The safe treatment, monitoring and management of severe traumatic brain injury patients in a monoplace chamber

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ABSTRACT
This report describes how 27 patients with severe traumatic brain injury were safely treated, monitored and managed in a monoplace chamber that was compressed with air to 1.5 atmospheres absolute (152 kPa). A total of 75 hyperbaric oxygen treatments were delivered using the monoplace system described, with all patients receiving 100% oxygen via mechanical ventilation. Specific pieces of equipment, components and features were selected, and modifications were interfaced to safely and effectively treat these critically ill patients in a monoplace chamber. Patient monitoring included cardiovascular and ventilatory parameters as well as intracranial pressure, brain tissue oxygen levels, brain temperature and cerebral microdialysis. The chamber and all the supporting equipment for ventilating, monitoring and managing the patient functioned well.

INTRODUCTION
Oxygen delivered in supraphysiological amounts as a therapy is currently under consideration for use in severe traumatic brain injury (TBI) (1-5). Hyperoxia can be delivered to the brain both under normobaric as well as hyperbaric conditions. Normobaric hyperoxia is defined as a patient breathing 100% oxygen at normal atmospheric pressure. Hyperbaric oxygen (HBO₂) is defined as a patient inhaling 100% oxygen under increased atmospheric pressure.

One of the challenges in establishing HBO₂ as an accepted therapy for severe TBI is to establish its safety and practicality as well as the efficacy of the treatment. The purpose of this study is to report our unique experience in the management, monitoring and safety of patients with severe TBI undergoing HBO₂ treatment. Our discussion will detail some of the adaptations made to allow us to treat these patients in a monoplace chamber. In three prospective clinical studies evaluating the efficacy of HBO₂, a total of 167 patients with severe TBI received 1,984 HBO₂ treatments (5-7). All three clinical trials were approved by the Hennepin County Medical Center (HMC) Institutional Review Board. From 1983 to 1996, a total of 116 of these TBI patients received 1,830 treatments in a Sechrist monoplace chamber (Model 2500B) that was adjacent to the Surgical Intensive Care Unit (SICU). Following this, another 24 TBI patients were transported by ambulance to the HCMC multiplace chamber and received a total of 79 treatments.

In order to minimize transport, a new BARA-MED monoplace chamber (Model XD) was placed adjacent to the SICU in 2006. The final 27 patients received 75 treatments in this monoplace chamber. Overall, a total of 143 patients with severe TBI received 1,905 HBO₂ treatments in a monoplace chamber. The work of others, our experience and advances in patient monitoring have contributed to an improved capacity to safely monitor and manage patients with severe TBI in a monoplace chamber.
METHODS

HBO₂ treatments
The protocol for the HBO₂ treatment was the same for all three clinical trials. Using pounds per square inch (psi) for units of pressure, a slow compression rate of approximately 0.44 psi/minute was performed (or 1 foot of sea water/minute). Compression took 17 minutes. Decompression occurred at the same rate of 0.44 psi/minute for 17 minutes. The maximum treatment pressure was 1.5 atmospheres absolute (atm abs) or 22.05 psi absolute (152 kPa).

Treatment duration was 60 minutes at maximum pressure. No air breaks were given or required for this treatment protocol. Total time, including pressurization and depressurization, was 1 hour and 34 minutes. Patients were ventilated with 100% oxygen throughout their hyperbaric treatment.

Monoplace selection
The selection of a monoplace chamber and preparing it to treat these critically ill patients required several areas of consideration. All of the study patients were unresponsive, intubated, and mechanically ventilated. They had an array of intravenous (IV) lines, monitoring devices, and a head bolt for monitoring intracranial pressure (ICP), brain tissue oxygen levels (PbtO₂), brain temperature and microdialysis. The head of the bed had to be elevated at 30 degrees for ICP control. The new 34-inch diameter BARA-MED XD chamber manufactured by Environmental Tectonics Corporation (ETC) was selected. It had good head clearance and other desirable features such as a computerized operating system and a blowout safety system in the event of excessive chamber pressures.
Ventilator selection

We were aware of only two monoplace ventilators on the market. One was the Sechrist Hyperbaric Ventilator, Model 500A, manufactured by Sechrist Industries, Inc. The limitations of the Sechrist 500A ventilator are described by Weaver (8). The other ventilator was the Omni-Vent from Allied Healthcare Products Inc. In our search for a ventilator we also found the Magellan ventilator (Figure 1, opposite page) manufactured by Oceanic Medical Products, Inc. and learned that it was only slightly different than the Omni-Vent.

