Tongue Movement during Phonation: A Rapid Quantitative Visualization Using Tagging Snapshot MR Imaging

Mamoru Niitsu*, Masanobu Kumada, Seiji Niimi and Yuji Itai*

Introduction

A new imaging technique for the rapid assessment of tissue motion was developed by combining spatially selective RF (radio frequency) tagging pulses with T1 weighted snapshot MR(magnetic resonance) imaging [1]. This procedure allows the labeling and tracking of skeletal muscle motion during the interval between tagging and the start of image acquisition. Image acquisition is less than 2 seconds without the need for gated acquisition. This study was an initial trial to apply tagging snapshot imaging to tongue motion during phonation.

Methods and Subjects

The basis of our technique was magnetization-prepared gradient echo imaging. The magnetization in a middle sagittal section of the tongue was initially inverted by a 180-degree RF pulse. Subsequently, several vertical and/or horizontal RF tags were superimposed with the oropharynx initially at rest. Compared to dark tagging stripes in previous techniques with spin echo sequences mainly for cardiac imaging [2], the tagged area by the snapshot method appears as a high intensity band due to two successive RF excitations (Fig.1). Prior to start of a GRASS (gradient recalled acquisition in the steady state) using centric phase encoding [3], phonation begins and is maintained approximately one second until the end of image acquisition (Fig.2).

All studies were performed on a whole-body MR imager (SIGNA, GE Medical Systems, Milwaukee, USA) operating at 1.5 T, with standard, activity shielded gradients. A 5-inch circular surface coil was used for the human study. The data acquisition was done using a GRASS sequence with a TR of 9.0 msec; a TE of 5.0 msec; one excitation; a full, symmetric 256-point echo; 128 phase encoding steps; and a 30-degree readout flip angle.

Prior to the human studies, a series of phantom experiments was performed to assess the accuracy of the tagging technique. No substantial distortion of the phantom

*Tsukuba University

images was seen on successive acquisitions with and without linear and rotational motions [1].

Ten native Japanese speakers were examined during the phonation of the major Japanese vowels.

Results

Tagging stripes were successfully superimposed on a midline sagittal section of the tongue(Fig.3). The motion of the tongue and oropharynx during various vowels is shown in Figure 4. With the change in the shape and form of the oral cavity, the displacement and alteration of the tagging stripes within the extrinsic and intrinsic muscles were clearly visible. For /a/ production, the dorsum of the tongue showed a concave curve at a low position in the oral cavity. This tongue position and shape might have been achieved by a relaxation of the genioglossus muscle and a lowering of the hyoid bone. On the other hand, for /i/ production, the tongue dorsum was higher, and the whole tongue body moved forward to make a bigger pharyngeal cavity with a higher density of vertical tagging stripes. These observations for /i/ production can be explained by a contraction in the posterior part of genioglossus muscle. In similar fashion, tongue position and muscle contraction were well visualized for the phonation of other sounds, including Japanese /u/,/e/ and /o/.

Discussion

The principle advantage of this new technique relative to previous tagging techniques is the substantial reduction in acquisition time (less than 2 seconds), which obviates the need for the motion under study to be performed repeatedly with gated acquisition. This also facilitates progressive trials to obtain
high-quality tagging images with easy repeats for both the volunteer's phonation and the scanner's acquisition.

Incorporation of a centric phase encoding order [3] for data acquisition was essential to preserve a high contrast between the tagged and untagged regions. If a conventional sequential view order is used, the difference in the signal intensity established by the tagging pulses is not preserved at the time of the low spatial-frequency phase encodings because the tagged and untagged regions both approach their steady-state value.

A possible limitation of this tagging technique is the reduced tag-to-background contrast in tissues with short T1 values, such as fat. However, this limitation is common to all magnetization tagging methods [2].

With less than a 2 second period of acquisition, our technique can be easily performed and has a potential for kinematic studies of not only the tongue, but also of many mobile parts, including the skeletal muscles, joints and viscera.

Conclusion

The new tagging snapshot MR technique allows the quantitative labeling and tracking of tongue motion during phonation with an image acquisition of only a few seconds.

