Inhalational Therapy in Pediatrics

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The applications of inhalational therapy cover the entire life span, more so, in fact, than any other form of medical treatment, for the lungs of an inert infant may first be expanded with bag and mask, just as the dying patient's lungs are inflated passively until all signs of life have disappeared.

Throughout infancy and childhood, the use of various forms of inhalational therapy are manifold. The child's narrow respiratory passages, his increased susceptibility to communicable diseases and allergic reactions, his characteristic development of inflammatory swelling and edema, and the avidity with which he aspirates foreign materials, all combine to make him one of the most challenging subjects of the inhalational therapist.

Most of the forms of therapy used in older patients are employed in children with only minor alterations indicated by the size of the child and his changing metabolic requirements. Since the pathological conditions encountered in children are often distinctly different than those seen in adults, therapy will be discussed as it is applied to specific diseases, rather than by modifying general statements about each type of apparatus and technique. In most phases of inhalational therapy, apparatus has been widely emphasized, perhaps because of commercial reasons, while many important details concerning patient care have received relatively meager attention. Throughout this article, an attempt will be made to emphasize the indications for therapy, the evaluation of treatment, and the various types of supplemental care that may be essential in each condition.

Resuscitation of the Newborn Infant

When initiation of ventilation is delayed by depression due to maternal sedation, pathologic changes, or airway obstruction, prompt treatment should be instituted by clearing the airway, elevating the chin, and stimulating sensory responses—as by slapping the feet. If these measures do not succeed at once, the lungs are passively inflated by bag and mask, or mouth-to-mouth techniques. Numerous variations on this basic approach have been advocated, but since the fundamental need is to get air (20 per cent oxygen is sufficient) into the infant's lungs, practical methods usually are most expedient.

Mechanical resuscitating devices delivering oxygen at designated pressures (usually 15-20 cm. of water) prevent over-distention of lungs, but in many instances do not deliver recorded pressures and often prove ineffective. Some infants require considerably higher pressure than 20 cm. of water for initial inflation. The Day technique of brief, high pressure (40 cm. of water for 0.15 second) has had popularity, but has not produced convincing results. As yet, it appears that establishment of the airway, followed by intermittent inflation at rational increments of pressure should be carried out until pulmonary exchange is evidenced by auscultation or visible expansion of the chest. If usual methods are not successful, one should immediately consider underlying causes such as narcotic depression, diaphragmatic hernia, mediastinal collapse, or intra-cranial hemorrhage.

Such moderately or severely embarrassed patients may require endotracheal intubation and prolonged respiratory assistance in addition to specific therapy for the basic lesion. Narcotic antagonists usually employed if indicated are nalorphine (Nalline) 0.2 to 0.4 mg or levallorphan (Lorfan) 0.05 to 0.10 mg given intramuscularly or into the umbilical vein and preferably not repeated. During all such resuscitative therapy it is important to maintain the infant's body temperature, since cooling alone will produce severe respiratory depression.
Respiratory Problems of the Neonatal Period

During the first months of life the newborn infant may run afoul of any one of the several critical respiratory hazards. These include the weakness of prematurity, neonatal atelectasis, the brief but usually fatal syndrome of hyaline membrane disease, and surgical lesions such as tracheo-esophageal fistula, diaphragmatic hernia and omphalocele, all of which severely tax exchange, during or after operation.

The weak premature infant occasionally needs increased atmospheric oxygen, but usually requires only protection, warmth, and isolation. Incubator-type apparatus fitted with rigid plastic tops, and heating and humidifying controls are standard equipment in most hospital nurseries. The majority of premature infants are best cared for by being placed in such incubators incorporating fans to circulate warm and humidified air, but not employing additional oxygen. In the presence of tachycardia, tachypnea, retraction or cyanosis, oxygen may be added. Usually flows of 3 to 5 liters per minute will provide the desired level.

While one should be careful not to exceed a tent oxygen concentration of 40 per cent in treating premature infants with unobstructed exchange, this rule does not apply to infants that have lesions that impair ventilation or oxygen transport.

Atmospheric oxygen concentrations should be raised until the infants show adequate tissue oxygenation, as evidenced in relief of distress, clinical improvement, or increased oxygen saturation measured by ear oximeter or blood sampling.