The Magellan was tested and evaluated for this clinical trial as well as for our future use in treating critically ill patients in the monoplace. The Magellan ventilator required modifications for monoplace use which were made by the manufacturer. The Magellan ventilator supplies the patient’s tidal volume (Vt) from outside the chamber as opposed to a ventilator that uses a venturi or entrainment device that draws part of the patient’s Vt from inside the chamber atmosphere. Because of this, the chamber can be pressurized with air or oxygen.

Evaluation of the Magellan ventilator

The Magellan ventilator was tested using a test lung in an animal research hyperbaric chamber (Model 20000) manufactured by Mechidyne Systems, Inc., Houston, Texas. Following several trials at lower supply pressures, the ventilator supply pressure was set at 130 psi (the Magellan’s gas inlet pressure range is 30-150 psi). The Vt was set at 1290 milliliters (ml) and the respiratory rate (RR) at 20.5, resulting in a minute ventilation (MV) of 26.4 liters per minute (lpm).

The inspiratory to expiratory ratio (I:E ratio) was at 1:2, the positive end expiratory pressure (PEEP) was set at 17 centimeters of water (cmH2O), and the test lung’s compliance was decreased to produce a peak inspiratory pressure (PIP) of 51 cmH2O. The chamber was compressed to 3 atm abs with the Magellan running on these parameters. Adjustments were made to the ventilator to keep the Vt and RR stable, and it was still able to maintain an MV of over 26 lpm.

The Magellan responded well to these various parameters and still permitted parameter adjustments by the attendant. One key to the Magellan’s performance was the inlet supply or driving pressure set at 130 psi. At this pressure, the Magellan’s performance up to 3 atm abs was shown to be acceptable for both adult and pediatric parameters, even with PEEP and decreased lung compliance.

A common problem

Ventilators used for monoplace patients, including the Magellan described here, share a common problem as described by Weaver (8). The Vt decreases during compression and increases during decompression, which requires close observation and adjustments to the ventilator to compensate for the changes in Vt (8, 9).

These fluctuations in Vt are a result of the inverse pressure/volume relationship expressed by Boyle’s Law. Because of these volume changes, a patient can be underventilated during compression or overventilated during decompression with a potential risk for pulmonary barotrauma. Monitoring the ventilated TBI patients was critical, as they were medically sedated and paralyzed and not able to compensate for any loss or gain of Vt.

Patient breathing circuit

A simple corrugated and expandable, anesthesia ventilator circuit (Figure 3, Page 39) was used inside the chamber. The maximum tubing compliance factor for this circuit was 2.42ml/cmH2O, measured by a Nellcor Puritan Bennett 840 Ventilator System. Tubing compliance was not a significant factor for patients inside the chamber. During HBO2 treatment, the pressure inside the tubing is elevated above the pressure inside the chamber only by the amount of PIP the patient requires, which is the same or slightly above, as the PIP required to ventilate the patient under normobaric conditions.

However, tubing compliance outside the chamber is a major factor. Supply tubing used outside the chamber, coming from the ventilator, must have nearly zero compliance in order to safely handle the pressure differentials between the outside (normobaric) atmosphere and the inside (hyperbaric)
atmosphere. For our outside supply tubing we used medical-grade green oxygen hose rated for 200 psi (Figure 4, Page 40). Because of the pressure differential, a check valve (Figure 2, above) was placed on the inspiratory limb of the patient’s breathing circuit to protect the patient against the possibility of excessive negative pressures in the event of a loss of supply pressure. This is a critical safety feature that should be incorporated into any breathing circuit that communicates between the inside and outside of the chamber.

Additionally, the inside ventilator circuit has an in-line valve that would open with excessive negative pressure allowing release of this negative pressure (Figure 2). To protect the patient from overpressure coming from the breathing circuit, several friction fit connections were installed on the inside as well as two inside pressure relief valves (Figure 2). PIPs were maintained at or slightly above their pre-treatment PIPs and never exceeded the pop-off pressure limits. The two pressure relief valves were set to open between 55 to 65 cmH₂O to avoid pulmonary barotraumas from excessive PIPs. The normal exhalation valve provided with the Magellan ventilator does not work for a monoplace application. The pressures are too high and resulted in a hole being blown through the diaphragm of the exhalation valve. A Bird Exhaust valve (Model 0-2575) from Viasys Respiratory Care, Division of Cardinal Health, Inc., was used in its place and worked well.

