Introduction of Integrated Oxygen-Communication Mask and Helmet in Army Aviation: An aeromedical view point

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ABSTRACT

Army Aviation has been operating in High Altitude regions of Northern and Eastern India for almost three decades. Till recently, the aviators had been using 'EROS' mask which was not harnessed to the helmet but used as 'Hookah' i.e. intermittent use of oxygen. Investigations in almost all accidents have had hypoxia as a contributing factor. Army Aviation has recently acquired Integrated Oxygen-Communication Mask and Helmet (IOCMH) aimed to provide continuous, on demand oxygen to aviators and thereby minimize chances of hypoxia. The usage of this new apparatus has brought into light a plethora of problems inherent to the design of this apparatus. After the preliminary testing at base i.e. on ground and in-flight trials, it is recommended that the system be withheld till further trials are carried out in the safe confines of lab environment followed by controlled in-flight trials the high altitude regions where it is expected to be used.

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Introduction

Army aviation has been operating in the high altitude (HA) regions in the Northern and Eastern part of India for more than three decades. The only aircraft available for operating in these regions is a light helicopter (Cheetah) which is un-pressurised. The service ceiling of the aircraft is about 23000 ft. The only helicopter squadron to be located in HA (along with the helicopter unit of IAF) is located at about 10,642 ft. The Ladakh region of our country is characteristically different by virtue of wide and extreme variations of temperatures and humidity. Coupled with these are vast expanses of featureless terrains, insurmountable passes over the great Himalayan, Karakoram and Saltoro ranges, which are in a perennial snow cover. Here, the limits of machine and the man are tested on a daily basis. Despite a very high standard of servicing and snag rectifications, there have been largest number of helicopter accidents in the region which could neither be attributed to enemy action or technical or material failure. Invariably, the aircraft accidents have brought out the possibility of aviators having suffered from hypoxia and hence being a crucial and a contributory factor in causation of these mishaps [1,2].

Till about last year, the army aviation was flying with an oxygen system, which was referred to as the 'Hookah system' as the EROS mask with regulator was not harnessed to the helmet. The aviator carried two cylinders each capable of delivering 300 L of aviation quality oxygen pressurised at 1800 psi or 150 bars. This was not considered a foolproof method to prevent hypoxia. Hence, a need for better integrated mask and helmet system was projected in late 1990's. Since the aviators were inhaling intermittent 100% oxygen at regular intervals and in addition, during the crucial phases of flight, there was nothing to prove or negate whether they, at some point of time, were

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rendered hypoxic leading to impaired judgment. Extremely low temperatures, very low humidity, high stress and long durations of exposures (2-5 hrs) coupled with hypobaric environment due to un-pressurised cabin with intermittent oxygen inhalation provided with perfect recipe for hypoxia. Hence a need for continuous oxygen delivery system has been projected. An Integrated oxygen, communication mask and helmet (IOCMH) from Ulmer Aero -technique, France (comprising of Gallet helmet, Ulmer 82 H Mask and F 6171 demand dilution regulator) was approved after extensive trials at IAM Bangalore and the Army Project Team of test pilots at Bangalore during 1999-2000. The army aviation squadrons were issued with the scaled IOCMH as 'sector stores', with helmet and mask in different sizes. It was envisaged that the IOCMH would find a major solution by ensuring no aviator is hypoxic at any point of time even inadvertently in flight. The use of IOCMH at all times was mandatory after a month of introduction.

After about a month of use of IOCMH, an aviator reported to his squadron Medical Oficer with symptoms of severe headache after a four hour sortie. He revealed that he had been having persistent problem after flying with the new Oxygen system. The issue was discussed in detail after the flying briefing on the subsequent day. The problems brought forth during discussion with the aviators in base and the other flights are tabulated in Table 1.

It was therefore considered prudent to carry out preliminary ground testing for assessing the problems in an objective manner.

