Chinese Journal of Physiology 52(3): 169-172, 2009
DOI: 10.4077/CJP.2009.AMH060

Case Report

A Hyperbaric Oxygen Therapy Approach to Heat Stroke with Multiple Organ Dysfunction

Ko-Chi Niu[1], Chen-Kuei Chang[2], Mao-Tsun Lin[3], and Kuo-Fong Huang[3]

[1]*Department of Biotechnology, Southern Taiwan University and Department of Hyperbaric Oxygen, Chi Mei Medical Center, Tainan*
[2]*Department of Surgery, Mackay Memorial Hospital, and Graduate Institute of Injury Prevention and Control, Taipei Medical University, Taipei*
and
[3]*Department of Medical Research and Department of Plastic Surgery, Chi Mei Medical Center, Tainan, Taiwan, Republic of China*

Abstract

Here in we report the case of a patient who displayed a classic heat stroke with multiple organ dysfunction and hypercoagulable state resistant to conventional whole body cooling and antipyretic therapy, and necessitating the use of hyperbaric oxygen therapy (HBOT) to rescue him from death. A 49-year-old male laborer, suffering from heat stroke syndromes (*e.g.*, hyperpyrexia, seizure and coma, and hypotension), was admitted to an emergency unit of a medical center hospital. The patient displayed multiple organ dysfunction with rhabdomyolysis, hepatic, renal, respiratory, and cerebral dysfunction, and disseminated intravascular coagulation (DIC). Both hyperpyrexia and multiple organ dysfunction were resistant to conventional treatment measures. HBOT was adopted to rescue the patient from heat stroke-induced death. Before HBOT, analyses of serum revealed hypercoagulable state or DIC as well as signs of rhabdomyolysis, and renal and hepatic failure. In addition, pulmonary edema, coma, hypotension, and hyperpyrexia occurred. HBOT was used successfully to combat these syndromes and to rescue the patient from heat stroke death. This case suggests that HBOT is useful for treatment of heat stroke with multiple organ dysfunction.

Key Words: heat stroke, hyperbaric oxygen, blood coagulation, multiorgan dysfunction

Introduction

Heat stoke is a life-threatening illness defined as hyperpyrexia and multiple organ dysfunction (2, 5). The neurologic dysfunctions during heat stroke were characterized by delirium, convulsion or coma. Hyperbaric oxygen therapy and, to some extent, hyperbaric air, reduced ischemic brain and behavioral dysfunction in patients (15) and experimental animals (4). A more recent report demonstrated that the hypotension and cerebral ischemia and damage during heat stroke were suppressed by HBOT in the rat (17). Herein we further report a case of heat stroke with multiple organ dysfunction being successfully treated with a hyperbaric oxygen therapy (HBOT).

Case Report

Subject

A previously healthy 49-year-old male laborer was presented to the emergency department of Chi Mei Medical Center (Tainan, Taiwan, ROC) because of disturbance of consciousness and hyperpyrexia at 18:30, on June 30, 2006. The ambient temperature was 37°C, the humidity was 52% and the wind velocity was 3.0 m/s at that time in the area.

Diagnosis

On arrival at our emergency department, he had

Corresponding authors: Kuo-Fong Huang, MD and Mao-Tsun Lin, DDS, Ph.D., Department of Plastic Surgery and Department of Medical Research, Chi Mei Medical Center, Tainan 710, Taiwan, Republic of China. Tel: +886-6-2832639, E-mail: 891201@mail.chimei.org.tw
Received: September 4, 2008; Revised: November 21, 2008; Accepted: December 4, 2008.
 ISSN : 0304-4920. http://www.cps.org.tw

