

Towards real-time MR imaging of the soft palate for clinical evaluation of velopharyngeal closure

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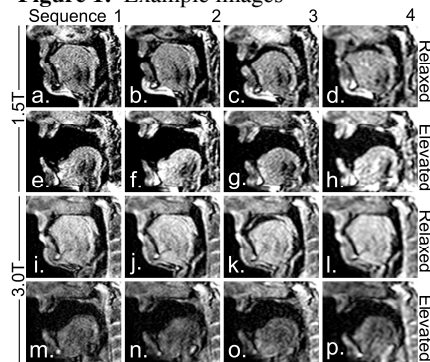
Introduction: Assessment of the motion of the soft palate (velopharyngeal closure) is performed clinically to guide and evaluate cleft palate repair surgery [1]. Such diagnostic tests are most commonly performed using x-ray videofluoroscopy and nasendoscopy [1]. Alternatively, MR imaging has been used to dynamically image the vocal tract [2-5]. However, previous real-time MR studies of the soft palate have been limited by low frame rates (~6fps) [2, 3] or have used advanced real-time spiral imaging techniques [4, 5] only available in a few research centers. In this study we compare four widely available high frame rate (9 – 20fps) real-time sequences at 1.5T and 3.0T.

Methods: Six healthy subjects without linguistic training (5M, median age 35 years, range 29-56) were imaged with both a 1.5T and 3.0T Philips Achieva using a 16-channel neurovascular coil. Real-time images were acquired in the mid-sagittal plane covering the head and neck to below the level of the epiglottis. Four sequences were implemented on each scanner using steady state free precession (SSFP) at 3.0T and balanced SSFP (bSSFP) at 1.5T. Key sequence parameters are given in table 1. Sequences were designed at 1.5T and matched in spatial and temporal resolution at 3.0T. All sequences used a 300×280mm² field of view, parallel imaging (SENSE), 10mm slice thickness, 0.625 partial Fourier and 256×256 reconstruction matrix. The flip angle was 30° at 1.5T and 15° at 3.0T.

Subjects were imaged while completing a speech task consisting of counting (1-10), nonsense words (“zu-nu-zu”, “za-na-za”, “zi-ni-zi”) and sustained vowels (“Ah” and “ee”). Audio was simultaneously recorded using a fiber-optic MR microphone (FOMRI II, Opto-acoustics) system and retrospectively synchronized to the images.

Analysis: Images were compared using signal to noise (SNR) measurements and a visual image quality score. SNR measurements were obtained in the soft palate when the palate was in the relaxed (nasal breathing) and elevated (while sustaining “Ah”) positions. SNR was also measured in an intensity-time plot (I-t SNR) created from an image intensity profile placed along the primary direction of motion in the soft palate. Images were scored from 1 (very poor/non-diagnostic) to 4 (very good) by two independent observers (physicists) with over 20 years combined MR experience.

Figure 1: Example images



Results: Example images are shown in figure 1 and SNR measurements are summarized in table 2. SNR was higher at 3.0T in the relaxed position ($p<0.0005$) and higher at 1.5T in the elevated position ($p<0.05$). There is a significant drop in SNR at 3.0T in the elevated palate position ($p<0.05$ in 3 of 4 sequences). The median image score was not different between field strengths (3.0 in both cases), but at 3.0T 23/24 acquisitions were rated 2 or 3, whereas at 1.5T 11/24 acquisitions were rated 4 and 4.5/24 acquisitions were rated 1 (1 acquisition rated 1 by the first observer and 2 by the other). SNR was highest in sequence 2 in the 1.5T elevated, 1.5T relaxed and 3.0T relaxed data. I-t SNR values increased from sequence 1 to sequence 4 ($p<0.05$ between sequences in both cases) with increasing frame rate and the improved temporal fidelity is evident in the intensity-time plots (see figure 2). Image quality scores did not demonstrate any significant differences between sequences.

Table 2: SNR Results

Seq.	1.5T					3.0T				
	Relaxed	Elevated	Ratio	p	I-t SNR	Relaxed	Elevated	Ratio	p	I-t SNR
1	5.7 (1.9)* [†]	5.1 (1.7)* [†]	1.2 (0.6)	NS	5.4 (3.4)* [†]	9.8 (2.8)	5.0 (1.0)	2.0 (0.6)	<0.01	6.0 (2.4)
2	9.1 (2.1)*	8.4 (1.8)*	1.1 (0.3)	NS	5.8 (3.2)	13.7 (2.8)	6.5 (1.2)	2.2 (0.7)	<0.005	6.3 (2.3)
3	6.9 (1.7)	7.9 (1.2) [†]	0.9 (0.2)	NS	8.2 (4.2)*	11.8 (3.9)	6.8 (1.9)	1.9 (0.8)	<0.01	7.4 (1.8)
4	7.1 (1.6) [†]	8.1 (3.6)	1.1 (0.7)	NS	9.7 (4.1) [†]	9.0 (3.6)	7.1 (1.8)	1.4 (0.9)	NS	8.4 (2.1)
p	<0.0005	<0.05	-	-	<0.05	<0.005	NS	-	-	<0.005

Values given as mean (standard deviation). * - $p<0.05$ pairwise comparison. [†] - $p<0.05$ pairwise comparison.

Discussion: At 3T using SSFP, diagnostic quality images were reliably obtained with all sequences. However, images rated 4 were obtained in more 1.5T bSSFP acquisitions (46% vs. 4%). Greater differences in image quality were evident between field strengths and subjects than between sequences. For high SNR images, when measurements of the soft palate or other dynamic anatomy are required, sequence 2 (10fps, 1.9×1.9×10mm) was the optimal of those tested here. In order to assess the motion of the soft palate, higher frame rates are required and some spatial resolution should be traded for temporal resolution. Sequence 4 (20fps, 2.7×2.7×10.0mm) was optimal in this respect and achieved a similar frame rate to real-time spiral studies [5]. Future studies will use these sequences to study velopharyngeal closure in a cleft palate population.

References: 1. Rudnick. Curr Opin Otolaryngol Head Neck Surg 2008;16:530. 2. Anagnostara. JMRI 2001;14:194. 3. Beer. JMRI 2004;20:791. 4. Narayanan. J Acoust Soc Am 2004;115:1771. 5. Sutton. JMRI 2010;32:1228.

Figure 2: Intensity-time plots