Table 1: Problems experienced by Pilots during various stages of flying

S. N.	Problem	No. of Pilots (n=21)	% age	Probable cause
1.	Undue effort of inhalation (Normal setting)	16	76.2	?Inadequate flow rates
2.	Feeling of inadequate oxygen (at normal setting)	12	57.1	?Inadequate percentage of oxygen
3.	Inadequate size/fitment of helmet	3	14.3	?Helmet issue not customized
4.	Inadequate size/fitment of mask	3	14.3	?Mask issue not customized
5.	Early emptying of cylinder (at 100%)	18	57.1	Smaller capacity of cyl
6.	Undue effort of inhalation (100% setting)	18	85.7	?Inadequate flow rates
7.	Excessive Fluttering noise (at 100% setting) at ground and in air	18	85.7	?Manufacturing defect
8.	Headache after long(>3h) sortie)	3	14.3	?Inadequate percentage of oxygen
9	Fatigue after long (>3h) sortie	4	19.0	?Inadequate percentage of oxygen
10.	No indication of oxygen getting over When at normal setting			
11.	No Indication of inadvertent disconnection			Possible to breathe even when not connected

Material and Methods

The testing of IOCMH was carried out in field (High Altitude Area) in two phases:

(a) *Phase 1.* Ground trials to assess subjective comfort, oxygen saturation (with help of SpO_2, and availability of oxygen in terms of duration.

(b) *Phase 2.*Testing of demand dilution regulator for available percentage of oxygen at 'Normal Air' and '100% Oxygen' setting at High Altitude Medicine Research Centre (HAMRC).

Phase 1 (Ground Trials): Ground trials were carried out in the month of Apr 2008 at the base with elevation of 10682'. A total of nine subjects, of which, seven pilots who had been using IOCMH for more than a month were selected. Presence of any disease was ruled out. All subjects had been in high altitude for a period of more than 3 months. One out of seven pilots and one of the other two subjects were smokers. The mean age was 32.5 yrs (range – 28 yrs to 35 yrs). The mean Hemoglobin percentage amongst nine subject was 17.2 (range – 16.2 to 18.2gm %). Mean Height was 1.71m (Range – 162-182cm). Mean weight was 69Kgs (range 59-82Kgs). Only one subject was overweight with BMI of 25.9.

The trials were conducted in a room with temperature 16ºC at about 1700h. The relative humidity was 19%. Two nursing assistants and an engineering officer were briefed in detail to collect the physiological parameters. Five hand held battery operated pulse oximeters (Make – Nonin® 8500) were provided by 'High Altitude Medicine Research Centre' (HAMRC). Pulse rate, respiratory rate, SpO2 [3] was assessed in all subjects after 10 min of sitting in an easy chair. After ascertaining all parameters to be with in normal range, the subjects were asked to don the mask with the helmet and attach the connector to the GLF 313 cylinders pressurized at 90 bars (Ulmer 82 H Mask and F 6171 demand dilution regulator). All the parameters were recorded at '0' to '30' mins at 5 min interval with 'Normal setting' ie Air-Ox mix followed by same protocol repeated with regulator setting at '100%'.

Phase 2: Tests at 'High Altitude Medicine Research Centre' (HAMRC) Randomly selected, two GLF 313 cylinders with EROS pressure reducer and two Ulmer regulators with masks were tested at HAMRC (elevation – 11560') for the percentage of available oxygen at the mask end by modifying the connector beyond the regulator, at both settings. The modified connector was ensured to be adequately sealed, in addition liberal usage of duct tapes ensured sealing. The oxygen analyser used was Miniox-1® oxygen analyser (MSA Medical Projects) with Maxtec® Oxygen sensor.

Results

The subjective problems experienced by pilots during various stages of flying are presented in Table 1. The results of the ground trials are presented in Table 2 & 3. The pulse rate, respiratory rate remained well with in the range throughout the trial period of 30 min at both settings. The SpO2 obtained at air–ox mix ranged from 91-93% in all subjects. The SpO2 obtained at 100% setting ranged from 95-97% in most of the subjects and higher than 97% on 8 occasions limited to two subjects. 05 pilots reported undue effort and sense of air hunger during air-ox breathing. The flutter at 100% setting was discernible in 4 subjects. The pressures noted in the cylinders at the end of air-ox breathing and 100% oxygen breathing is tabulated in Table 4.

