 ORIGINAL ARTICLES

Age-Dependent Changes in the Size of Adenotonsillar Tissue in Childhood: Implications for Sleep-Disordered Breathing

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Objective To analyze age-associated changes in linear and cross-sectional area (CSA) measurements of adenoid, tonsils, and pharyngeal lumen.

Study design Measurements were completed in head magnetic resonance imaging examinations performed for diagnostic purposes. Linear and nonlinear regression models were applied to describe the effect of age on the size of soft tissues and upper airway.

Results Magnetic resonance imaging data were analyzed in 149 children without snoring (aged 0-15.9 years) and in 33 children with snoring (aged 1.6-15 years). In the children without snoring, adenoid size increased during the first 7-8 years of life and then decreased gradually [% (adenoid oblique width/mental spine–clivus length) = 11.38 + 1.52 (age) − 0.11 $(age)^2$, $R^2 = 0.22$, $P < .01$; adenoid CSA = 90.75 + 41.93 (age) − 2.47 $(age)^2$; $R^2 = 0.50$; $P < .01$]. Nasopharyngeal airway CSA increased slowly up to age 8 years and rapidly thereafter. Similar patterns were noted for the tonsils and oropharyngeal airway. In contrast, in children with snoring, adenoid and tonsils were large irrespective of age, and nasopharyngeal airway size increased slowly with age.

Conclusions In children without snoring, growing adenotonsillar tissue narrows the upper airway lumen to variable degrees only during the first 8 years of life. In contrast, in children with snoring, appreciable pharyngeal lymphoid tissue enlargement is present during the preschool years and persists beyond the eighth birthday. *(J Pediatr 2013;162:269-74)*.

Snoring is the most common clinical manifestation of obstructive sleep-disordered breathing (SDB), a spectrum of disease entities including primary snoring, upper airway resistance syndrome, obstructive alveolar hypoventilation, and obstructive sleep apnea-hypopnea.[1] Increased upper airway resistance related to enlarged adenoids and tonsils is the main pathogenetic abnormality in children with obstructive SDB, and adenotonsillectomy is the standard treatment for the disorder.[2,3] The natural history of adenotonsillar tissue growth in childhood remains poorly understood, however.

A previous study using magnetic resonance imaging (MRI) proposed that in children without snoring, irrespective of age, adenoids and tonsils grow proportionally to the skeletal structures without restricting the pharyngeal airway lumen.[4] This concept is in contrast to results of earlier investigations based on plain cranial radiographs which have revealed that during preschool years, the adenoids grow progressively in children without SDB, restricting the upper airway lumen to variable degrees.[5,6]

In the present MRI study of the upper airway, we hypothesized that during the first 8 years of life, children without snoring experience more rapid growth of the adenoids and tonsils compared with the airway lumen. After the eighth birthday, the pharyngeal lymphoid tissue shrinks progressively, while the pharyngeal lumen continues to grow. In contrast, children who snore have persistent adenotonsillar tissue enlargement starting early in life that leads to pathological restriction of the pharyngeal space available for airflow.

Methods

Consecutive children undergoing MRI of the head for clinical purposes between April 2009 and June 2010 were eligible to participate in this study. Exclusion criteria were: (1) symptoms of acute upper or lower respiratory infection; (2) history of adenoidectomy or tonsillectomy; (3) history of a craniofacial, neuromuscular, or genetic

AOW	Adenoid oblique width
BMI	Body mass index
CSA	Cross-sectional area
IML	Intermandibular length
MRI	Magnetic resonance imaging
MSCL	Mental spine–clivus length
NP	Nasopharyngeal
OP	Oropharyngeal
SDB	Sleep-disordered breathing
TW	Tonsillar width

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disorder; and (4) brain tumors. Information on SDB symptoms was collected from parents using a questionnaire (**Appendix 1**; available at www.jpeds.com) based on the Pediatric Sleep Questionnaire of Chervin et al[7] and on the definition of snoring applied in the Cleveland Children's Sleep and Health Study.[8] Weight and standing height were recorded, and body mass index (BMI) *z*-score was calculated in subjects aged ≥2 years.[9,10] Subjects with a BMI *z*-score ≥1.645 (95th percentile) were defined as obese. The study protocol was approved by the Ethics Committees of Mitera Maternity and Children's Hospital and Aghia Sophia Children's Hospital. Parental informed consent was obtained for participation in the study, and assent was obtained from children aged >8 years.

