Intermittent Positive Pressure-Aerosol Therapy in Pediatrics*

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Introduction

For the past three years the Pediatric Research Department of the Lovelace Foundation has been engaged in investigative and clinical studies of the use of intermittent positive pressure breathing (hereinafter termed IPPB) therapy in the field of pediatrics. Studies in infant resuscitation have proved its worth in (1) expanding the non-expanded lungs of newborns who do not breathe at birth, (2) assisting in the correction of partial atelectasis and anoxia, and (3) promoting bronchial drainage, and preventing infection and resorption atelectasis.

The demonstration of the effectiveness of IPPB in pulmonary conditions in adults by Motley, et al.† raised the question of whether this type of therapy might be beneficial to children with respiratory problems, and whether by early treatment we might be able to restore normal pulmonary function in this younger age group. The physiologic basis here for IPPB was to (1) provide uniform alveolar aeration with improvement in blood-gas exchange, (2) overcome spasm and promote bronchial drainage with decrease in irritation and infection, and (3) provide breathing exercise with improvement in muscle tone and compliance.

Plan of Investigation

Routine Studies—Children, ranging in age from one to 17 years, and suffering from various respiratory conditions, were included in the investigative studies. Routine studies consisted of thorough history and physical examination, complete blood count, throat or sputum culture with sensitivities, x-ray films of the chest and sinuses, and allergenic skin tests.

Pulmonary Function Tests—Pulmonary function tests included studies of the air flow, lung volumes, and intrapulmonary mixing and distribution. These tests gave the required objective information, since 99 percent of pulmonary impairment in children is in ventilation, with less emphasis on diffusion. A ventilation chart was devised to simplify factor-impairment-cause relationship.

Obstructive, restrictive and dynamic impairment was easily and rapidly visualized by pneumotachographic studies, employing a flow orifice as previously reported.§ Timed vital capacities gave an accurate estimate of the extent of obstruction. Spirograms during quiet breathing and max-

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imal inspiration and expiration (vital capacity) provided information on
the bellows function of the lungs and chest (restrictive impairment).
Residual volume determined by the open circuit method and combined with
the spirogram provided total lung capacity and relative subdivisions.

Mixing and distribution was determined by means of a nitrogen meter
from the clearance of pulmonary nitrogen when breathing oxygen. The
total ventilation required to reduce the nitrogen in the expired gas to 1
per cent was measured. The nitrogen clearance ratio was computed by
dividing the total clearance ventilation by the functional residual capacity.
The nitrogen clearance equivalent or (ratio) thus obtained is a measure
of ventilatory efficiency independent of lung volume. (Nitrogen clearance
methods published elsewhere in detail).4

Role of Psychotherapy—It is recognized that many allergic conditions
in children may be associated with emotional problems. Therefore, many
of these children were referred to the Clinical Psychology Department
for aid. Psychometric tests included: (1) Intelligence (Wechsler Intelli-
gence Scale for Children), (2) Achievement (arithmetic, spelling, reading),
(3) Personality and Projective Tests (drawing of a man and a
woman, Roger's Personality Test), (4) Apperception (Children's Apper-
ception Test or CAT, Thematic Apperception Test or TAT) and (5)
Play Observation.

To simplify treatment and to promote interest and continuity of therapy,
children with respiratory conditions received their IPPB in a special
room called the Jet Room, so named by themselves, and from the ceiling

![Ventilation Chart]

**FIGURE 1:** Ventilation Chart.
of which hang models of jet airplanes which they have constructed. Each child is a member of the Jet Room Club and his specific therapy is transcribed on the back of his membership card.

**Therapeutic Measures**

**AIDS TO IPPB THERAPY**

*Climate:* The low humidity of the Southwest helps to dry up bronchial secretions, and the lower air density in Albuquerque reduces respiratory work.

*General:* Adequate diet, proper clothing, prevention of fatigue, avoidance of respiratory infections, avoidance of respiratory irritants (dust, smoke, allergenic irritants), and immediate treatment of respiratory infections.

*Specific:* Expectorants to promote bronchial drainage, relief of bronchospasm with nebulized bronchodilators, mechanical clearing of the respiratory tract by coughing or postural drainage, antihistamines, combination medications (such as Tedly), hormones (ACTH, Cortisone), and suppositories (Aminophylline, Tedly).