The results of trial at HAMRC are presented in Table 5. The oxygen concentration obtained at normal setting was 22.8 and 24.1. The oxygen

Table 2: Ground trials with mask at normal 'Air-Ox' setting(Ulmer82 H Mask and F 6171 demand dilution regulator)

S No.	0 Min			5 Min			10 Min			15 Min			20 Min			25 Min			30 Min		
	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2
1	67	16	93	67	18	92	66	16	92	67	16	91	68	16	91	70	17	93	65	18	93
2	71	18	91	73	17	92	72	17	93	75	18	93	73	17	91	70	17	92	73	17	92
3	84	17	91	82	16	91	81	17	91	83	18	91	84	16	91	82	16	91	88	16	93
4	68	18	91	67	18	92	68	16	91	69	16	93	66	18	92	68	18	92	67	19	91
5	75	18	91	72	16	91	74	18	91	72	16	92	74	18	91	76	18	91	78	17	91
6	79	17	92	76	16	92	75	17	91	77	17	91	71	17	90	72	17	91	74	16	92
7	72	16	91	72	15	92	74	17	91	72	16	93	78	17	91	74	16	93	74	17	93
8	87	16	93	82	16	91	82	16	91	70	17	91	73	16	92	74	17	92	81	18	91
9	88	14	91	88	16	91	82	16	92	80	16	93	82	17	93	77	16	91	84	16	93

Table 3: Ground trials with Ulmer F 6171 regulator at 100 % setting

S No.	0 Min			5 Min			10 Min			15 Min			20 Min			25 Min			30 Min		
	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2	Pulse	RR	SpO2
1		65	18	93	70	17	97	72	16	97	71	16	97	73	16	98	74	16	97	75	16
2		73	17	92	70	16	97	69	16	97	69	16	96	71	15	97	70	15	98	72	16
3		88	16	93	78	17	97	75	16	97	72	16	97	70	16	96	70	15	97	74	16
4		67	19	91	69	19	97	68	16	96	67	16	96	66	16	97	68	16	97	67	16
5		78	17	91	80	16	97	74	15	96	74	15	96	76	15	96	74	16	99	72	15
6		74	16	92	74	16	97	72	17	95	72	15	97	72	16	97	70	15	96	74	16
7		74	17	93	72	16	98	73	17	97	70	16	97	73	16	97	70	15	98	72	15
8		81	18	91	68	18	99	74	15	98	72	15	97	70	15	97	71	15	97	75	16
9		84	16	93	82	16	97	82	16	97	84	14	97	82	16	96	79	16	95	76	15

Table 4: GLF 313 Cylinder Pressure (bars) reading with time lapsed

Sl. No.	0 min	30 min	60 min
1	90	85	10
2	90	88	70
3	90	87	20
4	90	88	15
5	90	84	10
6	90	83	10
7	90	81	12
8	90	85	19
9	90	83	11

Table 5: Oxygen percentages as obtained by Oxygen analyser at the level of mask at HAMRC

Sl. No.	Air-Ox	100%
1	22.8	96.5
2	24.1	98

concentration in percentage at '100%' setting was found to be 98% and 96.5%.

Discussion

Army Aviation has been operating in the high altitude regions for almost three decades. The flying operations in the vast expanse, of Ladakh region pose a challenge. Most of the routine operations include crossing passes, the passage through the insurmountable heights of the great mountainous ranges. These are invariably 17000'-18000' high. A good oxygen system is basic need for safe operations in this region for the un-pressurized military helicopters. The temperatures as low as –50ºC further add to the possibility of hypoxia. In past, most of the accident investigations have reflected hypoxia as a direct or indirect cause in accidents involving human error.

The squadron has been using the EROS mask with a demand dilution regulator till about 1 yr back. The aviators used this system as 'Hookah', taking oxygen on demand at every 5-6 min and in addition crucial phases of the flight. This system was presumed to be inefficient and adequate oxygenation at all times could not be ensured. Thus, the need for continuous inhalation of oxygen by a demand dilution mask and regulator system was projected. The new oxygen system was procured and given for use by the squadrons about a year back after extensive trials. The issues mentioned in table-1 were taken into account and the trials for delivery of oxygen are discussed. The other issues which require solution other than scientific are also discussed as below.

The Integrated oxygen communication mask and helmet was issued as sector stores in varied sizes. Though the anthropometric criteria were apparently taken into account, a total of 6 pilots reported having difficulties in having a comfortable adjustment (Table 1 refers). This was despite a wide range of possibility of adjustments in the mask as well as the helmet. The reason can be due to the fact that the choice of size for the new comers was not available since the mask and helmet were not issued as personal flying clothing and the selection for best fitment happened on first come first serve basis, out of the total number made available for use. More problems came into light when pilots reported undue effort of inhalation and feeling of air hunger after some time during the sortie with the normal setting (air-ox) of the regulator. This was followed by frequent reports of headaches and undue fatigue after the sortie. It was at this time initial ground testing with the crew was carried out. Pulse Oximetry served as a guideline in determining the physiologic adequacy of the prototype combinations in the developmental process. This well known technique was found to be highly dependable in field trials [4].

