Validity of Tidal Breathing Flow Volume Loops in Diagnosing Obstructive Sleep Apnea in Young Children with Adenotonsillar Hypertrophy: A Preliminary Study

Suchada Sritippayawan MD*, Tayard Desudchit MD*,
Nuanchan Prapphal MD*, Chanthana Harnruthakorn BSc*,
Jitladda Deerojanawong MD*, Rujipat Samransamruajkit MD*

** Department of Pediatrics, Faculty of Medicine, Chulalongkorn University*

Tidal breathing flow volume loops (TBFVL) can indicate the site/severity of upper airway obstruction (UAO). The authors did a pilot study to determine 1) the correlation between TBFVL and obstructive sleep apnea (OSA) as well as its severity and 2) the validity of TBFVL in determining OSA and desaturation during sleep in young children with adenotonsillar hypertrophy (ATH). A cross sectional analytical study was performed in 10 patients with ATH (age 4.2±0.4 yrs; 40% female) at King Chulalongkorn Memorial Hospital during January-June 2004. All had polysomnography and TBFVL performed during sleep. Median apnea/hypopnea index (AHI) was 3.4/hr. Eight (80%) patients had OSA. The TBFVL was normal in 2, variable UAO in 3, and fixed UAO in 5 patients. Among these 3 groups, the number of OSA patients (2, 3 and 3, respectively; ns) and the number of those who had desaturation (2, 3 and 3, respectively; ns) were not different. There was no correlation between mid tidal expiratory flow rate/mid tidal inspiratory flow rate (Me/Mi) ratio and AHI (r=0.5; ns) or lowest arterial oxygen saturation during sleep (r=-0.4; ns). The accuracy of Me/Mi>1.5 for diagnosing OSA and desaturation was 50% and 60%, respectively. The abnormal TBFVL also had the same accuracy in defining these 2 conditions. In conclusion, TBFVL did not correlate with OSA and its severity and had low accuracy in determining either OSA or desaturation in young children with ATH.

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

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Obstructive sleep apnea (OSA) can be found in children of all ages, especially during the preschool period when there is a substantial growth of the adenoid and tonsils [1]. The definite demographic data of OSA in children has not been well established. Prevalence of OSA in children varies from 0.7-10.3% 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 upper airway narrowing during sleep in OSA patients [1].

Tidal breathing flow volume loops (TBFVL) can determine the site of airway obstruction in infants and children[8,9]. In adults, several studies demonstrated the characteristic signs of extrathoracic airway obstruction and flow limitation in flow volume loops of OSA patients[10,11]. Yet, many studies demonstrated the low sensitivity and specificity of the tests in screening for OSA[12-15]. However, all of these studies were performed in awakening patients and in non-tidal breathing maneuver which might not indicate the real condition of upper airway patency during sleep or at the times when OSA occurs. Evaluation of TBFVL during sleep should provide useful information regarding the size of the upper airway and may be helpful in defining OSA, especially in young children who may not have good compliance with the complicating, standard, overnight polysomnography (PSG).

The authors did a pilot study to determine whether there was a correlation between the configuration of TBFVL and the occurrence as well as the severity of OSA in young children with adenotonsillar hypertrophy and snoring. The validity of TBFVL in determining OSA and desaturation during sleep were also studied.

Correspondence to : Sritippayawan S. Division of Pulmonology and Critical Care Medicine,Department of Pediatrics, Faculty of Medicine, Chulalongkorn University. Rama IV Rd., Bangkok 10330, Thailand. Phone: 0-2256-4951, Fax: 0-2256-4911, E-mail: suchadacu@hotmail.com

Material and Method

A pilot, cross sectional study was performed in 10 patients, aged not greater than 5 years who presented at King Chulalongkorn Memorial Hospital during January-June 2004 with the history of snoring and suggestive symptoms for OSA such as difficult or stop breathing during sleep, restless sleep, failure to thrive and poor school performance. All had adenotonsillar hypertrophy and were admitted to the hospital for the overnight PSG and had TBFVL evaluated during sleep on the following day. Patients with neuromuscular diseases, craniofacial disorders and those who had other causes of airway obstruction were excluded from the present study. Tonsillar hypertrophy was defined if the patient demonstrated at least 3+ size of both tonsils. All patients had adenoid hypertrophy diagnosed by the x-ray of the lateral nasopharynx which were reviewed by the radiologists.

