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## The effect of intermittent positive-pressure breathing on airway resistance in normal and asthmatic children

**Ralph B. Moore, M.D., and Ernest K. Cotton, M.D.** *Denver, Colo.,*  
*with the assistance of Margo A. Pinney, B.S.N.*

*The airway resistance of 20 children with chronic asthma and 8 normal children was measured before and after intermittent positive-pressure breathing (IPPB) and nebulizer treatments. There was a significant increase in airway resistance in both groups of children following IPPB. No significant increase in resistance was found following the nebulizer treatment. It is concluded that the delivery of air under pressure to the airway can act as an irritant, especially in individuals with asthma.*

Intermittent positive pressure breathing (IPPB) is used in the treatment of asthma to produce mechanical bronchodilatation, improve distribution of aerosols, and promote clearing of bronchial secretions.<sup>1</sup>

Many authors<sup>2-5</sup> comment favorably on the use of IPPB in asthma. A review of the recent literature, however, revealed few objective studies<sup>6-10</sup> on the effects of IPPB on airway function in asthmatics.

Clinical<sup>11-13</sup> and animal<sup>14-15</sup> studies have shown that irritation of airway mucosa can cause reflex bronchoconstriction. In adult asthmatic patients, IPPB without bronchodilators decreases ventilatory function.<sup>9</sup>

Our purpose was to determine if the pressure generated by IPPB (15 to 20 cm. H<sub>2</sub>O pressure) without a bronchodilator acts as an irritant to the airway mucosa in children, causing a reflex bronchoconstriction rather than the desired mechanical bronchodilatation.

From the Department of Pediatrics, University of Colorado Medical Center, and Department of Pediatric Allergy, National Jewish Hospital.

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Reprint requests to: Dr. Moore, Dept. of Pediatrics, National Jewish Hospital and Research Center, 3800 East Colfax Ave., Denver, Colo. 80206.

**TABLE 1.** Magnitude of change observed with time after IPPB therapy in normal and asthmatic children

| Subjects                | TGV $\times$ R <sub>AW</sub> * |                      |                       |
|-------------------------|--------------------------------|----------------------|-----------------------|
|                         | Base line                      | 1 min. After therapy | 15 min. After therapy |
| Normal                  |                                |                      |                       |
| 1                       | 4.8                            | 5.8                  | 5.1                   |
| 2                       | 4.4                            | 4.6                  | 3.2                   |
| 3                       | 4.9                            | 5.8                  | 4.9                   |
| 4                       | 4.5                            | 6.8                  | 4.9                   |
| 5                       | 6.4                            | 9.6                  | 5.6                   |
| 6                       | 2.3                            | 2.8                  | 2.1                   |
| 7                       | 2.7                            | 6.8                  | 3.1                   |
| 8                       | 4.6                            | 5.9                  | 4.2                   |
| Significance of changes |                                | p < 0.05             | Not significant       |
| Asthmatic               |                                |                      |                       |
| 1                       | 5.4                            | 4.9                  | 5.6                   |
| 2                       | 6.8                            | 7.6                  | 4.7                   |
| 3                       | 7.7                            | 11.4                 | 6.2                   |
| 4                       | 5.0                            | 5.0                  | 3.0                   |
| 5                       | 9.9                            | 16.2                 | 11.9                  |
| 6                       | 10.8                           | 16.9                 | 16.9                  |
| 7                       | 8.3                            | 14.3                 | 7.4                   |
| 8                       | 13.1                           | 17.8                 | 12.2                  |
| 9                       | 10.3                           | 20.0                 | 14.3                  |
| 10                      | 6.2                            | 10.8                 | 5.9                   |
| 13                      | 9.4                            | 8.4                  | 10.7                  |
| 14                      | 7.6                            | 19.0                 | 7.1                   |
| 16                      | 8.0                            | 8.7                  | 8.6                   |
| 17                      | 11.8                           | 19.7                 | 16.5                  |
| 19                      | 11.3                           | 15.7                 | 15.9                  |
| 20                      | 17.0                           | 25.1                 | 5.8                   |
| Significance of changes |                                | p < 0.01             | Not significant       |

\*TGV  $\times$  R<sub>AW</sub> = product of lung volume and airway resistance.**MATERIALS AND METHODS**

Twenty asthmatic children, 13 boys and 7 girls ranging in age from 8 to 13 years, and 8 normal children, 4 boys and 4 girls from 8 to 12 years, were studied. The asthmatic children, 8 of whom were receiving alternate-day prednisone, were patients at National Jewish Hospital in Denver, Colorado. No bronchodilators were given to the children for 9 hours prior to the study. All of the children were free from clinical symptoms at the time of the study.

