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The Treatment of Respiratory Insufficiency

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PULMONARY DISEASES

The Treatment of Respiratory Insufficiency

THE management of the patient with acute pulmonary insufficiency requires rapid recognition of the defect and its multiple complicating factors. Accurate diagnosis with establishment of the level of impairment is mandatory in providing appropriate therapy. A useful classification given in a recent Ciba guest symposium separates such patients into clinical groups:[1]

Group	Physical-Laboratory Data	Disease Severity
I	Asymptomatic or objective evidence of air flow obstruction (Spirogram)	Lung Impairment
II	Continual dyspnea, with exertion usually. Evidence of abnormal lung studies.	Lung Insufficiency
III	Hypoxemia, hypercarbemia at room air. Aggravated by exertion.	Lung Failure

Variable etiological factors may result in a final common state, respiratory acidosis. Acute

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and chronic factors may interact in any type of patient. The more normal the lung, the more severe and obvious are the precipitating factors (paralysis of muscles in poliomyelitis); the more severe the chronic lung disease, the less dramatic may be the acute precipitating event (fatigue, mild sedation, minor infection), both may be severe enough to require therapy.

In patients with underlying obstructive chronic lung disease, episodes of acute respiratory insufficiency result in a low arterial oxygen tension, elevation of carbon dioxide, and ultimately in respiratory acidosis. Pulmonary hypertension and pulmonary heart disease occur quite commonly in these patients.[2] The mortality rate increases because of the host of extra-pulmonary complications, namely, heart failure, shock, gastrointestinal bleeding, renal failure, etc. The high morbidity and mortality rates of these patients will be reduced with optimum care.

Physiologic therapy usually demands immediate action, preferably in the environs of an intensive cardiorespiratory care unit, involving multiple disciplines and the repeated monitoring of hemodynamics, metabolic and ventilatory functions. The goal of such therapy is to improve useful function to normal or relatively normal tissue which has been involved in the acute process, thus precipitating the ventilatory failure.

Dyspnea and cyanosis are usually observed in patients with combined mechanical and alveolar insufficiency. Hyperventilation without cyanosis may be observed in patients with salicylate poisoning, acute meningitis, diabetic coma, gram negative septicemias, uremia and hepatic coma. This increased ventilation is a pulmonary response to the underlying disease and its metabolic components and respiratory insufficiency is not observed.

Clinical Evaluation of Ventilatory Function

The initial evaluation of such patients should, of course, include background history, details of possible precipitating factors (changes in sputum, use of drugs) and the physical examination. The general appearance of the individual and the respiratory attitude must be observed. Some patients will be obviously in respiratory distress from airway obstruction; others may be too depressed to sustain a high respiratory effort. The respiratory rate, the state of skin and mucous membranes, the findings in the thorax, and the assessment of the cardiovascular system are important. An assessment of contributory factors such as fever, renal status, metabolic disorders, and congestive heart failure, must be considered with ventilometric and blood gas data in planning the complete therapeutic approach. The presence of peripheral cyanosis and the absence of central cyanosis suggests peripheral vascular collapse and increased local O_2 extraction, rather than pulmonary insufficiency.

Laboratory evaluation is then necessary to determine if pulmonary ventilation is adequate. This implies that the patient is well oxygenated and carbon dioxide eliminated. On a gross level, adequate minute volumes are valuable (minute volume = tidal volume $\times$ respiratory rate). Of more importance is the alveolar ventilation; (alveolar ventilation) viz. the actual exchange of these gases at the alveolar level, taking into account physiological dead space ventilation factors. One may estimate alveolar ventilation by multiplying the respiratory rate times the tidal volume minus the dead space viz. alveolar ventilation = (Tidal volume-dead space) $\times$ (respiratory rate). The dead space may be estimated as being roughly equivalent in cc. to body weight in pounds; tidal volume may

be measured by conventional methods. Thus in an average normal adult of 150 pounds, with a respiratory rate of 14/min. and a tidal volume of 500 cc. the alveolar ventilation would be: alveolar ventilation = (500-150) × (14) = 4.9 L/min. The alveolar ventilation may be measured more accurately, if the expired and alveolar pCO_2 are known. Since alveolar ventilation is a direct reflection of arterial P_aCO_2 levels one may attempt to estimate the P_aCO_2 by rebreathing techniques which bypass arterial puncture, by calculation from CO_2 content and pH if available, or with arterial carbon dioxide tensions as a direct index.