Laboratory studies

The overnight PSG was performed in each patient by using the Easy II system (Cadwell Laboratories; Seattle, WA). The monitored parameters included:

- electroencephalogram
- electro-occulogram
- electromyogram
- electrocardiogram
- nasal/oral airflow (by using the thermocouple)
- chest/abdominal wall movement
- arterial oxygen saturation (by using pulse oximeter)
- sleep position (by using body position detector)

The overnight PSGs were performed by the sleep lab technicians and were scored by the pediatric neurologist and pediatric pulmonologist who were blinded to the results of TBFVL assessment. An obstructive apnea event was defined if the patient demonstrated the absence of oro-nasal airflow signal lasting longer than 2 respiratory cycles times without the reduction in respiratory effort. An obstructive hypopnea event was defined if the patient demonstrated a 50% or greater decrease in the amplitude of the oro-nasal airflow signal lasting longer than 2 respiratory cycles times without a reduction in respiratory effort. Obstructive sleep apnea was diagnosed if the patients demonstrated apnea/hypopnea events greater than 1 per hour of the total sleep time (apnea/hypopnea index >1/hour), either with or without desaturation. Desaturation event was defined if the SpO_2 was lower than 92%.

The TBFVL was assessed during sleep on the following day by a pulmonary lab technician who was blinded to the results of the overnight PSG. The TBFVL 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 could not sleep by themselves. Four acceptable TBFVL (complete loops 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 (Fig. 1), and averaged from the selected loops. The patients were classified into 3 groups (normal loop, variable upper airway obstruction [UAO] and fixed UAO) according to the configuration of the loops (Fig. 2) and the following criteria[16]:

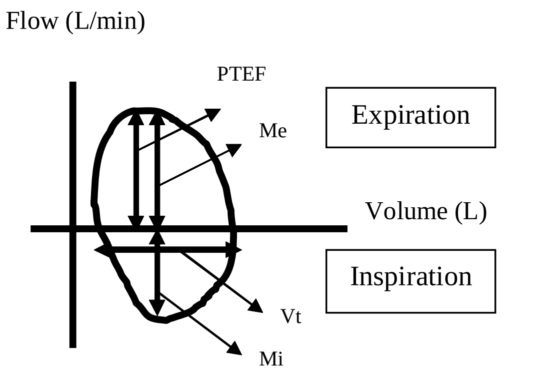
- Normal loop: Me/Mi = 0.7 - 1.5 and PTEF/Vt = 1.0 - 4.0
- Variable UAO: Me/Mi > 1.5 and PTEF/Vt = 1.0 - 4.0
- Fixed UAO: Me/Mi = 0.7 - 1.5 and PTEF/Vt < 1.0

The following data were collected:

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

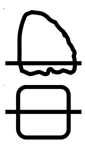
Statistical analysis

Comparison of age 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 apnea/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



(PTEF = Peak tidal expiratory flow rate, Me = Mid tidal expiratory flow rate, Mi = Mid tidal inspiratory flow rate, Vt = Tidal volume)

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



(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)

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

the 3 groups of patients by using Fischer Exact test. The *p* value of < 0.05 was considered to have statistical significance.

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

Results

Ten patients with the mean age of 4.2 $\pm$ 0.4 yrs (range 3.5-5.0 yrs) and 40% female were studied. The data of the studied patients (demographic data, TBFVL parameters, apnea/hypopnea index and lowest SpO_2 observed during sleep) are shown in Table 1. Median apnea/hypopnea index was 3.4/hr (range 0.4-17.3/hr). OSA was found in 8 (80%) patients. The TBFVL was normal in 2, variable upper airway obstruction (UAO) in 3, and fixed UAO in 5 patients. There was no correlation between the Me/Mi ratio and either apnea/hypopnea index (r=0.5; *ns*) or lowest SpO_2 during sleep (*r*= -0.4; *ns*). The number of patients who had OSA or desaturation was not different among those who had normal loops, variable UAO and fixed UAO (Table 2). The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of Me/Mi >1.5 and abnormal TBFVL for diagnosing OSA and desaturation are shown in Table 3 and 4, respectively.

Discussion

Despite being a gold standard test for diagnosing OSA, the overnight PSG has several limitations especially in young children and was not widely available except in developed countries. Besides the high cost of the test, other factors that limit its use in children include the time consumed and the complexity of the monitoring system. Therefore, other cardiorespiratory monitoring and pulmonary function studies have been studied in order to substitute PSG.

