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RESEARCH ARTICLE

Wu et al: COME prediction in adenoidal hypertrophy

Chronic otitis media with effusion in children with adenoidal hypertrophy: Development of a diagnostic prediction model

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ABSTRACT

Chronic otitis media with effusion (COME) is a prevalent condition that poses significant risks to the growth and development of children with adenoidal hypertrophy (AH). This study investigates the risk factors associated with COME in children diagnosed with AH and establishes a clinical prediction nomogram to enhance diagnostic accuracy. The study included 311 children with AH, diagnosed through lateral nasopharyngeal radiographs, from the Department of Otorhinolaryngology Head and Neck Surgery at the First Affiliated Hospital of Anhui Medical University. Risk factors were identified using the least absolute shrinkage and selection operator (LASSO), while Firth's penalized logistic regression analysis was employed to further refine the variables and develop a predictive model. The model's performance was assessed using the C-index, calibration curve, and decision curve analysis, with internal validation conducted through bootstrapping. The resulting predictive nomogram included four key risk factors: young age, vitamin D3 deficiency, degree of AH, and tympanometry results. The model exhibited strong predictive capabilities, achieving a C-index of 0.945 (95% confidence interval: 0.941, 0.949). Bootstrapping validation confirmed a high C-index of 0.934. The calibration curve demonstrated good alignment, while the decision curve indicated a net benefit across thresholds of 10%–90%. This nomogram—incorporating tympanometry, AH degree, serum vitamin D3 levels, and age—serves as a valuable tool for clinicians and families in assessing the risk of COME in children with AH.

Keywords: Adenoid hypertrophy, children, chronic otitis media with effusion, nomogram, risk factor.

INTRODUCTION

Otitis media with effusion (OME) refers to middle ear effusion without acute inflammation. A course of OME lasting >3 months is called chronic otitis media with effusion (COME)[1]. COME is one of the most common diseases occurring in early childhood. Epidemiological surveys at home and abroad have reported incidence rates of COME in adolescents of approximately 15%–30% in the United States, 32.3% in India, 16.5% in children attending primary clinics in South Africa, and 1.16%–30.7% in some areas of China[1-4]. Tos et al. showed that children experienced OME at least once since birth[5]. COME is one of the main causes of hearing loss in children and has various effects on speech and social development[6]. Furthermore, long-term negative pressure in the middle ear tympanic cavity may affect vestibular function in children and they may have varying degrees of balance disorders in their daily activities[7].

Studies have demonstrated the varying etiology of COME, including respiratory tract infection, adenoid hypertrophy (including the degree of AH and the location of adenoid), maxillofacial deformity, allergic and immune factors, family environment, breastfeeding methods, etc[8-12]. Adenoids are the immune lymphoid tissues of the nasopharynx. As a part of the immune tissue of the upper respiratory tract, they help prevent upper respiratory tract infections during infancy. The lymphoid tissues of the adenoids of young children often undergo proliferative changes under repeated stimulation by various pathogens, such as bacteria and viruses. This can cause children to open their mouths to breathe. Prolonged mouth breathing can cause maxillofacial deformities. Austin et al. demonstrated that hyperplastic adenoids mechanically block the pharyngeal ostium of the Eustachian tube, resulting in long-term negative pressure in the middle ear and tympanic cavity, which is a common cause of COME in young children[13,14].

Tympanometry is a good non-invasive method for assessing middle ear pressure, which requires a certain degree of cooperation among children. However, traditional tympanometry is not a 100% accurate method for diagnosing the presence of fluids in the middle ear[15,16], especially in type C tympanogram at 226 Hz[11]. Myringotomy

and tympanocentesis are considered the gold standards for the diagnosis of middle ear tympanic effusion and also require a high degree of cooperation between the child and the family. Myringotomy and tympanocentesis not only must be performed under general anesthesia in children but also have operative risks such as poor healing of the tympanic membrane and injury of the auditory ossicles. Therefore, a noninvasive and accurate method for diagnosing COME can be developed on the basis of tympanometry in conjunction with other factors. As visualization tools for statistical models, nomograms can integrate multiple clinical factors, which increase the readability of the results of prediction models.

This study analyzed and explored the risk factors for COME in children with adenoid hypertrophy (AH), constructed a diagnostic prediction model, and displayed it as a nomogram. This model was developed to provide a complementary method for clinical diagnosis in Chinese primary hospitals while avoiding the risks associated with invasive operations.

MATERIALS AND METHODS

The children included in this study because of persistent nocturnal mouth breathing underwent surgical treatment between October 2021 and September 2022 at the Department of Otorhinolaryngology, Head and Neck Surgery, The First Affiliated Hospital of Anhui Medical University. These children all had symptoms of persistent mouth breathing and were diagnosed with AH via lateral nasopharyngeal radiographs with or without hearing loss. Before undergoing surgery, all children received conservative treatment for at least 3 months, including, but not limited to, intranasal steroid treatment and oral montelukast sodium, etc. The children in this study showed poor improvement after these conservative treatments. All pediatric patients underwent fasting blood sampling within 24 hours of admission and, in the absence of contraindications, received surgical intervention within 72 hours. Children with a history of head, middle, or inner ear trauma; nasopharyngeal tumor; Down syndrome; mental illness; mental retardation; congenital hearing impairment; primary disease (heart, liver, kidney, hematopoietic system, etc.); severe malnutrition; severe rickets;

congenital cleft palate; craniofacial; or nervous system development abnormalities were excluded. The family members of the patients agreed with and understood the study.