There are calculators available to determine the tidal volumes (Radford-Ohio, etc.) necessary for adequate alveolar ventilation in normal man. One must bear in mind that such predicted values for alveolar ventilation may fail to maintain normal blood gases because of altered compliance-resistance factors, increased metabolic rates, alterations in perfusion and of great importance increases in physiologic dead space.[3]

Practically the most meaningful approach is to measure arterial pCO_2 (and pO_2) as an index of ventilatory adequacy. In this manner while the above-mentioned parameters may not be absolutely clarified, the end result of the ventilatory process may be established. This is in fact what is necessary for proper management. A P_aCO_2 of 60 mm. or more, [a P_aO_2 of 60 mm. or less and a pH of 7.30 or less] should be considered as evidence of ventilatory failure, unless previously established data indicates that such values were present in the chronic stable state.

Having determined that an abnormality of ventilation is great enough to modify the arterial blood gases, the next step is to decide whether the observed changes in arterial pH and in the concentrations of electrolytes in the plasma are the result of the altered ventilation or are secondary to metabolic factors.

The relationship of P_aCO_2, pH and bicarbonate content can be placed on the Davenport, or other comparable tables designed to illustrate the degree of respiratory acidosis or alkalosis and the possible presence of complicating metabolic acidosis or metabolic alkalosis. However, it should be emphasized that such nomograms have been established only for events in normal man. In such instances, the concept of a mixed disorder, i.e., a respiratory acidosis with a secondary metabolic alkalosis should be extended to determine whether this secondary metabolic alkalosis is compensatory in origin or would have been present if respiratory acidosis had not occurred. To evaluate properly the degree and origin of the complicating abnormality one must know how much metabolic alkalosis is normally to be expected for a given P_aCO_2 increment. To date, this is only partially clarified. The work of Schwartz[4, 5] has defined the acute titration curve for man and this data may be useful in interpreting acute changes in a previously normal patient. However, the lack of sufficient data providing expected values for rises in P_aCO_2 complicates the interpretation of data from patients with chronic pulmonary insufficiency. The chronic "predicted bands" for dogs, by Schwartz or of Dulfano and Ishikawa[6] in man give somewhat similar though not identical slopes and may be used to assist in predicting the presence of complicating metabolic factors in respiratory insufficiency. Often the clinical reconstruction of the metabolic state is the only available method to derive a working concept of the acid-base disorder of the given case in conjunction with measurement of P_aCO_2, pH, bicarbonate concentration and other pertinent electrolyte-renal parameters.

Specific Therapeutic Measures to Improve Respiratory Function

Immediate therapy must be directed toward accomplishing the following:

1. Tracheobronchial "catharsis."
2. Correction of hypoxia.
3. Providing adequate alveolar ventilation (assisted or controlled mechanical ventilation).
4. Supporting the circulation.
5. Controlling infections.
6. Reversing airway obstruction.
7. The use of respiratory analeptics.
8. Managing complications.

