Journal of Paediatrics and Child Health

doi:10.1111/jpc.15430

ORIGINAL ARTICLE

Incidence of allergen-specific and total immunoglobulin E positivity in children undergoing adenotonsillectomy

Matthew E Lam [1,2] Leon Kitipornchai,[1] Natelle Ball,[1] Lernik Sarkissian,[1] Terry Sands,[1] Liam Grundy[1] and Stuart G MacKay[1]

[1]Illawarra Shoalhaven Local Health District, The Wollongong Hospital and [2]Illawarra Health Medical Research Institute, University of Wollongong, Wollongong, New South Wales, Australia

Aim: To conduct a prospective, consecutive cohort study to evaluate the incidence of allergen-specific and total immunoglobulin E (IgE) in a paediatric population undergoing adenotonsillectomy for sleep-disordered breathing.

Methods: A total of 64 consecutive patients presenting for adenotonsillectomy at a single centre were recruited over a period of 3 months. All patients underwent adenotonsillectomy and had allergen-specific and total IgE serum testing at the time of anaesthesia induction. Pre-operative history and examination were conducted to determine clinical allergy. Caregivers completed the Sleep-Related Breathing Disorder scale of the Paediatric Sleep Questionnaire and the Mini Rhinoconjunctivitis Quality of Life Questionnaire at baseline and at 6 weeks post-operatively.

Results: A total of 37 (57.8%) patients had either allergen-specific or total IgE positivity. House dust mite was the most prevalent allergen-specific IgE finding, being present in moderate to high levels in 14 (21.9%) patients. A total of 17 (26.6%) patients had a history of atopy, while 34 (53.1%) had examination findings suggestive of allergy. Neither serum IgE testing nor clinical history and examination were independently associated with residual symptoms post adenotonsillectomy. Patients with concomitant serum IgE positivity and clinical allergy had higher residual symptom scores compared to those who did not using both Sleep-Related Breathing Disorder scale of the Paediatric Sleep Questionnaire (P = 0.035) and Mini Rhinoconjunctivitis Quality of Life Questionnaire (P = 0.02) questionnaires.

Conclusions: Our prospective, consecutive cohort of patients reflect a greater incidence of serum IgE positivity compared to historical figures. When utilised with clinical findings on history and examination, serum IgE is a useful adjunct that is associated with greater residual symptoms post-adenotonsillectomy.

Key words: allergic rhinitis; immunoglobulin E; incidence; radioallergosorbent test; sleep-disordered breathing; tonsillectomy.

What is already known on this topic

1 Adenotonsillar hypertrophy is the most recognisable contributing factor to sleep-disordered breathing in children.
2 Allergic rhinitis is associated with sleep-disordered breathing in a bidirectional manner.
3 Retrospective data suggest there is a correlation between immunoglobulin E positivity and residual sleep symptoms post-tonsillectomy.

What this paper adds

1 Prospective data demonstrating a correlation between residual sleep symptoms post-adenotonsillectomy and patients who have clinical findings of allergy and immunoglobulin E positivity.
2 Contemporary data on the incidence of clinical and serum allergy in an urban Australian population.

Sleep-disordered breathing (SDB) refers to a spectrum of disorders that range from primary snoring to obstructive sleep apnoea (OSA). Its aetiology in children is linked to structural and neuromuscular factors, including airway obstruction, hypercapnic response and arousal threshold.[1] The health effects on a paediatric population are well known, including growth impairment, neurocognitive deficits, behavioural disturbances,[2] nocturnal enuresis[3] and adverse cardiovascular impact.[4]

Adenotonsillar hypertrophy is the most recognised treatable contributing factor to SDB in children.[5] The rate of reported symptom resolution post-adenotonsillectomy is variable (from 60% to 85%).[6,7] Incomplete resolution is often associated with individual anatomical, physiological and pathological factors. Postulated causes of residual symptoms include ethnicity, craniofacial abnormalities, elevated body mass index and allergic rhinitis (AR).[8]

AR is a prevalent disorder characterised by immunoglobulin E (IgE)-mediated inflammation of the nasal mucosa. It is often

Correspondence: Dr Matthew E Lam, Department of Otolaryngology, Wollongong Hospital, Wollongong NSW 2500, Australia. Fax: +61 4040 21993; email: lam.me.323@gmail.com

Conflict of interest: SG MacKay declares he is a Chief Investigator on National Health and Medical Research Council, and The Garnett Passe and Rodney Williams Memorial Foundation Grants. The other authors have no other conflicts of interest to declare.