**ADMINISTRATION OF IPPB TO CHILDREN**

*Method:* The child is seated on a high swivel stool called the “pilot’s seat.” All positive pressure therapy in older children has been given via the Bennett flow sensitive pressure breathing therapy unit (Model TV-2P).

The pressure gage is set for eight to 10 cm. positive water pressure. A

*Children from ages one to five received therapy via the Bennett Infant Pressure Breathing Therapy Unit, modified from the TV-2P Model to give greater flow sensitivity and less dead space in the connecting and face piece attachments. All Bennett Therapy Units furnished by V. Ray Bennett & Associates, Inc., Los Angeles, Cal.

**Apparatus for measuring Functional Residual Capacity and recording Pulmonary Nitrogen Clearance**

![Diagram of apparatus](image-url)

**FIGURE 2:** Apparatus for mixing and distribution studies.
special sized mask to fit the child is rolled down from the nose and over the mouth to fit snugly. The child is then instructed to breathe deeply, raising the upper chest up to meet the doctor's hand during inspiration, and then to exhale completely until the abdomen or lower chest meets the doctor's other hand. Emphasis is placed on breathing deeply and slowly in order to avoid hyperventilation. (One hundred per cent oxygen is used both for pressure and nebulization). After the child has adjusted to the positive pressure breathing, the aerosol mixture is added to the treatment by adjusting the flow rate to the nebulizer to produce a true aerosol which will be inhaled during the inspiratory phase. The child watches the control pressure and mask pressure dials as they move, and many of the small children make believe they are jet pilots on a mission, flying high up in the skies, breathing in oxygen as many of their Air Force father pilots do. Initial pressures of eight to 10 cm. may eventually be increased to 10 to 15 cm., depending on the age of the child and the severity of his condition. Initial treatments range from five to ten minutes; most routine treatments are of ten minutes duration; occasionally some may be increased to 12 minutes. Frequency of treatments is based on acuteness and severity of the child's respiratory problem. Status asthmaticus is usually treated twice daily until significant improvement occurs, as may be bronchiectasis, complicated by acute pneumonitis. Treatments are gradually reduced in number and discontinued when the child's condition so warrants. The mask is held either by the nurse or the older child himself during the entire treatment, and children are encouraged to stop and blow their nose or cough, or get up any secretions loosened up during the treatment.

FIGURE 3: IPPB therapy being administered to five-year old bronchiectasis patient with Bennett Unit.
Following therapy they are instructed to do only moderate activity during the next four-hour period and, in many instances, to engage in postural drainage. Occasionally some older children can aid themselves between treatments by further postural drainage and breathing exercises.

*Aerosol Medications*: Aerosol medications are of four types: bronchodilators, antibiotics, wetting agents, and digestive enzymes. The most satisfactory bronchodilator in children has been isopropylarterenol (Isuprel 1/200 dilution) hydrochloride**; a racemic epinephrine solution (Vaponefrin) has been used in those initially or eventually non-responsive to Isuprel; Aerolin compound was discontinued because of its oily characteristics and atropine-procaine fractions. Among the antibiotics, Terramycin aerosol has been most generally used, when organisms were shown to be sensitive to the drug (it remains stable when combined with the other aerosol agents); penicillin and streptomycin have been helpful. Alevaire** has been used almost exclusively as a wetting agent to help in the reduction of surface tension, liquefaction and emulsification of mucus, and potentiation of antibiotic agents. The enzymatic agent Tryptar*** has been used sparingly where indicated for the further liquefaction of thick tenacious secretions in children with asthma, bronchiectasis, and cystic fibrosis of the pancreas.

*Supportive Therapy*: Those children who have definite allergies are desensitized by the administration of weekly, bi-weekly or monthly allergenic extracts (in most cases Hollister-Stier extracts were used). Where respiratory attacks are precipitated by colds, children may also receive cold shots (H. influenzae Serobacterin—Sharp & Dohme).

Psychotherapy has benefited many children whose respiratory or systemic complaints are associated with emotional disturbances. Play therapy in many instances may be continued over many months, as similarly recounted in Baruch's "One Little Boy."**

**EVALUATION OF THERAPY**

The benefits which children derive from IPPB therapy are evaluated subjectively by symptomatic and physical changes. Of prime consideration in symptomatic improvement are changes in appetite, breathing character, cough or wheezing, fatigability, infections, medications required, and sleeping. Physical changes observed are alertness, color, vigor, weight, type and quality of respirations, change in thoracic or other configurations, exercise tolerance, breath sounds, pulse and blood pressure, and temperature.

