Project Title

Different types of hypoxia with special reference to causes, oxygen content in both venous and arterial blood, presence, or absence of cyanosis

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Abstract

Hypoxia, in biology and medicine, condition of the body in which the tissues are starved of oxygen. In its extreme form, where oxygen is entirely absent, the condition is called anoxia. Four types of hypoxia are distinguished in medicine: (1) the hypoxemic type, in which the oxygen pressure in the blood going to the tissues is too low to saturate the hemoglobin; (2) the anemic type, in which the amount of func-tional hemoglobin is too small, and hence the capacity of the blood to carry oxygen is too low; (3) the stagnant type, in which the blood is or may be normal but the flow of blood to the tissues is reduced or unevenly distributed; and (4) the histotoxic type, in which the tissue cells are poisoned and are therefore unable to make proper use of oxy-gen. Diseases of the blood, the heart and circulation, and the lungs may all produce some form of hypoxia.

The hypoxemic type of hypoxia is due to one of two mechanisms: a decrease in the amount of breathable oxygen—often encountered in pilots, mountain climbers, and people living at high altitudes—due to reduced barometric pressure (see altitude sick-ness) or (2) cardiopulmonary failure in which the lungs are unable to efficiently transfer oxygen from the alveoli to the blood. In the case of anemic hypoxia, either the total amount of hemoglobin is too small to supply the body's oxygen needs, as in anemia or after severe bleeding, or

hemoglobin that is present is rendered nonfunctional. Exam-ples of the latter case are carbon monoxide poisoning and ac-quired methemoglobinemia, in both of which the hemoglobin is so altered by toxic agents that it becomes unavailable for oxygen transport, and thus of no respiratory value. Stagnant hypoxia, in which blood flow through the capillaries is insufficient to supply the tissues, may be general or local. If general, it may result from heart dis-ease that impairs the circulation, impairment of venous return of blood, or trauma that induces shock. Local stagnant hypoxia may be due to any condition that reduces or prevents the circulation of the blood in any area of the body. Examples in-clude Raynaud syndrome and Buerger disease, which restrict circulation in the extremi-ties; the application of a tourniquet to control bleeding; ergot poisoning; exposure to cold; and over-whelming systemic infection with shock.

Introduction

Hypoxia is a state in which oxygen is not available in sufficient amounts at the tissue level to maintain adequate homeostasis; this can result from inadequate oxygen delivery to the tissues either due to low blood supply or low oxygen content in the blood (hy-poxemia). Hypoxia can vary in intensity from mild to severe and can present in acute, chronic, or acute and chronic forms. The response to hypoxia is variable; while some tissues can tolerate some forms of hypoxia/ischemia for a longer duration, other tissues are severely damaged by low oxygen levels.

Project Aim and Outline

1. What hypoxia is
2. Types of hypoxia.
   - 2.1. Hypoxic Hypoxia
     - 2.1.1. Causes of hypoxic hypoxia
     - 2.1.2. oxygen content in both venous and arterial blood in case of Hypoxic hy-poxia
     - 2.1.3. Hypoxic hypoxia Cyanosis
   - 2.2. Hypemic Hypoxia

2.2.1. Causes of hypemic hypoxia
2.2.2. oxygen content in both venous and arterial blood in case of hypemic hypoxia
2.2.3. Hypemic hypoxia Cyanosis
2.3. Stagnant Hypoxia
2.3.1. Causes of stagnant hypoxia
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2.4. Histotoxic Hypoxia
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2.4.2. oxygen content in both venous and arterial blood in case of Histotoxic hypoxia
2.4.3. Histotoxic hypoxia Cyanosis
2.5. Anemic hypoxia
2.5.1. Causes of Anemic hypoxia
2.5.2. oxygen content in both venous and arterial blood in case of Anemic Hypoxia
2.5.3. Anemic Hypoxia Cyanosis

Results

1. Hypoxic Hypoxia

In hypoxic hypoxia, there is a lack of oxygen in the arterial blood. The oxygen tension is lowered in both the lungs and the arterial blood, and the hemoglobin is not saturated with oxygen to its normal extent. This type of hypoxia affects the body as a whole and is one of the most serious forms of hypoxia. Hypoxic hypoxia is often produced by low tensions of oxygen in the inspired air as is seen in high altitudes, breath-ing of inert gases, and the inhalation of anesthetic agents. Abnormal lung conditions may also produce hypoxic hypoxia. Emphysema, asthma, pneumonia, or pneumothorax encourage the formation of this type of hypoxia. Mechanical obstruction of the airway by foreign objects, laryn-gospasm, or bronchospasm inhibits the flow

of oxygen from the atmos-phere into the lungs, creating a state of oxygen want. Shallow respirato-ry movements from any cause, with either a decrease in rate or ampli-tude, may cause hypoxic hypoxia. A chronic state of hypoxic hypoxia

may result from a patent foramen ovale and other embryological mal-formations of the heart and blood vessels.

