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Prediction of acute asthma exacerbation severity and interrater reliability of manual pulsus paradoxus measurement

Donald H. Arnold, MD, MPH^{a,b}, Adam A. Vukovic, MD, MEd^a, Cosby G. Arnold, MD, MPH^c, Cody Penrod, MD^d, and Jonas A. Pologe, BSEE^e

^aDepartment of Pediatrics, Division of Emergency Medicine, Vanderbilt University School of Medicine, Nashville, TN;

^bCenter for Asthma Research, Vanderbilt University School of Medicine, Nashville, TN;

^cDepartment of Emergency Medicine, University of Tennessee Health Sciences Center, Memphis, TN;

^dDepartment of Pediatrics, Division of Emergency Medicine, University of Louisville School of Medicine, Louisville, TN;

^eKestrel Labs, Inc., Boulder, CO

Keywords

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Pulsus paradoxus (PP) represents an exaggeration of the normal fluctuation of left ventricular stroke volume and systolic blood pressure during the respiratory cycle.¹ This physiologic phenomenon was first described by Lower in 1669 and the term *pulsus paradoxus* first applied by Kussmaul in 1873.² PP measurement is recommended to identify or assess the severity of acute asthma exacerbations, tension pneumothorax, cardiac tamponade and other potentially life-threatening disorders.³

Although the traditional definition of PP is systolic blood pressure variation > 10mm Hg, we have demonstrated that healthy adults frequently have greater levels of variation.⁴ In addition, manual PP measurement using a stethoscope and sphygmomanometer is difficult in the presence of tachycardia, tachypnea or noisy clinical environments and, further, may be subjective. We sought to determine in pediatric patients with acute asthma exacerbations (1) The extent to which manually measured PP predicts acute asthma exacerbation severity measured using the validated Acute Asthma Intensity Research Score (AAIRS);⁵ and (2) The interrater reliability of manually measured PP among clinicians.

Corresponding author: Donald H Arnold, MD, MPH, Professor of Pediatrics, Vanderbilt University School of Medicine, Vanderbilt Children's Hospital, 2200 Children's Way, Nashville, TN 37232, don.arnold@vumc.org, Phone: 615-579-0516.

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Conflicts of interest: none

We conducted an observational study of participants aged 5 – 17 years with doctor-diagnosed asthma who presented to our urban, academic children's hospital emergency department with acute asthma exacerbations. Using methods described in our previous reports,^{4, 5} pretreatment AAIRS was calculated and a minimum of three PP measurements were performed in the right arm using a Welch Allyn 767 sphygmomanometer (Welch Allyn, Skaneateles Falls, NY) and electronic stethoscope (Thinklabs One, San Diego, CA). High-fidelity audio was fed from the stethoscope to a high-resolution digital video camera (Blackmagic Design, Fremont, CA) that simultaneously recorded the sphygmomanometer dial. One investigator (DA) reviewed all recordings and identified the best audio-video recording from each participant. These recordings were independently reviewed for PP calculation by four clinicians (AV, CA, CP, DA), who were masked to the measurements of other reviewers.

Multiple linear regression, adjusted for age, was used to examine the association of mean PP values calculated by the four clinicians for each participant with the AAIRS. Inter-rater reliability was calculated as the percent agreement between any two clinicians' PP readings on any given data set with agreement defined as measurements on the same recording within 5 mmHg. We used a modification of a Bland-Altman plot to visually examine agreement of PP measurements between clinicians.⁶ The study was approved by the Vanderbilt University Institutional Review Board (protocol #160184) and written informed consent was obtained from each participant.

Among 28 participants, 22 had at least one high-quality recording for PP calculation, with median [IQR] age 10.2 [7.8, 14.0] years, 10 (45%) female, 19 (86%) black race, AAIR Score 6 [3, 7] and PP 14.0 [12.2, 16.0]. In a multiple linear regression model adjusted for age, mean PP did not predict the AAIR Score (Table 1).

With four clinicians making measurements on each recording and 22 recordings, there were 132 paired comparisons. The mean level of agreement between clinicians and the limits of agreement are displayed in Table 1. Defining agreement between any two clinicians on the same data set as the difference between their measurements of ≤ 5 mmHg, percentage agreement was 57%.

There are limitations of our study. First measuring PP with the high-fidelity electronic stethoscope and audio-video recording used in this study is not the traditional method of PP measurement using a stethoscope and sphygmomanometer. Second, although the four physicians who measured PP from these recordings were instructed on the accepted method of PP calculation, there may be inter-rater variability of auditory acuity and ability to make this measurement that was not evaluated or measured. The results of this investigation suggest that manually measured PP in children with acute asthma exacerbations does not predict clinical severity using a validated bedside severity score and is further limited by low interrater reliability.

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Abbreviations:

AAIRS	Acute Asthma Intensity Research Score
PP	Pulsus paradoxus

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Table 1.

Performance of manual pulsus paradoxus measurement Performed by four clinicians.

Multivariable linear regression model adjusted for age, PP predicting AAIRS ¹ Beta-coefficient -0.02; 95% confidence interval: -0.54, 0.51
Bland-Altman plot analysis Level of agreement: mean 5.6 (SD 4.7) mm Hg Limits of agreement (mean $\pm$ 1.96*SD): -3.6 to +14.8mmHg

¹. Acute Asthma Intensity Research Score