INVESTIGATIONS AND TESTS

EXERCISE TESTING

Standard graded exercise tests (GXTs) are used in clinical applications to assess a patient's ability to tolerate increasing intensities of exercise while electrocardiographic (ECG), hemodynamic, and symptomatic responses are monitored for manifestations of myocardial ischemia, electrical instability, or other exertion related signs or symptoms. Gas exchange and ventilatory responses also are commonly assessed during the exercise test, particularly in patients with chronic heart failure, in those whom preoperative risk is indeterminate, among post myocardial infarction (post-MI) patients who wish to return to occupational or leisure-time pursuits requiring vigorous physical activity, or in patients with known or suspected pulmonary limitations.

Indications and Applications

The exercise test may be used for diagnostic, prognostic, and therapeutic applications, especially in regard to exercise prescription

- Exercise Testing for Disease Severity and Prognosis

  Exercise testing is useful for the evaluation of disease severity among persons with known or suspected

  CVD. Data derived from the exercise test are most useful when considered in context with other clinical data. Information related to demographics, risk factors, symptoms, functional capacity, exercise hemodynamics, and ECG findings at rest and during exercise must be considered together to reliably predict long-term mortality after exercise testing

- Functional Exercise Testing

Exercise testing is useful to determine functional capacity. This information can be valuable for activity counseling, exercise prescription, return to work evaluations, disability assessment, and to help estimate prognosis.

Exercise Test Modalities

The treadmill and cycle ergometer are the most commonly used modalities for clinical exercise testing. Treadmill testing provides a more common form of physiologic stress (e.g., walking) in which subjects are more likely to attain a slightly higher oxygen consumption ([V with dot above]O2) and peak heart rate than during cycle ergometer testing.

Cycle ergometers are less expensive, require less space, and make less noise than treadmills.

Arm ergometer tests can be used for activity counseling and exercise prescription for certain disabled populations (e.g., spinal cord injury) and individuals who perform primarily dynamic upper-body work during occupational or leisure-time activities

Exercise Protocols

The protocol employed during an exercise test should consider the purpose of the evaluation, the specific outcomes desired, and the characteristics of the individual being tested (e.g., age, symptomatology).

The Bruce treadmill test remains one of the most commonly used protocols; however, it employs relatively large increments (i.e., 2–3 METs per stage) every 3 minutes. Protocols with larger increments (e.g., Bruce, Ellestad) are better suited for screening younger and/or physically active individuals, whereas protocols with smaller increments, such as Naughton or Balke-Ware (i.e., 1 MET per stage or lower), are preferable for older or deconditioned individuals and patients with chronic diseases.

Submaximal testing can be an appropriate choice for predischarge, post-MI evaluations and for patients who may be at high risk for serious arrhythmias, abnormal blood pressure responses, or other adverse signs or symptoms. These tests are generally terminated at a predetermined level, such as a heart rate of 120 beats·min-1, perceived exertion of 13 (somewhat hard; 6–20 category scale), or a MET level of 5, but this may vary based on the patient and clinical judgment. When performed in this manner, submaximal tests may be useful in risk stratifying post-MI patients.

Components of the Pre-exercise Test Physical Examination

- Appropriate components of the physical examination may include the following:
- Body weight; in many instances, determination of body mass index (BMI), waist girth, and/or body composition (percent body fat) is desirable
- Apical pulse rate and rhythm
- Resting blood pressure, seated, supine, and standing
- Auscultation of the lungs with specific attention to uniformity of breath sounds in all areas (absence of rales,wheezes, and other breathing sounds)
- Palpation of the cardiac apical impulse, point of maximal impulse (PMI)
- Auscultation of the heart with specific attention to murmurs, gallops, clicks, and rubs
- Palpation and auscultation of carotid, abdominal, and femoral arteries
- Evaluation of the abdomen for bowel sounds, masses, visceromegaly, and tenderness
- Palpation and inspection of lower extremities for edema and presence of arterial pulses
- Follow-up examination related to orthopedic or other medical conditions that would limit exercise testing
- Tests of neurologic function, including reflexes and cognition (as indicated)
- Inspection of the skin, especially of the lower extremities in known diabetes patients

The Concept of Maximal Oxygen Uptake

Maximal oxygen uptake ([V with bar above]O2max) is accepted as the criterion measure of CR fitness.

