AVIATION, HIGH ALTITUDE AND SPACE PHYSIOLOGY
Why P02 decreases at high altitude???
Barometric pressure of 760mmHg at sea level fall to----------------------
-----253 mmHg at mount Everest
CO₂ continuously excreted from blood into alveoli

+ water vaporizes from respiratory surface into inspired air

Further dilute oxygen concentration

Hypoxia
Acute Effects Of Hypoxia

- Drowsiness
- Mental and muscle fatigue
- Headache
- Nausea
- Euphoria

Further increase in altitude;
Twitching and seizures
Coma or death.

- Decrease judgment and memory
- Inability to perform fine motor movement
- Decrease work capacity of cardiac and skeletal muscles.
AT HIGH ALTITUDE

Decrease in Oxygen saturation

Breathing air
At 10000 feet-----arterial O2 saturation remain 90%
But at 20000 feet----02 saturation fall to 70% and so on.

Breathing pure O2
At 39000 feet-----arterial O2 saturation remain 90%
But at 47000 feet----02 saturation fall to 50%.
Thus aviator/climber breathing pure oxygen can ascend far higher then one breathing air(ceiling).
What is the effect of breathing pure oxygen on P02??
PAO2 = (PB – PH2O)FiO2 – (PaCO2)

- **PB** is the barometric pressure
- **PH2O** (usually 47mmHg),
- **FiO2** is the fractional concentration of inspired oxygen (0.21 if breathing air and 1 if breathing pure oxygen),
- **PaCO2** (40mmHg)
\[ PAO2 = (PB - PH2O)FiO2 - (PaCO2) \]

**At sea level; breathing air**

\[ PAO2 = (760 - 47)0.21 - (40) \]
\[ PaO2 = 109 \text{mmHg} \]

**At sea level; breathing pure oxygen**

\[ PAO2 = (760 - 47)1 - (40) \]
\[ PaO2 = 673 \text{mmHg} \]
ACCLIMATIZATION:
WHAT YOU NEED TO KNOW
ACCLIMATIZATION

• A person remain at high altitude for days, weeks or for years become more and more acclimatized to low PO2, so cause few delirious effects on body.

• After acclimatization person is able to work harder or ascend to still higher altitudes without hypoxic effects.
How acclimatization to low PO2 occur???
Hypoxia/↓ O2 availability

- Stimulate chemoreceptors
- Stimulate dorsal respiratory center of medulla
- ↑ pulmonary ventilation

↓ PCO2 + ↑ PH of body fluid (respiratory alkalosis)

This is compensated by kidney;

• ↓ H ion secretion
• ↑ Bicarbonate excretion

↓ PH of fluid surrounding chemosensitive neurons of respiratory center

↓ Bicarbonate concentration in CSF and brain tissues
Hypoxia/\(\downarrow\) O2 availability

Stimulate Hypoxic inducible factors HIF (master switch)/DNA binding transcription factor

Activate genes

Erythropoietin genes
- \(\uparrow\) RBC production
- \(\uparrow\) Hemoglobin concentration

Vascular and endothelial growth factor genes
- Angiogenesis
- \(\uparrow\) no. of systemic circulatory capillaries
- Increase blood volume

Mitochondrial genes
- \(\uparrow\) Cellular mitochondria
- \(\uparrow\) Cell ability to use O2 despite \(\downarrow\) PO2.

Glycolytic genes
Hypoxia/↓ O2 availability

Stimulate Hypoxic inducible factors HIF (master switch)/DNA binding transcription factor

Activate genes

↑ Nitric oxide availability

Pulmonary vasodilation

Pooling of blood

↑ hydrostatic pressure

↑ pulmonary arterial blood pressure

Force blood into large no. of capillaries

↑ O2 diffusing capacity

Expand capillaries

↑ surface area
Hypoxia/↓ O2 availability

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Stimulate chemoreceptors
Stimulate dorsal respiratory center of medulla

↑pulmonary ventilation

↑ pulmonar arterial blood pressure

Force blood into large no. of capillaries

Increase blood volume

↑no. of systemic circulatory capillaries

↑Cell ability to use O2 despite ↓PO2.
• Acclimatization of natives of high altitude is superior to lowlanders in all aspects because of these additional factors;

• Increase chest size.
• Increase COP
• Increase hemoglobin

ALL THESE FACTORS FAVOURS EFFECTIVE OXYGEN TRANSPORT DESPITE OF LOW PO2.
• Native persons of high altitude daily work output = low landers at sea level

**But;**

• Even well acclimatized lowlander can never have same workout when compared with native.
ACUTE MOUNTAIN SICKNESS

