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Pulmonary arterial pressure and nasal obstruction in mouth-breathing children: Similarities between adenotonsillar hypertrophy and allergic rhinitis

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Background: **Upper airway obstruction may cause pulmonary hypertension in childhood. In this study we aimed to identify a possible correlation of systolic pulmonary arterial pressure (SPAP), using Doppler echocardiography, with nasal patency (NP), as measured by rhinomanometry, in mouth-breathing (MB) children with allergic rhinitis (AR) and adenotonsillar hypertrophy (ATH).**

Methods: **In this cross-sectional study we evaluated 183 patients, from 2 to 12 years of age, at an MB referral clinic in Brazil, from December 2013 to 2017. We allocated patients to 4 etiology groups: group 1, 60 MBs with ATH; group 2, 47 MBs with AR; group 3, 43 MBs with both ATH and AR; and group 4, 33 nasal breathing control subjects. The ratio of total nasal inspiratory flow (assessed by active anterior rhinomanometry) and expected inspiratory flow adjusted for height determined the percent NP (%NP).**

Results: **The median %NP was higher in controls than in the MB groups (controls, 114% [79-147%]; ATH: 65% [5-116%]; AR: 57% [23-144%]; ATH and AR: 64% [3-120%]; $p < 0.001$). Median SPAP was higher in the MB groups than in controls (SPAP: ATH, 26.0 [20.0-35.0] mmHg; AR, 26.0 [22.0-32.0] mmHg; ATH and AR, 26.30 [20.0-34.0] mmHg; control, 22.0 [16.0-30.0] mmHg; $p < 0.001$). SPAP showed a negative association with %NP (Spearman's rho = −0.24; $p < 0.001$).**

Conclusion: **Reduced nasal airflow in MB children showed a correlation with higher levels of systolic pulmonary arterial pressure. The AR and ATH groups were similar in nasal obstruction severity and systolic pulmonary arterial pressure level distribution.** © 2020 ARS-AAOA, LLC.

Key Words:
allergic rhinitis; Doppler echocardiography; mouth breathing; nasal airway obstruction; pulmonary hypertension; rhinomanometry

***How to Cite this Article*:**
Ferreira Nader CMF, Capanema FD, Franco LP, et al. Pulmonary arterial pressure and nasal obstruction in mouth-breathing children: Similarities between adenotonsillar hypertrophy and allergic rhinitis. *Int Forum Allergy Rhinol.* 2021;11:128–135

The most common causes of upper airway obstruction (UAO) are adenotonsillar hypertrophy (ATH) and allergic rhinitis (AR), both of which can lead to mouth breathing (MB) in children. Patients with AR show a hypersensitivity reaction of the nasal mucosa mediated by immunoglobulin E and T helper 2 (Th2) cells. This reaction causes mucosal edema and may increase upper airway resistance (UAR).[1-4]

A cardiovascular consequence of this increased UAR is pulmonary hypertension (PH). Persistent UAO can result in chronic and severe PH and eventually cause cor pulmonale. UAO can lead to hypoxemia, hypercarbia, and

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Funding sources for the study: Fundação de Amparo à Pesquisa do Estado de Minas Gerais (Project 01/11 CDS APQ 01).

Received: 9 October 2019; Revised: 7 May 2020; Accepted: 8 May 2020
DOI: 10.1002/alr.22651
View this article online at wileyonlinelibrary.com.

respiratory acidosis, which are potent mediators of pulmonary vasoconstriction. This pulmonary vasoconstriction increases the systolic pulmonary arterial pressure (SPAP). In the acute phase, pulmonary vasoconstriction is insidious, asymptomatic, and reversible. However, chronic vasoconstriction results in structural remodeling of the pulmonary vascular bed and subsequently causes irreversible PH.[5,6] The reported prevalence of PH among children with ATH in echocardiography studies varies from 0% to 84.6%.[5-12] Although AR is associated with increased UAR and sleep-disordered breathing in pediatric patients, only a few studies have investigated PH in patients with AR.[13-16]

Although one can question whether tonsil hypertrophy and UAR pose a cardiovascular risk, the correlation between nasal obstruction and SPAP levels remains underexplored. Active anterior rhinomanometry (AAR) is a reliable method to assess nasal obstruction severity and UAR by providing objective measurements of nasal patency.[17-20] Therefore, it is possible to score functional nasal obstruction with AAR and correlate it with other variables, such as SPAP levels.

In this study we aimed to correlate SPAP measurements, obtained through Doppler echocardiography, with nasal patency (NP), as measured by AAR in MB children with AR and/or ATH.

Patients and methods

Study design and subjects

This cross-sectional study was conducted from December 2013 to 2017 at the MB outpatient clinic of the Hospital das Clínicas at the Universidade Federal de Minas Gerais (HC-UFMG). All assessments performed in this study are part of the MB clinic protocol routinely used at the HC-UFMG. Participants' rights were protected, and informed consent and assent were obtained according to the ethics committee of the Universidade Federal de Minas Gerais (UFMG), which approved our study.

The MB clinic has had a multidisciplinary team since 2002, which specializes in MB syndrome. In the Brazilian Public Health System (SUS), pediatricians from Minas Gerais state refer children aged 2 to 12 years who need specialized otolaryngologic care to the MB outpatient clinic.

