Coma Reversal With Cerebral Dysfunction Recovery After Repetitive Hyperbaric Oxygen Therapy for Severe Carbon Monoxide Poisoning

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The accepted beneficial effects of hyperbaric oxygen (HBO) include a greatly diminished carboxyhemoglobin (COHgb) half-life, enhanced tissue clearance of residual carbon monoxide (CO), reduced cerebral edema, and reversal of cytochrome oxidase inhibition, and prevention of central nervous system lipid peroxidation. Debate regarding the criteria for selection of HBO versus 100% normobaric oxygen therapy continues, and frequently is based solely on the level of COHgb saturation. Patients who manifest signs of serious CO intoxication (unconsciousness, neuropsychiatric symptoms, cardiac or hemodynamic instability) warrant immediate HBO therapy. An unresponsive 33-year-old woman was found in a closed garage, inside her automobile with the ignition on. Her husband admitted to seeing her 6 hours before discovery. 100% normobaric oxygen was administered in the prehospital and emergency department settings. The patient had an initial COHgb saturation of 46.7%, a Glasgow coma score of 3, and was transferred for HBO therapy. Before HBO therapy, the patient remained unresponsive and demonstrated decerebrate posturing and a positive doll's eyes (negative oculocephalic reflex). The electroencephalogram pattern suggested bilateral cerebral dysfunction consistent with a toxic metabolic or hypoxic encephalopathy. The patient underwent HBO therapy at 2.4 ATA for 90 minutes twice a day for 3 consecutive days. On day 7, the patient began to awaken, was weaned from ventilatory support, and was soon verbalizing appropriately. A Folstein mental status examination showed a score of 26 of 30. Neurological examination demonstrated mild residual left upper extremity weakness and a normal gait. There was no evidence of significant neurological sequelae at 1 month follow-up. Aggressive repetitive HBO therapy resulted in significant resolution of coma and cerebral dysfunction after severe acute CO poisoning. HBO should be considered even in patients suffering from severe neurological damage that was CO-induced. (Am J Emerg Med 1993;11:616-618. Copyright © 1993 by W.B. Saunders Company)

Although there is considerable debate regarding the appropropriateness of hyperbaric oxygen (HBO) therapy for every patient after an acute carbon monoxide (CO) exposure, a significant body of scientific and clinical information currently is available that show that patients who manifest signs of serious intoxication (unconsciousness or altered neurological function, cardiac or hemodynamic instability) should be considered candidates for HBO therapy in addition to other appropriate supportive care.[1-3] It is ethically difficult to perform prospective double-blinded, randomized clinical studies for patients with COHgb levels of more than 25 mm Hg and a prolonged loss of consciousness, in the face of many reports demonstrating the clinical efficacy of HBO therapy.[4-8] Although there may be relative consensus regarding the more obvious indications for HBO, the role of multiple or repetitive HBO therapies in profoundly comatose patients is more nebulous. This case of severe CO poisoning presented with profound neurological signs that reversed HBO.

CASE REPORT

A 33-year-old woman was transferred to the hyperbaric medicine program at the University of Pittsburgh Medical Center (UPMC) after having attempted suicide by CO poisoning. The patient had a history of depression and was being treated with bupropion. Her husband admitted to seeing her 6 hours before discovering her in a closed garage, sitting inside the family's automobile with the ignition on.

The patient was transported to the local community health care facility by a basic life support ambulance that provided 100% normobaric oxygen via a non-rebreather mask. Her vital signs on arrival included a blood pressure of 90/50 mm Hg, a spontaneous respiratory rate of 16 breaths/min, and a heart rate of 104 beats/min. Orotracheal intubation was performed, and the patient was ventilated with 100% oxygen. The initial COHgb level was 46.7%, and arterial blood gases showed a pH of 7.24; P_{CO_2} of 34.4 mm Hg; P_{O_2} of 162 mm Hg; and bicarbonate of 14.6 mm/L. The initial electrocardiogram and chest x-ray were normal. The patient had a Glasgow coma score of 3 and was immediately transferred for HBO therapy by rotocraft.

On arrival at UPMC, the patient remained unresponsive and demonstrated decerebrate posturing with painful stimuli. Her pupils were equal, round, reactive to light, and there were roving eye movements. The patient demonstrated a positive *doll's eyes* (oculocephalic movements), with a normal comatose response to cold water calorics. There was occasional spontaneous movement of both upper and lower extremities without purpose. Her dependent reflexes were 4/4 and symmetric throughout. The patient had 4/4 sustained clonus of both lower extremities and bilateral upward going toes. The patient's comprehensive drug screen was negative, and the remainder of the laboratory data were within normal limits.

The patient underwent HBO therapy at 2.4 ATA for 90 minutes twice a day for 3 consecutive days. During this same period, she developed what was believed to be an aspiration pneumonitis and was placed on Unasyn (Roerig, Division of Pfizer Pharmaceuticals, New York, NY). An electroencephalogram (EEG) demonstrated generalized abnormalities without focal features or epileptiform ac-

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Manuscript received March 21, 1993; revision accepted May 9, 1993.

Presented at the AAPCC/AACT/ABMT/CAPCC 1992 Annual Scientific Meeting in Tampa, FL.

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Key Words: Carbon monoxide poisoning, coma reversal, repetative hyperbaric oxygen therapy.

0735-6757/93/1106-0016$5.00/0

tivity. The EEG pattern suggested bilateral cerebral dysfunction consistent with a toxic metabolic or hypoxic encephalopathy. Computerized axial tomography of the head was performed after her first HBO treatment and failed to demonstrate evidence of cerebral edema.

