More and more frequently, nurse anesthetists are being called upon to demonstrate proficiency in respiratory therapy techniques. The author outlines the pathological and treatment triads involved in respiratory care, along with the treatment regimens for prophylactic care, and for acute and chronic pulmonary diseases. She includes the rationale for the administration of bland aerosols and potent aerosols, controlled oxygen administration, and describes the three most commonly used mechanical ventilators employed to assist or control respirations.

Artificial ventilation is as old as man himself. This fact is evident in Genesis 2:7, “and the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life, and man became a living soul.” Further evidence can be found in II Kings 4:32-34, “and when Elisha was coming into the house, behold, the child was dead, and laid upon his bed. And he went up, and lay upon the child, and put his mouth upon his mouth, and his eyes upon his eyes, and his hands upon his hands: and he stretched himself upon the child, and the flesh of the child waxed warm.”

It was not until the mid-sixteenth century, when Andreas Vesalius demonstrated that animals could be kept alive by the rhythmic inflation of their lungs with air pumped through an opening into the windpipe with a bellows, that anyone else made use of the concept of artificial ventilation. During the 1700’s, the use of the bellows was gaining in popularity in the resuscitation of human drowning victims. However, because of overzealous efforts, alveoli were ruptured, pneumothoraces were produced, and death ultimately resulted. Artificial ventilation fell into disrepute by the 1800’s. Seventy years later, artificial ventilation was given serious medical consideration.

During the twentieth century, we have come full circle in an effort to sustain life, from mouth-to-mouth resuscitation to a multiplicity of simple-to-complex mechanical ventilators, oxygen therapy devices, and mist generators requiring expertise in their application to human beings.

As nurse anesthetists, we are expected to know when to use these apparatus and how they can be manipulated to achieve the desired therapeutic results. My objective in this article is to outline the pathological and treatment triads, and the treatment regimens for prophylactic care and for acute and chronic pulmonary diseases. I will include the rationale for the administration of bland aerosols and potent aerosols, controlled oxygen administration, and describe the three most commonly used mechanical ventilators employed to assist or control respirations.
The pathological triad

The primary goals of respiratory therapy are: (1) to improve alveolar ventilation, and (2) to restore arterial blood gases to as near normal as possible. If these are our goals, our mission has been defined: that is, to minister therapy to those patients who, for one reason or another, suffer from ventilatory impairment and diffusion abnormalities. Respiratory therapists treat cases ranging from minor prophylactic (preventive therapy) to major acute and chronic obstructive to restrictive pulmonary disease patients who are approaching or are in respiratory failure.

Most patients, whether they suffer from asthma, chronic bronchitis, cystic fibrosis, chronic emphysema, pneumonia, bronchiectasis, atelectasis, and so on, more or less are faced with the same dilemma—bronchospasms, retained thick tenacious secretions, and mucosal and submucosal edema. This pathological triad leads to: obstruction of the bronchioles, diminished alveolar ventilation, intra-pulmonary shunting, decreased arterial oxygenation, and increased arterial carbon dioxide tensions. When first seen, all patients are not obviously in acute respiratory failure. But, if we ignore or haphazardly treat minor conditions, they could progress to acute respiratory failure, especially if the patient has a chronic lung disease with a superimposed lung infection.

The decision as to what approach should be taken is left up to the attending physician. Sometimes, we as nurse anesthetists and respiratory therapists can suggest to the physician our views concerning the resolution of the problem at hand. We could let the physician know what equipment we have available, its capability to accomplish the desired results, and alternate techniques that might be helpful.

The crux of the entire treatment regimen depends upon the store of knowledge each of us possesses, and our expertise in utilizing or improvising the necessary tools to effect a successful resolution of the problem. If the disorder is a chronic one, we cannot solve all the problems, but we can endeavor to restore the patient to a state of activity commensurate with his/her disease entity.

The treatment triad

The objectives of the treatment triad are: (1) to combat bronchospasms, (2) to constrict the fine blood vessels of the bronchial mucosa, and (3) to loosen and thin retained secretions. The administration of bland and potent aerosols is an attempt to achieve these objectives.

Perseverance and vigorous treatment is necessary, especially in those patients who have severe ventilatory insufficiency. It may take three or four days of vigorous intensive therapy before any appreciable improvement in the patient’s condition is noted. When improvement does come, the time and effort spent leaves one with a sense of great joy at a job well done.

Bland aerosol therapy

The less potent but absolutely necessary aerosols are administered to deposit large quantities of wetting agents within the respiratory tract. The most commonly used agents are:

1. Propylene glycol, 2.5-20.0%.
2. Sterile normal saline.
3. Sterile distilled water.
4. 5% sodium bicarbonate: intermittently nebulized by a small medicinal nebulizer.

Propylene glycol, normal saline, and distilled water may be administered as cool or heated mist, continuously or intermittently, depending upon the individual needs of the patient. Five percent sodium bicarbonate is an effective liquifying agent which is not commonly used because it frequently causes mechanical difficulty with jet nebulizers. Its mode of action is simply one of an alkaline medium (sodium bicarbonate) chemically reacting with the acid medium of the tracheobronchial mucus,
Table I
Bronchodilator and bronchovesoconstrictor drugs

Aerolone Compound®: Contains cyclopentamine, isoproterenol, propylene glycol, ascorbic acid, and water:

- **Usual dose:** 6.1 cc/20 lbs of body weight
- **Dose range:** 0.3-0.5 cc (maximum dose = 3X minimum effective dose). Use only for intractable bronchospasm!
- **Usual Diluent:** 1:3 - 1:4 with normal saline or distilled water. Compatible with mucolytics and steroids.
- **Administration:** By aerosol only!
- **Action:** Bronchodilatation.

Bronkosol®: Contains isoetharine, Phenylephrine®, thenyldiamine, aqueous-glycerin, saccharin sodium, sodium chloride, sodium citrate, and sodium bisulfite.

