The Journal of Laryngology & Otology (2015), ***129***, *473–477.*

doi:10.1017/S0022215115000523

MAIN ARTICLE

Assessment of upper airway obstruction by measuring peak oral and nasal inspiratory flow

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Abstract

Objective: We wanted to access upper airway obstruction in patients undergoing tonsillectomy by measuring peak oral and nasal inspiratory airflow.

Methods: We recruited study participants from a cohort of patients on the waiting list for tonsillectomy, with or without adenoidectomy, at University Hospital of Wales, Cardiff, UK. Fifty patients enrolled on phase I of the study and underwent pre-operative measurement of the rate of peak oral and nasal inspiratory flow; 25 of these patients returned after one month for phase II of the study and underwent post-operative measurement of the rate of both peak oral and nasal inspiratory flow.

Results: Of the 25 participants who completed phase II of the study, 17 (68 per cent) showed an increase in post-operative peak oral inspiratory flow rate by an average of 45 per cent, while 18 (72 per cent) showed an increase in post-operative peak nasal inspiratory flow rate by an average of 22 per cent.

Conclusion: Both peak oral and nasal inspiratory flow rate measurements may be useful measures of oral and nasal obstruction. Further larger studies are needed to develop these measurements as screening and efficacy measures for adenotonsillectomy to relieve upper airway obstruction.

Key words: Tonsillectomy; Snoring; Sleep Apnea, Obstructive

Introduction

Adenotonsillectomy is currently indicated as a treatment for sleep-related breathing disorders in children because removal of the tonsils opens the airway and lowers airway resistance to breathing. Overnight pulse oximetry and polysomnography are two common investigations used to diagnose sleep-related breathing disorders.[1] In this article, we propose that a simple, non-invasive measurement of peak inspiratory flow rates may help in deciding which patients are suitable for surgical treatment of sleep-related breathing disorders. Since the upper airway cause of any sleep-related breathing disorder is believed to be due to obstruction of oral and nasal airways because of enlarged tonsils or adenoids, it seems reasonable that patient selection for surgery could be better managed by simple measurements of the severity of airway obstruction rather than the consequences of this obstruction as determined by overnight studies.

The increasing interest in sleep-related breathing disorders has led to more diagnoses; a position paper published by ENT-UK (the British Association of Otorhinolaryngologists – Head and Neck Surgery)[2] estimated that about a quarter of the 27 400 paediatric tonsillectomies in 2008–2009 in the UK were carried out for obstructive conditions. Polysomnography (sleep study) and pulse oximetry are time-consuming. Peak expiratory flow is a simple, non-invasive measure of lower airway obstruction and the peak flow meter may also be used to measure obstruction of the upper airway due to adenotonsillar enlargement. Peak oral inspiratory flow would give a measure of oral obstruction due to enlarged tonsils and peak nasal inspiratory flow would give a measure of nasal obstruction due to enlarged adenoids. Peak nasal inspiratory flow has been previously used to measure nasal airway resistance in children,[3,4] but peak oral inspiratory flow has not been previously measured in children, although it has been used in lung function tests in adults.[5]

Methods

Aim

We wanted to assess the severity of airway obstruction in patients undergoing tonsillectomy, with or without adenoidectomy, by measuring the rate of peak nasal and oral inspiratory flow.

Accepted for publication 8 May 2014

Study design

This was a prospective study carried out at University Hospital of Wales and at the Common Cold Centre, Cardiff University. We recruited participants from a cohort of patients on the waiting list for tonsillectomy, with or without adenoidectomy, at University Hospital of Wales, Cardiff. We sent patients a letter of invitation along with a patient information leaflet to explain the research project and a response letter to convey their decision on participation. Once patients confirmed their willingness to take part, then the investigator contacted them over the telephone to discuss the study and answer any questions they had regarding the project. On the day of surgery, the investigator obtained their informed consent, carried a thorough otorhinolaryngology examination and graded the tonsils according to the Brodsky scale. The investigator measured each patient's peak oral and nasal inspiratory flow using a portable inspiratory flow meter. We sent out an invitation after surgery for a follow-up visit one month later, to repeat peak oral and nasal inspiratory flow measurements. Fifty patients underwent pre-operative measurement of peak oral and nasal inspiratory flow; 25 patients returned for the follow-up visit. Inclusion criteria included patients referred for tonsillectomy, with or without adenoidectomy. Exclusion criteria included children younger than five years of age and tonsillectomy carried out to rule out malignancy.

