Coma Reversal and Functional Recovery after Hyperbaric Oxygen Therapy and Rehabilitation in the Subacute Phase of Carbon Monoxide Poisoning: A casereport and Literature Review

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Coma Reversal and Functional Recovery after Hyperbaric Oxygen Therapy and Rehabilitation in the Subacute Phase of Carbon Monoxide Poisoning: A Case Report and Literature Review

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Hyperbaric oxygen (HBO) effectively decreases the morbidity and mortality of carbon monoxide poisoning . Immediate HBO treatment is indicated as it yields a more rapid and greater neuropsychological recovery. HBO significantly decreases the half life of carboxy hemoglobin (COHb) and increases the tissue clearance of residual carbon monoxide, thus decreasing the neuropsychological deficit. HBO enhances the outcome even in the subacute phase of CO poisoning as in this case. A thirteen year old girl was admitted to our hospital in a deep coma after severe CO poisoning from gas leakage and was referred for HBO treatment one month after carbon monoxide poisoning. She was administered and received the second course of HBO 8 months later . Ten months after carbon monoxide poisoning, she regained consciousness but remained mute. After four weeks of rehabilitation she started talking. Her speech was coherent and relevant. However, her thought content was childish and superficial. She became partially independent in daily activities. Based on this case study, we highly recommend HBO therapy and intensive rehabilitation in the management of an acute and subacute CO poisoning patient with serious neurological sequelae. (J Rehab Med Assoc ROC 2000; 28(3): 163 – 170)

Key words: hyperbaric oxygen, normobaric oxygen, carbon monoxide poisoning, activities of daily living

INTRODUCTION

Carbon monoxide poisoning accounts for the majority of accidental and suicidal morbidity and mortality worldwide [1,2] including Taiwan [3]. Hyperbaric oxygen (HBO) therapy yields a more rapid and better neuropsychologic recovery [3-10]. Thus, immediate HBO treatment [11-13] is preferred. However, the end point of the therapeutic window is unclear. The following question arises: when does HBO become ineffective in managing carbon monoxide poisoning ? Previous investigations have examined coma reversal and neuropsychological recovery after HBO therapy in the subacute phase [14-17], up to one month of CO poisoning. In this article, we report on a thirteen year old girl who regained consciousness from a

deep coma about ten months after carbon monoxide poisoning and regained speech about fourteen months after carbon monoxide poisoning. She received two courses of repetitive HBO and intensive rehabilitation.

CASE REPORT

On August 19, 1997, a thirteen year old girl was admitted to the Emergency Department of our hospital after severe carbon monoxide poisoning. She had been found unconscious with urine and stool incontinence. Her family had left her unattended for four hours before discovering her condition. She had not attempted suicide. After advanced cardiac life support ACLS, 100% normobaric oxygen was administered via endotracheal tube. During hospitalization, she had experienced some complications: such as upper gastrointestinal bleeding, increased intracranial pressure, seizure and pneumonia; they were dealt with expediently. After remaining in a deep coma throughout her one month hospitalization, she was transferred for HBO therapy with GCS: $E_4M_2V_1$. She received two courses of repetitive HBO in October 1997 and May 1998, respectively.

Around June 1998 she regained consciousness, but remained mute and had minimal facial expressions. She gradually improved and could eventually cooperate a little. She could comply with keeping her nasogastric tube on. She responded to simple commands such as "grasp my hand" and "Close your eyes". Hence, she began intensive rehabilitation on September 25 1998.

Upon admission, she was a pleasant girl, capable of maintaining good visual contact but having a poor attention span. She was restrained to a wheelchair to prevent catapulsion caused by extension spasticity in her legs. She had no head, trunk or limb control. Her deep tendon reflexes were generally increased with bilateral positive Hoffman and Babinski signs, as well as sustained ankles clonus. Her feet showed severe plantar flexion and supination tightness. She was double hemiplegic with her left side weaker and less coordinated than the right. Her hand functions were limited to a weak and coarse grasp below the shoulder level. She manifested emotional incontinence with a loud, prolonged cry under minimal stress.

