT and MRI. With the passage of time, hypertrophic alterations might occur in ¹⁸F-FDG-PET-positive areas on CT and MRI. This may be why there was little change in the distributions of ¹⁸F-FDG-PET-positive areas in the intrinsic muscles of the tongue between before and after surgery in MD. In addition, there was little change in the distribution of ¹⁸F-FDG-PET-positive areas in the mylohyoid, genioglossus, geniohyoid and hyoglossus muscles that are directly and mainly involved in tongue movements. Moreover, no significant difference in the distribution of ¹⁸F-FDG-PET-positive areas was found between the presence and absence of RT.

The other interesting result was that there were significant correlations between the surgical procedures for

tongue cancers and the SUVmax of ¹⁸F-FDG in the posterior areas of the intrinsic muscles in patients after surgery. The more invasive the surgical procedure was, the higher the SUVmax of ¹⁸F-FDG in the posterior areas of the intrinsic muscles was. This result substantiates our conjectures mentioned above. In addition, in some cases, the lower limit of the range of SUVmax in ¹⁸F-FDG-PET-positive areas of intrinsic muscles was 3.0, and some values overlapped those of primary tumours. Therefore, in the differential diagnosis of recurrent tumours, it is very important that the location of the ¹⁸F-FDG-PET-positive area of the posterior area of intrinsic muscles is confirmed and that the imaging findings are precisely evaluated on CT and MRI.

In the present patients with tongue cancers, the most common pathological diagnosis was SCC; the other cancers included one spindle-cell carcinoma and one cystadenocarcinoma. Based on the previous reports, the present patients appear to reflect the histopathological distribution of patients with tongue cancer in Japan.^{5–7} The SUVmax for all primary lesions ranged from 1.5 to 22.70 in the present study, which is relatively standard in oral cancers.^{10,11}

One possible limitation of the present study is that the sample size was small. The variables of age, race and sex could not be studied in this study sample. At the same time, the analysis did not examine the precise dissection areas and the methods and quantities of the reconstructions. In addition, all surgical procedures could not be performed by the same surgeon and at once. Therefore, inter- and intraoperator variabilities may be confounding factors resulting in a further limitation.¹²

Conclusions

The present study retrospectively examined the changes in the distributions of ¹⁸F-FDG accumulations on PET-CT in the remaining tongue-related muscles of 50 patients before and after four kinds of surgical operations for tongue cancers. It was found that ¹⁸F-FDG-PET-positive areas changed to the back of the intrinsic muscles of the tongue after invasive surgery for

tongue cancers from the anterior area before surgery. The surgical procedures for tongue cancers were significantly correlated with the SUVmax of ^{18}F -FDG in the back of the intrinsic muscles of the tongue.

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