From December 2013 to 2017, the MB clinic multidisciplinary team evaluated 476 children. The team consisted of an allergist, a pulmonologist, a pediatrician, an otorhinolaryngologist, a sleep doctor, an orthodontist, a speech therapist, and a physiotherapist. A questionnaire to assess the symptoms of UAO, with a sensitivity of 0.85 and specificity of 0.87 to detect respiratory sleep disorders, was applied in all patients, as proposed by Chervin et al.[21] The parents provided information about the frequency and quality of snoring, breathing problems, MB, daytime sleepiness, inattention, or hyperactivity. Other symptoms were also reported, such as nocturnal enuresis, morning headache, history of allergy or asthma, delayed growth, and obesity.[21]

The otorhinolaryngologic examination involved collection of medical history, weight and height measurements, otoscopy, oroscopy, anterior rhinoscopy, and fibronasolaryngoscopy. An otorhinolaryngologist evaluated the pharyngeal tonsil hyperplasia by performing endoscopy with a 3.2-mm flexible nasal fiberscope (Machida ENT IIIP). To assess the adenoid tissue present in nasal cavities, an otorhinolaryngologist estimated the percentage of nasopharynx obstruction. The allergologic assessment included a structured medical interview, a physical examination, and a skin test (ST). An allergist performed the ST in accordance with the standard volar forearm skin-prick method, using extracts from International Pharmaceutical Immunology of Brazil.

We selected 150 children with MB (mean age, 6.47 ± 2.47 years; median body mass index [BMI], 16.3 [15-18] kg/m^2) who met the diagnostic criteria for the study, and we divided them into 3 etiologic groups as follows (Fig. 1):

1. *ATH*: Patients with sleep-disordered breathing symptoms and one of the following indications for adenotonsillectomy[22-24]: (1) pharyngeal tonsils occupying >75% of the nasopharynx lumen in the fibronasolaryngoscopy; and (2) grade 3 or 4 palatine tonsil hypertrophy, according to the Brodsky classification.[22-24]
2. *AR*: Patients with a history of AR for at least 2 years, a positive family history of atopy, and a positive ST for inhalant allergens. The reading was obtained 15 minutes after the puncture, and the test was considered to be positive if the papules had a mean diameter at least 3 mm larger than the negative control.[25]
3. *ATH and AR*: Patients who met the diagnostic criteria for both groups 1 and 2.

The researchers selected 33 control participants who did not present with MB or clinical symptoms of nasal obstruction and were referred by pediatricians for a routine outpatient visit at the HC-UFMG. They had the same age range as the MB group (2-12 years) and similar age, height, weight, and BMI distribution (mean age, 7.02 ± 2.60 years; median BMI, 15.8 [range, 13-22] kg/m^2).

We excluded patients using corticosteroids, nasal decongestants, or antihistamines in the last 30 days and children who could not perform the assessments proposed at admission or whose parents refused to participate in the study. We also excluded patients presenting with MB who were diagnosed with any of the following conditions:

- Neuromuscular disease, genetic syndromes, and chronic comorbidities (except for asthma).
- Perforation of the nasal septum and craniofacial alterations.
- Pulmonary hypertension due to heart disease or other causes that were previously detected by echocardiography.
- Previous adenotonsillectomy.
- Upper or lower respiratory tract infection in the last 14 days.

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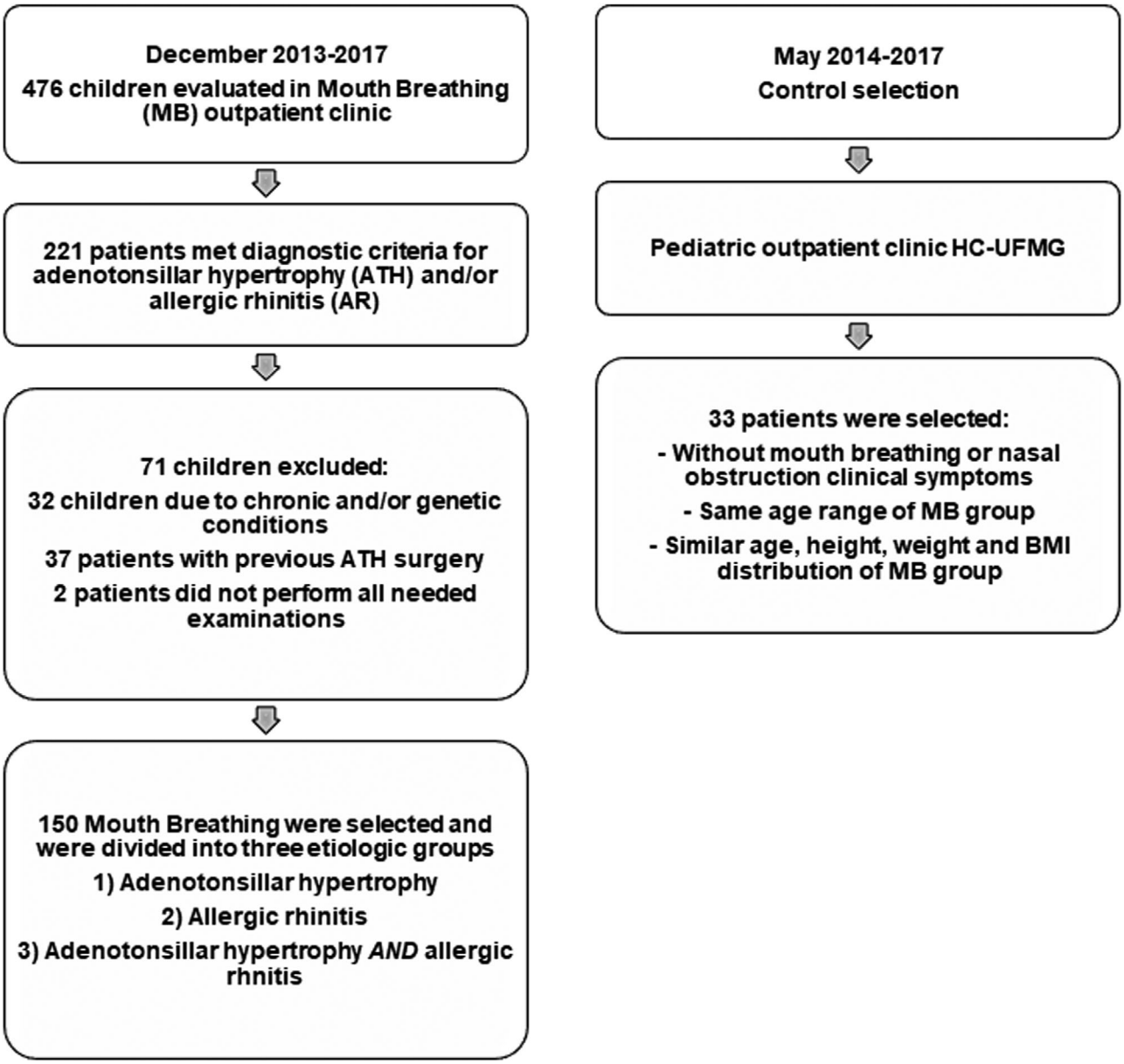