Accepted for publication 22 February 2021.

diagnosed based on clinical symptoms of rhinorrhoea, nasal obstruction, itching and sneezing.[9] Nasal obstruction in SDB may contribute to partial or complete airway obstruction and consequent increased upper airway resistance, often more pronounced during sleep. In addition to other atopic conditions (asthma and eczema[10]), AR is closely associated with SDB in a bidirectional manner.[11] Children with a history of AR and other atopic conditions are more likely to have habitual snoring[12] and higher rates of SDB symptom recidivism following treatment.[8,13] Diagnosis of AR is usually clinical,[9] with laboratory tests used to define types of allergy.[14] Total and allergen-specific serum IgE levels (previously radioallergosorbent test 'RAST') are contemporary measures of IgE-mediated allergy. Tests can be directed to common inhalant allergens such as grasses/pollens, dust mite, animal mix and dander and moulds. We have previously identified an association between allergen-specific IgE positivity or elevated total IgE titres with residual snoring or sleep symptoms post-operatively in a large retrospective cohort of paediatric patients undergoing adenotonsillectomy.[8]

We aimed to conduct a consecutive, prospective cohort study to evaluate the incidence of specific and total IgE positivity in a paediatric population undergoing adenotonsillectomy for SDB, as well as residual symptoms post treatment, using validated symptom and quality of life instruments.

Methods

Ethics approval was obtained from the University of Wollongong Human Research Ethics Committee (HE16/155).

A power analysis to determine the number of patients required to assess incidence accurately was undertaken. A prospective, consecutive cohort study of 69 paediatric patients with SDB was conducted over a period of 3 months between September 2016 to November 2016. All patients met clinical or polysomnographic criteria for adenotonsillectomy. Informed consent to perform total and specific IgE assessment was obtained at enrolment. Of these 69, two patients did not have total IgE performed. Three patients were lost to follow up or did not complete all of the questionnaires required, leaving 64 complete data sets for analysis.

Patient ages and gender were collected. Other demographic data was de-identified. A proportion of patients (n = 30) underwent polysomnography testing following clinical assessment and prior to their operation. Key indicators of OSA severity in children including apnoea-hypopnoea index (AHI) and lowest oxygen saturation were compared and contrasted in this subgroup.

Accompanying caregivers completed two questionnaires (Appendix S1 and S2, Supporting Information) to assess symptoms of SDB and AR, respectively: the Sleep-Related Breathing Disorder scale of the Paediatric Sleep Questionnaire (PSQ:SDB)[15] and the Mini Rhinoconjunctivitis Quality of Life Questionnaire (MiniRQLQ).[16] Questionnaires were completed at baseline and 6 weeks post-operatively.

Pre-operative history was obtained to establish the severity, chronicity and impact of sleep, daytime and rhinitis symptoms. Examination findings of tonsil size, rhinoscopy and otoscopy, presence of allergic stigmata, orthognathic and occlusal abnormalities were documented. If patients had examination findings of allergic stigmata (rhinitic nasal mucosa, mucous stranding, inferior turbinate hypertrophy or eye 'shiners') and/or previous documented medical history of AR, asthma, reactive airways disease or eczema they were considered as 'clinically atopic patients'.