It is a fundamental, but often neglected rule, that any patient suffering from respiratory insufficiency must be positioned correctly at all times. Efforts to provide high oxygen concentration are futile if a child is allowed to lie slumped down, with chin sagging on chest, and the tongue blocking the weak ventilatory effort. This can only be matched by the nurse (or doctor) who blows oxygen over the face of an apneic infant.

Although the cooling of neonates has been advocated in order to reduce oxygen demands, studies thus far reported do not substantiate the theory, and an environment which will keep infant temperatures at 96–98°F is favored.

In caring for infants in incubator beds, it should be remembered that these devices provide unexcelled opportunities for bacterial growth, and can be extremely dangerous unless cleaned frequently and thoroughly.

Neonatal atelectasis and other types of continued severe respiratory depression, whether due to birth injury or pathological changes, may offer insurmountable problems in ventilation. Weak and rapidly failing respiratory attempts may be treated repeatedly by bag and mask resuscitation, but the condition may be prolonged and require extended support. Mechanical devices for continuous ventilation of infants without tracheal intubation or tracheostomy have been constructed, such as the Emerson Ucylit® cuirass envelope, but airway obstruction is almost certain to occur. Endotracheal intubation can be tolerated for 24–48 or perhaps 72 hours, but is attended by danger of edema, obstruction and dislodgment of the tube while tracheostomy involves hazards both in operative and postoperative phases. A small infant with a tracheostomy is plagued with problems of irritation, bleeding, obstruction, and weaning difficulties. Moreover, even if tracheal intubation or tracheostomy is risked, mechanical respirators still have not reached a satisfactory stage of dependability and controllability. In this field, the Bird Mark VII and has shown great sensitivity, and under constant supervision will perform adequately. The Engström ventilator is said to be suitable for neonates, although its excessive cost renders it beyond the reach of the average hospital. Improvements are developing and better machines can be anticipated.

An interesting concept now being developed is that of Beerman, who has produced increased tissue oxygenation by exposing subjects to three atmospheres of oxygen, thus increasing plasma content and tissue saturation. Successful application of this method in infants might be advantageous. However, it would still be necessary to provide a patent
airway, and the question of carbon dioxide excretion would require solution.

Again, we are left with the belief that a simple method will be devised which will not require intubation or tracheostomy. External pressure devices, plus traction on a tongue-stitch may yet prove to be what is wanted.

Acute respiratory distress syndrome of the newborn, referred to as hyaline membrane disease, is perhaps the greatest challenge of the neonatal period. It is of short duration, and leaves survivors without any stigma, yet is thought to be fatal to 5,000 to 20,000 infants yearly in this country alone. Etiology is yet uncertain, but leads point to pathologic changes of the placenta, with resultant deficiency of fibrinolytic enzyme and change in airway surface tension, atelectasis, pulmonary vascular transudate, cardiac failure, and severe respiratory and metabolic acidosis. While therapy must be directed toward all of these factors, at present it seems that much may be gained by simple assistance of ventilation. In addition to the many severely affected infants there are a number of marginal patients who can be saved if continuous respiratory assistance can be provided over the 48 to 72-hour critical period. Humidified oxygen, supplied by assistance with bag and mask or ventilator, is indicated as a logical approach. Since alveolar obstruction is marked, and compliance is poor, high pressure may be needed. Monitoring breath sounds by stethoscope is fundamental throughout treatment. In severe cases endotracheal intubation will be mandatory. One group has reported successful outcome after tracheostomy followed by controlled ventilation using an Engström respirator. The essential feature is that a team of physicians be so organized that at least one can be with the infant continuously until the outcome is decided. While efforts are made to support the circulation and correct metabolic imbalance, an all-out attempt must be made to forestall the obvious progress of anoxia and overwhelming respiratory fatigue.

Prior to operation, infants with tracheoesophageal atresia usually have pneumonitis and difficulty with secretions; those with diaphragmatic hernia, mediastinal emphysema or pneumothorax may have critical restriction of ventilating lung tissue, while intestinal obstruction causes distention and high fixed diaphragm. Supportive treatment with warm and humidified oxygen is indicated in all infants with diaphragmatic hernia and pneumothorax often have such severe respiratory embarrassment that survival requires immediate relief by operation or chest aspiration.

During operation, ventilation of these patients can be handled effectively, but the post-operative phase brings added problems of fatigue, metabolic imbalance and shock. Following repair of diaphragmatic hernia or omphalocole, dangerous limitation of ventilation occurs due to relocation of viscera, increased intra-abdominal tension, and fixation of the diaphragm.

