

Respiratory 3D Cine MRI of Upper Airway Dynamics in Obstructive Sleep Apnea

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Introduction: Obstructive sleep apnea syndrome (OSAS) is a growing public health problem affecting children and adolescents, which is linked to the rapidly rising prevalence of obesity in these age groups. Transient upper airway obstruction during sleep as well as during wakefulness leads to a host of physiological, cognitive and social problems in OSAS patients (1). Although interventions such as weight loss and adenotonsillectomy are thought to improve OSAS, the effectiveness of interventions and which patients are likely to benefit remain unclear. Earlier a high resolution technique was introduced, using retrospective, respiratory gating in order to obtain 3D dynamic, high resolution, isotropic images of the upper airway during normal tidal breathing (2). Here, we use this technique and demonstrate the ability to obtain quantitative, dynamic information about upper airway motion in OSAS.

Methods: Imaging was done in adolescent girls, ages 13-18, being evaluated for polycystic ovary syndrome, which has been associated with a high prevalence of OSAS. The study was approved by the local IRB and all patients provided appropriate consent prior to participation. All images were acquired on a 3T Philips Achieva system. The dynamic images used cine, 3D-SPGR, retrospectively gated to the respiratory cycle; respiratory gating was facilitated via flow from a nasal cannula. Thirty-six sagittal slices were collected covering the majority of the extent of the airway to the level of C7. Sequence parameters were: 1.1 mm isotropic, FOV 24x18 cm, TE/TR = 3.5/6.9 ms, flip angle = 8°, turbo factor = 42, SENSE factor 2, 10 dynamics over the respiratory cycle. Images were reconstructed in the axial plane, and a cluster-based segmentation algorithm was used to extract the airway and calculate airway cross sectional area. Waveforms of airway size over time were extracted, and a Fourier transform method was used to calculate airway motion timing (i.e., phase of the FFT) as a quantitative measure for probing changes in airway motion over the length of the upper airway.

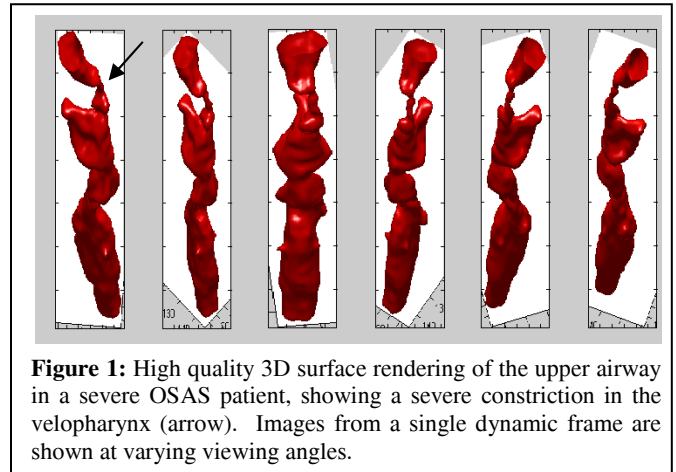


Figure 1: High quality 3D surface rendering of the upper airway in a severe OSAS patient, showing a severe constriction in the velopharynx (arrow). Images from a single dynamic frame are shown at varying viewing angles.

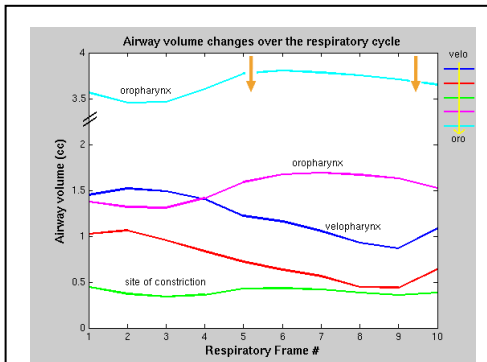


Figure 2: Airway motion in one subject with a severe airway constriction reveals an abrupt change at the site of the constriction; peak airway size occurs in mid-inspiration above, and in mid-expiration below the constriction. Brown arrows indicate start of expiration (left) and inspiration (right). Yellow arrow indicates the order of plots from higher to lower positions along the airway.

Results: Figure 1 shows a 3D surface-rendered reconstruction from one patient with a severe constriction in the velopharynx region. Airway motion for most subjects was roughly synchronous with maximum airway size occurring near the end of inspiration or beginning of expiration. In contrast, in two patients with a severe constriction (narrowing to $< 10 \text{ mm}^2$), airway motion above and below the constriction demonstrated an abrupt change in the timing of airway motion. This change can be best appreciated in Figure 2; precisely at the level of the constriction peak airway size abruptly shifts from occurring at mid-inspiration to mid-expiration. Phase analysis clearly showed a 180 phase shift in the airway motion from above to below the constriction, while in non-OSA patients, as well as one OSA patients who did not demonstrate a significant airway constriction, the phase of airway motion was either near-constant throughout the airway, or had more gradual changes. The asynchronous airway motion may be an indication of neuromuscular activation and was confirmed in one patient with independent rhinometry measurements showing negative airway compliance in the velopharynx.

Discussion: The ability to monitor airway dynamics in OSAS will allow us to study the underlying pathophysiology of the syndrome. In comparison to single-shot, real-time MRI of the upper airway, where each slice is collected during a different breath (3), with potentially different respiratory dynamics, retrospective, 3D cine imaging ensures that the entire airway is imaged over the same physiological conditions. This in turn allows quantitative comparisons of airway motion, such as the amplitude or

timing of changes in airway size, to be made from one position along the length of the airway to another. The technique has revealed unique respiratory dynamics in patients with significant airway constriction and indicates that MRI can provide important physiological information about tissue-airway interactions in sleep apnea patients.

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References

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