1. TRACHEOBRONCHIAL CATHARSIS

It is absolutely essential to provide and maintain a patent tracheobronchial airway and improve bronchopulmonary drainage. This calls for immediate suctioning, tracheal or bronchoscopic, and irrigation with either saline, Mucomyst® or Dornavac®. There are two basic types of sputum each requiring its own type of management. Mucoid sputum is white, gelatinous and adhesive due to mucopolysaccharide and muco-protein gels. The more water the gel contains, the less viscid is the secretion; i.e., when water is lost through dehydration, its viscosity increases. Mucoid sputum may be quite troublesome because of its greater viscosity problems and the fact it cannot be altered by antibiotics. Mucomyst® (N-acetylcysteine) by opening disulfide bonds in mucous tends to lessen its viscosity and thereby facilitate removal. On the other hand, purulent sputum contains Desoxyribonucleic Acid (DNA) from necrotic parenchymal and inflammatory cell nuclei and from bacteria. Dornavac® (desoxyribonuclease), a pancreatic enzyme, may be employed for enzymatic degradation of DNA and assist removal of lodged and inspissated material. Finally if both of these components are present, combination therapy should be employed. Mucomyst® in the form of a 20 percent solution may be directly instilled and aspirated through the tracheostomy tube or the bronchoscope; it is best not aerosolized because of rapid oxidative destruction. Dornavac® may be directly instilled or aerosolized. Adequate hydration by oral and/or intravenous routes is most essential. Aerosols of water or saline (normal or slightly hypertonic), employing aerosol generators equipped with heating coils, such as the Puriton® or Mistogen® units, powered by air or oxygen, may be directed into the IPPB unit or into the tracheostomy. Alevaire® seems to be effective only by virtue of its water content and is not generally recommended. Positioning of the patient and chest-tapping therapy, employing the services of the trained physiatrist further helps to free trapped sections. Such therapy is most beneficial once the patient is hydrated and sputum thinned as above. Bronchodilators, such as aminophylline[7] and the adrenergic preparations are very useful. Aminophylline should be promptly administered intravenously 0.5 gm. per one liter of 5 percent D/W for the relief of persistive bronchospasm. In general, not more than 2,500 cc. of fluids should be administered intravenously in 24 hours, usually 1,500 cc. plus the amount voided in the previous 24 hours is safe. Bronchodilator aerosols, isoproterenol (Isuprel®) or racemic epinephrine (Vaponephrine®) may be nebulized in doses of 0.2-0.5 cc. in 2 cc. of saline, delivered slowly over a period of 10-15 minutes, preferably with simultaneous IPPB therapy. These should be employed with caution in the arrythmia-prone patient; in fact, persistent tachycardias may result from their use and should be discontinued in such cases. The use of iodides either orally or intravenously helps to

liquify the trapped secretions; glyceryl guiacolate preparations (Robitussin®) are also efficacious, and may be valuable in cases of iodide sensitivity. On occasion the use of one of the "cough machines" (alternating positive-negative pressures) may dramatically help move trapped secretions outwards. All of these measures improve bronchopulmonary drainage. The patient may literally drown in his own secretions, if effective suctioning is not undertaken, particularly when debilitated, semiconscious or suffering from the loss of an effective cough mechanism.

Bronchoscopy

It is not desirable to wait the development of bronchial obstruction before carrying out bronchoscopy and lavage. When an intensive program of therapy, with the use of all of the principles referred to under tracheobronchial catharsis, have not effectively thinned and evacuated the trapped secretions, bronchoscopic lavage must be carried out. This should be done with warmed saline, Dornavac® or Mucomyst®. Saline lavage is particularly indicated in patients with status asthmaticus not responding to aminophylline, bronchodilator aerosols and steroids, and in patients with aspiration pneumonitis or atelectasis. Bronchoscopic lavage and aspiration facilitates the removal of trapped secretions, improves drainage and reestablishes an effective coughing mechanism. A word of caution—in patients with underlying bronchospastic disease, aerosols of Mucomyst® may prove irritating and actually produce bronchoconstriction. Its greatest effectiveness has been observed in the form of tracheobronchial lavage therapy, through the bronchoscope or tracheostomy tube, in patients with obstructive lung disease and respiratory insufficiency. It is necessary to properly oxygenate the patient during bronchoscopic procedures.

Tracheostomy

Tracheostomy is frequently necessary and lifesaving to facilitate the removal of secretions, decrease the dead space, prevent further hypoventilation and provide a route for continuous ventilation as well as endoscopic therapy. It is best done in an unhurried manner in the operating room. Under emergency conditions, when performed at the bedside, the complication rate has been very high. Prior to tracheostomy, a cuffed endotracheal tube may be employed to insure ventilation and facilitate suctioning. This tube may be inserted nasally or orally into the trachea and requires assiduous attention in order to prevent mucosal and laryngeal damage. Once the tracheostomy is established an inflatable cuff should be fit snugly around the end of the tube. It should be deflated for at least one minute every half hour in patients on continuous ventilation with an IPPB attachment. The frequent replacement of the tube, deflations of the balloon, cleansing of debris and strict aseptic techniques are mandatory for the successful application of this technique. Local or tracheal infections may result quickly in the traumatized area, the organism varying with hospital environment. Isolation technique may be useful in halting the spread of offending staphylococci or other gram negative organisms.[8] The presence of organisms in tracheal secretions requires clinical evaluation as to the need for antimicrobial therapy. With proper use, prolonged endotracheal intubation alone has been employed for as long as one week without deleterious effects. On the other hand, if mechanical ventilation is to continue for a longer period, a tracheostomy should be performed and a cuffed tracheostomy tube inserted. It is essential that adequate humidification of the lower airway be provided at all times in these patients to prevent drying of mucosa and secretions. Heated water aerosols

