Original Article

NEURO-COGNITIVE AND PATHOPHYSIOLOGICAL CHANGES IN HYPOBARIC CHAMBER IN PILOTS OF PAKISTAN AIR FORCE

Sikandar Ali Khan, Kamran Adil, Mansoor Mangi

Aero medical Institute PAF Base Masroor Karachi

ABSTRACT

Objective: To determine the effects of hypoxia in hypobaric chamber and correlation of effects with time.

Design: Descriptive study.

Place and Duration of Study: Study was carried out at Aero medical Institute Masroor Base Karachi from July to December 2009.

Patients and Methods: All those aviators coming to aero medical Institute for various courses during the period of July 2009 to December 2009 were included in this study. In hypobaric chamber time of useful consciousness was measured after removing the oxygen mask at 25,000 ft and at 18,000 ft (with dimmed lights to observe hypoxia effects on vision during night flying). Simultaneously with the removal of mask we delivered to the aviators a form to fill. This form depicts the cognitive-motor degradation that occurs with the lack of oxygen.

Results: Total number of aviators that participated in this study was hundred and four. Time of useful consciousness in 68.3% was 5 minutes. 22% developed drowsiness, 11.5% developed nausea and headache each, 18.3% felt weakness, tingling was present in 12.5%, fatigue in 15.4%, 2.9% developed euphoria, feeling of insects crawling under skin, shortness of breath and decreased coordination of movements, 1% developed toothache and loss of color vision, burning sensation in body, decreased visual acuity, confusion and finger getting blue accounted for 4.8% each, hot and cold sensations were present in 8.7%, palpitations and spots before eyes were observed in 3.8%, blurred vision was present 10.6%, numbness in 5.8%, impaired judgment in 1.9% and no symptoms occurred during hypoxia in 8.7% of aviators.

Conclusion: It can be safely concluded on the basis of this study that at high altitudes with hypoxia useful consciousness in majority lasts only 5 minutes and majority will present with the symptoms of drowsiness, nausea, headache, weakness, fatigue and even euphoria. Results clearly indicate that time of hypoxia is directly proportional to the severity of hypoxic symptoms.

Keywords: Hypoxia, Hypobaric chamber.

INTRODUCTION

Hypobaric hypoxia occurs during flight at high altitude because barometric pressure falls and breathing of such air will result in reduction of oxygen in the lungs. Even 25% of reduction of partial pressure of oxygen in the atmosphere with ascent to altitude of 8000 feet produces detectable impairment in some aspects of mental performance. Sudden exposure to 50,000 feet reduces partial pressure of oxygen within lungs to 10% of its sea level value and it will cause unconsciousness within 12-15 seconds and death in 4-6 minutes[1].

A hypobaric chamber, or altitude chamber, is a chamber used during aerospace or high terrestrial altitude research or training to simulate the effects of high altitude on the human body, especially hypoxia (low oxygen) and hypobaria (low ambient air pressure). Aviators are placed in the chamber. Before "ascending" to the desired altitude, aviators breathe oxygen from oxygen masks to purge nitrogen from their bloodstream so decompression sickness (DCS) does not occur. With masks in place, the atmospheric pressure inside the chamber is then reduced to simulate altitudes of up to tens of thousands of feet. The subjects then remove their oxygen masks and experience the symptoms of hypoxia. An inside safety observer, breathing oxygen by mask, is always present to place a subject's mask back on in the event a subject passes out unconscious. Outside observers monitor the subjects' condition via closed circuit television and

Correspondence: Squadron Leader Sikandar Ali Khan Classified Psychiatrist PAF Hospital Masroor Base, Karachi
Email: alpha1khan@yahoo.com
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viewing ports[2]. While the mask is off, subjects may be asked to do trivial tasks, such as arithmetics and signing their own name. When such tasks start taking excessive lengths of time to be done or are done poorly, it is usually a sign that the "Time of Useful Consciousness" has been exceeded and that the mask should be replaced. Subjects may also insure that they are able to do tasks such as clear their nose and sinuses easily, as pain from such problems can be a major distraction in an emergency such as rapid decompression. Time of Useful Consciousness (TUC) is defined as the amount of time an individual is able to perform flying duties efficiently in an environment of inadequate oxygen supply. It is the period of time from the interruption of the oxygen supply or exposure to an oxygen-poor environment to the time when useful function is lost, and the individual is no longer capable of taking proper corrective and protective action. It is not the time to total unconsciousness. The TUC has also been called Effective Performance Time (EPT). At the higher altitudes, the TUC becomes very short; considering this danger, the emphasis is on prevention rather than cure[3].

The primary purpose of the altitude chamber is for the subjects to determine what their hypoxia symptoms are. The symptoms of hypoxia are different for each individual, and this is helpful for aviators to be able to recognize these symptoms during actual flight so as to avoid in-flight oxygen emergencies. Military pilots who fly aircraft at altitudes in excess of 10,000 feet, and civilian pilots who fly un-pressurized aircraft above 12,500 feet, must use oxygen equipment[4].

