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Correlation between tidal breathing flow volume loops and obstructive sleep apnea in young children with adenotonsillar hypertrophy

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Background : *The availability and cost of polysomnography limit its use as a diagnostic test for obstructive sleep apnea (OSA). Tidal breathing flow volume (TBFV) loops can determine the site and severity of airway narrowing in infants and young children.*

Objective : *To determine whether the configurations of TBFV loops assessed during sleep correlated with OSA and its severity in young children with adenotonsillar hypertrophy (ATH).*

Methodology : *Retrospective study was performed in the patients aged ≤ 5 years who presented at King Chulalongkorn Memorial Hospital during 1999-2000 with ATH and suggestive symptoms for OSA. All patients had overnight 4-channel cardio-respiratory monitoring and TBFV loops assessment performed during sleep in the same admission. OSA/hypopea index, lowest arterial oxygen saturation (SpO_2) during sleep and TBFV loops parameters such as mid tidal expiratory flow rate/mid tidal inspiratory flow rate (Me/Mi) ratio and peak tidal expiratory flow rate/tidal volume (PTEF/Vt) ratio were reviewed.*

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Results : *Twenty patients with the mean age of 4.0 ± 0.8 yrs (range 3-5 yrs) were reviewed. Median OSA/hypopnea index was 2.7/hr (range 0-19.8/hr). OSA was found in 16 patients (80 %). The TBFV loops showed normal in 6, variable upper airway obstruction (UAO) in 9, and fixed UAO in 5 patients. In patients who had variable UAO, there was no correlation between Me/Mi and either OSA/hypopnea index (r=0.4; ns) or lowest SpO_2 during sleep (r= -0.3; ns). The number of the patients who had OSA was not different among those who had normal loops, variable UAO and fixed UAO (4, 9 and 3, respectively; ns). There was no difference in the number of those who had SpO_2 <92 % during sleep among these 3 groups of patients (3, 7 and 2, respectively; ns).*

Conclusion : *The configuration of TBFV loops assessed during sleep did not correlate with the occurrence as well as the severity of OSA and could not predict OSA nor its severity. We speculate that the occurrence and the severity of OSA should depend on other factors rather than the size of upper airway during sleep alone.*

Keywords : *Obstructive sleep apnea, Tidal breathing flow-volume loops, Adenotonsillar hypertrophy.*

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สุชาดา ศรีทิพยวรรณ, เธียรชัย บรรณาลัย, นวลจันทร์ ปราบพาล, จันทนา หาญฤธากร, จิตลัดดา ดีโรจนวงศ์. ความสัมพันธ์ระหว่าง Tidal breathing flow volume loops กับการเกิดภาวะทางเดินหายใจอุดกั้นในขณะนอนหลับ (Obstructive sleep apnea) ในผู้ป่วยเด็กเล็กที่มีต่อมทอนซิลและอะดีนอยด์โต. จุฬาลงกรณ์เวชสาร 2547 เม.ย; 48(4): 223 – 34

ปัญหา/เหตุผลการทำวิจัย : *การวินิจฉัยภาวะทางเดินหายใจอุดกั้นในขณะนอนหลับ (OSA) ในผู้ป่วยเด็กโดยวิธี overnight polysomnography มีข้อจำกัดในเรื่องค่าใช้จ่ายที่สูงและเครื่องมือที่ใช้ยังมีไม่แพร่หลาย การตรวจดูลักษณะของ tidal breathing flow volume (TBFV) loops เป็นวิธีที่ทำได้ง่ายในเด็กเล็ก ใช้บอกตำแหน่งและความรุนแรงของการตีบแคบในทางเดินหายใจได้*

วัตถุประสงค์ : *เพื่อหาความสัมพันธ์ระหว่างลักษณะของ TBFV loops กับการเกิด OSA และความรุนแรงของภาวะนี้ในผู้ป่วยเด็กเล็กที่มีอาการนอนกรนร่วมกับมีต่อมทอนซิล/อะดีนอยด์โต*

วัสดุและวิธีการ : *เป็นการศึกษาแบบย้อนหลังในผู้ป่วยเด็กอายุไม่เกิน 5 ปีที่มีต่อมทอนซิล/อะดีนอยด์โตและสงสัยภาวะ OSA และเข้ารับการตรวจการนอนหลับโดยวิธี overnight 4-channel cardio-respiratory monitoring และ TBFV loops ขณะหลับ ที่โรงพยาบาลจุฬาลงกรณ์ในปีพ.ศ. 2542-2543 ค่า OSA/hypopea index, ค่าความอิ่มตัวของออกซิเจนในเลือดแดง (SpO_2) ขณะนอนหลับ และค่าที่วัดได้จาก TBFV loops ในขณะนอนหลับ ได้แก่ mid tidal expiratory flow rate/mid tidal inspiratory flow rate (Me/Mi) ratio และ peak tidal expiratory flow rate/tidal volume (PTEF/Vt) ratio ได้ถูกบันทึกไว้*

