Tongue muscle volumes and percentages in two glossectomy patients

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INTRODUCTION AND GOAL

Large lingual tumors are often replaced with a tongue flap after the glossectomy surgery. Patients must utilize their remaining muscles in potentially novel ways to move the tongue and flap in order to produce understandable and audible speech as well as assist in the process of swallowing.

- Our objective is to look at the anatomical differences in the volumes of genioglossus, vertical, transverse, superior longitudinal, inferior longitudinal, and geniohyoid muscles after glossectomy surgery and replacement with a tongue flap.
- According to the Oral Cancer Foundation, over 50,000 people will be diagnosed with oropharyngeal cancer this year. Some of the most commonly affected sites of oral cancer are the tonsils, oropharynx, and lateral border of the tongue.[2] The tumor is resected along with 1-1.5 cm of clean tissue around the periphery. In the oral cavity, T2 tumors are 2-4 cm in the largest direction. Glossectomy surgery typically includes resection, primary closure with sutures, or flap reconstruction (Fig. 1).
- There are eight tongue muscles. We have measured five of them. The tongue muscles that contribute to AP length are SL, IL, and GG posterior. To SI and LR width are V, T, and GG anterior. T and V lengthen the tongue, GG posterior protrudes the tongue, SL and IL shorten the tongue, GG anterior and V flatten the tongue, and T narrows the tongue.[1] These muscles control 86% of the tongue volume.[3] In addition, one floor muscle that we have also measured, geniohyoid, whose action elevates the tongue, composes 6% of the oral cavity muscles.

MATERIALS AND METHODOLOGIES

SUBJECTS:
- 14 Control patients (C1-C14) ages 22-59
- 2 Glossectomy patients with flap reconstruction

Fig. 1. Tongue pictures of subjects

Figure 1: The first image demonstrates the symmetry of a healthy tongue. Patients 1 and 2 have undergone flap reconstruction. Patient 1 underwent a 5.5 x 4.5 x 2.0 cm resection with flap replacement encompassing the majority of the right and tip of the tongue crossing the midline onto the left side. Patient 2 underwent a 6.0 x 3.5 x 2.5 cm resection with flap replacement on the right side and mucosa extending across the midline.

MATERIALS AND METHODS (cont'd)

- Patient 1 - Age 40: T2N2cMx, RFFF (radial forearm free flap), anterior tongue flap reconstruction
- Patient 2 - Age 38: T2N0M0, pedicled submental island flap, right lateral tongue flap reconstruction

MRI DATA :
- High-resolution MRI data were collected from each subject in the sagittal, axial, and coronal planes:
  - Sagittal=7-9 slices; Coronal=10-14 slices; Axial=10-14 slices
  - The three data orientation were combined to make one super-resolution volume with a spatial resolution of 1 x x 1 x 1 mm^3 for each subject.

SEGMENTATION AND VOLUME CALCULATION:
- Six muscles were segmented from the super-resolution volumes: inferior longitudinal, superior longitudinal, transverse, vertical, genioglossus, and geniohyoid.
- The volume of each muscle was calculated using ITK Snap. The program allows the user to manually segment the muscle and label it with a unique color. The voxels with that label are added to provide a muscle volume.
- The flap is seen below in yellow.

Fig. 2a. Segmented tongue muscle volumes in PT 1

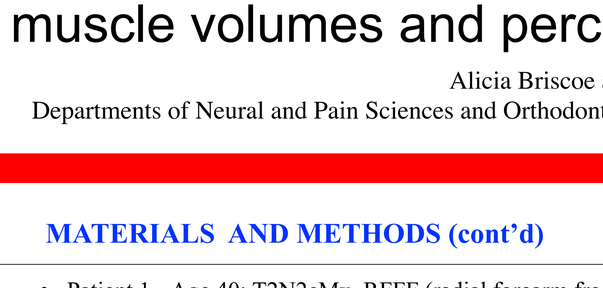
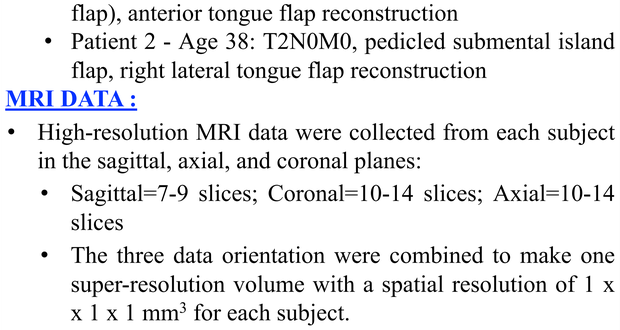


Fig. 2b. Segmented tongue muscle volumes in PT 2



Figures 2a and 2b: Segmented tongue masks for PT 1 and 2 for the flap (yellow), superior longitudinal (dark green), transverse (teal), genioglossus (purple), inferior longitudinal (light blue), geniohyoid (red), and vertical (orange) using ITK-Snap. In Fig 2a., the yellow flap is on the tip and right side of the tongue with bilateral muscles posteriorly. In Fig 2b., the yellow flap is on the right lateral side of the tongue down to the floor of the mouth surrounded by mucosa (pink). This patient only has unilateral muscles present on the left side of the tongue.

