The Hebrew University of Jerusalem

Syllabus

Respiratory system of the healthy person - 96202

Last update 14-09-2022

HU Credits: 3.5

Degree/Cycle: 1st degree (Bachelor)

Responsible Department: Medicine

Academic year: 0

Semester: 1st Semester

Teaching Languages: Hebrew

Campus: Ein Karem

Course/Module Coordinator: Dr. Anna Nachshon

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Course/Module description:

The course will review the structure and normal functions of the respiratory system

Course/Module aims:

To attain comprehensive knowledge and understanding of the respiratory system in terms of function and basic structure.

Learning outcomes - On successful completion of this module, students should be able to:

Comprehend the macroscopic structure of the lung and the respiratory system, its innervation and vascularization.

Comprehend the histological structure of the lung and the respiratory system and explain the physiology of blood and air flow in the lung.
Describe the functional anatomy of the different areas of the lung focusing on aeration, blood flow and their coordination.

Describe the basis and methodology for determining lung functionality.

Describe the role played by the lung in regulating oxygen concentration, carbon dioxide concentration and acid/base balance in arterial blood.

Describe the main respiratory diseases and their physiological basis.

Describe the nervous and autonomous regulation of the respiratory system.

Cognize the interaction of the respiratory system with the cardiovascular and renal system for the homeostasis of the extracellular fluid.

Attendance requirements(%):

Attendance is mandatory in lectures -at least 80%
Attendance is mandatory in the laboratory 100% attendance required in the labs, study groups and the anatomical dissections.

Teaching arrangement and method of instruction: Frontal lectures given by experts in each section and module as well as small study groups going over central and important modules. In addition there will be anatomical dissections as well as histological labs

Course/Module Content:

1. Anatomy of the lungs and airways: 2 hrs
Respiratory system anatomy lab: 3 hrs

2. Histology: 2 hrs
Histology lab (computerized): 3 hrs

3. Imaging: 2 hrs

4. Physiology:23 hours
Lab: 8 hours
PBL: 2 hours

4.1. Respiration definition, applied anatomy

4.2. Respiratory Mechanics: static and dynamic

Lung Volumes: Volumes actively involved in ventilation, volumes participating in augmented ventilation, residual volume
Physical properties relevant to respiratory mechanics: Boyle’s law, Surface Tension
Model of excised lung, Pressure-volume relations in excised lungs
Lung Compliance and Elasticity

Dynamic Mechanics:
Respiratory muscles
Recoil forces of chest wall & lung
Relaxation pressure-volume curve of the lung and chest wall
Intrapleural pressure
Functional residual capacity
Spirometry, flow-volume loops, Obstructive vs. Restrictive Defect
Airway Resistance and Conductance: Characteristics and their relation to lung volume
Dynamic Occlusion

4.3. Oxygen transport in the blood
O_2 present in: ambient air, blood, either dissolved or combined to Hemoglobin
Barometric pressure, Inspired air PO_2, alveolar PO_2, partial pressure of water vapor
Oxygen is transported in Blood in two forms: 1) dissolved O_2 2) combined O_2 with Hgb
Hemoglobin structure
Amount of O_2 in blood (Hgb capacity, saturation, content)
The O_2 dissociation curve
Direct measurement of O_2 consumption (with right heart catheterization)
Right and left shifts of O_2 dissociation curve, Bohr effect

CO_2 transport in blood
Three forms of CO_2 transport in blood: dissolved, bicarbonate, bound to protein (carbamino compound)
CO_2 dissociation curve
The Haldane effect

4.4. Pulmonary blood circulation
Extra-alveolar and alveolar blood vessels
Pulmonary vascular resistance and its calculation (comparison at sea level and at high altitude)
Factors affecting pulmonary vascular resistance, recruitment and distention of pulmonary capillaries
Effect of Left atrium pressure on pulmonary vascular resistance (myocardial insufficiency and mitral disease)
Lung volume effect on pulmonary vascular resistance
Distribution of blood flow in the lung, balance between alveolar pressure, arterial and venous pressure
Hypoxic Pulmonary Vasoconstriction: description, mechanisms, physiologic role and impact
Pulmonary edema:
Extra-cellular water balance in the lung
Starling’s law: fluid exchange across the capillary endothelium, hydrostatic and colloid pressures

4.5. Ventilation-Perfusion Relationships
Ventilation & Perfusion Matching
O_2-CO_2 diagram
Distribution of ventilation and blood flow in the upright lung
Mismatching of VQ
Possible abnormalities: Non-uniform ventilation or Non-uniform perfusion
Non-uniform Ventilation assessment
Expired N_2 after single inhalation of 100% O_2 from Residual Volume (RV)
Closing volume in Emphysema
Multiple N_2 wash-out test (breathing 100% O_2)

Non-uniform Perfusion assessment
Radioactive Tracers
Pulmonary Embolism detection, The Ventilation-Perfusion lung scan

V/Q mismatch
Physiologic shunt &eq; anatomic shunt + intrapulmonary shunt
Intrapulmonary shunt (venous admixture) &eq; absolute shunts + “shunt like” states
“Shunt like” states (venous admixture): blood draining from alveoli with low V/Q ratios
Shunt equation: Based on calculating O2 amounts in Blood
Absolute shunt calculation after giving 100% oxygen

Dead Space: Ventilation to non-perfused alveoli (wasted ventilation)
Physiologic Dead Space &eq; anatomic dead space and alveolar dead space (ventilation of un-perfused alveoli