ผลการศึกษา : *ผู้ป่วย 20 ราย อายุ 3-5 ปี (อายุเฉลี่ย 4.0 $\pm$ 0.8 ปี) ได้รับการศึกษา ค่า OSA/hypopnea index อยู่ระหว่าง 0-19.8/ชั่วโมง (เฉลี่ย 2.7/ชั่วโมง) ผู้ป่วย 16 ราย (ร้อยละ 80) มี OSA ผลการตรวจ TBFV loops พบลักษณะปกติในผู้ป่วย 6 ราย, variable upper airway obstruction (UAO) 9 รายและ fixed UAO 5 ราย จำนวนผู้ป่วยที่มี OSA ไม่แตกต่างกันระหว่างกลุ่มที่มี loop ปกติ (มี OSA 4 ราย) กลุ่มที่มี variable UAO (มี OSA 9 ราย) และกลุ่มที่มี fixed*

UAO (มี OSA 3 ราย) นอกจากนี้ ยังไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติของจำนวนผู้ป่วยที่มีค่า SpO_2 ต่ำกว่าร้อยละ 92 เมื่อเปรียบเทียบระหว่าง 3 กลุ่มดังกล่าว (จำนวนผู้ป่วยที่มีค่า SpO_2 ต่ำกว่าร้อยละ 92 ในแต่ละกลุ่มเท่ากับ 3, 7 และ 2 รายตามลำดับ) ในกลุ่มที่มี variable UAO พบว่า ไม่มีความสัมพันธ์ระหว่างค่า Me : Mi ratio กับ OSA index (r = 0.4; ns) หรือค่า SpO_2 (r = -0.3; ns)

สรุป : *ลักษณะของ TBFV loops ไม่สัมพันธ์กับการเกิด OSA หรือความรุนแรงของ OSA การเกิด OSA ในเด็กอาจเกี่ยวข้องกับปัจจัยอื่น ๆ นอกเหนือไปจากการตีบแคบของทางเดินหายใจในขณะนอนหลับ การดูลักษณะของ TBFV loop ไม่ช่วยทำนายภาวะ OSA ในผู้ป่วยเหล่านี้*

คำสำคัญ : *ภาวะอุดกั้นของทางเดินหายใจในขณะนอนหลับ, tidal breathing flow volume loop, ภาวะต่อมทอนซิลและอะดีนอยด์โต*

Obstructive sleep apnea (OSA) can be found in children of all ages, especially those in the preschool period when there is a substantial growth of the adenoid and tonsils.[1] Definite demographic data of OSA in children has not yet been well established. The prevalence of OSA in children varies from 0-10.3 % with the prevalence of 0.7 % among Thai school-age children.[2-7] The disease is characterized by recurrent episodes of partial or complete upper airway obstruction occurring during sleep.[1] It has been believed that a combination of structural and neuromotor defects contributes to the narrowing of the upper airway during sleep in OSA patients.[1]

Tidal breathing flow volume (TBFV) loops can determine the site of airway obstruction in infants and children.[8, 9] Several studies demonstrated the characteristic signs of extrathoracic airway obstruction and limitation in flow volume loops of OSA in adults.[10, 11] However, many studies revealed low sensitivity and specificity of the tests in screening for OSA.[12-15] All of these studies were performed while the patients were awake and in non-tidal breathing maneuver which might not represent the real status of upper airway patency during sleep or when OSA occurs. Evaluation of TBFV loops during sleep should provide useful information regarding the size of the upper airway that may be useful for the prediction of OSA, especially in young children who may not well tolerate the standard monitoring of overnight 16-channel polysomnography (PSG).

The aim of our study was to determine if there was a correlation between the configuration of TBFV loops and the occurrence as well as the severity of OSA in young children with adenotonsillar hypertrophy and snoring.

Material and Method

We retrospectively reviewed 20 patients, aged $\leq$ 5 years who presented with snoring and adenotonsillar hypertrophy as well as suggestive symptoms for OSA such as difficult or stop breathing during sleep, restless sleep, failure to thrive and poor school performance. All patients were admitted during 1999-2000 at King Chulalongkorn Memorial Hospital for an overnight 4-channel cardio-respiratory monitoring and had TBFV loops assessed during sleep in the following morning. Patients with neuromuscular or craniofacial disorders predisposed to OSA as well as those who had other causes of airway obstruction were excluded from the review. Tonsillar hypertrophy was defined when the patient demonstrated at least 3+ size of both tonsils. All patients had adenoid hypertrophy diagnosed by the x-rays of the lateral nasopharynx which were reviewed by the radiologists.