FIGURE 1. Sample selection. AR = allergic rhinitis; ATH = adenotonsillar hypertrophy; MB = mouth breather.

Thus, after the MB clinic visit and group selection based on the inclusion criteria, children were prospectively enrolled in the study.

Procedures

All children underwent fibronasolaryngoscopy, anterior active rhinomanometry (AAR), and Doppler echocardiography. The study population did not undergo polysomnography because of the limited accessibility of this examination in the SUS.

Anterior active rhinomanometry

A trained medical doctor performed the AAR using the SR 2000 N 010000300189 Rhinoscan 0272CFB2 rhinomanometer with Rhinostream 038CC5C3. In each nostril at a transnasal pressure of 150 Pa,[26] the inspiratory nasal flow values were measured between 1:00 and 5:00 PM, with temperature ranging from 71.6° to 86°F. Before the examination, we asked the participants to proceed to nasal hygiene, sit quietly for 30 minutes for acclimatization, and maintain a seated upright posture throughout the measurements. All measurements were done separately in each nostril during normal breathing with the mouth closed. The opposite nostril was blocked with an appropriate nasal plug. Patients' nostrils were fitted with nasal adapters of adequate size to obtain the measurements, and these adapters were connected to the flow and pressure sensors. Three normal breaths were required for each measurement.

To determine total inspiratory nasal airway flow (TINAF), we added the nasal inspiratory airflow in the left and right nostrils. First, we used the inspiratory nasal flow values to define the nasal resistance variables obtained by rhinomanometry, as proposed by Zapletal et al.[26] To estimate the inspiratory nasal flow as expected by height, we used the following formulas: male gender, 1.64115 + 0.96143 × Neperian height log (in centimeters); and female gender, 1.71609 + 0.9479 × Neperian height log (in centimeters). In addition, the percent nasal patency (%NP) was calculated by dividing the total nasal airflow by the total expected nasal airflow, according to a height-predicted value.[26]

Doppler echocardiography

After the otolaryngologic visit, the researchers referred the selected patients to the HC-UFMG echocardiography center. Two pediatric echocardiographers at the HC-UFMG performed Doppler echocardiography using color flow mapping (Philips IE33). The echocardiographers performed these assessments without the knowledge of the patient groups or otolaryngology data.

For SPAP analysis, tricuspid regurgitation jet (TcV) velocity was measured using the apical window in the 4-chamber apical section, which allowed evaluation of the systolic peak velocity, right atrial pressure (RAP), and the modified Bernoulli formula (4 × Vtc2 + DTAP). By assessing the interval between the beginning and the peak of the pulmonary flow wave, the pulmonary velocity acceleration time (TAc) was calculated. We used an average of 3 beats. The SPAP's upper limit of normality was 34.99 mmHg.[27-30]

Statistics

Patient sample size was calculated by performing comparative studies[7,8,10] involving 2 proportions: comparison of PH prevalence in the MB group vs the control group (CG). We considered a PH prevalence of 10% in the CG and ≥60% in the MB group. Then, to detect differences between the 2 groups of at least 50% ($\alpha = 0.05$ and $\beta = 0.10$), a minimum of 21 patients would be needed in each group.

Data are expressed as median with 95% confidence intervals (CIs). Nonparametric methods were used with R version 3.4.3 software.[31] $p < 0.05$ was considered significant. Fisher's exact test with the mid-p method (an odds ratio function of the epitools library) was used to compare binary variables between the groups.[32] The Mann-Whitney-Wilcoxon test (wilcox.test function, basic library) was used to compare the other variables. To check for associations between 2 continuous numerical variables, Spearman's correlation test was applied (cor.test function, basic library). Logistic regression was used to correct confounding variables in the p-value calculation (glm function, basic library). The library ggplot2 was used to design the graphs.[33]

Results

Demographics of study population and clinical features of MBs

Our study consisted of 183 patients, including: 33 controls (10 boys; mean age, 7.02 ± 2.60 years; median BMI, 15.8 [13-22] kg/m^2) and 150 MBs (102 boys; mean age, 6.47 ± 2.47 years; median BMI, 16.3 [15-18] kg/m^2), divided into the following 3 etiologic groups: group 1, 60 children with ATH; group 2, 47 children with AR; and group 3, 43 MB children with ATH and AR (Table 1).