- **Dose range:** 1/4 - 1 cc
- **Usual dose:** 0.5 cc
- **Usual dilution:** 1.3 with normal saline or other diluent. Compatible with antibiotics, mucostat and wetting agents.
- **Administration:** Usually by aerosol.
- **Action:** Isoetharine causes bronchodilatation; Phenylephrine® causes broncho-vasoconstriction; thenyldiamine causes antihistamine release. Preferential B2 receptor activity.

Bronkosol 2®: Contains the same ingredients as Bronkosol®, except the antihistamine (thenyldiamine) has been omitted.

- **Dose range:** Same as Bronkosol®.
- **Usual dose:** Same as Bronkosol®.
- **Usual dilution:** Same as Bronkosol®.
- **Administration:** Same as Bronkosol®.
- **Action:** Same as Bronkosol® except for the histamine blockade effect.

Isuprel® (isoproterenol hydrochloride): Contains sodium chloride, sodium citrate, glycerin with chlorobutanol 0.5%.

- **Dose range:** 0.3 - 0.5 cc (1:200)
- **Usual diluent:** 0.3:3 cc - 0.5 cc:5 cc normal saline or other diluent. Compatible with mucostat.
- **Administration:** By aerosol.
- **Action:** Bronchodilatation and 4+B1 stimulation.

Micronefrin® and Vaponefrin®: Contains racemic epinephrine.

- **Usual dosage:** 4 drops.
- **Usual dilution:** 80 drops of water (5 cc). May use 20% Ethanol®, saline up to 4%, aminophylline or a mucolytic agent.
- **Administration:** Usually by aerosol.
- **Actions:** Bronchodilatation, bronchovesoconstriction, and 2+B1 stimulation.

Mucolytics (Mucomyst® and Dornavac®):

1. **Mucomyst® (acetylcysteine)**
   - **Usual dose:** 5-10 cc of 20% solution.
   - **Action:** Attacks mucin.

2. **Dornavac® (deoxyribonuclease)**
   - **Usual dose:** 100,000 units.
   - **Action:** Attacks pus and cellular debris.
   - **Administration:** 1:2, by intermittent positive pressure breathing or by intraluminal instillation.
   - **Precautions:** Mucolytics may cause bronchospasm, give an adequate dose of bronchodilator along with or prior to mucolytic therapy.

Theophylline and microphyllin:

- **Usual dose:** 5 cc (62.5 mg)
- **Compatibility:** Bronchodilators and bronchovesoconstrictors.
- **Administration:** By aerosol inhalation.
- **Action:**
  1. Smooth muscle relaxation.
  2. Stimulates respirations centrally.
  3. Vasodilation by direct action on vascular musculature.
  4. Cardiac stimulation and increases cardiac output.

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causing liquifaction of the mucus. It is nebulized and inhaled by the patient about four times per day.

**Potent aerosols**

All bronchodilator and/or broncho-vasoconstrictor drugs used in respiratory therapy are sympathomimetic amines. The most commonly used drugs are: Aerolone Compound®, Bronkosol®, Bronkosol.®, Micronefrin®, Vaponefrin®, and Isuprel®. When nebulizing sympathomimetic amines to the tracheobronchial tree there are (because of the large vascular area involved) certain side effects or adverse reactions which may occur. We should be alert for tachycardia, palpitations, nausea and vomiting, headache, flushing of the skin, tremors, dizziness, weakness, sweating, precordial distress or angina-type pain.

Should any of these symptoms occur, the treatment should be immediately discontinued, the physician notified, and normal saline substituted for the drug currently in use. These drugs should also be used with caution in pregnancy, cardiovascular disorders, diabetes, hypertension, hyperthyroidism, and cardiac asthma.

It should be noted that Dornavac® is an important proteolytic in cases where purulent sputum interferes with alveolar ventilation. Its primary usefulness is in pneumonia, pulmonary abscess, bronchiectasis, cystic fibrosis, and especially in an acute respiratory infection superimposed on chronic lung disease. Its mode of action is depolymerization of deoxyribonucleic acid (DNA). The therapist should be prepared to evacuate, by aspiration, the liquified secretions if the patient's cough is inadequate or if the patient is unable to handle the secretions himself.

We have covered the pathological triad and the treatment triad. The next section will cover the different techniques and equipment used to administer aerosol therapy, as well as the simplest methods of oxygen administration.

**Oxygen therapy**

Oxygen administration becomes necessary in disease conditions requiring an increased fractional concentration of inspired oxygen (referred to as FiO₂) to overcome a severe decrease in the partial pressure of oxygen in the alveoli and subsequently in the arterial blood.

Oxygen per se is not the panacea we once thought it was. We have come to realize that oxygen can be dangerous when indiscriminately administered to patients with chronic pulmonary disorders. Furthermore, studies show that a high concentration of oxygen (over 60% at 1 atmosphere) given over a sustained period of time causes a condition known as oxygen toxicity. Some authorities believe that 50% oxygen administered for 5 minutes is excessive. At atmospheric pressure of sea level, the prolonged inhalation of pure oxygen primarily produces pulmonary changes: atelectasis, pulmonary congestion, pneumonitis, and leukocytic infiltration.

In human beings, the vital capacity decreases from 400-1400 ml. after 24 hours of breathing oxygen. After 67 hours of living in an oxygen chamber at 1 atmosphere, two human beings experienced paresthesia, and one had substernal stress and a decreased vital capacity. The central nervous system effects range from transient paresthesia to convulsions, which may terminate in death. Cerebral blood flow is reduced about 13% in normal man. This reduction in cerebral blood flow caused by cerebral vasoconstriction may account for the convulsive phenomenon.

Realizing that oxygen can be harmful as well as helpful to the human body, we have begun to classify oxygen as a drug, just as morphine, antibiotics, steroids, and so on. Oxygen's use and desired concentration must be ordered by a physician. Of course, we all know that in emergency life-saving situations, such as cardiopulmonary arrest, we are obligated to administer oxygen whether a physician is present or not.
According to Fick's Law, the higher the concentration gradient, the quicker we will be able to reoxygenate the brain cells. If our resuscitative efforts are successful, we must follow the patient's arterial blood gases and decrease the FIO₂ as soon as it is feasible to prevent damage to the patient's lungs and the central nervous system.