All operations were performed under the care of a single surgeon in both public and private institutions. Patients underwent adenotonsillectomy. A proportion of patients also underwent concomitant procedures for other indications: insertion of middle ear ventilation tube(s) (n = 8), microear toilet (n = 5), flexible or rigid laryngoscopy/bronchoscopy/oesophagoscopy/sleep endoscopy (n = 5), division of tongue tie (n = 1) and cautery to prominent Little's area vessels (n = 1).

If patients were already prescribed intranasal corticosteroid medication and their allergic symptoms were significant, they were allowed to remain on such therapy up until surgery (n = 3).

Definition of specific and total IgE positivity

Caregivers consented to testing of allergen-specific IgE and total IgE. Samples were analysed at an independent laboratory via ImmunoCAP assays. Allergens tested included grasses/pollens, house dust mite, staple food, animal mix and dander and mould mix.

The test was considered positive if the specific IgE for each allergen was greater than 0.1 kU/L. In addition, the laboratory also provided three tiers of reactivity: low (0.1–1 kU/L), moderate (1–4 kU/L) or high (>4 kU/L). Total serum IgE was considered significant for allergy if greater than 55 IU/mL based on normative values provided by the laboratory.

If specific IgE reactivity to airborne allergens was identified at a moderate level or above (>1 kU/L) concomitant with clinical symptoms or history suggestive of allergy, patients were recommended to continue or commence intranasal corticosteroids on a regular basis post-operatively (n = 12).

Definition of residual symptoms

Residual symptoms related to SDB after tonsillectomy were divided into categories of snoring, sleepiness and behaviour according to the PSQ:SDB. Raw scores for each of these categories were obtained, and an overall percentage score was derived from the sum of these categories divided by the number of questions to which the caregiver responded. A total score greater than 0.33 (33%) was considered suggestive of persisting SDB, as defined by Chervin *et al.*[15]

Residual symptoms related to AR were categorised into: activities, practical problems, nasal, eye and other symptoms (tiredness, thirst, irritability) according to the MiniRQLQ. Any other caregiver concerns not stipulated on the questionnaires were noted.

Data collection and analysis

All data were collated using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Statistical analysis and figures were created using Prism 8 (GraphPad Software Inc., La Jolla, CA, USA). An alpha level of 0.05 was used for all statistical tests. Normality was determined using Shapiro–Wilk test. Fisher's exact test and χ^2 test were used to evaluate sensitivity and specificity of

clinical examination and history with serum findings and questionnaire subdomains. Wilcoxon-signed rank test was used to compare pre- and post-operative questionnaire scores. Mann–Whitney test was used to compare questionnaire scores of serum positive and serum negative patients pre- and post-operatively.

Results

Patient demographics

Participants were 54.7% (35/64) male and 45.3% (29/64) female (male : female 1.2:1) aged 2–14 years, with median age 4.5 (interquartile range (IQR) 3–6). Age was non-normally distributed, with skewness of 1.44 and kurtosis of 2.31.

Total and specific IgE positivity

Median total IgE was 26 IU/L (IQR 11.25–143.8). Specific IgE reactivity as stratified by the strength of the response to allergens is summarised in Table 1.

A total of 50% (32/64) of patients had a positive allergen-specific IgE test, while 34.4% (22/64) had total IgE >55 IU/L. A total of 26.6% (17/64) patients had both elevated allergen IgE and total IgE. A total of 57.8% (37/64) patients had either positive allergen-specific IgE or total IgE, with 42.2% (27/64) having neither (Fig. 1). One patient had specific reactivity to staple food mix alone with no aeroallergen reactivity and was therefore analysed in the total/specific IgE negative group. Mould mix results were not reported in the same patient.

Correlation with clinical history and examination

A total of 26.6% (17/64) of patients who had a previous diagnosis of asthma, AR or reactive airways disease were considered to have a history of atopy. On examination 53.1% (34/64) patients who had appearances consistent with allergic nasal mucosa, inferior turbinate hypertrophy or eye 'shiners' were considered to have clinical features of allergy. Sensitivity of specific/total IgE testing for a history of atopy was 64.7% (95% confidence interval = 41.3–82.6), and sensitivity of specific/total IgE testing for clinical features of allergy was 58.8% (95% confidence interval = 42.2–73.6). Neither of these were significant on Fisher's exact test (Table 2).

