HYPOXIA

Characteristics of Hypoxia

Hypoxia results when the body lacks oxygen. Hypoxia tends to be associated only with flights at high altitude. However, many other factors – such as alcohol abuse, heavy smoking, and various medications – interfere with the blood’s ability to carry oxygen. These factors can either diminish the ability of the blood to absorb oxygen or reduce the body’s tolerance to hypoxia.

Types of Hypoxia

There are four major types of hypoxia: hypoxic, hypemic, histotoxic, and stagnant. They are classified according to the cause of the hypoxia.

1. **Hypoxic Hypoxia** – Hypoxic hypoxia occurs when not enough oxygen is in the air or when decreasing atmospheric pressures prevent the diffusion of O2 from the lungs to the bloodstream. Aviation personnel are most likely to encounter this type of hypoxia at altitude.

2. **Hypemic Hypoxia** – Hypemic, or anemic, hypoxia is caused by a reduction in the oxygen-carrying capacity of the blood. Anemia and blood loss are the most common causes of this type. Carbon monoxide, nitrites, and sulfad drugs also cause this hypoxia by forming compounds with hemoglobin and reducing the hemoglobin that is available to combine with oxygen.

3. **Stagnant Hypoxia** – In stagnant hypoxia, the oxygen-carrying capacity of the blood is adequate but circulation is inadequate. Such conditions as heart failure, arterial spasm, and occlusion of a blood vessel predispose the individual to stagnant hypoxia. More often a crew member experiences extreme gravitational forces, disrupting blood flow and causing the blood to stagnate.

4. **Histotoxic Hypoxia** – This type of hypoxia results when there is interference with the use of O2 by body tissues. Alcohol, narcotics, and certain poisons – such as cyanide – interfere with the cell’s ability to use an adequate supply of oxygen.

Susceptibility to Hypoxia

1. Physiological Altitude
2. Smoking – blood has 200 to 300 times greater affinity for carbon monoxide than for oxygen.
   a. Loss 20% of night vision at sea level
   b. Physiologica altitude of 5,000 feet at sea level
3. Alcohol – creates histotoxic hypoxia
   a. 1 ounce of alcohol = 2,000 feet physiological altitude
Stages of Hypoxia

There are four stages of hypoxic hypoxia: indifferent, compensatory, disturbance, and critical.

1. **Indifferent Stage** – Mild hypoxia in this stage causes night vision to deteriorate at about 4,000 feet. Aircrew members who fly above 4,000 feet at night should be aware that visual acuity decreases significantly in this stage because of both the dark conditions and the developing mild hypoxia.

2. **Compensatory** – The circulatory system and, to a lesser degree, the respiratory system provide some defense against hypoxia at this stage. The pulse rate, systolic blood pressure, circulation rate, and cardiac output increase. Respiration increases in depth and sometimes in rate. At 12,000 to 15,000 feet, however, the effects of hypoxia on the nervous system become increasingly apparent. After 10 to 15 minutes, impaired efficiency is obvious. Crew members may become drowsy and make frequent errors in judgment. They may also find it difficult to do even =simple tasks requiring alertness or moderate muscular coordination. Crew members preoccupied with duties can easily overlook hypoxia at this stage.

3. **Disturbance Stage** – In this stage, the physiological responses can no longer compensate for the oxygen deficiency. Occasionally, crew members become unconscious from hypoxia without undergoing the subjective symptoms. Fatigue, sleepiness, dizziness, headache, breathlessness, and euphoria are the symptoms most often reported.

4. **Critical Stage** – Within three to five minutes, judgment and coordination usually deteriorate. Subsequently, mental confusion, dizziness, incapacitation, and unconsciousness occur.

**Prevention of Hypoxia**

Hypoxic hypoxia can be prevented by ensuring that sufficient oxygen is available. Preventive measures include:
- Limiting time at altitude
- Using supplemental oxygen
- Pressurizing the cabin

**Treatment of Hypoxia**

Individuals who exhibit signs and symptoms of hypoxia must be treated immediately. Treatment consists of giving the individual 100% oxygen. If oxygen is not available, descent to an altitude
below 10,000 feet is mandatory. When symptoms persist, the type and cause of the hypoxia must be determined and treatment administered accordingly.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Indifferent Stage (89%–80% O₂ saturation)</th>
<th>Compensatory Stage (89%–80% O₂ saturation)</th>
<th>Disturbance Stage (79%–70% O₂ saturation)</th>
<th>Critical Stage (60%–60% O₂ saturation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (thousands of feet)</td>
<td>0–10</td>
<td>10–15</td>
<td>15–20</td>
<td>20–25</td>
</tr>
<tr>
<td>Symptoms</td>
<td>Decrease in night vision</td>
<td>Drowsiness Poor judgment Impaired coordination Impaired efficiency</td>
<td>Impaired flight control Impaired handwriting Impaired speech Decreased coordination Impaired vision Decreased sensation to pain Impaired intellectual function Decreased memory Impaired judgment</td>
<td>Circulatory failure CNS failure Convulsions Cardiovascular collapse Death</td>
</tr>
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**STRESS AND FATIGUE**

**Stress Defined**

Stress is the nonspecific response of the body to any demand placed upon it.

