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Application of diffusion tensor imaging after glossectomy

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Introduction

Difficulty in visualizing the intricate architecture of the tongue has limited our understanding of its function during speech, mastication, and swallowing, as well as its adaptation to surgical procedures. Tractography visualization using diffusion tensor imaging (DTI), a semi-automatic technique, can detect and display the spatial distribution of the muscle fiber bundle orientations as 3D trajectories in human and calf tongues.[1],2 DTI is a magnetic resonance imaging technique that measures the diffusivity of water in different directions3 and estimates fiber bundle orientation at each voxel, mathematically measuring the spatial distribution of diffusion tensors.4 It has been successfully applied to the study of neurologic conditions, including stroke, multiple sclerosis, brain tumors, and dementia. We have combined DTI with structural MRI as a means of observing residual tongue anatomy and yielding insight into the tongue's reconstruction after tumor resection in a glossectomy patient.

Material And Methods

Subjects

A 34-year-old woman underwent to a right partial-glossectomy, primary closure, and a selective neck dissection for a stage 1 (T1N0M0) squamous cell carcinoma 3-1/2 years prior to the present study. Clinically, the tumor, a 15×10mm ulcer, was located in the mid-third of the right lateral oral tongue. A 30× 26×12mm block was excised surgically and the pathologic study confirmed an 11×11mm tumor. After surgery, the patient reported numbness of the right tongue, but no swallowing or speech problems. A 24-year-old male served as a control. This study was approved by University of Maryland Institutional Review Board (protocol H28269).

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Equipment—A 3-Tesla MR system (Magnetom Trio, Siemens, Germany) was used with a head and neck coil. The DTI parameters were: spin echo, echo planar imaging (EPI), field of view (FOV)=240 mm, repetition time (TR)=5000ms, echo time (TE)=68ms, voxel size=3.1×3.1×3.0mm, matrix size=64×64, slice thickness=3mm. Diffusion weighting was applied in 12 co-linear directions, with a b-value of 500s/mm^2 and three averages. Structural MRI T2-weighted images (T2) were taken as anatomical references in three orthogonal orientations. The parameters were: FOV=240mm, TR=3310ms, TE=62ms, voxel size=0.9375 × 0.9375 × 3.0mm, matrix size=256 × 256. T2 has a much better spatial resolution than DTI and was therefore used to manually delineate a region of interest (ROI) on the target muscles bilaterally where they were clearly seen. Since the T2 and DTI images are spatially aligned, the ROI could be automatically transferred to the DTI and the corresponding fibers automatically determined, visualized, and quantified. Two muscles were targeted, due to tumor location and the surgical excision size, one extrinsic, the genioglossus (GG), and one intrinsic, the inferior longitudinalis (IL).

The DTI data analysis and tractography were performed using dTV-II, implemented in VOLUME-ONE software (http://ut-radiology.umin.jp). The principal eigenvector from the three directions was assumed to correspond to the predominant fiber direction in the voxel. The fibers were estimated by connecting voxels according to the predominant fiber directions. Fibers were continuously tracked through voxels whenever the fractional anisotrophy (FA) was >0.18. Fractional anisotrophy, which varies from 0<FA<1, uses the anisotropic relationship of the eigenvalues to determine the fiber direction.

Results

T2 MRI images for both the control subject and patient showed two target muscles, GG and IL, and the residual scar from the patient's surgery as expected. In the control subject, the tongue septum was at midline and divided the GG symmetrically into right and left halves. The IL muscles were lateral to each GG muscle. In the patient, on the other hand, the septum and both GGs were deviated to the right and had lost the fan-shaped characteristics seen in normal tongues. Instead, there was a dark asymmetrical pattern in the tongue body that coincided with the area of excised tissue and surgical primary closure.

The DTI-tractography showed major changes in the IL, but little change in GG. Most of the IL bundles in the control were horizontal and oriented anterior-posterior (green), symmetrical and presented similar thickness (Fig 1). The patient's IL showed more striking changes. The right IL was thinner and shorter. Its interruption coincided with scar tissue in the T2-image. Although most of the left IL bundles were anterior-posterior (green), there were several bundles with right-left orientation (pink-red). The thickest red bundle (white arrow, Fig 2) depicted a direction change of some anterior-posterior left IL bundles to the right side of the tongue. The primary closure or tissue retraction after scar formation on the right side of the tongue may have caused this to occur. As expected, the GG showed a fan-shape pattern in the control, but not in the patient. In the control, the anterior GG bundles were vertical (blue), the posterior were horizontal (green) and the medial GG bundles were colored with tones between blue and green. In the patient, the GG muscle bundles were mainly horizontal (green) and lateralized to the right side of the tongue as observed in T2-images.