On the seventh hospital day (after six HBO treatments), the patient began to appropriately follow verbal commands. She was quickly weaned from ventilatory support and subsequently began answering questions appropriately using short sentences. Her neurological examination demonstrated persistent upgoing toes on Babinski reflex, and mild left upper extremity weakness. Her gait was normal.

On the 14th hospital day, the patient's Folstein mini-mental status examination showed a score of 26 of 30. She continued to have a depressed affect but demonstrated significant improvement in her overall cognitive ability. Discharge to a long-term psychiatric care facility occured on the 17th hospital day. A 1-month follow-up demonstrated no evidence of significant neurological sequelae.

DISCUSSION

Oxygen administration is considered the mainstay of treatment for CO poisoning. This case represents evidence that severe CO poisoning, which can result in devastating neurological compromise, can dramatically improve with repeated use of HBO. The administration of 100% normobaric oxygen (NBO) under ideal conditions using a tight-fitting nonrebreathing mask will reduce the half-life of COHgb from 320 minutes to approximately 80 to 100 minutes.[9] A hyperbaric chamber delivers 100% oxygen under elevated atmospheric pressure, COHgb half-life is reduced to 23 minutes at 3.0 atm of 100% oxygen. In addition to decreased COHgb elimination half-life, potential benefits may include increased tissue clearance of residual CO, restoration of tissue oxygenation by improvement in peripheral oxygen delivery, reduced cerebral edema, and reduced cytochrome oxidase inhibition.[10] Theoretically, because HBO therapy competitively displaces CO from hemoglobin four to five times more rapidly than NBO, many feel it should be used routinely in the treatment of CO poisoning.[6,8,11,12] Opponents of liberal use of HBO point to the cost, complications, availability, and the absence of controlled studies designed to validate the clinical claims of reduced morbidity and mortality.[9,13]

Acute toxic manifestations associated with CO poisoning are the result of hypoxia-sensitive tissue damage (especially the heart and the brain).[9] Although COHgb levels must be interpreted cautiously (they are frequently discordant with clinical effects), table 1 lists symptoms associated with varying levels of CO poisoning. Individual responses to CO vary, and predicting who will develop severe neurological sequelae (demyelination) is currently problematic.[14-16] Subtle neurological/psychological changes or "delayed neurological sequelae" is reported in 2% to 12% of CO poisoned patients, and may be persistant. The most common findings of this syndrome include mental deterioration, fecal and/or urinary incontinence, and gait disturbances.[17] Mental deterioration is exemplified by symptoms such as headaches, personality changes, confusion, memory loss, and irritability.[6] Although there is no controversy surrounding the toxic clinical manifestations of acute CO poisoning, there is considerable debate regarding criteria for selection of HBO therapy versus NBO therapy and whether it will reduce the incidence of delayed neuropsychiatric effects does indeed.[6,9,12]

TABLE 1. Clinical Effects of Carbon Monoxide Poisoning

% COHb	Symptomatology
5-10	Impaired driving skills and decreased exercise tolerance
10-20	Headache, fatigue
20-25	Increased lactic acid with compensated metabolic acidosis
20-30	Severe headache, weakness, dizziness, dimness of vision, syncope, nausea, vomiting diarrhea, interference with motor dexterity-mild
30-40	Syncope, increased respiration, increased heart rate, nausea, vomiting, confusion
40-50	Coma, convulsions, confusion, increased respirations, increased heart rate
50-60	Coma, convulsions, Cheyne-Stokes respiration, depressed cardiovascular status-severe
60-70	Coma, convulsions, cardiorespiratory depression, bradycardia, hypotension often fatal
70-80	Respiratory failure and death

The use of HBO is generally recommended in cases of CO poisoning when patients have (1) a COHgb level of 25% or more; (2) anginal pain or ischemic changes on an electrocardiogram; (3) any degree of neurological impairment, regardless of the COHgb level, including transient loss of consciousness; or (4) pregnant patients with a COHgb level that exceeds 20% or fetal monitoring that show signs of distress.[18,19] These are the criteria that were applied in determining the need for HBO treatment in this patient. Some proponents of HBO feel patients may lack all of these criteria and still have significant CO intoxication leading to the development of delayed neuropsychiatric sequelae. Neuropsychiatric testing has been proposed as a method for detecting individuals with subtle neurological impairment.

Perhaps more controversial than HBO versus NBO, is establishing a definitive endpoint for HBO therapy. As illustrated in this patient, multiple episodes of HBO may have contributed to this patient's recovery. Conventional HBO of only one or two dives may not have produced the favorable outcome witnessed in this case. In 1989, Raphael et al demonstrated in patients presenting with initial coma, that two sessions of HBO therapy had a slightly better effect on recovery rate over a single session (49% vs 39%, LP = NS), yet the number of serious sequela or deaths was not influenced.[3] Sawada et al showed that the correlation between initial computerized tomographic findings and the occurrence of severe neurological sequela persisted irrespective of the number of HBO sessions, ranging from 3 to 23, at 3.0 ATA.[15]

This case suggests aggressive repetitive HBO therapy can result in significant resolution of profound coma and cerebral dysfunction after severe acute CO poisoning. Although it is conceivable that longer periods with proper NBO therapy may reverse CO-induced coma, this patient's devastating neurological compromise mandated immediate HBO therapy. This patient showed no evidence of significant neurological sequelae at 1-month follow-up.

CONCLUSION

This case suggests that repetitive HBO therapy should be considered even in patients with apparent devastating neurological compromise secondary to severe CO poisoning. Perhaps the reverse or plateau of neurological function might be considered by clinicians to be a reasonable end point for HBO therapy.

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