Dynamic Real Time Magnetic Resonance Imaging of the Pharynx and Larynx Evaluating Swallowing and Stridor at 3 Tesla

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Introduction: Functional deficits of the pharynx or larynx can cause severe medical problems such as aspiration or stridor. Even "minor" malfunctions include recurrent aspiration or voice malfunctions. Typical clinical functional evaluation of oropharyngeal function required either invasive techniques or ionizing radiation. Therefore, it could not be repeatedly evaluated. In recent years a growing effort has been made to evaluate the oropharynx noninvasively by Magnetic Resonance Imaging (MRI). Nevertheless, even previously reported MRI applications suffered from relatively low temporal image update rates on the order of one image per second [1]. In this study, we evaluated an optimized MR imaging protocol at 3T which permits temporal update rates of 4-10 images per second and large fields of view. Image quality with respect to acquisition modes with different trade-offs between spatial and temporal resolution was evaluated in a volunteer study. An initial clinical application illustrates the potential of the method for detailed assessment of laryngeal function pre- and post surgery and during swallowing.

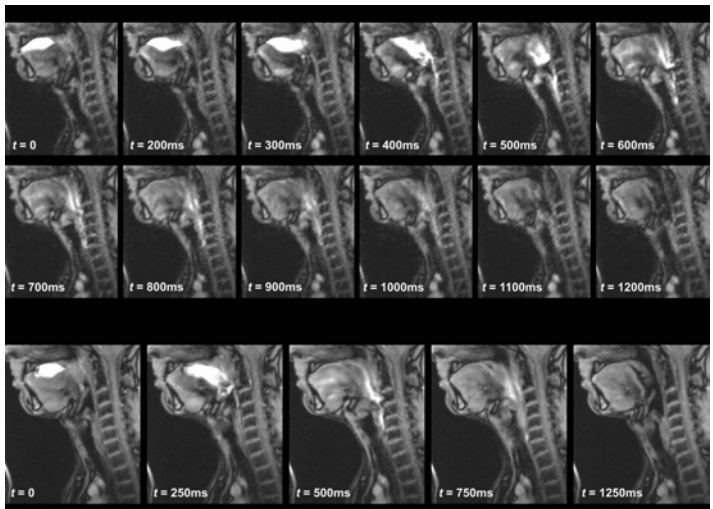

Figure 1 Blueberry bolus passage during 1200ms, 100ms / image (upper panels) and with 250ms / image (lower panel).

Methods: Real time MR imaging was performed with a temporal resolution of 4 and 10 images per second measuring one sagittal slab of 11-16mm thickness using a rf-spoiled 2D GRE sequence (3.0 T TIM TRIO, Siemens, Germany, Gmax = 40mT/m, rise time = 200ms) with the following sequence parameters: 4 image acquisitions/sec.: TE 1.2 ms, TR 3.5 ms, FA 10°, bandwidth 450 Hz/Px, matrix 192x144, FOV 240x240 mm2, GRAPPA = 2; 10 image acquisitions / sec.: TE 1.3 ms, TR 2.7 ms, FA 10°, bandwidth 795 Hz/Px, matrix 128x82, FOV 220x220 mm2, GRAPPA = 3. Up to 512 consecutive image acquisitions were measured with real time image reconstruction in both temporal resolutions. The sagittal slab was positioned medially covering the whole oropharynx and hypopharynx. For evaluation different tasks were analyzed in 10 healthy volunteers at 4 and 10 images/sec. Tasks included movement of the tongue, breathing at rest and swallowing, with and without oral contrast medium (figure 1). Pure blueberry juice as oral contrast agent gave strong T1 contrast due to its paramagnetic properties [2]. All measurements were transformed into avi-movies and analyzed by two independent radiologists and one ENT-specialist, blinded for clinical and technical image acquisition data. Image evaluation included several categories: delineation of anatomical details (tongue, velum, epiglottis, glottis, trachea), dynamics of tongue movement and swallowing as well as artifact level (ghosting, blurring, aliasing). Semi-quantitative grading of image quality was performed using a four point (0-3) scale for each of the individual categories (0 = poor, 1 = moderate, 2 = good, and 3 = excellent). In addition, three professional singers and one patient with inspiratory stridor were also evaluated during breathing at rest, tongue movements and swallowing and singing.

Results: Continuous real time visualization of the oropharynx was feasible in all subjects. All readers found overall good-excellent image quality for lower temporal and higher spatial resolution (mean grading = 2,5 +/- 0.5) which was significantly ($p < 0.01$) higher compared to the high temporal resolution measurements (mean grading = 1,3 +/- 0,6). More detailed grading results are summarized in table 1.