In the field of respiratory therapy, a number of devices have been invented and put into practice, drastically reducing the necessity of administering oxygen over 40%. In almost all the cases of prolonged ventilatory support that I have encountered, oxygen concentrations well below 40% maintained arterial blood oxygenation within the desired range of 80-100 mmHg.

**Techniques and equipment**

Before we can administer oxygen or other gases to patients, we must have a supply source, a pressure regulator, and a flowmeter. Most hospitals are now equipped with piped-in gas supply sources that are maintained at or slightly above 50 pounds per square inch (PSI). Where we do not have a piping system, a high pressure regulator is necessary to reduce cylinder gas pressure (usually 2000-2200 PSI) to a workable pressure of 50 PSI. Once a workable pressure is attained, a flowmeter or flow gauge is attached to the high pressure regulator to further reduce cylinder pressure and to control the amount, in liters per minute, of gases going to the patient. There are two types of flowmeters and one flow gauge used in most hospitals. They are: the Bourdon flow gauge, the uncompensated Thorpe tube flowmeter, and the 50-PSI compensated Thorpe tube flowmeter.

*The Bourdon flow gauge* operates on the principle of back pressure. It actually measures the pressure of gases flowing from the pressure chamber of an adjustable reducing valve. When the cylinder valve is opened and the flow gauge control knob is turned on, the indicator needle represents the pressure of the gas flowing from the reducing chamber. At the factory, the flow gauge is calibrated to indicate flow volumes of gases at different pressures, with the outlet opened to the atmosphere.

Because this type of gauge measures back pressure, no restricting devices such as nebulizers, humidifiers, or small bore tubes should be connected to it. Restricting devices create back pressure, which the Bourdon gauge responds to, hence, decreasing the flow of gases to the patient.

Should one occlude the outlet from the Bourdon flow gauge, the indicator needle would read the same or higher, even though no gases are escaping beyond the outlet. This factor is extremely hazardous to patients who are confined in a closed space, such as an oxygen tent, croupette, or isolette. We sometimes use either latex tubing or plastic oxygen tubing as a conduit to transport oxygen or other gases to the patient. Otherwise, should the line become kinked or blocked, the patient would receive no gases, carbon dioxide would build up in the enclosed space, and the patient would become asphyxiated and die.

*The uncompensated Thorpe tube flowmeter* is constructed on the same principle as those we use on our anesthesia machines, except that it is not back-pressure compensated. Uncompensated means that the flowmeter does not compensate for back pressure created at the outlet. It, like the Bourdon flow gauge, is calibrated in liter-flow-per-minute with the outlet opened to the atmosphere.

An uncompensated flowmeter can usually be identified by the location of its needle valve. The needle valve is placed between the source of cylinder gas and the Thorpe tube. This means that the needle valve is upstream of the flowmeter, and only that portion of the tube proximal to the flowmeter is kept at a constant pressure of 50 PSI. Therefore, as back pressure is created by distal restricting devices, it is transmitted retrograde through the entire flowmeter to the point of the needle.
valve. This back pressure also increases the pressure above the float, causing a decrease in both the pressure above and below the float, and in turn, the float falls lower in the tube.

As long as the back pressure does not exceed the source pressure of 50 PSI, gases will continue to flow into the tube at the same rate as before the restricting devices were connected. Thus, a situation is created whereby the flowmeter registers a lower flow than the patient is actually receiving.

Since we know that a high concentration of oxygen causes retrolental fibroplasia and blindness in the premature infant, injury to the retina of normal adults, and oxygen narcosis in the chronic obstructive disease patient, this feature of the uncompensated Thorpe tube flowmeter assumes great importance to the well being of our patients. Like the Bourdon gauge, the uncompensated Thorpe Tube is of very little value in the administration of respiratory therapy. In fact, they can be very dangerous and detrimental to our patients.

The compensated Thorpe tube flowmeter should be the flowmeter of choice because it is 50-PSI compensated, and it measures precise gas flows whether we use restricting devices or not. The construction of the compensated flowmeter is similar to the uncompensated, except that its needle valve is located distal to the flowmeter. This means that the entire flowmeter up to the needle valve is pressurized to 50 PSI.

Restricting devices added at the outlet will only cause back pressure up to the needle valve. As long as the back pressure does not exceed 50 PSI, gases will continue to flow into the flowmeter, and the float will measure the exact flow of gases going to the patient. Should the back pressure exceed 50 PSI, the float will fall to the bottom of the tube, indicating no flow.4

Humidification is another important consideration in the administration of gases to patients. All medical gases, regardless of the source—piped or cylinder—are considered dry gases. One of the greatest sins we can commit and one of the greatest assaults to the patient is to administer dry gases to the tracheobronchial tree. We previously made a statement that one of the patient's dilemmas was large amounts of thick tenacious mucus. From our pulmonary physiology studies, we learned that no matter how dry the gases the patient inhales, they are 100% saturated with water vapor when exhaled.

Where does this water come from that fully saturates the exhaled gases? The water is extracted from the tracheal mucosa which derives its moisture from the systemic circulation. Drying of the mucosa will lead to inspissation of mucus on the walls of the respiratory tract—setting up an excellent underlying media for the growth of bacteria, systemic dehydration, and a patient who is in worse condition than before we interfered. This, then, is the rationale for the humidification of all gases administered to patients.

Whatever technique is selected to administer gases determines what type of humidifying apparatus we will use. Humidification can be accomplished in two ways: molecular water and particulate water. Humidifiers are used to add molecular water or water vapor to the air stream. The two types most familiar to us are the bubble-jet and the diffuser types. Humidifiers will add from 24-43% humidity to the inspired air, depending upon the liter flow of gases passing through the apparatus. The higher the liter flow, the lower the humidity. Conversely, the lower the liter flow, the higher the humidity.