The change in routine laboratory evaluations—blood count, decrease in bacterial organisms, change in x-ray films of chest and sinuses, and change in allergic sensitivities—offer some objective measures of improvement. The most impressive objective observations come, however, from comparative "before and after therapy" pulmonary function studies.

**Alevaire and Isuprel furnished by Winthrop Laboratories, Inc., New York, N. Y.***

**Tryptar Aerosol furnished by Armour Laboratories, Chicago, Ill.***
CLINICAL RESULTS

Newborns and Infants—One hundred and seven newborns have been resuscitated employing the Goddard-Bennett-Lovelace Infant Hand Resuscitator, with an average number of treatments ranging from one to 10, and a duration of two to 20 minutes. Eighty-seven of these newborns survived, and if correction is made for extrapulmonary deaths (intracranial bleeding and congenital cardia), the survival rate rises to 90 per cent. Ten infants, ranging from three days to one year of age were treated with IPPB via the GBL Infant Hand Resuscitator for segmental atelectasis, pneumonia, acute laryngo-tracheo-bronchitis, bronchiolitis and various congenital anomalies (tracheo-esophageal fistula, incomplete tracheal rings, etc.). The average number of treatments ranged from two to 10, duration 10 to 15 minutes, with 70 per cent survivals. (One death was in an infant with multiple congenital anomalies, one in a 20 days old infant with tracheo-esophageal fistula and post-operative atelectasis, and the third was in a four months old infant with amyotonia congenita who had recurrent bouts of pneumonitis.)

Children—Ninety children ranging from one to 17 years of age have received IPPB therapy. Eighty-eight, (98 per cent) have improved with therapy. In over 1800 treatments in 100 children ranging in age from a few days to 17 years, and in over 200 treatments in 107 newborns, we have not produced pathological damage from intermittent inspiratory positive pressure breathing. The only ill effects noted have been dizziness and headache, with occasional vomiting, in children who have breathed too rapidly and hyperventilated.

Childhood Asthma—Forty-six children with different degrees of severity of asthma have been treated with IPPB. In each case 0.5 cc. of Isuprel or Vaponefrin was used, diluted in one cc. of distilled water. In cases where indicated other aerosols have been added—0.5 cc. Terramycin for combating infection, 0.5 cc. Alevaire and/or 0.5 cc. Tryptar to liquefy secretions. Ninety-six per cent of these children were helped by IPPB. The significant findings in this series is that the younger the child, the better response he shows to IPPB therapy.

Age Group One to Five Years: Ten children were treated in this age group. One severe case died following an acute anoxic attack, 15 months after IPPB was initiated. Post mortem examination revealed chronic anoxic changes with extensive secondary degenerative changes in the ganglion cells of the cerebral cortex, the spinal cord, the dentate nucleus and olive, and focal degenerative changes of the peripheral nerve bundles. Acute anoxic hemorrhagic areas were present in the brain, heart and lungs. Respiratory pathology revealed mild chronic laryngitis and tracheitis, chronic bronchitis and bronchiolitis, some focal pneumonia, pulmonary emphysema and hypertrophy of the right heart (cor pulmonale). The only other child in the entire group of asthmatics who did not continue to improve with IPPB therapy was a
two-year old boy who took one treatment and refused any more; treatment was discontinued, as his asthma was mild. Two other children in this age group were hospitalized in *status asthmaticus* and have improved to the point of where one weekly treatment suffices to keep them subjectively and objectively free of asthmatic symptoms and signs. The remaining six children in this group range in severity from mild to moderate and may receive treatment once a week, once a month, or only as needed. These children are treated with IPPB in an attempt to: (1) prevent mild chronic or acute anoxia, (2) improve lung and chest compliance and overcome emphysema, (3) and in three cases to supplant ACTH therapy.