The patient then underwent intensive comprehensive rehabilitation with physical, occupational and speech therapies and therapeutic games. A task-oriented approach [18] was adopted. Our long term rehabilitation goal was social reintegration in a wheelchair if she does not regain ambulation. Our short term goal was to increase her mobility and independence in activities of daily living, thus improving her quality of life. Therapy involved stretching her tight ankle joints and soft tissues with modalities such as ultrasound when required. Standing activities were undertaken on tilt able, and progressed to static standing with gaiters. Psychosocial stimulation was also included in her therapy. After four weeks of rehabilitation, she started talking and singing in a low voice. Her other functions also improved. For instance, she could stand with support for forty minutes. She could push a wheelchair while walking with trunk support for about twenty meters with much coaxing. She could perform light hygiene tasks, as well as groom and feed herself with a spoon. She could make very simple additions. However, she remained infantile with poor insight, foresight and coping strategies. She had low tolerance for physical or psychological stress, poor motivation and required much coaxing. Thus, more laborious tasks or evaluations failed. Bladder training by intermittent clean catheterization failed even though she had an upper motor neurogenic bladder. She would cry when seated on the toilet despite coaxing and explanations as to the benefits and pleasures of voiding control. Because her family could not participate in her rehabilitation program, she was discharged partially independent in ADL.

Tables 1 and 2 summarized relevant findings.

DISCUSSION

Carbon monoxide is a colorless, odorless and tasteless gas produced by incomplete combustion of hydrocarbon such as faulty heating systems with poor ventilation, and exhaust fumes in a closed garage. Methylene chloride in a paint remover when adsorbed through the skin is converted to carbon monoxide, possibly causing covert [19] cumulative carbon monoxide poisoning. Thus, CO can kill overtly as in flames or covertly as when the patient unintentionally inhales a large enough dose acutely or a small dose on a long cumulative basis. CO causes widespread tissue damage [5,20], most critical in the

central nervous system and the cardiovascular system. CO poisoning may cause cardiac arrest, cardiac ischemia (as in this case) and dysrhythmia. In the central nervous system, CO can cause coma, high cortical dysfunction, e.g. apraxia, agnosia, aphasia, extrapyramidal dysfunction such as choreoathetosis and seizures, and behavioral dysfunction such as psychosis, and abulia apathy. Mild CO poisoning produces 'Flu' like non-specific symptoms and signs such as headache, confusion, clumsiness, and hysteria. Thus, carbon monoxide can harm or kill overtly or covertly, acutely or produce late sequelae. CO coma is a unique type of anoxia , and is often followed by recurrent or delayed neurological deficit in 40% normobaric oxygen (NBO) treated subjects, and occurs two to forty days after initial CO poisoning [21-23].

Table 1. Relevant data

Emergency ward	BP	100/40 mmHg
	RR	24/minute
	GCS	$E_2M_2V_1$
	Pupils	4./4.5 mm
	L/R +/+	Sluggish
	COHb	62.2%(then down to 1% after 100% normobaric oxygen therapy)
	Glucose	413 mg%
	PH	7.4
	K^+	2.8 mEq/L
	CKMB	37U
	CK	>1818 U
	LDH	862 U
	EKG	ST depression in V4 V5
	EEG	Severe diffuse cortical dysfunction
	Brain CT	Diffuse brain edema
	Brain CT (fig 1,2) (Eight days later)	Intracerebral hemorrhage in bifrontal areas and gray-white matter junctions
	SPECT 1997,12/8	Bifrontal perfusion defects compatible with hypoxic encephalopathy
	SPECT 1998,10/30	Resolution of bifrontal perfusion defects
	MR T_2 images 1997,12/10 (fig 3, 4)	Bilateral symmetric confluent high intensity in the periventricular white matter, centrum semiovale, may comply with demyelination
	MR T2 images 1998,10/24 (fig 5, 6)	Decrease in extent of above mentioned bilateral high intensity. Increase bilateral ventricles including 3rd ventricle

Table 2.   Summary of the patient's clinical course

Date	Physical findings and symptoms
1997/8/19	$E_2M_2V_1$ Emergency Department
1997/9/22	$E_4M_2V_1 \leqq 1^{st}$ Course HBO
1998/4/27	$E_4M_4V_1 \leqq 2^{nd}$ Course HBO
1998/6 around	Awakes from coma, mute ,spastic double hemiplegia(left>right)
1998/9/24 10 months >CO poisoning	Begin rehabilitation Mute, no control of head and trunk, severity left > right
1998/10/21 >1 month Rehabilitation	Talks
1998/10/27 >6 weeks Rehabilitation	Discharged from Rehabilitation Dept. Talks + ADL partially independent , pushing wheelchair for a short distance

SPECT in our patient displayed severe bifrontal perfusion defects that partially resolved with her clinical improvement, which correlates with other reports [24-25].