Laboratory studies

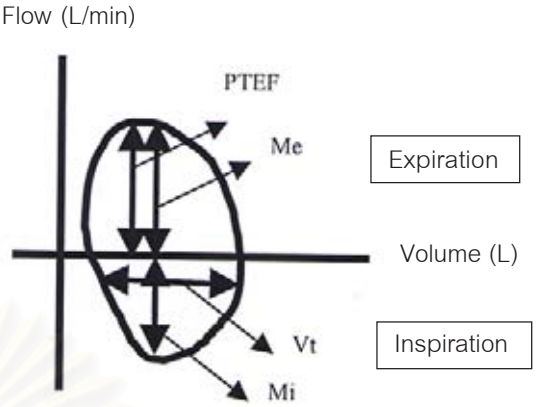
Each patient had an overnight 4-channel cardio-respiratory monitoring performed by using Sleep I/T® (CNS, Inc. Chanhassen, MN) at the hospital. The monitored parameters included, namely :

- nasal and oral airflow measured by using the thermisters
- chest and abdominal wall movements
- arterial oxygen saturation (SpO_2) including pulse waveforms
- electrocardiogram

The total sleep times were 6-8 hours. Parents or caregivers were allowed to stay with the patients throughout the study nights. The sleep onset and sleep termination were clinically observed by the parents or caregivers. Movement artifacts were noted when

the patients demonstrated irregularities of chest/abdominal movement signals in addition to the irregularities of the pulse waveform signals, which were confirmed by the observations of the parents or caregivers.

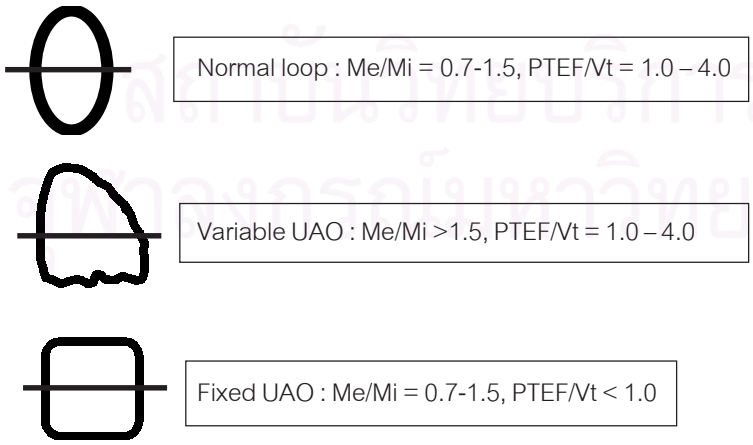
The cardio-respiratory monitoring was scored by attending pediatric pulmonologists. An obstructive apnea event was defined when the patient demonstrated an absence of oro-nasal airflow signal lasting longer than 2 respiratory cycles times without a reduction of respiratory effort. An obstructive hypopnea event was defined when the patient demonstrated a 50 % or greater decrease in the amplitude of oro-nasal airflow signal lasting longer than 2 respiratory cycles times without a reduction of respiratory effort. Obstructive sleep apnea was diagnosed when the patients demonstrated OSA/hypopnea events greater than 1 per hour of total sleep time (OSA/hypopnea index >1/hour), either with or without desaturation. Desaturation event was defined when the SpO_2 was lower than 92 %.



(PTEF = peak tidal expiratory flow rate, Me = Mid tidal expiratory flow rate, Mi = mid tidal inspiratory flow rate, Vt = tidal volume)

Figure 1. Normal tidal breathing flow volume loop [16]

The TBFV loops were assessed during sleep on the following day by a pulmonary lab technician who blinded to the results of the overnight 4-channel cardio-respiratory monitoring. The TBFV loops were obtained by using the Pediatric Pulmonary Function Cart (Sensormedics 2600®; Yorba Linda, CA). Chloral hydrate (50 mg/kg/dose) was given if the patients



(PTEF = peak tidal expiratory flow rate, Me = Mid tidal expiratory flow rate, Mi = mid tidal inspiratory flow rate, UAO = Upper airway obstruction, Vt = tidal volume)

