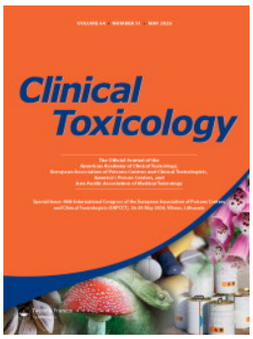

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CLINICAL RESEARCH

The effects of hyperbaric oxygen dosing on the delayed neuropsychiatric sequalae of carbon monoxide poisoning

Ivan Gur[a,b], Alon Safrai[b#] and Yuval Nov[b]

[a]Internal Medicine C, Rambam Healthcare Campus, Haifa, Israel; [b]School of Public Health, Faculty of Social Welfare and Health Sciences, University of Haifa, Haifa, Israel

ABSTRACT

Introduction: A paucity of evidence exists as to the comparative effectiveness of various hyperbaric oxygen regimens in preventing delayed neuropsychiatric sequelae. We aimed to compare the effect of four such treatment regimens: (1) PO_2 = 2.0_{ATA} for 90 min once; (2) PO_2 = 2.0_{ATA} for 90 min thrice; (3) PO_2 = 2.8_{ATA} for 90 min once; and (4) PO_2 = 2.8_{ATA} for 90 min once followed by two sessions of 2.0_{ATA}.

Methods: We retrospectively reviewed the records of all patients treated in a large regional hyperbaric referral facility over the past 30 years, and identified patients displaying any new cognitive, motor or psychiatric symptoms within 2–40 days from exposure to carbon monoxide – any of which was defined as delayed neuropsychiatric sequelae. Excluded were patients not complying with the full prescribed treatment course or those lacking a full medical record for at least a year following exposure.

Results: Of 312 patients included in the final analysis, the incidence of delayed neuropsychiatric sequelae was 31/87 (36%), 20/54 (37%), 20/102 (20%) and 13/69 (19%) in the 2.0_{ATA} once, 2.0_{ATA} thrice, 2.8_{ATA} once and 2.8_{ATA} thrice treatment groups, respectively (P=0.011). Patients treated with the lower-pressure regimen (2.0_{ATA} once and thrice) had a significantly higher delayed neuropsychiatric sequelae rate compared to those treated with higher PO_2 (2.8_{ATA} once and thrice) – 36.2% versus 19.3% respectively (P=0.0013). In a multivariate logistic regression model adjusting for age, carboxyhemoglobin levels, and presenting symptoms, the higher-pressure protocol was independently associated with a 55% reduction in the odds of developing delayed neuropsychiatric sequelae (adjusted odds ratio = 0.45; 95% confidence interval: 0.26–0.77; P=0.004). Increasing the frequency of sessions from one to three was not associated with a statistically significant benefit (P=0.9). The presence of seizures on admission was the strongest predictor of poor outcome (adjusted odds ratio = 4.27; P=0.023).

Discussion: The observed 55% reduction in the odds of developing delayed neuropsychiatric sequelae with the 2.8_{ATA} protocol suggests that achieving a higher initial partial pressure of oxygen is critical to effectively interrupting the inflammatory cascades associated with carbon monoxide toxicity. Because additional sessions did not confer a statistically significant benefit, meeting this initial therapeutic threshold appears more impactful than treatment frequency. Notably, the neuroprotective benefits of the higher-pressure regimen were sustained even among high-risk patients presenting with seizures.

Conclusions: A PO_2 of 2.8_{ATA} rather than 2.0_{ATA} in the initial hyperbaric oxygen session, is associated with superior neuroprotective outcomes, while the overall number of sessions is not.

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Introduction

Carbon monoxide (CO), a product of incomplete combustion of hydrocarbon fuels, is the leading inhalation poisoning worldwide, affecting about 13 patients per 100,000 population each year [1]. In the long term, a significant concern is delayed neuropsychiatric sequelae (DNS), manifested in as many as 40% of CO poisoning cases as varying cognitive and personality changes, with the occasional focal deficit or movement disorders [2]. Hyperbaric oxygen (HBO) administration reduces the CO half-life ($t_{1/2}$) in the blood from 4 to 5 h to as low as 30 min [1]. Furthermore, HBO directly increases the amount of oxygen dissolved in the serum (PaO_2) by as much as twenty-fold (Henry's law).

CONTACT Ivan Gur ostyly@gmail.com 8 HaAlia Street, Haifa 3109601, Israel.
Supplemental data for this article can be accessed online at https://doi.org/10.1080/15563650.2026.2666318.
[#]Mr Safrai, a brilliant medical student, was killed on October 25th, 2024. May he rest in peace, knowing that his quest to alleviate human suffering in all its forms lives on in his scientific contribution.