Hypoxic hypoxia occurs when the PO2 of arterial blood falls. This could occur because inspired PO2 is lower than normal (high altitude) or it could be due to a respiratory problem (e.g., hypoventilation, diffusion impairment caused by pulmonary edema, ventilation-perfusion mis-match, or anatomic shunt of blood past the gas exchange region). In terms of O2 transport, decreased arterial blood oxygenation (hypoxemia) is the primary limitation, and thus, the problem resides with the respira-tory system. Oxygen delivery is abnormal since [O2] is less than normal. The circulatory system responds in two ways to improve tissue oxygena-tion. First, additional capillaries open to reduce diffusion distances and increase the surface area for oxygen exchange; oxygen extraction subse-quently increases. Second, resistance vessels (arterioles) dilate in re-sponse to decreased tissue PO2 to increase perfusion and, hence, oxygen delivery. Venous oxygen content, [O2] v, and PvO2 will be less than normal due to the higher oxygen extraction. Since PaO2 is lower than normal (and presumably lower than the 50 mm Hg threshold for respira-tory chemosensory response), this defect is sensed by the respiratory chemoreceptors (i.e., carotid bodies). Thus, increasing the inspired oxy-gen fraction will be helpful except for the case of a pulmonary shunt.

Restricted oxygen flow to the body's tissue that leads to hypoxia can be caused by a variety of situations or other underlying conditions.

1. High altitude (above 3048 m/10,000 feet)
2. Hypoventilation – failure of the respiratory pump due to any cause (fatigue, barbiturate poisoning, pneumothorax, etc.)
3. Ventilation-perfusion mismatch
4. Obstructed airway
5. Drowning

6. Abnormal pulmonary function
7. Chronic obstructive pulmonary diseases (COPD)
8. Neuromuscular diseases or interstitial lung disease
9. Constrained blood flow to tissue (such as atherosclerosis or vasoconstriction)
10. Blockage in blood flow like a sickle cell crisis
11. Low or no blood flow caused by bleeding or heart attack
12. A malformed vascular system such as an anomalous coronary artery
13. Limited oxygen transportation due to anemia

2. Hypemic Hypoxia

Occurs when the blood is not able to carry enough oxygen to the body's cells. Caused by anemia, disease, blood loss, deformed blood cells, or carbon monoxide (CO) poisoning and with smokers.CO at-taches itself to hemoglobin about 200 times more easily than oxygen. After CO poisoning, it can take up to 24 hours to recover. Can be a result of donating blood, resulting in a higher physiological altitude

Stagnant Hypoxia

Stagnant hypoxia is due to a decrease in the rate of flow of the circulat-ing blood. Local regions of the body are usually involved, but it may af-fect the entire body. The blood is saturated normally with oxygen, and the oxygen load, as well as the tension under which it is held, also may be normal. Hypoxia is produced because

the amount of oxygen reaching the tissues is inadequate. Sluggishness in the rate of the circulating blood allows the blood to stagnate and give up a greater percentage of its oxygen. This slow circulation also permits the accumulation of a greater quantity of carbon dioxide in the tissues. Stag-nant hypoxia is produced by failure of the circulation, impairment of ve-nous return, and shock.

This form of hypoxia is caused by inadequate blood flow, which results in less oxygen available to the tissues. Causes include: -

- **Edema**: Edema, a swelling of the tissues (like from heart failure), can limit the ability of oxygen present in the blood to adequately reach the tissues.

3. • **Ischemic hypoxia**: Obstruction to the flow of blood carrying oxygen, like from a clot in a coronary artery (a heart attack), can prevent the tissues from receiving oxygen.**Histotoxic Hypoxia**

As the term suggests, the tissue cells are poisoned and are unable to ac-cept oxygen from the capillaries. In this type of hypoxia, the cells are not able to utilize the oxygen, although the amount of oxygen in the blood may be normal and under normal tension. Histotoxic hypoxia is pro-duced by cyanides. Theoretically, it may be produced by any agent which depresses cellular respiration.

With histotoxic hypoxia, an adequate amount of oxygen is inhaled through the lungs and delivered to the tissues, but the tissues are unable to use the oxygen that is present. Cyanide poisoning is a possible cause.

Histotoxic hypoxia refers to a reduction in ATP production by the mito-chondria due to a defect in the cellular usage of oxygen. An example of histotoxic hypoxia is cyanide poisoning. There is a profound drop in tis-sue oxygen consumption since the reaction of oxygen with cyto-chrome c oxidase is blocked by the presence of cyanide. There are other chemicals that interrupt the mitochondrial electron transport chain (e.g., rotenone, antimycin A) and produce effects on tissue ox-ygenation similar to that of cyanide. Oxygen extraction decreases in parallel with the lower oxygen consumption, with a resulting increase in venous oxygen content and PvO2. Although cyanide stimulates the peripheral respiratory chem-oreceptors, increasing the inspired oxygen fraction is not helpful, since there is already an adequate amount of oxygen which the poisoned cells cannot use.

