Real-time MRI can differentiate sleep-related breathing disorders in children

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Introduction: Sleep-related breathing disorders (SRBD) in children have five phenotypes: primary snoring, hypoventilation, high arousal frequency, obstructive sleep apnea, and central sleep apnea [1]. Obstructive sleep apnea is defined by an obstructive apnea hypopnea index (AHI) greater than 5 per hour of sleep. Overnight polysomnography is widely used to determine SRBD phenotype and its severity, but it does not provide direct information of the upper airway anatomy. Nasal endoscopy has been used for imaging, but it is invasive and requires local anesthesia. We propose a novel real-time MRI with synchronized recording of physiological signals to assess the dynamics of the pharyngeal airway during natural sleep.

Methods: Experiments were performed on a GE HDxt 3T scanner with a 6-ch carotid receiver coil. Seven obese adolescents (3M/4F, 13-17 yo) with SRBD and three adult healthy volunteers (3M, 25-35 yo) participated in the study. Each subject lay supine and wore 1) mask that covered the nose and mouth, 2) respiratory bellows, 3) finger plethysmograph for measurement of heart rate and oxygen saturation (see Fig1(a-d)) [2]. 2DFT/3DFT gradient echo sequences were used for real-time imaging. 2DFT parameters: FOV=16×16cm^2, slice thickness=5mm, in-plane resolution=1.6×1.6mm^2, TR=8.66ms, partial k-space (70/100), scan time=28min. Images were obtained with a frame rate 3.3 fps using POCSENSE [3]. 3DFT parameters: FOV=20×16×8cm^3, 2.0mm isotropic resolution, scan time=18min. Dynamic 3D reconstruction was based on L1-SPIRiT [4,5]. Airway cross-sectional areas were computed using semi-automatic segmentation based on seeded region growing [6]. SRBD events and associated airway shapes were identified by experienced pediatric pulmonologists using a custom image-viewer that facilitated inspection of MRI frames with associated physiological signals.

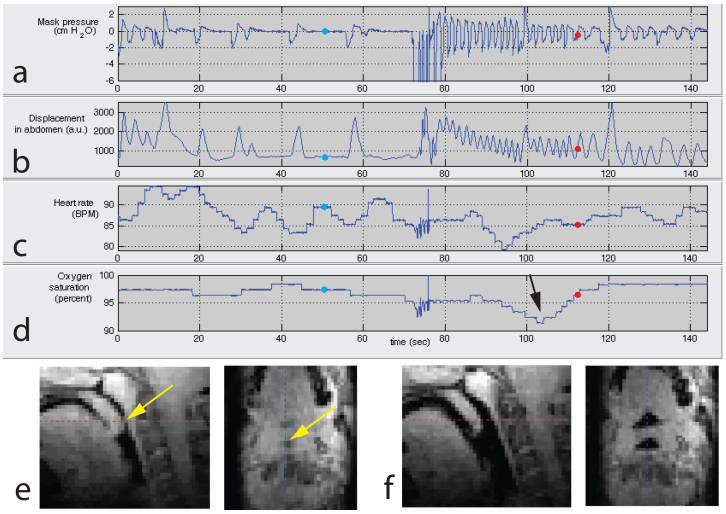

Figure 1. Sample physiological signals (a-d) and captured 3D-MRI frames (e,f), with only mid-sagittal and axial images shown, during central sleep apnea (light blue dots) (e) and tidal breathing (red dots) (f). Oxygen saturation nadir (arrow in (d)) indicates an apnea. The arrows in (e) indicate retropalatal airway obstruction during central apnea.

Subj	Sex	Age	PSG		MRI	
			SRBD Phenotype	Obstructive AHI	Respiratory Events	# of Events
1	M	14	Obstructive sleep apnea	10.6	Central apneas	27
2	F	17	Primary snoring	1.7	Central apneas	19
3	F	14	Hypoventilation	0.2	None	0
4	F	14	Primary snoring	0.3	Central apneas	4
5	M	14	Central apnea	3.8	Central apneas	6

Table 1. Subjects' phenotype assessed by baseline polysomnography (PSG), and respiratory events captured while asleep during the 28-min real-time MRI scan.