Rhinomanometry

All controls showed normal patency (Table 2), and 73.3% of the patients with MB showed decreased nasal patency (80% in the AR group, 68.3% in the ATH group, and 72.1% in the ATH and AR group). The %NP median values were 64% (3-144%) in the MB group, 57% (23-144%) in the AR group, 65% (5-116%) in the ATH group, and 64% (3-120%) in the ATH and AR group (Fig. 2). We classified all %NP medians in the MB groups with moderate obstruction. In the control group, the %NP median was 114% (79-147%), classified as normal patency and significantly greater than that in the MB group ($p < 0.001$).

Doppler echocardiography

All children had grade 1 tricuspid regurgitation. SPAP was markedly higher in MB patients than in controls (Table 3); TAc was noticeably lower in MB patients ($p < 0.001$), and ejection fraction (%) had a normal value, but was lower in MB patients ($p = 0.024$). Median SPAP was higher in MB patients (Fig. 3) than in controls (STH, 26.0 [20.0-35.0] mmHg; AR, 26.0 [22.0-32.0] mmHg; ATH and AR, 26.30 [20.0-34.0] mmHg; vs control, 22.0 [16.0-30.0] mmHg; $p < 0.001$). One of 150 MB patients presented with PH (0.67%), whereas 21 MB patients (14%) presented with SPAP ≥30 mmHg.

The presence of asthma did not influence the SPAP or %NP in MB patients. Median SPAP was 27 mmHg in patients with asthma and 26 mmHg in patients without asthma ($p = 0.112$). Median %NP was 63.5% in patients with asthma and 62.8% in those without asthma ($p = 0.112$).

Correlation between %NP and SPAP

In a comparison of MB patients and controls, those with MB had higher SPAP ($p < 0.001$) and lower %NP ($p < 0.001$). Spearman's correlation coefficient indicated an inverse relationship between the SPAP and %NP (Spearman's rho = −0.24; $p < 0.001$; Fig. 4).

Discussion

Our study is among the first to compare systolic pulmonary arterial pressure (SPAP) levels with nasal

TABLE 1. Demographics of the study population and MB clinical features

Variables	Controls (n = 33)	MB (n = 150)	95% CI[a]	*p*	Effect size
Boys (n)	30% (10)	68% (102)		<0.001[b]	
Age (years)	7.02 (SD, 2.60)	6.47 (SD, 2.47)	(−0.40 to 1.55)	0.247[c]	0.217
Weight (kg)	24.5 (range, 11-50)	21.3 (range, 10-58)	—	0.332[d]	0.446
Height (m)	1.23 (SD, 0.18)	1.18 (SD, 0.17)	(−0.01 to 0.11)	0.117[c]	0.286
BMI (kg/m^2)	15.8 (range, 13-22)	16.3 (range, 15-18)	—	0.343[d]	0.447
ATH (n)		60			
AR (n)		47			
ATH and AR (n)		43			
Diagnosed asthma		34.7%			
Snore		90.9%			
Witnessed apnea		59.4%			
Daytime sleepiness		42.5%			
Restless sleep		72.6%			
Nocturnal enuresis		29.5%			
Nocturnal bruxism		41.1%			
Arousals		45.5%			
Morning headache		37.2%			
Learning disabilities		35.3%			

AR = allergic rhinitis; ATH = adenotonsillar hypertrophy; BMI = body mass index; CI = confidence interval; MB = mouth breather; SD, standard deviation.
[a]95% CI for mean difference.
[b]Fisher´s exact test.
[c]*t* test for independent groups (normal distribution).
[d]Mann-Whitney *U* test (non-normal distribution).

TABLE 2. Nasal airway measurements in MB and controls

	Controls (n = 33)		MB (n = 150)			
Variable (cm^3/s)	Median	Range	Median	Range	*p*[a]	Effect size[b]
RNF_{insp}	292	180-374	148	4-448	<0.001	0.127
RNF_{exp}	294	134-401	148	3-455	<0.001	0.140
LNF_{insp}	312	196-442	144	2-484	<0.001	0.101
LNF_{exp}	318	195-505	146	1-524	<0.001	0.106
INF_{esp}	538.36	386-681	501.43	356-665	0.096	0.407
FINT	606	376-795	326	10-587	<0.001	0.019
NP%	114%	79-147%	63%	2-144%	<0.001	0.055

FINT = total nasal inspiratory flow; INF_{esp} = nasal inspiratory flow expected by height; LNF_{insp} = left nasal inspiratory flow; LNF_{exp} = left nasal expiratory flow; MB = mouth breather; NP% = nasal patency percentage; RNF_{exp} = right nasal expiratory flow; RNF_{insp} = right nasal inspiratory flow.
[a]Mann-Whitney *U* test (non-normal distribution).
[b]Adjusted effect size for nonparametric measure.