T2 weighted MR images [26] in delayed encephalo-pathy of CO poisoning patient reveal bilateral symmetrical confluent high signal intensity in the periventricalar white matter and centrum semiovale. This high intensity signal extends through the corpus callosum, subcortical U fibers, external and internal capsules. Ischemia or necrosis of the globus pallidus are also observed in severe CO poisoning. Bilateral symmetrical putamen and thalamus ischemia may also be noted. Such changes decrease with clinical improvement. The above findings imply that CO-related delayed encephalopathy is a reversible demyelination [26]. Our case also demonstrated the above reversible demyelination changes (Fig. 3-6). Globus pallidus isch-emia is the hallmark of ischemic hypoxic process in arterial border zone found on CT scan [27]. Ginsberg [28] postulated that the morphological changes represent gradations in intensity of a pathological process rather than distinct pathologic processes.

The exact pathophysiology of carbon monoxide mediated poisoning is complex and not well understood [5,20]. The relative affinity of carbon monoxide for hemoglobin is two hundred times that of oxygen[4]. Thus, carbon monoxide significantly decreases the oxygen transport and delivery at tissues. However, cellular oxygen supply disturbance by itself can not account for CO poisoning. Haldane [29] in 1927 demonstrated that animals breathing oxygen at 3 atmosphere absolute (ATA) could be poisoned at sufficiently high CO levels. Such poisoning could occur even though these animals were totally oxygenated under hyperbaric conditions with adequate oxygen dissolved in their plasma to support all their metabolic needs. Neither can cytochrome system dysfunction elucidate CO poisoning. In 1951, Ball [30] found that the cytochrome A_3 oxidase system preferentially combines with oxygen in a 9 to 1 ratio over CO in beef heart extract. Thus, understanding the pathomechanics of CO poisoning appears to be through defining CO biochemistry in vivo .However, the exact biochemical changes of CO poisoning remains unclear. Related investigations have pointed out the involvement of ischemia related brain damage [27-28,31-34]. Thom recently indicated that CO mediated brain injury [35] is at least

partly a leucocyte-mediated post-ischemic reperfusion injury. CO mediated endothelial dysfunction attracts leucocytes PMN which adhere to microvasculature. PMN proteases then convert xanthine dehydrogenase to xanthine oxidase, subsequently forming oxygen radicals [36]. Doing so causes lipid peroxidation and subsequent cellular damage and neurological deficit. Thus, evidence suggests that CO-mediated brain injury is both an ischemic and post ischemic anoxic reperfusion injury [27-28,31-32]. Whether CO directly or indirectly aggravates the ischemic and post ischemic reperfusion autocatalytic lipid peroxidation cell damage requires further elucidation of in vivo CO biochemistry.

HBO is more beneficial than NBO in terms of treating a wide range of CO poisoning [3-10]. Immediate HBO therapy is preferred to achieve optimum results [11-13]. HBO may be beneficial, even in the subacute phase of CO poisoning as in our case and others [14-17]. HBO decreases the half-life of CO to 18 minutes under 2.5 ATA[7]. Thom [37] demonstrated one way in which HBO could antagonize CO-mediated brain lipid peroxidation, subsequently reducing brain damage. His in vitro results indicated that HBO could functionally inhibit PMN β_2 integrins, thereby interfering with the ischemia–reperfusion autocatolytic lipid peroxidation pathway. Tomaszewski et al [38] also revealed that HBO prevents hippocampal damage in rats. HBO also results in faster and more extensive recuperation. HBO therapy is becoming an increasingly accepted means of treating CO poisoning, particularly when severe neurologic and cardiac dysfunctions occur [22]. However, the optimal protocol must still be defined. Problems encountered by HBO therapy as oxygen toxicity [39] related seizure risk 0.3% at 2.45 ATA, barotrauma to ear drum, claustrophobia can be all dealt without interfering with HBO therapy.

