

Noninvasive Bedside Assessment of Acute Asthma Severity Using Single-Breath Counting

Lindsay R. Roofe, MD, Donald J. Resha, EMT-P, Thomas J. Abramo, MD, and Donald H. Arnold, MD, MPH

Objective: The single-breath counting (SBC) method for assessment of asthma exacerbation severity has been evaluated in adults during exacerbations and in pediatric patients during routine settings. Single-breath counting has not been evaluated in children during exacerbations. We sought to assess criterion validity and responsiveness of SBC with percent-predicted FEV₁ (%FEV₁) and the Pediatric Respiratory Assessment Measure (PRAM), a validated acute asthma severity score.

Methods: We prospectively enrolled subjects aged 7 to 17 years with acute asthma exacerbations. Single-breath counting, %FEV₁, and PRAM were obtained before treatment and 2 hours after initiating therapy. Multivariable linear regression models were used to examine associations of pretreatment SBC with %FEV₁ and PRAM (criterion validity) and 2-hour change of these measures (responsiveness). With a 2-sided α of 0.05, SBC SD of 8.5, and 90% power to detect an adjusted R^2 of greater than 0.36 for SBC with each outcome measure, a minimum sample of 20 participants was necessary.

Results: From June to November 2011, 51 participants were enrolled, with median (interquartile range) age of 8.46 years (6.92–11.4 years); male sex, $n = 40$ (78%); and African American race, $n = 33$ (64%). Before treatment, 42 (92%) were able to successfully perform SBC, and 24 (51%) %FEV₁. Median pretreatment SBC obtained was 16 (10–24); %FEV₁, 50 (26–71); and PRAM, 5 (1–5).

Conclusions: Single-breath counting demonstrates modest criterion validity for predicting the pretreatment PRAM score and a trend for predicting %FEV₁. Single-breath counting does not appear to be responsive to change of these measures in response to treatment and has limited validity as a measure of acute asthma severity.

Key Words: acute asthma exacerbation, severity score, single-breath counting

(*Pediatr Emer Care* 2014;30: 8–10)

Asthma is a chronic respiratory disease that affects 8.5% of children in the United States. Annually, there are approximately 4.1 million acute exacerbations and approximately 696,900 emergency department (ED) visits among children with asthma.¹ As a significant pediatric disease, diagnosis and assessment of acute asthma exacerbation severity are important in the care of these pediatric patients. Criterion measures of airflow obstruction and acute exacerbation severity include spirometry and airway resistance by forced oscillometry. However, these tests are not available in most acute

care settings, and there are limited bedside measures of severity that are validated and reproducible. Peak expiratory flow rate is one such tool that is widely available for asthma assessment; however, it has been shown to poorly assess asthma severity in the acute and home pediatric settings.^{2,3} Inconsistent and inaccurate assessment of asthma exacerbations may lead to inappropriate treatments for patients, affect disease course, and incur unnecessary costs.

Needed is an objective, simple, and accurate measure to quickly assess exacerbation severity in the pediatric asthma population. Such an assessment tool should also be easily communicated among providers and incur only minimal costs. The single-breath counting (SBC) method has been reported to fulfill these criteria. Single-breath counting involves the patient counting as high as possible after a vital capacity breath at a cadence of 2 numbers/second. Single-breath counting is an easily obtained parameter with limited need for equipment and personnel and is also easily communicated among providers. Bartfield et al⁴ first described this test in 1994 in a study that examined routine pulmonary function testing in adult population with different underlying lung diseases. The investigators found that SBC correlated with FEV₁ ($r = 0.68$), which is comparable to the correlation of peak expiratory flow rate with FEV₁ ($r = 0.63$). Subsequently, SBC was applied to adults with acute bronchospastic disease in an ED and appeared to correlate with peak expiratory flow for individual patients.⁵ Finally, Ali and colleagues⁶ examined SBC in pediatric subjects with stable asthma undergoing routine spirometry, among 67 pediatric participants who had either restrictive or obstructive lung disease and demonstrated correlation of SBC with FEV₁ ($r = 0.66$).

We are not aware of prior investigations of SBC in pediatric patients with acute asthma exacerbations. We sought to examine the criterion validity of SBC as a measure of acute asthma exacerbation severity and as a measure of responsiveness to change after treatment in pediatric patients presenting to an academic, tertiary pediatric ED (PED).

METHODS

Patients and Setting

This study was undertaken in an urban, academic, children's hospital PED. We prospectively enrolled a convenience sample of children aged 7 to 17 years who had doctor-diagnosed asthma and signs or symptoms of an asthma exacerbation and who presented between 7 AM and 10 PM. Study data were acquired and recorded at 2 time points: pretreatment, defined as before administration of systemic corticosteroids or continuous albuterol, and at 2 hours into PED treatment if the patient still remained in the PED at that time. Treatments incorporated into patient care were part of our PED asthma protocol and include inhaled and systemic β -agonists, systemic steroids, magnesium, and subcutaneous and inhaled epinephrine. The study protocol (#080058) was approved by the institutional Human Research Protection Program.

