Measurement of End-Expiratory Pressure as an Indicator of Airway Patentcy above Tracheostomy in Children

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The tracheostomy speaking valve is a one-way valve that closes during exhalation. It causes redirection of exhaled gas into the larynx, mouth and nasal cavity, thus enabling children with long-term tracheostomies to speak. Whether a child can tolerate the valve depends mainly on the patency of the upper airway around and above the tracheostomy tube. To measure end-expiratory pressure (EEP) at the tracheostomy tube when the speaking valve is being put in place may be a useful noninvasive tool to assess the patency of the exhalation pathway. The authors, therefore, measured EEP when the patients were first put on the speaking valves and tried to follow-up the patients thereafter. Twenty-two tracheostomized children (aged 3.2 months to 17 years, male/female 16/6) were recruited for the present study and EEP was measured. It was found that 13 children having the EEP in the range of 2-6 cmH_2O could breathe normally through the valves and later could use the valves without any problems, whereas 9 children with EEP in the range of 10-40 cmH_2O demonstrated breathing difficulties and the valves had to be taken off immediately. Bronchoscopy revealed upper airway narrowing in all of those children with unsuccessful valve placements. It was concluded that EEP was exceedingly high in children with upper airway narrowing. The measurement of EEP via speaking valves can, thus, be used as an objective indicator to evaluate the patency of upper airway proximal to the tracheostomy tube.

Keywords: *Tracheostomized children, Ttracheostomy speaking valve, End-expiratory pressure, Assessment of the upper airway pathology*

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Verbal communication for children with tracheostomies has long been a problem. The tracheostomy speaking valve is one alternative for enhancing communication skills in children with long-term tracheostomies. It is a one-way valve that closes during the exhalation causing a redirection of exhaled gas into the larynx, mouth and nasal cavity, thus allowing the child to speak. Children's tolerance to the speaking valve depends mainly on the upper airway patency proximal to the tracheostomy tube. Thus, the assessment of the upper airway patency in children is very important prior to the use of speaking valves.

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Brochoscopy is known to be the best method to evaluate the upper airway pathology[1,2]. However, it is invasive and requires specialists to perform such a procedure. A number of bedside evaluations of upper airway patency are performed including chest auscultation before and during finger occlusion over the tracheostomy tube, chest auscultation when the speaking valve is being put in place, observation for exhaled air through the mouth and nose by using items such as tissue, feathers, mirror, blowing bubbles or whistles. Absent or decreased breath sounds during finger occlusion on the tracheostomy tube or when the speaking valve is being put in may indicate inadequate upper airway patency[3]. Spirometry measuring the amount of exhaled gas through the mouth is another method to objectively assess the upper airway patency in tracheostomized children[3].

However, some children are too young to follow the instructions and perform spirometry properly. The authors, therefore, proposed a new noninvasive technique to assess the upper airway patency which hopefully can be used in all tracheostomized children regardless of age. The authors' technique was to measure the end expiratory pressure (EEP) while the patient was being put on the speaking valve. This technique was practical, simple, safe and less time-consuming. The purpose of the present study was to evaluate the EEP measurement via speaking valves in tracheostomized children and to follow them up thereafter.

Material and Method

Subject selection

All tracheostomized children, who were prescribed speaking valves by physicians in charge on the parents' request for using the speaking device, were recruited for the present study from July 1999 to January 2002 at Ramathibodi Hospital, Mahidol University, which is a teaching hospital with more than 900 beds. The inclusion criteria included good consciousness and ability to breathe spontaneously in room air while awake without signs of breathing difficulties. The exclusion criteria were as follows; copious secretion, hypersecretion, severe upper airway stenosis, medical instability and having bronchoscopy or laryngoscopy or tracheostomy performed within the past 7 days.

Method of EEP measurement

The technique of EEP measurement is described and shown in Fig. 1. The Passy-Muir valve (Passy-Muir Inc, California, USA) was selected since it was well constructed and was shown to be safe for use in infants and children of less than 2 years of age[4]. A pressure manometer (DHD, Healthcare, NY, USA) was used to measure EEP while the speaking valve was being put in place. A pulse oximeter (N-180 pulse oximeter, Nellcor Inc, Hayward, CA, USA) was used to measure oxygen saturation and heart rate before and after the speaking valve placement.

