Journal of Hyperbaric Medicine, Vol. 7, No. 3, 1992

Treatment of Carbon Monoxide Poisonings in Multiplace Hyperbaric Chambers

N. B. Hampson, R. G. Dunford, and D. M. Norkool

Virginia Mason Medical Center, Hyperbaric Department, Seattle, Washington 98111

Hampson NB, Dunford RG, Norkool DM. Treatment of carbon monoxide poisonings in multiplace hyperbaric chambers. J Hyperbaric Med 1992; 7(3):165–171.—To determine the frequency and type of hyperbaric treatments administered for carbon monoxide (CO) poisoning in North America, we surveyed all multiplace hyperbaric facilities listed in the 1990 UHMS Chamber Directory. In 1990, 42 facilities treated 1023 CO poisonings, with 38 U.S. chambers treating 832 patients and 4 Canadian chambers treating 191 patients. Individual facilities treated from 1 to 93 patients in that year. A total of 18 different hyperbaric protocols are used at these facilities for primary treatment of CO poisoning. These include 3 protocols with a maximum pressure of 3.0 atm abs, 13 protocols with a maximum pressure of 2.8 atm abs, and 2 protocols with a maximum pressure of 2.4–2.5 atm abs. In 1990, 284 patients were treated at facilities utilizing 3.0 atm abs, 561 at facilities utilizing 2.8 atm abs, and 178 at facilities utilizing 2.4–2.5 atm abs. Among treating facilities, 24% never re-treat patients for the same episode of CO poisoning. With regard to pregnancy, 31 of 42 chambers have treated or would treat pregnant patients with significant CO intoxication. Among these, 28 utilize the same primary treatment protocol as for non-pregnant patients. In summary, a large number of CO poisonings are treated in North American multiplace chambers annually, utilizing a wide variety of treatment profiles.

carbon monoxide poisoning, hyperbaric oxygen therapy, multiplace hyperbaric chambers

Introduction

Hyperbaric oxygen (HBO) is widely recommended and applied for the treatment of significant carbon monoxide (CO) poisoning. Rationale for the use of HBO includes enhancement of clearance of CO from hemoglobin and tissue stores, provision of dissolved oxygen sufficient to support aerobic demands of hypoxia-sensitive tissues (especially heart and brain), and reduction of cerebral edema (1).

The application of HBO for CO intoxication, however, is not standardized, and different treatment protocols are reported in the clinical literature. This has the potential to cause at least two problems when interpreting clinical trials. First, comparison of the results from clinical studies may be difficult when different HBO protocols have been utilized and conflicting results reported. Second, negative results from a clinical trial may not be accepted if

the HBO treatment protocol applied is felt to have been "unconventional." For these reasons, we sought to define the protocols in use at multiplace HBO chambers in North America for CO poisoning to determine whether any unanimity regarding treatment practices exists.

Methods

Study data were obtained through a mail survey sent to all North American multiplace hyperbaric facilities listed in the 1990 Undersea and Hyperbaric Medical Society (UHMS) directory (2). Repeat mailings and telephone contacts were performed as necessary to achieve a high response rate.

Facilities were questioned regarding their treatment experience for patients with CO poisoning in calendar year 1990. Responses from facilities treating at least 1 patient during that year were included in subsequent data analysis. Excluded from analysis were nonclinical facilities, clinical facilities that did not treat a case of CO poisoning in 1990, and facilities that had ceased operations since publication of the UHMS directory.

Information was collected regarding treatment protocols utilized for acute CO poisoning, re-treatment of patients for the same episode of CO intoxication, and practices related to the treatment of pregnant patients with CO poisoning.

Results

Survey responses were obtained from 100% of the 83 multiplace hyperbaric facilities listed in the 1990 UHMS directory. A total of 42 active North American facilities were identified that treated at least 1 case of CO poisoning in 1990, combining to treat a total of 1023 patients in that year. In the United States, 38 multiplace hyperbaric facilities treated 832 patients, with a range of 1 to 83 patients per facility. Four Canadian facilities treated 191 patients, ranging from 3 to 93 patients per facility.

A total of 18 different treatment protocols were reported by the 42 facilities. As detailed in Table 1, 3 protocols use a maximum pressure of 3.0 atm abs, 13 different protocols use a maximum pressure of 2.8 atm abs, and 2 protocols apply a maximum pressure ranging from 2.4 to 2.5 atm abs. Protocols are listed in Table 1 in order of the maximum pressure used and time of oxygen breathing at that pressure. Differences among protocols using similar maximum pressures include duration of time at that pressure and differences in subsequent pressures applied. Utilization of protocols by facilities and number of patients treated are outlined in Table 2. Also included is the oxygen dose per protocol, calculated by multiplying the minutes of oxygen breathing by atm abs pressure.