Invasive examination was easy to cause resistance and violent crying in children, which affected subjective judgment of AH degree classification. Due to the lateral nasopharyngeal projection is more accessible in Chinese primary hospitals and easier for children to accept, this study used the results of lateral nasopharyngeal projections rather than electronic laryngoscopy to determine whether the children had AH[17,18]. The A/N ratio was used to determine the degree of AH. The thickness of the adenoid (A) was the vertical distance from the most prominent point of the inferior margin of the adenoid to the tangent line of the occipital clivus. The width of the nasopharyngeal cavity of the most prominent part of the adenoid (N) was defined as the vertical distance from the posterior end of the hard palate to the intersection of the pterygoid plate and the skull base. The ratio of these two values was recorded as the A/N ratio. There were many methods to diagnose AH in children by lateral nasopharyngeal projection at home and abroad， such as the Fujioka diagnostic criteria[19]. After comprehensive consideration of various standards, we chose the criterion that was more suitable for Chinese national condition. Based on a review of the literature[19-23], the degree of AH is categorized as normal (A /N ≤0.60), moderate (0.60 <A /N ≤ 0.70), and pathological (A/N>0.70). Two senior attending physicians independently interpreted lateral nasopharyngeal radiographs. For the few cases with discrepant A/N ratio measurements among these patients, a chief physician provided final adjudication. Otherwise, the more experienced senior attending physician's measurement was adopted. All physicians were blinded to all of the clinical data. The A/N ratios of the patients participating in this study were >0.60. The tympanometry test was conducted using AT235 by Interacoustics in a quiet room, with a probe tone of 226 Hz. It was classified according to the Liden-Jerger classification system. All patients underwent tympanometry twice: first during the initial clinic visit and again within 24 hours after admitted to the hospital. The tympanometry results obtained during the hospitalization were used for data analysis.

For further statistical analysis, these children were divided into three groups by tympanometry results. Group A consisted of children with tympanogram A in both ears (AA), group C of children with tympanogram C (CC, AC, CA), and group B of children with tympanogram B (BB,BC,CB,AB,BA)[24]. They underwent adenoidectomy and tympanocentesis under general anesthesia. If clinically indicated, these pediatric patients may subsequently undergo myringotomy with or without grommet insertion. The patients were divided into two groups according to the presence or absence of middle ear effusion: AH with and without COME.

Relevant demographic data were obtained from the medical records. The baseline data collected included sex, age, course of AH, height, weight, and season of hospitalization divided using astronomical division method. We evaluated the nutritional status of children using age- and sex-corrected body mass index (BMI). According to the World Health Organization (WHO) 2006 child growth standards, subjects with BMI <P5 of the corresponding sex and age group were considered underweight, those with BMI ≥P85 and < P95 were considered overweight, and those with BMI ≥P95 were considered obese[25,26]. Serum vitamin D3 level was measured using the hospital's chemiluminescence immunoassay (CLIA) platform (CL-8000i, mindray) which coefficient of variation was =<10%. Vitamin D3 deficiency was defined as a serum vitamin D3 level ≤20ng/ml[27]. The percentages of neutrophils, lymphocytes, eosinophils, monocytes, and basophils were counted during routine blood examinations. Allergen test results and total immunoglobulin E (IgE) levels in the blood were also included.

Ethical statement

The study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the ethics committee of The First Affiliated Hospital of Anhui Medical University (Approval No. PJ 2023-13-30). Informed consents were obtained from patients' parents.

Statistical analysis

Descriptive statistics were performed using IBM SPSS Statistics for Windows, version 26.0. Continuous data with normal distributions were expressed as means ± standard deviation, while continuous data with skewed distributions were displayed as medians (p25, p75), and discrete data were presented as N (%). Prior to data filtering, all continuous variables were segmented based on the 5th, 35th, 65th, and 95th percentiles and were consequently converted into categorical variables[28]. The least absolute shrinkage and selection operator (LASSO) method, which is suitable for the reduction in high dimensional data, was used to select the optimal predictive features in risk factors from children with AH[29,30]. A Firth's penalized logistic regression was performed for final variable selection and predictive model development, using the selected features to estimate the probability of the outcome occurrence[31]. A two-sided $p < 0.05$ was considered statistically significant. The prediction model was displayed as a nomogram.

RESULTS

This study included 311 children with AH. The male-to-female ratio of children participating in the study was approximately 3:2. The participants included 186 male patients and 125 female patients divided into two groups (AH with COME and AH without COME) according to the tympanocentesis findings. Table 1 summarized the demographic and clinical characteristics of the participants included in this study.