It is in this early postoperative phase in newborn infants that the highest mortality in all surgery takes place. Weak infants that can be supported through operation are unable to continue on their own, become fatigued, hypoxic, acidotic, suffer cardiovascular collapse, are resuscitated several times, and then finally die.

Here as with hyaline disease, the immediate problem seems to be that of providing continuous observation with respiratory assistance when needed, but it is probably wrong to impose mechanical assistance or tracheal intubation before it is needed. On the other hand it is essential not to wait for the appearance of advanced stages of hypoxia such as bradycardia or apnea, for then the outcome will have been determined. In several instances, it has been possible to bring such weak infants through a critical 48-hour period solely by the efforts of dedicated anesthetists and surgeons providing continuous moment-to-moment care with bag and mask assistance, suction, endotracheal intubation, and supportive care as it became necessary. Mechanical respirators may be employed here, but still require constant supervision by a physician. Cardiovascular support must not be overlooked in these cases for it is easy to concentrate on ventilation, only to find that the infant is in shock. Then the best treatment for ventilation is the restoration of blood volume and cardiac contractility.
Upper Airway Obstruction in Infants and Children

Croup and its many congeners have been the proving ground for inhalational therapy for many decades.\textsuperscript{14-18} Inflammation of the upper respiratory tract may occur as localized bacterial infection in the form of epiglottitis, or laryngotracheobronchitis, or may occur as a local manifestation of a generalized infection such as diphtheria. In either case, the progress of edematous obstruction may be rapid and lethal. A previously normal child may develop fever, prostration and respiratory distress and be dead within three or four hours. This should be borne in mind by anyone treating this condition.

The first question in therapy is whether tracheostomy is needed. The answer is obvious if the child is cyanotic, comatose, or shows marked respiratory distress. If only mild signs of obstruction, such as crowing, stridor, and minimal retraction are present, the decision may rest on other factors. When around-the-clock attendance by expert physicians is not available, as in many small hospitals, tracheostomy should be done at the first signs of airway obstruction. In areas where capable surgeons are never more than five minutes away, it is permissible to observe the child until signs are more definite. Since many cases can be brought under control, tracheostomy for these can be avoided. Even under optimal conditions of personnel and equipment decision should be made in time to allow performance of the tracheostomy with deliberation and safety, rather than in a frantic debacle. Important signs to watch for are increasing stridor and retraction, restlessness, and especially a definite rise in pulse rate. Refusal of food by a child is also a subtle sign.

When symptoms of obstruction are gradual in development, inhalation therapy comes into full play.\textsuperscript{16-18} Small infants are treated in incubators, infants over 10 to 12 pounds are placed in enclosed, plastic-draped Croupettes\textsuperscript{\S} or open-top Burgess tents, while children are accommodated in a small adult-type tent, such as in Plymouth tent.\textsuperscript{\P} Oxygen is flushed into the tent until concentrations of 35–40 per cent are registered (Beckman analyzer).

Humidification has always been considered essential in treatment of dry, inflamed respiratory membranes. Early methods of steam instillation resulted in high elevation of temperature, consequently cold mist generators were introduced. While large droplets accomplish supersaturation of the air, nebulized particles of 2 to 5 microns, as produced by Mistogen\textsuperscript{\T} and similar apparatus are preferable, because the smaller droplets are carried down into the bronchioles\textsuperscript{20} (see article by Lovejoy and Morrow in this symposium). The actual advantage of droplet type humidification as compared to warm saturated air is still disputed.\textsuperscript{21} The use of “fog rooms” has also been employed especially for situations where high humidity is considered more essential than high oxygen concentration\textsuperscript{22, 23} (see article by Tovell and D'Ambruoso, this symposium).

The addition of medicaments to the inhalant has been tried frequently in children. Soothing agents such as tincture of benzoin now have been relegated to the home-and-drugstore trade, and wetting agents such as Alvaire and Tergemist appear to be similarly directed, since evidence of their effectiveness has been unimpressive.\textsuperscript{24}

Supplemental therapy that must be stressed in upper airway inflammation includes prompt use of antibiotics and generous fluid intake, usually by parenteral route. If membranes are crusted and dry, hydration by vascular channels may more effectively penetrate local tissues and at the same time will contribute to general fluid requirements.

