CRITICAL CARE PROCEDURES & EQUIPMENT

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For those hyperbaric medicine services that decide to treat critically ill patients, specialized equipment, procedures and training will be required. This may also result in providing services on a 24/7 basis with an "on-call" schedule and increased staffing. The emergencies that could arise can range from carbon monoxide poisoning to decompression illness and air embolism, to rapidly progressing infections such as necrotizing fasciitis. Here I will examine the unique and challenging issues that are involved in treating the critically ill patient in a high pressure, limited access, hyperbaric environment.

A monoplace (single person) chamber for hyperbaric treatment makes treating critical patients more challenging than in a larger multiplace (multi-person) chamber. The most obvious difference is access to the patient. In a multiplace chamber, not only may there be more patients but also an attendant trained to handle various situations, which might arise. An attendant, for example, can re-connect a ventilator circuit, suction the patient and perform other procedures since they share the same environment. In a monoplace chamber direct access is only possible by removal of the patient from the chamber. Before removing the patient, the chamber must be decompressed and whether this process takes a few seconds or many minutes must be determined. The critical nature of the problem must be weighed against the associated risks of rapid decompression.

The demands of this environment require special training for new or modified procedures and operation of various types of equipment. Mechanical ventilation of the patient in a monoplace is one of the more interesting and challenging of these procedures. The ventilator we use is manufactured by Sechrist Industries, who also made the chambers. It is a model 500A adult ventilator and consists of two components. One component is a time limited, time cycled ventilator, which is positioned outside the chamber door. It has an input connection to an oxygen and air source and a high-pressure output line, which enters the door of the chamber. Inside the chamber this line is connected to a second component, which consists of a exhalation valve mechanism, PEEP valve, reservoir bag for spontaneous breathing and a Wright respirometer to measure exhaled volumes. Critical in the operation of this system and process is the measurement of volume and pressure. Continuous adjustment is required as the patient is pressurized due to changes in thoracic compliance. As pressure in the chamber increases, the volume must be maintained by increased adjustment of the inspiratory time and /or flow. The reverse is true when the treatment is completed and decompression is initiated in order to prevent overexpansion. Since the chamber is fed from a 50-PSI wall source in our institution, the ventilator must be pneumatically operated from a separate and higher 70-PSI gas source. This higher pressure is necessary to overcome higher in chamber pressures. When ventilating a patient with a cuffed endotracheal tube in place two important issues arise immediately. First the ventilator connection must be secured because if it becomes disconnected in the chamber, access for re-connection is not readily possible. The second issue is the air-filled cuff, which will respond to Boyle's law and shrink in size as pressure increases in the chamber. In order to eliminate this leak situation, we remove the air from the cuff and replace it with saline, thus maintaining a tight seal. An "air-break" is a procedure routinely performed during hyperbaric therapy where the patient is switched from breathing 100% oxygen to room air for the purpose of reducing the risk of oxygen toxicity. This can easily be accomplished by connecting the ventilator to a wall blender to permit oxygen percentage adjustments. If using a reservoir bag for spontaneous breathing, a secondary gas line will be required to supply a room air mixture to the reservoir bag during the air break. A standard heat-moisture exchanger is utilized for humidification.

The application of soft restraints may be required to prevent self-extubation within the chamber. Due to the change in chamber pressure at the start of therapy each patient must be able to equalization ear pressure or risk rupture of his or her tympanic membrane. In the case of patients on a ventilator or for any unconscious patient, a myringotomy is frequently performed. This is a procedure whereby a small incision is made in the patients' eardrum to allow automatic equalization for pressure changes. In non-emergent cases, we have an ENT physician place small tubes in the ears, which will allow repeated treatments without ear equalization problems.

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ized algorithms that characterize the frequency spectrum of the detected sound, wheezes and rales can be classified and counted from each sampling zone. A crude three dimensional map that localizes the origin of the sound can be drawn using information relating to the intensity of the sound signal at each pick-up and its arrival time. Sound transmission can also be probed by "injected" standardized signals. Events such as mucus plugging, the development of a pneumothorax, and the onset of pulmonary edema are within the scope of this emerging tool, theoretically allowing for more timely intervention.

