American Journal of Emergency Medicine 33 (2015) 1497–1500

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Brief Report

Development and preliminary test of a new plateau hyperbaric chamber

Liang Sun, MD [a,b], Meng-jiang Ding, MD [c], Tian-cai Cai, MD [d], Hao-jun Fan, MD [e], Jian-peng Zhang, MD, PhD [f,*]

[a] Medical College of Chinese People's Liberation Army General Hospital, Teaching center Building, No. 28, Fu-Xing Road, Haidian District, Beijing, 100853, China
[b] Department of Respiratory and Critical Care Medicine of Ping Jin Hospital, Affiliated Hospital of Logistic University of Chinese People's Armed Police Force, No. 220, Cheng-Lin Road, Tianjin, 300162, China
[c] Tianjin Municipal Corps Hospital of Chinese People's Armed Police Forces, No. 206,Wei-guo Road, Tianjin, 300162, China
[d] Xiamen Sanatorium of Chinese people's Armed Police Forces, No. 189,Two West Zeng Cuo Road, Siming District, Xiamen, China
[e] Institute of Disaster Medicine and Public Health, Affiliated Hospital of Logistic University of Chinese People's Armed Police Force, No. 220, Cheng-Lin Road, Tianjin, 300162, China
[f] Department of Respiratory, General Hospital of Chinese People's Armed Police Force, No. 69, Yong-ding Road, Haidian District, Beijing, 100039, China

ARTICLE INFO

Article history:
Received 2 June 2015
Accepted 3 June 2015

ABSTRACT

Objective: The objective of this study is to validate the performance, define its limits, and provide details on a new plateau hyperbaric chamber at 355-, 2880-, and 4532-m high altitude.
Methods: A new multiplace plateau hyperbaric chamber was designed to satisfy the needed of patients who have acute mountain sickness. Tests were conducted inside the chamber at 355-, 2880-, and 4532-m high altitude. The safely and conveniences of the new plateau hyperbaric chamber were estimated.
Results: Minimum pressures of the main compartment can reach up to 0.029, 0.022, and 0.02 MPa at 355-, 2880-, and 4532-m high altitude. During pressurization, there was no leak of air around the chamber. The time lag of pressure equilibration between main and buffer compartment varies from 30.3 ± 2.01 to 200.5 ± 5.44 seconds and between buffer compartment and ambient pressure varies from 60.2 ± 4.13 to 215.9 ± 6.76 seconds.
Conclusions: The chamber can be applicated for acute mountain sickness treatment safety and convenience. However, further experience about animals and human within the chamber is needed to improve the hardware and establish conditions of effective utilization of this equipment in the high altitude.

1. Introduction

Acute mountain sickness (AMS) is a common clinical problem affecting otherwise fit individuals who ascend to high altitude. The severity of AMS depends upon a number of factors, including rate of ascent, altitude achieved, recent previous acclimatization, and the susceptibility of the individual to the syndrome. Overall, in laborers [1] and soldiers [2], the incidence of AMS was much higher due to the requirements for laboring or completion of missions under hypobaric hypoxia.

As a common pathogenesis of high-altitude illnesses has been suggested, early successful treatment of AMS may prevent the development of high-altitude cerebral edema or pulmonary edema [3,4]. Studies had been shown that the severity of AMS correlates inversely with arterial oxygen saturation [5,6]. Therefore, the most important treatment for AMS is rapidly improving arterial oxygen saturation of the patients. Supply of additional oxygen is effective [7]; but cylinders are heavy, expensive, and only a limited supply can be carried.

Rapid descent is another important treatment; however, the treatment of choice is often not possible while trekking for topographical reasons or while mountaineering because of adverse weather conditions or difficult terrain. If immediate descent is not possible, using a portable hyperbaric chamber to simulate descent is recommended [8]. A portable hyperbaric chamber is an inflatable cylindrical tube made of heavy rubber or durable fabric that increases the atmosphere sealed within it to that of a much lower altitude. However, treatment of sick subjects within the very confined space of the chamber can be difficult, and prolonged treatment makes considerable demands on the individuals required to maintain pressure with the foot pump [9]. And this is not always an acceptable therapy alternative in a predominantly elderly population. Moreover, most type of portable hyperbaric chambers are monoplace chambers. If many persons have AMS, such as laborers and soldiers, the portable hyperbaric chamber may be ineffective.

Hyperbaric oxygen therapy has been recommended and used in a wide variety of medical conditions, and its efficacy has been validated by extensive clinical experience and scientific studies for decompression sickness and high-altitude illnesses [10,11]. And most types of hyperbaric oxygen chambers are multiplace chambers. However, the potential risks, shortage of oxygen supply, and complexity of the operation of hyperbaric oxygen have often been limited its application in the treatment of AMS.