Airway pressures were monitored using a standard respiratory manometer with increments of -10 to +120 cmH₂O. ETC supplied the inner chamber module (ICM) unit, which provides a convenient place to connect the various parts of the breathing circuit. Although the ICM is convenient, it is not necessary. An alternative breathing circuit can easily
be set up without the ICM. PEEP was accomplished using a weighted ball valve from Boehringer Laboratories, Inc. This PEEP valve works well but needs to be in an upright position in order to maintain its rated pressure. The exhaled breath of the patient has a high percent of oxygen. This exhaled breath was directed through corrugated tubing to close proximity of the chamber exhaust to help maintain the inside oxygen percent at an acceptable level, as described under ‘Oxygen monitoring’ (Page 41).

**Respiratory monitoring**

During the early testing and evaluation of the Magellan ventilator, the Vt was measured using a standard Wright™ respirometer. This is a mechanical device placed inside the chamber to continuously measure the patient’s ventilator volumes. During a monoplace treatment, the reset button on this device cannot be pushed, so the Vt must be visually approximated from the last stopping point of the needle on the dial. This can be especially challenging during compression and decompression of the chamber when there are Vt changes. Additionally, during hyperbaric exposure, these mechanical spirometers may behave differently (9).

**Ohmeda 5410 volume monitor**

The Ohmeda volume monitor was evaluated as a replacement for the Wright respirometer. The Ohmeda 5410 volume monitor has been used for many years in multiplace chambers. Youn, *et al.*, (10, 11) has described the benefit of this monitor for use under hyperbaric conditions. It was tested in this facility’s multiplace chamber with pressures to 6 atm abs and has worked well over the last 11 years. It was accurate, easy to use and provided audio and visual alarms for high and low MV and for apnea. The screen displays Vt, RR, MV and alarm status. When the monoplace chamber was used, the clip assembly (*Figure 3, above*) was placed inside on the
ventilator’s exhaust side, and the monitor unit was mounted on the outside (Figure 1). This sensor clip contains two light-emitting diodes (LEDs) and two photodetectors for measuring the patient’s volumes. The LED circuit measured 5.8 volts and 117 milliamps (mA). The sensor clip also has two small heat resistors to reduce condensation from the patient’s exhaled breath, which under current load measured at 6.5 volts and 115 mA. These heat resistors were not needed and were disconnected by our bioelectronics department for safety.

Subsequent to this study it was felt that two additional risk management measures should be instituted for future trials. These two measures are described in the following risk management list as items No. 4 and 6. These are also included in the pre- and post-treatment checklists (See Pages 56-58.)

**Risk management regarding this sensor clip includes the following measures.**

1. The heat resistor circuit is disconnected.
2. The chamber oxygen level is kept below 23.5%.
3. The Ohmeda monitor is operated only on battery power during treatments, i.e., no battery charging during treatment.
4. Place current limiting fuses of 0.15 amperes on supply and return current path of the sensor clip circuit.
5. The oxygen level of the chamber atmosphere is continuously monitored.
6. A Wright respirometer was placed on the exhaust tubing as a fail-safe measure.
7. A pre- and post-treatment checklist is used to confirm the above steps.
Penetrations and split-bolts and wiring harness

The manufacturer provided four additional penetrations in addition to the standard penetrations that came with the ETC chamber (Figure 4, opposite page). Two of these penetrations were used for the Magellan ventilator. The other two penetrations were used for the Camino and Licox monitor cables.

The inserts for these penetrations were machined from brass by a local metal fabrication shop to make an airtight seal through the penetration hole. The two inserts for the Magellan ventilator were made as a gas passthrough, and the two inserts for the Camino and Licox monitor cables were made as split bolts described by Weaver (12).

Some monitoring was interfaced using the chamber’s wiring harness. This included the Ohmeda volume monitor, the electrocardiogram leads, and ICP and blood pressure readings. The chamber manufacturer increased the number of connectors to accommodate these additional monitors. These monitors had wires that could be spliced and a new connection made (soldered) by our bioelectronics department. Fiberoptic cables, used with the Camino monitor and other specialized monitoring equipment, cannot be spliced. These cables were passed through the chamber door via a customized penetration and a split bolt insert (Figure 4).

