Understanding Airway Tissue Mechanics is a Step Towards Improving Treatments in OSA


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In this issue of SLEEP, Brown and colleagues1 report the results of a new study examining breath-to-breath changes in the movement of upper airway tissues in patients with obstructive sleep apnea (OSA). In doing so, they successfully provided a method to measure soft tissue movement and developed an analysis protocol that can account for various patterns of movement that can occur among the heterogeneous and multifunctional structures in the upper airway.

More than 20 years ago, a method was developed to apply a temporary grid pattern of fiducial markers on cardiac soft tissues so that within a short time period (approximately one second) a series of images could be obtained that would show how the grid lines moved during the cardiac cycle and thus very accurate measurements of specific tissue motion could be evaluated.2,3 This MRI protocol—named spatial modulation of magnetization (SPAMM)—is now available on most medical scanners used in cardiac evaluation and has become particularly useful in the assessment of regional ventricular function (e.g., systolic wall thickening or systolic circumferential strain) and in the detection of pericardial adhesion and myocardial involvement.4-6 Although noninvasive methods have been available, large scale controlled studies with 3D computed tomography (CT) are difficult to justify in consideration of unnecessary x-ray dosage,7 while MRI studies without a specific method of tissue tracking and time sensitive acquisition and analysis do not yield precise information on breath-to-breath or respiratory related movement of the airway tissues.8

Application of SPAMMI MRI to the airways in rodent studies have provided detailed information as to how tongue muscle stimulation dilates the oral airway in a primarily ventral-dorsal airway expanding motion,9 while noninvasive tissue motion studies on the effect of obesity in the airways of Zucker rats10 showed an overall narrowing of obese airways in expiration and inspiration but fewer differences in airway wall motion between the obese and non-obese rat airways. One of the challenges to such studies is deciding how to segment the airways for comparison and how to compare differences in motion between similar wall structures but in different airspaces such as the nasopharyngeal and oropharyngeal airways.

What is unique in the study by Brown and colleagues1 is that they developed methods to examine the whole respiratory cycle using MRI with tissue tracking.11 They analyzed data from a small but representative sample of OSA patients and normal subjects with the objective of capturing the patterns of airway shape and size changes during inspiration and expiration then comparing how OSA severity altered the patterns of airway size changes. Quantitative results included the finding that the apnea hypopnea index (AHI) correlated negatively with movement of the lateral walls (R = 0.542, P = 0.006), while qualitatively, four different patterns of upper airway motion were defined and compared among the OSA patients and normal subjects.1

As presented by Brown et al.,1 tissue tracking in the upper airway was accomplished using a cine-MRI SPAMM sequence modified so image acquisition was triggered by start of the respiratory cycle rather than triggered by the cardiac (ECG) signal. Two previous studies by this same laboratory11,12 described how image sequences are obtained, aligned and measured from the cine-MRI acquisitions. Their current study1 includes methods for both the acquisition MRI in awake subjects in two planes using SPAMM, and quantitative analysis techniques using harmonic phase analysis.13

The authors base their work on the concept that OSA is a multifactor disorder involving anatomical and neuromuscular alterations, where approximately one-third of the variability of the AHI is ascribed to increased mechanical load (resistance in the airway), while two-thirds is attributed to blunted neuromuscular responses.14 Passive mechanical loads are elevated in severe OSA, but some normal subjects with elevated load are able to increase neuromuscular activity and overcome airway collapse.15 However, overall movement of the muscles in response to neuromuscular input during sleep is poorly understood. Thus, the objective of the report by Brown et al.1 was to determine if AHI (as a measure of severity of OSA) was related to differences in soft tissue movement in the upper airway. While their results showed that overall movement (especially in the lateral airway walls) was reduced in more severe OSA, much more information was uncovered, since there were several patterns of airway movement among patients. Some of these patterns of tissue movement in the upper airway appear to be less capable of compensating for increased mechanical loads, while the patients with the most severe OSA (highest AHI) had the least number of variations in airway movement, which tended to limit their airway dilation during inspiration.

Given that current treatments for OSA are limited because of poor patient compliance16 or overall efficacy,17 questions remain as to what new information from the study by Brown et al.1 helps elucidate the pathogenesis of OSA and what information can be used to help develop new treatments or improve current therapies for OSA syndrome. One possible answer has
been recently highlighted by Lee et al., 18 who have developed new methods of robotic assisted surgery for the pharyngeal airway in the region of lower tongue. Consider that the study by Brown et al. describes a variety of movement patterns in OSA patients who may be unable to compensate or provide inspiratory dilation. MRI with tissue tracking may become a method for differential diagnoses of potential surgery patients and provide evidence in postsurgical examinations of success, failure, or how to improve techniques in new cases.

A second possible extension of the approach reported by Brown et al. 1 would be to combine another new technique called magnetic resonance elastography (MRE) with noninvasive tissue tracking. MRE is also being explored in the Bilston labs, 19 and this method has the capability to measure in vivo tissue stiffness in the tongue and other pharyngeal tissues. Thus, a combination of MRI with motion tracking and MRE (to measure tissue elasticity) may provide insight as to whether treatments that augment neural activation, or that merely increase airway luminal space would be best suited for specific patients. Thus, Brown et al. 1 have provided an excellent basis for further studies using MRI software that is widely available and that can be combined with new studies as continued understanding of pathology and treatment options in OSA are sought.

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REFERENCES