CONCLUSION

This case study has demonstrated that a satisfactory outcome can be achieved with aggressive HBO and intensive rehabilitation, even in the subacute phase. The optimal protocol of HBO therapy in CO poisoning must be defined to increase the effectiveness of HBO treatment. Ideally, a network should be set up to provide a scientific patient selection and service provision. Helicopter transport
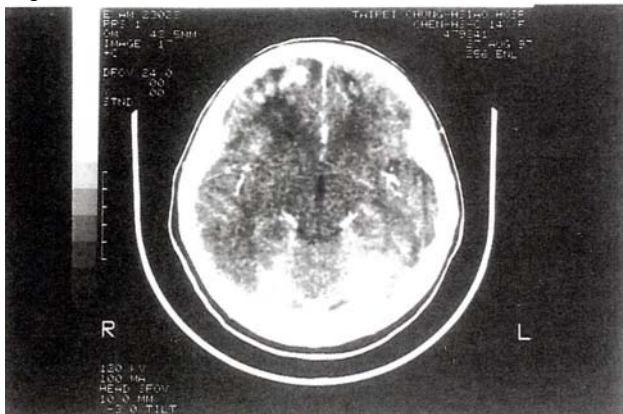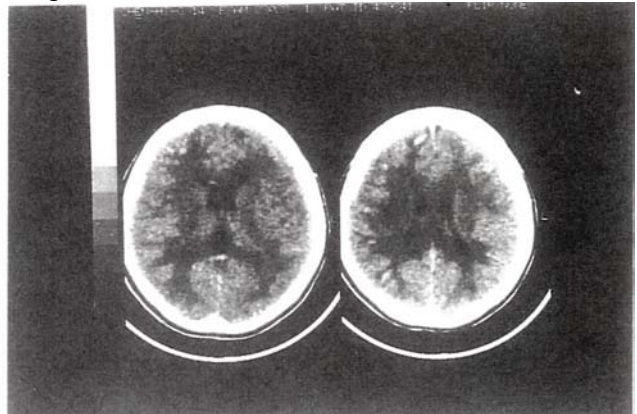
Fig 1.

Fig 2.

Fig 1 and 2   Intracerebral hemorrhage bifrontal areas and gray-white matter junctions (8 days later).

Fig 3.

Fig 4.

Fig 3 and 4   MRI, T2 images (1997/12/10). Bilateral symmetric confluent high intensity in the periventricular white matter and centrum semiovale may comply with demyelinatoin.
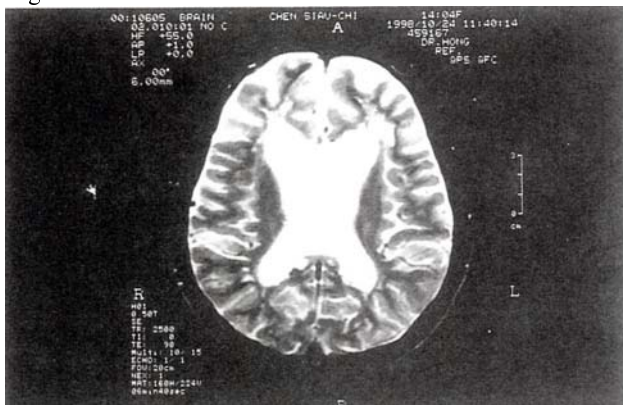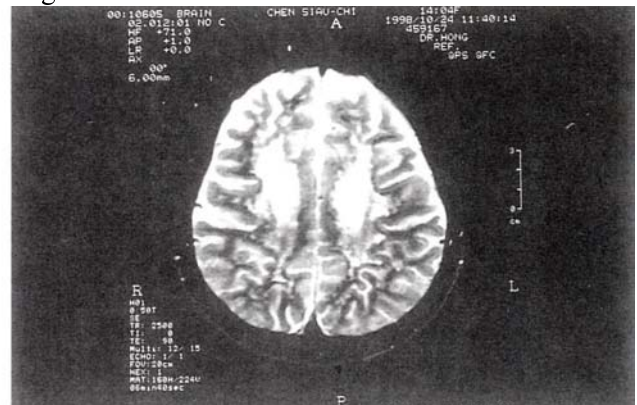
Fig 5.

Fig 6.

Fig 5 and 6   MRI, T2 images (1998/10/24). Decrease in quantity of bilateral periventricular white matter change. Dilated bilateral ventricles including 3rd ventricle (white arrow).

and even transportable HBO system could be added if necessary[40]. Prevention of accidents with grave sequelae such as those occurred after CO poisoning should be minimized by more effective public and health education. This case report further reiterates what rehabilitation enhances quality of life, regardless of how poor the initial prognosis was. Whether rehabilitation facilitates functional recovery by enhancing neuroplasticity needs further study.

