Dynamics of the Upper Airway and Application to 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. Adequate assessment of interventions requires a comprehensive understanding of the underlying pathophysiology of the disorder including the precise temporal and anatomic features of upper airway obstruction. We have developed an approach to capture the dynamics of airway anatomy across the respiratory cycle toward fully understanding the disorder. This approach can immediately be applied to the investigation of OSAS and assessment of treatment.

Methods: Two methods were used for capturing airway dynamics. 1) Images were collected on a 1.5T Philips Intera, in both controls and patients, using a pseudo-real-time, 2D T1-weighted, turbo spin echo sequence, with half-Fourier, single-slice acquisitions. This resulted in 3 s temporal resolution and was repeated eight times to capture various portions of the respiratory cycle. Respiratory data were sampled via a respiratory bellows but not gated. Two axial slices were collected at the level of adenoids and tonsils. Sequence parameters were: 1 mm in-plane, 4-5 mm slice thickness, TE/TR = 5.4/140 ms. 2) Because this first sequence did not offer real-time imaging of the respiratory dynamics, and did not allow full airway coverage, a 3D sequence was developed. The criteria for the sequence were isotropic, or near isotropic resolution, full airway coverage and real-time dynamic information with ~ 300 ms temporal resolution. Images were collected on a 3T Philips Achieva, in healthy controls only. The sequence was a cine, 3D-SPGR, retrospectively gated to the respiratory cycle. Respiratory data were sampled via a pressure transducer coupled to a nasal cannula. Forty slices were collected sagittally covering the majority of the extent of the airway to the level of T3. Sequence parameters were: 1x1.5 mm in-plane, 1 mm slice thickness, TE/TR = 3.5/7.5 ms, flip angle = 8°, turbo factor = 42, SENSE factor 2, 10 dynamics over the respiratory cycle, and AP phase-direction saturation bands were used to suppress potential aliasing artifacts. Images were reconstructed to 1 mm isotropic resolution, and displayed in the axial plane to visualize local changes in airway cross section over the respiratory cycle. Total image acquisition time was between 3-8 minutes depending on the respiratory rate and the degree of variations in this rate.

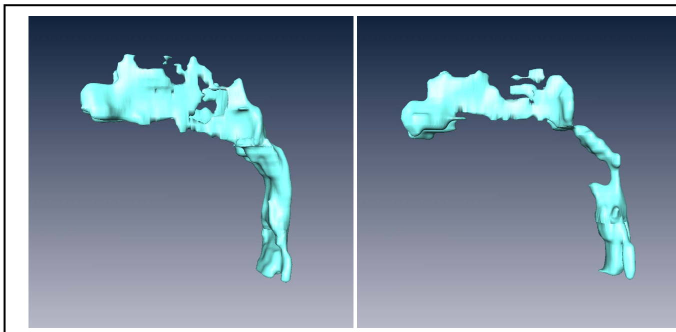

Figure 1: 3D surface rendering of the upper airway in a healthy control (left) and OSAS patient (right), generated from static MRI images and clearly demonstrating the marked narrowing of the airway in sleep apnea patients.

Results: Figure 1 shows a 3D surface-rendered reconstruction from a healthy control (left) and from an OSAS patient (right), reconstructed from static, turbo spin echo images, showing marked narrowing of the upper airway in sleep apnea. The capabilities of the 3D retrospectively-gated sequence are highlighted in Figure 2, where enhanced temporal resolution and signal-to-noise ratio allow reconstruction from a single dynamic frame. In addition, the isotropic acquisition allowed reconstruction in any plane, as illustrated in the adjoining figure showing the temporal changes of the airway cross section over the respiratory cycle.

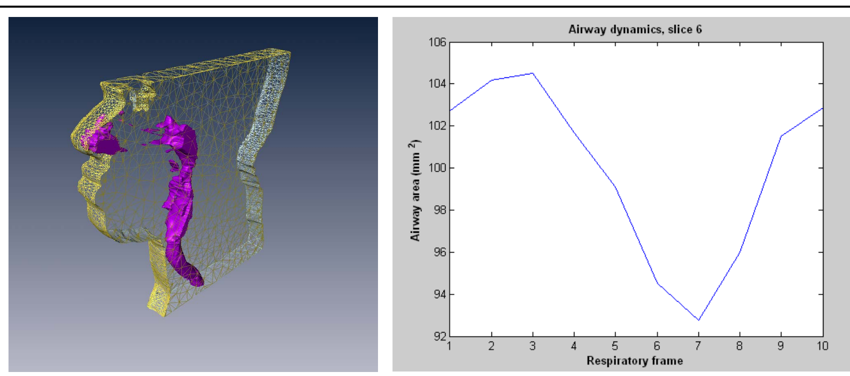

Figure 2: Surface rendering of the airway take from a single frame of a respiratory-gated dynamic acquisition. Accurate determination of airway dynamics at the single axial slice level is possible with this technique

Discussion: OSAS is a major health problem and the ability to monitor airway dynamics will allow us to study the underlying pathophysiology of the syndrome.

References

1. R. Arens, C. L. Marcus, *Sleep* **27**, 997 (Aug 1, 2004).