This helps correct tissue hypoxia and reduce oxidative damage [3].

Clinically, these effects have been linked to several long-term outcomes. Some observational data suggest that prompt treatment with HBO can significantly reduce CO poisoning-associated long-term mortality (often attributed to myocardial damage) [4]. Most of the research thus far was focused on HBO's effects on DNS [5]. While some well-designed randomized clinical trials demonstrated a twofold decrease in DNS at 6 weeks due to HBO therapy [3], others did not [2,6–8].

Importantly, the dose of HBO administered is not well established [9]. Prospective trials implemented a myriad of HBO protocols, both in terms of peak pressure, duration, treatment frequency and overall number of treatments [2,8]. The lack of a standardized tool that would allow to assess HBO cumulative dose hampers the clinicians ability to interpret and compare these results [7]. As a result, current clinical guidelines for CO poisoning remain heterogeneous, with scarce and varying recommendations regarding the optimal dosing of HBO sessions [10].

We aimed to utilize this lack of standardized approach, and the resultant variability in the HBO protocols administered, to study the association between different HBO doses (as manifested in the partial pressure of O_2 in each session and the overall number of HBO sessions) and DNS.

Methods

Population and setting

This retrospective cohort study reviewed the medical records of all patients diagnosed with an acute CO inhalation and subsequently referred to a tertiary hyperbaric center, serving as the sole hyperbaric referral facility for a population of ~2 million. The study period was from January 1st, 1995 to December 31st, 2024. The indications for HBO therapy were evidence of CO inhalation (per direct or collateral history), coupled with any of the following: 1) a carboxyhemoglobin fraction of 25% or higher; 2) known or suspected loss of consciousness or new focal neurological findings; 3) pregnancy; 4) electrocardiographic changes or troponin elevation (provided an acute coronary etiology was reasonably ruled out); 5) evidence of severe acidosis, particularly if serum lactate is above four times the upper limit of normal. Contraindications for HBO therapy included hemodynamic instability, or when the treating physician deemed the transport of two hours long to receive a HBO therapy session would be unsafe for the patient.

All patients were started on normobaric oxygen by the treating physician, who consulted the hyperbaric chamber for referral. Then, the patient was examined by a hyperbaric specialist to rule out any contraindications to HBO therapy, as specified elsewhere [11]. From the cases offered HBO therapy, included in this study are patients of any age, provided the entire prescribed HBO therapy protocol was completed. Patients unable or refusing to complete all prescribed sessions to the full extent, or those without medical records for at least one year following exposure, were excluded. This approach was chosen to ensure even more subtle symptoms recorded later on (but first presented within 2–40 days) were reported. All patients also received standard supportive care, including normobaric oxygen, cardiovascular and respiratory support as indicated, and management of complications according to contemporary guidelines.

Treatment protocol

HBO therapy was administered in a multiplace chamber (HAUX-STARMED 2200, Haux-Life-Support GmbH, Karlsbad, Germany).

For the HBO10 protocol, the patient was pressurized to 2.0_{ATA} over ~10 min, following the administration of 100% FiO_2 through a sealed mask for 90 min (with a 5-minute air break in the middle), following a gradual depressurization with a 3-minute stop at 1.3_{ATA} (breathing air throughout). For the HBO18 protocol, the oxygen (at 100% FiO_2 through a sealed mask) [12] was administered at 2.8_{ATA} (for 90 min with a 5-minute air break), and the depressurization was additionally stopped at 1.6_{ATA} for 22 min (while breathing air) to allow for a decompression stop for the pressure chamber attendant (who breathed oxygen during this period). In the HBO10x3 and HBO18/10/10 groups, following the initial session (at 2.0_{ATA} or 2.8_{ATA}, respectively), the patient received two additional HBO10 sessions within 24 h (typically spaced by 3–9 h from the previous session). These four protocols are depicted in Figure 1.

Due to shifting institutional practices and differing preferences by the individual physician, any one of four therapeutic options could have been offered: one treatment session with the HBO10 protocol (HBO10x1); three treatments with the HBO10 protocol (HBO10x3); one treatment with the HBO18 protocol (HBO18x1); and one treatment with the HBO18 protocol followed by two additional HBO10 treatments (HBO18/10/10). The choice of protocol was not systematically influenced by any criteria, nor was the patient's clinical condition, exposure history, symptom