To mitigate the constraints of linear assumptions, this study did not construct a full restricted cubic spline (RCS) model. Instead, we directly adopted the four knot positions (p5, p35, p65, p95) recommended to convert continuous variables into multi-categorical variables (Table 2) simplified the analytical process while still capturing potential nonlinear trends[28]. Using least absolute shrinkage and selection operator (LASSO) regression, eight features were retained based on the 311 children in this study. These features were age, preoperative tympanometry results, vitamin D3 deficiency, A/N ratio, AH degree, season of hospitalization, the percentages of

lymphocytes and the percentages of basophils (Figure 1). These variables were included in Firth's penalized logistic regression analysis (Table 3), and were reduced to four independent risk factors (preoperative tympanometry results, vitamin D3 deficiency, AH degree and age) that were statistically significant. We established a predictive model including these four factors, which was displayed as a nomogram (Figure 2). The calibration curve of the nomogram for predicting the risk of COME in children with AH showed that the apparent and ideal lines fit well (Figure 3). The C-index for the prediction nomogram was 0.945 (95% confidence interval [CI] 0.941, 0.949). Bootstrap validation, which refitted the coefficients for the final set of predictors, yielded a C-index of 0.934. This further confirmed the high discriminative power of the nomogram. The incidence of AH with COME in this predictive model was 21.2% (66/311) which was similar to Niedzielski et al' s research (20.4% , 110/539)[32]. Within this threshold range of 21.2%, the decision curve was above the none and all lines (Figure 4). The nomogram showed that all patients could benefit from this predictive model within a threshold range of 10%–90%. Therefore, this model showed a significant net benefit for clinical applications.

DISCUSSION

In this study, we developed a tool to aid in the noninvasive diagnosis of COME in children with AH. Traditional examination methods for COME include physical examination and tympanometry and so on. Physical examination of the ear is performed using ordinary otoscopy or the manoeuvre method, both of which determine the presence of fluid in the middle ear by directly observing the color of the tympanic membrane and the state of the tympanic cavity. Electronic otoscopy can cause fear and crying in children and tympanic membrane congestion caused by crying may affect the examiners' judgment. Thus, children with COME may be missed or misdiagnosed. Watters et al. showed that using endoscopy alone was not reliable in determining the presence of middle ear effusion[16].Ma et al. reported that only 63.75% of children with COME showed middle ear effusion during ear examination[33]. All children in the present study underwent a complete physical

examination before the operation. The diagnostic rate of middle ear effusion in the AH with COME group was 65.2% (43/66). The reason for the missed diagnoses might be that the judgment results of the otoscopy were subjective and influenced by the experience of the examiners. Tympanometry, a non-invasive and objective method for detecting pressure changes in the middle ear, is often used to assist in the diagnosis of COME. Wu et al. reported that the preoperative tympanometric pattern of the B-type curve had a higher diagnostic rate for tympanic effusion[34]. However, for patients with COME, there was scope for improvement in the detection rate of traditional otological examination methods. During our study, we indeed had considered including audiological factors. Only auditory brainstem response (ABR) can accurately determine the degree of hearing loss in children of all ages [10]. However, this inspection item is not easily available in Chinese primary level hospitals.

In recent years, the guidelines in various countries have strongly recommended pneumatic otoscopy as an important examination method for the diagnosis of otitis media with effusion [10,35,36]. Because pneumatic otoscopy requires a high degree of cooperation from children and has not been widely popularized, a low proportion of middle ear effusion cases is diagnosed using a pneumatic otoscope. In primary health care, only 7%–33% of physicians use a pneumatic otoscope to diagnose middle ear effusion[10]. Some researchers have reported high specificity and sensitivity of routine middle ear and mastoid scans for diagnosing middle ear effusion[37]. As this examination requires radiation exposure, it is not recommended to confirm the diagnosis of COME for younger patients.

Therefore, the present study developed an easy-to-use noninvasive tool by analyzing the independent risk factors for COME in children with AH and evaluated the efficacy and clinical significance of this tool. The nomogram combines traditional otological examinations with easily collected clinical data. For children with AH, the probability of COME can be obtained by substituting the results of outpatient examinations into the nomogram.

The risk factors for COME in children with AH have been extensively

studied[38]. Although its pathogenesis remains unclear, the development of COME is caused by many factors. Respiratory tract infection, adenoid hypertrophy, maxillofacial deformity, allergic and immune factors, family environment, breastfeeding methods, family economic status, and parental education level are risk factors for COME[8-10], although the results of previous studies differed. The independent risk factors for COME in children with AH identified in this study were AH degree, vitamin D3 deficiency, age, and preoperative tympanometry results.

The study employed lateral nasopharynx radiograph to assess the severity of AH. The results of the present study suggested that the AH degree was associated with the development of COME in children with AH. The more severe the degree of AH, the higher the risk of developing COME. The Eustachian tube is an important anatomical structure that balances air pressure in the middle ear. Hypertrophic adenoid tissue mechanically blocks the pharyngeal orifice of the Eustachian tube, causing negative pressure in the middle ear and promoting middle ear effusion[13]. Furthermore, hypertrophic adenoids act as reservoirs for bacteria that form biofilms. Microorganisms from the upper respiratory tract may travel up the Eustachian tube mucosa to the middle ear tympanic cavity, causing retrograde infection[39]. Although lateral nasopharynx radiograph only provides a two-dimensional assessment of AH and cannot fully depict the specific anatomical relationship of adenoid tissue obstructing the pharyngeal opening of the eustachian tube, a series of studies have demonstrated a significant correlation between measurements obtained from lateral radiographs and those from endoscopic evaluation[40,41]. It remains a valuable tool for estimating the actual size of adenoids and guiding decisions regarding surgical indications.