References

[1] Niitsu M, Campeau NG, Holsinger-Bampton AE et al: Tracking motion with tagged rapid gradient-echo magnetization-prepared MR imaging. JMRI 2:155-163, 1992

[2] Zerhouni E, Parrish D, Rogers Wj et al: Human heart: tagging with MR imaging-a method for noninvasive measurement of myocardial motion. Radiology 169:59-64, 1988

[3] Holsinger-Bampton AE, Riederer SJ, Campeau NG et al: T1-weighted snapshot GRASS MR imaging of the abdomen. Radiology 181:25-32, 1991

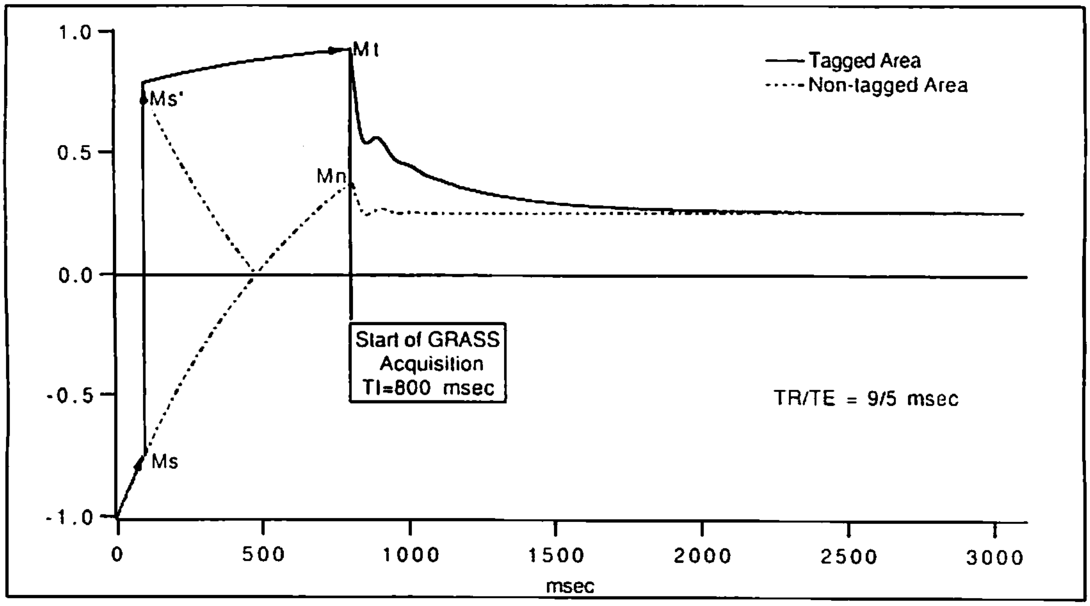

Figure 1. Calculated longitudinal magnetization of tagged and untagged areas of human skeletal muscle (T1=692 msec. T2=47 msec). The tagged regions experience a second inversion pulse (Ms -> Ms'). From the end of the tagging until the start of the data acquisition, a nearly full recovery of the magnetization of the tagged area occurs (Mt). The untagged areas follow a normal inversion recovery pattern (Mn).