**Age Group Six to 11 Years:** This is the largest group in our asthmatic series. All 29 children in this group, with mild to severe asthma, have shown improvement. There has been improvement in general well-being, in appetite; less wheezing, coughing and sneezing; less fatigability; fewer infections; less medication required; and improvement in sleeping. Many children confined to bed or the home have returned to normal activities and school. Physically, these children are more alert, their color has improved, they have less respiratory difficulty, and little dyspnea, with improvement in exercise tolerance. Some have obvious decrease in anteroposterior chest diameter and emphysematous configuration of the chest, and many have shown substantial weight gains. Objectively, there has been improvement in obstructive, restrictive, and ventilation impairment in 100 per cent of the cases. This response to IPPB therapy in these school age children indicates the likelihood of reversal of pulmonary pathology when long term therapy is carried out. Response to isolated treatment may be of little significance or value.

**Age Group 12 to 17 Years:** Seven children, three of whom were suffering from severe asthma, showed remarkable improvement. Pulmonary function studies in this age group have been most successful.

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**TABLE I**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Number Treated</th>
<th>Average Range of Treatments</th>
<th>Improved with Therapy No.</th>
<th>Number Receiving Other Therapy</th>
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<td>1 - 10</td>
<td>87</td>
<td>81</td>
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<td>Infants</td>
<td>10</td>
<td>2 - 10</td>
<td>7</td>
<td>70</td>
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<tr>
<td>Children</td>
<td>90</td>
<td>12 - 75</td>
<td>88</td>
<td>98</td>
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<td>Asthma</td>
<td>46</td>
<td>10 - 50</td>
<td>44</td>
<td>96</td>
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<tr>
<td>Bronchiectasis and Bronchitis</td>
<td>10</td>
<td>6 - 24</td>
<td>18</td>
<td>100</td>
</tr>
<tr>
<td>Chronic Cough</td>
<td>18</td>
<td>6 - 24</td>
<td>18</td>
<td>100</td>
</tr>
<tr>
<td>Cystic Fibrosis of Pancreas</td>
<td>1</td>
<td>46</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Sinusitis and Misc.</td>
<td></td>
<td></td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Respiratory Conditions</td>
<td>15</td>
<td>1 - 12</td>
<td>15</td>
<td>100</td>
</tr>
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</table>
due to the better cooperation from these children and the larger pulmonary volumes which can be more accurately measured. This group not only shows the objective changes seen in adults with emphysema (increased vital capacity, maximal breathing capacity, and instantaneous inspiratory and expiratory flow rate patterns) but also significant changes in residual volume and pulmonary emphysema, with a reversal toward restoration of normal lung volumes.

Chronic Cough—Eighteen children who were first seen for a chief complaint of chronic cough were treated with IPPB, together with an aerosol comprised of a bronchodilator, antibiotic, and distilled water. The duration of the symptoms ranged from six weeks to four years. All previous treatments, including antibiotics, chemotherapeutic agents, allergy diets, antihistaminics, and cough preparations were unsuccessful. The investigative studies revealed no specific cause other than low grade bacterial infection and occasional mild allergic sensitivity. Roentgenograms were usually negative; occasionally there was a questionable increase in the bronchovascular markings of the lungs. Pneumotachographic tracings frequently showed some obstructive impairment, which improved with IPPB therapy. Other pulmonary function tests rarely showed any restrictive or ventilatory impairment. This group of children showed the best results in our entire series. In 100 per cent of the cases, six to 24 10-minute treatments “cured” these children of their coughs, and none have returned except for other non-associated complaints.

Bronchiectasis and Bronchitis—Ten children, four with bronchiectasis and six with chronic bronchitis, have improved with IPPB therapy and aerosols consisting of a bronchodilator, antibiotic, distilled water, and in some cases Alevaire and/or Tryptar. There has been disappearance of cough and fatigue, increased appetite, ability to sleep and increased resistance to infection. Fever has disappeared, color and vigor have returned, with weight gain, clearing of the chest, and increase in exercise tolerance.

FIGURE 4A

FIGURE 4B

*Figure 4:* X-rays of three-year old girl with cystic fibrosis of pancreas. (A) Before IPPB started. (B) After 46 treatments over an eight-month period.
X-ray films have shown improvement (both chest and sinuses); pneumotachographic tracings have shown decrease in obstructive impairment; other tests have shown an increase in the tidal volume, with a more even intrapulmonary mixing.

