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Original Article

Detection of pediatric obstructive sleep apnea syndrome: history or anatomical findings?

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ABSTRACT

Objective: To assess how history and/or anatomical findings differ in diagnosing pediatric obstructive sleep apnea (OSA).
Methods: Children aged 2–18 years were recruited and assessed for anatomical (ie, tonsil size, adenoid size, and obesity) and historical findings (ie, symptoms) using a standard sheet. History and anatomical findings, as well as those measures significantly correlated with OSA, were identified to establish the historical, anatomical, and the combined model. OSA was diagnosed by polysomnography. The effectiveness of those models in detecting OSA was analyzed by model fit, discrimination (C-index), calibration (Hosmer–Lemeshow test), and reclassification properties.
Results: A total of 222 children were enrolled. The anatomical model included tonsil hypertrophy, adenoid hypertrophy, and obesity, whereas the historical model included snoring frequency, snoring duration, awakening, and breathing pause. The C-index was 0.84 for the combined model, which significantly differed from that in the anatomical (0.78, $p = 0.003$) and historical models (0.72, $p < 0.001$). The Hosmer–Lemeshow test revealed an adequate fit for all of the models. Additionally, the combined model more accurately reclassified 10.3% ($p = 0.044$) and 21.9% ($p = 0.003$) of all of the subjects than either the anatomical or historical model. Internal validation of the combined model by the bootstrapping method showed a fair model performance.
Conclusion: Overall performance of combined anatomical and historical findings offers incremental utility in detecting OSA. Results of this study suggest integrating both history and anatomical findings for a screening scheme of pediatric OSA.

1. Introduction

Sleep-disordered breathing (SDB) includes a spectrum of upper-airway disorders ranging from primary snoring to obstructive sleep apnea (OSA) [1–5]. Untreated OSA in children is associated with cardiovascular [2], neurocognitive [3], and somatic growth consequences [4], while primary snoring (or non-OSA) in children may be a more benign condition and its management remains a contentious issue [1]. Clinical physicians thus highly prioritize identifying children with OSA, which is associated with decision-making and treatment recommendations.

Overnight polysomnography (PSG) is still the 'gold standard' for diagnosing pediatric OSA [1,6]. However, PSG involves thoroughly evaluating cardiopulmonary parameters in a sleep lab, explaining why it is time-consuming, expensive, and sometimes not promptly available [6]. Consequently, a simplified method must be developed to determine the need for early intervention and referral for overnight PSG [7]. Previous studies found that, when compared against overnight PSG, clinical symptoms (ie, history) or physical examinations (ie, anatomical findings) are unreliable in detecting childhood OSA [7–9]. Recent studies have suggested that integrating history and anatomical findings might facilitate the screening of childhood OSA [10,11]. However, diagnostic abilities of history

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and/or anatomical findings have not been thoroughly evaluated in terms of detecting OSA in pediatric populations. Furthermore, previous studies evaluated model discrimination (C index) [10,11], whereas, to our knowledge, none examined calibration (Hosmer–Lemeshow test) [12] or reclassification properties [13]. The ability to reclassify risk is increasingly recognized as an effective means of evaluating the diagnostic performances of clinical measures [13].

Therefore, this study compares the diagnostic abilities of history and anatomical findings, and then combines both measures to detect pediatric OSA. In particular, the feasibility of applying OSA risk reclassification provides valuable insight into the clinical usefulness of these models.

2. Methods

2.1. Study population

The study protocol was approved by the Ethics Committee of the National Taiwan University Hospital. From June 2012 to January 2014, children aged 2–18 years old were recruited. All children with symptoms suggestive of SDB were invited to participate. The response rate was 89% (222/249) and there were no differences between responders and non-responders in demographics. Children with symptoms suggestive of SDB were defined as those having snoring or at least one of the following symptoms: mouth breathing, witnessed breath pause, awakening, hyperactivity, bedwetting, daytime sleepiness, or attention problems [10]. Initially, our participants were recruited from the respiratory (Lee P.-L.), pediatric (Weng W.-C.), and otolaryngologic clinics (Hsu W.-C.). All children with symptoms suggestive of SDB were then sent to the otolaryngologic clinic for historical and anatomical assessments. The historical and anatomical assessments for all subjects were evaluated by the same examiner (Hsu W.-C.). The exclusion criteria were (1) prior tonsil, adenoid, or pharyngeal surgery, (2) craniofacial anomalies, (3) genetic disorders, neuromuscular diseases, cognitive deficits, or mental retardation, and (4) children younger than12 months old.