Humidifiers should be used only when the following are employed: a nasal cannula, nasal catheter, the partial-or non-rebreathing bag and mask assemblies, or any other devices requiring the use of a long, slender, small-bore tube. When these devices are being used, the patient is breathing through his normal respiratory passages; therefore, by
the time the gases reach the alveoli, they will be 100\% saturated with water vapor. Needless to say, the humidifier should never be used for patients who are intubated or tracheotomized. The exception to this is when the humidifier, like the cascade, can be heated, resulting in 100\% saturation of the gases flowing through it.

Nebulizers are used to produce particulate matter. The nebulizer provides particles of water or water-containing medication for deposition at various levels of the respiratory tract. Particles from 3-6 microns in size will be deposited in the upper airway; 0.5-3.0 microns are deposited in the lower portions of the respiratory tract.

Particle size is determined by the architecture and physical principle of the nebulizer used, composition and vapor pressure of the solution being nebulized and the temperature of the air being used to produce nebulization or to carry the mist to the patient. We always talk in terms of particle size or spectrum and where they are deposited within the lungs. The truth is that it is not clear whether aerosols—especially potent aerosols—are effective because of their topical action on the bronchi or because of their systemic absorption.

Utilizing radioactive tagged materials administered by intermittent positive pressure breathing, we find that very little aerosolized material reaches the peripheral lung parenchyma, while large amounts appear in the midline structures and in the stomach following inhalation. We do know through experience that patients who are given large amounts of water aerosols and intermittent nebulized potent aerosols do improve clinically no matter what the site of action, topical or systemic.

Two commonly used nebulizers are the venture jet and the ultrasonic nebulizers. The jet-type aerosol generators must have a driving source, either compressed air or oxygen. Some jet-type generators are so designed that it is possible to power the jet with oxygen and dilute the driving stream with room air. An adjustable Venturi-type vent located at the top of the generator cap allows the oxygen to be diluted from 100\% to 40 or 70\%.

The use of the dilutor is questionable, especially if cool mist particles are being generated. The problem is the entrainment of bacteria-laden room air. Bacteria will attach themselves to the cool particles and are thus administered directly to the patient. It is recommended that instead of using the dilutor, use a large-bore tube with an aerosol mask or a face tent where dilution will occur at the patient end and not in the large reservoir of water; this tends to keep the water contamination at a minimum.

When a heating element (Underwriters' Laboratory approved) is incorporated, the temperature of the reservoir water is somewhere around 140°F. Bacteria cannot grow in very high temperatures, plus the nebulizer then generates molecular water. The molecules are too small and are not capable of transporting bacteria.

The ultrasonic nebulizer uses high frequency ultrasonic waves to produce an abundance of ideal-sized water particles. It is an extremely efficient high density mist generator capable of delivering super-saturated cool mist to the patient. It works best employed with an open system, such as face tents, face masks, or tracheotomy masks for short periods of time. It has been of great value in the treatment of croup and cystic fibrosis, when the croup tents or the croupettes are used.

The consensus seems to be that heated mist, in most instances, has proved to be more effective than cool mist in adding bulk water to the respiratory tract. Most of the conventional jet-type nebulizers require the utilization of a heating element before they can 100\% saturate the air stream. Both heated mist and the ultrasonic nebulizers are useful in treating many diseases, but they are not void of side effects.

Heated mist can cause hyperther-
mia in the infant and the small child and cardiac acceleration. The heated mist is delivered to the patient at or about body temperature, which prevents the patient from using calories to convert the inhaled liquid into water vapor. Core cooling does not occur, resulting in a sustained or elevated body temperature. This fact might be of some consequence to the patients just mentioned. Also, it may be undesirable to cause a rapid heart beat in the cardiac patient. This does not preclude the use of heated mist if the patient's condition warrants it.

One should be alert for body temperature elevations and increased pulse rates when heated aerosols are administered. The ultrasonic nebulizer, because it generates such large quantities of water, should never be used continuously on any patient over a prolonged length of time. Infants, small children, cardiac patients, and patients with kidney conditions may well suffer water intoxication or the stiff lung syndrome as a result of a too vigorous washing of the surfactant from the lungs.

Under conditions where the ultrasonic nebulizer must be used over a long period of time, the patient—especially infants and small children—should be weighed daily to determine if the patient is gaining weight. Blood electrolytes should also be taken daily. If the patient is gaining weight or if the blood electrolytes are altered, treatment with the ultrasonic nebulizer must be terminated and other methods instituted. Appropriate medicaments should be given to diurese the patient and the electrolytes should be returned to within normal range.

I think it would be useful at this point to mention two factors which are sometimes overlooked when large reservoirs of water or other medicaments are used. First, all the solutions used in humidifiers and nebulizers should be sterile. These solutions should be handled with the same precautions in mind as one would use when handling intravenous solutions or medications.

Secondly, all large reservoir jars, if not changed every eight hours, should be emptied, rinsed with sterile distilled water, and refilled to the full line every 8 hours. Should the water level fall to the refill line before the end of 8 hours, the same procedure should be followed. You must empty the reservoir completely. Do not add liquid to a half empty reservoir jar! We are not sterilizing the equipment at this point, we are merely discarding and mechanically washing away bacteria that may have been introduced into the reservoir.

**Oxygen catheters and cannulas**

The simplest method for the addition of supplemental oxygen to the inspired air is by using the nasal catheter or the nasal cannula. The nasal cannula, at a flow rate of 6-8 liters/min, will enrich the inhaled mixture from 35-50%. The nasal catheter, at a flow rate of 4-7 liters/min, will deliver an oxygen concentration of 35-50%.

It is recommended that oxygen flow rates be maintained between 1 and 4 liters/min. The reasons are: first, the drying effect upon the nasal and oropharyngeal mucosa; and second, the desired concentration of oxygen by whatever method employed is at or below 40%.

It is not absolutely necessary that the patient be instructed to breathe through the nose when these devices are employed. Because of the Bernoulli effect, if the patient is a mouth breather, the velocity of the gases being inhaled will create a Venturi action and the nasal oxygen will be drawn into the inhaled air stream.