The use of steroids in treatment of airway inflammation appears promising and deserves further evaluation. Deming and Oech\textsuperscript{25} report favorably on their experience using dexamethasone-21-phosphate (Decadron) in a series of children who developed severe tracheitis following endotracheal intubation. They advise single intramuscular dosage of 4 mg. for infants under 1 year, and 8 mg. for older children.

\textsuperscript{\S} Air Shields Co., Hatboro, Pennsylvania.
\textsuperscript{\P} National Cylinder Gas, Chicago, Illinois.
\textsuperscript{\T} Mistogen Equipment Co., Oakland, California.
The term 'croup' usually suggests respiratory obstruction with some inflammatory etiology, while that of 'stridor' often is loosely associated with obstructive anatomical lesions such as redundant aryepiglottic folds (the most common), foreign body, vascular ring, or absent tracheal rings (rare). Treatment can only be effective when one attacks the cause and not the symptom, consequently, inhalational therapy should never be relied upon blindly. Recently a small child was admitted following a three-day upper respiratory infection with fever, crowing, retraction, and signs of dehydration. Obviously presenting the picture of tracheobronchitis, the child was prepared for the "steam room," and croup routine. Acting upon a wild guess, however, a roentgenogram was taken, following which a button was removed from the child's trachea! Diagnostic laryngoscopy, as well as flat plates and contrast films of esophagus and trachea should always be considered in assessing obstructive ventilatory problems.

Obstruction by noninflammatory lesions may cause fatal hypoxia, and inhalational therapy can prove life saving. Tracheostomy must always be considered, and until that step is taken oxygen therapy plus humidification is indicated. The advantages of helium have been stressed, but if helium is used in 80-20 proportion with oxygen, as theoretically necessary to provide maximum benefit, patients have appeared less well oxygenated than when receiving 100 percent oxygen. Before abandoning this approach, it would be interesting to test the effect of various mixtures of oxygen and helium with the aid of an ear oximeter.

Proper positioning of patients with airway obstruction is imperative, but optimal position is not always the same. Infants with vascular ring obstructing the trachea often lie in extreme opisthotonos and should be encouraged to do so if it is helpful.

It seems questionable if steroids or antibiotics could be of assistance in controlling anatomical lesions, unless other factors complicate the situation.

Acute Pulmonary Conditions

Infants with acute bronchiolitis and/or pneumonia are benefitted by treatment in warm humidified oxygen incubators until respiratory distress, tachycardia and fever have abated. Inspired oxygen concentration should be at least 40 percent, and more if the infant does not respond to initial treatment. Filling of the incubator with thick fog has become a widely accepted routine, but demands controlled comparisons before the practice can be scientifically justified. If infants are treated in supersaturated atmospheres, it should be remembered that normal elimination of body fluid through skin and respiratory tract will not take place and retention of such fluid may result in undesirable edema formation in lungs, brain or larynx. Unexpected weight gain of infants should be a warning of such a development. Obviously, antibiotics and general supportive care will be of primary importance in such patients.

A more heroic approach has been advocated in treatment of infants who are suffering from pneumonia. In order to overcome pulmonary insufficiency, patients have been tracheostomized, then respirated mechanically until able to support ventilation by themselves. Atelectasis whether related or unrelated to operation, may respond markedly to inhalational therapy. Treatment of the infant or child resembles that of the adult. Prior to initiation of such therapy, maximal clearing of the tracheobronchial tree should be attempted. Here tracheal aspiration or bronchoscopy may be required, and occasionally must be repeated several times. Intermittent positive pressure breathing is then instituted using humidified oxygen-air mixtures. While innumerable machines have been advocated for this, the Infant Bennett IV-1A has given satisfactory performance and is acceptable to patients. The introduction of this therapy to children should be gradual and gentle, using pressure of 5 cm. of water for one or two breaths at the start, then working up to 12 to 15 cm. of water. Duration of treatment should not be prolonged, especially in sick children who become exhausted rapidly. A short period repeated hourly will be more beneficial than a five-minute struggle every three hours.

The theory of using various agents to alter secretions is inviting, especially so following the demonstration that respiratory surface ten-
sion changes may underlie certain forms of atelectasis. As yet, however, saline appears to be as effective as any aerosol, and less harmful than most. In atelectasis in which mucopurulent or high viscosity secretions are not evident, warm normal saline should be nebulized in standard vaporizers.