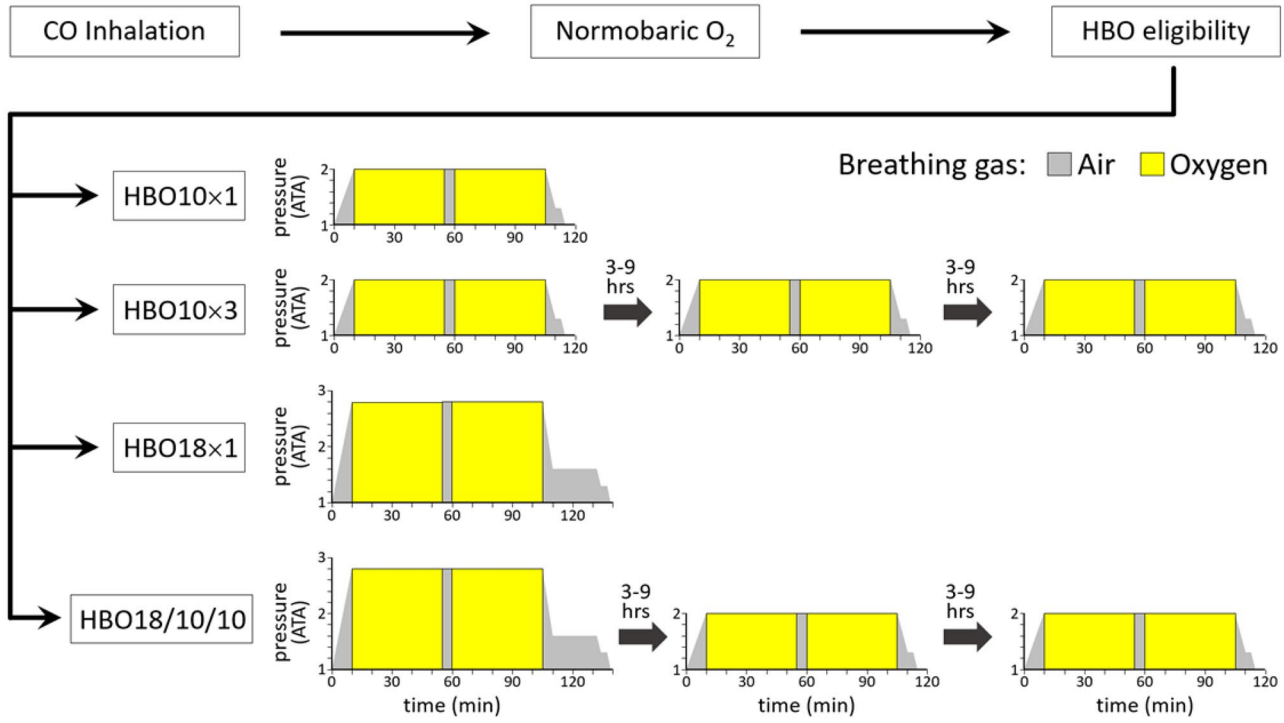

Figure 1. Treatment protocols. *Abbreviations: HBO: hyperbaric oxygen.*

severity or laboratory values an indication for any particular treatment.

Outcome measure

The primary outcome was DNS frequency, as determined by a structured review of the patient's medical record. During this review, we also abstracted the signs and symptoms present on patient arrival from the emergency department notes. To account for baseline chronic symptoms before exposure, the patients' past medical histories were reviewed to establish a baseline neurological and psychiatric status. Delayed neuropsychiatric sequelae was defined as the development of new or a clear worsening of neurological or psychiatric symptoms after an initial period of clinical improvement (lucid interval) following the acute CO poisoning episode, occurring within 2–40 days of the index presentation, and not attributable to an alternative diagnosis.

Two trained physician reviewers, blinded to the HBO regimen and clinical presentation, independently reviewed the electronic medical records, including emergency department notes, inpatient progress notes, discharge summaries, neurology and psychiatry consultations, and follow-up outpatient clinic documentation. The reviewers abstracted specific clinical diagnoses and symptoms documented by the treating providers, rather than relying on billing diagnosis codes. They looked for reported cognitive (cDNS; specifically memory impairment, concentration difficulties, and executive dysfunction), motor (mDNS; specifically dysarthria, gait disturbances, movement disorders, and focal deficits) or psychiatric (pDNS; specifically depression, anxiety, psychosis, and affective changes) symptoms.

The presence of at least one such symptom defined DNS, which was the primary outcome in this study. The presence of cDNS, mDNS and pDNS were the secondary outcomes. For patients who developed DNS, treatment was generally supportive and symptom-directed, managed by the consulting specialists. Reviewer disagreements were resolved by consensus.

Statistical analysis

Patient characteristics (Table 1) were summarized overall and by group (HBO regimen) using appropriate descriptive statistics (means and standard deviations or medians and interquartile ranges for continuous variables; counts and percentages for categorical variables). Group differences in baseline variables were assessed via ANOVA or Kruskal–Wallis tests for continuous data and chi-square or Fisher's exact tests for categorical data, as appropriate. The primary analysis compared the incidence of DNS among the four HBO regimens using chi-square tests. Pairwise post-hoc comparisons with Bonferroni correction were planned if the overall test was significant.