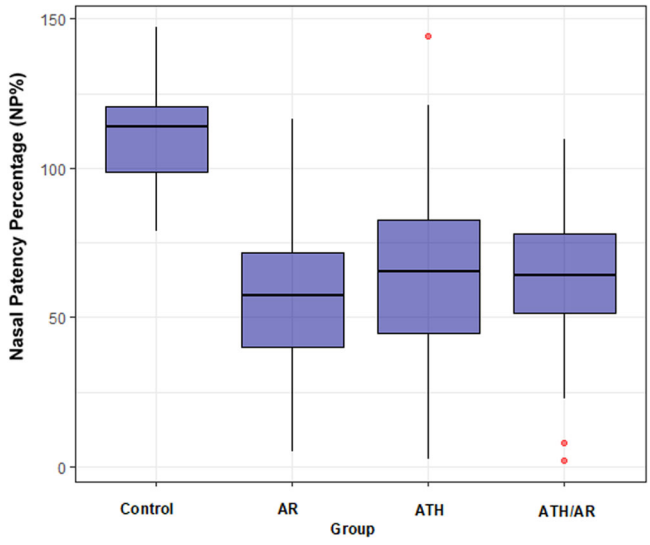

FIGURE 2. Boxplot graph of NP% distribution in controls and in groups of MB. AR = allergic rhinitis; ATH = adenotonsillar hypertrophy; MB = mouth breather.

patency in nasal breathing vs MB in children, allowing discrimination of upper airway obstruction etiology. The data suggest that increased UAR may similarly increase the SPAP in AR and ATH, indicating cardiovascular risk in both conditions.

TABLE 3. Doppler echocardiography variables in MBs and controls

Variables	Controls (n = 33)		MBs (n = 150)		p^a	Effect size[b]
	Median	Range	Median	Range		
RV	13.8	12-15	12.8	9-19	0.124	0.341
Ved	38	32-47	37	15-45	0.842	0.489
Ves	22	18-30	23	17-46	0.306	0.443
SIV	6	4-7	5	4-29	0.093	0.409
PW	5	4-7	5	4-8	0.709	0.480
FE%	74	63-79	71	6-79	0.015	0.365
FS%	38	10-45	39	32-75	0.397	0.453
Ao	19	16-25	21	15-37	0.060	0.396
LA	24	18-29	24	18-33	0.627	0.473
SPAP	19	16-30	26	20-35	<0.001	0.158
MPAP	14	12-20	18	14-23	<0.001	0.158
Tac	133	100-148	121	83-148	<0.001	0.253

Ao = aorta; FE% = ejection fraction percent; FS% = systolic fraction percent; LA = left atrium; MB, mouth breather; MPAP = mean pulmonary arterial pressure; PW = posterior wall; RV = right ventricle; SIV = interventricular septum; SPAP = systolic pulmonary arterial pressure; TAc = acceleration time of pulmonary fraction; Ved = diastolic ejection volume; Ves = systolic ejection volume.
[a]Mann-Whitney *U* test (non-normal distribution).
[b]Adjusted effect size for nonparametric measure.

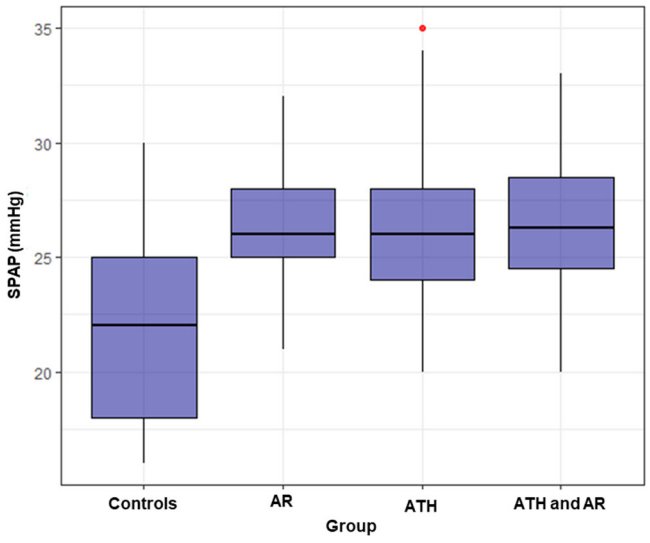

FIGURE 3. Boxplot graph of systolic pulmonary arterial pressure distribution in controls and mouth-breathing groups.

Furthermore, the similarity between nasal obstruction and SPAP elevation reinforces the importance of properly treating AR. In childhood, although AR is a chronic condition associated with obstructive sleep apnea (OSA) and its possible cardiovascular complications, it is often neglected and seen as less severe than ATH. Although tonsil hypertrophy in children is frequently treated with adenotonsilectomy or shows physiologic regression during childhood, AR is a lifelong disease. Nevertheless, only a few studies have evaluated SPAP in children with AR, with higher levels of SPAP seen in AR patients when compared with controls.[6,14-16]

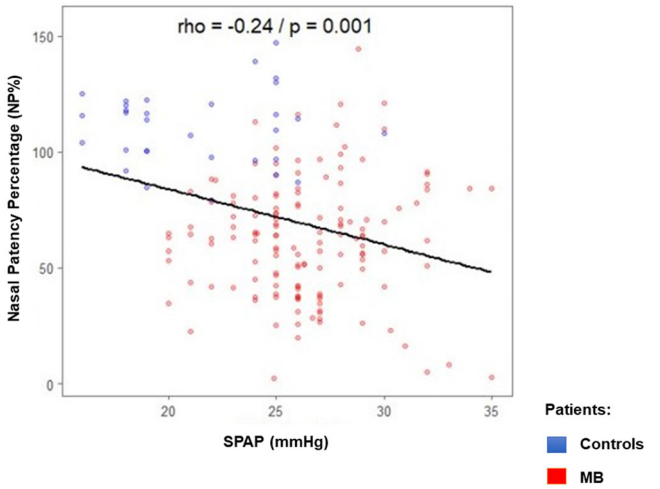

FIGURE 4. Correlation between systolic pulmonary arterial pressure and percent nasal patency.