From the Department of Pediatric Emergency Medicine, Children's Hospital at Vanderbilt, 2200 Children's Way, Nashville, TN.

Disclosure: The authors declare no conflict of interest.

Reprints: Lindsay R. Roofe, MD, Department of Pediatric Emergency Medicine, Children's Hospital at Vanderbilt, 2200 Children's Way, 1014 VCH, Nashville, TN 37232 (e-mail: Lindsay.roofe@vanderbilt.edu).

Funding source: NHLBI K23 [Dr. Arnold]; NCATS UL1TR000445 [REDCap].

Copyright © 2014 by Lippincott Williams & Wilkins
ISSN: 0749-5161

TABLE 1. Demographic and Acute Exacerbation Severity Measures in Participants Aged 7 to 17 Years With Acute Asthma Exacerbations

Age	8.46 (6.92–11.4)*
Sex, Male	40 (78%) [†]
Race, African American	33 (64%) [†]
Able to perform SBC [‡]	42 (92%) [†]
Able to perform %FEV ₁ [‡]	24 (51%) [†]
SBC [‡]	16 (10–24)*
% Predicted FEV ₁ [‡]	50 (26–71)*
PRAM score [‡]	5 (1–5)*

*Median (IQR).

[†]Performed pretreatment upon initial evaluation in the ED.[‡]n (%).

Variables Examined

Predictor variables included race, age, and sex. Outcome variables were the Pediatric Respiratory Assessment Measure (PRAM) score and percent-predicted FEV₁ (%FEV₁). Each outcome variable, as well as SBC values, was measured and recorded for all participants present at each time point.

The PRAM score components were recorded and managed using REDCap electronic data capture tools hosted at Vanderbilt University, and the score was calculated electronically. Possible PRAM values range from 0 to 12, with 12 most severe. Spirometry for %FEV was performed in accordance with the American Thoracic Society and European Respiratory Society guidelines.⁷ A dedicated research assistant enrolled participants and was trained in performance of portable spirometry by a certified pediatric pulmonary function technician. We performed spirometry using a MicroDirect MicroLoop spirometer (Micro Medical, Kent, England) calibrated daily using a 3-L syringe.

The SBC score was obtained by asking participant to count as high as they could on a single vital capacity inhalation. Counting was set to a 2-second beat with the use of standard metronome (Seiko model DM50; Seiko Corporation, Tokyo, Japan). Participants were allowed up to 3 attempts if needed (as a result of coughing or inadequate technique), and their highest test score was recorded.

Statistical Analysis

We assessed SBC criterion validity using pretreatment PRAM score and %FEV₁ and assessed responsiveness using proportionate change of the PRAM score and %FEV₁ between pretreatment and 2-hour time points.

Multivariable linear regression models were used to examine associations of pretreatment SBC with %FEV₁ and

PRAM (criterion validity) and 2-hour change of these measures (responsiveness) while adjusting for age, race, and sex. With a 2-sided α of 0.05, SBC SD of 8.5, and 90% power to detect an adjusted R^2 of greater than 0.36 for SBC with each outcome measure (based on prior studies), a minimum sample of 20 participants was necessary. We report demographic data as median (interquartile range [IQR]) and proportions as appropriate. Multivariable linear regression results are reported as β coefficients and 95% confidence interval (CI). Analyses were performed with STATA version 12 (STATA Corp, College Station, Tex).

RESULTS

During the study period, June to November 2011, 51 participants were enrolled with a median (IQR) age of 8.46 years (6.92–11.4 years); male sex, 40 (78%); and African American race, 33 (64%) (Table 1). Before treatment, 42 (92%) were able to successfully perform SBC, and 24 (51%) %FEV₁. Median pretreatment SBC obtained was 16 (10–24), %FEV₁ 50 (26–71), and PRAM 5 (1–5) (Table 2). Results of demographic data and multiple linear regression models are presented in Tables 1 and 2, respectively.

DISCUSSION

Single-breath counting demonstrates modest criterion validity for predicting pretreatment PRAM score and a trend for predicting %FEV₁. However, SBC does not appear to be responsive to change of these measures in response to treatment. We were surprised by our results as we expected SBC to decrease in a significant and clinically meaningful way because of decreased lung function and the ability to enunciate speech during acute asthma exacerbations. Speaking tasks influence ventilation by increasing the ventilatory demand above what is required during quiet breathing. However, it is possible that factors such as respiratory rate, athletic conditioning, or baseline asthma control may influence SBC and therefore limit the validity of this score as a measure of exacerbation severity. Single-breath counting is also performer-dependent, and factors such as cognitive ability, participant motivation, and anxiety could affect the score. As well, our results question whether speech is a marker that calibrates well to respiratory status and may indicate that speech measures may not be valid assessment tools for respiratory function in children with acute asthma exacerbations.