Table 1. Baseline characteristics by treatment group.

Variable	Overall, $n=312$	HBO10x1, $n=87$	HBO10x3, $n=54$	HBO18x1, $n=102$	HBO18/10/10, $n=69$	P
Age mean (±SD)	33 (±18)	31 (±18)	35 (±16)	32 (±21)	37 (±14)	0.054
Type of exposure						
Waterpipe	203 (65%)	65 (75%)	34 (63%)	63 (62%)	41 (59%)	0.16
Home heating	26 (45%)	7 (8.0%)	11 (20%)	6 (5.9%)	2 (2.9%)	0.003
Car exhaust	14 (4.5%)	4 (4.6%)	1 (1.9%)	7 (6.9%)	2 (2.9%)	0.5
Fire	33 (11%)	8 (9.2%)	4 (7.4%)	10 (9.8%)	11 (16%)	0.4
Home cooking	35 (11%)	3 (3.4%)	3 (5.6%)	16 (16%)	13 (19%)	0.004
Presenting symptom						
Syncope	201 (64%)	55 (63%)	44 (81%)	59 (58%)	43 (62%)	0.030
Headache	139 (45%)	50 (57%)	16 (30%)	48 (47%)	25 (36%)	0.005
Nausea	74 (24%)	30 (34%)	5 (9.3%)	33 (32%)	6 (8.7%)	<0.001
Dizziness	125 (40%)	29 (33%)	29 (54%)	34 (33%)	33 (48%)	0.024
Seizures	12 (3.8%)	3 (3.4%)	6 (11%)	0 (0%)	3 (4.3%)	0.004
Incontinence	5 (1.6%)	2 (2.3%)	0 (0%)	0 (0%)	3 (4.3%)	0.072
COHb % (±SD)	25 (±10)	22 (±9)	26 (±9)	24 (±11)	27 (±8)	0.002
Elevated troponin[a]	6 (1.9%)	4 (4.6%)	0 (0%)	1 (1.0%)	1 (1.4%)	0.3
Time from exposure to normobaric oxygen hours, median [IQR]	1.0 [1.0–2.5]	1.0 [1.0–2.4]	1.5 [0.8–2.6]	1.0 [1.0–1.9]	1.2 [1.0–4.0]	0.10
Time from exposure to carboxy hemoglobin measurement hours, median [IQR]	3.6 [2.5–5.0]	3.5 [2.8–4.9]	3.6 [2.5–4.7]	4.1 [2.5–6.1]	3.3 [2.1–5.0]	0.5
Time from exposure to hyperbaric oxygen hours, median [IQR]	5.5 [4.0–7.5]	5.9 [4.7–7.6]	5.2 [3.9–7.5]	5.5 [3.1–7.4]	5.5 [4.3–8.0]	0.7
Time between 1st and 2nd session hours, median [IQR]	8.6 [7.2–10.6]	NA	8.6 [7.2–10.4]	NA	8.6 [7.1–10.7]	0.8
Time between 2nd and 3rd session hours, median [IQR]	8.0 [6.4–12.8]	NA	7.5 [6.3–12.5]	NA	8.3 [6.5–12.8]	0.5

Abbreviations: COHb - Carboxy hemoglobin percentage.
[a]Elevated troponin was defined as a value exceeding the 99th percentile upper reference limit of the specific assay in use at the time of presentation.

Multivariable logistic regression was then used to estimate adjusted odds ratios for DNS associated with each regimen, using one regimen as the reference, and adjusting a priori for potential confounders including age, clinical presentation, initial carboxyhemoglobin level, and treatment latency. To isolate the independent effects of treatment intensity versus treatment frequency, the multivariate model decomposed the treatment groups into two binary variables: HBO pressure (High versus Low) and session count (Single versus Multiple), rather than treating the four protocols as a single nominal variable. A sensitivity analysis for this approach, treating each of the four treatment groups as distinct nominal variables, is presented in the Supplementary Material. Briefly, when analyzed separately with HBO10x1 as the reference, the higher-pressure regimens still demonstrated lower odds of DNS, although the diminished sample sizes reduced statistical power (HBO18/10/10 adjusted OR = 0.41, $P=0.029$; HBO18x1 adjusted OR = 0.51, $P=0.053$; HBO10x3 adjusted OR = 1.07, $P=0.9$). Model fit and multicollinearity were assessed using standard diagnostics. All tests were two-sided with a significance threshold of $P<0.05$, and analyses were performed using R 4.2.1.