Air filtration system

HCMC has a high standard for their medical air that is piped into the wall outlets of each patient room and each ICU. This air is continuously monitored for carbon monoxide and dew point. This air is used for all of the patient ventilators in the ICU and was used for pressurizing our monoplace chamber. To address any concerns regarding hospital medical air to pressurize the monoplace chamber, an air filtration system was installed to complement the hospital air filtration system. This system consists of three Finite H-Series filters from Parker Hannifin Corporation. These three high-quality filters sequentially remove all liquid, particulate and vapor contaminants in the air, including trace amounts of hydrocarbons down to 0.008 parts per million (ppm). This would include all condensable hydrocarbons as well (13). Under the National Fire Protection Association (NFPA) 99 standards, hospital medical air is required to have less than 25 ppm gaseous hydrocarbons (14).

The downstream outflow (effluence) of these filters was sampled and analyzed by an independent professional testing service using trace gas analysis to verify the high quality of air being used to pressurize the monoplace chamber. Pressurization of the monoplace chamber with air has the advantage of reducing flammability inside the chamber. Furthermore, if monoplace hyperbaric chambers are to be deployed militarily and used in more remote areas, the consumption of oxygen to pressurize the chamber would be prohibitive. To pressurize the monoplace chamber with oxygen requires approximately 13 times more oxygen than is required for the ventilator alone.

High-pressure oxygen and air supply

As noted above, the Magellan ventilator requires oxygen to be delivered at 130 psi to treat these ventilator-dependent patients. The hospital’s oxygen pressure is normally kept at 50 psi at each of the wall oxygen outlets. In order to supply oxygen (or air) at this elevated pressure range, a separate gas room was installed with hospital-grade regulators and an alarm system. These high-pressure gas lines for oxygen and air are clearly tagged and have specific threaded connections from the Compressed Gas Association termed diameter-indexed safety system (DISS) fittings that are unique to each specific gas. They also have individual shut-off valves for each line. This is to prevent any inadvertent connection to another piece of oxygen-supplied equipment that normally uses a 50 psi wall outlet.

Oxygen monitoring

Under NFPA 99 standards, a chamber compressed with air requires the concentration of oxygen to be continuously monitored with audible and visual alarms for “oxygen concentrations in excess of 23.5 percent” (15). A continuous gas sample is taken from the forward area of the chamber since this is the area of highest potential for oxygen accumulation. This continuous gas flow coming out of the chamber
is controlled by an adjustable flow meter and runs to the oxygen sensor to be analyzed. The chamber is continuously ventilated to help control temperature and oxygen levels.

**Preparation of the patient with severe TBI for HBO₂ treatment**

Many details required special attention prior to the placement of a critically ill patient in a monoplace chamber, much of which has been described by Weaver, et al. (8, 9, 16-21). A ground strap was connected from the patient to the metal of the chamber. Chest tubes were connected to a Heimlich valve and drained passively into a sterile receptacle such as a Foley drainage bag or a sterile glove. The air from the endotracheal tube cuff was completely evacuated and replaced with normal saline. Gastric tubes were attached to a sputum trap or drainage bag. Subdural Jackson-Pratt drains were securely occluded for the duration of treatment. A specialized monoplace hyperbaric extension set (No. 11647) from Abbott Laboratories, Chicago, Illinois, was used to pass the IV lines through the chamber door penetrations. Only one IV line is used for each penetration. Each IV line requires its own infusion pump which was set to the maximum occlusion limit of 750 millimeters of mercury. These were the standard B/Braun Outlook 100 IV pumps used by the hospital, and no modifications were needed at this treatment pressure.

The patients were connected to the hyperbaric ventilator at least 15 minutes prior to being pressurized in the HBO₂ chamber. Ventilatory parameters were set and stabilized and arterial blood gasses checked to verify that the ventilator parameters were appropriate. If secretions were present, the patient was suctioned thoroughly prior to the HBO₂ treatment. A bilateral myringotomy was performed prior to the first HBO₂ treatment. This procedure reduces middle ear barotrauma and thus avoids the painful stimulation which raises ICP (6).