Peak nasal inspiratory flow rate. We measured the peak nasal inspiratory flow rate (PNIFR) (l/min) with an In-Check portable nasal flow meter (Clement Clarke International, Harlow, UK) according to the documented procedure for measuring PNIFR used at the study site.

Peak nasal inspiratory flow rate has been used previously to measure nasal obstruction.[5–7] The technique involves the patient placing a mask over the nose and making a maximum effort to breathe in through the nose. We asked each patient if they wished to gently blow their nose prior to any measurement.

Peak oral inspiratory flow rate. We used the In-Check portable nasal flow meter to measure the peak oral inspiratory flow rate (l/min), according to the documented procedure for measuring peak oral inspiratory flow rate used at the study site. The measurement of peak oral expiratory flow rate is often used to measure lower airway obstruction. However, measurement of peak oral inspiratory flow rate can be used as a measure of oral obstruction, as oral resistance due to the anatomical narrowing secondary to enlarged tonsillar tissue occurs during inspiration.

Statistical analysis

The measurement of pre- and post-operative PNIFR and peak oral inspiratory flow rate consisted of three attempts; the best (highest) of three attempts, which defined their oral inspiratory flow rate, was used as the measurement for analysis.

We tested the null hypothesis that there would be no difference between pre- and post-operative peak inspiratory flow rate. We used the Pearson's correlation coefficient to determine if there was a correlation between pre- and post-operative peak inspiratory flow rate (both oral and nasal flow rates). We used SPSS, version 20 (IBM Corporation, Armonk, New York, USA), for our analysis.

Results

Demographics

Phase I. We recruited the first 50 patients on the waiting list for tonsillectomy, with or without adenoidectomy, who confirmed their acceptance to take part in the first phase of the study. There were 28 females (56 per cent) and 22 males (44 per cent). The mean age was 18.08 years (range, 5–46 years).

All patients were suffering from recurrent tonsillitis at the time of surgery. Among the 50 patients, 39 (78 per cent) had a history of snoring, 17 (34 per cent) had symptoms suggestive of obstructive sleep apnoea (OSA; 12 in the age group 5–10, 2 in the age group 11–18 and 3 in the age group > 19) of which 3 had overnight pulse oximetry to confirm the diagnosis of OSA. The past medical history of four patients included asthma, and they were on regular inhalers. They had been stable on these medications for many years. None of the patients were allergic to any medications. All of the patients underwent tonsillectomy and none underwent adenoidectomy, although this procedure was allowed in the study protocol.

Phase II. Twenty-five (50 per cent) of those who participated in the first phase of the study agreed to take part in the second phase. There were 13 females (52 per cent) and 12 males (48 per cent). The mean age was 20.76 years (range, 5–46 years). All patients were suffering from recurrent tonsillitis at the time of surgery. Among the 25 patients, 19 (76 per cent) had a history of snoring and 5 (20 per cent) had symptoms suggestive of OSA.

Effects of age on pre-operative peak oral inspiratory flow rate

Linear regression models were used to find the relationship between age as the independent factor and peak oral inspiratory flow rate as the dependent factor. Age appeared to have an influence on peak oral inspiratory flow rate, as shown in Figure 1. The Pearson's correlation coefficient was $r = 0.603$, $p < 0.0001$. For every year increase in age, the peak oral inspiratory flow rate increased by 4.394 l/min.

https://doi.org/10.1017/S0022215115000523 Published online by Cambridge University Press

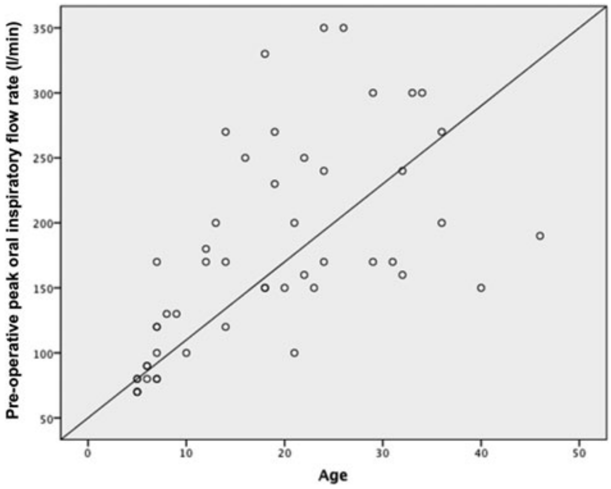

FIG. 1
Relationship between age and pre-operative peak oral inspiratory flow rate.