should be nebulized in conjunction with IPPB, and bronchodilator aerosols (Isuprel® or Vaponephrine®) should be used intermittently when indicated. The patient receiving continuous ventilation must be checked frequently to see that no leaks are present, a patent airway exists and adequate tidal volumes are maintained at all times.

2. Correction of Hypoxia

Normal oxygen tension should be maintained in all types of respiratory failure. Hypoxia may cause increased pulmonary vascular resistance with pulmonary hypertension and contribute indirectly to cardiac decompensation or directly by influencing normal myocardial metabolism. In addition mental impairment and anoxic encephalopathy, reduced respiratory responses to increments of CO_2 which may intensify ventilatory failure and a metabolic effect upon oxygen dependent enzyme systems, may be seen with oxygen lack. Irreversible changes in the brain may follow three minutes of complete apnea. However, correction of hypoxia will not necessarily relieve associated hypercarbemia.

For routine use, the plastic nasal cannula will deliver oxygen concentrations up to 35 percent in the inspired air with flow rates of 6-8 L/minute and the Eliot open top face tent, concentrations of 35-50 percent with 6-10 L/minute flow rates. However, for higher concentrations (45-95 percent) one employs a rubber face mask with a non-rebreathing valve, separating the large rubber oxygen collecting bag from the face piece. Oxygen, adequately moistened, may be administered directly into an endotracheal or tracheostomy tube. In the tracheostomy patient, the soft plastic tracheostomy box should be used, with oxygen flowing through a water aerosol chamber warmed to body temperatures (Puritan). The IPPB unit is attached by adaptors to the endotracheal or tracheostomy tube.

High concentrations of oxygen (95%+) are indicated in the following: acute pulmonary edema; acute poisonings from carbon monoxide (95% oxygen with 5% carbon dioxide) or nitrates and aniline derivatives; pulmonary atelectasis; large areas of unventilated lung; massive pneumonias; arterial occlusions; massive pneumonias; arterial occulsions; massive myocardial infarctions; diffusion defects; cardiovascular shunts and most types of shock. Lower concentrations of oxygen (wall oxygen at flow 3-5 L/minute) are indicated in the following: poisonings with respiratory depressing drugs (barbiturates, opiates, chloral hydrate, etc.); chronic obstructive pulmonary emphysema; kyphoscoliosis and the newborn premature infant.

The patient with respiratory acidosis, complicating chronic pulmonary emphysema, is usually severely hypoxic and desperately in need of oxygen. To prevent depression of the chemoreflex centers in the carotid and aortic bodies, the oxygen concentration of inspired air is raised moderately at the start by the use of the nasal cannula technique, (ie 2-3L/min); if assisted or controlled ventilation with air-oxygen 40% mixtures is needed, rigid monitoring of the patient is necessary to prevent respiratory depression. It should be emphasized that oxygen *must* be given in states of advanced tissue hypoxia, and when not tolerated, adequate ventilation provided. (See case vide infra). Table I provides data on comparison of oxygen administration.[9]

3. Providing Adequate Alveolar Ventilation

This may be accomplished in numerous ways: by manual compression of a rebreathing bag in a closed or open circuit system; by use

TABLE I
COMPARISON OF OXYGEN ADMINISTRATION

Equipment	Approximate % O_2 at Alveolar Level	L/min. Flow required	CO_2 Accumulation (At 8L O_2 Flow
Rubber Oro-nasal Mask*	40	4	yes
	50	6	
	55	8	
	60	10	
Plastic Face Mask	30	4	no
Nasal Catheter	40	6	
Face Tent	45	8	
Nasal Cannula	50	10	
O_2 Tent	25	6	no
	35	10	
	43	15	