Study design

The present study was a prospective study. Children's information regarding primary disorder, indications for tracheostomy, age, duration after tracheostomy, type and size of tracheostomy tubes were recorded. Heart rate, oxygen saturation and signs of respiratory difficulties (e.g., increased respiratory rate, abnormal breathing pattern, coughing, chest tightness and air trapping) were monitored by two pediatric respiratory nurses. Each nurse followed their assigned children separately and carried out the study. Firstly, the nurse performed secretion clearance via tracheostomy tube, oral and nasal cavity as needed. Baseline heart rate and oxygen saturation were measured during quiet breathing. Next, the pressure manometer was attached to the speaking valve and connected to the patient for EEP measurement during quiet breathing as shown in Fig. 1. The maximum EEP, heart rate and oxygen saturation were recorded during relaxed breathing after placing the speaking valve for 5 minutes. Children who demonstrated no change in respiration, no cough nor discomfort at 5 minutes after placement of speaking valves were classified as the "tolerance group". Parents of these children were instructed on how to use the speaking valves and to observe and record signs of respiratory difficulties that might occur when the child was being placed on the speaking valve during the first one month. Children who exhibited breathing difficulty, chest tightness and air trapping with or without coughing were classified as the "intolerance group". The EEP, heart rate, and oxygen saturation of this group were recorded right before the speaking valve was taken off. Bronchoscopy was then performed in children of the intolerance group and the findings were recorded.

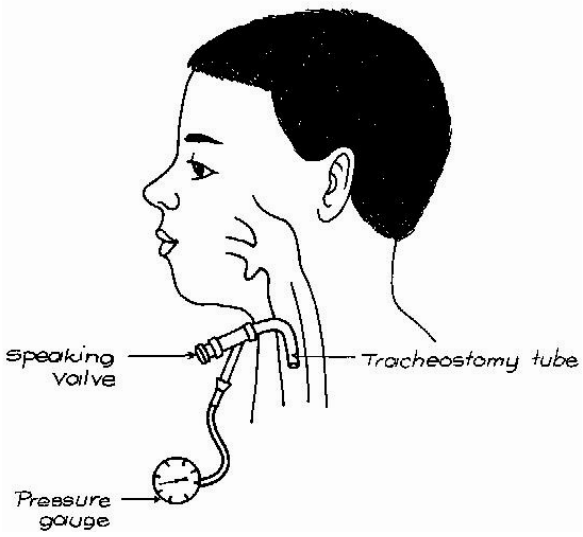

Fig. 1 Technique of EEP measurement. The pressure manometer was attached to speaking valve and connected to the patient for EEP measurement during quiet breathing

Statistical Methods

The results were expressed as mean ± SD. The mean values of heart rate and oxygen saturation were compared between baseline and 5 minutes after wearing the speaking valves by using the paired t-test. The statistical significant difference was detected at p-value < 0.05.

Results

There were 22 children enrolled in the present study. Thirteen children were classified as the tolerance group and 9 children as the intolerance group. The patients' baseline characteristics are summarized in Table 1 and Table 2. The primary disorders of the both groups are presented in Table 3. The two most common primary indications for tracheostomy in both groups were upper airway obstruction and pulmonary toilet.

The EEP measured in both groups are summarized in Table 1 and Table 2. The mean EEP of the tolerance group was lower than those of the intolerance group. All children in the tolerance group could be placed on speaking valves without any breathing difficulties. Heart rate at 5 minutes was significantly higher than the baseline level but the magnitude of the change in heart rate was only 4.4%.

Table 1. Patient characteristics of the tolerance group

Patient No.	Age (months)	Duration after tracheostomy (months)	Type of tracheostomy tube	EEP (cmH_2O)
1	3.2	0.2	Shiley 00	5
2	4	2	Portex 3.5	4
3	10	6	Shiley 1	4
4	12	1.5	Shiley 2	6
5	15	13	Shiley 2	4
6	31	25	Metal 2	4
7	40	32	Metal 2	4
8	48	45	Portex 5	3
9	50	1	Portex 5	4
10	54	1	Portex 5	4
11	122	9	Shiley 4	6
12	205	2	Portex 6	2
13	132	17	Metal 4	5
Mean	55.9	11.9	-	4.2
SD	60.9	14.2	-	1.1
Range	3.2-205	0.2-45	-	2-6