Maximal oxygen uptake is the product of the maximal cardiac output (L blood·min-1) and arterial-venous oxygen difference (mL O2 per L blood).

Open-circuit spirometry is used to measure [V with bar above]O2max. In this procedure, the subject breathes through a low-resistance valve with his/her nose occluded (or through a nonlatex foam mask) while pulmonary ventilation and expired fractions of oxygen (O2) and carbon dioxide (CO2) are measured. Maximal tests have the disadvantage of requiring participants to exercise to the point of volitional fatigue

Variable	Clinical Significance
ST-segment depression (ST↓)	An abnormal ECG response is defined as≥1.0 mm of horizontal or down sloping ST ↓ 60–80 msec beyond the J point, suggesting myocardial ischemia.
ST-segment elevation (ST ↑)	ST ↑ in leads displaying a previous Q-wave MI almost always reflects an aneurysm or wall-motion abnormality. In the absence ofsignificant Q waves, exercise-induced ST ↑ often is associated with a fixed high grade coronary stenosis
Heart rate (HR)	The normal HR response to progressive exercise is a relatively linear increase, corresponding to 10 ± 2 beats·MET-1 for inactive subjects.

Heart rate recovery (HRR)	An abnormal (slowed) HRR is associated with a poor prognosis. HRR has frequently been defined as a decrease ≤12 beats/min at 1 min (walking in recovery), or ≤22 beats/min at 2 min (supine position in recovery).
Systolic blood pressure (SBP)	The normal response to exercise is a progressive increase in SBP, typically 10 ± 2 mm Hg·MET-1, with a possible plateau at peak exercise. Exercise testing should be discontinued with SBP values of >250 mm Hg. Exertional hypotension (SBP that fails to rise or falls [>10 mm Hg]) may signify myocardial ischemia and/or LV dysfunction. Maximal exercise SBP of <140 mm Hg suggests a poor prognosis.
Diastolic blood pressure (DBP)	The normal response to exercise is no change or a decrease in DBP. A DBP of >115 mm Hg is considered an endpoint for exercise testing

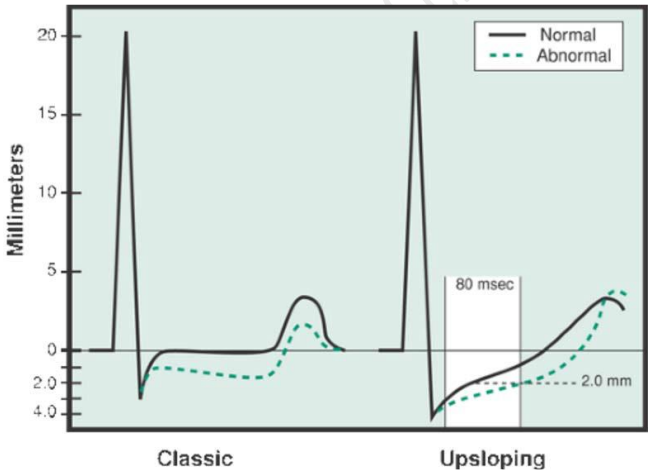


Fig 1: ST segment elevation and depression

Contraindications to Exercise Testing

Absolute Contraindications

- A recent significant change in the resting ECG suggesting significant ischemia, recent myocardial infarction
- (within 2 days), or other acute cardiac event
- Unstable angina
- Uncontrolled cardiac dysrhythmias causing symptoms or hemodynamic compromise
- Symptomatic severe aortic stenosis
- Uncontrolled symptomatic heart failure
- Acute pulmonary embolus or pulmonary infarction
- Acute myocarditis or pericarditis
- Suspected or known dissecting aneurysm
- Acute systemic infection, accompanied by fever, body aches, or swollen lymph glands

Relative Contraindications (individuals can be exercised with caution and/or using low-level end points)

- Left main coronary stenosis
- Moderate stenotic valvular heart disease
- Electrolyte abnormalities (e.g., hypokalemia, hypomagnesemia)
- Severe arterial hypertension (i.e., systolic BP of >200 mm Hg and/or a diastolic BP of >110 mm Hg) at rest
- Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise
- High-degree atrioventricular block