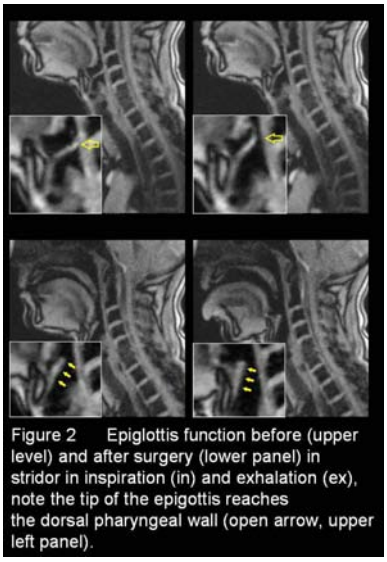
Figure 2 Epiglottis function before (upper level) and after surgery (lower panel) in stridor in inspiration (in) and exhalation (ex), note the tip of the epigottis reaches the dorsal pharyngeal wall (open arrow, upper left panel).

	Anatomic Delineation					
	Tongue	**Velum**	**Epiglottis**	**Glottis**	**Trachea**	**Total**
4 im /s	2,8±0,2	3,0±0,1	2,9±0,2	2,2±0,3	2,9±0,1	**2,8±0,4**
10 im /s	1,3±0,3	1,5±0,3	1,2±0,5	0,5±0,4	1,5±0,3	**1,2±0,5**
	Dynamics:	**Tongue**	**Swallow**			**Total**
4 im /s		2,5±0,3	2,4±0,3			**2,5±0,3**
10 im /s		1,6±0,4	1,4±0,6			**1,5±0,5**
	Artifacts:	**Aliasing**	**Ghosting**	**Blurring**		**Total**
4 im /s		2,2±0,2	2,7±0,3	2,4±0,5		**2,4±0,4**
10 im /s		1,9±0,3	0,8±0,4	1,6±0,5		**1,4±0,6**

Table 1: Summary of semi-quantitative grading of image quality on 0-3 scales. Values represent (mean +/- stdev) of 10 volunteers and 3 independent readers.

Especially for evaluation of the posterior oropharynx, velum palatinum and epiglottis, higher spatial resolution, i.e. lower temporal resolution of 4 frames/second, was found superior. Even though high temporal resolution (100 ms / image) was helpful in evaluating lips and fast movements of the tip of the tongue as well as swallowing, assessment of dynamics and artifact level was generally superior for the low temporal resolution images. Blueberry bolus was tracked well during swallowing at high and low temporal resolution in all subjects (figure 1). In a patient with stridor, the initial real time scan revealed an abnormal movement of the apical part of the epiglottis, closing the airway in a valve-like manner passively during inspiration causing stridor. The patient underwent laser-surgery of the tip of the epiglottis. Postoperatively the real time MR-imaging was able to visualize normal epiglottal function without stridor or aspiration of fluid (figures 2 and 3). The anatomical details of the shortened and slightly thickened epiglottis without pathological movement was clearly visible, aspiration of fluid could be excluded.

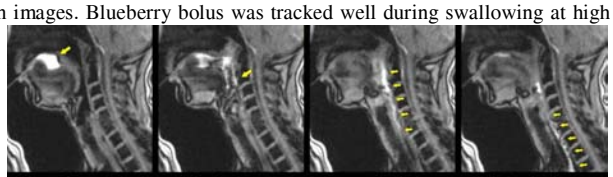
Figure3: Blueberry juice bolus passage (arrows) after surgery. Bolus in the esophagus, no visible contrast in the trachea.

Discussion: The results of this feasibility study illustrate the potential of our dynamic real time MR-imaging protocol at 3T for the visualization of the oropharynx and larynx under various functional conditions. For the first time, it is possible to visualize such complex movements non-invasively and without ionizing radiation in a very high temporal resolution of up to 10 images per second. Even very fast movements of the lips and tip of the tongue or during swallowing can be visualized allowing functional analyses. Stridor is a severe dysfunction of the larynx. With our new method we were able to demonstrate a valve-like dysfunction of the epiglottis in one patient as a rare cause of stridor. This demonstrates the capabilities of our new methods in evaluating oropharyngeal and laryngeal function with dynamic MRI at 3 tesla.

References: 1. Hartl, D.M., et al., Cine magnetic resonance imaging with single-shot fast spin echo for evaluation of Dysphagia and aspiration. Dysphagia, 2006. 21(3): p. 156-62. **2.** Karantanas, A.H., et al., Blueberry juice used per os in upper abdominal MR imaging: composition and initial clinical data. Eur Radiol, 2000. 10(6): p. 909-13.