In children, as in adults, treatment of atelec-
tasis demands thorough activation of cough, frequent postural changes, suctioning, and chest percussion, as well as use of antibiotics and fluids.

Following intracardiac operations performed with cardiopulmonary bypass, a severe form of atelectasis, sometimes called "pump lung," may be encountered which often starts shortly after operation with profuse respiratory secretions, increasing dyspnea, and marked fall in pulmonary compliance. Tracheostomy has been required to manage secretions and provide respiratory assistance. Auffed tracheostomy tube is used, preferably of metal with removable inner lining and an external fitting for attachment of ventilating apparatus. Since a tracheostomy often is not air-tight, a ventilator which has a large volume, and is not pressure limited, has been most valuable. The Emerson Controller-Assistor has served this purpose well. Due to the high resistance of the stiffening lungs, the ventilator should deliver high pressures (up to 60 cm. of water). Drying and crusti ng of respiratory passages take place rapidly and efforts must be taken to control this problem. Heated, aerosolized saline in large amounts is helpful, and here the Puritan nebulizer is especially effective. It may be coupled with the Emerson ventilator. In spite of this approach, it still may be necessary to irrigate the trachea directly with saline (approximately 1 ml. per 15 pounds body weight). Such fluid is rapidly absorbed and usually cannot be retrieved by immediate suctioning. The saline helps to loosen crusts which then may be suctioned or lifted from the trachea. Daily bronchosscopic suction has proved a life-saving maneuver in some cases.

Although this complication has been associated with a high mortality, death is by no means a foregone conclusion. The condition appears to be caused by pulmonary hypertension, but probably more directly the result of inadequate relief of pressure in both auricles during perfusion, with resultant backing up of blood in the lungs. In tetralogy of Fallot and similar conditions involving increased bronchial artery flow, the incidence of this complication is obviously increased.

Following more routine surgical cases, inhalational therapy is employed according to standard rational indications. Children whose condition has been impaired by extensive major procedures, who have severe underlying disease, who have respiratory depression or obstruction, or who are cold, are placed in suitable oxygen enclosures. Occasionally, short nasal tubes are used before a child is conscious. Although nasal oxygen administration is effective and cheap, the possibility of gastric distention and rupture has occurred in our own hospital and at others. The incidence of post-intubation tracheitis has been minimal in our experience, and therapy with oxygen or mist has never been adopted as a routine following endotracheal anesthesia.

After thoracic operations, it seems advisable to administer oxygen to all infants and to most children, however, following patent ductus operation and repair of coarctation on strong patients this often appears unnecessary and is omitted if the children are active and ventilating well.


Pain is often the cause of limited exchange following thoracic operations. Contrary to expectations, morphine, in reduced dosage (1 mg. per 25-30 pounds body weight) often produces sufficient relief to bring about marked improvement in ventilation.

The treatment of surgical or traumatic shock in the pediatric age group naturally includes the use of oxygen and airway control as highly important features. One must be careful when dealing with sick children, for it is common to watch a child become increasingly active and uncontrollable and to see attempts made to discipline or sedate him, when in actuality he is showing the signs of oxygen want.

Fe-Acetyl cysteine, a mucolytic agent, has recently proved highly effective in thinning out heavy tracheo-bronchial secretions.
** Puritan Compressed Gas Corporation, Kansas City, Missouri.
Children in cardiac failure, a common occurrence in clinics treating congenital heart disease, profit by oxygen, digitalis, and relatively large doses of morphine. In pediatric circles, 1 mg. of morphine per year of age is a conservative dose for younger children.

**Chronic Pulmonary Lesions**

Although inhalational therapy plays little or no part in the treatment of tuberculosis, it offers definite assistance to children suffering from asthma, emphysema, bronchiectasis and cystic fibrosis. In these diseases, one encounters combinations of spasm, air trapping, respiratory acidosis, inflammation, infection, altered secretions, and degenerative changes of pulmonary mucous membranes and supporting tissues.

**Asthma.** In the treatment of asthma, inhalation or aerosolized epinephrine 1/200,000 or isoproterenol (Isuprel) 1/200 will provide rapid bronchodilation and prompt relief of obstructive symptoms. However, the use of portable nebulizers invites frequent and excessive self-administration, with considerable danger of overdosage and severe side-effects. For this reason it is advisable to rely upon oral administration of bronchodilating agents, and to reserve aerosol preparation for occasional use, e.g., in treatment of sudden nocturnal attacks.

