Online Data Supplement

Upper Airway Structure and Body Fat Composition in Obese Children with Obstructive Sleep Apnea Syndrome

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METHODS:

Overnight Polysomnography:

Overnight polysomnography (Xltek, Oakville, ON, Canada) was performed at the Sleep Disorders Center at the Children's Hospital at Montefiore in a quiet darkened room with measurement of the following parameters: sleep stage by scalp electrodes (F_4-M_1, C_4-M_1, O_2-M_1, and F_3-M_2, C_3-M_2, O_1-M_2), muscle tone by EMG, thoracoabdominal movement by piezoelectric belts (Sleepmate, Midlothian, VA), inspired and expired end-tidal CO_2 tension ($P_{ET}CO_2$) by capnography (Capnogard 1265; Novametrix, Wallingford, CT), airflow by nasal pressure (Pro-Tech, Mukilteo, WA) and 3-pronged thermistor, (Nihon Kohden, Tokyo, Japan, arterial oxygen saturation (SpO_2, averaging time of 2 seconds) by pulse oximetry (Masimo, Irvine, CA), heart rate and ECG, and continuous infra-red video digital recording with audio.

Sleep staging and scoring of arousals were performed per standard criteria (E1) by one blinded scorer. Obstructive apnea was scored as the absence of airflow for the duration of 2 breaths in the presence of thoracoabdominal effort. Central apnea was scored when respiratory effort was absent for at least 20 seconds or at least 2 breaths and was associated with bradycardia, oxygen desaturation of at least 3%, or arousal. Hypopnea was defined as a 50% reduction in airflow associated with an arousal, or 3% or greater reduction in oxygen saturation. Apnea hypopnea index (AHI) was calculated as the number of apneas and hypopneas per hour; arousal index was calculated as the number of arousals per hour. OSAS was determined if the obstructive apnea index was > 1/hour or AHI was 5/hour (E2).

Magnetic Resonance Imaging:

MRI studies were performed in the Department of Radiology at the Children's Hospital at Montefiore within 4 weeks of recruitment and following polysomnography. Subjects were awake during the period of imaging and were monitored continuously by pulse oximetry and

direct observation. MRI was performed with a 16 channel Philips 3.0 Tesla Achieva scanner (Philips Medical Systems, Best, The Netherlands). Images were acquired by using a 16 channel commercially available volume neurovascular coil that amply covers the entire head and neck to the level of the mid-sternum (Sense Head Coil; Phillips Medical Systems). Subjects were positioned supine with head in neutral position, i.e., the Frankfort plane perpendicular to the table. All images included an initial rapid gradient echo three-plane localizer scan to confirm that the field-of-view and centering are appropriate and that the head is in neutral position (TR = 49 ms, TE = 1.4 ms, matrix = 256 x 179, 1 acq, and FOV = 25 to 30 cm).

Upper Airway Structure Imaging Sequence:. Sequential T1- and T2-weighted turbo spin echo axial sections were obtained, spanning from the orbital cavity to the larynx. The following parameters were used for the T1-weighted images; (TR = 621 ms, TE = 7.3 ms, matrix = 228 x 170, slice thickness=3 mm, 0.3 mm gap, 2 acq, FOV = 20 to 24 cm, Turbo factor = 5). For the T2-weighted images; (TR = 8224 ms, TE = 82 ms, matrix =174 x 228, slice thickness=3 mm, 0.3 mm gap, 2 acq, FOV=20 to 24 cm, Turbo factor= 29). Sagittal images spanning bilaterally from the midline T2-weighted images; (TR = 7638 ms, TE=78 ms, matrix = 130 x 176, slice thickness=3 mm, 0.3 mm gap, 2 acq, FOV = 20 to 24 cm, Turbo factor = 29). These scans provide detailed geometric measurements of the upper airway and soft tissue and were utilized for the volumetric analysis.