A hyperbaric pretreatment checklist was developed, and all items were compulsively performed and checked off prior to the patient entering the HBO₂ chamber. (See pre- and post-treatment checklists, Pages 56-58.)

**Monitoring of the severe TBI patient during HBO₂ treatment**

Routine systemic monitoring of the patient included continuous heart rate, blood pressure, electrocardiogram and central venous or pulmonary wedge pressures as needed. Patients were continuously monitored for Vt, RR, PIPs and other indicators of their respiratory status such as skin color and chest wall movement. Noninvasive blood pressure and heart rate monitoring was accomplished through the Oscillomat monitor (Model 1630) by CAS Medical Systems, Inc. Intracranial monitoring has evolved to include ICP, PbtO₂, brain temperature and cerebral microdialysis. ICP was monitored using either an intraventricular catheter or a parenchymal monitor such as the Camino (Integra Neurosciences).

A pressure transducer was connected to the ventriculostomy line inside the HBO₂ chamber. Cerebrospinal fluid (CSF) was allowed to flow from the ventriculostomy to the transducer, which converted the fluid pressure to a digital signal. This signal was then transmitted through the chamber door to the outside monitors via the electrical penetrations. CSF drained directly into a closed reservoir that was inside the chamber at the level of the head. Care was taken that the system was sealed to the environment, as any open system can predispose to the development of pneumocephalus.

In the case of the monoplace chamber, once the chamber door was closed, access to the ventriculostomy system was impossible without interrupting the treatment. Therefore, the ventriculostomy had to be left open or closed. If elevated ICP was a problem, the ventriculostomy was set up for continuous drainage during the HBO₂ session. An intraparenchymal ICP monitor was used in combination with the ventriculostomy to ensure that continuous ICP data was obtained while CSF was draining via the ventriculostomy. We have worked out a system that will allow an attendant on the outside of the monoplace chamber to turn the ventriculostomy stopcock valve either open for draining or closed for intermittent ICP monitoring during the monoplace treatment.
For the past seven years, all patients with severe TBI admitted to our neurosurgical unit have undergone routine monitoring of PbtO2 using a Licox intraparenchymal brain tissue monitor (Integra Neurosciences) as part of standard care. A temperature probe was also placed in the cortex. Both probes were connected to the Licox monitor for automatic temperature-corrected PbtO2 readings. The PbtO2 probe was routinely placed in the least injured frontal lobe. The positions of the PbtO2 probes were assessed by brain computed tomography (CT) scans. Brain PbtO2 monitoring was carried out routinely in both the monoplace and multiplace HBO2 chambers (5).

Cerebral microdialysis was monitored in all 27 patients participating in our most recent HBO2 study using a CMA 70 microdialysis bolt catheter (CMA Microdialysis) (5). The 10-millimeter membrane microdialysis catheters were perfused with an artificial CSF at a rate of 0.3 μL/minute using a CMA 106 microdialysis precision pump (CMA Microdialysis). Localization of the gold tip of the microdialysis catheter was confirmed by brain CT scan. The catheters have been routinely placed in the least injured frontal lobe. During HBO2 treatments, the CMA 106 precision pump was placed in the HBO2 chamber. The recovery rate of the microdialysate was reduced during compression and increased during the decompression phase of the treatment (22). In general, the increase and decrease in recovery rate seemed to balance out.

Fifteen to eighteen μL/hour were typically obtained during the one-hour HBO2 treatment, including the 17-minute compression and the 17-minute decompression phase. Routine microdialysis that used the same techniques outside the chamber usually delivered approximately the same volume of microdialysate over a 60-minute period.

1. One treatment was aborted because of a significant drop in PbtO2 and increased swelling in the neck. Total treatment time was 53 minutes. CT scan of the neck did not reveal a significant hematoma or other abnormality. HBO2 treatments were continued the following morning without event.

2. The third HBO2 treatment was aborted in another patient for increased PIP on the ventilator of approximately 45 cmH2O. There appeared to be “uneven inspiratory movements of the chest.” The patient was at 1.5 atm abs for 38 minutes. Chest X-ray revealed “bibasilar airspace disease with increasing left basilar pleural disease.” The patient had experienced aspiration pneumonitis on admission. The patient was subsequently discharged to a rehabilitation service and was doing well.