Vitamin D3, the active form of vitamin D in humans, is synthesized in the skin through ultraviolet-induced photoconversion of cholesterol and can also be acquired through dietary sources such as animal liver. In healthy individuals, sunlight-derived vitamin D3 is typically sufficient to meet physiological requirements. Growing evidence suggested a link between vitamin D3 deficiency and COME in children. A randomized controlled trial demonstrated that daily supplementation with 1000 IU of

vitamin D3 for four months significantly reduced the incidence of OME to 44.8%, compared to 66.5% in the placebo group ($p = 0.03$) among 116 children[42]. This finding is further supported by a cohort study conducted by Walker et al., which indicated that higher serum vitamin D3 levels correlate with a decreased risk of COME[43]. Consistent with these reports, the nomogram developed in our study revealed that lower serum vitamin D3 levels were associated with an increased risk of COME in children with AH. Notably, the prevalence of vitamin D3 deficiency was significantly higher in AH patients with COME compared to those without COME (65.2% vs. 24.9%, $p < 0.01$). This deficiency might contribute to pathological changes such as squamous metaplasia of the tympanic mucosa and impaired mucociliary clearance[44], facilitating the persistence of effusion. And the pathogenic process likely involved colonized bacteria from hypertrophic adenoids migrating via the Eustachian tube, thereby inducing goblet cell hyperplasia in the middle ear epithelium and leading to mucus-rich effusion with elevated mucin content[45]. Importantly, such goblet cell proliferation often persisted despite months of treatment, indicating potential irreversibility[46]. Vitamin D3 might modulate this process through multiple mechanisms. Higher serum levels enhanced the expression of cathelicidin, an antimicrobial peptide; however, high mucin concentrations in middle ear effusion might compromise its efficacy [47,48]. From an etiopathological perspective, vitamin D was involved in regulating several key processes implicated in COME, including immune cytokine networks, Th1/Th2 balance, eradication of pathogens, and Eustachian tube function[49-52]. Dysregulation of Th1/Th2 immunity, particularly Th2-cell overactivation, represented a critical mechanism in COME development. Experimental studies indicated that vitamin D3 could suppress T-lymphocyte proliferation and cytokine secretion, thereby attenuating immune-mediated tissue injury, inhibiting inflammatory cell activation, and reducing local mucin production[53,54]. However, the causal relationship between vitamin D3 deficiency and the development of COME remains unclear. Scholars have reported that the persistence of the inflammatory state affects the conversion of vitamin D[55-57]. The high rate of vitamin D3 deficiency in children with COME may be a

consequence of persistent otitis media.

This study also recorded the seasons of hospitalization of the children. 59.1% of the children in the group AH with COME were admitted for treatment in winter and spring, while the admission rate in the group AH without COME was only 35.5% in winter and spring. There was a significant statistical difference in the admission season between the two groups(χ^2=4.419 ， p=0.031). However, this feature was eliminated in LASSO regression analyses. This might be due to the correlation between seasons and serum vitamin D3 levels. LASSO regression reduces multicollinearity between factors by taking feature selection. In winter and early spring, the sunshine time becomes shorter and the outdoor activity time of children decreases. The vitamin D level was closely related to the degree of sunshine and generally decreased in winter and early spring which had shorter sunshine duration[45,58]. More studies are needed to explore the relationship between the incidences of COME in children with AH and daily sunshine duration.

The nomogram used in this study suggested that younger children were at a higher risk of developing COME. Previous domestic and international studies demonstrated that the incidence of COME tended to be associated with younger age groups[59,60]. The youngest patient in the AH with COME group in the present study was 3 years of age. Younger children are less articulate, have less concentration, and have difficulty understanding the concept of illness or distinguishing between different physical symptoms. Therefore, parents of young children with AH should pay close attention to the possibility of middle ear effusion.

This study developed a predictive model for childhood otitis media with effusion (COME) in patients with adenoid hypertrophy (AH) based on risk factors and tympanometry results, presented as a clinically applicable nomogram. The model provided a personalized and relatively accurate tool for predicting COME, which held significant clinical value given the challenges in early identification of this condition. Specifically, young children with AH often have limited ability to verbalize symptoms, and parental recognition of COME is frequently low[38]. As a result, medical attention is often sought only when children exhibit significant hearing loss or behavioral issues,

such as concentration difficulties noted by school teachers. Moreover, children in rural areas face a higher risk of undiagnosed hearing impairment compared to their urban counterparts[61]. In line with previous reports, our study found that only 31.7% of patients with AH and COME actively complained of hearing loss, a rate consistent with the findings of Brennan-Jones et al.[15].