**Identifying Stressors**

A stressor is any stimulus or event that requires an individual to adjust or adapt in some way – emotionally, physiologically, or behaviorally. Stressors may be psychosocial, environmental, physiological, and congnitive.

1. **Psychosocial Stressors** – life events. These stressors may trigger adaptation or change in one’s lifestyle, career, and/or interaction with others.
   a. Job Stress
   b. Illness
   c. Family Issues
2. **Environmental Stressors**
   a. Altitude
   b. Speed
   c. Hot or Cold Environments
   d. Aircraft Design
   e. Airframe Characteristics
   f. Instrument Conditions
3. **Physiological (Self-Imposed) Stressors** – Many aviators engage in maladaptive behaviors that are potentially debilitating and threaten aviation safety. This category can be remembered using the acronym DEATH, which stands for drugs, exhaustion, alcohol, tobacco, and hypoglycemia.

   a. **Drugs**
      i. Self Medication
      ii. Predictable Side Effects
      iii. Overdose Problems
      iv. Allergic Reactions
      v. Synergistic Effects (combining drugs)
      vi. Caffeine – central nervous system stimulant that counteracts and delays drowsiness and fatigue. Can elevate blood pressure, impair hand-eye coordination and timing, and cause nervousness or irritability.

   b. **Exhaustion**
      i. Lack of Rest and Sleep
      ii. Physical Conditioning

   c. **Alcohol**
      i. Depressant
      ii. Adversely affects normal body functions
      iii. Detrimental to judgment, perception, reaction time, impulse control, and coordination
      iv. Effects depend on amount consumed, rate of absorption, and body’s rate of metabolism (normally 1 oz/3 hours)
      v. Wait at least 12 hours or until no residual effects remain.

   d. **Tobacco**
      i. Irritation of nose and lungs (can interfere with pressure changes)
      ii. Blood 200 to 300 times the affinity for carbon monoxide than oxygen
      iii. Adds 5,000 feet of physiological altitude at sea level
      iv. Decreases night vision

   e. **Hypoglycemia**
      i. The liver stores energy in the form of glycogen which is converted to blood sugar.
      ii. Unless food is consumed at regular intervals, the stored glycogen is depleted and a low blood sugar level (hypoglycemia) develops.
      iii. Insulin also lowers blood sugar level, but at the same time, blood sugar is also decreasing through its normal function of fueling the body.
      iv. Insulin and glycogen conversion combined result in a rapid drop of blood sugar that causes further tiredness and inefficiency.

4. **Cognitive Stressors** – How one perceives a given situation or problem is a potentially significant and frequently overlooked source of stress. Pessimism, obsession, failure to focus on the present, and/or low self-confidence can create a self-fulfilling prophecy that will ensure a negative outcome.
**Types of Fatigue**

1. Acute Fatigue – physical or mental activity between two regular sleep periods.
2. Chronic Fatigue – More serious type of fatigue over longer period of time. Usually results from inadequate recovery from successive periods of acute fatigue.
3. Motivational Exhaustion or Burnout – If chronic untreated for too long, the individual will “shut down” and cease functioning occupationally and socially.

**SPATIAL DISORIENTATION**

Spatial disorientation is an individual’s inability to determine his or her position, attitude, and motion relative to the surface of the earth or significant objects.

**Vertigo**

Vertigo is a spinning sensation usually caused by a peripheral vestibular abnormality in the normal ear.

**Sensory Illusion**

A sensory illusion is a false perception of reality caused by the conflict of orientation information from one or more mechanisms of equilibrium.

**Types of Spatial Disorientation**

**Type I (Unrecognized)**

a. Does not perceive any indication of spatial disorientation.
b. Most dangerous type.
c. Fails to recognize or correct disorientation.
d. Usually fatal

**Type II (Recognized)**

a. Pilot perceives problem
b. Fails to recognize problem as spatial disorientation
c. May feel that a control is malfunctioning
d. May perceive instrument failure (attitude indicator)

**Type III (Incapacitating)**

a. Overwhelming sensation of movement
b. Cannot orient himself by using visual cues
c. Not fatal if copilot can gain control of aircraft

**Equilibrium Maintenance**

Three types of sensory systems – the visual, vestibular, and proprioceptive systems – are especially important in maintaining equilibrium and balance. During flight visual is most
reliable. In the absence of the visual system, the vestibular and proprioceptive systems are unreliable in flight.