REFERENCES

1. Cobb N, Etzel RA. Unintentional carbon monoxide-related deaths in the United States, 1979 through 1988. JAMA 1991;266:659-63.

2. Yun DR, Park BJ, Cho SH, et al. An epidemiological study of the neurological sequelae of acute carbon monoxide poisoning. In: Kindwal EP. Proceedings of the 8th International Congress on Hyperbaric Medicine. San Pedro, California: Best Publishing Co;1987. p.256 -7.

3. Hsu LH, Wang JH. Treatment of carbon monoxide poisoning with hyperbaric oxygen. Chin Med J 1996; 58:407-13.

4. Myers RAM, Snyder SK, Linberg S, et al. Value of hyperbaric oxygen in suspected carbon monoxide poisoning. JAMA 1981;246:2478-80.

5. Thom SR, Keim LW. Carbon monoxide poisoning: a review epidemiology, pathophysiology, clinical findings, and treatment options including hyperbaric oxygen therapy. Clin Toxicol 1989;27:141-56.

6. Tibbles PM, Perrotta PL. Treatement of carbon monoxide poisoning: a critical review of human outcome studies comparing normobaric oxygen with hyperbaric oxygen. Ann Emerg Med 1994;24:269-76.

7. Pace N, Strajman E, Walker EL. Acceleration of carbon monoxide elimination in man by high pressure oxygen. Science 1950;111:652-4.

8. Yang ZD. Clinical analysis of the effect with hyperbaric oxygen therapy on 672 cases with acute carbon monoxide poisoning. 5th Chinese Conference on Hyperbaric Medicine; 1986; Fuzhou, Fujian, China.

9. Zhang JD, Qu Zk, Jia SJ. 50 cases of HBO composite treatment of severe carbon monoxide intoxication. 5th Chinese Conference on Hyperbaric Medicine; 1986; Fuzhou, Fujian, China.

10. Kindwall EP. Carbon monoxide poisoning treated with hyperbaric oxygen. Resp Therapy 1975;5:29-33.

11. Norkool DM, Kirkpatrick JN. Treatment of acute carbon monoxide poisoning with hyperbaric oxygen: a review of 115 cases. Ann Emerg Med 1985;14:1168-71.

12. Mathieu D, Nolf M, Durocher A, et al. Acute carbon monoxide poisoning: risk of late sequelae and treatment by hyperbaric oxygen. Clin Toxicol 1985; 23:315-24.

13. Piantadosi CA. Carbon monoxide intoxication. In: Vincent JL. Update in intensive care and emergency medicine. New York: Springer-Verlan; 1990. p.460-71.

14. Coric V, Oren DA, Wolkenberg FA, et al. Carbon monoxide poisoning and treatment with hyperbaric oxygen in the subacute phase. J Neurol Neurosurg Psychiatry 1998;65:245-7.

15. Dean BS, Verdile VP, Krenzelok EP, et al. Coma reversal with cerebral dysfunction recovery after repetitive hyperbaric oxygen therapy for severe carbon monoxide poisoning. Am J Emerg Med 1993;11:616-8.

16. Ziser A, Shupak A, Halpern P, et al. Delayed hyperbaric oxygen treatment for acute carbon monoxide poi-soning. BMJ 1984;289:960.

17. Gibson AJ, Davis FM, Ewer T, et al. Delayed hyperbaric oxygen therapy for carbon monoxide intoxication - two case reports. N Z Med J 1991;104:64-5.

18. Carr JH, Shepherd RB. A motor relearning programme for stroke. 2nd ed. Maryland: Aspen; 1990. p.29-42.

19. Heckerling PS. Occult carbon monoxide poisoning: a cause of winter headache. Am J Emerg Med 1987;5: 201-4.

20. Myers RAM, Linberg SE, Cowley RA. Carbon monoxide poisoning: the injury and its treatment. JACEP 1979;8:479-84.

21. Choi IS. Delayed neurologic sequelae in carbon monoxide intoxication. Arch Neurol 1983;40:433-5.

22. Myers RAM, Snyder SK, Emhoff TA. Subacute sequelae of carbon monoxide poisoning. Ann Emerg Med 1985;14:1163-7.

23. Thom SR, Taber RL, Mendiguren I, et al. Delayed neurological sequelae following carbon monoxide poi-

poisoning. Ann Emerg Med 1994;23:612.

24. Turner M, Kemp PM. Isotope brain scanning with Tc-HMPAO: a predictor of outcome in carbon monoxide poisoning? J Accid Emerg Med 1997;14:139-41.