- Ventricular aneurysm
- Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxedema)
- Chronic infectious disease (e.g., mononucleosis, hepatitis, AIDS)
- Mental or physical impairment leading to inability to exercise adequately

General Indications for Stopping an Exercise Test (Termination Criteria)

- Onset of angina or angina like symptoms
- Drop in systolic BP of >10 mm Hg from baseline BP despite an increase in workload
- Excessive rise in BP: systolic pressure >250 mm Hg or diastolic pressure >115 mm Hg
- Shortness of breath, wheezing, leg cramps, or claudication
- Signs of poor perfusion: light-headedness, confusion, ataxia, pallor, cyanosis, nausea, or cold
- and clammy skin
- Failure of heart rate to increase with increased exercise intensity
- Noticeable change in heart rhythm
- Subject requests to stop
- Physical or verbal manifestations of severe fatigue
- Failure of the testing equipment

BRUCE PROTOCOL

- It is performed on treadmill.
- Standard Bruce protocol begins at 1.7mph speed, 10% treadmill grade; increase both speed and grade at every 3 min.

- First stage of Bruce protocol used roughly 5METS of energy.
- Bruce protocol is better suited for screening younger and/or physically active individuals,
- Modified bruce protocol begins at 1.7mph speed, 0% treadmill grade; increase both speed and grade at every 3 min.

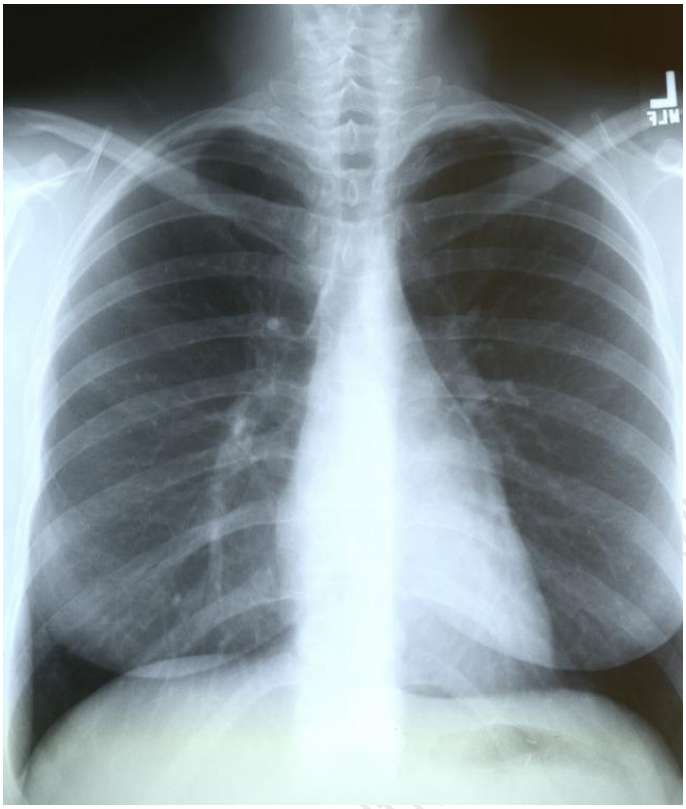
3 minutes stages	
Speed (mph)	% Grade (percentage elevation of treadmill)
1.7	0
1.7	5
1.7	10
2.5	12
3.4	14
4.2	16
5.0	18
5.5	20

SIX MINUTE WALK TEST

- The six minute walk test (6MWT) is an example of a functional walk test that is practical, self paced and simple and only requires the ability to walk.
- It is an objective assessment of sub-maximal level of functional capacity of a person by measuring the distance covered, as quickly as possible without exerting, on flat, hard surface in a period of six minute.
- The subject's resting heart rate, blood pressure, saturation and Rate of Perceived Exertion (RPE) is recorded before the test.