Results

A total of 320 patients referred for hyperbaric oxygen (HBO) therapy following carbon monoxide poisoning between January 1, 1995, and December 31, 2024, were assessed for eligibility. Of these, eight patients (2.5%) were excluded from the study: three patients refused therapy, three patients did not comply with the full treatment course, and the medical records for two patients were unavailable. Of the 312 patients included in the final analysis, 87 were treated with the HBO10x1 protocol, 54 with HBO10x3, 102 with HBO18x1 and 69 with HBO18/10/10. The patient selection process is presented in Figure 2.

The sample consisted of 312 patients with a mean age of 33 (±18) years. There were no statistically significant differences in age across the four groups ($P=0.054$). Waterpipe smoking was the predominant source of CO exposure, accounting for 65% of all cases, with a similar percentage in all groups ($P=0.16$). However, significant variations were observed in other exposure types, specifically home heating ($P=0.003$) and home cooking ($P=0.004$), the latter being more prevalent in the HBO18 groups. On admission, mean carboxyhemoglobin (COHb) levels differed statistically across the groups ($P=0.002$), ranging from a low of 22% (±9) in the HBO10x1 group to a high of 27% (±8) in the HBO18/10/10 group, and there was no significant difference in the time from exposure to COHb measurement in all four groups. Clinical symptoms at presentation varied significantly across groups: Syncope was the most common symptom (64%) and was most frequent in the HBO10x3 group (81%; $P=0.030$).

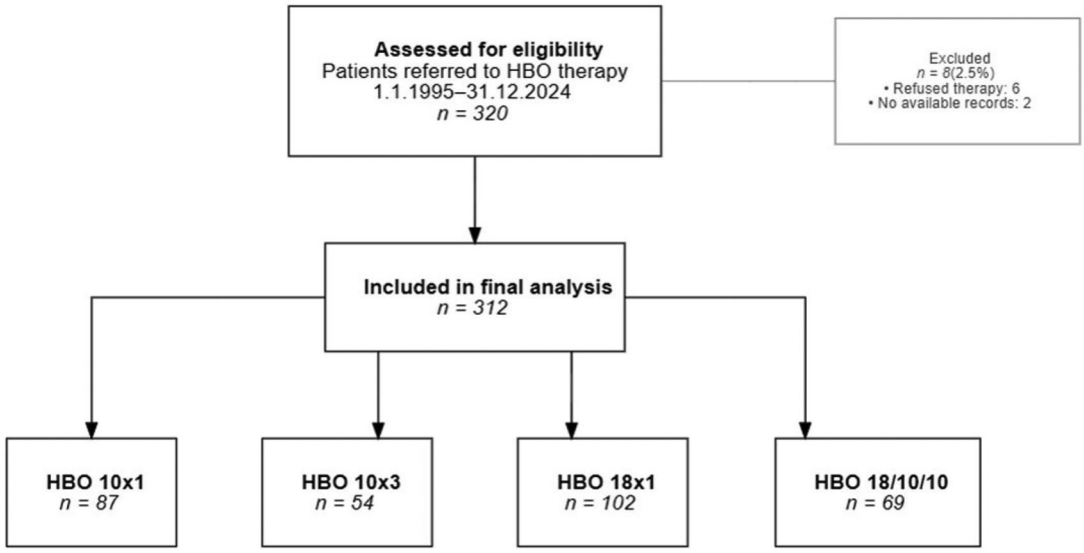

Figure 2. STROBE Diagram. The patient selection process is presented in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines. *Abbreviations: HBO: hyperbaric oxygen.*

Seizures occurred only before ED presentation and were rare (3.8% overall) but were significantly more prevalent in the HBO10x3 group (11%; $P=0.004$). Interestingly, nausea was reported more often in patients assigned to single-session protocols (34% in HBO10x1 and 32% in HBO18x1), compared to those receiving three sessions (<10% in both multi-session groups; $P<0.001$). Importantly, there were no significant differences in the time elapsed from exposure to the administration of normobaric oxygen ($P=0.10$) or to the initiation of hyperbaric therapy ($P=0.7$). See Table 1.

Regarding the safety of these protocols, adverse effects were minor across all treatment groups, limited primarily to mild sinus or middle ear discomfort during the pressurization phase. Notably, there were no documented cases of central nervous system oxygen toxicity or significant barotrauma in any of the patients.

