ACUTE CARDIOVASCULAR ADAPTATIONS IN HIGH ALTITUDES

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INTRODUCTION

- Changes in the altitude causes hypoxia in body.
- In response to that hypoxia adaptations occur in the cardiovascular system and the lungs of individuals which ensure life-sustaining oxygen delivery to the tissues despite a reduction in the partial pressure of inspired oxygen between 20% and 60% at 2500 and 8000 m.

CIRCULATION

- Hypoxia directly affects the vascular tone of the pulmonary and systemic resistance vessels.
- Which increases ventilation and sympathetic activity via stimulation of the peripheral chemoreceptors.
- Release of ATP from red blood cells and the generation of nitrogen oxide by various ways appear to regulate local oxygen delivery according to the needs of the tissue.

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- These mechanisms may decrease with prolonged stay at high altitude when oxygen content of the blood increases because of ventilatory acclimatization, an increase in hematocrit associated with plasma volume reduction, and an increase in red blood cell mass due to erythropoiesis.
- Ventilation and sympathetic activity increased, by increased urinary and plasma concentration of catecholamines and skeletal muscle sympathetic activity.
- With exposure over days to weeks, the sensitivity of the peripheral chemoreceptors to hypoxia increases, leading to further enhancement of ventilation (ventilatory acclimatization).

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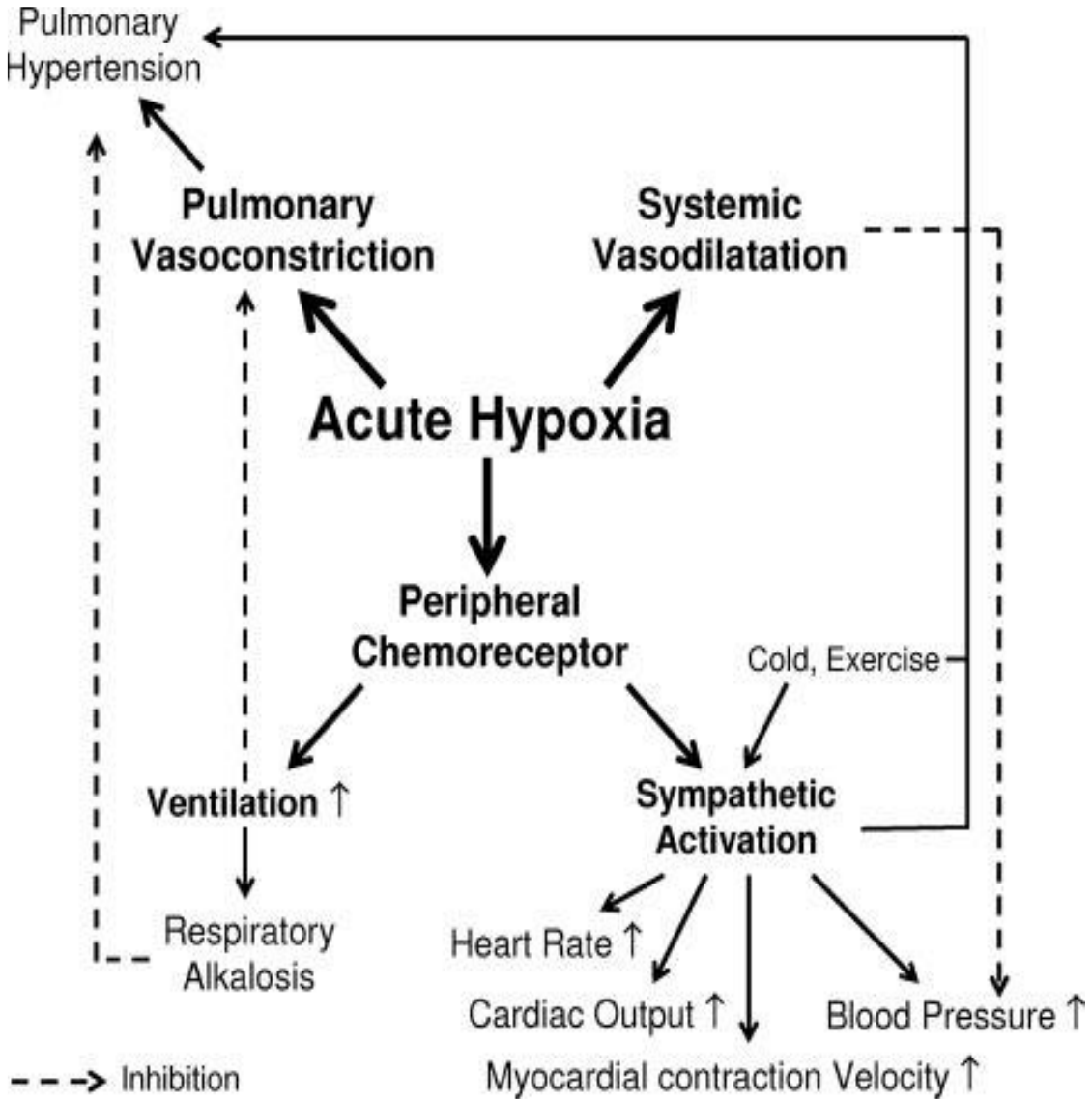
- This accounts for the further increase of sympathetic activity after 3 weeks at 5200m and elevated catecholamines in urine and plasma.
- During the first few hours of exposure, hypoxic vasodilatation tends to override sympathetic vasoconstriction in the systemic circulation, resulting in an unchanged or slightly decreased systemic blood pressure.
- Blood pressure and systemic vascular resistance then rise over at least 3 to 4 weeks because of increasing sympathetic activity and reduced tissue hypoxia associated with acclimatization.