Cystic Fibrosis of the Pancreas—Only one case of cystic fibrosis of the pancreas has been treated with IPPB therapy. We believe the results in this case warrant its publication. This three-year old girl had been admitted to hospitals four times in the nine months prior to initiation of her IPPB therapy. The main finding on all four occasions had been broncho-pneumonia and, on two occasions, atelectasis of the right middle lobe. IPPB therapy was started via the Bennett Infant Therapy Unit, using 1.5 cc. Tryptar aerosol (62.5 thousand units), 0.5 cc. Terramycin (75 mgm.), 0.5 cc. Alevaire, 0.5 cc. Isuprel and 0.5 cc. distilled water. She was treated daily for 10 days, during which time three treatments incorporated Tryptar aerosol. Following discharge from the hospital she has been treated in the outpatient department, first, three times weekly, then twice weekly, and now once weekly. In addition to IPPB therapy, she is on a cystic diet with daily pancreatin and erythrocin. Clinically, her cough has lessened, fever has disappeared, she has gained eight pounds, has fewer colds, and even less foul, bulky stools. Her x-ray films have shown some clearing of the typical "snowflake" shadows superimposed on chronic bronchitis and pneumonia of the right hilum and right lower lobe, although some shadows and increased bronchovascular markings remain (Fig. 4). Her pneumotachographic tracings have shown improvement in her obstructive-restrictive impairment.

Sinusitis and Miscellaneous Respiratory Conditions—Seven patients with sinusitis alone benefited from two to six IPPB treatments. Four children with sinusitis and allergic rhinitis have benefited from four to 10 treatments. In all 11 of these cases a bronchodilator-water aerosol mixture was employed, and in five an antibiotic. In the four with allergic rhinitis, allergenic extracts have now supplanted IPPB therapy. Four additional children with other respiratory problems have been treated with IPPB therapy alone or together with an aerosol. The left lung of a two-year old child with post-operative atelectasis was expanded by IPPB-aerosol therapy; tracheotomy in a two-year old with severe croup was circumvented by means of IPPB-aerosol therapy; a three-year old child with bulbar polio was aided by IPPB therapy; and a six-year old boy with triple fractures of the skull and bleeding at the base of the brain, with pressure on the cardio-respiratory center, was maintained over a two-hour period, using the GBL Infant Resuscitator with a large hand bulb, until a neurosurgeon operated and decreased the intracranial bleeding (10 cm. positive pressure).³

LABORATORY RESULTS

The clinical and subjective signs of improvement have been gratifying in our studies. The unequivocal objective results, however, have come from studies done before and after a single treatment, or before therapy
was initiated and after an appreciable period of therapy to show significant improvement.

**Pneumotachographs**—From these tracings, changes in not only the airflow but all three types of ventilatory impairment (obstructive, restrictive and dynamic) can be studied. The upper tracing in Fig. 5 shows the poor respiratory function of six-year old JS, whose asthma started at the age of two years. The usual asthmatic agents, plus ACTH, and even IPPB with a bronchodilator aerosol were unsuccessful in controlling his severe attacks. Finally, with the incorporation of Tryptar and Alevaire into the aerosol being administered by IPPB, he has made a good response and is attending school regularly. His pneumotachographic tracing before IPPB-Tryptar-Alevaire aerosol therapy was started shows: obstructive impairment evidenced by (a) shallow inspiration and (b) long exhalation time (1.8 second); restrictive and dynamic impairment with (c) prolonged time interval from the peak inspiratory flow to the peak expiratory flow (1.8 second). Following ten treatments, obstruction lessened considerably, as denoted by a more regular respiratory rhythm with (a') increase in the amplitude of both the inspiratory and expiratory phases and (b') decrease in the exhalation time (0.7 second). Dynamic and restrictive impairment show some improvement as evidenced by the now (c') fairly normal time interval between the peak inspiratory and peak expiratory flows (1.1 second).

**Pulmonary Function Tests**—While pneumotachographs serve as a rapid screening procedure of ventilatory function, and offer a psychological boost to the patient and parent, our most accurate determinations have come from our other pulmonary function studies.

Obstructive impairment in children is best analyzed from the timed vital capacity, since many children with severe pulmonary disease are unable to exert maximum breathing effort to give a maximum breathing capacity evaluation. The first second vital capacity is the most important, since a three second value may sometimes not be obtained. In the spirogram record (Fig. 6) of a 12-year old boy with asthma, marked

**J.S., age 6 years, Asthma**

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**Figure 5**: Pneumotachograph of six-year old boy with asthma.
obstruction is present, as denoted from a first second timed vital capacity of 52 and a three second timed vital capacity of 86. (His tidal volume, inspiratory capacity, expiratory reserve and vital capacity are within normal range for his age and height).