- The subject walks from one end to other of a 30m hallway at their own pace, while attempting to cover as much ground as possible in the allotted 6 minutes.
- Subjects can be encouraged with the standardized statements like “You are doing well” or “Keep up the good work”.
- Subjects allowed to stop and rest during the test, but to resume walking as soon as they felt able to do.
- Heart rate, RPE, BP and saturation will be monitored immediately after the test.
- The distance walked (6MWD) will be recorded immediately (number of laps + extra distance walked)

X-RAY (CHEST RADIOGRAPHS)



Pre-Reading

1. Check the name
2. Check the date
3. Obtain old films if available
4. Which view(s) do you have?
   - PA / AP, lateral

Quality Control

- Penetration
  - Should see ribs through the heart
  - Barely see the spine through the heart

Overpenetrated Film

- Lung fields darker than normal—may obscure subtle pathologies
- See spine well beyond the diaphragms
- Inadequate lung detail

Underpenetrated Film

- Hemidiaphragms are obscured
- Pulmonary markings more prominent than they actually are

Inspiration

  - Should be able to count 5-7 anterior ribs
  - Heart shadow should not be hidden by the diaphragm
- Rotation
  - Medial ends of bilateral clavicles are equidistant from the midline or vertebral bodies

Findings

- Soft tissue and bony structures
  - Check for

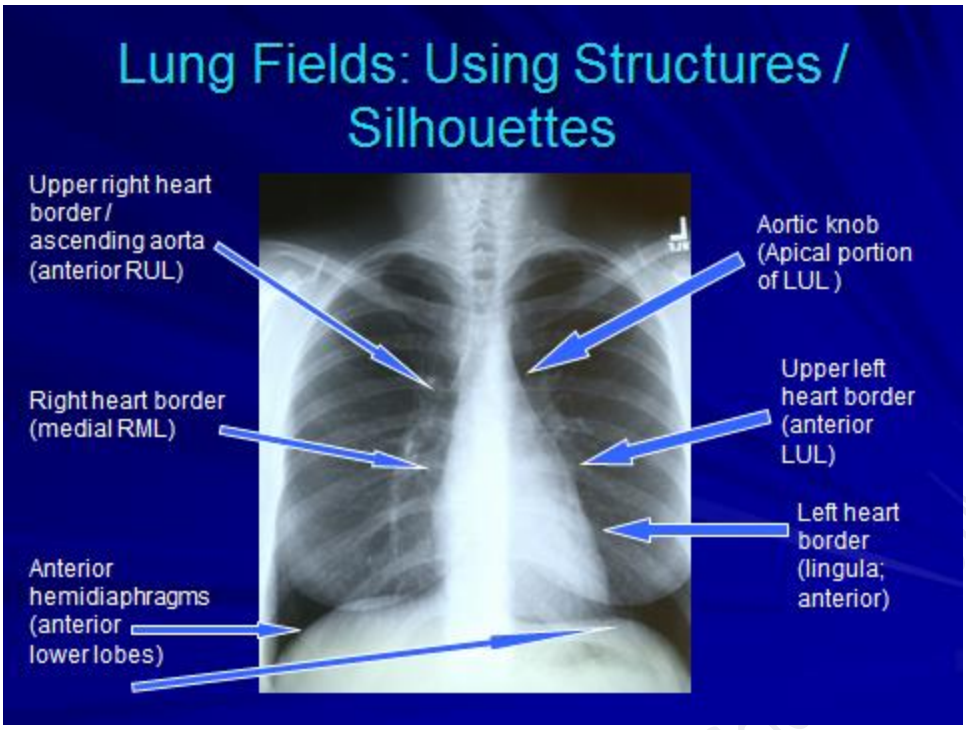
- Symmetry
- Deformities
- Fractures
- Masses
- Calcifications
- Lytic lesions

- Mediastinum
  - Check for
    - Cardiomegaly:
    - Mediastinal and Hilar contours for increase densities or deformities

Diaphragms

  - Check sharpness of borders
  - Right is normally higher than left
  - Check for free air, gastric bubble
  - Costophrenic Angle: acute angle
- The Lung Fields!
  - To help you determine abnormalities and their location…

Lung Fields: Using Structures / Silhouettes



The 12-Step Program

- **1**: Name
- **2**: Date
- **3**: Old films

} **Pre-read**

- **4**: What type of **view(s)**
- **5**: Penetration
- **6**: Inspiration
- **7**: Rotation
- **8**: Angulation

} **Quality Control**

- **9**: Soft tissues / bony structures
- **10**: Mediastinum
- **11**: Diaphragms
- **12**: Lung Fields

} **Findings**

PULMONARY FUNCTION TESTING

PURPOSE OF PULMONARY FUNCTION TEST

- How much air volume can be moved in and out of the lungs
- How fast the air in the lungs can be moved in and out
- How stiff are the lungs and chest wall - a question about compliance

