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Research Paper

Anatomic measures of upper airway structures in obstructive sleep apnea☆

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Abstract *Objective:* Determine if anatomic dimensions of airway structures are associated with airway obstruction in obstructive sleep apnea (OSA) patients.
Methods: Twenty-eight subjects with ($n = 14$) and without ($n = 14$) OSA as determined by clinical symptoms and sleep studies; volunteer sample. Skeletal and soft tissue dimensions were measured from radiocephalometry and magnetic resonance imaging. The soft palate thickness, mandibular plane-hyoid (MP-H) distance, posterior airway space (PAS) diameters and area, and tongue volume were calculated.
Results: Compared to controls, the OSA group demonstrated a significantly longer MP-H distance ($P = 0.009$) and shorter nasal PAS diameter ($P = 0.02$). The PAS area was smaller ($P = 0.002$) and tongue volume larger in the OSA group ($P = 0.004$). The MP-H distance, PAS measurements, and tongue volume are of clinical relevance in OSA patients.
Conclusions: A long MP-H distance, and small PAS diameters and area are significant anatomic measures in OSA; however the most substantial parameter found was a large tongue volume.

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Introduction

Craniofacial anatomical skeletal or soft tissue dimensions of the upper airway as measured from radiologic images in patients with obstructive sleep apnea (OSA) have been the focus of various studies for the last 25 years. However, the precise site of obstruction in OSA patients is still a matter of debate because different radiological methods have been used and none have been standardized.

In many institutions, radiocephalometry is the standard diagnostic approach used by otolaryngologists and sleep specialists to assess the site of obstruction in patients with OSA and ultimately, to plan surgical treatment. It is a simple, low-cost and easily available tool to assess skeletal morphology, especially maxillofacial abnormalities. It is widely used to measure the length, width and cross-sectional area of soft tissue susceptible to impinge on the posterior airway space.[1] Various cephalometric parameters correlate fairly well with the presence of OSA and its severity.[1,2] However, radiocephalometry is of limited potential when used for prognostic purposes regarding intervention.[3,4]

Radiocephalometry itself has several limitations. One important limitation is that the landmarks used to evaluate soft tissues or spaces are not very precise and therefore prone to analysis bias. Another limitation is that cephalometry gives only a two-dimensional representation that limits accurate representation of the three-dimensional structures of interest.

Three-dimensional information likely would be of tremendous value. Several 3-D imaging techniques have been developed, including computed tomography (CT), conebeam CT and magnetic resonance imaging (MRI).[4–7] Dynamic information also likely would be of great value. Several dynamic imaging techniques have been developed including cine-CT (cine fluoroscopy), electron beam computed tomography (EBCT), cine and real-time MRI.[3,8,9] The MRI methods have several advantages over radiocephalometry and CT by offering superior soft tissue contrast without exposure to ionizing radiation. None of these methods have been used specifically for airway measures in OSA patients though MRI has been used by Stuck et al[3] to assess anatomic dimensions of upper airway soft tissue morphology in subjects without OSA. Scarce information is found in the literature regarding anatomic sites of obstruction using MRI with simultaneous measures of respiratory events and function for subjects with sleep disordered breathing.

The purpose of our study was to determine what anatomic dimensions correlate with obstruction in adult sleep apnea compared to control subjects. Specifically, our study addresses the following questions: (1) What airway dimensions can be reliably ascertained from 2D and 3D imaging?; (2) Which skeletal and soft tissue dimensions of the upper airway structures are consistent with obstruction in patients with OSA?; (3) Do airway dimensions in OSA patients differ in comparison with non-OSA subjects?

Methods

Study design

A prospective, non-randomized case control series included 28 subjects (non-OSA = 14 and OSA = 14) recruited from, evaluated, and followed by the Department of Otolaryngology-Head and Neck Surgery, Stanford University, California. The study protocol was approved by the Institutional Review Board and written informed consent was obtained from all subjects.

Subjects

Inclusion criteria were (1) 18–70 years of age; (2) No evidence of claustrophobia; (3) No evidence of sleepiness or functional abnormality as determined by Epworth Sleepiness Score (ESS) and Functional Outcomes Sleepiness Questionnaire (FOSQ) for control subjects, and evidence of sleepiness or functional derangement in OSA subjects; (4) AHI $<$ 15 events/h in control subjects and an AHI $>$ 15 events/h for OSA subjects. We excluded patients who were pregnant, those with a body mass index (BMI) greater than 40 kg/m^2 and those with contraindications to MRI.

OSA was defined by conventional OSA sleep studies including an apnea-hypopnea index (AHI) and lowest oxyhemoglobin saturation score (LSAT), Fujita classification, FOSQ score, and ESS. All OSA subjects and three control subjects were evaluated using an attended overnight polysomnogram. Due to cost constraints, an alternative, unattended overnight assessment using a portable device (Watch-Pat 100, Itamar Inc., Israel) was used in the remaining 11 control subjects.

Cephalometry protocol

Lateral cephalometry was performed in 10 patients (control, $n = 5$; OSA, $n = 5$) with subjects awake and in a sitting position using a standardized technique described previously (C-Dental X-Ray, Inc, Palo Alto, CA).[1,10] During evaluation, the subjects were advised not to swallow and not to move.

From the lateral images (Fig. 1), the skeletal structures measured were the angle from sella to nasion to point A (SNA), angle from sella to nasion to point B (SNB), difference between SNA and SNB (ANB), and the distance from the mandibular plane to the hyoid (MP-H). The soft tissue structures measured were the length of the soft palate, and the posterior airway space (PAS) diameter at the mandibular plane. For cephalometric PAS, point B to gonion marked the reference plane.

Magnetic resonance imaging protocol

MRI investigations were performed in 28 patients (control, $n = 14$; OSA, $n = 14$) with the subject in the supine position in a 0.5 T MRI scanner (GE Medical Systems, Waukesha,