The incidence of Delayed Neurological Sequelae (DNS) varied significantly across the four treatment protocols ($P=0.011$). In the lower-pressure groups, the rate of DNS was notably high, affecting 36% of patients in the HBO10x1 group and 37% in the HBO10x3 group. In contrast, patients treated with the higher-pressure protocols exhibited significantly lower rates of DNS, with incidence dropping to 20% in the HBO18x1 group and 19% in the HBO18/10/10 group, as shown in Figure 3. In the combined lower-pressure group (HBO10, comprising both single- and multi-session protocols), 51 out of 141 patients (36.2%) developed DNS, compared with 33 out of 171 patients (19.3%) in the combined HBO18 group ($P=0.0013$). When combining the treatment groups by the number of sessions (once versus thrice), the rates of DNS are similar (51/189 versus 33/123, or 26.9% versus 26.8%), as depicted in Figure 4.

When analyzing the incidence of specific DNS subtypes, cognitive and psychiatric deficits followed a similar pressure-dependent pattern. Cognitive DNS was the most prevalent subtype, affecting approximately 30-31% of patients in the HBO10 groups, compared to only 16-18% in the HBO18 groups ($P=0.044$). Psychiatric DNS was also significantly more frequent in the lower-pressure groups, observed in 26% of HBO10x1 and 30% of HBO10x3 patients, versus 15% and 12% in the HBO18x1 and HBO18/10/10 groups, respectively ($P=0.016$). Motor DNS was rare, affecting only 6.7% of the sample. Unlike cognitive and psychiatric outcomes, the incidence of motor deficits was similar across all groups (ranging from 5.7% to 7.4%) with no statistically significant differences observed ($P>0.9$). See Figure 3.

To isolate the effect of hyperbaric dosing pressure on DNS, a multivariate logistic regression model was constructed to adjust for potential confounders, including age, carboxyhemoglobin levels (COHb), number of sessions, and presenting symptoms (syncope, headache, nausea/vomiting, dizziness, and seizures). After adjusting for these covariates, the protective effect of the higher pressure protocol remained statistically significant. Patients treated with the HBO18 protocols had 58% lower odds of developing DNS compared to those treated with the HBO10 protocols (adjusted OR = 0.45; 95% CI: 0.26–0.77; $P=0.004$). Conversely, the number of treatment sessions was not significantly associated with the incidence of DNS (adjusted OR =