Effects of age on pre-operative peak nasal inspiratory flow rate

Similar regression models were used to find the relationship between age as the independent factor and PNIFR as the dependent factor. Age appeared to have an influence on PNIFR, as shown in Figure 2. The Pearson's correlation coefficient was $r = 0.381$, $p < 0.0001$. For every year increase in age, the PNIFR increased by 0.756 l/min.

Relationship between pre- and post-operative peak flow measures

The pre- and post-operative measures of peak oral inspiratory flow rate and PNIFR are shown in Table I.

The table shows that there is a wide range between minimum and maximum values of peak flow rate as expected due to the wide age range of the patient population (5–46 years), and this is reflected in the large standard deviation values. However, there is a trend for an increase in post-operative peak flow rates compared to the pre-operative ones, with the mean peak oral inspiratory flow rate increasing by 45 per cent and the mean PNIFR increasing by 22 per cent after tonsillectomy. It is also apparent that the peak oral inspiratory flow values are approximately twice the PNIFR values.

The relationship between pre- and post-operative measurements of the peak oral inspiratory flow rate was tested using the Pearson's correlation coefficient. The correlation coefficient was $r = 0.850$, $p < 0.0001$. This showed that there was a good correlation between pre- and post-operative measurements of peak oral inspiratory flow rate, as shown in Figure 3. Figure 3 shows that there was a post-operative increase in peak oral inspiratory flow rate in 17 out of 25 (68 per cent) patients.

The relationship between pre- and post-operative PNIFR was also tested using the Pearson's correlation coefficient. The correlation coefficient was $r = 0.663$, $p < 0.0001$. This shows a good correlation between pre- and post-operative measures of PNIFR, as shown in Figure 4. Figure 4 shows that there was a post-operative increase in PNIFR in 18 out of 25 (72 per cent) patients.

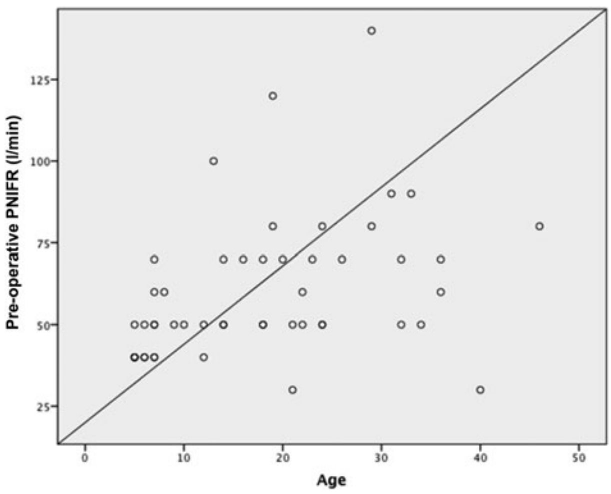

FIG. 2
Relationship between age and pre-operative peak nasal inspiratory flow rate (PNIFR).

Discussion

We aimed to assess the severity of airway obstruction in patients undergoing tonsillectomy, with or without adenoidectomy. Clinicians often rely on patient-reported symptoms of sleep-related breathing disorders and on clinical examination to decide whether to remove the tonsils, with or without the adenoids, to relieve upper airway obstruction. Limitation and feasibility to obtain overnight polysomnography, which is the gold standard investigation for sleep-related breathing disorders, is the main reason to look for alternative ways to assess upper airway obstruction. A simple, non-invasive, easily available, cost-effective and objective method to assess the severity of upper airway obstruction is thus needed.