Tonsil grade was documented for 63 patients with sizes grade 2 (17.5%, 11/63), 3 (60.3%, 38/63) and 4 (22.2%, 14/63). In instances where tonsils were asymmetrical the larger size was taken. χ^2 test for trend did not demonstrate a significant correlation between tonsil size and serum IgE positivity (Table 2).

Ear findings were documented for 64 patients with some patients demonstrating unilateral or bilateral (20.3%, 13/64) middle ear effusions, significant quantities of wax or normal appearing ears (79.7%, 51/64). χ^2 test comparing children with effusions to normal or waxy ears was not significant (Table 2).

Hard palatal phenotype was documented for 64 patients with patients exhibiting narrow, high arch palate (20.3%, 13/64), broad palate or normal appearances (79.7%, 51/64). Fisher's exact test showed no significance in the relation between palatal phenotype and IgE positivity (Table 2).

Pre-operative sleep studies were performed in a total of 30 patients, and divided into specific and total IgE positive (n = 14) and negative (n = 16). Median AHI was 7.5 events/h (IQR 5–10) in IgE positive and 9 events/h (IQR 6–11) in IgE negative patients. There were no significant differences between these two groups in their AHI as measured with Mann–Whitney test (U = 83.5, P = 0.24). This was also the case for lowest oxygen saturation for positive (standard error of mean (SEM) 85.7 ± 3.7%) and negative patients (SEM 86.1 ± 4.0%), as measured with unpaired t-test, $t(28)$ = 0.29, P = 0.77.

Correlation with questionnaires

PSQ:SDB questionnaire were divided into specific/total IgE positive and negative groups (Table 3).

Within each group, patients experienced an improvement in PSQ:SDB scores after adenotonsillectomy. Wilcoxon matched pairs signed rank test demonstrated a median improvement of 0.30 (IQR 0.21–0.39) in specific/total IgE positive (W = −664, P < 0.001) and 0.36 (IQR 0.26–0.43) in negative groups (W = −351, P < 0.001).

Between each group, patients who had specific/total IgE positivity were not significantly different to those who had negative

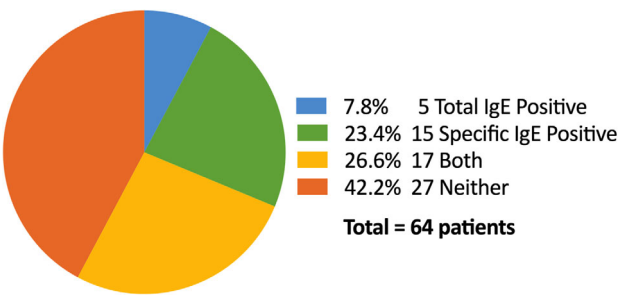

Fig 1 Total and allergen-specific immunoglobulin E positivity.

Table 1 Specific allergen immunoglobulin E (IgE) breakdown

Specific IgE reactivity	Grass (n = 64), n (%)	Dustmite (n = 64), n (%)	Staple food mix (n = 64), n (%)	Animal mix (n = 64), n (%)	Mould mix (n = 63), n (%)
Negative	60 (93.8)	43 (67.2)	43 (67.2)	56 (87.5)	45 (71.4)
Low (0.1–1 kU/L)	3 (4.7)	7 (10.9)	16 (25)	6 (9.4)	18 (28.6)
Moderate (1–4 kU/L)	0 (0)	6 (9.4)	3 (4.7)	2 (3.1)	0 (0)
High (>4 kU/L)	1 (1.6)	8 (12.5)	2 (3.1)	0 (0)	0 (0)