2.2. Anatomical measures

Anatomical measures included measures of tonsil size, adenoid size, and obesity, as described in the following. First, tonsils were graded based on the scheme of Brodsky [14]: grade I, small tonsils confined to the tonsil pillars; grade II, tonsils extending just outside the pillars; grade III, tonsils extending outside the pillars, but do not meet at the midline; grade IV, large tonsils that meet at the midline. Tonsil hypertrophy was defined as grade III or above [14]. Additionally, adenoid size was determined using lateral cephalometric radiographs. The adenoidal–nasopharyngeal (AN) ratio was measured as the ratio of adenoidal depth to nasopharyngeal diameter based on the method of Fujioka et al. [15]; an AN ratio ≥0.67 was considered adenoid hypertrophy [16]. Obesity was defined as a body mass index (BMI) higher than the 95th percentile for a child's age and gender [4,17]. The weight and height of each child were measured and BMI was calculated. Finally, based on the age of each child and gender corrected BMI, the BMI percentile was defined using established guidelines [17].

2.3. Historical measures

Caregivers were requested to complete the standard symptom record, which was adapted from that in the study of Xu et al. [10]. The symptom record consists of questions regarding the child's snoring patterns, night-time and daytime clinical symptoms, as well as other OSA-related symptoms. The snoring pattern is assessed by asking caregivers about the snoring frequency and duration of their children. The daytime symptoms included daytime sleepiness, hyperactivity, attention problems, depression, low self-esteem, shyness, and low academic performance. The night-time symptoms included breathing pause, awakening at night, bedwetting, nightmares, and diaphoresis. Other OSA-related symptoms were also included in the symptom record. The standard symptom record was administered by the same examiner (Hsu W.-C.).

2.4. Polysomnography

Full-night attained PSG (Embla, Medcare, Iceland) was performed at the sleep lab. The sleep stage and respiratory event were scored based on the pediatric scoring criteria from the 2007 American Academy of Sleep Medicine standard [6], following a protocol described elsewhere [4,5,18–22]. The disease severity was defined as OSA (apnea/hypopnea index, AHI ≥ 1) or non-OSA (AHI < 1) [4–6,18–23].

2.5. Statistical methods

Data were analyzed using SAS software version 9.3 (SAS Institute, Cary, NC, USA). OSA and non-OSA patients were compared using Chi-square test for categorical variables and independent sample *t*-test for continuous variables. Variables to be modeled later were selected by using a series of univariate logistic regression analyses in which those significant variables were incorporated into the historical, anatomical, and combined models, respectively. The model performance was assessed based on several aspects, including global model fit, discrimination, calibration, reclassification, and validation.

2.5.1. Global model fit

The global measure of model fit was evaluated by the likelihood ratio (LR) Chi-square statistic, Akaike information criterion (AIC) and Bayes information criterion (BIC) [24]. LR chi-square was the difference of residual between the null model (without predictor) and the default model (with predictor). A higher LR Chi-square value implies a better model fit. AIC and BIC were both statistical estimates of the trade-off between the likelihood of a model against its complexity, with a lower value indicating a better model fit.

2.5.2. Discrimination

Discrimination refers to the ability of a model to separate those individuals with OSA from those without OSA. The C index estimates the area under a receiver operating characteristic (ROC) curve constructed by the logistic model [25]. The difference between two ROC curves is compared by the pooled standard error. A p value <0.05 indicates that two compared areas significantly differ from each other [25].

2.5.3. Calibration

Calibration involves evaluating the differences between the predicted probability of OSA, based on a developed model and the observed OSA. Calibration is typically evaluated with the Hosmer–Lemeshow statistic [12]. The Hosmer–Lemeshow test statistic follows a Chi-square distribution, in which a smaller value implies a better calibration. A non-significant Hosmer–Lemeshow statistic indicates an adequate model calibration.

2.5.4. Reclassification

The reclassification of OSA risk was evaluated by comparing predicted risk estimates based on anatomical models with and without adding historical measures [13,26]. Also the reclassification was evaluated separately in individuals with and without OSA [13]. The estimated OSA probabilities were grouped into risk categories ≥50% and <50% in both models, subsequently followed by tabulation of a 2×2 cross-table. The OSA subjects who were classified as not having OSA in the anatomical model and those as having OSA in