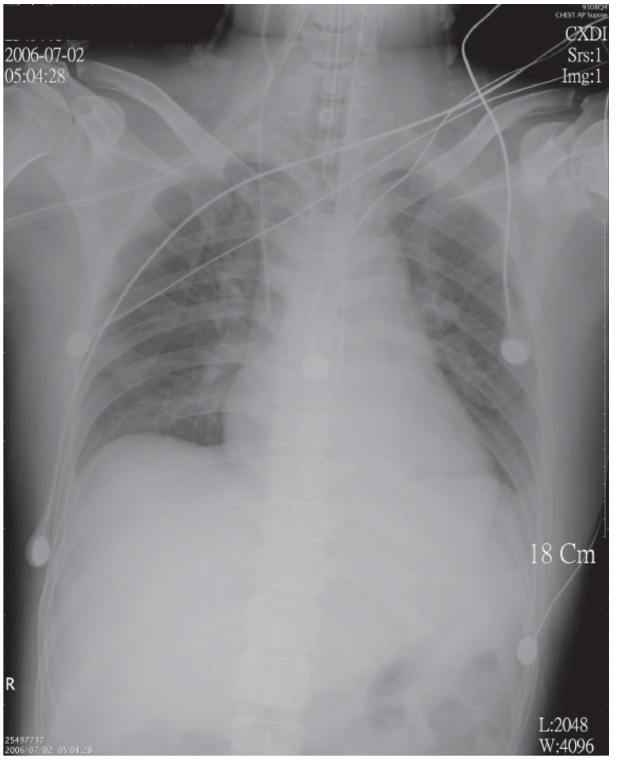

Fig. 1. Chest X-ray film showing left pleural effusion and pulmonary edema.

spontaneous respiration at the rate of 26 breaths per min. His pulse rate was 142 beats per min with a blood pressure of 79/35 mmHg. He was found to be comatose at grade 6 on the Glasgow Coma Scale (GCS; E_1 V_1 M_4) accompanied by seizure. The patient's core temperature measured inside the urinary bladder was 41.8°C. Physical examination showed a sluggish light reflex of bilateral pupils, a dry and hot skin without sweat, a normal heart beat, a normal respiratory sound, and a normal abdomen. His electroencephalogram (EEG) showed severe diffuse cortical dysfunction. His chest X-ray revealed pleural effusion and pulmonary congestion (Fig. 1). Laboratory data revealed hepatic dysfunction evidenced by increased glutamic-oxaloacetic transaminase 153 IU/l (normal range: 10 to 50 IU/l), increased glutamic-pyruvic transaminase 117 IU/l (normal range: 10 to 50 IU/l), renal dysfunction evidenced by increased creatinine, 2.8 mg/dl (normal range: 0.6-1.3 mg/dl), and increased blood nitrogen, 31 mg/dl (normal range: 5 to 25 mg/dl), rhabdomyolysis evidenced by increased myoglobin, 2,829 μg/l (normal range: <90 μg/l), and increased creatinine kinase, 4,682 IU/l (normal range: 56-244 IU/l), disseminated inadequate coagulopathy or hypercoagulable state evidenced by increased activated partial thromboplastin time APTT, 88 s (normal range: 20-32 s), decreased platelet count, 48 × 10^3/μl (normal range: 150-400 × 10^3/μl), and decreased protein C, 22% (normal range: 77-158%).

After a diagnosis of heat stroke, Jusomin 1.4 gm and lysing-acetylsalicylic acid 1 gm in 500 ml normal saline was infused intravenously. Active cooling was instituted with ice packs to the neck, axilla, and groin. A gastric lavage was undertaken 4 times using 2 liters of iced saline. Despite all these procedures, the patient remained hyperpyrexia (over 40°C), comatose and his respiratory functions deteriorated. He was intubated and transferred to the intensive care unit (ICU) for conventional HBOT. Before the start of HBOT, his GCS Scale was graded as 5 (E_1 Ve_1 M_4). Other laboratory data of the patient before and after the start of HBOT are summarized in Table 1.

The patient was refractory to conventional temperature control measures such as NSAIDS or external cooling devices (cooling blankets) applied even for several h. Then, the patient was subjected to HBOT regimen (twice a day for consecutive 3 days). Each time, the patient was exposed to 1.5 ATA 100% O_2 for 90 min. On day 4 after HBOT, the Glasgow coma scale had increased to 8. Both core temperature and blood pressure had returned to normal values on day 4 after HBO. In addition, the extent of hepatic and renal dysfunction, hypercoagulable state, brain dysfunction, and pulmonary edema were all suppressed after 3-day HBOT (Table 1). Therefore, the patient was extubated on day 4 and transferred to a regular neurological ward. On day 12 after the admission or HBOT therapy, laboratory parameters had returned to normal values (Table 1) and he was discharged from our hospital with neither signs of any focal neurological nor overt cognitive deficits.