The present results highlight the cardiovascular risk in MB children with ATH and AR, although the clinical and prospective significance of the SPAP increase in childhood remains unclear.[27,29] In our sample, the SPAP increase was mild, and only 1 of 150 children (0.67%) had PH (SPAP, 35 mmHg), yet 14% had SPAP >30 mmHg. We referred all those patients for cardiologic consultation.

The methods and cutoff values for SPAP measurements in diagnosing PH are variable and controversial, which can partly explain the wide variability of PH prevalence among UAO patients (0-84%).[5-12] Some studies used a **mean pulmonary arterial pressure** (MPAP) cutoff value of 20 mmHg in accordance with Park et al,[36] and the calculation of MPAP was performed using the acceleration time of pulmonary fraction (TAc). This parameter may be unreliable, especially in children. Heart rate is increased in children, which may shorten the pulmonary artery acceleration time. From 2009, the PH cutoff was regarded as PMAP ≥25 mmHg or PSAP ≥35 mmHg.[27,29]

We considered PH when SPAP was ≥35 mmHg, in accordance with recent cardiovascular guidelines,[10,29] but SPAP between 30 and 35 mmHg is considered altered.[27,29] Children with SPAP ≥30 mmHg should be followed up to prevent cardiovascular deterioration, the actual significance of which has not yet been elucidated.[27,29] Meanwhile, if UAO is left untreated, chronic hypoxia and hypercapnia could impair pulmonary vasculature and culminate in PH.[10,35]

Continuous-wave Doppler measurement of peak tricuspid regurgitation was used for the SPAP calculation with echocardiography because it has lower interobserver variability and is a noninvasive, safe, and low-cost assessment. In contrast, cardiac catheterization is the "gold

standard" for PH diagnosis, and it is often required before initiating treatment. Nevertheless, it is invasive and may pose a greater risk in children than in adults. In contrast, transthoracic echocardiography is the first examination performed in the diagnostic algorithm for suspected PH. We used it to infer a diagnosis, visualize the effects of PH on the heart, and estimate PAP from continuous-wave Doppler measurements.[10,29,34]

Two studies in African populations used the same measurement method and SPAP cutoff values we used for PH estimation. Both of those studies showed a significantly higher prevalence of PH in ATH children: 21.9% (27 of 123 Kenyans) and 43.6% (17 of 39 Nigerians).[5,9] However, the children in those study samples were younger than those in our sample, with a median age of 2.5 years and 3.4 years in Nigerians and Kenyans, respectively. UAO tends to be more severe in infants and young children. Consequently, it may reflect a more severe cardiovascular impact. Furthermore, their studies had different populations with different socioeconomic conditions.

Other studies did not find PH in their samples, although we noted ventricular dysfunction and higher SPAP levels in the ATH group when compared with controls. In addition, some studies also showed that SPAP levels decreased after adenotonsillectomy.[12,37]

On the other hand, other explanations for the variabilities in PH prevalence rely on differences in nasal patency, OSA presence, severity, and duration. The majority of studies did not estimate these variables. OSA is known to lead to cardiovascular alterations, and hypoxia during sleep can cause SPAP elevation.[18,35,38] Regardless, in a recent retrospective study, only 3 of 163 (1.8%) of patients with OSA were diagnosed with PH. Of these patients, 2 were obese, and all 3 had comorbid cardiac disorders.[6] According to Dehlink et al, PH is not commonly seen in children with OSA, who tend to have more subtle evidence of cardiovascular dysfunction, such as dysregulation of blood pressure (BP), cardiac remodeling, and endothelial dysfunction.[39]

A limitation of our study is that the presence of OSA was not estimated by polysomnography or sleep studies, because they are extremely expensive and difficult to access in the Brazilian Public Health System. Clinical symptoms of OSA, such as snoring and witnessed apnea, were present in 90.9% and 59.4%, respectively, of the MB patients. Nevertheless, in our earlier study at the same MB outpatient clinic with a smaller sample of 21 children who underwent polysomnography, we found that 61.9% of children with ATH had OSA before adenotonsillectomy.[42]

The major limitation of this research is related to the uncertainty and risk of developing PH or other cardiovascular complications. As a cross-sectional study, the prospective cardiologic meaning of increased UAR over time, and the impact of both clinical and surgical treatment of AR and ATH on SPAP were not assessed. As already demonstrated, SPAP may decrease 6 months after UAO is alleviated through adenotonsillectomy in ATH children. Nevertheless, it is also possible that, as children grow, their NP increases and adenotonsillar obstruction decreases. As demonstrated in our previous study, OSA is not resolved after adenotonsillectomy in all children. Therefore, OSA symptoms must be followed up after surgery. In contrast, it is important to consider that AR is chronic, persistent over the lifetime, and must always be clinically assessed and properly treated.[12,42]

The ejection fraction percentage was lower in the MB group but was still above the reference value and did not present apparent clinical meaning. Moreover, other studies demonstrated a reduction in ejection fraction and abnormalities in cardiac muscle contraction in children with OSA and ATH.[40,41]

Nasal patency calculation is based on the study by Zapletal et al,[20] who analyzed Caucasians using anterior active rhinomanometry (AARM). Studies have shown that nasal patency in Brazilians is greater than in Caucasian and Japanese patients.[18,20,44] To our knowledge, there are no studies with rhinomanometry reference values for the Brazilian population.