Discussion

This is the first study to apply DTI to the tongue of a glossectomy patient in order to evaluate the 3D post-surgical myoarchitecture *in vivo*. Altered fiber directions and loss of continuity, length, and volume of each muscle bundle were seen in the glossectomy patient when compared to the normal subject. Residual tongue anatomy visualization may explain compensatory motor strategies post-surgery.[5] Future use of DTI may facilitate diagnosis in pre-surgical patients with tongue cancer and contribute to our understanding of how the loss of tongue tissue and diverse reconstructive techniques might affect functional outcomes such as speech and swallowing.

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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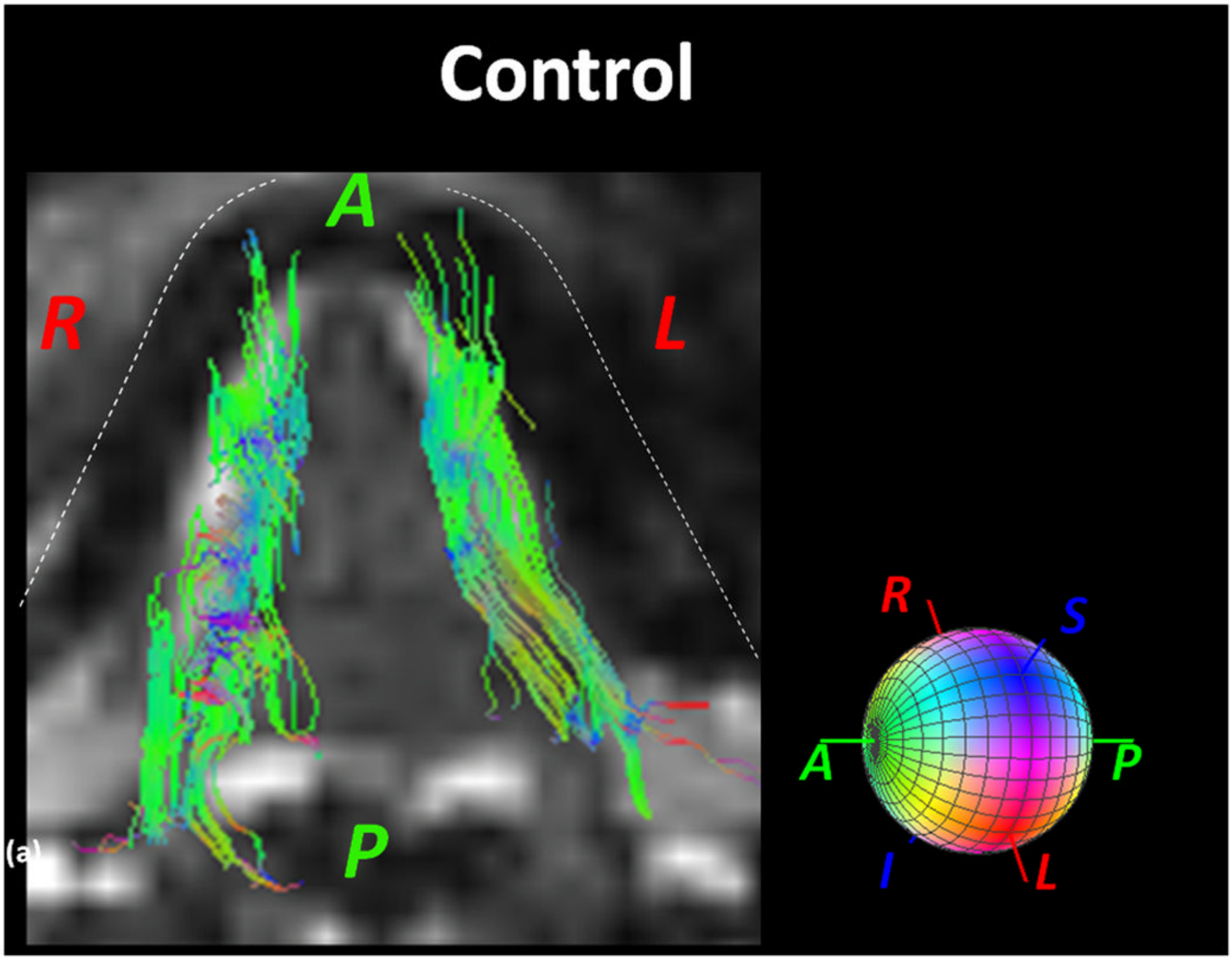

Figure 1.