The vital capacity and residual capacity offer good indices of restrictive impairment, and the residual capacity gives further evidence of the presence of emphysema, which is frequently associated with a loss of compliance and elasticity. Mixing and distribution impairment, we believe, is best studied by measuring the respiratory volume required to accomplish clearance of an inert gas (nitrogen) from the lungs while breathing oxygen. From these measurements we can then classify the degree of pulmonary function impairment from both a volumetric and a functional basis.

<table>
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<th>Type of Pulmonary Impairment</th>
<th>Measurement</th>
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<tr>
<td>Volumetric: (Emphysema)¹</td>
<td>RV/TC</td>
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<td></td>
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<td>.25</td>
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<tr>
<td>Functional: (Ventilatory inefficiency)¹</td>
<td>N2 Clearance Equivalent</td>
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FIGURE 6: Spirogram record of 12-year old boy with asthma.
In Table III we have analyzed the obstructive, restrictive, and mixing and distribution impairment and their changes after therapy in three different age groups of asthmatic patients. JS, age six years, (whose pneumotachographs appear in Fig. 5) has improved from an advanced degree of pulmonary function impairment to a moderate degree, after 10 IPPB treatments. There has been an increase in his vital capacity with an accompanying increase in his residual volume to normal for his age, sex, and height. Obstructive impairment has improved, with a 15 per cent increase in the first second timed vital capacity, and his improved nitrogen clearance demonstrates better mixing and distribution. RF, age nine years, suffering from mild asthma for six years, has shown slight improvement

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<tbody>
<tr>
<td>JS</td>
<td>M</td>
<td>6</td>
<td>1</td>
<td>1.72 75</td>
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<td>1.49 0.23</td>
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<td>2  1.95 90 97</td>
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<td>16.2 0.18</td>
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<td>RF</td>
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<td>3.07 68 92</td>
<td>2.30 0.86</td>
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<td>104 per cent of predicted</td>
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<td>2  3.01 72 98</td>
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<td>4.31 56 83</td>
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<td>2  4.03 61 90</td>
<td>2.86 1.17</td>
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<td>48.8 0.29</td>
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*Correlation is the agreement between volumetric and functional methods of evaluation of degree of Pulmonary Function Impairment.

**Vital Capacity.
in his timed vital capacity and his obstructive impairment, with a slight decrease in his residual volume and emphysema.

GE, age 17 years, demonstrates reversibility in all types of pulmonary function impairment. She had eczema as an infant, with wheezing from the age of two years. The usual asthmatic agents, plus vitamins and cortisone, failed to control her asthma. She was admitted to the hospital in status asthmaticus, and IPPB therapy employing an aerosol mixture of Isuprel-Alevaire-Tryptar-water was given initially twice daily, then daily. She was discharged home 10 days later to continue IPPB therapy at home. In six months she had gained weight and returned to normal activities, with a decrease in the number and severity of her attacks. Her x-ray films showed clearing of the sinuses, with some decrease in the bronchovascular lung markings; her pneumotachographs showed considerable decrease in obstructive and restrictive impairment. From Table III and Fig. 7, changes in her pulmonary function show less obstruction, evidenced by an increase in timed vital capacity. The residual volume has decreased by 50 per cent to approximately the estimated normal value, with a corresponding 33 per cent increase in vital capacity. Her degree of pulmonary function impairment, based on the volumetric RV/TC ratio, has changed from advanced to slight. Her nitrogen clearance ventilation has decreased 25 per cent due to improvement in her functional residual capacity.

*The Place of IPPB Therapy in Pediatrics*

IPPB, with high positive pressures given over short, safe time intervals, is successful in the resuscitation of newborns. In 70 per cent of infants IPPB-aerosol therapy has been beneficial, and in 98 per cent of children from one to 17 years of age it has improved their respiratory condition. In childhood asthma not only has IPPB provided relief and control of symptoms and arrested the progress of the disease but it has reversed the chronic changes due to edema, bronchospasm and emphysema, and promoted the restoration of normal lung compliance and elasticity. We