This study has demonstrated, with an adequate sample size, that AR and ATH groups are similar in nasal obstruction severity and SPAP levels, and that nasal patency may correlate with SPAP increase. In severe cases of elevated UAR, Doppler echocardiography could be performed to evaluate SPAP.

Conclusion

Reduced nasal airflow in children with AR and ATH correlates with higher levels of SPAP. The AR and ATH groups are similar in nasal obstruction severity and SPAP level distribution. Only 1 of 150 MB patients presented mild PH, and 14% had SPAP $\geq$30 mmHg. Further study is needed to identify the clinical significance of these cardiologic alterations over time.

The authors are grateful for the funds provided by the Minas Gerais Research Support Foundation, which also supported acquisition of the rhinomanometer. We also thank the patients who participated in our study. Finally, we thank the entire multidisciplinary team of the MB outpatient clinic at the HC-UFMG for their commitment and dedication to comprehesive health care of patients and ongoing scientific development.

References

1. Lee DJ, Chung YJ, Yang YJ, Mo JH. The impact of allergic rhinitis on symptom improvement in pediatric patients after adenotonsillectomy. *Clin Exp Otorhinolaryngol*. 2018;11:52-57.
2. Cao Y, Wu S, Zhang L, Yang Y, Cao S, Li Q. Association of allergic rhinitis with obstructive sleep apnea: a meta-analysis. *Medicine (Baltimore)*. 2018;97:e13783.
3. Maripov A, Mamazhakypov A, Sartmyrzaeva M. Right ventricular remodeling and dysfunction in obstructive sleep apnea: a systematic review of the literature and meta-analysis. *Can Respir J*. 2017;1-13. https://doi.org/10.1155/2017/1587865.