The model demonstrated strong discriminative ability, with a C-index of 0.934 in internal validation, supporting its robustness and potential for broader application in identifying and managing COME in children with AH. To facilitate clinical use, we established a three-tier risk stratification system based on predicted probabilities: low-risk (<20%), intermediate-risk (20%–60%), and high-risk (>60%). Corresponding management strategies were proposed, including watchful waiting with periodic follow-up for low-risk patients, referral for specialized audiological testing for intermediate-risk cases, and consultation with a specialist for high-risk individuals. This framework was intended as a clinical decision support tool, with final treatment tailored to individual patient conditions.

This retrospective study had some limitations. The selected risk factors were derived from previous studies and clinical observations. While previous studies have shown that family socioeconomic status, indoor air pollution, family size, and pet feeding are associated with the occurrence of COME in children[9,62,63], these potential socioeconomic risk factors were not included in the present study. Evidence also suggests that COVID-19 and its variants may contribute to the development and persistence of middle ear effusion[64]. Further studies are needed to determine the extent to which these factors contribute to the development of COME in children with AH. The bootstrap resampling was limited to refitting the model coefficients for the final set of predictors without repeating variable screening and this single-center retrospective study requires larger external datasets to validate the accuracy and specificity of the nomogram. In this study, given the practical constraints, including limited equipment and technical capabilities in Chinese primary hospitals, this study did not analyze hearing loss in children or use wideband acoustic immittance (WAI) to assess middle ear effusion. Although existing research has shown that WAI

provides higher sensitivity and specificity than conventional 226 Hz acoustic immittance in detecting middle ear effusion[65-67], such methods were not feasible in the current setting. In future studies, we aim to incorporate more comprehensive audiological assessments to further investigate the mechanistic relationships between COME and AH.

CONCLUSION

This study established a supplemental risk prediction model for COME in children with AH based on preoperative tympanometry, AH degree, age, and serum vitamin D3 levels. Clinicians can estimate the probability of this outcome event using this nomogram and provide targeted medical interventions to avoid the adverse effects of COME on the growth and development of children with AH as much as possible. The results of this study must be verified using external data, and further experiments are required to verify the clinical significance of this nomogram.

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TABLES AND FIGURES WITH LEGENDS

Table 1. Univariate analysis of potential risk factors for chronic otitis media with effusion (COME) in children with adenoid hypertrophy (AH)

Variables		AH with COME (*n*=66)	AH without COME(*n*=245)	Total(*n*=311)	Test statistics	p value
Age（year）		6(5,8)	6(4,8)	6(4,8)	Z=-1.217	0.223
Sex					χ^2=0.022	0.881
	Male	40(60.6%）	146(59.6%)	186(59.8%)		
	Female	26(39.4%)	99(40.4%)	125(40.2%)		
AH course (month)		18(9.75,36)	18(12,33)	18(12,36)	Z=-0.114	0.909
Season					χ^2=4.419	0.031
	Winter and spring	30(59.1%)	87（35.5%）	126（40.5%）		
	Summer and autumn	27(40.9%)	158（64.5%）	185（59.5%）		
BMI					χ^2=2.210	0.530
	Normal	41(62.1%)	150(61.2%)	191（61.4%）		

	Underweight	0(0.0%)	7(2.9%)	7（2.3%）		
	Overweight	8(12.1%)	33(13.5%)	41(13.2%)		
	Obesity	17(25.8%)	55(22.4%)	72(23.1)		
A/N ratio		0.82(0.76,0.88)	0.79(0.72,0.86)	0.80(0.72,0.86)	Z=-2.257	0.024
Degree					χ^2=2.417	0.116
	Moderate	9(13.6%)	55(22.4%)	64(20.6%)		
	Pathologic	57(86.4%)	190(77.6%)	247(79.4%)		
Tympanometry					χ^2=106.857	<0.001
	Normal	2(3.0%)	178(72.6%)	180(57.9%)		
	C type	24(36.4%)	34(13.9%)	58(18.6%)		
	B type	40(60.6%)	33(13.5%)	73(16.7%)		
VD3					χ^2=37.851	<0.001
	Normal	23(34.8%)	184(75.1%)	211(67.8%)		
	VD3 deficiency	43(65.2%)	61(24.9%)	100(32.3%)		
Allergen test					χ^2=0.017	0.896
	Normal	34(51.5%)	124(50.6%)	158(50.1%)		
	Positive	32(48.5%)	121(49.4%)	153(49.9)		
Total IgE		60.25(27.80,166.00)	56.30(23.40,134.00)	56.40(25.30,135.00)	Z=-0.500	0.617
NEUT%		44.90(37.15,53.15)	43.80(35.10,51.50)	44.00(36.00,52.20)	Z=-1.406	0.160

LY%	43.29±9.91	45.46±11.46	45.00±11.17	t=1.403	0.162
MONO%	5.90(4.90,7.03)	6.10(5.10,6.90)	6.0(5.10,7.00)	Z=-0.029	0.977
EOS%	2.95(1.80,5.90)	3.10(2.10,5.35)	3.10(2.00,5.40)	Z=-0.731	0.465
BASO%	0.50(0.30,0.80)	0.50(0.40,0.70)	0.50(0.40,0.70)	Z=-0.092	0.927

BASO%: Percentage of basophils in routine blood examinations; BMI: Body mass index; EOS%: Percentage of eosinophils in routine blood examinations; LY%: Percentage of lymphocytes in routine blood examinations; MONO%: Percentage of monocytes in routine blood examinations; NEUT%: Percentage of neutrophils in routine blood examinations; Season: Season of hospitalization.