Table 2 Clinical findings compared with serum immunoglobulin E (IgE) positivity

Feature	Specific/total IgE positive (+), *n* (%)	Specific/total IgE negative (–), *n* (%)	*P* value (* < 0.05)
History			
History of atopy	11 (17.2)	6 (9.4)	0.58
No history of atopy	26 (40.6)	21 (32.8)	
Examination			
Allergic examination	20 (31.3)	14 (21.9)	>0.99
Normal examination	17 (26.6%)	13 (20.3%)	
Palatine tonsil grade			
4	9 (14.3)	5 (7.9)	0.60
3	21 (33.3)	17 (27)	
2	6 (9.5)	5 (7.9)	
Ear findings			
Unilateral effusion	2 (3.1)	0	0.76
Bilateral effusions	6 (9.4)	5 (7.8)	
Wax	5 (7.8)	3 (4.7)	
Normal	24 (37.5)	19 (29.7)	
Palatal phenotype			
High arch palate	9 (14.1)	4 (6.3)	0.53
Broad/normal palate	28 (43.8)	23 (36)	

testing in overall outcomes, using a Mann–Whitney test pre- and post-operatively.

Further analysis for residual symptoms was undertaken. A total of 53 patients were identified as having an overall pre-operative PSQ score greater than 0.33 and analysed according to specific/total IgE positivity (56.6%, 30/53) and negativity (43.4%, 23/53). If the corresponding post-operative scores for this cohort remained greater than 0.33 they were considered to have residual symptoms of SDB.[15] Fisher's exact test did not demonstrate any significant difference between the two groups.

Raw scores were also taken from all 64 completed PSQs and divided into categories of snoring, sleepiness and behaviour. A score greater than 0 post-operatively was considered evidence of residual symptoms. Fisher's exact test did not demonstrate any significant difference between the groups.

MiniRQLQ questionnaires were also divided into specific/total IgE positive and negative groups, compared within themselves and between each other (Table 3).

Within each group, patients also experienced an improvement in MiniRQLQ scores after adenotonsillectomy. Wilcoxon matched pairs signed rank test demonstrated a median improvement of 13 (IQR 6–19) in positive ($W = 606$, $P < 0.001$) and 19 (IQR 10–26) in negative groups $W = -374$, $P < 0.001$).

Between each group, there was no significant difference between positive and negative groups in terms of their scores either pre- or post-operatively (Mann–Whitney).

Residual symptoms in MiniRQLQ scores were divided into the pre-defined categories of activities, practical, nose, eye and other. A score greater than 0 post-operatively was considered evidence of residual symptoms. Fisher's exact test demonstrated a significant difference in the post-operative subdomain of practical problems with residual symptoms being present to a greater degree in the IgE positive group. No difference of statistical significance was seen in the other subdomains of RQLQ.

Table 3 Questionnaire scores compared with serum immunoglobulin E (IgE) positivity

Questionnaires	Specific/total IgE positive (+)	Specific/total IgE negative (–)	*P* value (* < 0.05)
Overall PSQ scores, median (IQR)			
Pre-op median	0.50 (0.38–0.63)	0.5 (0.36–0.58)	0.74
Post-op median	0.20 (0.08–0.27)	0.13 (0.08–0.21)	0.19
Pre-op (*n* = 64), *n* (%)			
>0.33	30 (46.9)	23 (35.9)	0.75
<0.33	7 (10.9)	4 (6.3)	
Post-op (*n* = 53), *n* (%)			
>0.33 (residual symptoms)	4 (7.5)	2 (3.8)	0.69
<0.33	26 (49.1)	21 (39.6)	
Raw PSQ scores, *n* (%)			
Snoring > 1	12 (18.8)	10 (15.6)	0.79
Snoring 0	25 (39.1%)	17 (26.6)	
Sleepiness > 1	18 (28.1)	12 (18.8)	0.8
Sleepiness 0	19 (29.7)	15 (23.4)	
Behaviour > 1	27 (42.2)	19 (29.7)	>0.99
Behaviour 0	10 (15.6)	8 (12.5)	
Overall RQLQ scores, median (IQR)			
Pre-op median	23.5 (11.5–37.5)	25 (18–40.3)	0.73
Post-op median	6.5 (2–13)	4 (1–9.3)	0.14
Raw MiniRQLQ scores, *n* (%)			
Activities > 1	23 (35.9)	15 (23.4)	0.62
Activities 0	14 (21.9)	12 (18.8)	
Practical > 1	21 (32.8)	8 (12.5)	0.043*
Practical 0	16 (25)	19 (29.7)	
Nose > 1	20 (31.3)	14 (21.9)	>0.99
Nose 0	17 (26.6)	13 (20.3)	
Eye > 1	9 (14.1)	6 (9.4)	>0.99
Eye 0	28 (43.8)	21 (32.8)	
Other > 1	27 (42.2)	20 (31.3)	>0.99
Other 0	10 (15.6)	7 (10.9)	