EEP = End Expiratory Pressure

Table 2. Patient characteristics of the intolerance group

Patient No.	Age (months)	Duration after tracheostomy (months)	Type of tracheostomy tube	EEP (cmH_2O)
1	5	1	Portex 3.5	40
2	7.9	2.2	Shiley 2	12
3	8.4	4	Shiley 0	30
4	9	5	Shiley 1	14
5	11	1.5	Shiley 2	10
6	12	0.5	Shiley 2	16
7	12	14	Shiley 3	10
8	36	18	Portex 5	40
9	41	5	Metal 4	14
Mean	15.8	5.7	-	20.7
SD	13.1	6.2	-	12.5
Range	5-41	0.5-18	-	10-40

Table 3. Primary disorder of the two groups of children in the present study

Primary disorder	Tolerance (n = 13)	Intolerance (n = 9)
Pulmonary disorder	4	2
Neurological disorder	5	3
Cardiac disorder	1	1
Congenital anomaly	2	1
Others	1	2

See details in text

Significant difference in oxygen saturation at the baseline and 5 minutes was not found (Table 5). None of the children in the tolerance group exhibited breathing difficulty nor any discomfort. Twelve children could wear the speaking valves as long as they needed. One child had to stop using the speaking valve due to recurrent seizures. In the intolerance group, only 2 patients (22.2%) could wear the speaking valve as long as 5 minutes. All the children in this group had either dyspnea, chest tightness or hyperinflation. Heart rate and oxygen saturation could be measured in 6 out of 9 children. There was no significant difference in heart rate and oxygen saturation between baseline and before the speaking valve was taken off. The results of bronchoscopy were shown in Table 6.

It should be noted that upper airway narrowing was confirmed in all children in the intolerance group.

Discussion

It was found that the EEP of the intolerance group was significantly higher than that of the

Table 4. Primary indications of the two groups of children for tracheostomy

Indication	Total (n = 22)	Tolerance (n = 13)	Intolerance (n = 9)
Upper airway obstruction	15 (68.2%)	7 (53.8%)	8 (88.8%)
Pulmonary toilet	6 (27.3%)	5 (38.5%)	1 (11.1%)
Prolong mechanical ventilation	1 (4.5%)	1 (7.7%)	0

Table 5. Heart rate and oxygen saturation at baseline and 5 minutes after speaking valve placement

	Tolerance (n = 13)		Intolerance (n = 6)	
	Baseline	5 minutes	Baseline	5 minutes
Heart rate	112.6±20.5	117.1±19.0*	133.0±20.1	135.3±21.8
Oxygen saturation	97.7±2.2	98.1±1.9	97.2±1.7	91.3±6.7

Results are expressed as mean ± SD
* Significant difference form baseline (p-valve = 0.007)

Table 6. Bronchoscopic findings of the intolerance group

No.	Time duration between EEP measurement and bronchoscopy after EEP (days)	Results
1	6	Floppy upper airway, pharyngomalacia
2	27	Subglottic stenosis
3	270	Severe pharyngomalacia
4	6	Swelling of hypopharynx
5	12	Subglottic stenosis, laryngomalacia
6	9	Severe laryngotracheomalacia
7	51	Tracheal stenosis
8	3	Granulation tissues at subglottic area
9	9	Subglottic area collapse

tolerance group. The results indicated that with EEP of 6 cmH_2O or less the speaking valve would be well tolerated at the beginning and thereafter. The EEP above 10 cmH_2O was associated with immediate breathing difficulties and hyperinflation. The possible causes for EEP of greater than 10 cmH_2O included upper airway narrowing or the relatively large size of the tracheostomy tube. Thus, the technique of EEP measurement via a speaking valve was helpful for the evaluation of upper airway patency above and around the tracheostomy tube. This method could be performed in all of the tracheostomized children regardless of age. It was safe, simple and practical and can be used to predict the children's toleratation to the speaking valve, which should be performed prior to the valve placement. It was noted that the measurement of EEP should be performed only when the patient is relaxed and breathes quietly. If the patient breathe irregularly or forcefully, the EEP might not be stable and hardly interpretable. Bronchoscopic findings in the intolerance group all confirmed the narrowing of upper airway proximal to the tracheostomy tube.

In conclusion, the measurement of EEP via speaking valves cough be used as an objective indicator to evaluate the patency of upper airway proximal to the tracheostomy tube. The success of the speaking valve placement requires an EEP of less than 6 cmH_2O. The EEP above 10 cmH_2O was associated with upper airway narrowing which might be used to predict an unsuccessful placement of the speaking valve.