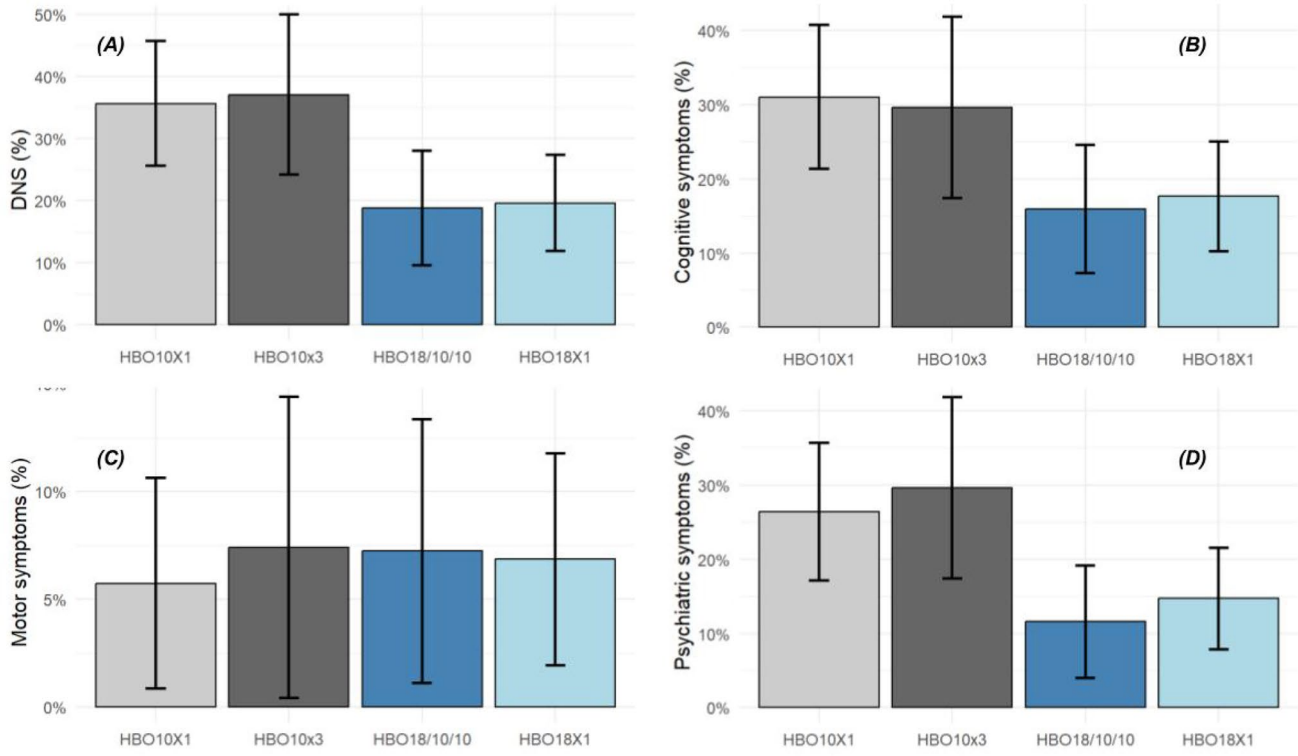

Figure 3. Delayed neuropsychiatric sequelae by treatment group. Incidence of delayed neuropsychiatric sequelae, by treatment group. (A) any symptom; (B) cognitive symptoms;, (C) motor symptoms; (D) psychiatric symptoms. Abbreviations: DNS: Delayed neuropsychiatric sequelae.

0.96; 95% CI: 0.53–1.71, $P=0.9$). Patients who presented with seizures exhibited more than a four-fold increase in the odds of developing DNS compared to those without seizures (adjusted OR = 4.27; 95% CI: 1.24–15.8; $P=0.023$). Other analyzed variables, including patient age ($P=0.12$) and initial carboxyhemoglobin levels ($P>0.9$), did not demonstrate a statistically significant association with the incidence of DNS, nor did any of the other recorded presenting symptoms. These findings are presented in Table 2.

Discussion

In this retrospective analysis of 312 patients treated for acute carbon monoxide poisoning, we identified a significant relationship between the hyperbaric oxygen pressure administered and the incidence of DNS. Our primary finding is that a treatment protocol utilizing a higher partial pressure of oxygen (2.8_{ATA}) HBO18 was associated with a 55% reduction in the odds of developing DNS, compared to a lower-pressure protocol (2.0_{ATA}) HBO10, independent of the number of sessions administered.

The physiological rationale for this finding likely lies in the complex pathophysiology of CO toxicity, which extends beyond simple competitive binding with hemoglobin. CO induces a cascade of mitochondrial dysfunction, lipid peroxidation, and neutrophil activation leading to immune-mediated reperfusion injury. Animal models have demonstrated that the clearance of CO from cytochrome C oxidase and the inhibition of lipid peroxidation are directly proportional to the PO_2 [13]. Additionally, higher-pressure HBO treatment more effectively suppresses inflammatory cascades and apoptosis, and upregulates neurotrophic factors such as brain-derived neurotrophic factor, which are essential for neuronal survival and repair [14]. It is plausible that 2.0_{ATA} does not achieve the sufficient partial pressure required to effectively interrupt this inflammatory cascade in the critical early window, whereas 2.8_{ATA} exceeds the necessary threshold. If the "therapeutic threshold" to halt the neurological injury is not met during the first session, subsequent sessions at sub-therapeutic pressures may offer diminishing returns. The crucial importance of the first session is supported by multiple evidence of the strong inverse association between first HBO session latency and DNS [6,15].

Conversely, increasing the frequency of treatment from one to three sessions did not confer a statistically significant protective benefit in our cohort. The seminal trial by Weaver et al. (2002) [3], which established the efficacy of HBO in preventing cognitive sequelae,