IQR, interquartile range; PSQ, Paediatric Sleep Questionnaire; RQLQ, Rhinoconjunctivitis Quality of Life Questionnaire.

Correlation with history, examination and questionnaires

Further analysis was performed on patients who had either history or examination findings correlated with serum IgE positivity at a moderate level or above (>1 kU/L) (Table 4). Of 64 patients, 14 had clinical findings that were concomitant with positive blood testing. These patients had higher median PSQ and RQLQ scores both pre-operatively and post-operatively. These scores were compared with Mann–Whitney testing. Pre-operative scores had a trend towards significance with PSQ and RQLQ, while post-operative scores were significantly different for both PSQ and RQLQ.

Contingency analysis was performed with Fisher's exact test for question domains in both PSQ and RQLQ. PSQ subgroups

Table 4 Concomitant clinical and serum immunoglobulin E findings compared with questionnaire scores

	Clinical and serum allergy (n = 14)	No clinical or serum allergy (n = 50)	Median difference	P value (* < 0.05)
Total Paediatric Sleep Questionnaire score, median (IQR)				
Pre-op	0.60 (0.39–0.71)	0.48 (0.35–0.58)	0.12	0.074
Post-op	0.26 (0.06–0.37)	0.13 (0.08–0.22)	0.13	0.035*
Total Rhinoconjunctivitis Quality of Life Questionnaire score, median (IQR)				
Pre-op	28.5 (19–60.8)	23.5 (12.5–32.5)	5	0.11
Post-op	13 (3.5–14.5)	4 (1–8.5)	9	0.02*

IQR, interquartile range.

were not significant for residual snoring, sleepiness or behaviour. RQLQ subgroup analysis was significant for activities (P = 0.035) only.

Discussion

Key findings

Higher rates of residual symptoms of SDB were seen in clinically atopic patients with simultaneously positive total and/or specific IgE tests. This was significant when a specific IgE result was at a moderate level or above (>1 kU/L). Clinical findings of allergy or serum IgE positivity diagnosed independently were not significantly associated with residual symptoms post-adenotonsillectomy.

Comparison to literature

This consecutive, prospective analysis of a symptom and IgE positivity in children undergoing adenotonsillectomy for SDB demonstrates a higher rate of atopy/allergy than the baseline population rate. In our consecutive cohort, 26.6% of patients had a history suggestive of atopy and 57.8% of patients had either an elevated specific or total IgE level. As expected, elevated house dust mite specific IgE was the most prevalent finding, with moderate to high levels of reactivity seen in 21.9% of all patients.

Griffin *et al*. compared children undergoing adenotonsillectomy for all indications (including recurrent sore throats) and found a 21% rate of IgE positivity (compared with 20% in their control arm).[17] A recent Korean series found 52.4% of patients undergoing surgery had symptoms of AR and a positive skin prick test or multiple allergen simultaneous test (MAST).[18] Finally, a series of British children with OSA diagnosed by type 4 sleep study who were undergoing surgery and RAST testing found a similar 20.8% positive for house dust mite allergens but no report on overall or total IgE rates.[19] In a comparable population of Australian children, high levels of self-reported rhinitis were seen in 6–7-year-olds (up to 29.9%) and 13–14-year-olds (up to 41.5%).[20]

Allergy has been shown to be associated with SDB and adenotonsillar hypertrophy[11,12,21] and been linked to recidivism of symptoms up to 1 year post-treatment.[13] Treatments aimed at allergic targets, such as leukotriene receptor antagonists[22] and intranasal corticosteroids[23] have been found to be effective at partially mitigating SDB.