The problem of the "adrenalin-fast" patient frequently recurs. This may be due in part to acidosis and reversal may be accomplished by correction with molar lactate solution.31

Asthma is seen in all stages and as noted by Goddard,32 therapy involves a many-sided approach including desensitization to allergens, immunization to bacterial agents, the use of steroids, gamma-globulin, diet, sedatives, expectorants, antibiotics, aminophylline, bronchoscopy and physiotherapy and psychotherapy as indicated. In severe asthmatic attacks acute hypoxia may occur, but oxygen therapy may be associated with development of carbon dioxide narcosis unless ventilation is supported. In extreme cases, heavy sedation with tribromethanol (Avertin, 60 to 80 mg./kg.) or light ether anesthesia has provided bronchodilation and increased ventilation.

Asthma which cannot be controlled may lead to emphysema, and the development of pulmonary hypertension and cor pulmonale. Increased residual volume and marked decrease in vital capacity and expiratory reserve render the child weak, dyspneic and an easy prey to further infection. At this point any exacerbation or intercurrent disease immediately sets the stage for acute hypoxia, cardiac failure and death. Treatment of the moribund asthmatic obviously demands prompt, decisive action. Tracheal intubation, intermittent positive pressure respiration with supplemental use of aminophylline (1 mg./pound by slow intravenous injection), and relief of gastric distention 33 plus cardiovascular support may prove life-saving.

**Bronchiectasis.** Since the introduction of penicillin the incidence of bronchiectasis in children has been strikingly reduced. Occasional resistant or neglected cases appear, however, with copious purulent secretions and recurrent inflammatory exacerbation. Formerly, many of these children received aerosolized penicillin, streptomycin, and subsequent drugs. However, use of oral antibiotics proved equally effective and more expedient, and inhalational therapy has largely been abandoned. Total therapy entails bronchography, bronchoscopic suction, the use of antibiotics indicated by bacterial sensitivity tests, and effective postural drainage. Excision of localized areas of advanced disease is indicated after purulent secretions have been controlled. Inhalation of aerosolized antibiotics or decongestants may be used preoperatively, and ventilation may be assisted in the immediate postoperative period, but the part of inhalation therapy is not a major one. In resistant, generalized disease not amenable to surgical procedures, inhalation of liquefying agents and proteolytic drugs may be attempted, but therapeutic effects have been equivocal.

**Cystic fibrosis of the pancreas,** also called pancreatic fibrosis or mucoviscidosis, represents one of the most complex and compelling problems in modern pediatrics.34 Digestive and pulmonary systems are primarily involved. The disease may be manifest at birth as meconium ileus, causing complete intestinal obstruction and high mortality.35 Survivors of this early form progress to experience the usual course of the disease with failure to digest fats, and advancing pulmonary involve-
Inhalants used in the attempt to control secretions have consisted chiefly of wetting agents to decrease viscosity, and proteolytic agents to digest and liquefy purulent material. An aerosolized solution of 10 per cent propylene glycol in water is safe and moderately effective. Critically ill children should sleep in tents in an atmosphere saturated with such a mist. This may be vaporized in the hospital using oxygen as a propellant or in the home in a blanket-tent using portable air pumps.

Proteolytic products which have been used as aerosols include trypsin (Tryptall), chymotrypsin, and pancreatic dornase. These have failed to produce convincing results, and have shown undesirable side effects. Trypsin has caused metaplasia of mucous membranes, while dornase and chymotrypsin have caused serious irritation or actual digestion of local tissues. Palmer, having studied the above methods, now finds a mixture of ascorbic acid, sodium percarbonate and copper sulphate (available as Ascoxal, Astra Pharm., Ltd.) to be safe and effective.

During the last stage of the disease, when children become dyspneic and exhausted, assistance with intermittent positive pressure respiration seems logical, but has been most discouraging. Tracheostomy at this stage prolongs life by decreasing dead space and facilitating suction, but at this point the benefit to the patient is questionable. This entire phase of inhalational therapy certainly demands intensive study.

**Penicillin**—50,000 to 100,000 units

**Streptomycin** 50—100 mg.

**Neomycin**—50 mg.

**Polymyxin (or colymycin)**—10 µg.

in 2 ml. water 4 i.d.

