Hyperbaric oxygen for the treatment of carbon monoxide-induced delayed neurological sequelae: a case report and review of the literature

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Abstract
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Introduction: Hyperbaric oxygen treatment (HBOT) remains a recognised treatment for acute carbon monoxide (CO) poisoning, but the utility of HBOT in treating CO-induced delayed neurological sequelae (DNS) is not yet established.
Case description: A 26-year old woman presented with reduced consciousness secondary to CO exposure from burning charcoal. She underwent a single session of HBOT with US Navy Treatment Table 5 within six hours of presentation, with full neurological recovery. Eight weeks later, she represented with progressive, debilitating neurological symptoms mimicking Parkinsonism. Magnetic resonance imaging of her brain demonstrated changes consistent with hypoxic ischaemic encephalopathy. The patient underwent 20 sessions of HBOT at 203 kPa (2 atmospheres absolute) for 115 minutes, and received intravenous methylprednisolone 1 g per day for three days. The patient's neurological symptoms completely resolved, and she returned to full-time professional work with no further recurrence.
Discussion: Delayed neurological sequelae is a well-described complication of CO poisoning. In this case, the patient's debilitating neurocognitive symptoms resolved following HBOT. Existing literature on treatment of CO-induced DNS with HBOT consists mainly of small-scale studies and case reports, many of which similarly suggest that HBOT is effective in treating this complication. However, a large, randomised trial is required to adequately determine the effectiveness of HBOT in the treatment of CO-induced DNS, and an optimal treatment protocol.

Introduction

Carbon monoxide (CO) poisoning affects an estimated 50,000 people and causes more than 1,000 deaths annually in the US.[1] In Singapore, the incidence of CO poisoning is low.[2] Most cases are caused by faulty vehicles and house fires, with a small proportion due to workplace accidents.[3,4] Besides acute signs and symptoms, up to 46% of patients with CO poisoning may also manifest delayed neurological sequelae (DNS) weeks to months after acute poisoning, including changes in personality, cognitive disturbances, disordered motor movement and focal neurological deficits.[5,6]

Aside from potentially reducing mortality in patients with acute CO poisoning,[7] hyperbaric oxygen treatment (HBOT) has been associated with a reduced incidence of DNS.[8] HBOT has also been reported as a potential treatment modality for DNS.[9] We report a case of CO-induced DNS successfully treated with HBOT, and assess the utility of HBOT for the prevention and treatment of CO-induced DNS.

Case report

A 26-year-old professional working woman with a background history of depression was brought to the emergency department after being found unconscious in an enclosed space next to a tank of burning charcoal. On arrival, she was haemodynamically stable but was drowsy and confused, with a Glasgow Coma Scale of 11 (Eye 3 Verbal 3 Motor 5) and a carboxyhaemoglobin level of 24%. Within six hours of discovery, she was treated with US Navy Treatment Table 5 (USN TT5) as per the HBOT protocol at our centre. Post-procedure, she regained her full mental faculty which allowed her to verbalise her left lower leg weakness and gluteal pain. Magnetic resonance imaging demonstrated bilateral gluteal myositis with left compressive sciatic neuropraxia, which was attributed to prolonged immobility in the supine position on the hard floor. This was complicated by severe rhabdomyolysis requiring medical management. On day seven of admission, she was transferred to a private healthcare institution for continuation of psychiatric care.

Table 1

Detailed neuropsychological assessment; neuropsychological assessment demonstrated significant impairment in multiple tested domains of general intelligence, executive function, attention and working memory, language, verbal memory, visuospatial, construction, and processing speed. RAVLT – Rey auditory verbal learning test; sec – seconds; WAIS – Wechsler adult intelligence scale

Domain	Test	Score/Percentile	Range
General intelligence	Advanced progressive matrices	2 out of 12	–
Executive function	Trail making test – B	215 sec (discontinued)	–
	Stroop: dots	< 1.00%	Extremely low
	Stroop: neutral words	9.2%	Low average
	Stroop: colour words	4.7%	Very low
	Stroop: colour words / dots	50.0%	Average
Attention and working memory	Digit Span	62.9%	Average
	Spatial Span	2.3%	Very low
Language	Controlled oral word association test	30%	Average
	Verbal fluency: Animals	75%	High average
	Modified Boston naming test 30 items	28 out of 30	Average
Verbal memory (RAVLT)	Trial A1	69.1%	Average
	Trial A5	14.8%	Low average
	Learning trial A1-A5	72.2%	Average
	Immediate recall (A6)	18.9%	Low average
	Delayed recall (A7)	75.9%	High average
	Delayed recognition	37.7%	Average
Visuospatial (WAIS)	WAIS-III block design test	4.7%	Very low
Construction	Clock drawing test	5%	Very low
Processing speed	Trail making test – A	< 10.0%	Low average
	Symbol search	0.1%	Extremely low

Eight weeks after her initial presentation, she presented again with progressive decline in her motor and cognitive function. On assessment, she exhibited new onset neurological disturbances with disorientation, inattention, and Parkinsons-like features including gait unsteadiness, hand tremors, bradykinesia, and apraxia. Coupled with her severe left chronic sciatic pain which evolved from her left sciatic neuropraxia, she was wheelchair-bound and unable to perform basic functional tasks and activities of daily living (ADLs). Her detailed neuropsychological assessment is presented in Table 1.