* B.L.B. O.E.M. Type

of a tank respirator; by the use of complicated, electromechanical devices that supply variable amplitudes and frequencies of respiration automatically responding to signals from servo mechanisms (activated by the arterial blood gases and pH and the circulation-pulse rate, arterial and venous pressures); and more usually by the use of IPPB units. Long-term ventilation with IPPB is employed to provide assistance with mechanical ventilators. No attempts should be made to continuously ventilate a patient for long periods by face mask or mouthpiece. The endotracheal tube or tracheostomy techniques must be employed in these patients as described above. Hypoventilation may occur with inadequate minute volumes because of trapped secretions and improper IPPB pressure, flow, or respiratory rates. On the other hand, deleterious hyperventilation may be observed with increased artificial ventilation and must be controlled, for in patients with respiratory acidosis, a rapid reversibility to respiratory alkalosis may lead to fatal circulatory and pulmonary collapse. The patient whose respiration becomes depressed while receiving oxygen, must be ventilated to prevent the retention of carbon dioxide in the blood and tissues.

Assisted ventilation may be run periodically or continuously, depending upon the clinical status and ability of the patient to cooperate. Intermittent positive pressure breathing therapy, with bronchodilator aerosols, is most effective for periodic-assisted breathing for periods of 15-20 minutes, 4-5 times a day. The effect of hyperventilation with IPPB therapy is transient, and the sustained lowering of elevated carbon dioxide levels cannot be accomplished by brief periodic treatments. An improvement in the patient being treated with IPPB is due in part to an effective delivery of a bronchodilator aerosol relieving bronchoconstriction and improving expectoration. It is not uncommon in patients with coma to lower the pCO_2

and particularly correct the Ph, and still observe persistence of a stuporous state.[10]

In general, *assisted mechanical breathing* is employed in the moderately ill patient, whereas *controlled mechanical breathing* with IPPB is employed in the critically ill patient.[11] Patients who cannot maintain effective ventilation or acid-base balance by means of assisted ventilation, or those uncooperative should be placed on controlled ventilation until a more compensated phase of the disease occurs which is responsive to assisted breathing. Controlled mechanical breathing may be performed with the endotracheal technique for brief periods, or with the tracheostomy technique for longer periods, and may require the use of demerol, morphine, or curare derivatives (e.g. succinylcholine) to slow or "knock out" spontaneous respiration. The latter procedure must be undertaken with constant control, established airway and monitoring of serial blood-gas data.

An example of drug control of respiration may be seen from the following case:

A 35-year-old white male was admitted to the Boston City Hospital with a history of chronic asthmatic bronchitis and a recent increase in productive cough, wheeze and dyspnea. The deterioration was due to bronchopulmonary infection and related airway obstruction. Initial therapy consisted of intravenous fluids, aminophylline, iodides, penicillin (based on gram stain of sputum), Solumedrol® and IPPB via assisted (mask) ventilation with nebulized Isuprel® and 40% oxygen. Blood gases shortly after admission are noted. (Table II). Early the next day, progressive bronchospasm and retention of secretions were associated with severe agitation, confusion and poor cooperation for IPPB. Tracheostomy was performed and assisted ventilation via Bird IPPB was begun. Blood gases under these conditions are recorded in Table II. The Lung Station (Tufts) was called in consultation because of obvious clinical deterioration and blood gas evidence of inadequate ventilatory support by assisted ventilation. Ventilation was limited even with optimal pressures and flow rates on the IPPB because of severe motor agitation and extreme uncooperation. Ten mgm. of Morphine Sulfate was then given intravenously with only moderate respiratory depression and persistent motor agitation. At this point 40 mgm. of Succinyl choline was given intravenously with complete apnea. Con-

TABLE II
CLINICAL USE OF CONTROLLED VENTILATION

Admission Assisted IPPB	Next Day—Assisted on Tracheostomy		Controlled Ventilation Assisted (hours after #2)				
	#1	#2 (one hour later)	1.45	2.50	4.00	5.50	next day
P_aCO_2 mm. Hg. 41	57	87	71	71	58	46	46
pH 7.40	7.31	7.15	7.18	7.19	7.27	7.26	7.46
P_aO_2 mm. Hg. 56	38	173	250	168	245	101	. . .
Tidal vol. ml. 220	. . .	350	500	550	450	400	400
Respiratory rate/min. 30		30	18	18	15	14	14

trolled machine ventilation with a preset flow, pressure and rate was begun. Blood gas monitoring over the next few hours are recorded below. With continued careful management of bronchospasm and secretions, clinical improvement was noted. When semi-awake 6 hours later, he was able to fully cooperate on an assisted-ventilatory schedule. Complete recovery was noted thereafter.