**Evaluation of Therapy in Chronic Pulmonary Disease**

It is possible to measure more critically the effect of various forms of therapy in the management of chronic diseases. This must be attempted if any intelligent comparison is to be made of the many techniques proposed.
General responses to be considered are days of absence from school, weight gain, recurrence of exacerbations, and superimposed infections, and finally in those with cystic fibrosis, duration of life itself. More definitive measurements should include measurement of pulmonary function, especially residual volume, vital capacity, and timed vital capacity.44, 45 Plain chest films and bronchograms are important in long-term evaluation of bronchiectasis. The sputum may be studied for control of bacterial flora, total amount, and viscosity.46 Of special importance will be measurement of arterial pH, P CO₂, and oxygen saturation. Only on such terms will therapeutic success be acknowledged.

Diseases of the Nervous System

Inhalational therapy for children with poliomyelitis, Guillain-Barré syndrome, tetanus, acute poisoning, surgical or traumatic neurological lesions, and those being treated by induced hypothermia have in common central respiratory depression without superimposed lesions of the lungs or respiratory passages. The essential features for proper oxygenation will be to insure an airway, and provide adequate and continuous ventilation for prolonged periods without complicating side effects. In tetanus, the picture is complicated by spasm, which fixes respiratory muscles, and by occluding secretions. Tracheostomy and control of muscle spasm with barbiturates, mephenasin, or other agents must be accomplished rapidly.27, 47

Remaining problems in airway maintenance and ventilation are common to patients of all ages, and will not be dealt with in detail. The airway can be managed without intubation or tracheostomy in patients who are not severely depressed or markedly obstructed by secretions. Those who are apneic for prolonged periods obviously should have tracheostomy. Metal tracheostomy tubes with inflatable rubber cuffs and removable inner sleeves are less irritating, and more easily cleaned. The decision concerning tracheostomy in partially paralyzed children will depend on the speed of the progress of the disease, the adequacy of nursing care, and upon ventilatory efficiency as measured by spirometer or arterial oxygenation.

Endotracheal intubation may be used for 48 to 72 hours if, as in poisoning or postoperative depression, prolonged dependence is not expected.

Ventilating devices applicable for use in prolonged respiratory depression are innumerable, and consist of tanks, rocking box, cuirass mechanisms, inflatable belts, and intermittent positive pressure machines driven by gases or electricity. Special features to be sought when used for the long-term, tracheostomized case are (1) reliability, (2) air dilution and (3) ability to deliver warm, highly humidified air or oxygen. Since it may be difficult to maintain an airtight system following tracheostomy, pressure limited ventilators may not cycle, thus it is essential to have a respirator with a volume-controlled inspiratory phase, with capacity to deliver 1,200–1,500 ml per cycle. Tank respirators still are favored in certain clinics, especially for patients who do not require tracheostomy. Among the machines devised for direct intra-tracheal ventilation, the Engström perhaps is most nearly the ideal at present, although in our experience the Emerson Controller-Assist has proved satisfactory for larger infants and children with depression of the central nervous system.

Special features in the management of these patients consist in prevention of local infection, prevention of airway drying and crusting, and hyperinflation of lungs at intervals of 20–30 minutes to overcome decreasing compliance.48, 49

It must be emphasized that the adequacy of ventilatory support can only be determined by repeated measurement. While children are dependent upon artificial ventilation, measurement should be performed two or three times daily by testing with a Wright spirometer or other ventilometer, using the Radford 50 or a comparable nomogram 51 for reference. More exact evaluation should be carried out at one to three day intervals by measuring arterial pH, carbon dioxide tension, and oxygen saturation.

Summary

Throughout the pediatric field there are many areas where inhalational therapy should be of tremendous importance. These include
medical and surgical problems of the newborn, especially the enigma of respiratory distress syndrome. In children various forms of croup, chronic pulmonary disease, cardiac lesions and central nervous system disorders demand concentrated attention. Among these conditions, by far the most distressing is cystic fibrosis.

In this, and in several other situations inhalational therapy has great potential benefit. As yet, however, many of our approaches are open to dispute, and our accomplishments often completely unsatisfactory.

It must be emphasised that there is great need for a more critical evaluation of methods and results in this field. Documentation of numerous measures is totally lacking. It is obvious that until considerable improvement is made, survival of patients will continue to depend upon prolonged immediate personal supervision rather than the application of any of the currently popular practices.

The present situation in regard to mechanical ventilators is judged to be that of a dynamic but as yet imperfect state of development.

References


42. Shwachman, H.: Personal communication.