**Visual System**

Of the three sensory systems, the visual is the most important in maintaining equilibrium and orientation. Eighty percent of our orientation information comes from the visual system.

**Vestibular System**

The inner ear contains the vestibular system, which contains the motion and gravity detecting sense organs. Each vestibular apparatus consists of two distinct structures: the semicircular canals and the vestibule proper, which contain the otolith organs. Both the semicircular canals and the otolith organs sense changes in aircraft attitude. The semicircular canals of the inner ear sense changes in angular acceleration and deceleration.

**Otolith Organs**

The otolith organs are small sacs located in the vestibule. Sensory hairs project from each macula into the otolithic membrane. The otolith organs respond to gravity and linear accelerations/decelerations. Changes in the position of the head, relative to the gravitational force, cause the otolithic membrane to shift position on the macula. The sensory hairs bend, signaling a change in the head position.

**Semicircular Canals**

The semicircular canals of the inner ear sense changes in angular acceleration. The canals will react to any changes in roll, pitch, or yaw attitude. They are situated in three planes, perpendicular to each other. They are filled with a fluid called endolymph. The inertial torque resulting from angular acceleration in the plane of the canal puts this fluid in motion. The motion of the fluid bends the cupula, a gelatinous structure located in the ampulla of the canal. This, in turn, moves the hair cells situated beneath the cupula. This movement stimulates the vestibular nerve. These nerve impulses are then transmitted to the brain where they are interpreted as rotation of the head.

**Proprioceptive System**

This system reacts to the sensation resulting from pressures on joints, muscles, and skin from slight change in position of internal organs. Forces act upon the seated pilot in flight.
**Vestibular Illusions**

The vestibular system provides accurate information as long as an individual is on the ground. Once the individual is airborne, however, the system may function incorrectly and cause illusion. These illusions pose the greatest problem with spatial disorientation.

**Somatogyral Illusions**

Somatogyral illusions are caused when angular accelerations and decelerations stimulate the semicircular canals. Those that may be encountered in flight are the leans, graveyard spin, and Coriolis illusions.

- **Leans** – pilot fails to perceive angular motion.
- **Graveyard spin** – the pilot’s semicircular canals reach equilibrium; no motion is perceived.
- **Coriolis Illusion** – overwhelming disorientation. Results from prolonged turn and head motion in different geometric plane.

**Somatogravic Illusions**

Somatogravic illusions are caused by changes in linear accelerations and decelerations or gravity that stimulate the otolith organs. The three types of somatogravic illusions that can be encountered in flight are oculogravic, elevator, and oculoagravic.

**Oculogravic Illusion**

This type of illusion occurs when an aircraft accelerates and decelerates. The aviator falsely perceives that the aircraft is in a nose-high attitude. A pilot correcting for this illusion without cross-checking the instruments would most likely dive the aircraft.

**Elevator Illusion**

This illusion occurs during upward acceleration. Because of the inertia encountered, the pilot’s eyes will track downward as his body tries, through inputs supplied by the inner ear, to maintain visual fixation on the environment or instrument panel. With the eyes downward, the pilot will sense that the nose of the aircraft is rising.

**Oculoagravic Illusion**

This illusion is the opposite of the elevator illusion and results from the downward movement of the aircraft. Because of the inertia encountered, the pilot’s eyes will track upward. The pilot’s senses then usually indicate that the aircraft is in a nose low attitude. This illusion is commonly encountered as a
The helicopter enters autorotation. The pilot’s usual intuitive response is to add aft cyclic, which decreases airspeed below the desired level.

**Prevention of Spatial Disorientation**

Spatial disorientation cannot be totally eliminated. To prevent disorientation, aviators should:

a. Never fly without visual reference points (actual horizon or artificial)

b. Trust the instruments

c. Avoid fatigue, smoking, hypoglycemia, hypoxia, and anxiety

d. Never try to fly VMC and IMC at the same time

**Treatment of Spatial Disorientation**

Spatial disorientation can easily occur in the aviation environment. If disorientation occurs, aviators should:

a. Refer to the instruments and develop a good cross-check

b. Delay intuitive actions long enough to check both visual references and instruments

c. Transfer control to the other pilot if two pilots are in the aircraft.