If the nasal cannula is utilized and the patient has significant bilateral nasal congestion, the concentration of inspired oxygen will be minimal. This is because the oxygen cannot get through the congested areas into the oropharynx. If the nasal catheter is partially plugged with mucus, the results will be the same. The oxygen catheter and cannula are extremely useful at low flows, 1 to 2...
liters/min. for the chronic obstructive pulmonary disease patients whose FIO₂ must be controlled and monitored very carefully.

**Oxygen bag and mask assemblies**

There are two types of assemblies in use today, namely the partial rebreathing bag and mask and the non-rebreathing bag and mask assemblies. The two types are self explanatory.

The partial rebreathing technique, which is employed to conserve oxygen, permits the patient to rebreathe the first third of the exhaled air. During exhalation, the first third of the patient's exhaled air, laden with oxygen, enters the reservoir bag; the other two-thirds are forced out of the exhalation ports at the sides of the mask.

With a well-fitted mask and an adequate flow of source oxygen (6-10 liters/min, depending upon the patient's tidal volume), the partial rebreathing technique will deliver a concentration of oxygen from 35-60%. The port holes at the sides of the mask serve both as the exhalation site for the last two thirds of exhalations and also as an emergency source for the inflow of room air, in case the supply gas is inadequate or the source gas is depleted or fails.

**Non-rebreathing technique**

As indicated, the non-rebreathing technique incorporates a one-way valve which allows the patient to inhale from the system but will not allow exhaled gases to enter into the reservoir bag. This is the only non-mechanical technique used in the administration of oxygen where concentrations upwards to 100% can be obtained. This technique is not as widely used as in previous years because we try to avoid administering high concentrations of oxygen.

When utilizing either the partial rebreathing or the non-rebreathing technique, it is important to prevent the reservoir bag from completely collapsing after inhalation has ceased. The bag should be distended at least one-third its capacity at the end of inhalation. When a patient is permitted to breathe on a collapsed bag, pulmonary edema may ensue. This is especially true if someone has occluded the emergency ports or, as the result of open ports, the desired concentration of oxygen is not achieved and the inhaled mixture is diluted with room air.

**Venti mask**

Since the administration of oxygen became popular, many devices and techniques have come into vogue and, to a great extent, an equal number have vanished from the scene. The Venti mask, termed high air flow with oxygen enrichment "HAFOE", utilizes the Venturi effect to entrain room air, which dilutes the oxygen to a lower concentration. Each mask assembly is designed for a specific concentration of oxygen (24%, 28%, 35% or 40%), provided the liter flow recommended by the manufacturer is used.

The greatest draw-back to this mask is the fact that the original assembly was not designed to be used with a humidifying device. It became a choice of administering dry gases or adding humidity and sacrificing the concentration of oxygen being administered. The first Venti mask consisted of a single unit calibrated for only 1% concentration. If acceptable blood gases were not obtained using one assembly, another entirely different assembly would be used until arterial blood gases were satisfactory. In our department, this practice became very expensive because we discarded each assembly after it was used.

Later, another more economical mask was designed with a sleeve effect which would accommodate a large-bore tube. We then connected the large-bore tube to a nebulizer powered with compressed air. The patient would get the precise concentration of oxygen as indicated on the mask chimney, plus the added humidification necessary.

This mask assembly is more economical simply because there are four
venturi jets (24%, 28%, 35% or 40%) that are interchangeable with the chimney piece. Such an arrangement eliminates having to change the entire mask assembly if the desired concentration of oxygen has not been attained. You merely change the jet to a higher or lower per cent, whichever is applicable. An additional bonus is gained because the entire unit can be cleaned, sterilized, and reused.

The Venti mask is especially useful in the treatment of chronic obstructive pulmonary disease patients. It is also useful in those patients with abundant secretions, where high concentrations of oxygen might cause alveolar collapse leading to pulmonary shunting and low arterial blood gas values. The Venti mask, it appears, will be around for some time to come.

Aerosol masks

When we think of a mask, we usually visualize something that covers the mouth and nose. There are other types of masks available, but for the sake of simplicity, I will include only the tracheotomy collar or mask, aerosol face mask without a reservoir bag, the T-piece, the face tent, and the head tent. All of these devices have two things in common. They are designed to deliver high-flow, high-density aerosol mist in combination with a nebulizer and a large-bore tube.

These devices are not necessarily used to administer oxygen because the percentage of oxygen is not easily determined nor controlled. Should the patient require oxygen, the easiest way to control the oxygen concentration is to adapt the particular device being used to the Venturi jet.

Equipment used for the premature infants, neonates, and small children

The administration of respiratory therapy to premature infants, neonates, and small children follows the same principles as that for adults, except the equipment and environmental control must be adjusted. Three major differences that affect the method of administration of respiratory therapy are: the patient’s size, his/her ability to cooperate with the therapist, and the prevalent respiratory diseases.

The most common diseases of infants and small children are: croup, laryngotracheobronchitis, bronchitis, cystic fibrosis, and severe respiratory tract infections. The proper equipment and early intervention is absolutely necessary to prevent severe airway obstruction. Isolettes and incubators are used to control the oxygen concentration, humidity, temperature and for isolation of the small infant’s environment.

The head hood is another method suited to the cooperative child. Since the advent of the radiant warmer, the head hood in combination with the radiant warmer might prove useful for the small infant.

The croup tent is another device that is useful in treating respiratory disorders in infants and small children. Most croup tents are equipped with a humidifying device (usually a jet nebulizer). The jet nebulizers are hard to clean and keep sterile. It seems that the ultrasonic nebulizer with a large-bore tube is the most effective method for humidifying the atmosphere in a croup tent, that is, providing precautions are taken to prevent water toxicity and a decrease in oxygen tension within the tent.

