

Can we assess asthma severity using expiratory capnography in a pediatric emergency department?

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Asthma is a common presenting problem in pediatric emergency departments (EDs). Accurate evaluation of asthma severity is important for acutely ill children, and pulmonary function tests are the current gold standard. Peak expiratory flow rates (PEFR) are possible in some children, but FEV₁ (forced expiratory volume in one second) requires specialized equipment and a respiratory technician, a combination not available in most EDs. Both these manoeuvres require cooperation and are difficult to perform in young children. Clinical scores and oxygen saturations are simpler and more widely applicable, but are poor severity markers unless airflow is markedly decreased.¹ Similarly, transcutaneous or expired carbon dioxide (CO₂) levels, or blood gas analysis are mainly useful in severe asthma. The ideal measure of airway obstruction should be simple, non-invasive, objective and valid in mild and severe asthma. It should also be effort-independent, therefore feasible in young and acutely ill asthmatic children.

Capnography is a technique that provides both a waveform and a numerical value for the partial pressure of expired CO₂ during each respiratory cycle (Fig. 1). Capnographs capture 2 key respiratory parameters: the rate of rise of [CO₂] during the final phase of alveolar gas exhalation (alveolar plateau slope), and the Q angle, the angle between the initial rapid expiratory [CO₂] rise and the alveolar plateau. This angle is normally very distinct, approaching 90°, but in asthma, airway obstruction and air trapping delay the mixing of alveolar and dead space gases, which results in a slower rise in [CO₂] in expired air, an increased Q angle and a greater slope of alveolar plateau.²

Capnography correlates with spirometry in acutely ill

adult asthmatics.³ Our objective was to assess the reproducibility, feasibility and validity of expiratory capnography in children presenting to the ED with acute asthma relative to other standard measures of bronchospasm. To our knowledge, these have not been previously studied.

Methods

In a busy urban pediatric ED we enrolled a convenience sample of acutely asthmatic children. Children were eligible if they were aged 7–17 years and had reversible airway obstruction in accordance with the American Thoracic Society criteria. They were excluded if they had congenital lung, heart or neuromuscular disease, other intercurrent illness, or severe asthma precluding capnography measurement prior to initial treatment.

In addition to capnography, the following measurements were done immediately before and after the first treatment with 0.03 mL/kg of 5% salbutamol: pulmonary index (PI) score, oxygen saturation, pulmonary function testing (FEV₁, PEFR and respiratory resistance using a standardized forced oscillation [Rfo] technique⁴).

Capnography was performed using a standard mouthpiece with nasal occlusion. All expired gases passed through the CO₂ sensor to which the capnography device was tightly connected. We recorded, on paper, capnograph tracings until we had obtained 5 visibly similar and adequate waveforms. Adequacy was defined as the absence of artifact (including cough, sneeze or speech) and by similarity (i.e., coefficient of variation of repeated measures within 10%). Feasibility was assessed by determining the percentage of patients in

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whom reproducible measurements were obtained.

Two separate waveform analyses (Fig. 1) were performed by an investigator who was blinded to the patient's clinical status and to the other measures of asthma severity. Capnograph analysis included the determination of the slope of the alveolar plateau and the Q angle using a goniometer. The 10 (2 measurements of 5 values) Q angles and 10 slopes for each patient were averaged before and after bronchodilator therapy. To test reliability, intra-class correlation coefficients and 95% confidence intervals (CIs) were calculated for Q angles and slopes before bronchodilator use. To test validity, mean Q angles and slopes were compared to mean Rfo, FEV₁, PEFR and PI using the Pearson's correlation coefficient reported with the 95% CI. Responsiveness was tested by comparing capnography parameters before and after bronchodilator treatment, analyzed using a paired *t*-test.

Results

Twelve children were enrolled (2 girls and 10 boys) with a mean age 9.5 years (range 7–14 yr). One patient, who had pneumonia, was excluded, and no patients refused consent.

The intra-class coefficients of the repeated measures of the slopes and Q angles obtained using the mouthpiece, prior to any bronchodilator therapy, were 0.91 for the slope (95% CI, 0.78–0.97) and 0.94 for the Q angle (95% CI, 0.86–0.98), indicating excellent test–retest reproducibility.

An adequate strip of 5 visibly similar waveforms was obtained in all 12 patients. Five of 12 patients (ages 7–9) were unable to perform the forced expiratory manoeuvre for spirometry without extra coaching and repeated attempts.

The Q angle and alveolar plateau slope showed no statistically significant correlation with the pulmonary index, FEV₁, PEFR, and Rfo.

Bronchodilator treatment led to significant improvement in pulmonary function measures. The FEV₁ rose from 57% to 66% ($p = 0.02$), and the PEFR from 54% to 66% ($p = 0.01$). Concurrently, PI fell from 2.9 to 1.8 ($p = 0.02$), and

Rfo fell from 129% to 106% ($p = 0.05$). However, capnography showed no significant changes in Q angle (139° to 134°; $p = 0.3$) or alveolar plateau slope (0.14 to 0.10; $p = 0.3$).

Discussion

Our evaluation suggests that the capnography indices tested correlate poorly with standard measures of bronchospasm. These results contrast with previous studies on capnography in adult asthmatics.^{3,5} The absence of statistically significant correlation with other measures of airway obstruction indicates that the capnography indices tested do not demonstrate criterion validity. Further, while bronchodilator treatment led to significant improvement in spirometry and pulmonary indices, capnography failed to detect these improvements. This suggests that, although a larger study might have uncovered statistically significant differences, these smaller differences are unlikely to be of clinical importance.

Our study involved a small sample size that did not exemplify the whole spectrum of asthma severity. For this reason, it is difficult to know to whom we can generalize our results. In addition, the difficulty obtaining spirometry measures in our young subjects may have limited the validity assessments.

Conclusion

Capnographs are feasible and reproducible in previously untrained asthmatic children. Unfortunately, they do not appear to be valid measures of airway obstruction, therefore show little promise for evaluating asthma severity in the pediatric ED.

Competing interests: None declared.

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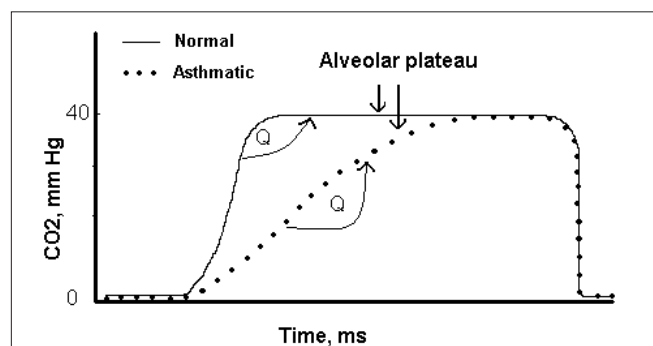


Fig. 1. The capnograph waveform