It is advisable to have brief alternate rest periods during IPPB therapy. Repeated overdistension of the lungs may depress the Herring-Brauer reflex and reduce the effective ventilatory drive. With continuous, assisted or controlled IPPB therapy, tidal volume should be measured periodically through the exhalation port with a Wright respirometer or a similar device and adequate minute ventilation provided. Periodically, an arterial blood sample for pCO_2, pO_2 and pH should be obtained to provide a more reliable index of artificial ventilatory support. For example, a patient may have a tidal volume of 500 cc. at 15 cm. pressure when first put on the IPPB unit and as secretions collect and pulmonary compliance changes (stiffer lung), a pressure setting at 15 cm. of water may now deliver a tidal volume of only 200 cc., which would be inadequate. The IPPB pressure setting should be the minimum that will provide adequate ventilation; this may require adjustment of flow and rate controls to obtain optimal tidal volume. Leaks may develop around the tracheostomy tube, machine compensation may not follow and hence, inadequate tidal volumes will be delivered. This requires immediate attention. Thus assiduous nursing care, and careful monitoring of equipment throughout is mandatory.

Finally, patients with long-term hypoxia and severe carbon dioxide retention may have respiratory depression on assisted IPPB when high concentrations of oxygen are employed. In these patients, concentrations of 30-40% are usually adequate. In some patients a negative phase pressure may be employed with the Bennett or Bird units during the *expiratory phase* of IPPB. This lowers the intrapulmonary pressure, increases the venous return to the heart, and may increase the volume of capillary blood with some improvement of perfusion. However, using negative pressures in patients with obstructive plumonary emphysema when lung compliance is low and airway resistance high, decreases the expiratory flow by a "check flow" mechanism. The small airways tend to collapse in such patients, which could be disastrous, and hence it is not routinely recommended.

4. Support of Circulation

It is well to keep in mind that intermittent positive pressure breathing may effect the cardiovascular system by increasing the resistance to pulmonary blood flow by obstructing the central venous return to the right heart. Venous return to the right side of the heart depends on an adequate pressure and flow gradient between the peripheral veins and the right atrium. Positive pressure breathing may block this gradient. This is a detrimental factor in patients with shock, following low spinal anesthesia or other conditions with inadequate peripheral vasoconstrictor mechanisms.

In patients with cardiopulmonary failure secondary to severe chronic obstructive lung disease, frequent monitoring of the arterial and central venous (right atrial) pressures, cardiac output, blood volume, electrocardiograms, arterial blood gases, renal status and electrolytes provide useful information to guide therapy. Treatment includes vasopressors, isoproterenol, digitalis, diuretics, (avoid ammonium chloride since this may promote acidosis), low salt diet, (patients requiring rigid sodium

restriction should not be given sodium iodide as an expectorant in their intravenous infusions), corticosteroids, blood replacement with transfusions or low-viscosity dextran, venesections, replacement of electrolytes, fluid restriction, and assisted, continuous or controlled mechanical breathing. Aminophylline used for bronchodilitation may have an added benefit in patients with cor pulmonale since a lowering of pulmonary artery pressure is observed in some cases.