25. Sesay M, Bidabe AM, Guyot M, et al. Regional cerebral blood flow measurements with xenon-CT in the prediction of delayed encephalopathy after carbon monoxide intoxication. Acta Neurol Scand 1996;166: 22-7.

26. Chang KH, Han MH, Kim HS, et al. Delayed encephalopathy after acute CO poisoning: MR imaging features and distribution of cerebral white matter lesions. Radiology 1992;184:117-22.

27. Kim KS, Weinberg PE, Suh JH, et al. Acute carbon monoxide poisoning: computed tomography of the brain. Am J Neuroradiol 1980;1:399-402.

28. Ginsberg MD, Myers RE, McDonagh BF. Experimental carbon monoxide encephalopathy in the primate. Arch Neurol 1974;30:209-16.

29. Haldane JBS. Carbon monoxide as a tissue poison. Biochem J 1927;21:1068-75.

30. Ball EG, Strittmatter CF, Cooper O. The reaction of cytochrome oxidase with carbon monoxide. J Biol Chem 1951;193:635-97.

31. Kobayashi K, Isaki K, Fukutani Y, et al. CT findings of the interval form of carbon monoxide poisoning compared with neuropathological findings. Eur Neurol 1984;23:34-43.

32. Okeda R, Funata N, Takano T, et al. The pathogenesis of carbon monoxide encephalopathy in the acute phase: physiological and morphological correlation. Acta Neuropathol 1981;54:1-10.

33. Lapresle J, Fardeau M. The central nervous system and carbon monoxide poisoning. II. Anatomical study of brain lesions following intoxication with carbon monoxide (22 cases). Prog Brain Res 1967;24:31-75.

34. DeReuck J, Decoo D, Lemahieu I, et al. A positron emission tomograry study of patients with acute carbon monoxide poisoning treated by hyperbaric oxygen. J Neurol 1993;240:430-4.

35. Thom SR. Leucocytes in carbon monoxide-mediated brain oxidative injury. Toxicol Appl Pharm 1993;123: 234-47.

36. Cao W, Carney JM, Duchon A, et al. Oxygen free radical involvement in ischemia and reperfusion injury to brain. Neurosci Lett 1988;88:233-8.

37. Thom SR. Antagonism of carbon monoxide-mediated brain lipid peroxidation by hyperbaric oxygen. Toxicol Appl Pharmacol 1990;105:340-4.

38. Tomaszewski C, Rudy J, Wathen J, et al. Prevention of neurologic sequelae from carbon monoxide by hyperbaric oxygen in rats. Ann Emerg Med 1992;21:631-2.

39. Hampson NB, Simonson SG, Kramer CC, et al. Central nervous system oxygen toxicity during hyperbaric treatment of patients with carbon monoxide poisoning. Undersea Hyperbaric M 1996;23:215-9.

40. Shimada H, Morita T, Kunimoto F, et al. Immediate application of hyperbaric oxygen therapy using a newly devised transportable chamber. Am J Emerg Med 1996;14:412-5.

一氧化碳中毒患者在亞急性期接受高壓氧及復健
治療後之復甦與功能恢復：病例報告暨文獻回顧

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　　高壓氧療法能有效地減少一氧化碳中毒之致病率與死亡率。急性期在立即使用高壓氧後有助於神經生理功能之恢復。

　　高壓氧能有效地縮短一氧化碳血紅素之半衰期，增加組織對殘餘一氧化碳之廓清，以及減少神經心理方面之障礙。

　　對於一氧化碳中毒亞急性期的患者，高壓氧療法仍有其卓越的效果，在本病例報告中，一位１３歲女孩，因嚴重一氧化碳中毒而深度昏迷，1個月後，她接受２段療程的高壓氧治療；10個月後，其意識逐漸改善，但仍舊無法說話。經過４週密集的復健治療後，她開始能夠說話，且其日常生活能力達到部份的獨立自主性。由此病例得知，即使是亞急性一氧化碳中毒的患者，在接受高壓氧與積極的復健治療後，其功能仍能獲得相當明顯的改善。（中華復健醫誌 2000; 28(3): 163 - 170）

關鍵詞：高壓氧(hyperbaric oxygen)，常壓氧(normobaric oxygen)，一氧化碳中毒(carbon monoxide poisoning)，日常生活能力(activities of daily living)

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