INDICATIONS

- Screening for the presence of obstructive and restrictive diseases
- Evaluating the patient prior to surgery
- Evaluating the patient's condition for weaning from ventilator.
- Documenting the progression of pulmonary disease
- Documenting the effectiveness of therapeutic intervention

EQUIPMENT

SPIROMETER

Factors affecting normal values

- Age
- Gender
- Body Height and Size
- Race

TYPES OF PULMONARY FUNCTION TESTS

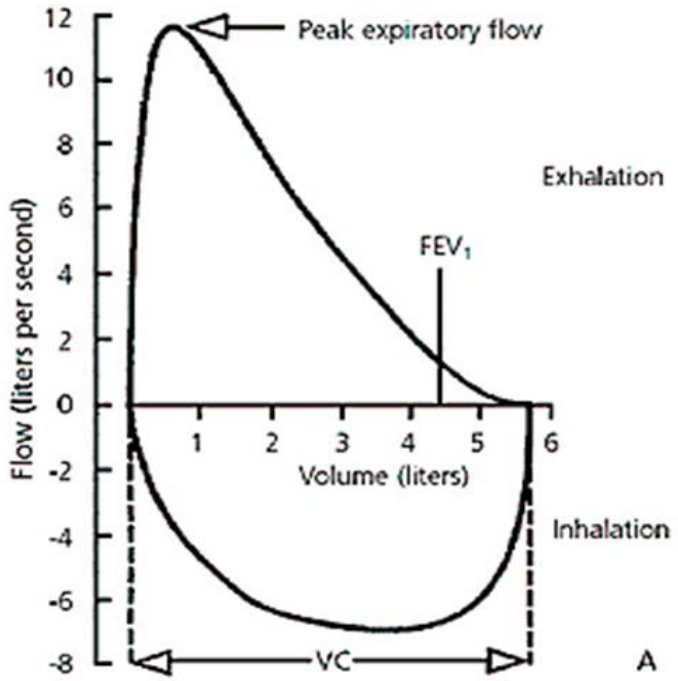
- Lung Volumes

- Lung Capacities
- Diffusion Capacities
- Inhalation Challenge Test
- Body plethysmography