Among the 42 treating facilities, 17 (40%) use a 3.0 atm abs protocol for CO poisoning, 19 (45%) a 2.8 atm abs protocol, and 6 (14%) a 2.4–2.5 atm abs protocol. Protocol no. 2 in Table 1 is the most common profile, identified

Table 1: Multiplace Hyperbaric Protocols for CO Poisoning

Protocol	Pressure no. 1, atm abs	Time[a]	Pressure no. 2, atm abs	Time[a]	Pressure no. 3, atm abs	Time[a]
1	3.0	69	2.0	50		
2	3.0	46	2.0	50		
3	3.0	46	2.0	30/60/90		
4	2.8	80	1.3	10		
5	2.8	75	1.9	20		
6	2.8	60	1.9	120		
7	2.8	46	1.9	50		
8	2.8	46	1.9	46		
9	2.8	46	2.4	80	1.6	10
10	2.8	40	1.9	40		
11	2.8	40	1.9	20		
12	2.8	30	2.0	90		
13	2.8	92				
14	2.8	90				
15	2.8	60				
16	2.8	46				
17	2.4–2.5	90				
18	2.4–2.5	60				

[a]Times reported are minutes of oxygen breathing at the specified pressure.

Table 2: Utilization of Protocols and Oxygen Dose Characteristics

Protocol	Facilities Utilizing	Patients Treated, 1990	Oxygen Dose[a]
1	1	42	307
2	14	158	238
3	2	84	198/258/318
4	1	15	237
5	1	82	248
6	1	6	396
7	1	55	224
8	1	26	216
9	1	3	337
10	1	2	188
11	5	106	150
12	1	50	264
13	1	83	258
14	1	1	252
15	1	11	168
16	3	121	129
17	5	176	220
18	1	2	147
	Total 42	Total 1,023	Mean 235

[a]Oxygen dose per protocol is minutes of oxygen breathing multiplied by atm abs pressure.

as the primary treatment protocol at 14 of the 42 treating facilities (33%). This protocol applies a maximum pressure of 3.0 atm abs and is commonly known as the "United States Air Force table," developed and applied by the United States Air Force for treatment of CO poisoning (3). Next most common among facilities is protocol no. 17 in Table 1, used at five facilities (12%), treating patients at a maximum pressure of 2.4–2.5 atm abs.

In 1990, 284 patients (28%) were treated at 3.0 atm abs, 561 (55%) at 2.8 atm abs, and 178 (17%) at 2.4–2.5 atm abs (Fig. 1 and Table 2). The two most

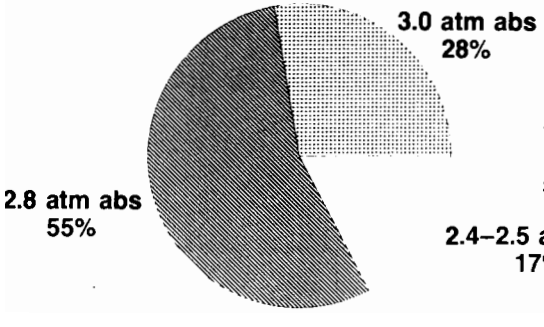

FIG. 1—Percentage of patients treated for CO poisoning in 1990 at various maximum pressures.

common protocols with regard to numbers of patients treated were no. 17 (176 patients, 17%) and no. 2 (158 patients, 15%).

In addition to these primary treatment tables, 18 facilities (43%) reported that an alternate or secondary protocol is available for use depending on clinical circumstances. No attempt was made to collect or tabulate data on secondary protocols. Also with regard to general management, 32 facilities (76%) sometimes re-treat patients for the same episode of CO poisoning, whereas 10 facilities (24%) never re-treat.

Among facilities in this survey, 31 (74%) have treated pregnant CO-poisoned patients with HBO, and 11 (26%) do not or have not treated pregnant patients. Among the 31 facilities treating pregnant patients, 28 use the same primary treatment protocol as for nonpregnant patients, 2 attenuate the treatment by exposing the patient to less maximum pressure, and 1 augments the treatment by extending the duration of oxygen breathing for pregnant patients. Among facilities treating pregnant patients, 43% use a maximum pressure of 3.0 atm abs, 39% use 2.8 atm abs, and 16% use 2.4 to 2.5 atm abs (Fig. 2).