Our findings are consistent with a significant improvement in quality of life in both sleep-specific and rhinitis-specific symptom scores associated with adenotonsillectomy. The improvement in RQLQ with adenotonsillectomy, although unexpected, could be partially explained by a small proportion of patients treated with intranasal corticosteroids and crossover in symptom improvement associated with adenoidectomy. The presence of atopy/allergy at baseline has been shown to be predictive for residual sleep symptoms.[13,18] Our results are compatible with a retrospective study demonstrating an association between elevated total and specific IgE and residual snoring.[8]

Significant geographical and temporal differences are seen in the incidence of rhinitis and atopy; however, the high rates of positive findings in this cohort are likely reflective of sampling patients with SDB in a developed urban centre. Disconcordance between serological and clinical findings in children with rhinitis is common in the literature[24] and our findings (26.6% versus 57.8%) are no exception.

Drawbacks of the study

Follow-up outcomes were measured at 6 weeks after surgery which is consistent with routine practice in our clinic; however, this study was not designed to measure long-term incidence of disease recrudescence or its relationship to atopy, rhinitis or allergen sensitisation. Longer follow-up (up to 1 year) may have demonstrated a closer association between IgE positivity and re-emergence of symptoms of SDB.

Serum IgE is easily accessible, sensitive and of low impact to a child when sampled under general anaesthesia. By comparison skin prick testing can be time consuming and uncomfortable for children. However, both methods lack specificity, and a drawback of this study is the usage of allergen mixes in which low to very low reactivity (<1 kU/L) may be of no significance.[24]

Conclusion

The results of this study provide prospective data that supports the notion that persistent short- to medium-term symptoms of SDB after adenotonsillectomy may be attributable to AR. Those who present pre-operatively with clinical atopy should have total and specific IgE testing considered at the time of anaesthetic induction. If positive, discussion with parents should occur regarding potential treatment of allergy as a cause of residual SDB with medical therapy such as intranasal corticosteroids or leukotriene receptor antagonists.

Acknowledgements

Acknowledgements made to SueEllen Holmes for administrative support. There are no funding sources to declare.