The alveolar partial pressure of oxygen reduces with ascend to HA [5] and hence the SpO2. The ground trial brought into light that the SpO2 of the well acclimatized pilots was about 91-93% at room air, this corroborates well with the SpO2 levels of most of the healthy individuals in the base. As it can be made out from the table-2, the subjects maintained the SpO2 level between 91-93% despite breathing through the IOCMH. The values were measured at 5 min intervals in 9 subjects. There was no significant change in the pulse rate, respiratory rate and SpO2 throughout this duration. The demand dilution regulator and mask is required to give oxygen in increasing percentage (with increase in altitude) by virtue of an inbuilt barostatic device in the regulator. In ideal situation the percentage should be such that the partial pressure in lungs is maintained at sea level. It was not found to be so, as it can be indirectly surmised from the findings. All the subjects maintained 97% saturation with regulator setting of 100% which is expected.

With these findings, in Phase 2, randomly selected mask with regulators were tested at HAMRC for the percentage of oxygen at these two settings. Applying the alveolar gas equation the percentage of oxygen required at the altitudes 10000' and 11500' is 31% and 33% respectively. It was not found to be so. The two regulators tested, showed 22.8 and 24.1% respectively. That is to say that the regulators are not delivering the desired and correct percentage of oxygen to maintain adequate alveolar pressure of oxygen. Though a little higher percentage than the physiologic requirement may be desirable, the lesser percentage delivery as observed is certainly not acceptable. The reliability of mask regulator with normal setting was therefore deemed doubtful.

The system delivers 96.5-98% oxygen as assessed at HAMRC. And hence there is no problem with this fact keeping in view the findings of ground trials at the same setting which reflected adequate SpO2 in all the subjects. Now, the problem faced was the availability of oxygen for the duration of sortie. Earlier trial reports availability of 20 Min of oxygen at sea level when the GLF 313 cylinder is pressurized to 150 bars (300L). As the altitude increases the availability increases in terms of volume and therefore duration. A problem peculiar to high altitude and certain instances of bursting and leaking of oxygen cylinders, the cylinders can only be filled upto 90 bars. At this pressure the available volume is about 260 L at 10,000 ft, 304L at 14,000 ft and 360 L at 18,000 ft AMSL. Since most of the flying operations are between these altitudes it can be assumed that a cylinder would last for duration of 20±5 minutes. Applying this to the requirement by each pilot for a 3 hr sortie would be, in ideal conditions anywhere from 6-9 cylinders each! The cylinders required for passenger on board is additional to this requirement.

Providing 100% oxygen may not be a problem by introducing large capacity, lighter carbon composite cylinders in helicopter but the fact remains, it is not necessary besides adding to the problems like substernal discomfort due to irritation of the mucosal lining of respiratory passage by high partial pressure of oxygen. Additionally, there is a risk of delayed barotraumas.

Conclusions and Recommendations

The IOCMH is made available as one time issue sector stores; this has lead to a problem of inadequate fitting in aviators who have not selected their masks initially at the time of issue. It is recommended that the same be issued as personal flying clothing. Undue effort and feeling of air hunger can be explained to some extent by the ground trial and the trial at HAMRC which reveals that the regulator is not delivering the adequate percentage of oxygen to maintain adequate arterial oxygen saturation. Using regulator at normal setting is probably unreliable requires testing for adequate percentage delivery in simulated conditions and field trials for adequacy of oxygen delivered in terms of percentage.

Early emptying of cylinder is due to the fact that the oxygen at 100% setting is available for much less duration due to reduced filling pressures at HAA and continuous inhalation. Larger capacity cylinder or onboard oxygen generating system can be considered for introduction for un-pressurized aircrafts in this sector. Undue effort (negative/ suction pressure) required for inhalation and the persistent flutter needs to be addressed as the latter may interrupt with RT communication in crucial phases of flight/emergencies. The test for delivery pressures required to reduce the effort of suction needs to be carried out at aeromedical laboratory. There is no indication of inadvertent disconnection of the oxygen hose and no indication of emptying of oxygen cylinder (at normal setting). A plunger at the level of hose connection to cylinder can be introduced to present negative pressure in case of inadvertent disconnection.

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