Anatomic dead space estimation (Fowler’s method)
Physiologic Dead Space estimation (Bohr Equation) based on end-tidal CO2 measurement

Estimating Ventilation-Perfusion Inequality
The Alveolar-arterial PO2 difference
Alveolar Gas Equation

Mechanisms & conditions causing Hypoxemia:
Hypoventilation
Low inspiratory O2 pressure
Diffusion limitation
Low VA/Q ratio units
Shunt occurs in areas with VA/Q &eq; 0

4.6. Respiratory function evaluation

Lung Volumes Measurement, including non-actively ventilated lung volumes & airway resistance determination
Body Plethysmography
Physical Principles behind the Measurements
Boyle’s Law
Airway Resistance and conductance
Laminar &Turbulent flow
Thoracic gas volume (plethysmographic functional residual capacity) determination
Helium-Dilution Technique to determine functional residual capacity

Restrictive vs. Obstructive Lung Abnormalities

Quality of Measurements

4.7. Diffusion of O2 across blood-gas barrier
Fick’s Diffusion Law
Factors affecting gas diffusion: area, thickness, driving pressure, diffusion constant
Carbon monoxide (CO) use to determine diffusion
Transfer factor of the Lung for Carbon Monoxide (TLCO)
KCO the diffusion constant
Clinical significance of TLCO & KCO determination

4.8. Control of Breathing:
Elements playing role in Breathing Control
Respiratory neurons, Respiratory motor pools, respiratory muscle generating airflow

Chemosensors: central, peripheral; blood gases & pH alterations, altering ventilation
Central Controller: Brain cortex & other components, Limbic system and hypothalamus.
Effectors: Diaphragm, Intercostal muscles, Abdominal muscles
Accessory muscles (e.g., sternomastoids)
Muscle activity should be coordinated

Other receptors:
Lung receptors (e.g., stretch, irritant, J),
Peripheral receptors (nasopharyngeal, joint & muscle mechanoreceptors (incl. intercostal), baroreceptors, pain)

Effects of ventilation-perfusion mismatch on PCO2
Response to PO2 and PCO2 are inter-related
Ventilatory Drive: Response to increasing PCO2 is depressed in higher PO2
Intensity of response to CO2 elevation is related to sleep
Response to PO2 decrease: increased ventilation in response to hypoxia is related to PCO2

4.9. Acid Base balance
Definitions
Acid, base, acid strength, buffer systems, pH
Acid Dissociation & the Henderson-Hasselbalch equation
Davenport Diagram
Kidney tubular function role in acid-base balance

Acid-Base Disturbances
Respiratory acidosis and alkalosis
Metabolic acidosis and alkalosis

Anion gap acidosis

4.10. Respiratory system under stress: Diving and High altitude
Scuba Diving
Breathing gases choices: Normal air, Nitrogen- enriched with oxygen mixture (Nitrox)
Helium-nitrogen-oxygen “trimix” mixture (Heliox)

Effects of high barometric pressures, increased air density, increased work of breathing
Helium substituting N2 has low density and reduces resistance to flow and increase conductance

Nitrogen (N2) physical properties
Gas alterations during diving
Decompression sickness and treatment by hyperbaric chamber
Inert Gas Narcosis

High altitude
Relation between altitude and inspired O2
Acute acclimatization to high altitude
Respiratory alkalosis may suppress ventilation and impair acclimatization
Carbonic anhydrase (CA) pharmacologic inhibition
Secondary Polycythemia
Shifts in O2 dissociation curve: hypoxia and metabolic acidosis vs. respiratory alkalosis

Chronic hypoxia and pulmonary hypertension
Acute/chronic mountain sickness

Pre-flight advice in chronic lung disease
High altitude simulation test (HAST)

4.12. Exercise Physiology:

4.12.1 Response to exercise, role of nutrients and metabolic pathways (anaerobic and aerobic) at different exercise intensities, oxygen uptake (consumption), cardiovascular response, respiratory response.

4.12.2 The anaerobic threshold: definition and identification, ventilatory compensation in response to metabolic acidosis, isocapnic phase. Thermodynamics in exercise, energetic efficiency

4.12.3 Principles of incremental cardiopulmonary exercise testing.
12.3.1 Normal response to exercise during incremental cardiopulmonary exercise

test, determination of maximal exercise capacity.
4.12.3.2 Exercise pathophysiology, response to exercise in COPD, heart failure and pulmonary hypertension.

4.13. Basic pulmonary Physiological lab:
Mechanical lung model – Pa, IPP, positive breathing, pneumotorax
Gas exchange- alveolar gas equation, inspiratory point, alveolar point
Simple spirometry – SVC, FVC

4.14. Advanced pulmonary Physiological lab:
Endurance test – partial gas pressures, TV, heartbeat, anaerobic threshold, isocapnic period
Plathysmograph – diffusion, airway resistance, physiological FRC, anatomical FRC

<u>Required Reading:</u>
Respiratory physiology, J. West.

<u>Additional Reading Material:</u>
pneumothorax
prone positioning for hypoxemia
(provided in the moodle platform)

<u>Course/Module evaluation:</u>
End of year written/oral examination 75 %
Presentation 0 %
Participation in Tutorials 0 %
Project work 0 %
Assignments 10 %
Reports 0 %
Research project 0 %
Quizzes 10 %
Other 5 %
Anatomy (practical)

<u>Additional information:</u>