To the author's best of knowledge currently there is no such study present in Pakistan. Although aviators are being actively trained for quite some time regarding recognition of there symptoms but there was lack of evidence based projection. This effort is to highlight the frequencies of most commonly occurring symptoms and to establish correlation of symptoms with the time duration of hypoxia. This study hopefully will provide template for further studies on the subject of hypoxia and effects of high altitude.

PATIENTS AND METHODS

This descriptive study was carried out at the Aeromedical Institute Masroor Base Karachi from July to December 2009. Healthy and active hundred and four aviators were placed in the chamber. Before "ascending" to the desired altitude, an inside safety observer, breathing oxygen by mask, was always present to place a subject's mask back on in the event a subject passes out unconscious.

The study was preceded by a period of denitrogenation of 30 minutes by breathing oxygen from oxygen masks to purge nitrogen from their bloodstream so decompression sickness (DCS) does not occur. With masks in place, the atmospheric pressure inside the chamber was then reduced to simulate altitudes of 5,000 feet and then descended back to sea level to perform ear and sinus check.

Again the atmospheric pressure inside the chamber was reduced to attain the height of 25000 feet with ascent rate of 4000 feet per minute where subjects removed their oxygen masks and experienced the symptoms of hypoxia. Simultaneously with the withdrawal of the masks we delivered to the aviators a form to fill. This form is approved by the Air Headquarter. When aviators started to take excessive time to fill the form or done poorly or aviators themselves declared and felt the appearance of symptoms of cognitive-motor degradation that appears with the lack of oxygen it was taken as a sign that the "Time of Useful Consciousness" has been exceeded and the mask was replaced. Subsequently with descent of 2,000 feet per minute height of 18,000 feet was attained where lights were dimmed to simulate night flying. At this height again oxygen masks were removed to note effects of hypoxia on vision in night flying and finally descent was made to ground level. After this the Physiological Training Officer in charge discussed with each of the aviator their symptoms and their order of appearance. Data had been analyzed using SPSS version 15. Descriptive statistics were used to describe the results.

RESULTS

Total of hundred and four aviators were included in the study. Seventy one aviators i.e. 68.3% had five minutes of useful consciousness, 9.6% had four minutes while other 9.6% had six minutes of useful consciousness as shown in the table-1.

Time of useful consciousness

The most frequent symptom experienced by aviators during hypoxia was drowsiness that occurred in 21.2%, followed by weakness in 18.3%, fatigue in 15.4%, tingling sensation in 12.5% nausea and headache in 11.5% each and blurred vision in 10.6% of individuals as shown in table-2. In addition 8.7% of individuals did not experience any symptom during hypoxia.

When correlation of symptoms with time of useful consciousness was drawn it appeared that most of the symptoms correlated with five minutes duration of time of useful consciousness. Twenty two individuals developed drowsiness out of which fifteen had drowsiness at five minutes of time of useful consciousness. Total nineteen individuals developed weakness out of which fourteen individuals had weakness at five minutes. Similarly nine out of sixteen individuals had developed fatigue, seven out of twelve developed nausea and nine out of eleven developed blurred vision at five minutes of useful time of consciousness. Although symptoms are scattered over a period of 2 minutes to ten minutes but in majority of individuals symptoms are clustered around fifth and sixth minute of time of useful consciousness as depicted in table-3. At two minutes just one individual developed fatigue, at three minutes two individuals developed drowsiness while one individual each had nausea, weakness and burning sensation. At 4 minute 3 individuals developed drowsiness, one for each nausea, weakness, tingling sensation, headache and fatigue, two had blurred vision. At six minutes one for each developed drowsiness, tingling sensation, headache, euphoria and hot and cold sensations, two individuals for each nausea, weakness and burning sensation. It can easily inferred from the results that time of oxygen deprivation that is hypoxia is directly proportional to the severity of the symptoms

Table-1: Description of time of useful consciousness(n=104).

Time of useful consciousness in minutes	Frequency	Percent
2	1	1.0
3	5	4.8
4	10	9.6
5	71	68.3
6	10	9.6
7	4	3.8
8	1	1.0
9	1	1.0
10	1	1.0
12	1	1.0

Table-2: Description of symptoms during hypoxia

Symptom	Frequency	Percentage
Drowsiness	22	21.2
Nausea	12	11.5
Weakness	19	18.3
Tingling	13	12.5
Fatigue	16	15.4
Euphoria	3	2.9
Headache	12	11.5
Toothache	1	1.0
Burning sensation	5	4.8
Hot and cold	9	8.7
Finger getting blue	5	4.8
Decreased visual acuity	5	4.8
Blurred vision	11	10.6
Spots before eyes	4	3.8
Numbness	6	5.8
Palpitations	4	3.8
Decreased coordination	3	2.9
Confusion	5	4.8
Impaired judgment	2	1.9
Feeling of crawling insects	3	2.9
Loss of color vision	1	1.0
Shortness of breath	3	2.9
No symptoms during hypoxia	9	8.7

Multiple symptoms were observed in a patient.

Table-3: Correlation of symptoms with time.