Each individual study consisted of three parts: control, treatment, and posttreatment.

The control period consisted of two base-line measurements of airway resistance (R<sub>AW</sub>) 15 minutes apart to assure that the child's airway reactivity was stable. Thoracic gas volume (TGV) and airway resistance (R<sub>AW</sub>) were measured and used as the objective measurements for evaluation of the pressure effect. Airway resistance was measured in the body plethysmograph by the method of DuBois and associates.<sup>16</sup> The product of thoracic gas volume and airway resistance—TGV  $\times$  R<sub>AW</sub>—was used as the index of airway resistance because of the strong dependence of airway resistance on the state of lung inflation.<sup>17</sup>

During the treatment period, each child was given either IPPB or nebulizer treatment. The IPPB treatment was given with water using a Hand-E-Vent<sup>18</sup> at pressures of 15 to 20 cm. H<sub>2</sub>O. Each child took 30 deep breaths. A No. 40 DeVilbiss air-driven nebulizer with water was used for the nebulizer treatment. The child took 30 deep breaths of the mist from the nebulizer which was held at his mouth. The pressure at the mouthpiece of the nebulizer was 6 cm. H<sub>2</sub>O. The temperature of the mist from the Hand-E-Vent was 26° C. and that from the nebulizer was 24° C. The volume of mist produced per minute

**TABLE II.** Magnitude of change observed after nebulizer therapy in normal and asthmatic changes

| Subjects                | TGV $\times$ R <sub>AW</sub> * |                      |                       |
|-------------------------|--------------------------------|----------------------|-----------------------|
|                         | Base line                      | 1 min. After therapy | 15 min. After therapy |
| Normal                  |                                |                      |                       |
| 1                       | 5.1                            | 5.9                  | 4.8                   |
| 2                       | 3.2                            | 4.9                  | 4.4                   |
| 3                       | 4.9                            | 6.6                  | 4.9                   |
| 4                       | 5.3                            | 4.0                  | 4.5                   |
| 5                       | 5.6                            | 5.6                  | 6.4                   |
| 6                       | 2.1                            | 1.0                  | 2.3                   |
| 7                       | 5.4                            | 5.9                  | 2.7                   |
| 8                       | 4.9                            | 4.5                  | 4.6                   |
| Significance of changes |                                | Not significant      | Not significant       |
| Asthmatic               |                                |                      |                       |
| 1                       | 6.3                            | 7.6                  | 6.8                   |
| 2                       | 17.4                           | 29.4                 | —                     |
| 3                       | 9.1                            | 9.1                  | 9.7                   |
| 4                       | 5.4                            | 7.5                  | 5.3                   |
| 5                       | 18.1                           | 16.7                 | 18.5                  |
| 6                       | 8.7                            | 9.0                  | 10.4                  |
| 7                       | 6.0                            | 6.4                  | 5.9                   |
| 8                       | 15.8                           | 12.9                 | 10.9                  |
| 9                       | 10.8                           | 11.6                 | 12.5                  |
| 11                      | 11.1                           | 8.6                  | 11.4                  |
| 12                      | 8.6                            | 8.4                  | 6.8                   |
| 15                      | 6.1                            | 8.1                  | 7.8                   |
| 18                      | 5.6                            | 19.0                 | 7.8                   |
| Significance of changes |                                | Not significant      | Not significant       |

\*TGV  $\times$  R<sub>AW</sub> = product of lung volume and airway resistance.

was 0.3 ml. from the Hand-E-Vent and 1 ml. from the DeVilbiss nebulizer. The size of the particles produced averaged from 5 to 7  $\mu$  from the Hand-E-Vent and 6 to 8  $\mu$  from the DeVilbiss nebulizer. Both types of treatment were given by a nurse trained in pediatric respiratory therapy.

The posttreatment period consisted of airway resistance measurements at one minute and 15 minutes after the treatment. The greatest change in airway resistance between the base-line measurement and either of the posttreatment measurements was interpreted as being a cause of the treatment given.