Based on the principles of increasing pressure in the chamber, a new multiplace plateau hyperbaric chamber was designed to satisfy the patients who have AMS. The specific merits of the plateau hyperbaric chamber are big volume, removable, and ease of operation. Different from other portable hyperbaric chamber, atmospheric pressure is

* Corresponding author. Tel.: +86 22 60578941; fax: +86 22 60578671.
E-mail address: zjp99@vip.sina.com (J. Zhang).

http://dx.doi.org/10.1016/j.ajem.2015.06.005
0735-6757/

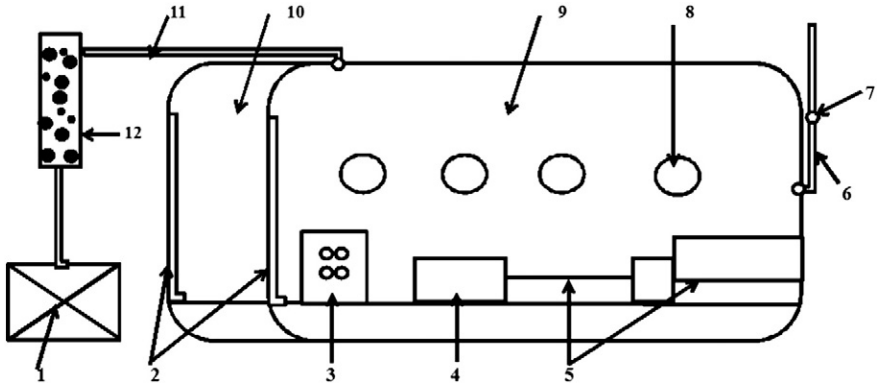

Fig. 1. The new multiplace plateau hyperbaric chamber (1, compressor; 2, doors; 3, control device; 4, desk; 5, beds; 6, gas vent; 7, air evacuation valve; 8, windows; 9, main compartment; 10, buffer compartment; 11, intake tube; and 12, silencer).

increased inside the chamber by adjusting the opening of the expiration valve in proportion to the ambient pressure. Hence, carbon dioxide inside the chamber will not be accumulated during pressurization. This study was carried out to assess the feasibility of the new plateau hyperbaric chamber for the treatment of AMS.

2. Subjects and methods

2.1. Location and subjects

The tests were carried out at 3 different high altitude in Xian City and Kunlun Mountains. The new plateau hyperbaric chamber was stored in a truck and transported to different high altitude by the truck when it was tested.

The chamber is a windowed cylindrical hyperbaric chamber constructed of 3-layer material (anticorrosion steel plate inner, inorganic foaming material thermal insulation in middle layer, and glass steel in outer layer). The complete device is 800-cm long, has a diameter of 340 cm, and a volume of 72.63 m^3 (Fig. 1). The chamber was divided into main and buffer compartment, which connected with a door. Pressure was supplied by a electrically driven centrifugal compressor, which power is 3.5 kW, and the high air flow was 200 m^3/h. The electrically driven centrifugal compressor continuously flushes ambient air into the chamber through the chamber environment resulting in a no-risk environment to the occupant. The plateau hyperbaric chamber compensates for hyperbaric pressure by adjusting the opening of the expiration valve in proportion to the ambient pressure.

Living facilities (stool, bed, and the bureau) are installed in the chamber, ensuring a more comfortable chamber environment (Fig. 2).

Fig. 2. The new multiplace plateau hyperbaric chamber.

The custom sound baffle system decreases the sound signature of the compressor, making it quiet enough to use in a medical office or small apartment. The patient in the chamber can be observed through the window.

2.2. Study design

Because this plateau hyperbaric chamber is said to provide a useful tool for the treatment of AMS, this needed us to estimate the following: (1) minimum pressure can be achieved in main compartment at different high altitude, (2) time lag of pressure equilibration between main and buffer compartment, (3) time lag of pressure equilibration between buffer compartment and outside, (4) noise in the main compartment at working, and (5) temperature changes before and after pressurization. Pressures of the main and buffer compartment were measured by an M307086 barometer (Western Instrument Technology Co, Ltd, WuHan Hu Bei of China). Noise in the main compartment at working was measured by a CEL-231 digital sound level meter (Casella CEL, London of England). The temperature was measured by a CENTER 313 digital temperature and humidity meter (Taiwan Qunte Company, New Taipei City of China). Time was measured by a Casio stopwatch (Iraq Business Electronic Technology Co Ltd, Shen Zhen of China).

The procedure is as follows:(1) place the chamber on a surface as smooth as possible; (2) check that the equipments are in proper location; (3) tester enter into the main compartment; (4) close all the doors and ensure valve stem in a closed position; (5) adjust pressure value of barometer to zero and record the temperature, noise in the main compartment as basic data; (6) begin pressurization; (7) record time required and temperature, noise changed when pressure rise every 0.01 MPa until minimum pressure in main compartment acquired; (8) open valve stem of the door between main and buffer compartment; (9) record time when pressure equilibration between main and buffer compartment; (10) open valve stem of the door between buffer compartment and outside; (11) record time when pressure equilibration between buffer compartment and outside; (12) return valve stem to closed position; (13) check whether leak of air around the chamber; (14) stop pressurization; and (15) document procedure.

Table 1
The results obtained at 355 m are displayed

Pressure	Time (s)	Noise	Temperature
0.00	0	48.3 ± 3.25	0
0.01	90.3 ± 3.63	67.4 ± 2.92	1.1 ± 0.32
0.02	210.1 ± 4.12	68.5 ± 3.34	1.2 ± 0.53
0.029	510.4 ± 4.78	69.0 ± 2.45	1.5 ± 0.21