**G.E., age 17 years, Asthma**

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<th>Estimated Normal</th>
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<th>Test 2</th>
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<th>Residual Volume</th>
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<th>Residual Volume</th>
<th><strong>N₂ Clearance Ventilation:</strong></th>
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<th>Residual Volume</th>
<th><strong>N₂ Clearance Ratio:</strong></th>
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**FIGURE 7:** Improvement in pulmonary function tests in 17-year old asthmatic after six months IPPB therapy.
believe chronic cough, chronic bronchitis and bronchiectasis are probably all progressive stages of the same "end" respiratory disease process. The first is cured with minimal IPPB therapy; bronchitis is helped with more intensive therapy, while bronchiectasis requires a long-term approach. With the dispersion of aerosol to all parts of the respiratory system in IPPB therapy, it is proving not only effective in alleviating symptoms and physical signs in these conditions, but playing a larger role in prophylaxis. While IPPB-aerosol therapy in cystic fibrosis of the pancreas does not correct the basic enzymatic deficiency, it protects against the recurrence of atelectasis so commonly seen in these children, holds down infection, and makes for a more normal lung compliance and elasticity—thus being not only active treatment, but prophylaxis against further infection and chronic lung changes. In sinusitis and miscellaneous respiratory conditions IPPB offers a more rapid, effective means of therapy. Therefore, in the respiratory conditions of children herein treated and reported on, IPPB-aerosol treatment has offered an adjunctive method of therapy in some, a "cure" in others, and prophylaxis against further infection and the development of chronic pulmonary pathology in others. Continued observation of these children over a long follow-up period will substantiate these conclusions.

Our studies have been limited to the application of intermittent positive pressure in the inspiratory phase. Expiratory positive or negative pressures have not been applied because of the labored effort required in this type of therapy, and the desire to hold at a minimum the respiratory work required of many of these small children with severe pulmonary involvement. Bronchodilators alone or IPPB alone were not studied, as we believe sufficient evidence has been presented by Segal, et al. to show the superiority of the combination of IPPB with bronchodilator agents. We believe the addition of a wetting agent enhances the liquefaction of sputum and potentiates the action of antibiotic aerosols. Tryptar, when used sparingly and only when necessary, due to its irritative qualities, has made the difference in success or failure in several of our chronic cases. The use of antibiotic aerosols has been beneficial in cases with chronic infection—sinusitis, bronchiectasis, and cystic fibrosis of the pancreas. We have not studied the diethylaminoethyl ester of penicillin advocated by Barach, et al. or have we been able to induce deliberate coughing in the younger age groups. Coughing chamber methods have not been studied, due to their impractical use in children. The use of supportive measures has been helpful in desensitizing children against allergies and upper respiratory infections. Short intensive courses of ACTH and cortisone allow remissions without the risk of adverse reactions. Psychotherapy plays an important role in many of these children.

The optimal method of use of IPPB in children seems to be an initial concentrated effort of one to two treatments daily, followed by two to three times a week treatments, and then weekly treatments until improvement or "cure" warrants discontinuance of therapy. In many asthmatics and children with chronic respiratory conditions long term therapy on a weekly or occasional "booster" type program is advocated. Children
must be instructed to breathe deeply and slowly and avoid hyperventilation which may cause headache, dizziness and vomiting. No case has been studied in which there is a contra-indication to the use of IPPB-aerosol therapy in children, nor has there been any pathological damage seen due to the use of positive pressure.

SUMMARY

1. A method for the use in pediatrics of intermittent positive pressure breathing (IPPB) therapy with supplementary use of bronchodilator drugs, antibiotic drugs, a wetting agent, and an enzymatic agent has been discussed.

2. A plan of investigation for studies in children to determine the effectiveness of such therapy is reviewed.

3. A ventilation chart has been proposed to simplify the factor-impairment-cause relationship of pulmonary function.

4. An accurate evaluation of the degree of pulmonary function impairment in children has been made from the following physiological tests: pneumotachographs, timed vital capacity, residual capacity, RC/TC (residual capacity) (total lung capacity) ratio, and the nitrogen clearance equivalent.

5. It has been shown that IPPB-aerosol therapy in pediatrics has proved to be an adjunctive, a curative, and a prophylactic type of treatment in children with asthma, chronic coughs, bronchiectasis and bronchitis, cystic fibrosis of the pancreas, sinusitis and miscellaneous respiratory conditions.

6. Significant reversible changes, not heretofore seen in IPPB therapy in adults, have been noted in some children with chronic emphysema, with as much as 50 per cent decrease in the residual volume, 83 per cent increase in vital capacity, and 25 per cent decrease in nitrogen clearance ventilation.