Ultrasonic imaging ("Echo") is a technique highly developed for applications in cardiology. For many years, it was left unexplored for most pulmonary purposes other than pleural liquid detection, as air filled lung is not amenable to this imaging medium. Abandonment of ultrasound for lung imaging acute respiratory failure, however, may have been premature. Edematous and consolidated tissues often present sound-reflecting interfaces that yield characteristic patterns of the underlying process. Although experience with pulmonary ultrasound is quite preliminary, this technique may offer an entirely different type of imaging information - the nature of abnormality, rather than the anatomic configuration of the density.

The electrical conductivity of lung tissue declines as it fills with air. When many electrodes are placed along a transverse plane, the pattern of regional impedance to an injected electrical current can image the lung according to those properties, producing a cross sectional "tomographic" image that complements the more detailed anatomic image obtained from CT slices of the region. This electrical impedance tomography (EIT) provides continuous dynamic information that may be of use in assessing such questions as tidal recruitment. This methodology, although still in the developmental research stage, is among the most exciting of these newer imaging modalities with implications for critical care.

Many incursions of digital technology into the daily life of the hospital are justifiably looked at with concern as well as amazement. The field of ICU imaging, however, may well be the exception. To this point we have received little but benefit, with lavish promises of more to come.

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Monitoring equipment utilized with the monoplace chamber include ECG and noninvasive blood pressure devices, which is modified for use in the hyperbaric environment. These along with a transcutaneous tissue oxygen measurement can be utilized by connection through the side of the chamber door. Medication delivery to hyperbaric patients must be given intravenously using specially calibrated pumps. The use the Abbott/Shaw Lifecare model 3HB pump is frequently used and calibrated for medication delivery at 2 ATA. It can be used up to 3 ATA using a conversion chart in order to calculate the appropriate fluid delivery rate. In most cases try to avoid the use of lines and cap them whenever possible. The Sechrist chamber can be fitted to receive a total of four IV ports. A specially sized IV line is used that can pass through the door of the chamber and maintain an airtight seal. A back check valve is located within this tubing in case of accidental disconnection of tubing outside the chamber. Since Intravenous pressures can reach those expected from arterial catheters, a disconnect must be corrected immediately. Intramuscular or subcutaneous medications should not be given prior to therapy because they will have a delayed absorption when the patient is pressurized during therapy. This is due to the vasoconstriction effect of hyperbaric therapy. This effect is important when administering such medications as insulin, narcotics, or barbiturates and can result in inadvertent over-medicating.

Other considerations when managing the critical patient are the various catheters and drainage devices connected to the patient. Chest tubes are managed by connecting the drainage tube to a one-way valve called a Heimlich valve. The Heimlich valve is connected to a vented drainage bag for fluid collection. Nasogastric tubes are left open to drain usually in a vented collection bag or plastic glove. A vented collection bag, emptied prior to treatment, is used for Foley catheters. The Foley retention balloon may need to be filled with water in order to maintain placement. Surgical drains can be maintained with vented collection bags and vacuum type drains will continue to operate in the chamber.

Temporary pacemakers are safe to use in the chamber but an external pulse generator should not be placed within the chamber. The use of automated implanted cardiac defibrillators is acceptable up to 6 ATA. Nebulizer therapy of bronchodilators for COPD patients is possible in the monoplace chamber by use of an attached gas source through the door connected to a prefilled small volume nebulizer placed in the chamber with the patient. The flow is turned on from outside the chamber when administration is desired. The use of this therapy is desired at times due to the concern of air trapping associated with COPD patients and pressure changes effecting weakened blebs within their lungs. A patient who experiences a 10% pneumothorax in the chamber at 3 ATA will have an increase to 40% upon ascent (pressure reduction).

This was not meant to be a comprehensive examination at all equipment and procedures for treating critically ill patients but an attempt to shed light on the intricacies of practicing in a limited access, high pressure hyperbaric environment. It is important to continually practice with the equipment and procedures on a regularly scheduled basis in order to maintain proficiency. It is amazing how fast one can forget steps in a procedure or in the operation of a piece of equipment. So schedule a practice session soon.