Hemodynamic defects in these critically ill patients are often difficult to recognize clinically. A low cardiac output in the face of an elevated central venous pressure would indicate the advisability of using isoproterenol rather than vasoconstrictor agents to correct the cardiac deficit. A low cardiac output with a low central venous pressure indicates the need for transfusions to correct the volume deficit. Peripheral vascular failure and pooling of blood may be apparent when transfusion fails and the addition of vasoconstrictors and supporting elastic stockings are then advisable. It is best to employ small doses of digoxin and gradual digitalization in patients suspected of cardiac failure but only after oxygen has been effectively administered for the priority demand of cardiac muscle is for oxygen to alleviate failure. The hypoxic myocardium appears to be unusually sensitive to the effects of digitalis. When indicated in plethoric patients with elevated red cell masses, venesection is best carried out ofter oxygenation and before digitalization. This should be considered only with excessively high hematocrit values (60) where problems of increased viscosity would outweigh the obvious beneficial effect of the increased red cell mass. Cardiac standstill (ECG evidence) has been observed in the course of acute respiratory insufficiency and, of course, demands immediate attention. Pertinent to the cardiovascular aspects of IPPB, it has been shown that an increase in pulmonary pressure of 30 cm. H_2O may cause a displacement of about 500 cc. of blood from the lungs into the abdomen and extremities. A reduction in urine volume may also be seen. In normal volunteers, subjected to continuous 25 mm. Hg positive pressure for ½-hour, an increase in aldosterone secretion (without 17-hydroxy-corticoid change) with a decrease in urinary sodium/potassium ratio was reported.[12] Still incomplete, these studies focus further attention on associated cardiovascular-metabolic problems that may arise with IPPB therapy in the routine management of such patients. Thus, it appears essential to improve primarily the ventilatory failure in order to relieve the associated congestive heart failure.

5. The Management of Infection

Viral or bacterial infections of the respiratory tract may precipitate acute respiratory failure in patients with chronic obstructive lung disease. Since bacterial complications may be present in any case, one is justified in administering an antibiotic at the onset where clinically indicated.[13] When specific organisms are identified by gram stain, the antibiotic to use follows standard indications. The Pneumococcus and Hemophilus influenzae are the two most common organisms cultured from the sputum of patients with underlying chronic bronchitis and/or pulmonary emphysema.

When gram positive diplococci predominate, adequate penicillin, in dosages of 2 million units daily should be administered. When circulatory failure and/or shock are a part of the syndrome, then intravenous antibiotics, vasopressors, isoproterenol, volume replacement, and possibly steroids should be employed. When mixed infections are present, or

if the bacterium is difficult to identify, intravenous penicillin with streptomycin or chloromycetin are probably the best initial antibiotics to use. However, tetracycline or chloramphenacol alone in dosages of 2 gm. daily may be initially employed. Repeated cultures of the blood should be obtained to document the presence of a complicating bacteremia. In practice, a gram stain would indicate the rationale for immediate antibiotics with modification once cultures and sensitivities are reported. Follow-up examination of sputum is always needed. The presence of tuberculosis or fungal lesions as precipitating or underlying causes must always be kept in mind.

6. Reversing Airway Obstruction (steroids)

The major defect in patients with respiratory insufficiency is hyposia and/or hypercapnea. When improvement by reduction in bronchial spasm, edema and inflammation does not follow conventional treatment, then ACTH or corticosteroids should be attempted. Intravenous solutions of 5% D/W with 100 mg. hydrocortisone per liter at flow rates of 30 drops per minute may be employed. To each 1 liter of solution, aminophylline 0.25-0.50 gm. may be added. This technique should supply 300 mg. hydrocortisone in a 24-hour period. On occasion (e.g., shock), higher dosages of hydrocortisone may be necessary. In critical states, 100 mg. hydrocortisone should be injected directly intravenously when the slow drip is started. With cardiac failure or other fluid retentive states, intravenous fluids should be restricted to approximately 2 liters (5% D/W) per 24 hours avoiding intravenous saline. The therapy is usually continued for 3-10 days (on occasion, even longer) with dosages tapered downward as improvement is noted.

Unfortunately, the incidence of peptic ulceration, occult and manifest, in our patients with chronic obstructive lung disease is high (20-25%). Other complications to be watched for include intensification of diabetes mellitus, progressive osteoporosis, hypocalcemia, fluid retention, risk of associated infections or spread of a tuberculous process and uncovering of underlying psychosis. Such hazards must be constantly evaluated particularly when long-term therapy is undertaken. The use of the alternate day schedule given in the morning will help reduce undesirable side effects. The use of supplemental potassium, regulation of sodium intake, antacid therapy and monitoring of blood sugar, electrolytes and films indicating bone density will aid in appropriate management. Reversibility of the underlying bronchospastic obstructive state is striking in status asthmaticus but not in chronic obstructive lung disease. Steroid therapy may be considered in aspiration processes of the lung when diagnosed early. Specific methods for the use and withdrawal of steroids have been recently reviewed by Thorn.[14]