4. Mahajan M, Thakur JS, Azad RK, Mohindroo NK, Negi PC. Cardiopulmonary functions and adenotonsillectomy: surgical indications need revision. *J Laryngol Otol*. 2016;130:1120-1124.
5. Marangu D, Jowi C, Aswani J, Wambani S, Nduati R. Prevalence and associated factors of pulmonary hypertension in Kenyan children with adenoid or adenotonsillar hypertrophy. *Int J Pediatr Otorhinolaryngol*. 2014;78:1381-1386.
6. Burns AT, Hansen SL, Turner ZS, Aden JK, Black AB, Hsu DP. Prevalence of pulmonary hypertension in pediatric patients with obstructive sleep apnea and a cardiology evaluation: a retrospective analysis. *J Clin Sleep Med*. 2019;15:1081-1087.
7. Yilmaz MD, Onrat E, Altuntas A, et al. The effects of tonsillectomy and adenoidectomy on pulmonary arterial pressure in children. *Am J Otolaryngol*. 2005;26:18-21.
8. Naiboglu B, Deveci S, Duman D, et al. Effect of upper airway obstruction on pulmonary arterial pressure in children. *Int J Pediatr Otorhinolaryngol*. 2008;72:1425-1429.
9. Orji FT, Ujunwa FA, Umedum NG, Ukaegbe O. The impact of adenotonsillectomy on pulmonary arterial pressure in West African children with adenotonsillar hypertrophy. *Int J Pediatr Otorhinolaryngol*. 2017;92:151-155.
10. Martha VF, Moreira JS, Martha AS, Velho FJ, Eick RG, Goncalves SC. Reversal of pulmonary hypertension in children after adenoidectomy or adenotonsillectomy. *Int J Pediatr Otorhinolaryngol*. 2013;77:237-240.
11. Tatlipinar A, Biteker M, Meric K, Bayraktar GI, Tekkesin AI, Gokceer T. Adenotonsillar hypertrophy: correlation between obstruction types and cardiopulmonary complications. *Laryngoscope*. 2012;122:676-680.
12. Ramos VM, Nader CM, Meira ZM, et al. Impact of adenotonsilectomy on nasal airflow and pulmonary blood pressure in mouth breathing children. *Int J Pediatr Otorhinolaryngol*. 2019;125:82-86.
13. Lima MS, Nader CMFF, Franco LP, et al. Pulmonary hypertension evaluation by Doppler echocardiogram in children and adolescents with mouth breathing syndrome. *Braz J Otorhinolaryngol*. 2017;83:292-298.
14. Bayrak P, Kirmaz C, Sekuri C, Yuksel H. Is pulmonary arterial pressure affected by allergic rhinitis with nasal obstruction? *Asian Pac J Allergy Immunol*. 2007;25:121-126.
15. Reisli I, Oran B, Baspinar O, Baysal T, Karaaslan S. Pulmonary arterial pressure in children with allergic rhinitis. *Am J Rhinol*. 2004;18:227-232.
16. Yuksel H, Coskun S, Onag A. Doppler echocardiographic evaluation of pulmonary arterial pressure in children with allergic rhinitis. *Int J Pediatr Otorhinolaryngol*. 2001;60:21-27.
17. Ren L, Zhang L, Duan S, Zhang W, Zhang Y. Nasal airflow resistance measured by rhinomanometry in a healthy population of China. *Int Forum Allergy Rhinol*. 2018;8:1308-1314.
18. Kobayashi R, Miyazaki S, Karaki M. Measurement of nasal resistance by rhinomanometry in 892 Japanese elementary school children. *Auris Nasus Larynx*. 2011;38:73-76.
19. Eccles R. A guide to practical aspects of measurement of human nasal airflow by rhinomanometry. *Rhinology*. 2011;49:2-10.
20. Demirbas D, Cingi C, Cakli H, Kaya E. Use of rhinomanometry in common rhinologic disorders. *Expert Rev Med Devices*. 2011;8:769-777.
21. Chervin RD, Hedger K, Dillon JE, Pituch KJ. Pediatric sleep questionnaire (PSQ): validity and reliability of scales for sleep-disordered breathing, snoring, sleepiness, and behavioral problems. *Sleep Med*. 2000;1(1):21-32. https://doi.org/10.1016/s1389-9457(99)00009-x.
22. Cassano P, Gelardi M, Cassano M, Fiorella ML, Fiorella R. Adenoid tissue rhinopharyngeal obstruction grading based on fiberendoscopic findings: a new approach to therapeutic management, *Int J Pediatr Otorhinolaryngol*. 2003;67:1303-1309.
23. Brodsky L. Modern assessment of tonsils and adenoids, Pediatr. *Clin North Am*. 1989;36:1551-1569.
24. Valera FCP, Avelino MAG, Pettermann MB, et al. OSAS in children: Correlation between endoscopic and polysomnographic findings. *Otolaryngol Head Neck Surg*. 2005;132(2):268-272. https://doi.org/10.1016/j.otohns.2004.09.033.
25. Barros JRC, Becker HMG, Pinto JA. Evaluation of atopy among mouth-breathing pediatric patients referred for treatment to a tertiary care center. *J Pediatr (Rio J)*. 2006;82:458-464.
26. Zapletal A, Chalupová J. Nasal airflow and resistance measured by active anterior rhinomanometry in healthy children and adolescents, *Pediatr Pulmonol*. 2002;33:174180.
27. Galié N, Humbert M, Vachiery JL, et al. ESC/ERS guidelines for the diagnosis and treatment of pulmonary hypertension: the Joint Task Force for the Diagnosis and Treatment of Pulmonary Hypertension of the European Society of Cardiology (ESC) and the European Respiratory Society (ERS): endorsed by: Association for European Paediatric and Congenital Cardiology (AEPC): International Society for Heart and Lung Transplantation (ISHLT). *Eur Heart J*. 2015;37:67-119.
28. Jone P, Ivy D. Echocardiography in pediatric pulmonary hypertension, *Front Pediatr*. 2014;2:124.
29. Abman SH, Hansmann G, Archer SL, et al. Pediatric pulmonary hypertension: guidelines from the American Heart Association and American Thoracic Society. *Circulation*. 2015;132:2037-2099.
30. Hansmann G, Apitz C. Expert consensus statement on the diagnosis and treatment of paediatric pulmonary hypertension. The European Paediatric Pulmonary Vascular Disease Network, endorsed by ISHLT and DGPK. *Heart*. 2016;102(suppl 2):ii86-100.
31. R Core Team. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing; 2017. https://www.R-project.org/.
32. Aragon TJ. epitools: epidemiology tools. R package version 0.5-9. 2017. https://CRAN.R-project.org/package=epitools.
33. Wickham H. ggplot2: elegant graphics for data analysis. New York: Springer; 2009. https://CRAN.R-project.org/package=ggplot2]
34. Weber SA, Pierri Carvalho R, Ridley G, Williams K, El Dib R. A systematic review and meta-analysis of cohort studies of echocardiographic findings in OSA children after adenotonsilectomy. *Int J Pediatr Otorhinolaryngol*. 2014;78:1571-1578.
35. Park MK, Troxler RG. Pulmonary hypertension in pediatric cardiology for practitioners. 4th ed. St Louis, MO: Mosby; 2002.
36. Koc S, Aytekin M, Kalay N, et al., . The effect of adenotonsillectomy on right ventricle function and pulmonary artery pressure in children with adenotonsillar hypertrophy. *Int J Pediatr Otorhinolaryngol*. 2012;76(1):45-48. https://doi.org/10.1016/j.ijporl.2011.09.028.
37. Ehsan Z, Ishman SL, Kimball TR, Zhang N, Zou Y, Amin RS. Longitudinal cardiovascular outcomes of sleep disordered breathing in children: a meta-analysis and systematic review. *Sleep*. 2017;40(3):zsx-015.
38. Dehlink E, Tan HL. Update on paediatric obstructive sleep apnoea. *J Thorac Dis*. 2016;8:224-235.
39. Duman D, Naiboglu B, Esen HS, Toros SZ, Demirtunc R. Impaired right ventricular function in adenotonsillar hypertrophy. *Int J Cardiovasc Imaging*. 2008;24:261-267.
40. Amin RS, Kimball TR, Kalra M. Left ventricular function in children with sleep-disordered breathing. *Am J Cardiol*. 2005;95:801-804.
41. Galvão CP, Tinano MM, Nader CMFF, Franco LP, Becker HMG. Evolution of obstructive sleep apnea syndrome, nasal flow and systolic pressure of the pulmonary artery in children with indication for adenoidectomy and/or tonsillectomy over 18 months. *Int J Pediatr Otorhinolaryngol*. 2019;120:210-214.
42. Mendes AIS, Wandalsen GF, Solé Avaliações D. Objetiva e subjetiva da obstrução nasal em crianças e adolescentes com rinite alérgica. *J Pediatr (Rio J)*. 2012;88:389-395.