Figure 2. Characteristic of each type of tidal breathing flow volume loops [16]

could not sleep by themselves. Four acceptable TBFV loops (complete loop with less than 15 % of tidal volume variation) were selected. Tidal volume (Vt), peak tidal expiratory flow rate (PTEF), mid tidal expiratory flow rate (Me) and mid tidal inspiratory flow rate (Mi) were measured and analyzed from the selected loops (Figure 1). The patients were classified into 3 groups (normal loop, variable upper airway obstruction [UAO] and fixed UAO) basing upon the configuration of the loops (Figure 2) and the following criteria:[16]

- Normal loop : Me/Mi = 0.7 - 1.5 and PTEF/Vt = 1.0 - 4.0
- Variable UAO : Me/Mi > 1.5 and PTEF/Vt = 1.0 - 4.0
- Fixed UAO : Me/Mi = 0.7 - 1.5 and PTEF/Vt < 1.0

The following data were collected:

- Demographic data including ages and genders
- The lowest SpO_2 recorded during sleep
- OSA/hypopnea index
- The Me/Mi ratio and the PTEF/Vt ratio

Statistical analysis

Comparisons of ages and gender distribution among the 3 groups of patients (normal loops, variable UAO and fixed UAO) were made by using Anova test and Fischer Exact test, respectively. The correlation between Me/Mi ratio and OSA/hypopnea index as well as the lowest SpO_2 during sleep were assessed by using Pearson correlation. The number of patients who had OSA as well as the number of patients who had desaturation during sleep were compared among the 3 groups of patients by using Fischer Exact test. The p value < 0.05 was considered for a statistical significance.

The study protocol was approved by the Ethics Committee for Human Research Study of the hospital.

Results

Twenty patients, aged 4.0 $\pm$ 0.8 years (ranged 3-5 years; 25 % female) were reviewed. The data of the studied patients (demographic data, TBFV loops parameters, OSA/hypopnea index and lowest SpO_2 observed during sleep) were shown in Table 1. The OSA/hypopnea index ranged between 0-19.8/hour (median 2.7/hour). There were 16 patients (80 %) who had OSA/hypopnea index > 1/hour and 12 patients (60 %) who had significant desaturation (SpO_2 < 92 %) during sleep. Six of twenty (30 %) patients had normal TBFV loops while nine (45 %) had variable UAO, and five (25 %) had fixed UAO. The mean ages of those who had normal TBFV loop, variable UAO and fixed UAO were 4.3 $\pm$ 0.9, 3.9 $\pm$ 0.6, and 3.7 $\pm$ 0.8 years, respectively. The percentages of female gender were 33, 22, and 20 %, respectively. Among these 3 groups of patients, there was no difference in the mean age, gender distribution, the number of patients who had OSA, and the number of patients who had significant desaturation during sleep (Table 2).

All of those who had variable UAO had OSA. Seven of them (78 %) had significant desaturation. The Me/Mi ratio did not correlate with either OSA/hypopnea index (r = 0.4; *ns*) or lowest SpO_2 observed during sleep (r = -0.3; *ns*).

Table 1. Demographic data, TBFV loop parameters, OSA/hypopnea index and lowest SpO_2 observed during sleep of the studied patients.

Patients No.	Age (yrs)	Gender	Me/Mi	PTEF/Vt	Type of TBFV Loop	Lowest SpO_2 (%)	OSA/hypopnea index (/hr)
1	4	male	1.6	1.6	Variable UAO	80	6.8
2	4.5	male	2.1	1.4	Variable UAO	88	1.2
3	3.5	female	1.2	1.5	Normal	90	6.1
4	5	male	1.3	1.4	Normal	92	0.2
5	5	male	1.1	1.1	Normal	93	1.9
6	3	male	0.9	0.8	Fixed UAO	95	0.5
7	4	male	1.6	1.0	Variable UAO	94	1.1
8	3.5	male	1.7	1.2	Variable UAO	90	3.9
9	5	male	1.3	1.2	Normal	96	0
10	3	female	1.2	1.2	Normal	80	6.6
11	4.5	male	1.1	1.5	Normal	70	11.5
12	3	male	0.8	0.9	Fixed UAO	88	2.2
13	4	male	1.0	0.8	Fixed UAO	92	3.2
14	5	female	1.4	0.9	Fixed UAO	95	0.3
15	3.5	female	2.7	2.2	Variable UAO	84	8
16	5	female	1.8	2.1	Variable UAO	77	1.6
17	3.5	male	2.0	1.4	Variable UAO	85	4.3
18	3	male	1.9	1.9	Variable UAO	92	2.0
19	4.5	male	2.2	1.4	Variable UAO	70	19.8
20	3.5	male	0.9	0.9	Fixed UAO	80	5.2

(Me/Mi = Mid tidal expiratory flow rate/mid tidal inspiratory flow rate ratio, OSA = Obstructive sleep apnea, PTEF/Vt = Peak tidal expiratory flow rate/tidal volume ratio, SpO_2 = Arterial oxygen saturation, TBFV = Tidal breathing flow volume, UAO = Upper airway obstruction)

Table 2. Comparison of the number of patients with OSA and the number of patients with desaturation during sleep among the 3 groups of patients (normal loop, variable UAO and fixed UAO).