Table 2. Values of continuous variables at specific percentiles

Variable	P5	P35	P65	P95
Age（year）	3	5	7	11
AH course (month)	4	12	24	60
A/N ratio	0.636	0.760	0.830	0.920
Total IgE	5.485	34.760	99.280	510.600
NEUT%	26.66	38.72	48.70	63.08
LY%	26.50	41.20	49.90	62.34
MONO%	4.00	5.50	6.60	8.62
EOS%	1.1	2.4	4.1	9.5
BASO%	0.2	0.4	0.6	1.0

BASO%: Percentage of basophils in routine blood examination; EOS%: Percentage of eosinophils in routine blood examination; LY%: Percentage of lymphocytes in routine blood examination; MONO%: Percentage of monocytes in routine blood examination; NEUT%: Percentage of neutrophils in routine blood examination.

Table 3. Results of Firth's penalized logistic regression analysis of potential risk factors for chronic otitis media with effusion (COME) in children with adenoid hypertrophy (AH)

Variable	Comparison	Prediction model		
		β*	Odds ratio(95%CI)	*p* value
Age（year）	Age=<3 (Reference)			
	3<Age=<5	-3.880	0.021 (0.002, 0.176)	<0.001
	5<Age=<7	-3.744	0.024(0.002, 0.183)	<0.001
	7<Age=<11	-4.335	0.013 (0.001, 0.110)	<0.001
	Age>11	-4.643	0.010 (0.000,0.156)	<0.001
Tympanometry	Normal (Reference)			
	Type C	3.870	47.93 (13.54, 169.74)	<0.001
	Type B	5.004	148.94 (40.54, 547.43)	<0.001
VD3 deficiency	No (Reference)			
	Yes	1.431	4.18 (1.49, 11.75)	0.006
Degree	Moderate (Reference)			
	Pathologic	2.682	14.61 (1.93, 110.40)	0.008
Intercept		-6.731	0.001 (0.000, 0.20)	0.007

β is the regression coefficient. *

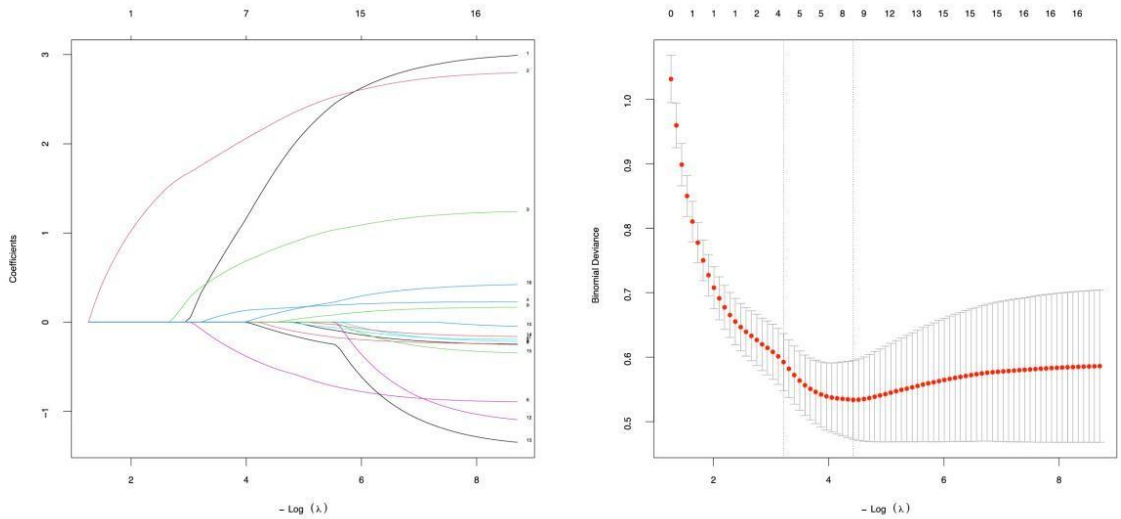

Figure 1. Factor selection utilizing LASSO regression analysis. Least absolute shrinkage and selection operator (LASSO) regression in 311 children with adenoidal hypertrophy produced coefficient profiles for all candidate variables across log(λ) (left) and the cross-validated deviance curve (right). At the optimal value of λ, eight predictors had non-zero coefficients: age, preoperative tympanometry results, vitamin D3 deficiency, A/N ratio, degree of adenoidal hypertrophy, season of hospitalization, percentage of lymphocytes, and percentage of basophils.