Discussion

Heat stroke is characterized by hyperpyrexia and multiple organ dysfunction (*e.g.* the renal, cardiovascular, hematologic, and hepatic abnormalities, and central nervous system disorders) (2, 5). By this standard, rodents displayed a uniform response and reacted similarly to humans with heat stroke (5). In the rat, activated coagulation or hypercoagulable state, tissue ischemia/injury and rhabdomyolysis all occur during heat stroke. Activated coagulation is evidenced by increased prothrombin time, aPTT, and D-dimer and decreased platelet count and protein C in plasma (6, 11). Tissue ischemia and injury is evidenced by increased serum urea nitrogen, creatinine, aspartate aminotransferase, alanine aminotransferase, and alkaline phosphatase levels in plasma. Increased intracranial pressure was also noted during heat stroke. In contrast, the mean arterial pressure, cerebral perfusion pressure, cerebral blood flow, and partial pressure of oxygen levels all decreased during the heat stroke. Indeed, as shown in the current results,

Table 1. Course of laboratory data in a patient with heat stroke

Parameters	Normal Range	Measured Values on Day 1	Measured Values on Day 4	Measured Values on Day 12
Body Temperature	36-38°C	41°C	38.2°C	38.4°C
Blood Pressure	120/80 mmHg	80/40 mmHg	115/76 mmHg	130/90 mmHg
Alasgow Coma Scale	15 (E_5, V_5, M_5)	5 (E_1, ve, M_4)	8 (E_2, V_1, M_5)	14 (E_4, V_5, M_5)
SGOT	10-50 IU/l	153 IU/l	86 IU/l	30 IU/l
SGPT	10-50 IU/l	117 IU/l	81 IU/l	40 IU/l
Creatinine	0.6-1.3 mg/dl	1.8 mg/dl	1.1 mg/dl	0.9 mg/dl
Blood Urea Nitrogen	5-25 mg/dl	31 mg/dl	28 mg/dl	22 mg/dl
Myoglobin	<90 μg/l	2829 μg/l	164 μg/l	44 μg/l
Creatine Kinase	56-244 IU/l	4682 IU/l	654 IU/l	34 IU/l
APTT	20-32 s	88 s	41 s	30 s
Platelet Count	150-400 × 10^3/μl	48 × 10^3/μl	148 × 10^3/μl	172 × 10^3/μl
Protein C	77-158%	22%	87%	110%
EEG Pictures: Diffuse Cortical Dysfunction	none	noted	reduced	none
X-Ray: Pleural Effusion, Pulmonary Congestion	none	noted	reduced	none

SGOT = Serum glutamic-oxaloacetic transaminase; SGPT = serum glutamic-pyruvic transaminase; APTT = activated partial thromboplastin time; EEG = electroencephalogram.

the heat stroke patient displayed arterial hypotension, cerebral dysfunction, renal and hepatic dysfunction, hypercoagulable state, and pulmonary edema. A more recent report has also demonstrated that HBOT may resuscitate rats that had a heatstroke by decreasing multiple organ dysfunction (13).

HBOT is a noninvasive medical strategy in which a person breathes in 100% oxygen at a pressure greater than normal (12). Herein we provide the first case that demonstrated the heat stroke-induced arterial hypotension, pulmonary edema, renal and hepatic dysfunction, rhabdomyolysis, hypercoagulable state, and comatose state can all be reversed by HBOT in a patient. The results obtained from this human study are supported by our recent studies conducted in animals. In a rat heat stroke model, we observed that HBOT resuscitates rats with a heat stroke by reducing multiple organ dysfunction, hypercoagulable state, and rhabdomyolysis (13, 17). In this case of heat stroke, which was resistant to conventional cooling and antipyretic therapies, hyperbaric oxygen therapy may have contributed significantly to the reduction of hyperpyrexia, hypercoagulable state, and multiple organ dysfunction or failure, and avoided a fatal outcome. In our patient, hyperbaric oxygen therapy was efficacious and feasible.

Heatstroke is defined as a condition in which core temperature is elevated to a critical level that induces multiorgan injury and dysfunction (8, 9, 16). The current choice for the treatment of heatstroke is whole body cooling (2). However, heatstroke is often fatal following adequate body cooling (7, 10). Tissue damage continues to develop after whole body cooling to normal body temperature in 25% of heatstroke patients (1). Normal volunteers can passively endure a core temperature of about 42°C with no or minimal tissue injury (3, 14). As demonstrated in our previous results (13, 17), in the absence of whole body temperature, HBOT prevent the occurrence of heatstroke syndrome without effecting the induced hyperthermia. Thus, it is likely that tissue ischemia and hypoxia, rather than hyperthermia, is the main cause for the occurrence of heatstroke (6). Our current results show that HBOT improve heatstroke mainly by reducing tissue ischemia and hypoxia.