Most of the pulmonary function studies and flow volume assessment in OSA were performed in awakening, non quiet breathing adults and could not demonstrate the consistency of the results among the studies[10-15]. Since OSA is a disease that occurs during sleep and is partly associated with the narrowing upper airway during sleep, studies to determine the abnormalities should be performed while the patients are sleeping.

It has been known that TBFVL can be used as a tool for evaluating the upper airway obstruction in children. The site of the obstruction 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 relative decrease of inspiratory flow rate and increase of Me/Mi ratio[8,16].

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

Patients No.	Age (yrs)	Gender	Me/Mi	PTEF/Vt	Type of TBFVL	Lowest SpO_2 (%)	AHI (/hr)
1	3.9	F	0.86	0.84	Fixed UAO	86	1.6
2	3.5	M	1.74	1.38	Variable UAO	81	11.1
3	4.0	M	0.84	1.18	Normal	88	4.6
4	4.3	M	0.88	1.02	Normal	84	4.1
5	4.0	M	1.29	0.93	Fixed UAO	91	0.4
6	4.2	F	0.89	0.82	Fixed UAO	94	0.5
7	4.3	M	2.20	1.94	Variable UAO	55	17.3
8	5.0	F	1.05	0.90	Fixed UAO	78	2.6
9	4.3	M	4.41	2.52	Variable UAO	81	13.3
10	4.5	F	0.71	0.65	Fixed	93	1.6

(AHI = apnea/hypopnea index, 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, TBFVL = Tidal breathing flow volume loop, 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=2)	Variable UAO (n=3)	Fixed UAO (n=5)	*p* value
No. of patients with OSA	2 (100%)	3 (100%)	3 (60%)	*ns*
No. of patients with $SpO_2 < 92\%$	2 (100%)	3 (100%)	3 (60%)	*ns*

(OSA = Obstructive sleep apnea, SpO_2 = Arterial oxygen saturation, UAO = Upper airway obstruction)

Table 3. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of Me/Mi > 1.5 and abnormal TBFVL for diagnosing OSA during sleep

	Me/Mi > 1.5	Abnormal TBFVL
Sensitivity (%)	37.5	75
Specificity (%)	100	0
PPV (%)	100	75
NPV (%)	28.6	0
Accuracy (%)	50	60

(Me/Mi = Mid tidal expiratory flow rate/mid tidal inspiratory flow rate ratio, OSA = Obstructive sleep apnea, TBFVL = Tidal breathing flow volume loop)

Table 4. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of Me/Mi > 1.5 and abnormal TBFVL for diagnosing desaturation during sleep

	Me/Mi > 1.5	Abnormal TBFVL
Sensitivity (%)	37.5	75
Specificity (%)	100	0
PPV (%)	100	75
NPV (%)	28.6	0
Accuracy (%)	50	60

(Me/Mi = Mid tidal expiratory flow rate/mid tidal inspiratory flow rate ratio, OSA = Obstructive sleep apnea, TBFVL = Tidal breathing flow volume loop)

If the obstruction is more severe, the expiratory flow rate will be affected, resulting in fixed loop pattern[8,16].

The presented pilot study assessed the site and severity of upper airway narrowing during quiet breathing sleep in young children with ATH by performing TBFVL assessment. The authors also correlated the configuration of TBFVL and the occurrence as well as the severity of OSA. Most of the studied patients had TBFVL that were compatible with fixed UAO. Normal TBFVL was found in 2 studied patients. Both of them had OSA. The authors could not demonstrate the correlation between the configuration of the TBFVL and the occurrence of OSA as well as its severity. In addition, the authors found a low accuracy of the TBFVL in determining the occurrence of OSA and desaturation. This might be due to the limited number of the studied patients. Furthermore, the variation of the patients' ability in creating the driving pressure across the narrowing airway might effect the configuration of the loops. Some children might be able to increase the driving pressure while consequently increasing the inspiratory flow rate during the tidal breath and then minimizing the flow limitation.

The poor correlation between the configuration of the TBFVL and the OSA as well as its severity could imply that not only the size of the upper airway during sleep, but also other factors that induced OSA and desaturation in sleeping children. Subtle decrease of hypercapnic ventilatory drive has been reported in some OSA children[17]. Further studies in a larger sample size as well as studies related to ventilatory drive in OSA children are still needed.