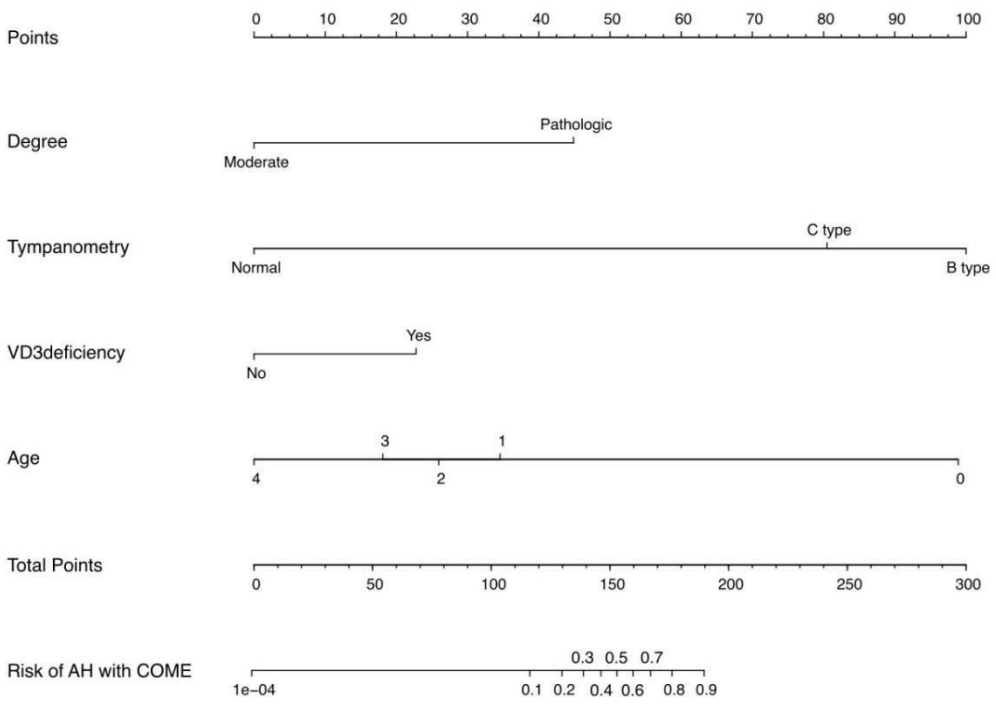

Figure 2. Nomogram for predicting adenoid hypertrophy (AH) in patients with chronic otitis media with effusion (COME). This nomogram is constructed using variables including age, tympanometry results, vitamin D3 deficiency, and the degree of adenoid hypertrophy. The age variable is encoded as follows: 0 indicates ≤3 years; 1 indicates >3 to ≤5 years; 2 indicates >5 to ≤7 years; 3 indicates >7 to ≤11 years; and 4 indicates >11 years.