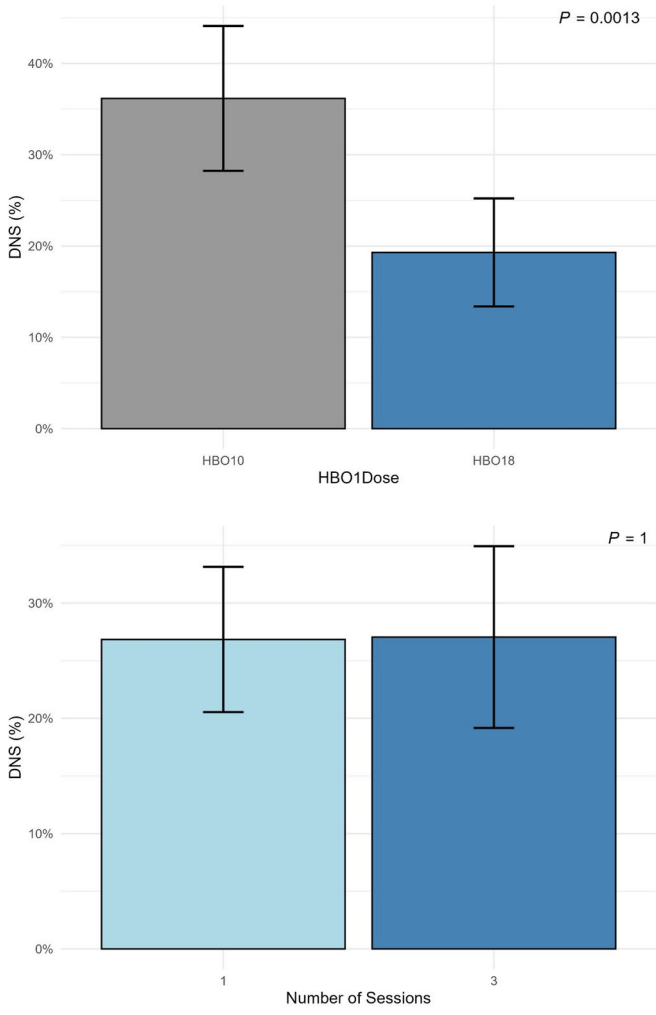

Figure 4. Delayed neuropsychiatric sequelae by aggregated treatment group. The incidence of delayed neuropsychiatric sequelae is presented by treatment dose and number of sessions. Abbreviations: DNS: Delayed neuropsychiatric sequelae.

Table 2. Logistic regression univariate and multivariate logistic regression analysis of factors associated with the development of delayed neuropsychiatric sequelae (DNS).

	Univariate logistic regression			Multivariate logistic regression		
Characteristic	Or	95% CI	*P*	Or	95% CI	*P*
Age	1.01	0.99–1.02	0.2	1.01	1.00–1.03	0.12
Syncope	0.80	0.48–1.35	0.4	0.70	0.39–1.24	0.2
Headache	1.26	0.76–2.09	0.4	1.29	0.69–2.41	0.4
N/V	1.10	0.61–1.95	0.7	0.93	0.46–1.83	0.8
Dizziness	1.02	0.61–1.70	>0.9	0.89	0.50–1.56	0.7
Seizures	4.05	1.26–14.1	0.020	4.27	1.24–15.8	0.023
COHb	0.99	0.97–1.02	0.6	1.00	0.97–1.03	>0.9
HBO Dose						
10	–	–		–	–	
18	0.42	0.25–0.70	<0.001	0.45	0.26–0.77	0.004
Number of Sessions	1.01	0.78–1.30	>0.9	0.98	0.73–1.31	0.9
1	–	–		–	–	
3	1.01	0.60–1.68	>0.9	0.96	0.53–1.71	0.9

Abbreviations: COHb: Carboxy hemoglobin percentage, OR: odds ratio, CI: confidence interval, N/V: nausea and vomiting.

utilized a regimen of three sessions within 24 h However, a recent prospective randomized study by Weaver et al. (2023) [16] did not find a difference between one and three sessions. Our finding is also in line with other observational evidence showing no additional benefit to more than one [6,15], or beyond three [17] HBO sessions.

Our analysis also reaffirmed the prognostic significance of initial clinical presentation. The presence of seizures on admission was the strongest individual predictor of poor outcome, increasing the odds of DNS by more than fourfold, in line with previous observational findings [6,15]. Importantly, the protective effect of the high-pressure (HBO18) protocols remained statistically significant even after adjusting for seizures and other markers of severity in the multivariate model. This suggests that high-pressure HBO is beneficial even – and perhaps especially – for highest-risk patients.

Limitations

This study is limited by its retrospective design and non-random allocation of treatment. Although we

adjusted for observable confounders such as age, COHb levels, and presenting symptoms, residual confounding by indication cannot be completely ruled out. However, this selection bias would typically skew results against the more aggressive treatment; the fact that our high-dose groups achieved superior outcomes despite potentially higher baseline severity strengthens the validity of the association. Additionally, our reliance on chart review means we likely detected only clinically overt DNS. Subtle cognitive deficits detectable only by standardized psychometric testing (e.g., neurocognitive batteries) may have been underreported.

Conclusion

Our findings suggest that the therapeutic efficacy of hyperbaric oxygen in preventing delayed neurological sequelae may be driven primarily by the partial pressure of oxygen, rather than by the number of treatment sessions. Protocols utilizing 2.0_{ATA} HBO10 may be suboptimal for neuroprotection, regardless of repetition. Future prospective trials should focus on optimizing the initial hyperbaric dose, potentially establishing $2.8–3.0_{ATA}$ as the minimum standard for acute CO poisoning.

Author contributions

IG conceptualized the study. IG and AS collected data. IG and YN devised the methodology, performed the statistical analysis, and wrote this manuscript.

Ethical approval

This study was conducted according to the Declaration of Helsinki. The human study was approved by our institutional ethics committee (approval #RMB-2024-0589).

Disclosure statement

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ORCID

Ivan Gur http://orcid.org/0000-0001-7702-2599

Data availability statement

Data is available upon request at ostyly@gmail.com

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