Single-breath counting is likely influenced by intraindividual and interindividual variability in speech production. For example, with regard to speech intensity, study subjects have been described to increase inspired lung volume for 1 or 2 breaths and then in the next breath use laryngeal adjustments

TABLE 2. Associations of SBC With PRAM and %FEV₁ in Participants Aged 7 to 17 Years With Acute Asthma Exacerbations

Outcome Variable	Pretreatment SBC*			2-h SBC Change [†]		
	R^2	β (95% CI)	<i>P</i>	R^2	β (95% CI)	<i>P</i>
PRAM score [‡]	0.27	−0.1 (−0.18 to −0.03)	0.008	0.11	0.30 (−1.2 to 2.6)	0.79
%FEV ₁ [§]	0.32	0.82 (−0.16 to 1.8)	0.10	0.24	−0.67 (−1.9 to 0.55)	0.23

*Multiple linear regression models of PRAM or %FEV₁ on pretreatment SBC, adjusted for age, sex, and race.[†]Prediction of 2-hour change of PRAM or %FEV₁ by proportionate change of SBC.[‡]Forty-seven of 51 participants able to perform SBC.[§]Twenty-four of 47 able to perform pretreatment %FEV₁ and 12 at both time points.

to increase intensity.⁸ Perhaps similar variability in speech production contributes to the results of this study. Investigators have described that counting tasks make more stringent demands on speech breathing than conversational speech.⁹ Perhaps, our negative study only pertains to speech tasks secondary to exhortation; conversational speech could correlate differently with acute asthma severity. When compared with healthy subjects during speech breathing, patients with asthma use a larger proportion of their percent vital capacity but similar volumes.⁹ Therefore, it is possible that SBC criterion validity based on a nonflow parameter would improve the assessment tools' validity in assessing severity of acute asthma exacerbations.

Limitations of our study include possible selection bias by recruiting children presenting to a PED. Results may differ in other clinical settings. There may also be selection bias for less severe exacerbations due to clinical urgency to initiate treatment, although a few cases of severe exacerbations were included. Also, there were more male patients in our study.

Based on our findings, we do not recommend incorporation of the SBC score into assessment of asthma severity in the acute pediatric setting. We continue to acknowledge the need for a bedside assessment tool in the assessment of acute asthma exacerbation that is affordable, simple, and also communicated between providers. However, such a tool should demonstrate criterion validity and responsiveness.

In conclusion, the SBC score is a simple bedside assessment tool for asthma assessment that has been described with some validity in both adult acute and pediatric nonacute settings. Based on our study, this score demonstrates insufficient criterion validity in the assessment of acute exacerbations in the pediatric acute setting. Valid but similarly simple tools for assessment of acute asthma exacerbations are needed in the PED.

REFERENCES

1. Moorman J, Rudd RA, Johnson CA, et al. National Surveillance for Asthma—US, 1980–2004. *MMWR*. Atlanta, GA: Division of Environmental Hazards and Health Effects, National Center for Environmental Health, CDC. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5608a1.htm>.
2. Klein RB, Fritz GK, Yeung A, et al. Spirometric patterns in childhood asthma: peak flow compared with other indices. *Pediatr Pulmonol*. 1995;20:372–379.
3. Eid N, Yandell B, Howell L, et al. Can peak expiratory flow predict airflow obstruction in children with asthma? *Pediatrics*. 2000;105:354–358.
4. Bartfield JM, Ushkow BS, Rosen JM, et al. Single breath counting in the assessment of pulmonary function. *Ann Emerg Med*. 1994;24:256–259.
5. Ushkow BS, Bartfield JM, Reicho PR, et al. Single-breath counting for the assessment of bronchospastic patients in the ED. *Am J Emerg Med*. 1998;16:100–101.
6. Ali SS, O'Connell C, Kass L, et al. Single-breath counting: a pilot study of a novel technique for measuring pulmonary function in children. *Am J Emerg Med*. 2011;29:33–36.
7. Miller MR, Hankinson J, Brusasco V, et al. Standardisation of spirometry. *Eur Respir J*. 2005;26:319–338.
8. Winkworth AL, Davis PJ. Speech breathing and the Lombard effect. *J Speech Lang Hear Res*. 1997;40:159–169.
9. Lee L, Loudon RG, Jacobson BH, et al. Speech breathing in patients with lung disease. *Am Rev Respir Dis*. 1993;147:1199–1206.
10. Loudon RG, Lee L, Holcomb BJ. Volumes and breathing patterns during speech in healthy and asthmatic subjects. *J Speech Hear Res*. 1988;31:219–227.