Imaging of the Pharyngeal Airway during Sleep using 3DFT Golden-Angle Radial Spokes Sampling

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Purpose: MRI has been used to visualize sites of airway collapse in patients with obstructive sleep apnea, but it has been often limited to a 2D slice of mid-sagittal orientation [1]. This provides only partial coverage of a narrowed airway and is sensitive to imperfect localization and patient motion. Real-time 3D acquisition is desirable because it would provide complete coverage of the airway and would not require prior knowledge of collapse location. We propose a real-time 3D acquisition technique based on 3DFT golden-angle radial spokes sampling.

Methods: Experiments were performed on a 3 T scanner (GE Healthcare), using a 6-ch carotid receiver coil. Each subject lay supine and wore a mask that covered the nose and mouth, a respiratory bellows, a respiratory transducer, and a finger plethysmograph for measurement of heart rate and oxygen saturation [2]. Imaging parameters: 3DFT GRE, 6cm slab, 80 k_y encodes, 40 k_z encodes, TR = 6.02ms, Scan time = 18min, FOV = 20×16×8 cm^3, 2×2×2 mm^3 spatial resolution. We adopted a golden-angle radial spokes view ordering (see Fig 1) similar to Ref [3]. We retrospectively took 100 consecutive TR's of raw data for every frame, so the time-per-volume was 602 ms. We considered 30 consecutive frames for 4D L1-SPIRiT [4], in which L1-norm regularization promoted wavelet and finite difference sparsity along all spatial and temporal dimensions. We continued to reconstruct next 30 frames, and so on. End result was an 18-min real-time movie of 3D pharyngeal airway dynamics. Our custom image-viewer facilitated inspection of MRI frames with associated physiological signals by pulmonologists. In addition, retrospective gating based on the respiratory transducer was performed to test the effectiveness of the proposed sampling scheme. SPIRiT reconstruction [5] was used to reduce spatial aliasing.

Results and Discussion: Fig 2e,f shows images reconstructed using 4D L1-SPIRiT from real-time acquired data. Airway narrowing in the retropalatal region (see arrows in Fig 2e) is well depicted and motion is not significant during the central apnea. L1-SPIRiT without respiratory gating resulted in incorrect depiction of the airway such as airway collapse during tidal breathing in a subject with high respiration rate. This may be attributed to either spatial/temporal regularization effect or insufficient spatial resolution. Hence, we performed retrospective respiratory gating using SPIRiT with no spatial/temporal regularization. Note that the retropalatal airway appears patent on expiration (see arrow in Fig 3c). In Fig 3b,c, both sampling patterns show radial-like variable density, which rendered estimation of coil calibration kernel from central part of k-space.

Conclusion: A real-time 3D MRI acquisition method based on 3DFT golden-angle sampling is proposed that is capable of 1) identifying sites of upper airway obstruction during natural sleep, and 2) efficient retrospective data binning for improved image quality during tidal breathing.

References: [1] Barrera, Laryngoscope 2011:121;1327-1335. [2] Kim et al., ISMRM 2012, p3688. [3] Doneva et al., ISMRM 2011, p641. [4] Lebel et al., ISMRM 2012, p10. [5] Lustig et al., MRM 2010:64;457-471.

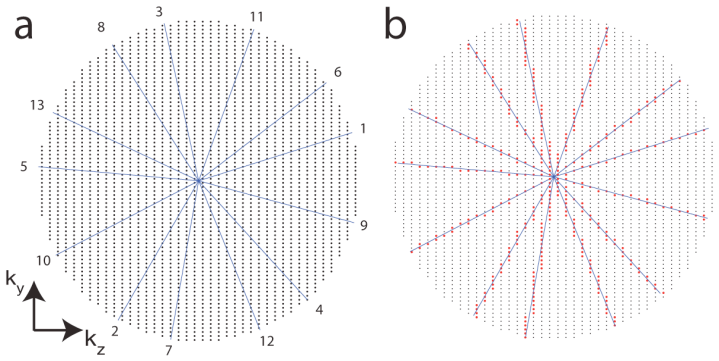

Figure 1. A proposed Cartesian golden-angle sampling scheme. (a) Grid with a circular footprint and temporal ordering of radial half spokes. Note that spatial resolution in k_y is the same as that in k_z, but FOV in k_y is twice as large as the FOV in k_z. Only 13 spokes are shown for illustration. (b) Samples (red dots) chosen along the spokes.

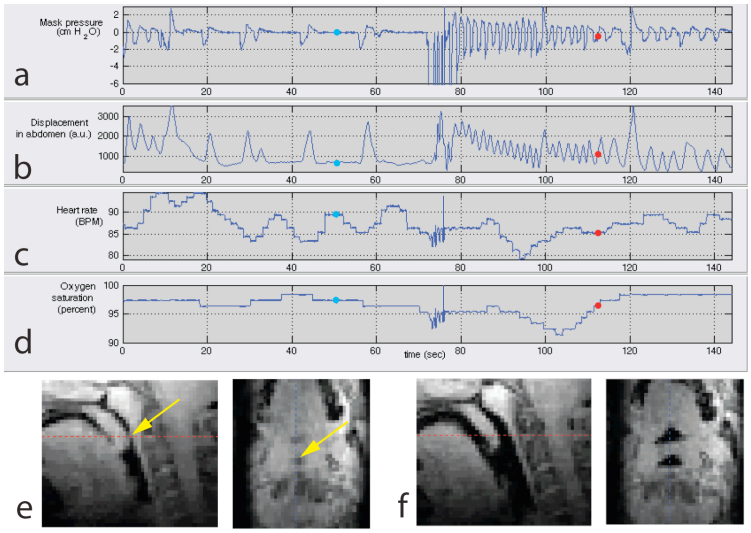

Figure 2. Physiological signals (a-d) and 3D-MRI frames (e,f), with only mid-sagittal and axial images shown, during central sleep apnea (light blue dots) (e) and normal breathing (red dots) (f).

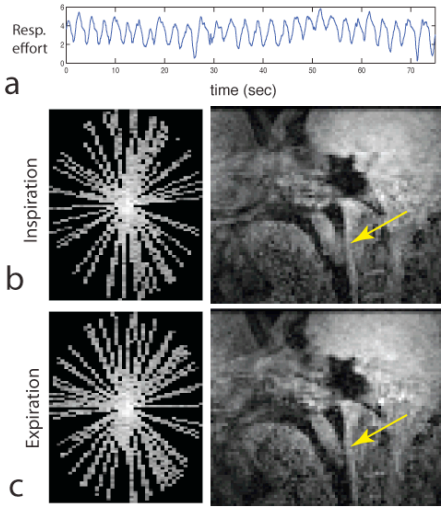

Figure 3. Retrospective respiratory gating with data of tidal breathing. (a): Respiratory signal used for retrospective gating. (b,c): (left) Samples in (k_y, k_z) space after data binning. (right) Mid-sagittal slice from 3D data after SPIRiT reconstruction. Airway obstruction is observed on inspiration (compare the arrows). Enlarged soft palate in (b) may result from motion blurring due to the soft palate's vibration, which is often involved in subjects with snoring.