No	Symptoms	Time of useful consciousness in minutes											Total no of indls
		2	3	4	5	6	7	8	9	10	11	12	
1.	Drowsiness	-	2	3	15	1	-	1	-	-	-	-	22
2.	Nausea	-	1	1	7	2	-	-	-	1	-	-	12
3.	Weakness	-	1	1	14	2	-	1	-	-	-	-	19
4.	Tingling sensation	-	-	1	10	1	-	-	1	-	-	-	13
5.	Fatigue	1	-	1	9	4	-	-	-	1	-	-	16
6.	Blurred vision	-	-	2	9	-	-	-	-	-	-	-	11
7.	Headache	-	-	1	9	1	-	1	-	-	-	-	12
8.	Euphoria	-	-	-	-	1	-	1	-	1	-	-	3
9.	Burning sensation	-	1	-	2	2	-	-	-	-	-	-	5
10.	Feeling hot and cold	-	1	2	4	1	-	1	-	-	-	-	9
11.	Finger getting blue	-	-	-	5	-	-	-	-	-	-	-	5
12.	Reduced acuity	-	-	-	5	-	-	-	-	-	-	-	5

with deterioration of neuro-cognitive and physiological faculties.

DISCUSSION

In a study by Mark Wolff it has been observed that at about 35,000 ft time of useful consciousness may be 30 seconds or less, at 25,000ft it is between 3-5 minutes while at 18,000 ft time of useful consciousness comes to 20-30 minutes[5]. Nuno Riberio in his study conducted on 43 Portuguese Air Force military people pointed out that there is no connection between the hypoxia time, age or smoking habits[6]. This study has shown that at 25000 ft the time of useful consciousness in majority of the aviators was 5 minutes. In other words at such a high altitude where oxygen is low, hypoxia starts to manifest its effects after 5 minutes and there remains constant need of oxygen. During flight at such a height inability of aviator to recognize hypoxia and its symptoms will result in disaster. Although hypoxia is manifested through wide range of symptoms in different individuals but in one study conducted at Beale Air Force base california by Kevin Svetcos it was demonstrated that at 10,000 ft there was reduced night vision, at height of 10 – 15000 ft drowsiness, poor judgment and impaired coordination, at 15-20000 ft there was impaired flight control, impaired hand writing, impaired speech, reduced coordination, reduced sensation to pain, reduced memory and impaired judgment while at 20-25000 ft there was circulatory collapse and convulsions[7]. Mark Wolff in his study indicated that first signs of hypoxia include mental and physical. Mental signs to appear first are loss of judgment, self criticism and short term memory loss. This can be accompanied by increased in reaction time, tunnel vision and even euphoria. Physical sign to appear first is hyperventilation along with in-co-ordination, impaired colored and night vision, hearing deteriorates, as hypoxia continues it causes semiconscious[5]. Bartholomew in his study observed that for read backs of high memory load there was significant defect in recall at 12500 ft and 15000 ft but no effect of altitude was observed on recall of read backs with low memory loads. It means that cognitive deficits are found at lower altitudes than previously observed[8]. In this study it was noted that drowsiness was most frequently experienced and initial symptom. Total of twenty two individuals experienced drowsiness out of which fifteen had it after five minutes of hypoxia at twenty five thousand feet. None reported drowsiness after two minutes only two individuals reported drowsiness after three minutes of hypoxia. Drowsiness was followed by weakness, fatigue, tingling sensation, nausea and headache in order of frequency. Other symptoms like burning sensation, feeling hot and cold, fingers getting blue were less frequent but they all developed mostly after five minutes of hypoxia at twenty five thousand feet. At eighteen thousand feet where visual disturbance due to

hypoxia were checked for night flying in dimmed lights it was noted that most frequent symptom that occurred was blurred vision. Other visual disturbance noted was reduced visual acuity. It is also interesting to note that euphoria was experienced by three individuals and it was not the symptom that occurred after five minutes of hypoxia but it appeared late i.e. in one individual after six minutes, second individual had it after eight minutes and the third individual developed euphoria after ten minutes of hypoxia. It was also noted in this study that memory deficits were not present at lower altitudes and were not remarkable.

CONCLUSION

On the basis of results of this study it been concluded that hypoxia at high altitude manifests itself in wide range of symptoms. All these symptoms have correlation with time of hypoxia. The earliest manifestation of hypoxia in majority is development of drowsiness while late manifestation is euphoria.

Limitations

Individuals participating in this study were all healthy and well trained aviators. Therefore results of the study can not be generalized to general population or the population dwelling at high altitudes.

Individuals rapidly ascended to the high altitudes without acclimatization. Therefore results of this study can not be generalized to population dwelling at high altitudes or mountaineers who ascend slowly and gradually with proper acclimatization.

Effects of variables like age, sex and smoking were not compared and considered in this study.

Clinical Implications

This study will provide base line understanding to the flight surgeons regarding the effects of hypoxia on our aviators flying at high altitudes.

It will help in effective training to the aviators.

It will help flight surgeons in educating aviators regarding effects of hypoxia based on indigenous data.

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