IL fiber bundles resulting from the DTI-tractography in the control. Majority of both IL bundles are directly horizontally in the anterior-posterior direction. The 3D straight lines in the colored globe indicate the main directions of the fiber bundles represented in the data. *R*, right; *L*, left; *A*, anterior; *P*, posterior; *S*, superior; *I*, inferior.

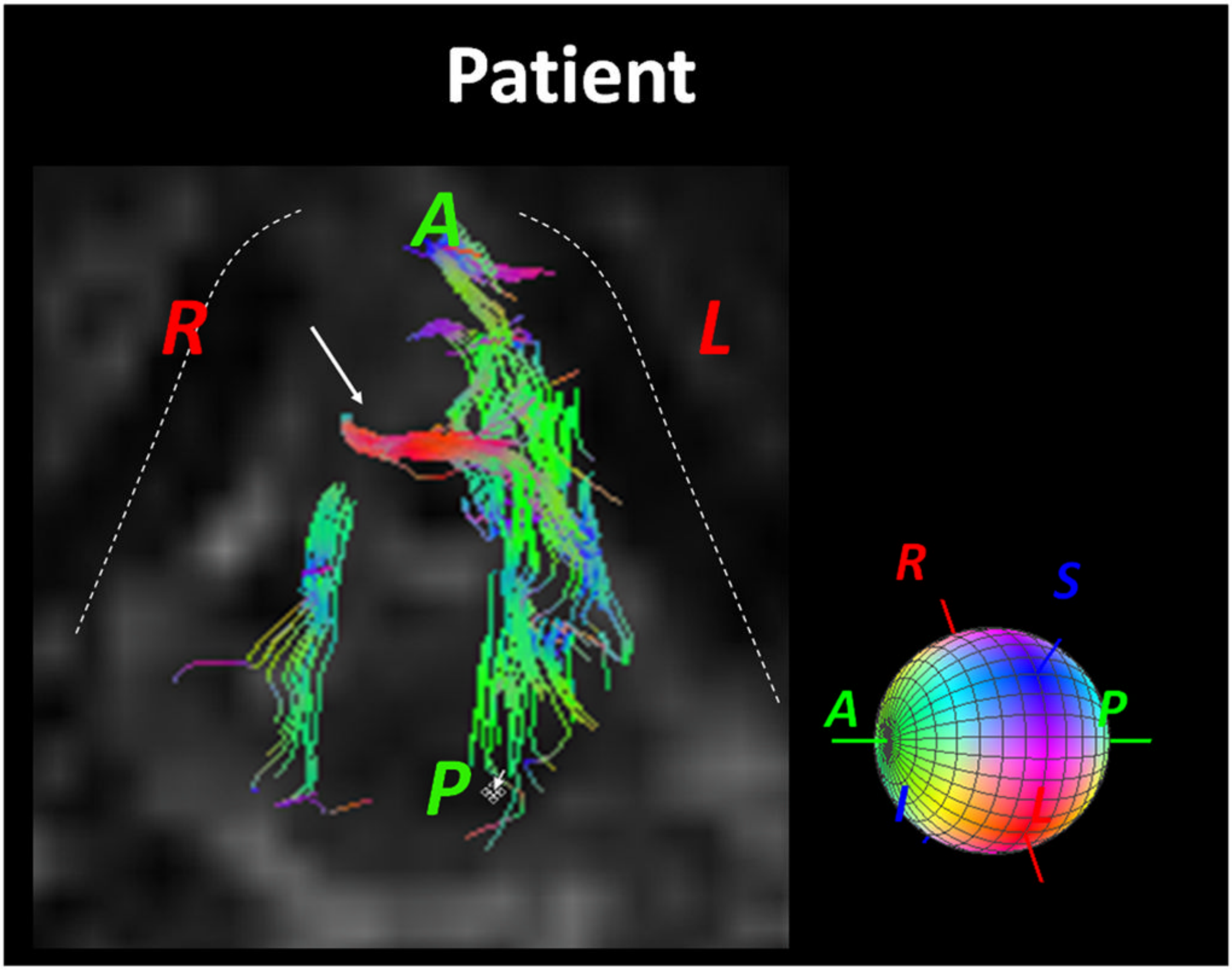

Figure 2.
IL fiber bundles resulting from the DTI-tractography in the patient. The right IL is thinner and shorter. Some contra-lateral IL bundles are directed horizontally in the right-left direction seen as red bundles (white arrow). The 3D straight lines in the colored globe indicate the main directions of the fiber bundles represented in the data. *R*, right; *L*, left; *A*, anterior; *P*, posterior; *S*, superior; *I*, inferior.