Results and Discussion: Five patients and two volunteers reported falling asleep during the MRI scan. Table 1 summarizes the PSG phenotypes and MRI results for the five asleep patients. Images from all scans had acceptable image quality and clear depiction of airway air-tissue boundaries. Fig 2 contains representative results. Left images show airway narrowing from (a) central apnea with periodic breathing and (b) hypopnea with periodic breathing, and (c) inspiratory phase of obstructive hypopnea. Right images show widened airway from normal oscillatory respiration (see yellow arrows). To our knowledge, Fig 2(a) illustrates the first real-time MRI demonstration of airway dynamics in central sleep apnea in a pediatric patient (BMI 44, Subject 1) during natural sleep. Note that during tidal breathing, airway area fluctuations are far less significant in (a) compared to (b,c) (see red dashed rectangles), suggesting that the airway compliance is the least in (a). Our findings from Subject 1 are consistent with the literature [7], which relied on invasive nasofluoroscopy to image the cross-sectional airway. We continue to enroll subjects, and plan to perform real-time MRI studies on 93 more pediatric SRBD patients and further investigate the patterns of pharyngeal airway dynamics with regard to SRBD phenotype.

Conclusion: We have found clear differences in the pattern of pharyngeal airway narrowing/obstruction among central apneas and obstructive hypopneas using real-time MRI.

References: [1] Katz and D'Ambrosio, Proc Am Thorac Soc 2008:5;253-262. [2] Y Kim et al., ISMRM 2012, p3688. [3] A Samsonov et al., MRM 2004:52(6); 1397-1406. [4] Y Kim et al., ISMRM 2012, p4233. [5] RM Lebel et al., ISMRM 2012, p10. [6] Adams and Bischof, IEEE T PAMI 1994:16(6);641-647. [7] MS Badr et al., J Appl Physiol 1995:78(5);1806-1815.

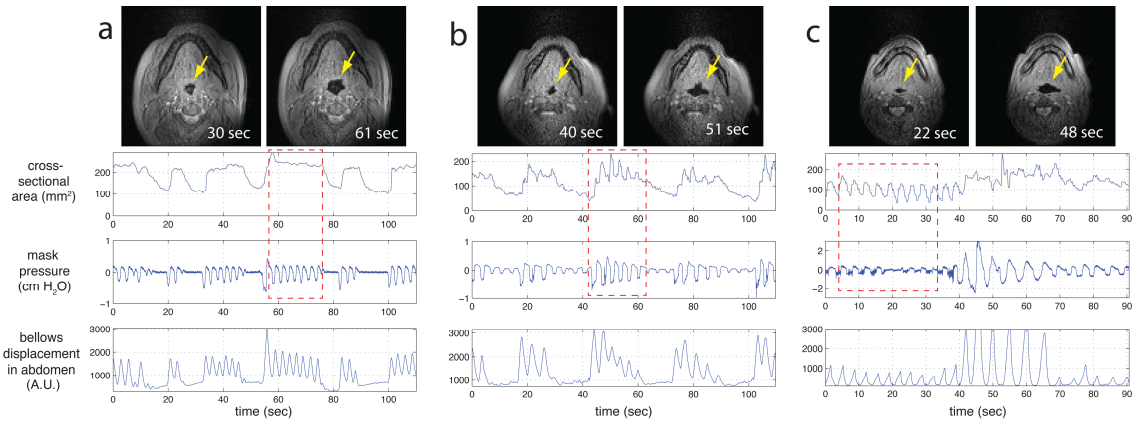

Figure 2. Selected retroglossal frames and plots of cross-sectional area, pressure, and respiratory effort from three subjects using real-time 2D MRI. These illustrate (a) central sleep apneas with periodic breathing (14-yr male), (b) hypopneas with periodic breathing (17-yr female), and (c) obstructive hypopneas (27-yr male). All events and airway dynamics were obtained during natural sleep.