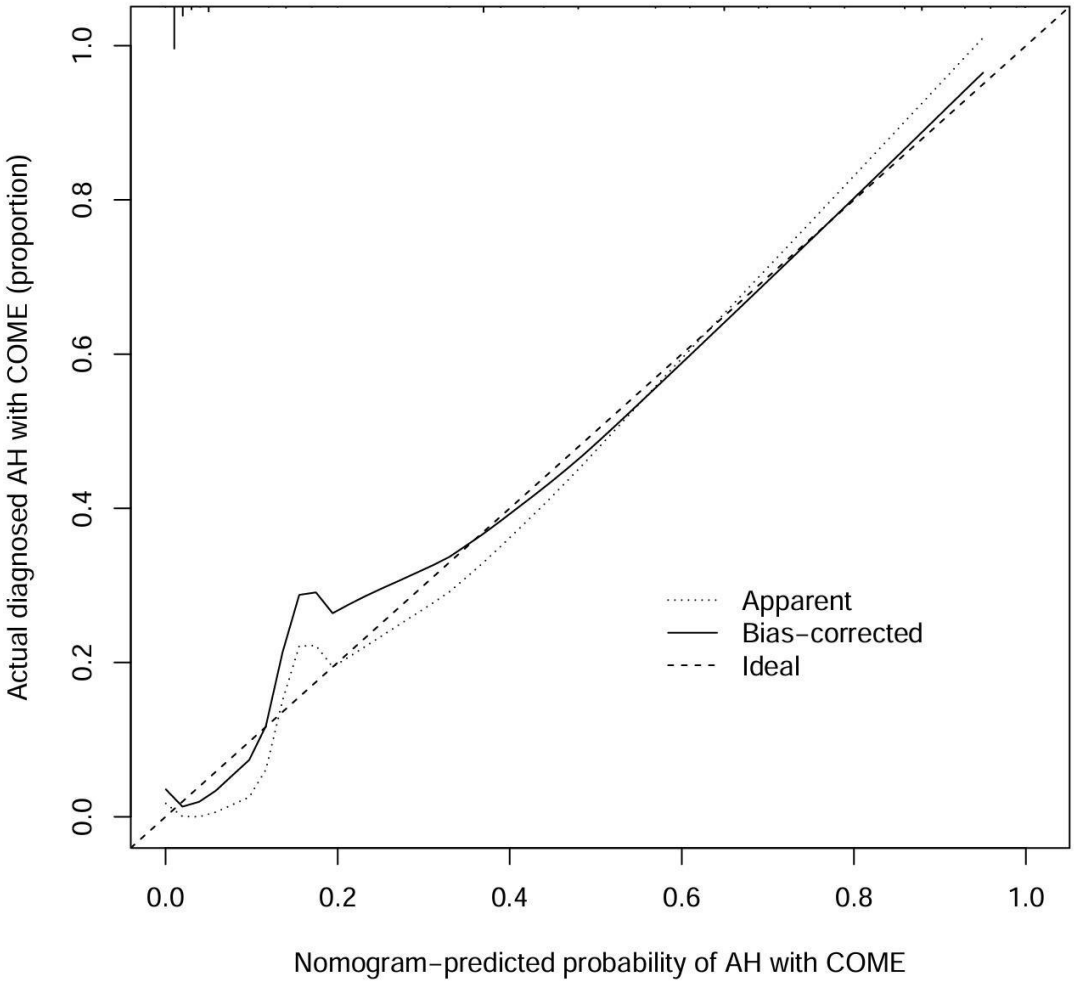

Figure 3. Calibration curves of the nomogram. The bias-corrected line closely aligns with the ideal line, indicating a strong consistency between the model's predicted probabilities and the observed outcomes. Abbreviations: AH: Adenoid hypertrophy; COME: Chronic otitis media with effusion.

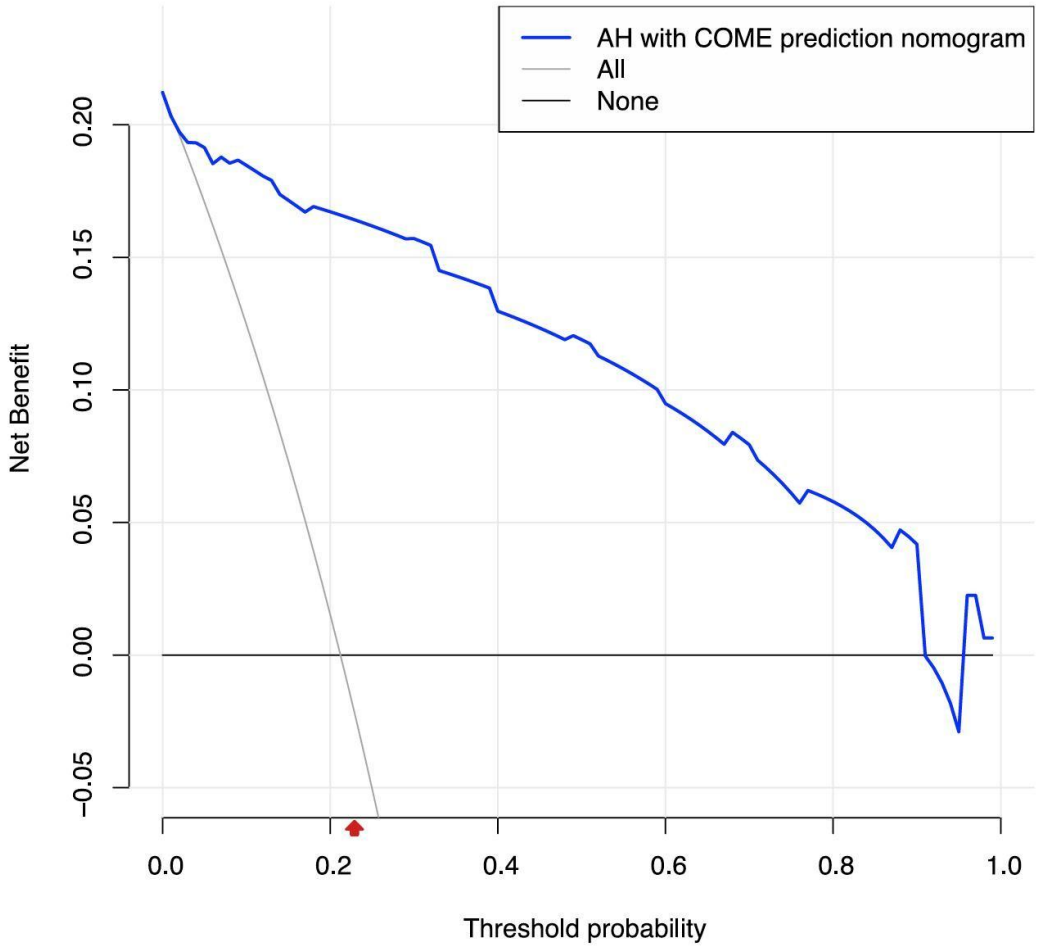

Figure 4. Decision curve analysis of the prediction nomogram of adenoid hypertrophy (AH) with chronic otitis media with effusion (COME). This curve is based on the predicted probabilities derived from the apparent model, represented by the blue line. The figure compares the net benefits of three strategies: (1) the predictive nomogram; (2) the "All" strategy (Treat All), where all children with AH receive routine intervention; and (3) the "None" strategy (Treat None), where no additional intervention is administered to any child. The results indicate that across a broad threshold probability range of 10% to 90%, utilizing our model for clinical decision-making provides a higher net benefit compared to both the "All" and "None" strategies. Across this range of threshold probabilities (10% to 90%), the model provides clinical value by effectively identifying high-risk patients for intervention at any chosen threshold, while avoiding overtreatment of low-risk individuals. The red arrow denotes the incidence rate (21.2%) of COME in children with AH as observed in this study.