Discussion

In its 1989 report, the Hyperbaric Oxygen Therapy Committee of the Undersea and Hyperbaric Medical Society mandated treatment of severe CO poisoning with HBO (4). Exact treatment pressures and times were not specified, although pressure between 2.5 and 3.0 atm abs was suggested. The generality of this recommendation has resulted in the use of a multiplicity of hyperbaric treatment profiles in North America. Eighteen different profiles are used in the United States and Canada for primary treatment of acute CO poisoning in multiplace facilities. The oxygen dose delivered by these profiles differs by a factor of up to 2.7-fold (Table 2). No single profile is either used to treat a majority of patients or chosen as a primary protocol at a majority of facilities. Profiles applying maximum pressures of 2.4–2.5 atm abs (no. 17) and 3.0 atm abs (no. 2) head each of these respective categories; however, neither pressure

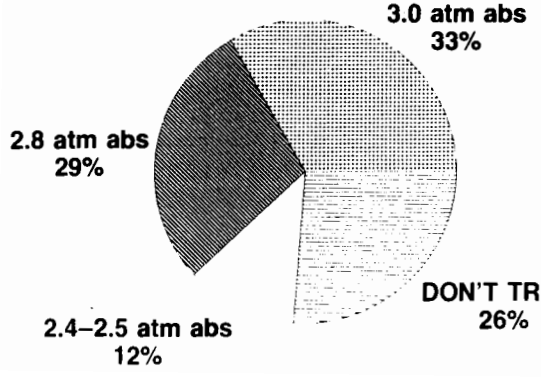

FIG. 2—Maximum pressures utilized by facilities for treatment of pregnant patients with CO poisoning.

is most commonly applied to CO-poisoned patients. An absolute majority of patients are treated with a pressure of 3.0 atm abs, divided among the 13 protocols using that pressure.

Data from recent animal research on CO poisoning demonstrate reduction in brain injury with HBO treatment, but at differing maximal pressures (5, 6). No laboratory investigation to date has compared HBO treatment over the entire range of oxygen doses and pressures that are demonstrated to be applied in clinical practice in the present study. An earlier report suggested excess brain lactate production when normal animals were exposed to HBO at 3.0 atm abs (7); however, the relevance of this observation to the CO-poisoned animal or human treated at this pressure remains uncertain.

Variability in clinical treatment protocols may cause confusion when attempting to interpret outcome data from clinical trials of CO poisoning. These differences in treatment add yet another variable that must be considered when attempting to compare disparate data from different hyperbaric centers. Furthermore, studies reporting a lack of benefit from HBO treatment may be criticized if the HBO treatment profile is not widely accepted. Such was the case when Raphael and coworkers reported their experience with a large series of CO poisoning (8), followed shortly thereafter by letters questioning the adequacy of the HBO treatment applied (9–11).

Randomized human clinical trials, possibly multicentered, are needed to compare both the benefits and side effects of various HBO treatment regimens for acute CO poisoning. The variability in current treatment practice attests to the fact that the optimal HBO regimen for this disease is currently unknown.

The authors thank Ms. Kathy Dalrymple for her excellent secretarial assistance.

References

1. Piantadosi CA. Carbon monoxide intoxication. In: Vincent JL, ed. Update in intensive care and emergency medicine. New York: Springer-Verlag NY Inc, 1990: 10:460–471.
2. Hyperbaric chambers, United States and Canada: a directory of hyperbaric treatment chambers. Bethesda, MD: Undersea and Hyperbaric Medical Society, 1990.
3. United States Air Force. Hyperbaric chamber operations. Air Force pamphlet 161-27; July 5, 1983:79–81.
4. Hyperbaric oxygen therapy: a committee report. Bethesda, MD: Undersea and Hyperbaric Medical Society, 1986:33–66.
5. Thom SR. Antagonism of carbon monoxide-mediated brain lipid peroxidation by hyperbaric oxygen. Toxicol Appl Pharmacol 1990; 105:340–344.
6. Brown SD, Piantadosi CA. Recovery of energy metabolism in rat brain after carbon monoxide hypoxia. J Clin Invest 1992; 89:666–672.
7. Plum F, Posner JB, Smith WW. Effect of hyperbaric-hyperoxic hyperventilation on blood, brain, and CSF lactate. Am J Physiol 1968; 215:1240–1244.
8. Raphael JC, Elkharrat D, Jars-Guincestre MC, et al. Trial of normobaric and hyperbaric oxygen for acute carbon monoxide intoxication. Lancet 1989; 2:414–419.
9. Brown SD, Piantadosi CA. [Letter] Hyperbaric oxygen for carbon monoxide poisoning. Lancet 1989; 2:1032.

10. Gorman DF, Gillian JEF, Clayton DG. [Letter] Hyperbaric oxygen for carbon monoxide poisoning. Lancet 1989; 2:1032.
11. Neubauer RA, Gottlieb SF. [Letter] Hyperbaric oxygen for carbon monoxide poisoning. Lancet 1989; 2:1032–1033.