## RESULTS

The timed responses of the normal and asthmatic children to IPPB and nebulizer treatments are recorded in Tables I and II. The mean base-line resistance of the asthmatic children was twice that of the normal subjects. The asthmatic group responded mainly to IPPB with a significant increase ( $p < .001$ ) in airway resistance (Fig. 1). Only one asthmatic child showed a decrease in airway resistance after receiving IPPB. A small but insignificant increase in airway resistance also followed nebulizer treatment in the asthmatic group. The group of normal children maximally showed a significant increase ( $p < .01$ ) in resistance after IPPB but not after the nebulizer treatment.

The response to IPPB was transient in the asthmatic patients. All but two showed some degree of return to base-line levels within 15 minutes after the treatment.

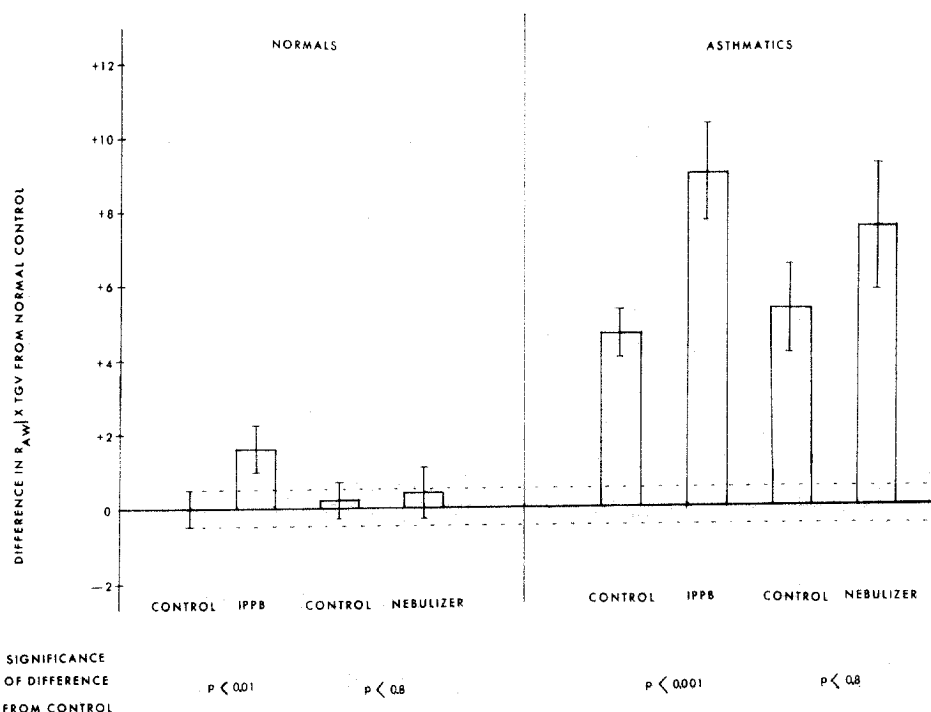


**FIG. 1.** Comparison of maximum effects of IPPB and nebulizer treatment on airway resistance ( $R_{AW}$ ) in asthmatic and normal children.

## DISCUSSION

In 1903, Dixon and Brodie<sup>14</sup> showed that mechanical, chemical, and electrical stimulation of nasal mucosa in animals caused bronchoconstriction. Since then, various investigators<sup>15, 20</sup> have attempted to define the reflex arc involved in bronchoconstriction. They have concluded that afferent stimuli originate in sensory nerve endings close to the ciliary plate of epithelium in the nasopharynx, pharynx, trachea, and bronchi.<sup>19</sup> In the upper airway, these nerve endings derive, in part, from the superior laryngeal nerve<sup>15</sup> and in the lower airway from the vagus.<sup>20</sup> These nerves synapse with the efferent limb of the vagus, and stimulation of this reflex arc leads to constriction of the trachea, bronchi, and bronchioles and an increase in airway resistance.

Not only do mechanical and electrical stimulation lead to bronchoconstriction, but inhalation of irritants such as sulfur dioxide,<sup>21, 22</sup> activated charcoal,<sup>23</sup> silicone particles,<sup>18</sup> and cold air<sup>11</sup> will produce the same effect.

The two differences between the IPPB and nebulizer treatments were pressure and the amount of water vapor delivered to the airway. Over three times more water was delivered by the nebulizer and 9 to 12 cm. more  $H_2O$  pressure was delivered by IPPB. If water were a cause of increased airway resistance in this experiment, this change should have occurred after the nebulizer treatment. Since this did not happen and since the increased resistance occurred after IPPB treatment, pressure was felt to be the cause for this change. Our study adds pressure to the list of airway irritants.

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