RESUMEN

1. Se discute un método para usar en pediatría la presión positiva intermitente (IPPB) con el uso suplementario de drogas broncodilatadoras, antibióticos, un agente humedecedor, y un agente enzimático.

2. Se revisa un plan de investigación para determinar en los niños la efectividad del método.

3. Se propone una gráfica de ventilación para simplificar el factor de deficiencia como causa en relación con la función pulmonar.

4. Una valuación exacta del grado de deficiencia de la función pulmonar en los niños se ha hecho mediante las pruebas siguientes: (a) neumotacografías, capacidad vital en relación al tiempo, capacidad residual, RC/TC (Capacidad residual) (Capacidad pulmonar total), y el equivalente de liberación de nitrógeno.

5. Se ha demostrado que el tratamiento por IPPB es un adjunto, curativo y profiláctico en el tratamiento de los niños con asma, tos crónica
bronquiectasia, bronquitis, fibrosis cística del páncreas, sinusitis otras variadas afecciones respiratorias.

6. Se han notado en los niños algunos cambios reversibles significativos que hasta ahora no han observado en los adultos mediante el IPPB, en casos de enfisema crónico, con tanto como 50 por ciento de decrecimiento del volumen residual, 33 por ciento de aumento de la capacidad vital, y 25 por ciento de disminución de la liberación de nitrógeno.

RESUME

1. L'auteur discute une méthode qui permet l'utilisation en pédiatrie du traitement par la respiration sous pression positive intermittente, avec usage associé de produits bronchodilatateurs, d'antibiotiques, d'un agent humidifiant, ou d'un agent enzymatique.

2. L'auteur développe un programme de recherches pour étudier chez les enfants le moyen de déterminer l'efficacité d'un tel traitement.

3. L'auteur propose un graphique de ventilation pour simplifier le rapport élément-troubles de la fonction pulmonaire.


5. Il a été démontré que le traitement par aérosols par la respiration sous pression positive intermittente en pédiatrie était un traitement du type adjuvant, curatif et prophylactique chez les enfants atteints d'asthme, de toux chronique, de bronchiectasie et de bronchite, de fibrose kystique du pancréas, de sinusite et de différents états respiratoires.

6. Des modifications réversibles significatives, qui n'étaient pas visibles auparavant dans le traitement par la respiration sous pression positive intermittente chez les adultes, ont été notées chez quelques enfants atteints d'empysemme chronique avec des chiffres tels qu'une diminution de 50% du volume de l'air résiduel, une augmentation de 33% de la capacité vitale, et une diminution de 25% du coefficient d'élimination de l'azote.

ZUSAMMENFASSUNG

1. Es wird eine Methode erörtert, die die Anwendung intermittierender Uberdruckatmung in der Kinderklinik unter zusätzlicher Benutzung bronchodilatatorischer und antibiotischer Medikamente sowie eines Befuchtungsmittels und eines Enzympräparates zum Gegenstand hat.

2. Ein Untersuchungsplan zum Studium der Wirksamkeit solcher Therapie bei Kindern wird dargelegt.

3. Eine Ventilationstabelle wurde vorgeschlagen, um die Ursachen ungenügender Lungenfunktion zu differenzieren.

4. Eine genaue Beurteilung des Minderungsgrundes der Lungenfunktion bei Kindern wurde aus folgenden physiologischen Tests gewonnen: Fneu-
motachogramm, Atemstoss, Residualkapazität, Verhältnis Residualkapazität: Totalkapazität und Stickstoff-Clearance-Äquivalent.

5. Es wurde gezeigt, dass intermittierende Überdruckatmung mit Aerosol in der Kinderheilkunde sich als zusätzliche Heil- und prophylaktische Behandlung bei kindlichem Asthma, chronischem Husten, Bronchiektasen und Bronchitis, zystischer Fibrose des Pankreas, Sinusitis und verschieden-\n\n6. Deutliche reversible Veränderungen, die bei der intermittierenden Überdruckatmung bei Erwachsenen bisher nicht gesehen werden konnten, wurden bei einigen Kindern mit chronischem Emphysem beobachtet mit Verminderung der Residualluft bis um 50%, Vergrößerung der Vitalkapazität bis um 33% und einer Herabsetzung der Stickstoff-Clearance bis um 25%.

REFERENCES