Mechanical ventilators

The most common mechanical ventilators used today exert a positive pressure at the patient’s upper airway in an attempt to improve alveolar ventilation. The classification of ventilators depends essentially upon the classifier. Some authorities have divided them into so called “constant pressure generators” and “constant flow generators,” “pressure cycled,” “time cycled,” and “volume cycled machines,” “volume preset” and “pressure preset” machines. Still others have
described ventilators as “pressure limited, volume variable.” and “volume limited, pressure variable.”

The classification I prefer is one which most accurately describes the mechanism by which the ventilators operate; that is, “pressure limited, volume variable” and “volume limited, pressure variable.” There is a third classification, not so very long ago put into practice, called a “constant flow ventilator” which was designed especially for premature infants, the neonates, and small children.

**Pressure limited, volume variable ventilators**

This ventilator is commonly referred to as a pressure generator. The operator sets the pressure, and the ventilator cycles off when the preset pressure is reached. The volume of gases delivered to the patient is determined by the flow rate, the sensitivity and pressure settings, resistance created by attachments distal to the ventilator, and the patient’s lung compliance. The more compliant the lungs, the greater the volume of gases the patient receives. In cases where the patient’s lungs offer increased resistance to the air flow, it becomes necessary for the operator to reset the pressure to overcome the decrease in lung compliance.

For example, suppose I have set the pressure to 20 cmH₂O, and have adjusted the flow rate and sensitivity so that the patient is receiving a tidal volume of 600 ml. Using a respirometer attached to the exhalation port, I have determined that the patient’s tidal volume is indeed 600 ml. Fifteen minutes later, I measure the tidal volume and find that it has decreased to 400 ml. The patient’s small airways are obstructed. The obstruction could be caused by either bronchospasms or mobile secretions, but the result is that the patient is now being underventilated.

To overcome the decrease in lung compliance, I must increase the pressure setting in order to achieve the original 600 ml tidal volume. Mechanical aspiration of the airway to remove the secretions may be the only maneuver necessary.

In the case of bronchospasms, a potent aerosol should be administered to relax the bronchial musculature. Once the patient’s compliance increases, the operator resets the pressure to a lower setting to prevent hyperventilation and possible rupture of the alveoli.

The pressure limited, volume variable ventilator should be reserved for intermittent positive pressure breathing treatments or for those depressed patients whose lungs and airways are otherwise normal. Another feature of this ventilator is that it must be used with a non-leaking system. In the presence of a leak, the preset pressure will never be reached, creating a situation whereby the ventilator will remain in the inspiratory phase until the leak is sealed or the operator manually terminates inspiration. This situation also results in less alveolar ventilation than desired.

Of special significance is that all pressure limited, volume variable ventilators demand a driving pressure of 50 PSI. Therefore, a ventilator must never be attached to a flowmeter or a flow gauge. They are designed to be used for controlled liter flows per minute and will not provide the necessary 50 PSI. Any number of these ventilators are capable of continuously assisting or controlling respirations, some are time cycled and can be used as guarantors.

**Volume limited, pressure variable ventilators**

This ventilator is commonly referred to as a volume generator. It operates on the reverse principle of the pressure limited, volume variable ventilator. The operator sets the volume of gases to be delivered to the patient, and the pressure gauge indicates how much pressure is required to deliver the preset volume. Regardless of the patient’s lung compliance, the volume of gases will be delivered; and the ventilator will cycle off after the volume of gases is...
delivered. An increase in lung compliance requires less pressure, and a decreased lung compliance requires more pressure to deliver the preset volume.

For example, in a compliant lung, a tidal volume of 800 ml may require 20 CmH\textsubscript{2}O pressure for delivery. In contrast, a noncompliant stiff lung may require double the pressure, 40 CmH\textsubscript{2}O, to deliver the tidal volume of 800 ml. The pressure will increase up to the limits of the ventilator (usually 80-100 CmH\textsubscript{2}O pressure) to deliver the preset volume. Then, as this ventilator is limited by the upper levels of its pressure, it takes on the characteristics of a pressure ventilator. If this should occur, there are other measures that can be instituted to maintain adequate alveolar ventilation.

Changes in lung compliance can be identified by monitoring the pressure gauge on the ventilator. If compliance decreases the same measures, removal of the secretions by mechanical suctioning or the administration of a potent aerosol to relax the bronchioles should be undertaken. When the patient's compliance increases, the pressure gauge will show a lower setting, and the operator is not required to adjust the volume setting.

The volume ventilator is ideally suited for treating patients with constantly changing resistance and compliance values. When using the volume ventilator, the operator must be alert to certain critical factors. A machine is just that! A mechanical piece of equipment—not capable of thinking. Should a leak occur between the ventilator and the patient, the ventilator will continue to cycle on and off, although the volume of gases may be partially vented to the atmosphere. Then, there is always the possibility that the patient may become detached from the ventilator.

Whenever a patient is being ventilated by a respirator, it is imperative that someone monitors the patient and the ventilator very closely. This fact holds true when any type of ventilator is used.

Safety features, if utilized, are built into many models. Some have low pressure alarms that will audibly signal when there is a leak in the system. Others utilize the expiratory bellows with an alarm mechanism at the top. When the programmed volume of gases do not reach the bellows, the alarm will audibly signal a leak in the system.

Most volume ventilators are powered by electricity which activates a Venturi action to entrain room air for delivery to the patient. Oxygen enrichment is accomplished by a special adaptor located on the ventilator. It is important to know that this mechanism does not measure oxygen concentrations; it does, however, respond to a 50 PSI supply source.

The supply source could well be compressed air or any other gas, as long as it is at the required 50 PSI. This is one of the most important reasons why the pin-index system or the diameter-index safety system must be used with all medicinal gases. It is impossible to substitute one gas for another. These ventilators are also time cycled, and they can be used as an assisitor/controller, as well as a guarantor.