Pulmonary Hypertension
Pulmonary Vasoconstriction
Systemic Vasodilatation
Acute Hypoxia
Peripheral Chemoreceptor
Cold, Exercise
Ventilation ↑
Sympathetic Activation
Respiratory Alkalosis
Heart Rate ↑
Cardiac Output ↑
Blood Pressure ↑
Myocardial contraction Velocity ↑
Inhibition

HEART

- Acute hypoxia are an increase in heart rate (both at rest and on exercise), myocardial contractility, and cardiac output for the first few days.
- With acclimatization, cardiac output falls at rest and on exercise in association with a decrease in left ventricular work but an increase in right ventricular work.

HEART RATE

- Increase in heart rate is related to increased sympathetic activity and vagal withdrawal.
- For a given level of exercise, heart rate is greater at altitude, although the heart rate that can be achieved at maximal exercise is reduced compared with at sea level and in parallel with maximum oxygen consumption.
- At 5260 m, vagal blockade by glycopyrrolate completely restored maximal heart rate to sea level values, whereas cardiac output did not increase.

CORONARY CIRCULATION

- On acute exposure to hypoxia, the epicardial coronary arteries dilate.
- To maintain the cardiac function, resting myocardial blood flow increases in response to reduced oxygen content of the blood.
- Studies showed that after 10 days at 3100 m,16 coronary blood flow is decreased compared with at sea level and in proportion to the fall in left ventricular work because of the increased oxygen content of arterial blood with acclimatization.
- Thus, myocardial oxygen extraction per volume of blood increases to maintain myocardial oxygenation.

CARDIAC FUNCTION

- Cardiac contractility increases acutely.
- Submaximal cardiac output for a given oxygen uptake is increased during the first few days at altitude.
- Maximal cardiac output is unchanged.
- Maximum oxygen consumption (VO2 max) declines by 1% per 100 m above 1500 m.
- Stroke volume falls during the first week at altitude and then tends to stabilize.