There was no increased incidence of pneumonia, fraction of inspired oxygen requirement greater than 50%, or PEEP greater than 10 cmH2O for the HBO2-treated patients as compared to the control group. There were no immediate emergency decompressions in any of the 1,984 HBO2 treatments delivered. There were no complications resulting in permanent injuries related to the HBO2 treatments in this series of patients.

RESULTS
Medical complications
There were two minor medical complications during the 75 treatments described that required the hyperbaric treatment to be aborted early. The ability to monitor and manage these patients was greatly enhanced by the system described in this report.

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Equipment malfunction
One treatment was aborted during compression due to a malfunctioning computer-controlled valve. The treatment was resumed 13 minutes later and safely completed using the manual controls. The cause of the failure was identified and fixed by the chamber manufacturer with no further problems. Other than this one incident, no treatment was aborted due to equipment issues.

DISCUSSION
Using this protocol for patients with severe TBI, 75 treatments have been successfully administered using the Magellan ventilator and the Ohmeda 5410 monitor system. The Magellan provides flexibility to manipulate the Vt, I:E ratios, RR and airway pressures. The Ohmeda volume monitor
has been effective in quickly assessing the patient’s respiratory status, and the alarms have been useful reminders to keep within the set parameters. Interfacing the various pieces of life support and monitoring equipment with the monoplace chamber has resulted in a safe system to deliver HBO2 treatment to these critically ill TBI patients.

The HBO2 chamber and its environment became an extension of the ICU to safely care for severely brain-injured patients. The HBO2 treatments were administered by the hyperbaric medicine staff. Routine systemic monitoring of the patient included continuous heart rate, blood pressure, electrocardiogram and central venous or pulmonary wedge pressures as needed.

Intracranial monitoring included ICP, Pbto2 levels and brain temperature, as well as cerebral microdialysis. Intermittent HBO2 treatments at 1.5 atm abs for 60 minutes resulted in a very low incidence of complications, all of which were reversible.

The expertise of appropriate personnel must be as readily available in the HBO2 environment as it is in the ICU. The safe application of HBO2 treatment requires an additional set of skills, knowledge base and experience that are unique to hyperbaric medicine and essential to patient and staff safety. A well-trained staff of hyperbaric nurses and technicians working under the supervision of a qualified hyperbaric physician, each of whom have a thorough knowledge of the procedures and physiology of HBO2 therapy, is required.

In our experience of using both monoplace and multiplex chambers to treat severe TBI patients, the critical safety issue is not the type of chamber but the meticulous preparation, proper monitoring and the constant attention of well-trained critical care and hyperbaric medicine staff. In the case of a monoplace chamber, the patient is physically isolated from the caretakers, but the chamber can be decompressed from 1.5 atm abs in two minutes (unless partial or complete airway obstruction is suspected) and immediate access to the patient achieved. Immediate decompression was not required for any of the study patients. Unlike ICUs where patients may be left unattended for brief periods of time, the patient is under the constant observation and supervision of several staff members during HBO2 treatment.

In addition to critical care and HBO2 expertise, the HBO2 chamber, particularly the monoplace chamber, has to be specifically designed to adequately monitor the patient and administer appropriate fluids and medications during the treatment. If this paradigm is maintained, our experience documents that HBO2 treatment can be safely delivered to the severe brain injured patient in monoplace as well as multiplex chambers.

CONCLUSION

HBO2 treatments at a depth of 1.5 atm abs can be delivered repetitively to the severe TBI patient with or without multiple injuries in either a monoplace or multiplex chamber with relative safety.