4. Anemic hypoxia

Anemic hypoxia occurs when the oxygen carrying ability of the blood decreases, and thus, this defect is specifically associated with the blood. This implies that fewer hemoglobin molecules (or oxygen-binding sites) are available for binding ox-ygen. There can be several causes of this. The most common example occurs with decreased hematocrit or true anemia. When the hemoglobin concentration inside RBCs decreases, this also reduces the capacity of the blood to carry oxygen. An-other example is CO poisoning, in which there is virtually irreversible combination of CO with some heme-binding sites on the hemoglobin molecule. Carbon monox-ide binding produces the additional adverse effect of a shift of the oxygen dissocia-tion curve to the left (in-

creased affinity of hemoglobin for oxygen). Finally, the conversion of some heme-binding sites on hemoglobin to methemoglobin renders those sites incapable of binding oxygen. This circumstance can occur when nitrites are used as vasodilators; iron is oxidized and changes from the ferrous to the ferric state. As with CO binding, the presence of methemoglobin produces the additional adverse effect of a shift of the oxygen dissociation curve to the left (increased affin-ity of hemoglobin for oxygen).The circulatory adjustments in response to anemia will be similar to those of the preceding case. In order to maintain tissue oxygen consumption at baseline levels associated with a normal oxygen carrying capacity of blood, the reduction in oxygen delivery will lead to an increase in capillary per-fusion, and oxygen extraction will increase. Arteriolar dilation and viscosity reduc-tion (for the case of a reduction in Hct) will cause blood flow and oxygen delivery to increase. Both oxygen extraction and oxygen delivery will continue to increase until the oxygen requirements of the tissues are met or until the capacity to in-crease oxygen extraction and delivery has been reached. The resulting situation is one in which venous oxygen content and PvO2 are less than normal. Since PaO2 is normal for all the anemic situations considered, this defect is not sensed by the respiratory chemoreceptors. Thus, increasing the inspired oxygen fraction is not helpful except for the case of CO poisoning, where high inspired oxygen (e.g., 100% oxygen at ambient barometric pressure or placement of the subject into a hyperbaric chamber) competes with CO binding at the heme site (recall Haldane's first law).

The arterial blood contains oxygen at its normal tension in anemic hy-poxia, but there is a shortage of functioning hemoglobin. Anemic hypox-ia, overall, is less serious than hypoxic hypoxia. However, it does affect the whole body. Anemic hypoxia may be caused by acute or chronic hemorrhage, primary or secondary anemia, alterations in the hemoglobin of the blood (caused by nitrates, chlorates, or coal tar derivatives), and carbon monoxide poisoning In the setting of anemia, low hemoglobin levels result in a reduced ability of the blood to carry oxygen that is breathed in, and hence, a diminished supply of oxygen available to the tissues. Causes include:

- Anemia of any cause: This can include iron deficiency anemia, perni-cious anemia, and chemotherapy-induced anemia.

- Hemorrhage: Hemorrhage can be obvious, such as from injuries sus-tained in an accident, or hidden due to internal bleeding.

- Methemoglobinemia: Methemoglobinemia, also known as affinity hy-poxia, is an

abnormal hemoglobin that does not bind oxygen very well.

Carbon monoxide poisoning: With Carbon monoxide poisoning, hemoglobin is unable to bind oxygen.

Conclusions

Hypoxia is a relative or absolute deficiency of oxygen (O2); anoxia is the complete lack of O2. Hypoxemia is a subset of hypoxia, referring specifically to low O2 levels in the blood. There are four broad categories of hypoxia: 1. Hypoxemic hypoxia is due to low blood O2 levels from pulmonary or environmental causes (e.g., pneumonia, high alti-tude, chronic lung disease, increased shunt from congenital heart disease). 2. Hypemic hypoxia is due to a decreased blood O2 carrying capacity (e.g., anemia, carbon monox-ide poisoning). 3. Is-chemic or stagnant hypoxia is due to decreased tissue O2 delivery (e.g., shock, arterial oc-clusive disease). 4. Histotoxic hypoxia is due to mitochondrial cytochrome poisoning (e.g., cyanide, carbon monoxide).1 Hypoxia and hypoxemia are common reasons for admission, usually in the context of a primary respiratory illness such as pneumonia or bronchiolitis. An understanding of hypoxia and the evaluation, diagnosis, and monitoring of patients with the condition improves patient care and re-source utilization.

References

1. Flight Standards Service. Pilot's Handbook of Aeronautical Knowledge: FAA Manual H-8083-25. Washington, DC: Federal Aviation Administra-tion, U.S. Dept. of Transportation, 2001. ISBN 1-56027-540-5.

2. Peers C, Kemp PJ. Acute oxygen sensing: diverse but convergent mechanisms in airway and arterial chemoreceptors. Respir Res. 2001; 2:145–149. [PMC free article] [PubMed] [Google Scholar]
3. Shirai M, Sada K, Ninomiya I. Effects of regional alveolar hypoxia and hyper-

capnia on small pulmonary vessels in cats. J Appl Physiol (1985) 1986;61:440–8. [PubMed] [Google Scholar]

4. Fishman AP. Hypoxia on the pulmonary circulation. How and where it acts. Circ Res. 1976;38:221–31. [PubMed] [Google Scholar]
5. Hochachka PW. Defense strategies against hypoxia and hypothermia. Science. 1986;231:234–241. [PubMed] [Google Scholar]