Hypoxia

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The pilot of an unpressurised twin engined Seneca requested Melbourne air traffic controllers clearance to climb over weather to FL220. The aircraft had no supplemental oxygen. The aircraft was noted to climb to FL230. When contacted for clarification the pilot’s speech was noted to be slurred and sounded intoxicated. The controller felt the pilot to be suffering from the effects of hypoxia. The pilot was requested to descend to FL150 at which time an improvement in his coherency was noted.Hypoxia is an insidious condition which develops due to a lack of oxygen in the bodies tissues. It is an inevitable consequence of flight at higher altitudes unless suitable precautions are taken.The Physiology

Altitude (ft)Barometric Pressure (mm Hg) Oxygen Pressure (mm Hg)Alveolar Oxygen (mm Hg)0760159104 5,00063213378 10,00052311067 20,0003497340 30,0002264721 40,000141298Our bodies tissues, and especially the nerve and sensory tissues require a constant stream of oxygen to support their function. Oxygen is inhaled into the lungs into tiny air sacs called alveoli. These sacs are covered with a network of tiny blood vessels; capillaries, where the the oxygen diffuses into the blood, and carbon dioxide diffuses from the blood under the effect of the pressure differences of these gases. Oxygen is then chemically bonded with a molecule in the blood; hemoglobin.

This is carried in the blood to the target tissues. The oxygen pressure in the tissues are lower than those in the blood and hence the oxygen diffuses due to this pressure gradient into the tissues (and carbon dioxide from the tissues into the blood). The essential requirement for this system to function is a pressure gradient for these gases between the atmosphere and tissues. The Physics

Dalton’s Law states the pressure of a gas is the sum of the partial pressures of its constituent gases. The air pressure at ground level is 760 mmHg. Air contains approximately 21% oxygen so the pressure of oxygen at ground level is 160 mmHg. The atmospheric pressure halves every 18,000 ft.Unfortunately the situation is aggravated by a number of other factors. Air in the alveoli is always fully saturated with water vapour, and at body temperature this represents a pressure of 46 mmHg. Also carbon dioxide production is constant by the body for a given level of activity resulting in a partial pressure of 40 mmHg (at higher altitudes; over 20,000’, we breath more deeply and “blow” some of this out but it never falls below 24 mmHg). Lastly as we remove oxygen from the alveolus the pressure of the remaining oxygen falls proportionately. Because of these factors the oxygen available in the alveolus falls with altitude to a greater extent than the fall in atmospheric pressure (table 1).The body’s one redeeming feature in this regard is the remarkable ability of the hemoglobin molecule to latch onto oxygen even when oxygen levels are low. Thus at 10,000ft (60% of ground level alveolar oxygen pressure) the hemoglobin still manages to carry 90% of the oxygen it carries at ground level (the “saturation”).

Similarly at 20,000ft the saturation is 70% despite an alveolar oxygen concentration of less than 40% of ground level.The Effects Altitude(ft)Time of useful consciousnessTime for coma 18,00020 minutes- 20,00010 minutes- 25,0003 minutes8 minutes 30,0001 minute2 minutesThe effects of hypoxia vary between individuals and are thus difficult to predict. They also depend on the time of exposure to the hypoxia. The following list represents typical effects for a fit young person exposed for a significant period (hours).

- 5,000’ - Decreased peripheral vision and light sensitivity;
- 8,000’ - Hyperventilation with tingling, light headedness, anxiety and possible muscle spasm mental fatigue and decreased mental proficiency;

- 12,000’ - drowsiness, lassitude, headache, euphoria and loss of self-criticism, disorientation, nausea, cyanosis (pale skin, blue lips and nails);

- 23,000’ - twitching, semi-consciousness, convulsions, coma;

- 25,000’ - death.

Exposure for shorter periods can usually be tolerated, the problem being to recognise when the symptoms are starting to occur in the presence of the impaired mental abilities, before the ability to take corrective action is lost (see Table 2.). The RemedySince the cause of hypoxia in flight is a lack of pressure of oxygen to drive the transport mechanisms for oxygen in the body the remedy is to increase the oxygen pressure.

In a larger aircraft the cabin can be pressurised and the cabin pressure increased to a level where no significant symptoms occur (about 8,000’ pressure in a modern air liner). In a glider this is not a realistic solution. Similarly the use of a pressure suit is not possible. For unpressurised operations as in a glider supplemental oxygen is essential. In theory breathing 100% pure oxygen one can fly to 47,000’ however the simple flow demand type oxygen systems used in gliders are incapable of supplying 100% oxygen. In fact they cannot supply reliably greater than 40% resulting in an operating ceiling of 28,000’. For higher altitudes a pressure fed system with a close fitting face mask is essential. This still leaves the problem that all oxygen systems are subject to failure due to blocking of supply lines, exhaustion of oxygen supply or leaks in the system. It is thus preferred that pilots flying with the use of supplemental oxygen have experienced hypoxia in a controlled setting enabling them to recognise the symptoms and take corrective action. This facility was available with the altitude chamber at the RAAF Institute of Aviation Medicine; Point Cook, but with its transfer to Adelaide this is no longer so. Pilot susceptibility to hypoxia depends on a number of factors. Smokers disable a significant proportion of their hemoglobin with carbon monoxide, cold decreases blood flow, respiratory infections decrease oxygenation, some drugs and alcohol all increase susceptibility.

How high can a pilot safely fly without oxygen? Medically this depends on a number of factors, but the simple answer is 10,000 ft., this being included as a requirement of the Civil Aviation Orders.