Investigations of upper airway obstruction pattern in sleep apnea benefit from real-time 3D MRI

Yoon-Chul Kim[1], Biswas Joshi[2], Shirleen Loloyan[2], Roberta Kato[2], Michael C.K. Khoo[1], Sally L.Davidson Ward[2], and Krishna S. Nayak[1]
[1]*Univ. of Southern California, Los Angeles, CA, United States,* [2]*Children's Hospital Los Angeles, Los Angeles, CA, United States*

Target Audience: Sleep medicine physicians and MR physicists who are interested in upper airway imaging.

Introduction: The feasibility of a novel real-time 3D MRI (rt3DMRI) of the upper airway has been demonstrated in overweight and obese adolescents who snore [1]. The rt3DMRI covers the entire airway with sub-second resolution, is less affected by head motion than rt2D mid-sagittal MRI [2] without making an abrupt change in acoustic noise and disrupting subject's natural sleep in a magnet, and is thus capable of reliably identifying the sites of airway obstruction. In this abstract, we investigate the patterns of airway obstruction during central or obstructive sleep apneas in adolescents who underwent both overnight polysomnography and real-time 3D MRI.

Methods: Experiments were performed on a GE HDxt 3T scanner with a 6-ch carotid coil, between 9pm and 1am. Sixteen overweight and obese adolescents (6M/10F, 13-17 yo) with a history of snoring during nocturnal sleep participated in the study. Each subject lay supine and wore 1) a mask that covered the nose and mouth, 2) respiratory bellows placed around the abdomen, and 3) fingertip plethysmograph for measurement of heart rate and oxygen saturation. MRI RF pulse triggered at every TR was recorded simultaneously and was used to synchronize images and physiological signals. 3DFT gradient echo sequence was used for continuous imaging. Imaging parameters: TE/TR=1.7/6.0 ms, flip angle = 5°, 6cm slab thickness, 2.0 (or 1.8) mm isotropic resolution, scan time = 13~18 min [1]. The imaging was based on golden-ratio Cartesian radial sampling (GR-CAPR) [1,3] and constrained reconstruction was based on L1-SPIRiT [1,4]. Images were reconstructed with a frame rate of 1.7 fps. Central or obstructive apneic events and associated airways were identified using a custom image-viewer that facilitated inspection of image frames and physiological signals such as pressure and respiration (see Fig 1). Sleep was inferred by heart and respiratory rate patterns with minimal variability and tracings free of artifact.

Results: Table 1 summarizes the subjects' obstructive apnea hypopnea index (oAHI) from overnight polysomnography, and the number of central or obstructive apneas from rt3DMRI scans. 7 out of 16 subjects showed central or obstructive apneas during the MRI scans. oAHI from the polysomnography did not correlate with the number of events from the rt3DMRI. For example, Subject 2 and 3 had similar oAHI but showed a large difference in the number of events (36 vs. 2). Subject 6 showed no apneas from a polysomnography but showed 40 apneas in an rt3DMRI. We speculate that some subjects have more obstructive symptoms when they are in supine position (only allowed position in MRI study) than when they are sleeping in lateral position (allowed in polysomnography study). Figure 1 shows representative results from 3 subjects. The white dotted lines indicate relative slice locations with respect to each other. Data suggests that Subject 2 may need a tonsillectomy (see Fig 1c).