Magnetic resonance imaging (MRI) of her brain demonstrated diffuse white matter signal abnormalities within both cerebral hemispheres consistent with hypoxic ischaemic encephalopathy.

The attending neurologist started her on intravenous methylprednisolone 1 g per day for three days without improvement. Her psychiatric medications were also stopped, although those were not known to be associated with extrapyramidal side effects. Hyperbaric medicine input was sought after a week of failed inpatient management. With a working diagnosis of CO-induced DNS, and with no other cause identified and no alternative treatment options, the patient was offered a trial of HBOT at 203 kPa (2 atmospheres absolute) for 115 min, which is the treatment protocol routinely conducted for wound care in our centre. She underwent a total of 20 HBOT sessions, demonstrating progressive improvement in her symptoms. At completion, she had regained independence in her activities of daily living, full resolution of her neurocognitive deficits, marked improvement in her chronic sciatic pain, and was able to mobilise independently and return to full-time professional work with no further recurrence.

Discussion

RADIOLOGICAL FINDINGS IN CO POISONING AND DNS

Radiological abnormalities of the globus pallidus and deep white matter are known to be associated with acute CO poisoning and similarly have been reported in patients with

CO-induced DNS.[10,11] A prospective observational study reported the presence of acute brain lesions on diffusion-weighted imaging to be an independent predictor of DNS.[12]

While our patient declined further interval and follow-up neuroimaging given the clinical improvement and subsequent full resolution of her neurological symptoms, similar studies have documented interval reduction in radiological abnormalities on serial MRI scans, in tandem with clinical improvements following prolonged treatment with HBOT.[13,14] This suggests that MRI may present a quantitative method to monitor and assess treatment response in patients with CO-induced DNS.

HBOT FOR PREVENTION OF DNS

The effects of HBOT on the prevention of DNS remain uncertain in the literature. Some studies showed a reduced risk,[5] while others conversely reported a higher risk of developing DNS with HBOT compared to normobaric oxygen therapy (NBOT).[15] A Cochrane review in 2011[16] presented a pooled analysis of six randomised controlled trials (RCTs) suggesting no statistically significant difference in DNS incidence between patients treated with HBOT versus NBOT. Notably, the only HBOT RCT meeting CONSORT criteria demonstrated a significant reduction in the incidence of DNS in CO poisoned patients treated with HBOT.[5] For our patient, due to more pressing medical management, she was only able to undergo one session of HBOT within a 24-hour period as compared to the three HBOT sessions as advocated by Weaver.[5] The patient's severe rhabdomyolysis was also suggestive of a prolonged duration of non-fatal CO exposure, which may have translated to increased cerebral insult. These two factors may have further contributed to her marked DNS manifestation despite full neurological recovery following HBOT in her initial presentation.

HBOT FOR TREATMENT OF DNS

From a review of the literature, no large-scale studies have investigated therapeutic outcomes of DNS patients treated with HBOT. In the available reports, Parkinsons-like symptoms are frequently described as part of the DNS spectrum with resolution post-HBOT. One series of nine patients reported that HBOT decreased the severity of impairment in patients with DNS.[9] While this finding is similarly supported in our case report, as well as other small series,[14,17] a large, randomised trial is required to adequately determine the effectiveness of HBOT in the treatment of DNS, as well as to recommend an optimal treatment protocol.

Conclusion

Delayed neurological sequelae is an established and potentially debilitating complication of CO poisoning. While HBOT remains a recommended treatment for acute CO poisoning, there are few reports of its efficacy in the treatment of CO-induced DNS.

This case report suggests that despite the lack of robust evidence for the use of HBOT in CO-induced DNS, it may still be very worthy of consideration, as our patient who was completely debilitated by her neurocognitive symptoms and severe chronic pain was able to regain full independence and function as an active member of her profession. Our experience in this case suggests that the possible benefits outweigh the relatively low risks of HBOT. However, more work needs to be done to quantify the effectiveness of HBOT in the treatment of CO-induced DNS, and define an optimal HBOT protocol.

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