Acknowledgments

This work was in part supported by grants from the National Science Council of the Republic of China (grants NSC 96-2314-B-384-002, NSC 96-2314-B-384-006-MY3, and NSC 96-2314-B-384-003-MY3).

References

1. Bouchama, A., Cafege, A., Devol, E.B., Labdi, O., el Assil, K. and Seraj, M. Ineffectiveness of dantrolene sodium in the treatment of heatstroke. *Crit Care Med*. 19: 176-180, 1991.
2. Bouchma, A. and Knochel, J.P. Heat stroke. *N. Engl. J. Med.* 346: 1978-1988, 2002.
3. Bynum, G.D., Pandolf, K.B., Schuette, W.H., Goldman, R.F., Lees, D.E., Whang-Peng, J., Atkinson, E.R. and Bull, J.M. Induced

hyperthermia in sedated humans and the concept of critical thermal maximum. *Am. J. Physiol* 235: R228-R236, 1978.
4. Chang, C.F., Niu, K.C., Hoffer, B.J. and Lin, S.Z. Hyperbaric oxygen therapy for treatment of post ischemic stroke in adult rats. *Exp. Neurol*. 166: 298-306, 2000.
5. Chang, C.K., Chang, C.P., Chiu, W.T. and Lin, M.T. Prevention and repair of circulatory shock and cerebral ischemia/injury by various agents in experimental heatstroke. *Curr. Med. Chem*. 13: 3145-3154, 2006.
6. Chen, C.M., Hou, C.C., Cheng, K.C., Tian, R.L., Chang, C.P. and Lin, M.T. Activated protein C therapy in a rat heat stroke model. *Crit. Care Med*. 34: 1960-1966, 2006.
7. Dematte, J.E., O'Mara, K., Buescher, J., Whitney, C.G., Forsythe, S., McNamee, T., Adiga, R.B. and Ndukwu, I.M. Near-fatal heat stroke during the 1995 heat wave in Chicago. *Ann. Intern. Med*. 129: 173-181, 1998.
8. Epstein, Y., Moran, D.S., Shapiro, Y., Sohar, E. and Shemer, J. Exertional heat stroke: a case series. *Med. Sci. Sports Exerc*. 31: 224-228, 1999.
9. Epstein, Y., Sohar, E. and Shapiro, Y. Exertional heatstroke: a preventable condition. *Isr. J. Med. Sci*. 31: 454-462, 1995.
10. Knochel, J.P. and Reed, G. Disorder of heat regulation. In clinical Disorder of Fluid and Electrolyte Metabolism, 5th ed.: Maxwell, M.H., Kleeman, C.R. and Maritin, R.G, Eds: McGraw-Hill: NY, 1994; pp1549-1590.
11. Lee, J.J., Lin, M.T., Wang, N.L. and Chang, C.K. Platonin, a cyanine photosensitizing dye, causes attenuation of circulatory shock, hypercoagulable state, and tissue ischemia during heat stroke. *Shock* 24: 577-582, 2005.
12. Leifer, G. Hyperbaric oxygen therapy. *Am. J. Nurs*. 101: 26-34, 2001.
13. Niu, K.C., Lin, M.T. and Chang, C.P. Hyperbaric oxygen improves survival in heatstroke rats by reducing multiorgan dysfunction and brain oxidative stress. *Eur. J. Pharmacol*. 569: 94-102, 2007.
14. Pettigrew, R.T., Galt, J.M., Ludgate, C.M., Horn, D.B. and Smith, A.N. Circulatory and biochemical effects of whole body hyperthermia. *Brit. J. Surg*. 61: 727-730, 1974.
15. Rusyniak, D.E., Kirk, M.A., May, J.D., Kao, L.W., Brizendine, E.J., Welch, J.L., Cordell, W.H. and Alonso, R.J. Hyperbaric oxygen therapy in acute ischemic stroke: results of the hyperbaric oxygen in acute ischemic stroke trial pilot study. *Stroke* 34: 571-574, 2003.
16. Shibolet, S., Coll, R., Gilat, T. and Sohar, E. Heatstroke: its clinical picture and mechanism in 36 cases. *Q. J. Med*. 36: 525-548, 1967.
17. Tsai, H.M., Gao, C.J., Li, W.X., Lin, M.T. and Niu, K.C. Resuscitation from experimental heatstroke by hyperbaric oxygen therapy. *Crit. Care Med*. 33: 813-818, 2005.