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- The fall in stroke volume is associated with reduction in left ventricular dimensions and filling pressure and in part may be a consequence of diuresis and reduction of plasma volume, which decreases over the first weeks at high altitude by as much as 20% at 3800 to 4500 m.
- Initial the reduction of plasma volume caused by chemoreceptors, increased release of atrial natriuretic peptide, and decreased synthesis of aldosterone.

- Further reduction of plasma volume occurs without a net loss of body water by a fluid shift from the extracellular to the intracellular compartment.
- Myocardial oxygen supply and left ventricular function are maintained in healthy individuals during maximal exercise at an altitude of 7625 m, at which maximal heart rate was reduced by 20% and cardiac output as well as exercise capacity was reduced by 40% to 50%.

PHYSIOLOGICAL CHANGES

- ✓ Increased ventilation.
- ✓ Hypocapnia.
- ✓ Increased pressure in the pulmonary arteries.
- ✓ Increased activity of the sympathetic system.
- ✓ Tachycardia.
- ✓ Increased blood pressure.
- ✓ At first stage-the increase then the decrease of stroke volume.
- ✓ Reduced plasma volume.
- ✓ Increased blood viscosity.
- ✓ Increased erythropoietin concentration.

PATHOPHYSIOLOGICAL CHANGES

- ✓Reduced oxygen supply to the heart—in patients with CAD as atherosclerotic plaques in the arteries prevent their dilatation.
- ✓Contraction of the pulmonary vessels and overload of the right heart in patient with pulmonary hypertension.
- ✓Increased activity of the sympathetic nervous system.
- ✓Increased neurohormonal activity—dangerous in patients with heart failure.
- ✓Higher increased systolic and diastolic blood pressure in patients with arterial hypertension.
- ✓Predisposition to arrhythmia due to hypoxia, right ventricular overload, alkalosis, and changes in the transmembrane potassium transport.
- ✓Edemas due to increased capillary filtration, reduced cabin pressure, reduced space, and mobility.
- ✓Predisposition to ischemic stroke due to polycythemia, hypoxia, and dehydration.

AFFECT OF HIGH ALTITUDE ON CARDIOVASCULAR SYSTEM

- Acute mountain sickness (AMS) is condition associated with high altitude.
- It affect mountain climbers, hikers, skiers, or travelers at high altitudes, usually above 8000 feet (2400 meters).
- Acute mountain sickness is caused by reduced air pressure and lower oxygen levels at high altitudes. The faster we climb to a high altitude, the more likely we will get acute mountain sickness.
- The best way to prevent altitude illness is to ascend gradually.

SYMPTOMS OF MILD TO MODERATE IN AMS

- Difficulty sleeping
- Dizziness or light-headedness
- Fatigue
- Headache
- Loss of appetite
- Nausea or vomiting
- Rapid pulse (heart rate)
- Shortness of breath with exertion

SYMPTOMS IN SEVERE AMS

- Blue color to the skin (cyanosis)
- Chest tightness or congestion
- Confusion
- Cough
- Coughing up blood
- Decreased consciousness or withdrawal from social interaction
- Gray or pale complexion
- Inability to walk in a straight line, or walk at all
- Shortness of breath at rest

- AMS symptoms usually resolve during the first days at altitude, but in some rare cases it progress to life-threatening diseases such as high-altitude cerebral edema (HACE) and/or high-altitude pulmonary edema (HAPE).
- Adverse effects of acute high altitude exposure are largely avoidable by proper acclimatization, ie, low ascent rates, or the use of appropriate pre-acclimatization strategies.
- These changes are important and avoid the potential risk o cardiovascular system.

PREVELANCE

- AMS shows increase from
  - 7% at 2200m height
  - 38% at 3500m height
  - 52% at 4559m height

At higher risk for acute mountain sickness if

- If person live at or near sea level and travel to a high altitude have had the illness before.
- If person ascend quickly.
- If individual have not acclimatized to the altitude.
- If person take alcohol or other substances have interfered with acclimatization.
- If person have medical problems involving the heart, nervous system, or lungs.

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THANK YOU

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