TARGET AUDIENCE: Sleep medicine physicians and MR physicists who are interested in upper airway imaging.

INTRODUCTION: Obstructive sleep apnea (OSA) is characterized by repetitive upper airway (UA) collapse during sleep. UA compliance, defined as the ratio of UA cross-sectional area and pressure, has been used to measure airway collapsibility. Single-slice compliance measurement has been performed using real-time imaging, however extended spatial coverage is essential in order to characterize collapse pattern. Here we present a method for simultaneous multi-slice compliance measurement based on sparse golden-angle radial CAIPIRINAH, with acceleration factor up to 33.3.

METHODS: I. Data acquisition: Experiments were performed on a clinical 3T scanner (EXCITE HDxt, GE) using a 6-channel carotid receive coil. Physiological signals including facemask pressure, abdomen bellow displacement, oxygen saturation and heart rate were simultaneously recorded to determine wakefulness/sleep. The mask was occasionally occluded to generate enough negative pressure for measuring compliance. To image N slices, a total of N unique multi-band RF pulses were applied alternatively. The Nth pulses was designed such that the phase difference between adjacent slices was 2πn/N, n ∈ [0, N – 1]. Continuous radial acquisition with 1/N golden-angle increment was used. Imaging parameters were: radial FLASH, 3° flip angle, 7mm/3mm slice thickness/spacing, 200 samples per readout, FOV 200x200mm², TR 4ms.

II. Reconstruction: 24 spokes were used to reconstruct each temporal frame without view-sharing, which led to 96ms temporal resolution. Each slice was reconstructed separately by iteratively minimizing the cost function: f_i = ||P_i k_E s_i− P_i k ||^2 + λ_i ||φs_i||, i ∈ [1, N], where P_i is the RF phase cycling pattern, k is NUFFT encoding, s_i is coil sensitivity map, k is the acquired k-space data, φ is temporal variation, and m_i is the image to be solved. λ_i was chosen empirically.

III. Post-processing: The airway was segmented in each frame using a semi-automated region-growing algorithm. The airway area was normalized by the maximum cross-sectional area among all slices during tidal breathing, in order to enable inter-subject comparison. For each slice, all data from one occluded breath were used to perform a linear regression (airway area vs pressure), from which the compliance (line slope) and projected closing pressure (Pcrit) can be estimated.

RESULTS & DISCUSSION: Figs. 1 & 2 contain some representative results from one OSA patient during sleep using 4-slice simultaneous acquisition. Fig.1 shows two frames, one with the airway partially collapsed (top & middle rows) and the other with it open (bottom row). Gridding reconstruction was not able to recover usable images due to severe aliasing artifacts, interference from other slices, and low SNR. The proposed reconstruction is able to recover all of the relevant UA boundary information. Minor residual streaking artifacts persist but did not affect airway segmentation in our experience. This could be mitigated by sacrificing temporal resolution. However, we purposely chose a high temporal resolution ≤100ms because it is critical to fully resolve the airway dynamics. Fig.2-a shows the cross-sectional area of each slice together with the mask pressure. Fig. 2-b shows the linear regression lines for all four slices. Table 1 compares the compliance and Pcrit between one OSA patient and one healthy volunteer. The healthy volunteer has more uniform compliance and Pcrit across the airway. While Pcrit and compliance are lower in most of the upper airway for the healthy volunteer, it can be the other way at certain locations.

CONCLUSION: We demonstrated simultaneous acquisition of 4 slices with our proposed method, which corresponds to 33.3x undersampling compared to fully sampled Cartesian acquisition. Our preliminary result suggests that both the compliance and Pcrit can indeed vary among different slices, which confirms the value of multi-slice measurements. To our best knowledge, it also shows for the first time that a narrower airway site does not always have higher compliance and Pcrit and therefore is not always easier to collapse (S2/S4 versus S1). This finding may impact future OSA surgical planning.


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