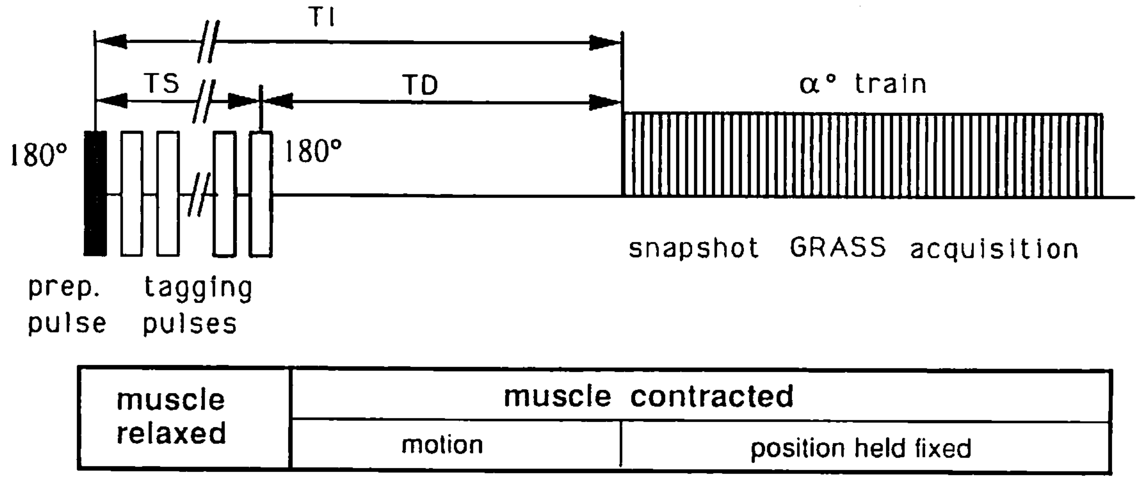

Figure 2. Diagram of the snapshot GRASS sequence with tagging pulses. After an inversion preparation pulse, a series of tagging pulses are applied in planes orthogonal to the imaging plane. The time TD is available for the voluntary motion before the start of data acquisition. With the oropharynx initially at rest, phonation is started after completion of the tagging pulse complex (TS) and is maintained until the end of the image acquisition (approximately one second).

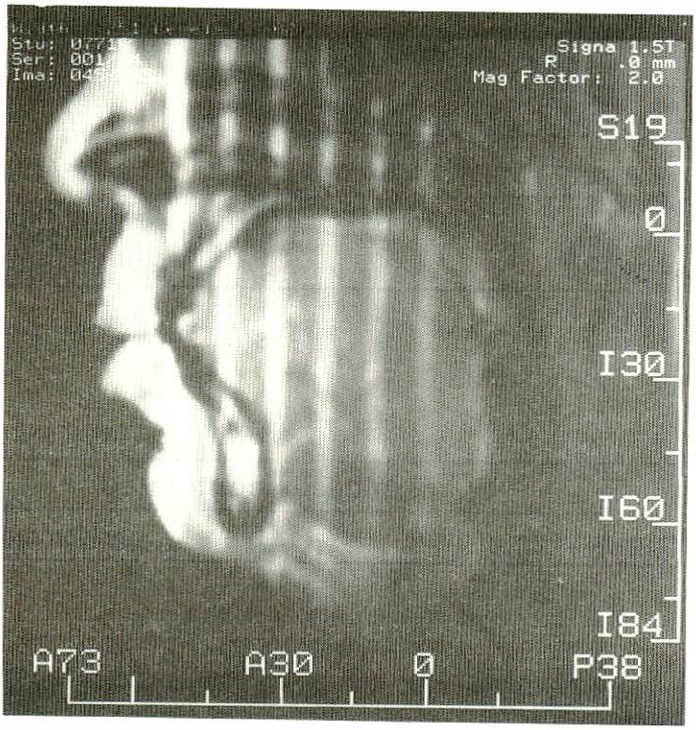

Figure 3. Midline sagittal section of the tongue using tagging snapshot MR imaging. Several high intensity tagging stripes are clearly seen against the dark untagged area. The choice of the number and thickness of the tagging stripes is the operator's option.

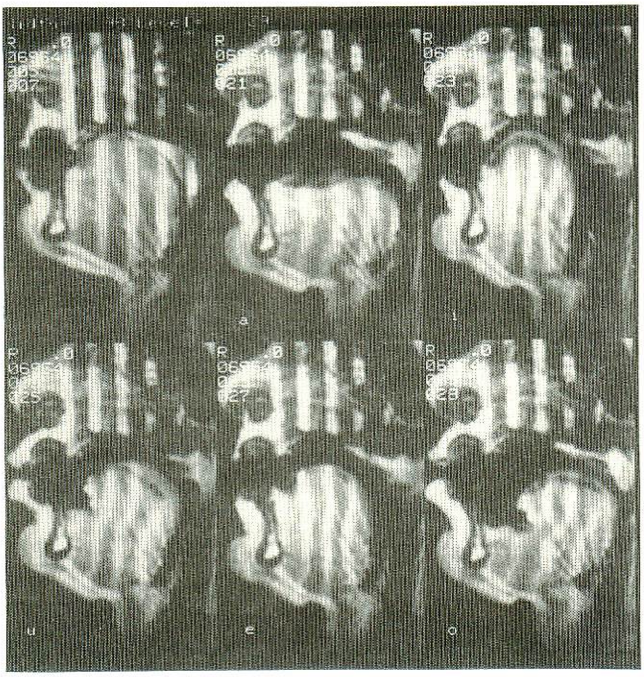

Figure 4. Tagging snapshot images of the tongue at rest (upper-left image) and during phonation of the Japanese vowels /a/, /i/, /u/, /e/ and /o/(bottom-right image).