Upper Airway Areas, Volumes, and Linear Measurements Determined on Computed Tomography During Different Phases of Respiration Predict the Presence of Severe Obstructive Sleep Apnea

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Purpose: The objective of this study was to analyze the potential of using low-dose volumetric computed tomography (CT) during different phases of respiration for identifying patients likely to have severe obstructive sleep apnea (OSA), defined as a respiratory disturbance index (RDI) higher than 30.

Patients and Methods: A prospective study was undertaken at the Ramathibodi Hospital (Bangkok, Thailand). Patients with diagnosed OSA (N = 82) were recruited and separated into group 1 (RDI, ≤30; n = 36) and group 2 (RDI, >30; n = 46). The 2 groups were scanned by low-dose volumetric CT while they were *1)* breathing quietly, *2)* at the end of inspiration, and *3)* at the end of expiration. Values for CT variables were obtained from linear measurements on lateral scout images during quiet breathing and from the upper airway area and volume measurements were obtained on axial cross-sections during different phases of respiration. All CT variables were compared between study groups. A logistic regression model was constructed to calculate a patient's likelihood of having an RDI higher than 30 and the predictive value of each variable and of the final model.

Results: The minimum cross-sectional area (MCA) measured at the end of inspiration (cutoff point, ≤0.33 cm^2) was the most predictive variable for the identification of patients likely to have an RDI higher than 30 (adjusted odds ratio [OR] = 5.50; 95% confidence interval [CI], 1.76-17.20; sensitivity, 74%; specificity, 72%,), followed by the MCA measured at the end of expiration (cutoff point, ≤0.21 cm^2; adjusted OR = 3.28; 95% CI, 1.05-10.24; sensitivity, 70%; specificity, 68%).

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Conclusion: CT scanning at the ends of inspiration and expiration helped identify patients with an RDI higher than 30 based on measurement of the MCA. Low-dose volumetric CT can be a useful tool to help the clinician rapidly identify patients with severe OSA and decide on the urgency to obtain a full-night polysomnographic study and to start treatment.

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Obstructive sleep apnea (OSA) syndrome is characterized by repetitive episodes of cessation of breathing during sleep and a decrease in blood oxygen saturation with certain sleep-related symptoms, namely daytime sleepiness, loud snoring, morning headaches, and dry mouth at awakening.[1] OSA affects at least 2 to 4% of the adult population.[2] Of this large number of adults with OSA, many are likely to be undiagnosed and could benefit from treatment.[3] The respiratory disturbance index (RDI) is defined as the average number of episodes of apnea, hypopnea, and respiratory effort-related arousals per hour of sleep.[2] The presence of an RDI of at least 15 in the absence of sleep-related symptoms or an RDI of at least 5 in the presence of sleep-related symptoms is adequate for the diagnosis of OSA. OSA severity is defined as mild (RDI, ≥5 to <15), moderate (RDI, ≥15 to ≤30), or severe (RDI, >30).[4]

The standard for diagnosis of OSA has been full-night polysomnography (PSG), but this requires an overnight hospital stay with trained specialists who monitor and interpret complicated physiologic data throughout the night. This process is labor and resource intensive and time consuming, leading to a limited number of available appointment slots in most hospitals. Because of these limitations, various alternative diagnostic techniques (such as the Mueller maneuver,[5,6] x-ray cephalometry,[7-12] upper airway endoscopy during sleep and sedated sleep) have been proposed as alternatives.[13-17] The potential benefits of these methods over simple clinical assessment remain under discussion.[18]

Advanced imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT) have been used for assessing the upper airways of patients with OSA. MRI has been used to evaluate abnormal pharyngeal tissues in these patients while they are awake and asleep.[19-22] Although MRI provides high-resolution images that visualize the upper airway soft tissues, it is slow and costly. Several CT techniques have been applied widely for determining pharyngeal narrowing in patients with OSA during wakefulness.[12,23-30] In their previous publication,[31] the authors reported that the presence of complete obstruction and complete concentric collapse of the upper airways during sleep apnea detected by CT combined with portable PSG were independently associated with severe OSA (RDI, >30).

It has been reported that moderate-to-severe OSA is an independent risk factor for higher all-cause mortality.[32] Furthermore, the quality of life of patients with severe OSA is decreased compared with normal control subjects and is strongly correlated with the depression scale.[33] Based on the authors' experience, although CT scanning during apneic episodes provided more informative anatomic and pathologic findings of severe OSA than did scans performed during the awake state,[31] scanning while awake (with no need for an asleep tracking system) can help clinicians to rapidly decide the urgency of obtaining a full-night PSG study and of treatment. The authors hypothesized that CT scanning while awake might identify variables with values predictive of severe OSA. Using CT for upper airway scanning during different phases of breathing of patients with OSA remains controversial. Schwab et al[34] reported that the upper airway narrowed substantially at the end of expiration in patients with OSA, whereas the upper airway diameter remained relatively constant during inspiration and enlarged in early expiration. Li et al[35] reported that minimum cross-sectional areas (MCAs) of the retropalatal region (P = .0036) and retroglossal region (P = .027) observed at the end of expiration were predictive of RDI (R^2 = 0.286), whereas Tang et al[36] reported that MCAs of the retropalatal region at the end of deep inspiration were smaller than those during quiet breathing. Thus, the purpose of this study was to determine which CT variables obtained during different phases of respiration (ie, quiet breathing, at the end of inspiration, and at the end of expiration) were predictive for identifying patients likely to have severe OSA as defined by an RDI higher than 30.

Patients and Methods

RECRUITMENT OF PATIENTS

The authors designed and implemented a prospective study. Subjects were recruited from among patients with diagnosed OSA at the Otolaryngology Outpatient Department of the Faculty of Medicine at the Ramathibodi Hospital (Bangkok, Thailand) from August 2011 through November 2016. The diagnosis of OSA was based on standard overnight in-laboratory PSG at the Ramathibodi Sleep Disorders Center using a Sandman Elite (Nellcor Puritan Bennett, Pleasanton, CA), which recorded the following