MRI Examination

MRI examinations were performed at the Radiology Departments of Mitera Maternity and Children's Hospital using a 1.0-T high-field, open-magnet MRI device (Panorama; Philips; Eindhoven, The Netherlands). Subjects aged <4 years and older uncooperative children were sedated with intravenous propofol. All sedated children were monitored continuously by pulse oximetry, with a pediatric anesthesiologist present until full recovery from sedation. Children not receiving sedation (aged ≥4 years) were asked to remain still during each MRI sequence, which lasted approximately 2-3 minutes. A toy magnet simulator was available before the scan to help children in the borderline age group become acquainted with the procedure through play therapy. In addition, a soothing environment with music and projection of cartoons ("ambient experience") was provided during the MRI examination for the unsedated children, and their parents were present in the MRI suite.

A head coil was used for image acquisition. The child lay supine, and the head was positioned with the ear tragus-to-orbital fissure plane perpendicular to the table. A rapid survey localizer was obtained to allow detailed planning of the examination sequences. The imaging protocol included T1-weighted, spin-echo images of 5 mm thickness on the axial and sagittal planes, along with T2-weighted sagittal images. Axial images included the area between the lower border of the orbital cavity and the upper level of the epiglottis. Sagittal images were obtained from the midline to the ears bilaterally.

Postprocessing of MRI Images

Sagittal Measurements (Adenoid). From a midsagittal T1-weighted image, an oblique linear measurement of the adenoid (adenoid oblique width [AOW]) was made along the mental spine–clivus length (MSCL). The percentage of AOW/MSCL was calculated to express the size of the adenoid in relation to the oblique dimension of the mandible.[4] Midsagittal T1-weighted images were also used to obtain the cross-sectional area (CSA) of the nasopharynx, and CSA of the adenoid was determined from T2-weighted sagittal images.[11]

Axial Measurements (Tonsils). The intermandibular length (IML) and bilateral tonsillar width (TW) were calculated on the axial plane and at the level of the maximal tonsillar CSA.[4] The percentage of bilateral TW/IML expresses the size of the tonsils relative to the transverse dimension of the mandible. The T1-weighed axial section at the widest tonsillar level was chosen for the calculation of bilateral tonsillar and oropharyngeal (OP) CSA.[11] More information on postprocessing of the images is provided in **Appendix 2** (available at www.jpeds.com). Landmarks and linear and CSA measurements are illustrated in **Figure 1** (available at www.jpeds.com).

Statistical Analyses

The subjects were classified into 2 study groups, children without snoring and those with snoring (≥1 night/week). The primary MRI variables of interest were percentage of AOW/MSCL and percentage of bilateral TW/IML. CSAs of the adenoid, tonsils, and nasopharyngeal (NP) and OP airways were the secondary MRI variables of interest.

Initially, the 2 study groups were compared in terms of age, sex, BMI *z*-score, frequencies of obesity, symptoms consistent with SDB and indications for the MRI exam, and percentage of children receiving sedation for MRI. MRI variables of interest were compared in children without snoring aged ≤8 years and those with snoring aged ≤8 years and in children without snoring aged >8 years and those with snoring aged >8 years. The choice of 8 years as a cutoff age for the definition of subgroups was based on data from previously published studies indicating that adenoids and tonsils reach their maximum size at around 7-8 years of life.[6,12]

To assess the effect of age on MRI measures of interest, children without snoring and children with snoring were considered separately. Linear and nonlinear (quadratic) regression models were applied to describe the effect of age on the primary and secondary MRI measures of interest. For each dependent MRI variable, the model maximizing the squared value of the correlation coefficient (R^2) and minimizing the SE of the estimate was selected. High R^2 values along with low SE values indicate that the selected regression method has minimized the differences between predicted values (based on age) and observed values of the MRI variables of interest. To identify the age at which the pharyngeal soft tissues and NP and OP airway lumens achieved their maximum size, the regression equations were solved by setting age to 0 years, 1 year, 2 years, and so on up to 16 years.

The effects of sex and obesity on MRI variables in children without or with snoring were assessed by fitting a general linear model using the SAS GLM procedure (SAS Institute, Cary, North Carolina). The model consisted of the main effects and the first-order interactions (ie, age and sex or obesity). The MRI variables of interest were set as responses (dependent variables).

Results

A total of 185 children underwent MRI of the head for clinical purposes during the study period. All parents provided