Rapid ascend to high altitude more than 8000 feet

HYPOXIA within hrs. to about 2 days

Local **vasodilation** of cerebral blood vessels
- Blood flow into capillaries
- ↑ Capillary pressure
- Fluid leakage into cerebral tissues
- Cerebral edema

Pulmonary arterial **vasoconstriction**
- Force blood into unconstricted vessels
- ↑ Capillary pressure
- Fluid leakage into pulmonary tissues
- Pulmonary edema
Move person to low altitude
Give pure oxygen
A person remain at high altitude for long time (1 year)

<table>
<thead>
<tr>
<th>Increase RBC + hematocrit</th>
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<tbody>
<tr>
<td>Increase blood viscosity</td>
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<td>Decrease blood flow to tissues</td>
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<td>Decrease oxygen delivery</td>
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<td>Increase pulmonary arterial pressure</td>
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<tr>
<td>+ Right side of heart enlarge</td>
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<td>+ Congestive heart failure</td>
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Move person to low altitude
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<th>Acute mountain sickness</th>
<th>Chronic mountain sickness</th>
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<tr>
<td>Rapid ascend to high altitude (8000 feet)</td>
<td>A person remain at high altitude for long time</td>
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<tr>
<td>Symptoms appear within hrs. to about 2 days</td>
<td>Symptoms appear gradually (appr. 1 year)</td>
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<td>Symptoms of hypoxia</td>
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<td>Pathogenesis:</td>
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<td>Increase altitude—decrease PO2—Hypoxia</td>
<td>Increase RBC + hematocrit——Increase blood viscosity——Decrease blood flow to tissues——decrease oxygen delivery——hypoxia</td>
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<tr>
<td>Complications are cerebral and pulmonary edema</td>
<td>Increase pulmonary arterial pressure which then lead to Heart failure is main complication</td>
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AVIATION PHYSIOLOGY
F = \frac{mv^2}{r}

F-- centrifugal accelerating force

• *Increase velocity*----*increase force*

• *Sharp turn*----*increase force*
Force with which he is pressed against the seat is due to Pull of gravity
Which is equal to his weight
+1G
Force with which he is held down by his seat belt is equal to his weight -1G
Effect of centrifugal accelerating force on the body (positive G)

- Increase pressure in veins of feet.
- Pooling of blood in lower part of body.
- Decrease COP.
- Decrease systolic and diastolic blood pressure (but for initial few minutes—after that recovered by activation of baroreceptor reflex).
- If acceleration is more—black out of vision followed by unconsciousness.

- Extremely high accelerating force-----fracture of vertebrae (more than 20G)
Effect of decelerating force on the body (Negative G)

- Hyperemia of head.
- Brain edema.
- Psychotic disturbances.
- Eyes often temporarily blinded with red outs.
- Increase cerebral blood pressure——cause small blood vessels on surface of head and in brain to rupture(not cranial blood vessels which are protected by cushioning effect of CSF).
Protection of body against centrifugal accelerating forces

- Tightening of abdominal muscles + Leaning forward to compress abdominal muscles-------prevent pooling of blood in large vessels of abdomen.

- Special anti G suits for abdomen and leg----------prevent pooling of blood.
LINEAR ACCELERATING FORCE

Space craft

SEMIRECLINING Position transverse to axis of acceleration

Can be withstood
Deceleration must be accomplished by decreasing the velocity
SPACE PHYSIOLOGY
Weightlessness in space

- A person in an orbiting satellite or a non-propelled space craft experiences weightlessness or a state of near zero gravity force --- microgravity.
- Simply float inside the chamber.
- **Reason:** gravity act on both space craft and person the **same time** so both are pulled exactly with **same force** and in **same direction**.
Challenges of weightlessness

- **Motion sickness** for first few days---because of unfamiliar motion signals to brain and due to lack of gravitational signals.
- **Translocation of fluids** within the body because failure of gravity to cause normal hydrostatic pressures.
- **Decrease physical activity** as no strength is required to work against gravity.
• Decrease bone mass.
• Cardiac and skeletal muscle atrophy.
• Decrease work capacity, blood volume, Reduced orthostatic tolerance, Impaired baroreceptor reflex (cardiovascular deconditioning).
How these effects can be prevented??

• Regular exercise.
• Application of intermittent artificial gravity.
• Why P02 is low at high altitude
• Acclimatization
• Compare and contrast acute and chronic mountain sickness.
• Effect of positive and negative gravitational force on body.
• Reason and challenges of weightlessness in space and how it can be prevented.
PARACHUTE JUMP
As velocity of fall increases.
Air resistance also increases.

After sometime,
velocity of fall = air resistance
Person begin to fall with Terminal velocity

But parachute usage decrease
this terminal velocity

proper training
and
knee bent, muscle taut position is
required to safely land on earth.
Thank You