RESULTS

MUSCLE VOLUMES FOR CONTROL & PATIENTS
- Means and SDs were computed for healthy volumes
- Muscle percentages are presented for controls (blue) in ascending order, flanked by PT1 (pink) and PT2 (purple).

Fig. 3a. Muscle Volumes - Controls and Patients

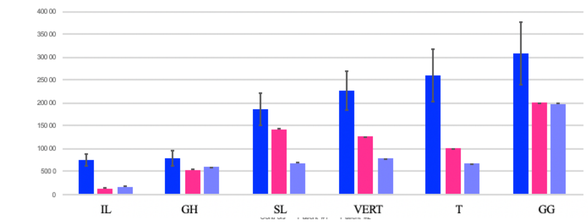
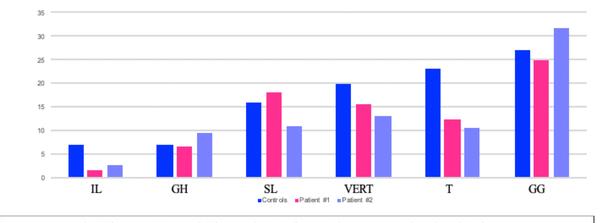
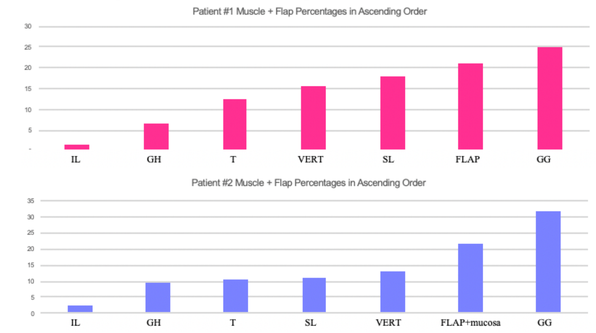


Fig. 3b. Muscle Percentages - Controls and Patients



- As seen in Figures 3a and 3b, patients do not increment in size in the same way as the controls do. Due to surgery in different locations on the tongue, the volumes of muscles vary accordingly. Genioglossus is the largest muscle and composes over 20% of the overall tongue volume for controls.[3] Transverse is second largest for controls (Stone et al, 2018), but not for these two patients.
- Superior longitudinal in PT1 and genioglossus in PT2 are proportionally larger than in controls and may be utilized more in order to perform the speech and swallowing movements of the tongue as compared to control subjects.

Fig. 4a and 4b. PT1 and PT2 Muscle + Flap Percentages in Ascending Order



Figures 4a and 4b illuminate the remaining muscle percentages as they relate to the percentage of the flap of PT1 and PT2 in patient percentage ascending order.
- Fig. 4a shows the anterior flap to be the second largest percentage in the tongue indicating the vast amount of muscle that was removed. The transverse muscle was greatly reduced, moving it from the second largest muscle to the fourth.
- Fig. 4b shows that the right lateral flap took up a large percent in this patient's tongue. Genioglossus was least affected by resection during surgery and makes the largest percentage of tongue muscle remaining. Geniohyoid, transverse, superior longitudinal, and vertical are all relatively the same percentage despite their large differences in normal subjects (see Fig 3a).
- The flap consists of a large percentage of both patients' tongues indicating the large amount of uncontrolled tissue that the patients' have to compensate for in order to perform natural behaviors such as speaking, chewing, and swallowing.

DISCUSSION

- Genioglossus, transverse, and vertical are the largest tongue muscles in healthy subjects, while both patients suffer the largest volume reductions in these muscles after glossectomy surgery (Fig 3a). This implies that in order for the tongue to deform to produce various sounds in speech or assist in swallowing, other muscles must compensate and function in new ways.
- Looking at the percentages (Fig 3b), genioglossus is still the largest muscle for both patients. T and V, however, are much smaller. For PT 1, the second largest muscle is SL, which may compensate for the very small IL. One could speculate that patients get tired easily because they need to recruit more fibers. PT1 might utilize superior longitudinal more in order to elevate the flap tip and side of the tongue as opposed to controls or PT2 (Fig. 3b).
- Geniohyoid, an oral cavity floor muscle, is relatively large in PT2 and may assist more in swallowing (and even speech to help with elevation of the tongue). Its function would typically be to pull the hyoid anteriorly (Fig. 3b).
- As seen on the MRI images (Fig 2a and 2b), PT1 has bilateral muscles, while PT2 has unilateral muscles. Although the tip has been removed in PT1, speech and swallowing might be less affected due to presence of bilateral muscles, while PT2 might have more trouble with these actions due to increased usage of only unilateral left muscles.
- Limitations to this study include small sample size and variation in muscle mapping by human error.
- Future directions would be to compare these data to muscle shortening during speech and swallowing to see how the patients differ from controls. Another future direction could be to look at an EMG and activation strength as compared to controls.
- Given that PT1 has a missing tip and PT2 has a missing right side, this can be compared with the speech error each of them make in order to get a better idea of how the different morphologies affect speech.

CONCLUSIONS

- This research project's goal was to map and determine the muscular anatomical differences of two glossectomy patients with differing sites of flap reconstruction as they compare to control subjects.
- For patients 1 and 2, the largest decrease in muscle volume were genioglossus, transverse, and vertical despite the different tumor locations.
- Superior longitudinal (PT1) and geniohyoid (P2) were bigger, respectively, and could be used to compensate in speech and swallowing.

REFERENCES

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