	Normal loop(n=6)	Variable UAO(n=9)	Fixed UAO(n=5)	*p* value
No. of patients with OSA	4 (67%)	9 (100%)	3 (60%)	*ns*
No. of patients with SpO_2 < 92%	3 (50%)	7 (78%)	2 (40%)	*ns*

(OSA = Obstructive sleep apnea, SpO_2 = Arterial oxygen saturation, TBFV = Tidal breathing flow volume, UAO = Upper airway obstruction)

Discussion

Tidal breathing flow volume loop can be used for evaluating the upper airway function in children. The site of the UAO can be determined by the characteristic of the loops and Me/Mi ratio.[8, 9, 16] Normal children demonstrate oval-shape flow volume loops during tidal breathing while those who have extrathoracic UAO demonstrate a relatively decrease of inspiratory flow rate and increase of Me/Mi ratio.[8, 16] If the obstruction is more severe, the expiratory flow rate can also be affected, resulting in fixed loop pattern.[8, 16] This implies that the configuration of TBFV loop may be useful for determining the severity of airway obstruction.

In our study, most of the patients had TBFV loops that were suggestive for variable UAO. All of them had OSA. We could not demonstrate the correlation between Me/Mi ratio and OSA severity. This may be explained by the variation of the patients' ability in creating the driving pressure across the narrowing airway. Some children might be able to increase the driving pressure with consequently increasing the inspiratory flow rate during the tidal breath and then minimizing the flow limitation.

Only 25 % of our patients demonstrated fixed UAO. We could not demonstrate the correlation between the configuration of the loops and the occurrence as well as the severity of OSA in our patients. Despite no statistical significance, the proportions of the patients who had OSA and desaturation in the fixed UAO group were less than those in variable obstruction group (60 % *vs* 100 %). This implied that not only the size of the upper airway during sleep, but also other factors determined the occurrence and severity of OSA in children. Subtle decrease of hypercapnic ventilatory drive has been reported in some OSA children.[17] Further studies regarding the ventilatory drive in OSA children are still needed.

Despite being a gold standard for diagnosing OSA, the overnight, attended 16-channel PSG has several limitations that limit its use especially in developing countries. Besides the high cost of the test, other factors that limit its use in children include the time consuming and the complexity of the monitoring system that may not be well tolerated by young children. Therefore, other techniques of cardio-respiratory monitoring have been studied in order to substitute PSG. Morielli et al reported that the accuracy of determining sleep and wakefulness in children by using cardio-respiratory and videotape recording at home was comparable with EEG monitoring using in PSG.[18] Other unattended, abbreviated cardio-respiratory monitoring such as nap study, overnight pulse oximetry and home videotaping have been reported to be useful for detecting OSA in children and adults despite having some limitations with their high false negative rates.[2, 19-25] The guidelines of the American Thoracic Society and the American Academy of Pediatrics suggested that the positive results of the unattended, abbreviated cardio-respiratory monitoring may be helpful and adequate for determining OSA in otherwise healthy children.[26, 27]

In our study, we did not use the overnight, attended 16-channel PSG as a diagnostic tool for OSA because of the high expense of the test, the shortage of the number of sleep- lab personel, and poor patients' compliance. Most small children could not provide a good compliance with the

electrodes applied on their heads for monitoring electroencephalogram, electromyogram and electro-occulogram during full PSG. Therefore, we decided to use the overnight 4-channel cardio-respiratory monitoring for diagnosing OSA in our patients. Their sleep onset and sleep termination were determined by the parents or caregivers who were familiar with the sleep pattern of the patients. Movement artifacts were carefully noted by observing the oximetry waveform, heart rate variability and parents or caregivers' observations. By carefully scoring, we believed that this monitoring system could provide good information for diagnosing OSA in our patients.

Conclusion

We found no correlation between the configuration of TBFV loops assessed during sleep and the occurrence as well as the severity of OSA in young children with adenotonsillar hypertrophy. The configuration of TBFV loops performed during sleep could not predict the occurrence and severity of OSA in these children. We speculate that not only the size of the upper airway during sleep but also other factors contribute to the occurrence and severity of OSA in young children with adenotonsillar hypertrophy.

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