Extended use of the mask mounted anti-suffocation valve

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Introduction

It is known that situations arise in which crew of fighter aircraft using breathing systems are required to breathe ambient air. Such a situation may arise following separation of the man portion of the personal equipment connector; failure of the breathing gas supply or on selection of continuous flow bypass.

The mask mounted anti-suffocation valve is a simple spring loaded valve which opens at a minimum suction of 5 inch wg to provide inward relief in situations where the wearer is required to breathe ambient air, avoiding removal of the mask, which may well be unacceptable. It is designed to open at this level of suction to ensure that whilst opening of the valve is immediately apparent to the user and will not occur during correct functioning of the oxygen system, the level of suction required does not cause severe impairment of respiration either in the conscious or unconscious wearer (Ernsting and Macmillan 1966)

Continuous flow bypass facility has been included in the design of several series of demand regulators to provide an alternative path for the flow of oxygen from the source, to the oxygen mask hose in the event of a failure of the demand valve of the regulator to pass oxygen. The flow of breathing gas which is typically employed in a continuous flow bypass is, in many conditions of altitude and respiratory demand, considerably less than the instantaneous flow of gas into the lungs during a significant proportion of the inspiratory cycle. An inward relief facility is therefore required whereby air may be drawn into the system when the instantaneous flow exceeds the flow of breathing gas provided by the bypass orifice. Use of the anti-suffocation valve following selection of the continuous flow bypass facility is likely to be more prolonged than in the other emergency situations such as during escape.

Previously there has been little experimental evidence as to the time for which breathing through a resistance of the magnitude imposed by the anti-suffocation valve can be tolerated, beyond about ten minutes. The present study examined the respiratory effects of breathing through the anti-suffocation valve for periods of up to 45 minutes whilst exercising on a cycle ergometer at ground level. A period of 45 minutes was chosen to be representative of the time for which the wearer may be expected to breathe through the valve having selected the by-pass facility in flight. Work levels of 40W and 80W were chosen to achieve levels of pulmonary ventilation equivalent to those measured during flight. It was decided to investigate breathing through the anti-suffocation valve alone, with no additional bypass flow, as this would represent the 'worst case' situation.
The study was designed to allow direct comparison between breathing through the anti-suffocation valve and performing the same levels of exercise without the added resistance to breathing. Each subject was asked to attempt two runs at each work level; once

breathing through the anti-suffocation valve and once breathing through the same experimental set-up with no additional resistance

Methods

The subject wore a type P/Q RAF oronasal mask without an anti-suffocation valve. The inlet hose of the mask was connected by a length of flexible hose to a two-way tap. One arm of the tap carried a standard RAF anti-suffocation valve and the other opened directly to the atmosphere, providing the two experimental conditions.

The study was carried out using six naïve volunteer subjects, mean age 20.6 years. After informed consent had been obtained, each subject was given a period of familiarisation with the breathing equipment being used in the study. The order in which the runs were undertaken was randomised. No more than two runs were completed during one visit to the laboratory and the subject was allowed at least one hour of rest between each run.

The following variables were recorded throughout each run.

- Inspiratory flow – this was measured using a capillary flowmeter inserted between the two-way tap and the inlet hose of the mask.
- Pulmonary ventilation – this was obtained by integration of the flow signal from the capillary flowmeter.
- End tidal carbon dioxide concentration – gas was sampled from the mask cavity using a rapid reponse carbon dioxide analyser.
- Respiratory frequency – obtained from the record of expired carbon dioxide concentration
- Mask cavity pressure was measured
- electrocardiogram was continuously recorded to allow heartrate to be monitored from the digital display of the monitor.

Results

The resistance to inspiration when breathing through the inspiratory circuit with and without air flowing through the anti-suffocation valve was determined from the dynamic records of inspiratory flow and mask cavity pressure. The suctions in the mask cavity at an inspiratory flow of 100 litre min^{-1} were 1.0 inch wg without the anti-suffocation valve and 6.6 inch wg when the anti-suffocation valve was in the circuit. The corresponding sections at an inspiratory flow of 5 litre min^{-1} were 0.2 and 5.1 inch wg.

All subjects were able to complete each of the four experimental runs. From the raw data, values were calculated for each subject at intervals of five minutes by taking the mean value of the period thirty seconds either side of this time. Mean values for the six subjects were calculated at 5min, 25 min and 45 min for each variable. These values are displayed in Table 1. It can be seen from the magnitude of the difference of the means compared to the SEM's that that there was no significant difference between the variables measured whilst breathing via the anti-suffocation valve compared with control, during the experiment.

Conclusions

A study has been carried out to examine the effects of extended use of the mask mounted anti-suffocation valve. Breathing via the anti-suffocation valve alone whilst exercising at 40W or 80W was well tolerated for 45 minutes by naïve subjects. There were no significant changes in respiratory variables or heart rate from those recorded when breathing without the anti-suffocation valve. It is concluded that the inspiratory resistance presented by the present RAF mask mounted anti-suffocation valve is well within acceptable limits.

Reference

Ernsting J and Macmillan A J F (1966) The provision of inward relief in miniature oxygen systems *IAM Technical Memorandum No 270* RAF Institute of Aviation Medicine, Farnborough, Hants

Table 1: Values for End-Tidal PCO_2, Pulmonary Ventilation, Respiratory Frequency and Heart Rate at 5 min, 25 min and 45 min - mean and (SEM), n=6

	5 min	25 min	45 min
$P_{ET}CO_2$ (mmHg)			
40 control	39.7 (2.9)	38.8 (1.9)	37.5 (1.1)
40 ASV	37.6 (1.6)	37.3 (1.4)	37.3 (1.7)
80 control	40.78 (1.9)	39.78 (1.7)	39.6 (1.7)
80 ASV	39.92 (1.4)	38.9 (1.3)	39.1 (1.7)
Pulmonary Ventilation (l[BTPS]/min)			
40 control	19.5 (1.1)	21.4 (1.1)	21.4 (0.7)
40 ASV	19.0 (1.2)	21.4 (1.6)	22.1 (1.7)
80 control	30.9 (2.0)	35.4 (2.1)	34.4 (1.4)
80 ASV	30.1 (1.0)	34.8 (0.9)	34.2 (2.7)
Frequency (breaths per minute)			
40 control	20.5 (1.7)	20.2 (1.5)	21.2 (1.8)
40 ASV	19.5 (1.7)	19.2 (2.0)	18.7 (2.6)
80 control	22.5 (2.2)	25.0 (2.1)	24.5 (2.0)
80 ASV	20.75 (1.6)	25.2 (1.9)	25.2 (3.1)
Heart rate (bpm)			
40 control	92 (4.6)	97 (6.7)	94 (4.6)
40 ASV	91 (4.4)	99 (5.9)	98 (6.0)
80 control	117 (9.2)	126 (10.0)	130 (9.5)
80 ASV	114 (7.8)	122 (9.3)	130 (9.7)