Upper airway obstruction in sleep-related breathing disorder patients occurs during the inspiratory phase of breathing.[7] Measurement of the severity of upper airway obstruction during inspiration could guide the decision-making process of relieving upper airway obstruction by removing the tonsils, with or without the adenoids. In this study, peak oral and nasal inspiratory flow measurements have been used to assess obstruction in the upper airway due to the pathology of tonsillar and adenoid tissue. The size of these lymphoid tissues in the upper airway could be the main determinant factor in causing obstruction. We graded tonsil size in our study population according to the Brodsky scale; we found that 66 per cent of patients had grade 3 tonsils and 6 per cent had grade 4 tonsils. In total, 72 per cent of patients had their oropharyngeal space narrowed by more than three quarters due to enlarged tonsils.

https://doi.org/10.1017/S0022215115000523 Published online by Cambridge University Press

TABLE I
PRE- AND POST-OPERATIVE MEASURES OF PEAK ORAL INSPIRATORY FLOW RATE AND PNIFR

	n	Minimum (l/min)	Maximum (l/min)	Mean (l/min)	SD
Pre-operative peak oral inspiratory flow rate	50	70	350	174.40	79.595
Post-operative peak oral inspiratory flow rate	25	80	350	232.40	90.290
Pre-operative PNIFR	50	30	140	60.00	21.665
Post-operative PNIFR	25	50	180	89.20	36.046

PNIFR = peak nasal inspiratory flow rate; SD = standard deviation

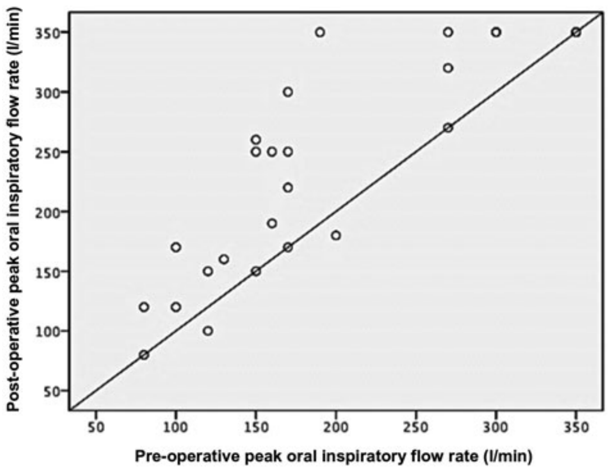

FIG. 3
Relationship between pre- and post-operative peak oral inspiratory flow rate.

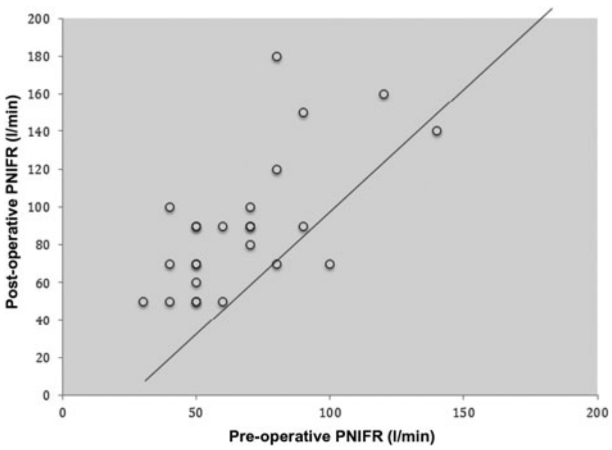

FIG. 4
Relationship between pre- and post-operative peak nasal inspiratory flow rate (PNIFR).

Peak nasal inspiratory flow rate has been used before to assess nasal patency in children aged from 5 to 18 years in a normal population[3,4] and in patients with upper and lower airway disease. Peak oral inspiratory flow rate has not been used before to assess upper airway patency. Patients in our population were aged from 5 to 46 years. At the start of the study, there were concerns about training a five-year-old child to perform PNIFR and peak oral inspiratory flow. Papachristou *et al.*[3] measured PNIFR in healthy children aged 5–18 years, suggesting that it was possible to teach children as young as 5. In this study, five patients were five years old and using appropriate instruction and demonstration, they performed both PNIFR and peak oral inspiratory flow.

