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 kₚ encodes, 40 k_y encodes, TR = 6.02ms, Scan time = 18min, FOV = 20×16×8 cm³, 2x2x2 mm³ 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.