Application of Tagged MRI in the Study of Synergistic Actions of Lingual Muscles during Contraction Tasks

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Purpose

The purpose of this study is to determine the feasibility of using tagged MRI (TMRI) to study the mechanical interactions of in vivo lingual tissue during dynamic contraction tasks and to identify the muscles contributing to the synergistic execution of lingual motor activities, especially those that may effect volumetric changes in the tongue.

Introduction

It is widely accepted that the human tongue functions as a muscular hydrostat [1]. Its incompressibility is regarded as an essential property for achieving various deformations efficiently. For example, lingual myofiber compression in one direction induces extension of the organ along the orthogonal direction. A recent MRI study revealed significant differences in tongue volume as a function of lingual contraction tasks [2]. The mechanism for such volumetric change remains undetermined. Tagged MRI has been successfully used for detailed cardiac muscle motion analysis and proposed for studying dynamic functional lingual muscle activities [3]. In this pilot study, we used TMRI to investigate the functions and interactions of different lingual muscle groups during tongue maneuvers that have been shown to result in volumetric change.

Methods

A subject was trained to perform oropharyngeal maximum voluntary isometric contractions starting from a posture requiring full tongue-palate contact. Ultrasound imaging was used for biofeedback and to ensure adequate task performance during the training sessions. During MR scanning, the subject performed this contraction task by systematically following the short beeps of an auditory cuing system synchronized with MR tagging and imaging. After standard 1-D SPAMM planar tagging applied at the time of the auditory cue, imaging was paused 500 ms for task completion and one complete image was acquired with a modified real-time TRUEFISP pulse sequence, using the following parameters: 26x20 cm FOV, 6 mm slice thickness, flip angle 60, 256 frequency direction resolution, phase: 50% resolution with 3/4 partial Fourier acquisition, 977 Hz/pixel bandwidth. TR was 3.55 ms; TE 1.78. The task was repeated every 9 seconds until all the 2D images were acquired for 3D strain mapping and analysis of the entire tongue. Ten sagittal and 10 axial images were acquired. The frequency direction was always perpendicular to the tag lines.

Results

Tagged MR images were successfully acquired, and sample images are shown in Fig.1. Tagging was applied at the resting position with full tongue-palate contact. Images were then taken when the subject was at rest and after the subject had achieved oropharyngeal maximum voluntary isometric contraction. It can be observed from the acquired images that during this task the apex of the tongue maintained its contact with the alveolar ridge while the root of the tongue was fully retracted and in maximal contact with the posterior pharyngeal wall, thereby occluding the entire oropharynx. The hyolaryngeal complex was maximally elevated, achieving full closure of the airway as well as occlusion of the hypopharynx. Analysis of the strain distribution maps and deformation patterns of the tag lines revealed synergistic contractile interactions of the styloglossus and hyoglossus muscles as well as the posterior part of the superior longitudinal muscle. Detailed quantitative 3D strain analysis is being performed applying a modified B-Spline based motion field tracking technique, previously used for cardiac analysis [4].

Discussion

Our preliminary results demonstrate that the activities of intrinsic and extrinsic tongue muscles during voluntary lingual contraction tasks can be adequately studied using TMRI. We are performing 3D strain analysis to examine the activation patterns, mechanical functions, and interactions of lingual muscle groups as related to the task-induced volumetric changes observed in the tongue. This study will be repeated for more subjects.

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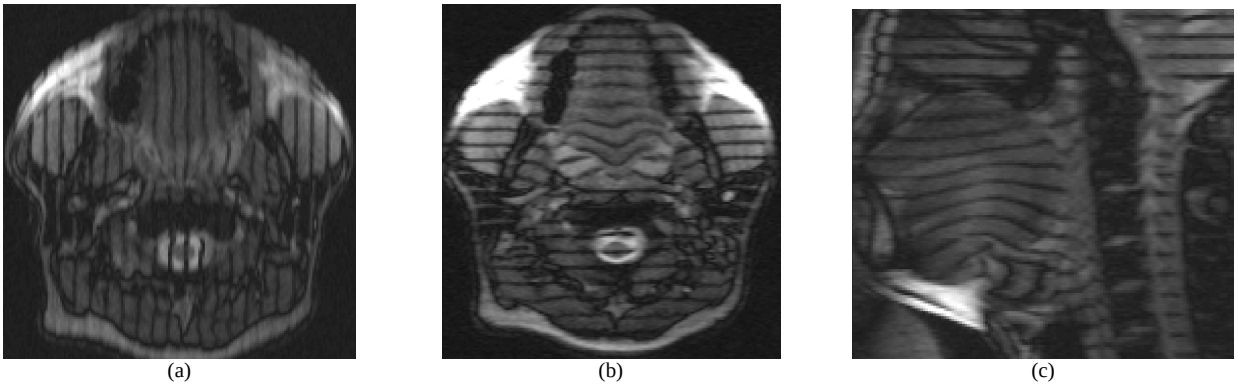

(a) (b) (c)

Figure 1. Sample images of tagged MR images during oropharyngeal maximum voluntary isometric contraction. (a) Axial image with anterior-to-posterior (AP) line tagging. (b) Axial image with left-to-right line tagging. (c) Sagittal image with AP line tagging.