Constant flow volume ventilators

The Baby Bird is one type of constant flow volume ventilator designed to be used in the treatment of hyaline membrane disease in premature infants and for respiratory distress syndromes in small children. The ventilator, without modifications, was specifically designed to include all the parameters necessary for treating infants and children in respiratory failure or respiratory insufficiency. It is equipped with all the mechanisms to effect IPPB, CPAP, CPPB, PEEP, and IMV. It simplifies the use of any one or a combination of these modalities to obtain the desired therapeutic results.
Intermittent positive pressure breathing

There are any number of terms circulating within the field of respiratory therapy which refer to the mode of treatment. Intermittent positive pressure breathing (IPPB) indicates that a pressure above sea level is used to create a positive pressure at the patient’s airway. IPPB is mechanical ventilation which increases pressure during the inspiratory phase, expiration is passive. Its basic purpose is twofold. If used properly, IPPB improves alveolar ventilation and lessens the work of breathing.

The addition of a medicinal nebulizer to administer bland or potent aerosols is an extra bonus factor. When administering IPPB, some form of humidification must be used. Be aware that the small, side-arm nebulizer, used for nebulization of medications, will only provide 40% humidity—regardless of whether a continuous drip of fluids into the nebulizer is used. A large mainstream nebulizer should be used, in combination with the medicinal nebulizer, especially for those patients with thick, bothersome secretions.

Continuous positive pressure breathing

Continuous positive pressure breathing (CPPB) is defined as the procedure in which (1) the positive mask pressure is kept as nearly constant as possible, (2) the variations are relatively small, and (3) the pressure at expiration is slightly higher than at inspiration. CPPB is non-ventilator breathing against a threshold of resistance.

CPPB was first effected by the use of a positive pressure mask, a pressurized head hood, and a negative pressure (subambient pressure) body chamber. The positive pressure mask and pressure head hood was set to exert from 2-10 CmH2O pressure on exhalation. The body chamber enclosed the entire patient except the head, and a continuous subambient pressure from

2-10 CmH2O pressure was maintained within the chamber.

CPPB has been used successfully in the treatment of patients with congestive heart failure, bronchial asthma, obstructive dyspnea, chronic emphysema, status asthmaticus, tracheolaryngeal obstructions, and pulmonary edema. The therapeutic value of CPPB is evident by clinical improvement in the patient’s condition.

The pathological, elevated intrapleural negative pressure which was noted in severe bronchial asthma and experimental obstructive dyspnea is lowered significantly by CPPB. The diameter of the small bronchi of patients with chronic respiratory disease was increased during the expiratory phase; the peripheral venous pressure and circulation were found to be little changed with 3-6 CmH2O pressure in the normal subjects. In patients with congestive heart failure, the venous pressure and circulation were markedly increased.

Positive end expiratory pressure

Positive end expiratory pressure (PEEP) is associated with mechanical ventilation and with exhalation against a threshold resistor. PEEP is used to prevent premature airway closure, alveolar collapse and to increase the FRC. Increasing the patient’s FRC increases oxygen transport across the lungs by reducing pulmonary shunting; thus, arterial blood gases improve.

Cardiovascular dynamics remain stable provided the level of PEEP does not significantly decrease venous return to the heart. Complicating features like hypovolemia, myocardial damage, and chronic pulmonary disorders are contraindications to the use of PEEP. When PEEP is employed, we should always be alert for complications, such as impaired cardiovascular function, pneumothorax, emphysema, and interstitial and/or mediastinal emphysema.

Continuous positive airway pressure

Continuous positive airway pres-
sure (CPAP) is a term that was coined instead of CPPB in the early studies of the infant respiratory distress syndrome. CPAP is also referred to as non-ventilator breathing against a threshold of resistance. CPAP is applied to infants by enclosing the head in a chamber for continuous positive pressure or by enclosing the entire body in a chamber for application of continuous negative pressure.

**Interruption mandatory ventilation**

Intermittent mandatory ventilation (IMV) is defined as a system of mechanical ventilation which allows the patient to breathe spontaneously with active mechanical inflation of the lungs at preset intervals. The usual mechanical tidal volume is calculated on the patient's body weight using 12-15 ml/kg. IMV was first used for the purpose of weaning the patient from the ventilator. However, IMV has since become the treatment of choice, with or without PEEP, for the infant and adult respiratory distress syndrome, and in other instances where a patient requires continuous mechanical ventilation for prolonged periods of time. Before IMV was added to the respiratory therapy inventory, it was difficult to maintain adequate levels of PCO₂ during continuous assisted or controlled ventilation. In addition, prolonged continuous controlled respirations caused discoordination between the diaphragmatic and accessory muscles of respirations in some patients. For this reason (muscular discoordination), it was difficult to wean the patient from the respirator.

IMV permits the patient to maintain his own PCO₂ levels, and physiologically, the respiratory musculature remains active and coordinated. When using IMV, the number of mechanical breaths can be decreased gradually, depending upon the patient's blood gases, until the patient is spontaneously breathing and can maintain acceptable blood gas values. If PEEP is used in conjunction with IMV, the PEEP should be continued until the patient is completely off IMV.

The duration of treatment with IMV or IMV and PEEP varies with the individual patient and the extent of the disease process or injury to the lungs. It may take from 2-10 days or even longer before the damage to or dysfunction of the lungs has improved sufficiently to remove the patient from the respirator.

**Patient monitoring**

Patients receiving IPPB should be instructed and monitored until the therapist is assured that the patient thoroughly understands the technique and is competent enough to carry out the treatment without constant supervision. However, the therapist should observe the patient taking a treatment at least once a day until therapy is discontinued.

When it becomes necessary to continuously assist or control ventilation, the entire picture changes. A qualified therapist must be in attendance at all times. The attending physician should do a physical examination to determine the status of all vital systems as soon as possible after the patient is placed on the ventilator. The physical examination should include: the central nervous, neuromuscular, respiratory, circulatory, genitourinary, and gastrointestinal systems.

The following checklist (Table II), based on *Mechanical Artifical Ventilation* by Dr. Terring W. Heironimus,² should be helpful in organizing the parameters to measure and in determining how frequently they should be measured.