As age ranged from 5 to 46 years in our study population, we expected a wide range in peak flow measurements, as lung volume would determine the magnitude of these measurements. Someone as young as 5 would have a lower lung volume, reflected by lower peak oral inspiratory flow rate and PNIFR measurements when compared to a 46-year-old patient. The minimum pre-operative peak oral inspiratory flow rate was 70 l/min and the maximum peak oral inspiratory flow rate was 350 l/min with a mean of 174.40 l/min. The minimum pre-operative PNIFR was 30 l/min and the maximum PNIFR was 140 l/min with a mean of 60 l/min. Linear regression models were used to show the relationship between age and both peak oral inspiratory flow rate and PNIFR. There appears to be a linear relationship, as shown in Figure 1, between age and peak oral inspiratory flow rate ($r = 0.603$, $p < 0.0001$); for every year increase in age, the peak oral inspiratory flow rate increased by 4.394 l/min. Similarly, for the relationship between age and PNIFR, the correlation coefficient was $r = 0.\ 381$, $p < 0.0001$, and for every year increase in age, the PNIFR increased by 0.756 l/min (see Figure 2).

During the inspiratory phase of breathing, the obstruction caused by the enlarged lymphoid tissue in the nasopharynx will have an impact on the PNIFR measurements, while the enlarged lymphoid tissue in the oropharynx will impact on the peak oral inspiratory flow rate measurements. In this study, all patients underwent tonsillectomy and none underwent adenoidectomy. Despite the absence of adenoidectomy, the post-operative PNIFR showed an increase, compared to the pre-operative PNIFR measurements. The improvement in nasal patency after tonsillectomy may be due to an increase in nasopharyngeal space, which was compromised before by enlarged tonsils displacing the soft palate into the nasopharynx.

This study was designed to see if there was any difference between pre- and post-operative oral and nasal patency by measuring peak oral inspiratory flow rate and PNIFR. Figure 3 shows the relationship between pre- and post-operative peak oral inspiratory flow

https://doi.org/10.1017/S0022215115000523 Published online by Cambridge University Press

rate. Of the 25 participants who completed the second phase of the study, 17 (68 per cent) showed an increase in post-operative peak oral inspiratory flow rate. The mean difference suggests that, on average, the post-operative peak oral inspiratory flow rate increased by 45 per cent when compared to the pre-operative peak oral inspiratory flow rate. The fact that the majority of patients had a post-operative increase in peak oral inspiratory flow rate may be explained by the removal of the tonsils obstructing the airway, and the good correlation between pre- and post-operative results ($r = 0.850$) indicates that there is good reproducibility of peak oral inspiratory flow rate measurements.

- **We have shown that a simple, non-invasive inspiratory flow meter can be used to measure both peak oral inspiratory flow rate (POIFR) and peak nasal inspiratory flow rate (PNIFR)**
- **Together, these measurements represent a cost- and time-effective method of assessing upper airway obstruction when compared with other objective assessment methods**
- **The results of this study show that the measurements of POIFR and PNIFR are reproducible**
- **There appears to be a correlation between pre-operative POIFR and PNIFR, and both these measurements show a linear relationship with age**
- **Post-operative POIFR and PNIFR increased compared to pre-operative peak oral inspiratory flow rate and PNIFR, and this was statistically significant**

Figure 4 shows the relationship between pre- and post-operative PNIFR. Of the 25 participants who completed the second phase of the study, 18 (72 per cent) showed an increase in post-operative PNIFR. The mean difference shows that, on average, post-operative PNIFR increased by 22 per cent when compared to pre-operative PNIFR. The fact that the majority of patients had a post-operative increase in PNIFR may be explained by the tonsils not only obstructing the oral airway but also contributing to some obstruction of the nasal airway. The good correlation between pre- and post-operative results ($r = 0.663$) indicates that there is good reproducibility of PNIFR measurements.

Acknowledgements

The authors would like to thank all the patients who took part in this study. The authors also acknowledge Mr Alan Tomkinson, Mr Stuart Quine and all the other ENT consultants at University Hospital of Wales, Cardiff for their advice in designing the study and allowing the smooth running of the study.

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Mr S Bathala takes responsibility for the integrity of the content of the paper
Competing interests: None declared