Acknowledgement

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References

1. Myer GM III, Cotton RT. A practical approach to pediatric otolaryngology. Chicago: Year Book Publishers, 1988: 169-205.
2. Nussbaum E. Usefulness of miniature flexible fibreoptic bronchocopy in Children. Chest 1994; 106: 1438-42.
3. Mason M, Watkins C. Protocol for use the Passy-Muir tracheostomy speaking valves. Eur Resp J 1992; 5(Suppl 15): 148s.
4. Engleman SG., Turnage-Carrier C. Tolerance of the Passy-Muir speaking valve™ in infants and children less than 2 years of age. Pediatr Nurs 1997; 23: 571-3.

การวัดแรงดันช่วงสุดของการหายใจออกขณะใส่อุปกรณ์ช่วยพูดเพื่อเป็นตัวบ่งชี้ สภาพของทางเดินหายใจเหนือท่อเจาะคอในเด็ก

จงรักษ์ อุตรารัชต์กิจ, จีราพร พงศาสนองกุล, อรุณวรรณ พฤทธิพันธุ์, ธีรชัย ฉันทโรจน์ศิริ

อุปกรณ์ช่วยพูดในเด็กที่มีท่อเจาะคอ มีลักษณะเป็นลิ้นเปิดได้ทางเดียว ลิ้นนี้สามารถเปิดในช่วงจังหวะหายใจเข้าเพื่อให้ลมหายใจผ่านเข้าสู่ปอด และจะปิดในช่วงหายใจออก ทำให้ลมหายใจออกไม่สามารถออกทางท่อเจาะคอ แต่จะไหลกลับขึ้นไปสู่หลอดลมคอ กล่องเสียง ปาก และช่องจมูก เด็กจึงสามารถเปล่งเสียงได้ ดังนั้นก่อนจะพิจารณาให้เด็กใช้อุปกรณ์ช่วยพูด จะต้องแน่ใจว่าทางเดินหายใจบริเวณรอบท่อเจาะคอ และเหนือท่อเจาะคอต้องโล่งเพียงพอที่ลมหายใจออกไหลผ่านได้สะดวก การวัดค่าแรงดันช่วงสุดของการหายใจออก (End-Expiratory Pressure: EEP) ขณะใส่อุปกรณ์ช่วยพูดในเด็กที่มีท่อเจาะคอ น่าจะเป็นวิธีการที่สามารถนำมา ใช้เพื่อประเมินพยาธิสภาพการตีบแคบทางเดินหายใจส่วนบน

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อประเมินการวัด EEP ในเด็กเจาะคอที่ใส่อุปกรณ์ช่วยพูดครั้งแรกและติดตามผลผู้ป่วยในเวลาต่อมา มีเด็กที่เข้าศึกษาทั้งหมดจำนวน 22 ราย อายุ 3.2 เดือน ถึง 17 ปี เป็นชาย 16 ราย หญิง 6 ราย ในจำนวนนี้มีเด็ก 13 รายที่มีค่า EEP วัดได้อยู่ในช่วง 2 – 6 ซม.น้ำ เด็กกลุ่มนี้สามารถหายใจปกติในขณะใส่อุปกรณ์ช่วยพูดครั้งแรก และสามารถใส่อุปกรณ์ช่วยพูดในชีวิตประจำวันได้โดยไม่มีอาการผิดปกติ ส่วนเด็กอีก 9 รายมีค่า EEP อยู่ในช่วง 10-40 ซม.น้ำ จะมีอาการหายใจลำบากขณะใส่อุปกรณ์ช่วยพูดครั้งแรก 3 ราย จำเป็นต้องถอดอุปกรณ์ช่วยพูดออกทันที เด็กกลุ่มนี้ได้รับการตรวจโดยการใช้กล้องส่องดูทางเดินหายใจ (bronchoscopy) ในเวลาต่อมาพบว่าทุกรายมีการตีบแคบของทางเดินหายใจส่วนบน การศึกษานี้สรุปได้ว่าในเด็กที่มีทางเดินหายใจส่วนบนตีบแคบจะมีค่า EEP อยู่ในระดับที่สูง การวัด EEP ในเด็กเจาะคอน่าจะมีประโยชน์ในการประเมินพยาธิสภาพการตีบแคบของทางเดินหายใจเหนือท่อเจาะคอว่าโล่งเพียงพอที่จะให้ลมหายใจออกผ่านได้สะดวกหรือไม่ ก่อนจะนำอุปกรณ์ช่วยพูดมาใช้ในชีวิตประจำวัน