7. The Use of Respiratory Analeptics

Respiratory analeptics stimulate ventilation; however, 1) they have a narrow margin of safety, especially when an abnormal electroencephalogram is present and 2) are conceded to have little clinical value. Patients with abnormal EEG changes are most sensitive to the effects of many of these drugs. Coramine® (nikethamide) is the drug we prefer; its margin of safety is considerably greater in our experience.[15] It should be administered, 20-50 drops per minute. The patient may itch about the nose or face, twitch, or convulse with higher doses or with speedy injections. Many patients can get along with lower concentrations of oxygen when Coramine® is efficiently em-

ployed. It should be limited to short-term therapy to alert the patient, restore the cough reflex and accelerate and deepen respiration, while appropriate basic measures are being established.

Nalline® (N-allyl-nor-morphine) is the specific antagonist when respiratory depression has been caused by morphine, etc. Ten mg. of Nalline should be administered at once, intravenously followed by a slow intravenous drip containing 30 mg. of Nalline® in 200 cc. of 5% D/W administered over a period of 15 minutes. The exact dosage depends upon the narcotic overdosage. The clinical response of the patient and study of the arterial blood gases determine the best rate of administration and the possible need for further Nalline® therapy.

Other respiratory analeptics may be employed: the carbonic anhydrase inhibitors—Diamox® (acetaxolamide) or Daranide® (dichlorphenamide): or Tham® (tris-hydroxymethyl-amino-methane), an organic buffer; however, they seldom improve over-all pulmonary function in the patient with respiratory acidosis. Diamox® and Daranide® act as diuretics and may prove of some value in combined cardiopulmonary failure. Tham® acts primarily as a buffer. Side effects noted with it include hypoventilation, hypoglycemia and arrythmias. It requires larger doses to achieve effective carbonic acid buffering. Its major advantage is in cases where sodium administration with sodium bicarbonate must be limited. On occasion, epinephrine sensitivity appears to be restored in patients who have received sodium bicarbonate intravenously for the correction of the acidosis, seen in status asthmaticus.

The vigorous use of a respiratory analeptic may result in very rapid reduction in the arterial pCO_2 and respiratory alkalosis which may be deleterious.[16] It is more important to correct the cerebral hypoxia in order to maintain adequate cerebral blood flow, while the pCO_2 is gradually reduced.

8. The Management of the Complications

The complications which occur during the management of the critically ill patient with respiratory acidosis should always be kept in mind.[17] It is important to prevent or correct complicating metabolic alkalosis or acidosis and electrolyte problems. Serial determinations of the serum sodium, potassium, chloride, calcium, hemoglobin, hematocrit and iron levels should be made simultaneously with the arterial pH, pCO_2, and oxygen saturation. Correction of these should be made, particularly during the troublesome period of decompensation in patients with respiratory acidosis. Intravenous solutions of potassium to replace potassium, and ammonium chloride or L-Arginine monohydrochloride to replace chlorides without increasing sodium or potassium are necessary for this purpose. Unfortunately, the mortality rate in our patients with respiratory acidosis remains high (approximately 36%) notwithstanding careful management. We have observed the following extrapulmonary complications contributing to this high mortality rate: cardiac decompensation, cardiac standstill, severe hypotension with shock. GI bleeding, renal tubular necrosis, pulmonary emboli, myocardial infarction and gram negative pulmonary infections. Circulatory collapse may on occasion be observed following tracheal intubation or tracheostomy. The prognosis, in the face of these complications, is grave and often extremely difficult to assess. When the patient is not doing well, one must have a high index of suspicion that one of these complications is

present. Finally one must avoid the indiscriminate use of respiratory depressant agents unless given specifically and with constant attention to the ventilatory response.

Summary

The management of the patient in respiratory failure represents a complex problem requiring hospitalization and thorough clinical-laboratory evaluation. Awareness of precipitating and complicating factors, and the need for critical laboratory monitoring in serial fashion is mandatory. It is only by such a multi-disciplined approach as described above that such patients can be managed successfully.

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