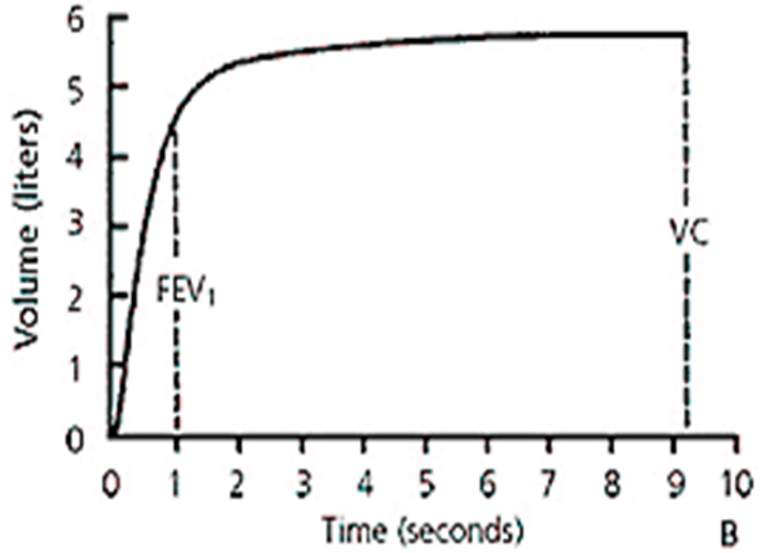
TERMINOLOGY

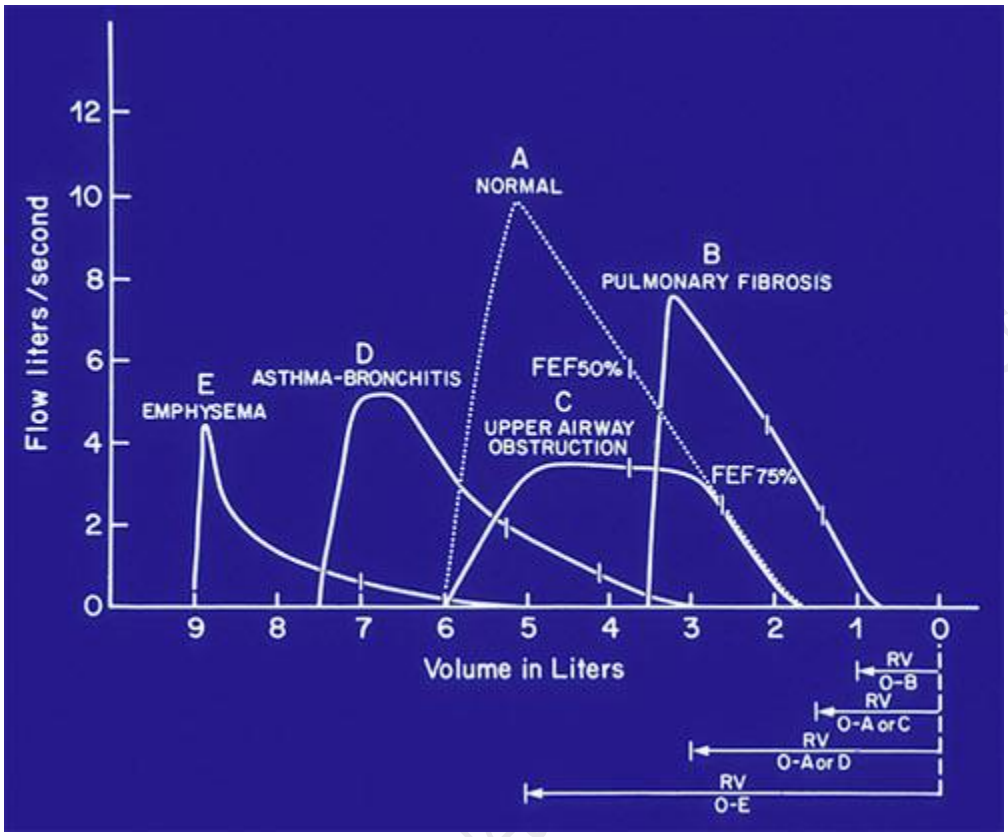
- FVC – Forced Vital Capacity
- FEV1 – Forced Expiratory Volume in One Second
- FEV1/FVC – FEV1 %
- FEV3 – Forced Expiratory Flow Rate
- FEV3/FVC – FEV3%
- PEFR – Peak Expiratory Flow Rate
- FEF – Forced Expiratory Flow
- FEF25% - First 25% of the total FVC
- FEF50% - First 50% of the total FVC
- FEF25%-75%
- MVV – Maximal Voluntary Ventilation