Head, Neck and Abdomen Fat Composition Imaging Sequence: Transaxial T1 weighted spin-echo sequences were performed for quantification of the fat distribution of the neck and abdomen. The imaging protocol includes the following sequences with scan parameters: (1) transaxial T1 weighted turbo spin-echo sequence of the neck parallel to the hard palate from most superior aspect of mandibular rami down to the false cords (TR = 645 ms; TE = 7.3 ms; 170 x 228 matrix size; 3 mm slice thickness-0.3 mm gap, 40 slices; scan time 4.40 min, FOV, 24

x 24 cm, Turbo factor = 5); (2) using a 16 channel surface array coil (SENSE XL; Philips Medical Systems, Best, The Netherlands), transaxial T2 weighted single shot fast spin-echo sequence of the abdomen centered at the level of lumbar vertebra L2/L3 from most superior hemi diaphragm down to iliac crest (TR = 1927 ms; TE = 112 ms; matrix size = 281 x 328; 8 mm slice thickness-2 mm gap, respiratory trigger).

Image Processing and Analysis:

The acquired MR studies were transferred via the PACS to the workstation of the Pulmonary Imaging Lab at Montefiore. All studies were anonymized and converted to the multidimensional version of the DICOM format. DICOM files of the images were analyzed for upper airway structure and regional fat distribution in the neck and abdomen. At first, semi-manual tracing of the anatomical object was performed on each axial slice based on threshold intensity of adjacent tissues. Later, using AMIRA®, a commercial software package for 3D reconstruction and volumetric analysis, volumetric quantification was performed.

Upper Airway Structure:

The volumes of the following structures were determined:

A) Airway: The upper airway was subdivided to the following segments: *Nasopharynx,* defined as the region located superior to the level of the soft palate and continuous anteriorly, through the choanae, with the nasal cavities. *Oropharynx,* defined as the region located between the level of the soft palate and the larynx, communicating anteriorly with the oral cavity, and having the posterior one-third of the tongue as its anterior border and *Hypopharynx,* defined as the region posterolateral to the larynx, and communicating with the cavity of the larynx through the auditus and included the pyriform recesses and the valleculae.

B) Lymphoid tissues: *Adenoid,* combined *palatine tonsils*, combined *retropharyngeal nodes;* (defined as lymph nodes located between the internal carotid arteries from the base of the skull to the hyoid bone), and the combined *deep cervical lymph nodes* (defined as level II nodes, located along the internal jugular vein from base of the skull to the level of the hyoid bone).

C) *Tongue (* including the genioglossus and geniohyoid muscles)

D) soft palate

E) *Mandible*

Head, Neck and Abdomen Fat Composition:

Fat distribution in the head and neck and abdomen was quantified and analyzed on a PC workstation using Amira® software. Volumetric measurements were performed on each slice using intensity threshold after normalization. Fat tissues of the head and neck included: parapharyngeal and subcutaneous fat, and in the abdomen: visceral and subcutaneous fat compartments

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E REFERENCES:

E1. Iber C, Ancoli-Israel S, Chesson A, SF Q. The aasm manual for the scoring of sleep and associated events: Rules, terminology and technical specifications. Westchester, Illinois: American Academy of Sleep Medicine; 2007.

E2. Muzumdar H, Arens R. Diagnostic issues in pediatric obstructive sleep apnea. *Proc Am Thorac Soc* 2008;5(2):263-273.

E MOVIE LEGENDS:

E Movie 1.1: Head and neck surface rendering with three dimensional reconstructions of the upper airway, soft tissues, and mandible of an OSAS subject shown in a vertical rotation in a superior view with superimposed sequential axial MRI slices. Airway (light blue), tongue (brown), mandible (white), soft palate (blue), fat-pads (gold) tonsils (yellow), adenoid (magenta), retropharyngeal nodes (red), deep cervical nodes (green).

E Movie 1.2: Head and neck surface rendering with three dimensional reconstructions of the upper airway, soft tissues, and mandible of an OSAS subject shown in a vertical rotation and superior view. Airway (light blue), tongue (brown), mandible (white), soft palate (blue), fat-pads (gold) tonsils (yellow), adenoid (magenta), retropharyngeal nodes (red), deep cervical nodes (green).

E Movie 2: Surface rendering of the head and neck with three dimensional reconstructions of the subcutaneous fat (grey) and parapharyngeal fat-pads (yellow) of an OSAS subject shown in a vertical rotation.

E Movie 3: Surface rendering of the abdomen with three dimensional reconstructions of the subcutaneous fat (grey) and visceral fat (yellow) of an OSAS subject shown in a vertical rotation.

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