References

1 Marcus CL. Sleep-disordered breathing in children. *Am. J. Respir. Crit. Care Med.* 2001; **164**: 16–30.
2 Biggs SN, Vlahandonis A, Anderson V *et al*. Long-term changes in neurocognition and behavior following treatment of sleep disordered breathing in school-aged children. *Sleep* 2014; **37**: 77–84.
3 Jeyakumar A, Rahman SI, Armbrecht ES, Mitchell R. The association between sleep-disordered breathing and enuresis in children. *Laryngoscope* 2012; **122**: 1873–7.
4 Vlahandonis A, Walter LM, Horne RS. Does treatment of SDB in children improve cardiovascular outcome? *Sleep Med. Rev.* 2013; **17**: 75–85.
5 Redline S, Amin R, Beebe D *et al*. The childhood adenotonsillectomy trial (CHAT): Rationale, design, and challenges of a randomized controlled trial evaluating a standard surgical procedure in a pediatric population. *Sleep* 2011; **34**: 1509–17.
6 Brietzke SE, Gallagher D. The effectiveness of tonsillectomy and adenoidectomy in the treatment of pediatric obstructive sleep apnea/hypopnea syndrome: A meta-analysis. *Otolaryngol. Head Neck Surg.* 2006; **134**: 979–84.
7 Friedman M, Wilson M, Lin H-C, Chang H-W. Updated systematic review of tonsillectomy and adenoidectomy for treatment of pediatric obstructive sleep apnea/hypopnea syndrome. *Otolaryngol. Head Neck Surg.* 2009; **140**: 800–8.
8 Sarkissian L, Sarkissian L, Stewart TE, Guy T, Mackay SG. Incidence of allergic rhinitis in children with residual snoring and sleep symptoms after adenotonsillectomy. *Aust. J. Gen. Pract.* 2018; **47**: 632–7.
9 Bousquet J, Khaltaev N, Cruz AA *et al*. Allergic rhinitis and its impact on asthma (ARIA) 2008. *Allergy* 2008; **63**: 8–160.
10 Greiner AN, Hellings PW, Rotiroti G, Scadding GK. Allergic rhinitis. *Lancet* 2011; **378**: 2112–22.
11 Lin SY, Melvin TAN, Boss EF, Ishman SL. The association between allergic rhinitis and sleep-disordered breathing in children: a systematic review. *International Forum of Allergy & Rhinology*. 2013; **3**: 504–509. http://dx.doi.org/10.1002/alr.21123.
12 Chng SY, Goh DYT, Wang XS, Tan TN, Ong NBH. Snoring and atopic disease: A strong association. *Pediatr. Pulmonol.* 2004; **38**: 210–6.
13 Kim D-K, Han DH. Impact of allergic rhinitis on quality of life after adenotonsillectomy for pediatric sleep-disordered breathing. *International Forum of Allergy & Rhinology*. 2015; **5**: 741–746. http://dx.doi.org/10.1002/alr.21529.
14 Gold MS, Kemp AS. 6. Atopic disease in childhood. *Med. J. Aust.* 2005; **182**: 298–304.
15 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**: 21–32.
16 Juniper E, Thompson A, Ferrie P, Roberts J. Development and validation of the mini rhinoconjunctivitis quality of life questionnaire. *Clin. Exp. Allergy* 2000; **30**: 132–40.
17 Griffin JL, Ramadan HH, Adham RE. Prevalence of IgE-mediated hypersensitivity in children with adenotonsillar disease. *Arch. Otolaryngol. Head Neck Surg.* 1994; **120**: 150–3.
18 Lee D-J, Chung Y-J, Yang Y-J, Mo J-H. The impact of allergic rhinitis on symptom improvement in pediatric patients after adenotonsillectomy. *Clin. Exp. Otorhinolaryngol.* 2018; **11**: 52–7.
19 Carr E, Obholzer R, Caulfield H. A prospective study to determine the incidence of atopy in children undergoing adenotonsillectomy for obstructive sleep apnea. *Int. J. Pediatr. Otorhinolaryngol.* 2007; **71**: 19–22.
20 Strachan D, Sibbald B, Weiland S *et al*. Worldwide variations in prevalence of symptoms of allergic rhinoconjunctivitis in children: The international study of asthma and allergies in childhood (ISAAC). *Pediatr. Allergy Immunol.* 1997; **8**: 161–8.
21 Sánchez T, Castro-Rodríguez JA, Brockmann PE. Sleep-disordered breathing in children with asthma: A systematic review on the impact of treatment. *J. Asthma Allergy* 2016; **9**: 83.
22 Kheirandish-Gozal L, Bandla HP, Gozal D. Montelukast for children with obstructive sleep apnea: Results of a double-blind, randomized, placebo-controlled trial. *Ann. Am. Thorac. Soc.* 2016; **13**: 1736–41.
23 Gudnadottir G, Ellegård E, Hellgren J. Intranasal budesonide and quality of life in pediatric sleep-disordered breathing: A randomized controlled trial. *Otolaryngol. Head Neck Surg.* 2018; **158**: 752–9.
24 Sicherer SH, Wood RA. Allergy testing in childhood: Using allergen-specific IgE tests. *Pediatrics* 2012; **129**: 193–7.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix S1. Sleep Disordered Breathing scale of the Paediatric Sleep Questionnaire

Appendix S2. Mini Rhinoconjunctivitis Quality of Life Questionnaire