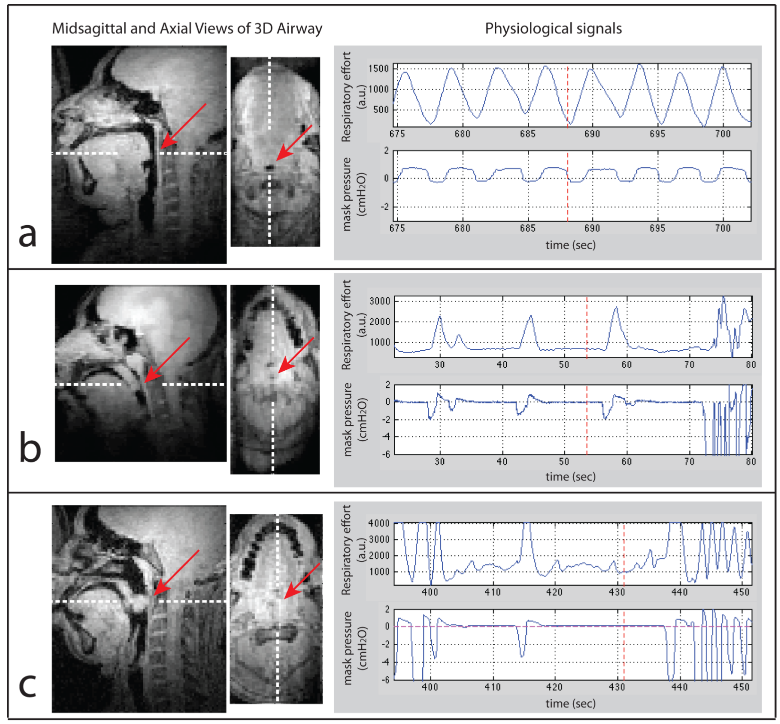

Figure 1. Shown are the mid-sagittal and axial slices taken from a 3D dataset at a single point in time (i.e., the red dashed line in the physiological signal plots). (a) Patent airway captured during normal breathing from a subject who did not show apneas. (b) Mild airway obstruction captured (red arrow) during a central apnea from Subject 1. (c) Severe airway obstruction (red arrow) captured during an obstructive apnea from Subject 2.

Subject	Age/Sex	BMI (kg/m^2)	oAHI*	# of events in rt3DMRI		Obstruction Sites	Severity of Obstruction
				Central	Obstructive		
1	14/F	45	0.3	4	0	Retropalatal	Mild
2	13/M	24	4.0	22	14	Retropalatal	Severe
3	14/M	28	3.8	2	0	Retropalatal	Mild
4	14/M	30	0.6	2	0	No obstruction	-
5	15/M	29	0.7	1	0	No obstruction	-
6	17/F	41	0.0	31	9	Retropalatal	Severe
7	14/F	25	6.7	6	1	Retropalatal	Mild

Table 1. The number of respiratory events, sites of obstruction, and its severity in overweight and obese adolescents who showed sleep apneas during the real-time 3D MRI scans. *: oAHI = obstructive apnea hypopnea index (i.e., the number of events per hour) measured from an overnight polysomnography study.

Discussion: Central apneas were more frequently observed than obstructive sleep apneas (68 for central vs. 24 for obstructive apneas from all subjects). This may be due to the fact that the scan time was only within 20 minutes and the subject might have light (e.g., non-REM) sleep [5]. In this study, central apneas allowed identification of the collapsible segment of the airway because a central apnea involves airway narrowing or collapse [6-8] and can result in an obstructive apnea when the breathing resumes [6]. Clinical implications of this work would be that the severity of airway obstruction during respiratory events measured from the rt3DMRI could inform pediatric pulmonologists and otolaryngologists of a proper planning of airway disorder treatment (e.g., continuous positive airway pressure, weight loss, tonsillectomy, etc). Future work may involve quantification of the obstruction severity (e.g., extent of the collapsed airway).

Conclusion: We applied a novel real-time 3D upper airway MRI to 16 overweight and obese adolescents who snore, and found differences in upper airway obstruction pattern and the severity of airway obstruction during sleep apneas in 7 adolescents.

References: [1] YC Kim et al., MRM 2013 (Early View). [2] L Shin et al., JMRI 2013:38(5);1261-1266. [3] Haider et al., MRM 2008:60(3);749-760. [4] Murphy et al., IEEE TMI 2012:31;1250-1262. [5] DP White, Am J Respir Crit Care Med 2005:172;1363-1370. [6] MS Badr et al., J Appl Physiol 1995:78(5);1806-1815. [7] YC Kim et al., ISMRM 2013, p251. [8] Loloyan et al., Proc Am Thorac Soc 2013, A5480.
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