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REFERENCES


PRE-TREATMENT CHECKLIST

VENTILATOR SETUP

- Plug in alarm box for gas in gas room
- Turn on gas room tanks / bottles
- In use HP O₂ at _______ psi (min. 700psi)
- Reserve HP O₂ at _______ psi (min. 1,500psi)
- O₂ regulator at _______ psi
- In use HP air at _______ psi (min. 700psi)
- Reserve HP air at _______ psi (min. 1,500psi)
- Air regulator at _______ psi
- Mixed-gas type________
- In use HP mix at _______ psi (min. 700psi)
- Reserve HP mix at _______ psi (min. 1,500psi)
- Mixed-gas regulator at _______ psi
- IMV/CPAP flow knob on ventilator turned off
- Open shut-off valve to ventilator drive gas hose
- Disconnect Ohmeda charger adapter
  (Run monitor on battery only)
- Verify sensor clip is labeled as “heat resistors disconnected”
- Verify current-limiting fuses (150mA) on supply and return of sensor clip circuit.
- Turn on Ohmeda volume monitor
- Ohmeda sensor on patient exhaust side
- Wright respirometer visible and connected to exhaust
- Set ventilator to approx. RR 10-12, Vt 400-600
- Set and test Ohmeda hi/low and apnea alarms
- Exhalation valve working properly
- Test pressure both pop-off valves
  (55 – 65 cmH₂O)
- Check valve in place
- Safety breathing valve with proper flow direction
- Both pressure manometers working
- PEEP valve in upright position
- All patient circuit connections secure
- Pre-run 15 – 30 min.
- Volume and rate stable after warm-up?

PRE-TREATMENT CHECKLIST

CHAMBER SET-UP

- Turn on power to chamber.
- Chamber “supply open” valve on
- Select chamber wall supply: air____ / O₂ ____
- Hospital wall pressure at 50 – 65 psi
- Turn on and calibrate oxygen monitor (21%)
- O₂ sensor connected to sample line and monitor alarms set for 23% O₂
- Log on to computer and select dive profile
- Inspect acrylic for scratches, cracks, crazing
- Inspect door gaskets & O-ring
- Inspect penetrations, IVs — secure and ready
- Inspect cables and tubes for kinks, etc.
- Manual vent control off on chamber
- Manual pressure control off on chamber
- Inside clean and no contraband items
- Oxygen delivery device ready for patient
- Gurney and litter ready for patient
- Ground strap ready
- Patient monitor on and ready
- CAS BP monitor ready
- Entry in Chamber Daily & Monthly PM logs
- Dive / Pt TX log ready

Comments: ___________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

Date/Time ___________________________ CHT sign ___________________________
**PRE-TREATMENT CHECKLIST**

**PATIENT SETUP CHECKLIST**

- Enter patient info in chamber computer
- Proper clothing
- No contraband, plastic sheets, etc.
- Ground strap on
- Log book ready with patient info and run info
- NG tube clamped or in glove if needed for drainage.
- Foley bag ready
- NS or water in ET cuff
- Vent circuits secure
- VT__________ RR__________
- PIPs_________ PEEP________
- BS equal
- Suction ET tube Yes / No
- Verify vent alarms (MV & apnea) set and working

- Patient circuit connections secure
- Wrist restraints on
- CAS BP monitor on patient. Values similar to arterial line value.
- O₂ monitor alarms set at 23% and sample line ready
- Ventric drain open
- JP line open
- ECG, IVs, pressure lines and monitors working
- ENSURE OHMEDA CHARGER IS DISCONNECTED (Battery power only during treatment)
- Current-limiting fuses (150mA) on supply and return of sensor clip circuit.
- Sensor clip labeled as ‘heat resistors’ disconnected
- Wright respirometer visible and working on exhaust tubing of ventilator.

Comments: _____________________________________________________________________________
_______________________________________________________________________________________
_______________________________________________________________________________________

Date/Time _______________________________ CHT sign ________________________________
**POST-TREATMENT CHECKLIST**

- Chamber, monitors, vent, etc., all off
- Treatment log completed
- Chamber maintenance log completed
- Clean all patient care equipment
- Wipe down wires, tubing, etc. and wind up
- Clean and disinfect chamber inside and out
- Restock and order supplies
  (See supply list below.)
- Set up chamber and ventilator for next TX
- Turn off all gases in gas room
- Unplug gas alarms in gas room
- Bleed gas room pressures to zero and silence alarm
- Turn off “shut-off” valve in vent supply line
- Order replacement “H” cylinders as needed
- Turn chamber wall supply gas to OFF
- Test vent circuit for volume with Ohmeda monitor
- Test pop-off valve and set to 60 cmH₂O
- Plug in Ohmeda monitor to battery charger
- Only use sensor clip labeled as “heat resistors disconnected”
- Ensure the current-limiting fuses (150mA) are on the supply and return current path of Ohmeda sensor clip circuit.
- Put Wright respirometer on exhaust side

### Supplies needed:

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### Comments:

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**Date/Time** _______________________________   **CHRN/CHT** _______________________________