Conclusions

The authors found no correlation between the configuration of TBFVL assessed during sleep and the occurrence as well as the severity of OSA in young children with ATH. The configuration of TBFVL performed during sleep could not predict the occurrence as well as the severity of OSA and had low accuracy in determining the occurrence of OSA and desaturation during sleep in these children. The authors speculate that not only the size of the upper airway during sleep but also other factors are involved that contribute to the occurrence and severity of OSA in young children with ATH. A further study in a larger population is still needed.

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Abbreviations:

Me	Mid tidal expiratory flow rate
Mi	Mid tidal inspiratory flow rate
NPV	Negative predictive value
OSA	Obstructive sleep apnea
PPV	Positive predictive value
PSG	Polysomnography
PTEF	Peak tidal expiratory flow rate

SpO_2	Arterial oxygen saturation
TBFVL	Tidal breathing flow volume loop
UAO	Upper airway obstruction
Vt	Tidal volume

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ความแม่นยำของ tidal breathing flow volume loops ที่ผิดปกติในการวินิจฉัยภาวะ obstructive sleep apnea ในผู้ป่วยเด็กเล็กที่มีต่อมทอนซิลและอะดีนอยด์โต

สุชาดา ศรีทิพยวรรณ, ทายาท ดีสุดจิต, นวลจันทร์ ปราบพาล,จันทนา หาญฤฐากร, จิตลัดดา ดีโรจนวงศ์, รุจิภัตต์ สำราญสำรวจกิจ

Polysomnography (PSG) มีข้อจำกัดเรื่องค่าใช้จ่ายในการวินิจฉัย obstructive sleep apnea (OSA) การตรวจ tidal breathing flow volume loop (TBFVL) สามารถบอกตำแหน่งและความรุนแรงของภาวะทางเดินหายใจตีบแคบได้ ผู้วิจัยทำการวิจัยแบบนำร่องเพื่อหาความสัมพันธ์ระหว่าง TBFVL กับการเกิดและความรุนแรงของ OSA และประเมินความแม่นยำของ TBFVL ในการวินิจฉัย OSA และภาวะ desaturation ขณะหลับในเด็กเล็กที่มีทอนซิล/อะดีนอยด์โต โดยทำการศึกษาเชิงวิเคราะห์ ณ จุดหนึ่งของเวลาในเด็ก 10 ราย (อายุเฉลี่ย 4.2 $\pm$ 0.4 ปี; เพศหญิงร้อยละ 40) ที่มีทอนซิล/อะดีนอยด์โต และตรวจ PSG และ TBFVL ขณะหลับที่รพ. จุฬาลงกรณ์ในเดือนมกราคม-มิถุนายน 2547 พบ OSA 8 ราย (ร้อยละ 80) ค่า apnea/hypopnea index (AHI) เฉลี่ย 3.4 ครั้ง/ชั่วโมง ผู้ป่วย 2 รายมี TBFVL ปกติ, 3 รายเป็น variable upper airway obstruction (UAO) และ 5 รายเป็น fixed UAO จำนวนผู้ป่วยในแต่ละกลุ่มที่มี OSA (2, 3 และ 3 รายตามลำดับ; ns) และ desaturation (2, 3 และ 3 รายตามลำดับ; ns) ไม่แตกต่างกัน ค่า mid tidal expiratory flow rate/mid tidal inspiratory flow rate (Me/Mi) ratio ไม่สัมพันธ์กับค่า AHI (r=0.5; ns) หรือค่าความอิ่มตัวของออกซิเจนในเลือดแดง (r=-0.4; ns) ค่า Me/Mi >1.5 มีความแม่นยำในการวินิจฉัย OSA และ desaturation ร้อยละ 50 และ 60 ตามลำดับ เช่นเดียวกับค่าความแม่นยำของ TBFVL ที่ผิดปกติในการวินิจฉัยภาวะดังกล่าว โดยสรุป ลักษณะของ TBFVL ไม่สัมพันธ์กับการเกิดหรือความรุนแรงของ OSA และมีความแม่นยำต่ำในการวินิจฉัย OSA หรือภาวะ desaturation ในเด็กเล็กที่มีทอนซิล/อะดีนอยด์โต
