Noninvasive Airway Compliance Measurement Using High Spatiotemporal Resolution Real-Time Multi-Slice Mri

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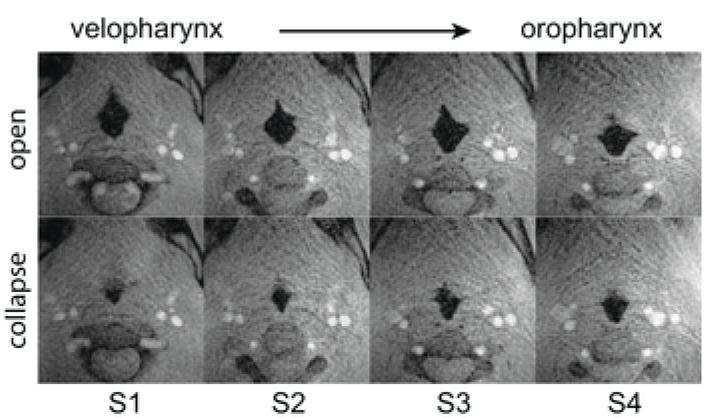
Introduction: Obstructive sleep apnea (OSA) is characterized by repetitive upper airway (UA) collapse during sleep. UA compliance, (ratio of UA cross-sectional area and pressure), has been used to measure airway collapsibility. Accurate measurement of compliance requires broader negative pressure range than tidal breathing, achieved by brief inspiratory load. Under such conditions, airway motion can be extremely rapid, requiring ≥10frames/s and ≤1mm resolution. Multi-slice coverage is desired because the airway does not collapse uniformly. MRI is a noninvasive technique to measure the cross-sectional area but is fundermentally limited by acquisition speed. Here we present a novel real-time method to simultaneously acquire four axial airway sites with 10.4frames/s and 1mm resolution, a 33-fold acceleration compared to conventional MRI.

Methods: A clinical 3T scanner was used to study 4 adult subjects (2 OSA/2 non-OSA). Physiological signals (facemask pressure, abdomen bellow displacement, oxygen saturation and heart rate) were simultaneously recorded with sleep inferred by regular heart and respiratory rate free of movement artifact. The mask was occluded for three consecutive breaths to generate negative pressure. Images were acquired using multi-band excitation with radial trajectory, and reconstructed with parallel imaging and compressed sensing. For each axial location, all data from one occluded breath were used to perform a linear regression (segmented airway area vs pressure), from which the compliance (line slope) and projected closing pressure (P_{crit}) were determined.

Results: Due to limited space, the figure below shows two representative temporal matched frames at four different axial locations for one OSA patient during sleep. All slices are 7mm thick, with 3mm spacing between, covering the region of interest from velopharynx to oropharynx. The top row shows an open airway during tidal breathing, the bottom row captures the maximal narrowing during the occlusion. The airway area was normalized by the maximum cross-sectional area of all four slices during tidal breathing. The estimated compliance is 0.094/0.082/0.085/0.041 cmH^2O^{-1} and estimated P_{crit} is -8.1/-8.7/-11.2/-16.9 cmH^2O for S1-S4 in Fig.1 respectively.



Conclusions: Our preliminary result suggests that both the compliance and P_{crit} can indeed vary among different axial sites, which confirms the value of multi-slice measurements. It also shows that a narrower airway site does not always have higher compliance and P_{crit}, and therefore is not always easier to collapse (e.g. S4 vs. S1). We believe this technique and these findings have the potential to impact future OSA surgical planning.

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