**Cleaning and sterilization**

It is important to establish routine procedures for cleaning and cold sterilization of respiratory therapy equipment. The instructions found in Table III afford one method for preventing nosocomial infections through the utilization of respiratory equipment.
Table II
Checklist for continuously assisted or controlled ventilation

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood gas determinations</td>
<td>prn</td>
</tr>
<tr>
<td>Care of airway</td>
<td>prn</td>
</tr>
<tr>
<td>Vital signs</td>
<td>every 30 min or prn</td>
</tr>
<tr>
<td>Tidal volume and airway pressure</td>
<td>every hour</td>
</tr>
<tr>
<td>Auscultation of chest</td>
<td>every 2 hours while awake</td>
</tr>
<tr>
<td>Turn side to side</td>
<td>every 4 hrs for 15 min</td>
</tr>
<tr>
<td>Venous pressure</td>
<td></td>
</tr>
<tr>
<td>Deflate tracheostomy or endotracheal cuff</td>
<td></td>
</tr>
<tr>
<td>Check the inspired oxygen concentration</td>
<td></td>
</tr>
<tr>
<td>Specific gravity of urine</td>
<td></td>
</tr>
<tr>
<td>Complete physical examination of chest</td>
<td></td>
</tr>
<tr>
<td>Passive motion of all joints</td>
<td></td>
</tr>
<tr>
<td>Guiac exam of naso-gastric drainage</td>
<td></td>
</tr>
<tr>
<td>Check dependent parts for pressure skin changes</td>
<td></td>
</tr>
<tr>
<td>Neurological exam (in obtunded patients)</td>
<td></td>
</tr>
<tr>
<td>Check weight</td>
<td></td>
</tr>
<tr>
<td>Guiac exam of stools</td>
<td>daily if possible</td>
</tr>
<tr>
<td>Sputum cultures</td>
<td>on all stools</td>
</tr>
<tr>
<td></td>
<td>weekly or prn</td>
</tr>
</tbody>
</table>

Table III
Procedure for cleaning and cold sterilization of respiratory therapy equipment

1. Completely disassemble all equipment and place in hot, soapy water. (Do not use Tide® or any other detergent containing the agent Superinone®.)
2. Use a brush to scour all equipment. A hand brush will be used to scour mouthpieces and capillaries; a cylindrical brush will be used to scour all hollow tubes, and so on.
3. Use the appropriate stylette to clean all small orifices of possible sediments.
4. After scouring, rinse all equipment under hot, running water, place in the currently used cold sterilizing agent, cover the container and soak equipment for at least 20 or 30 min.
5. Remove equipment from the cold sterilizing agent and follow the directions below:
   (a) When using Cidex® solution, two containers will be used; a large outer container for the Cidex® solution and a smaller perforated inner container for the equipment. Use protective gloves to prevent Cidex® from coming in contact with your bare skin.
   (b) After sterilization, lift tubes and let Cidex® drain back into the container, then lift the perforated inner container and let Cidex® drain back into the outer container.
   (c) Thoroughly rinse equipment under hot, running water including tubes. Hang tubes to drip and place all small parts (on bed pads) on counter top to dry.
   (d) After equipment is thoroughly dry, reassemble, place in plastic bags and store on shelf in bins for re-issue.
6. Cidex® solution will be changed and containers scoured every 14 days, or more frequently if solution becomes dirty or grossly discolored.
7. Spot cultures of equipment stored on shelves should be taken on the first Wednesday of each month in addition to random sampling of equipment on wards, clinics, and so on.

Chest physiotherapy

Chest physiotherapy is an integral part of respiratory care. My intention here is not to go into all the maneuvers involved in chest physiotherapy, I merely intend to stress the importance of this modality in evacuating secretions from the respiratory tract.

In each basic position, the therapist cups both hands and percusses over the
chest wall for several minutes. The patient is instructed to inhale slowly and deeply through the nose, then purse his/her lips (PLB) and slowly exhale to end expiration. During exhalation, the therapist applies vibrations to the chest wall. After this maneuver, the patient is instructed to inhale deeply and try to produce an explosive cough. If coughing is painful, such as after a surgical procedure, the patient should be instructed to take several little coughs during one exhalation.

The bear hug is useful to help stabilize the chest wall and aid exhalation in patients whose cough and deep-breathing is ineffective. If the involved lung segment is known, it will only be necessary to perform therapy on the area suspected of containing thick secretions.

Diaphragmatic breathing should be taught to patients suffering from chronic lung disease. This means that the patient uses the abdominal muscles to aid inspiration and expiration. The simplest way to teach diaphragmatic breathing is by asking the patient to pull in his abdominal muscles on exhalation and let them relax during inhalation. It may take a little time and several follow-up instruction periods before the patient masters the technique, but the time and effort spent is well worthwhile.

I also teach my patients to concentrate on breathing slowly in through the nose, pursing the lips, and then slowly exhaling through pursed lips. Nasal breathing filters out the larger particles of matter from the air. At the same time, the air is warmed and humidified. In addition, the air flow is less turbulent. Pursed lip breathing helps the chronic lung disease patient to exert a positive pressure on exhalation, preventing premature airway collapse and air trapping.

Conclusion

I have by no means covered all the minute details involved in the administration of respiratory therapy. I have, instead, skimmed the surface, covering some of the basic techniques and equipment and their principle of operation. The list of references I have included should assist you in delving more deeply into the area of respiratory care.

As the field of respiratory therapy expands, many anesthesiologists, chest physicians, and surgeons are becoming more and more involved. I feel that we, as nurse anesthetists, should be as involved as much in the care of our patients’ lungs as anyone else. We are aware of the fact that as medical technology advances, our life expectancy increases. Therefore, we will see many more elderly patients with varying types and degrees of pulmonary diseases requiring anesthetics for minor and major surgical procedures. Our knowledge and expertise in the field of respiratory care greatly enhances our image as members of a professional patient care team.

REFERENCES
ADDITIONAL REFERENCES

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This paper was presented as part of the Graduate Course of the American Association of Nurse Anesthetists 42nd Annual Meeting held in Chicago during August, 1975.