Pulsus paradoxus in asthmatic children

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Summary: Pulsus paradoxus is a useful physical sign in the assessment of the severity of asthma in adults. Whether this is also true for asthmatic children was determined by measuring respiratory fluctuations in systolic blood pressure during attacks of asthma in 24 children.

A decrease in systolic pressure during inspiration exceeding 15 mm Hg was found only when the 1-second forced expiratory volume was less than 60% of the predicted value. There was a highly significant (P < 0.001) correlation between the degree of pulsus paradoxus and the severity of airway obstruction. In nonasthmatic children the systolic pressure was found to fluctuate by as much as 7 mm Hg during the respiratory cycle. It is concluded that, as in adults, the presence of pulsus paradoxus (≥ 15 mm Hg) in children indicates that their asthma is very severe.

Résumé: Le pouls paradoxal chez des enfants asthmatiques

Le pouls paradoxal est un signe physique très utile pour évaluer la sévérité de l'asthme chez l'adulte. En vue de déterminer si ce signe a la même valeur chez l'enfant asthmatique, nous avons mesuré, chez 24 enfants pendant une crise d'asthme, les fluctuations respiratoires survenant au cours de la pression systolique.

Nous n'avons trouvé une diminution de la pression systolique dépassant 15 mm Hg que dans le cas où le volume d'expiration forcée de une seconde était inférieur à 60% de la valeur prévue. Nous avons noté une corrélation très significative (P < 0.001) entre le degré du pouls paradoxal et la sévérité de l'obstruction des voies aériennes. Chez les enfants non-asthmatiques la pression systolique subissait une fluctuation allant jusqu'à 7 mm de Hg durant le cycle respiratoire. Nous croyons donc pouvoir conclure que, comme chez l'adulte, la présence du pouls paradoxal (≥ 15 mm Hg) chez l'enfant signe un état asthmatique très sévère.

Pulsus paradoxus is a useful physical sign in assessing the severity of asthma. Rebuck and Read found that an inspiratory decrease in systolic blood pressure of more than 10 mm Hg always indicated that the forced expiratory volume in 1 second (FEV₁) was less than 1.25 l and usually less than 0.9 l. The importance of pulsus paradoxus and its pathogenesis in asthma were more recently discussed by Rebuck and Pengelly, who correlated the degree of the phenomenon with such variables as inspiratory flow, lung volume, blood gas tensions and pulse rate. Recently, Knowles and Clark confirmed that, in adults, the presence of pulsus paradoxus indicates asthma of considerable severity. It is not known, however, whether this is also true for asthmatic children, in whom the factors affecting variations in blood pressure during the respiratory cycle may well be different.

Patients and methods

The patients were 24 children who attended The Hospital for Sick Children, Toronto for treatment of asthma. They were aged between 5 and 19 years (mean, 11.7 years; standard deviation [SD], 3.6 years). All had a history of episodic dyspnea and wheezing; in none was there a history of chronic cough and sputum during remissions; and none had clinical evidence of cor pulmonale with cardiac failure.

To assess the degree of pulsus paradoxus the decrease in systolic blood pressure in the brachial artery during inspiration was measured with a sphygmomanometer. FEV₁ and vital capacity (VC) were measured when blood pressure recording was completed. Of the 24 patients 18 were studied both before and after receiving orciprenaline (metaproterenol) sulfate, 0.1 ml/kg body weight, by intermittent positive pressure ventilation; 6 patients had received bronchodilator therapy before the FEV₁ was measured.

The same measurements were also made on 24 normal children, whose ages ranged from 5 to 16 years (mean, 12 years; SD, 2.99 years), to assess the respiratory variation in blood pressure in the absence of airway obstruction.

The predicted values for FEV₁ and VC were those reported by Levison et al., with age and standing height as the independent variables.

Results

The amount by which systolic pres-

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FIG. 1—Relation of pulsus paradoxus to FEV₁ (expressed as percentage of predicted value) in asthmatic children. Closed circles = before bronchodilator therapy; open circles = after bronchodilator therapy. Degree of pulsus paradoxus, expressed in mm Hg, is amount by which systolic blood pressure decreased on inspiration.
sure decreased during inspiration, expressed as pulsus paradoxus, mm Hg, is shown in Fig. 1. The largest fluctuations in blood pressure were found in those children whose asthma was most severe. A decrease in systolic pressure during inspiration exceeding 15 mm Hg was found only when FEV₁ was less than 60% of the predicted value. Although a highly significant linear correlation existed between the degree of pulsus paradoxus and FEV₁ (r = 0.63; t = 4.78; P < 0.001), a power function gave a closer mathematical relationship (mm Hg paradox = 223.9 x FEV₁^0.667; r = 0.73).

In nonasthmatic children the systolic pressure varied by up to 7 mm Hg (mean, 5 mm Hg; SD, 0.96 mm Hg) during the respiratory cycle.

Discussion

The results of this study show that in children, as in adults, pulsus paradoxus is due to an exaggeration of the reduction in arterial pressure that occurs normally during inspiration. Furthermore, it appears that pulsus paradoxus exceeding 15 mm Hg is a reliable indicator of the degree of airway obstruction in children with asthma. As in adults, however, respiratory fluctuations of up to 7 mm Hg in systolic pressure may occur in the absence of asthma.⁸

Measurement of the degree of pulsus paradoxus may readily be done at the bedside by sphygmomanometry, as in this study, without the hazards of more complex invasive procedures such as arterial puncture. Confirmation that this indirect assessment is sufficiently sensitive and reliable is provided by the work of McDonald et al., who measured intravascular pressures by arterial catheterization and validated the accuracy of sphygmomanometry as a reflection of arterial systolic changes during the respiratory cycle.

The degree of pulsus paradoxus found in the asthmatic children was comparable to that found in asthmatic adults in both adults and children, with FEV₁ and decreased more rapidly in response to inhaled bronchodilator therapy. Pulsus paradoxus is observed in adults with airway obstruction when their functional residual capacity is increased greatly above resting level and when large fluctuations in intra-alveolar pressure occur.⁹

Why should the factors affecting variations in blood pressure during the respiratory cycle be different in children and adults? As in adults the FEV₁ of asthmatic children correlates well with peak and midexpiratory flow rates. However, in children the FEV₁ correlates poorly with the relationship between airway conductance and intrathoracic gas volume.⁷ This poor correlation may reflect the diminished outward recoil of the chest wall in children.² It follows that, although pulsus paradoxus in asthmatic children may not reflect the same degree of pressure and volume change as it does in adults, it is usually associated with a definite limitation of flow.

Our findings indicate that when a child with asthma has pulsus paradoxus in excess of 15 mm Hg the asthma is likely to be more severe than in the absence of this physical sign.

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References

3. KNOWLES GK, CLARK TJH: Pulsus paradoxus as a valuable sign indicating severity of asthma. Lancet 2: 1356, 1973