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Assessment of Tidal Breathing Patterns for Monitoring of Bronchial Obstruction in Infants

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ABSTRACT

Two parameters of tidal breathing, the ratio of time to reach peak tidal expiratory flow to the total expiratory time (Tme/TE) and the ratio of volume exhaled at peak tidal expiratory flow to the total exhaled volume (dV/VT) were used to assess lung function in 21 sedated infants (aged 6–14 mo) with different degrees of airway obstruction. These parameters were compared with airway resistance as percentage predicted (Raw%) and maximum expiratory flow at functional residual capacity corrected for lung volume ($\dot{V}_{max}$FRC/TGV). $\dot{V}_{max}$FRC/TGV values correlated significantly with Tme/TE ($r = 0.630$, $p = 0.002$) as well as with dV/VT ($r = 0.728$, $p = 0.001$). Raw% values showed only a weak correlation with dV/VT ($r = -0.435$, $p = 0.048$). We conclude that Tme/Te and dV/VT are both able to detect airway obstruction in infants and that these parameters correlate much better with the forced expiratory flow values obtained by the rapid thoracic compression method than with airway resistance, determined by body plethysmography. (*Pediatr Res* **38: 218–220, 1995**)

Abbreviations

dV/VT, ratio of volume exhaled at peak tidal expiratory flow to the total expiratory volume
Raw, airway resistance
Raw%, airway resistance as percentage of the predicted values
TGV, thoracic gas volume
FRC pleth, functional residual capacity measured by plethysmography
TE, total expiratory time
Tme/TE, ratio of expiratory time to reach peak tidal expiratory flow to the total expiratory time
$\dot{V}_{max}$FRC, maximum expiratory flow at functional residual capycity
$\dot{V}_{max}$FRC/TGV, maximum expiratory flow at functional residual capacity corrected for lung volume

During the past three decades pulmonary function tests have been successfully adapted or newly developed to measure lung function in neonates and infants. However, most methods still require sedation, expensive equipment, and highly skilled technicians. Therefore, such investigations have been restricted to few specialized research centers (1, 2).

Recently, the measurement of tidal breathing parameters by so-called body surface techniques was suggested to simplify lung function testing in infants and young children. However, there is still a lack of studies comparing standard lung function parameters with the recently described parameters of tidal expiratory flow. In patients with airway obstruction, a rapid rise to peak tidal expiratory flow has been observed (3, 4). Therefore, the time necessary to reach peak expiratory flow expressed as Tme/TE as well as the volume expired at peak expiratory flow expressed as dV/TV were proposed as simple indices of airway obstruction (4–6).

In the present study, we compared Tme/TE and dV/VT with Raw% and $\dot{V}_{max}$FRC/TGV to evaluate their potential to assess airway obstruction in infants.

METHODS

In 21 infants aged 6–14 mo (median 9.3 mo) with a mean body weight of 8.62 kg (range 5.6–11.0 kg) measurements were obtained. All infants suffered from obstructive airway diseases (Table 1) and received standard lung function tests for diagnostic reasons. All parents gave informed consent.

The infants were sedated with chloral hydrate (50–80 mg/kg, orally). Studies were performed during quiet sleep in the supine position with the neck slightly extended. Raw and TGV were measured in a volume constant baby body plethysmograph (Fenyves and Gut, Switzerland) under body temperature, standard pressure, and saturated water vapor (gas) conditions. Partial expiratory flow-volume curves were obtained by the rapid thoracic compression technique (7–9) using an inflatable plastic bag wrapped around the infants chest and abdomen.

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Table 1. *Subject characteristics*

Subject	Sex	Age (mo)	Weight (kg)	Diagnosis*
1	M	8	9.9	WB
2	F	12	8.8	WB
3	M	11	9.5	WB
4	M	11	10.5	WB
5	M	7	7.2	LS
6	M	14	10.0	WB
7	F	11	9.0	WB
8	M	9	6.9	BPD
9	M	7	8.5	LS
10	M	7	9.1	WB
11	F	6	6.0	BL
12	M	6	9.2	TS
13	F	10	9.0	WB
14	F	12	9.2	CF
15	F	7	5.6	BPD
16	M	10	11.0	WB
17	M	14	8.3	WB
18	F	11	7.6	BPD
19	F	6	7.2	WB
20	M	8	9.1	WB
21	F	9	8.0	BPD

* Clinical diagnoses: WB, wheezy bronchitis; LS, laryngeal stridor; BPD, bronchopulmonary dysplasia; BL, bronchiolitis; TS, tracheal stenosis; CF, cystic fibrosis.

Five maneuvers at optimal compression pressure were obtained, and the mean of the three best values of maximum flows at functional residual capacity ($\dot{V}_{max}$FRC) was used for analysis after correction for lung size ($\dot{V}_{max}$FRC/TGV).

At least 5 min after these measurements, tidal breathing parameters were obtained using pneumotachography and stored on a magnetic tape recorder (Sony three head, stereo tape corder). For analysis, flow curves and flow-volume curves were plotted with reduced speed on an X-Y recorder (Hewlett-Packard 741A). At least 10 breaths were used to calculate mean Tme/TE as well as the mean value of dV/VT (4). The correlation between different variables was calculated using linear regression analysis. Statistical significance was defined as $p = 0.05$.

RESULTS

Raw% values ranged from 81 to 280% (mean 165.7%) and $\dot{V}_{max}$FRC/TGV values ranged from 0.08 to 1.28 mL/s per mL (mean 0.448 mL/s per mL).

