Upper Airway Length is Predictive of Obstructive Sleep Apnea in Syndromic Craniosynostosis

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Purpose: Midfacial hypoplasia is a characteristic feature of the syndromic craniosynostoses and predisposes these patients to developing obstructive sleep apnea (OSA). The purpose of this study was to identify anatomic factors associated with airway obstruction in patients with syndromic craniosynostoses.

Materials and Methods: This was a retrospective cohort study. The authors enrolled a study sample composed of patients with syndromic craniosynostoses. The predictor variables were age, gender, body mass index (BMI), syndromic diagnosis, and parameters of upper airway length and size measured on lateral cephalograms. To control for age, upper airway length was corrected for differences in patient height. The outcome variable was OSA status (present or absent). Descriptive, bivariate, and regression statistics were computed. For all analyses, a *P* value less than or equal to .05 was considered statistically significant.

Results: The sample was composed of 50 patients with a mean age of 10.3 ± 0.6 years, 50% were boys, and 24 (48%) had OSA. Patients with and without OSA did not differ statistically in age, gender, BMI, or syndromic diagnosis. Those with OSA had increased upper airway length (*P* = .016), decreased posterior airway space (*P* = .001), and more severe midfacial retrusion (*P* = .022) compared to patients without OSA. After adjusting for covariates, the odds ratio for OSA was 32.9 in patients with an upper airway longer than 45.3 mm per meter of height (*P* = .018), and for every 1-mm decrease in posterior airway space, the risk of OSA increased by 30% (*P* = .022).

Conclusions: Patients with syndromic craniosynostosis and OSA have a longer upper airway, smaller posterior airway space, and more severe midfacial retrusion than those without OSA.

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Obstructive sleep apnea (OSA) is common in patients with syndromic craniosynostosis and is usually ascribed to midfacial hypoplasia with reduction of the nasopharyngeal and oropharyngeal airway space.[1-3] The prevalence of OSA in children with these conditions is reported to be 40 to 83%.[1-8]

The basic structure of the upper airway resembles a tube with airflow dynamics governed by Poiseuille's law: the resistance to flow is inversely proportional to the fourth power of the radius and directly proportional to the length of the tube.[9] Airway circumference, shape, and length play an important role in

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regulating upper respiratory air flow and determine an individual's propensity for airway collapse.[9,10] Increased airway length, more circular shape, and decreased posterior airway space are associated with an increased prevalence and severity of OSA in healthy patients.[9-16]

Reproducible and accurate methods for measuring airway dimensions radiographically have been validated.[15,16] The study's specific aims were *1)* to measure the airway of patients with syndromic craniosynostoses on lateral cephalograms and *2)* to identify airway characteristics that are associated with OSA in these patients. The authors hypothesized that those with OSA would have increased upper airway length compared to patients without OSA.

Materials and Methods

STUDY DESIGN AND SAMPLE

The authors designed and implemented a retrospective cohort study and enrolled a sample derived from the population of patients who presented to Boston Children's Hospital (Boston, MA) from 2000 through 2014 for the evaluation and management of syndromic craniosynostoses. Included were patients who had a lateral cephalogram obtained at 6 to 18 years of age; given the differences in pathophysiology of OSA in infants,[17] it was decided a priori to include only patients in the mixed or adult dentition. Excluded were patients who had previously undergone a midfacial advancement procedure. The authors did not exclude patients who had adenotonsillectomy because this procedure does not improve OSA in children with syndromic craniosynostosis.[18]

The study was approved by the institutional review board of the Committee on Clinical Investigation at Boston Children's Hospital and all research activities were conducted in accordance with the Declaration of Helsinki.

STUDY VARIABLES

Predictor Variables

The predictor variables included age, gender, height (meters), weight (kilograms), body mass index (BMI; kilograms per meter squared), syndromic diagnosis (Apert, Crouzon, Muenke, Pfeiffer, Saethre-Chotzen), operative history (intubation, midfacial advancement, adenotonsillectomy, septoplasty, turbinate reduction), and clinical course (polysomnographic diagnosis, subjective symptoms of sleep-disordered breathing, use of continuous positive airway pressure mask or home O_2 saturation monitor).

Measurements of the airway were made on lateral cephalograms as previously described.[10-12] All measurements were recorded by 1 investigator (K.D.) who was blinded to the OSA status of the patients at the time of analysis. Intra-rater reliability was verified by performing repeat measurements on all images after a 1-week interval (r = 0.912; P < .01). All measurements were made using Dolphin Imaging 11.7.05.59 (Patterson Dental Supply, St Paul, MN, 2014).

Cephalometric measurements included upper airway length (UAL; millimeters), posterior airway space (PAS; millimeters), hyoid-to-mandibular plane distance (HMP; millimeters), soft palatal length (millimeters), posterior vertical maxillary length (millimeters), mandibular length (millimeters), maxillary length (millimeters), maxillary sagittal position (SNA; degrees), mandibular sagittal position (SNB; degrees), and maxillomandibular relation (ANB; degrees). PAS was measured on a line connecting the B point to the gonion extending posteriorly through the retroglossal airway as the distance along this line from the base of the tongue to the posterior pharyngeal wall.[11] HMP is the length of a line perpendicular to the mandibular plane originating from the superior aspect of the hyoid bone.[11] UAL was measured along the long axis of the airway from a horizontal plane at the most anterosuperior aspect of the hyoid to a horizontal plane at the level of the posterior hard palate.[11] Airway changes associated with growth have been established for children in the mixed (6 to 12 yr old) and adult (12 to 18 yr old) dentition,[16] and an adjusted measurement of UAL per meter of height was obtained to control for the effect of age.

Outcome Variables

The primary outcome variable was OSA status (present or absent). The cohort of patients with OSA had the diagnosis confirmed by overnight attended polysomnography and had lateral cephalograms taken within 2 years of the polysomnographic diagnosis. The cohort without OSA was composed of patients who did not exhibit any sleep disturbance on polysomnography and patients who had no history of sleep-disordered breathing or obstructive symptoms by review of the medical records.[19] Secondary outcome variables were the apnea-and-hypopnea index (AHI) and the OSA severity, which was scored on an ordinal scale corresponding to the diagnosis given at polysomnography (mild = 1, mild to moderate = 2, moderate = 3, moderate to severe = 4, severe = 5).

DATA MANAGEMENT AND ANALYSES

Descriptive statistics were calculated for the study population and for the OSA and non-OSA cohorts. Bivariate analyses were performed to identify variables that differed between these 2 groups. Given the small