No significant correlation was found between Tme/TE (range 0.16 to 0.36) and Raw% ($r = -0.089$, $p = 0.695$, Fig. 1*A*). An inverse relationship was just significant between dV/VT (range 0.18 to 0.36) and Raw% ($r = -0.435$, $p = 0.048$, Fig. 1*B*).

Both Tme/TE ($r = 0.630$, $p = 0.002$) and dV/VT ($r = 0.728$, $p = 0.001$) correlated well with $\dot{V}_{max}$FRC/TGV (Fig. 2, *A* and *B*). There seems to be a more sensitive change of dV/VT compared with Tme/TE with decreasing $\dot{V}_{max}$FRC/TGV.

DISCUSSION

Both parameters of tidal breathing, Tme/TE as well as dV/VT are able to detect changes in the airway caliber. They correlated well with measurements obtained using more sophisticated and expensive standard lung function methods such as the rapid thoracic compression technique combined with body plethysmography.

Similar to our results in infants, Morris and Lane (4) demonstrated that in adults and school aged children both Tme/TE and dV/VT were significantly lower in subjects with obstructive airway disease. These values correlated well with the forced expiratory volume at 1 s predicted and with specific airway conductance. Morgan *et al.* (10) reported that infants suffering from bronchopulmonary dysplasia also had significantly lower values for Tme/TE than did healthy infants.

Similar results were reported recently by Clarke *et al.* (11) in infants with chronic obstructive lung disease, whereas there were no significant differences between healthy and mildly asthmatic infants. It was concluded that Tme/TE is an insensitive parameter to describe airway function compared with $\dot{V}_{max}$FRC. In our group of infants, Tme/Te values were consistently low only with $\dot{V}_{max}$FRC/TGV values below 0.5 mL/s per mL. Furthermore, Aston *et al.* (12) found no significant change of Tme/TE in infant bronchial challenge tests although $\dot{V}_{max}$FRC significantly decreased by 43%. They suggested that the infants had adopted a strategy of active expiration in response to bronchial challenge.

Up to now, the exact mechanisms producing the decrease of Tme/TE and dV/VT are not known. Tme/TE may reflect the neuromuscular response to changes in passive respiratory system time constant and resting volume (13, 14). Morris and Lane (4) suggested that in patients with airway obstruction the need for active braking during expiration may be diminished, resulting in an early peak of expiratory flow. In addition, because of the high expiratory time constant, TE must be long to allow exhalation to be completed, which results in Tme/TE being very low. However, as described by Seidenberg *et al.* (15), some infants suffering from acute bronchiolitis tend to breathe at higher lung volumes to reduce flow limitation, thereby avoiding a long expiratory time constant. This alternative response to airway obstruction may explain normal tidal

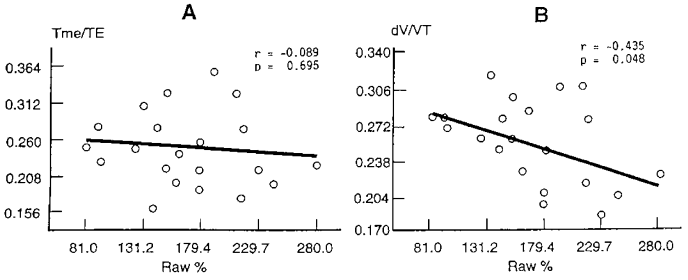

Figure 1. Correlation between Raw% and Tme/TE (*A*) and dV/VT (*B*).

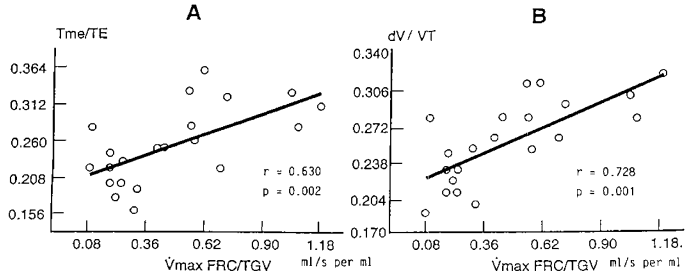

Figure 2. Correlation between $\dot{V}_{max}$FRC/TGV and Tme/TE (*A*) and dV/VT (*B*).

breathing parameters in spite of decreased values for $\dot{V}_{max}$FRC or $\dot{V}_{max}$FRC/TGV.

In our study Tme/TE and dV/VT correlated significantly with $\dot{V}_{max}$FRC/TGV, but only dV/VT had a close relationship to Raw%. Airway resistance is mainly determined by the central airways, and although some controversy exists regarding the proper methodology for the rapid thoracic compression technique (16, 17), $\dot{V}_{max}$FRC is generally agreed to reflect mainly the patency of the small airways (18). Therefore, our data might suggest that the decrease of Tme/TE and dV/VT indicate mainly changes in the smaller airways or in the lung parenchyma. This assumption is supported by the studies of Martinez *et al.* (5,19), which showed decreased values for Tme/TE and $\dot{V}_{max}$FRC in young infants who later developed wheezing illnesses.

CONCLUSION

In conclusion, our results suggest that both tidal breathing parameters, Tme/TE and dV/VT, may be able to assess airway obstruction in infants. Both parameters may not be as sensitive as $\dot{V}_{max}$FRC/TGV due to compensatory respiratory control mechanisms. Tme/TE as well as dV/VT are correlating better with measures of peripheral airway obstruction ($\dot{V}_{max}$FRC/TGV) than with Raw, reflecting mainly central airway patency.

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