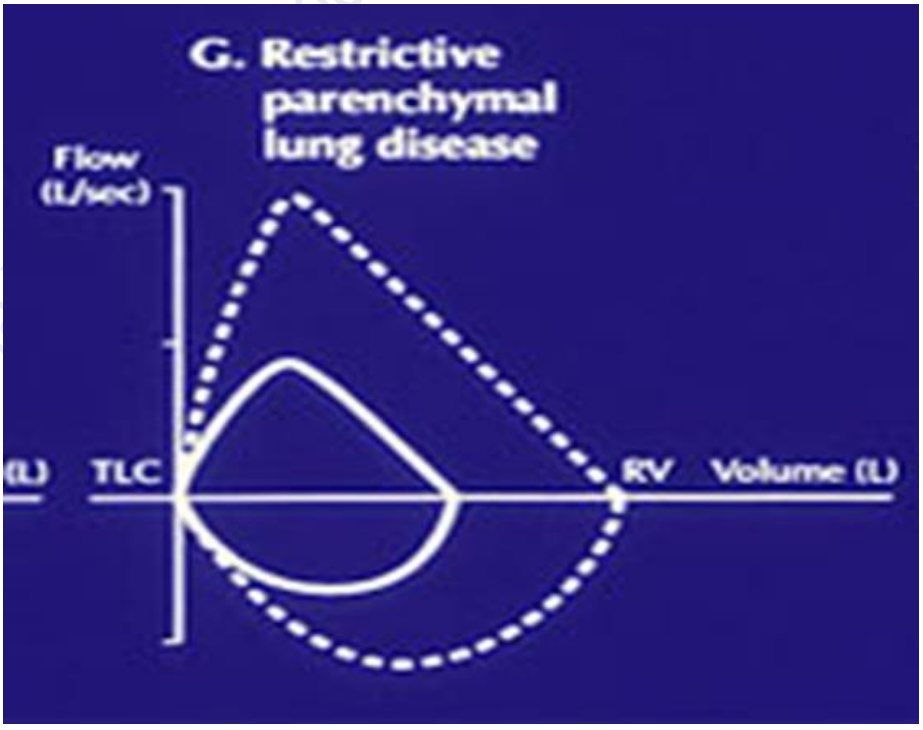
FLOW VOLUME CURVE



VOLUME TIME CURVE




Flow liters/second
12
10
8
6
4
2
0
A
NORMAL
B
PULMONARY FIBROSIS
D
ASTHMA-BRONCHITIS
E
EMPHYSEMA
C
UPPER AIRWAY
OBSTRUCTION
FEF50%
FEF75%
9 8 7 6 5 4 3 2 1 0
Volume in Liters
RV
O-B
RV
O-A or C
RV
O-A or D
RV
O-E


G. Restrictive
parenchymal
lung disease
Flow
(L/sec)
TLC
RV
Volume (L)

BRONCHOSCOPY

- Bronchoscopy is a technique of visualizing the inside of the airways (of lungs) for diagnostic and therapeutic purposes.

Diagnostic Indications

- Bronchoscopy can help find the cause of a lung problems:
- A tumor
- Signs of infection
- Excess mucus in the airways
- The site of bleeding
- A blockage (such as a piece of food) in your airway
- Samples of mucus or tissue from lungs can be taken to test in a laboratory .

Therapeutic Indications

- To treat lung problems

Eg: To insert a stent in an airway. An airway stent is a small tube that holds the airway open. It might be used if a tumor or other condition blocks the airway.

- To remove secretions, blood, or foreign objects lodged in the airways.

Procedure

- An instrument (bronchoscope) is inserted into the airways, usually through the nose or mouth or through a tracheostomy.
- The bronchoscope has a light and small camera that allows to visualize the windpipe and airways and take pictures.
- If an abnormality is discovered, it may be sampled using a brush, a needle, or forceps. Specimen of lung tissue (transbronchial biopsy) may also be sampled.

- The patient may be given antianxiety, generally atropine.
- A local anesthetic is often given to anesthetise the mucous membranes of the pharynx, larynx, and trachea.
- The patient is monitored during the procedure with periodic blood pressure checks, continuous ECG monitoring of the heart, and pulse.

Types of Bronchoscopes

1. Flexible bronchoscope

- Inserted with the patient in a sitting or supine position.
- Flexible bronchoscopy can also be performed on intubated patients, such as patients in intensive care. In this case, the instrument is inserted through an adapter connected to the tracheal tube.

2. Rigid bronchoscope

- Rigid bronchoscopy is performed under general anesthesia.
- Rigid bronchoscopes are wider.

Bronchogram

- Bronchogram is a radiograph of the bronchial tree after injection of a radiopaque substance.
- A radiopaque substance is put into the airway and X-rays are taken from various angles.

Bronchogram

ARTERIAL BLOOD GAS ANALYSIS

Analysis of the following variables in the blood in order to assess the condition of the patients

- pH, PaO2, PaCO2, HCO3, BE
- O2 Saturation
- Electrolytes: Na, K+, Ca+, Cl, BUN
- Haemoglobin
- Hematocrit

METHODS OF SAMPLING IN ICU

- Invasive arterial line
- Major superficial artery
- Flushing
- Heparinization of syringes
- ½- 1 ml
- No suction force in withdrawing
- No air bubble
- No time lag

NEED FOR ABG ANALYSIS

- ✓ To understand the patient's acid base balance, alveolar ventilation and oxygenation status
- ✓ Treatment planning
- ✓ Evaluate the therapy and progress of their diseases

OXYGEN SATURATION (SaO2)

- Denotes what percentage of haemoglobin is saturated with oxygen
- Calculated value from PaO2

- Normal value – 95 to 100%
- Below 90% - hypoxemia

PARTIAL PRESSURE OF OXYGEN IN BLOOD (PaO2)

- ❖ PaO2 = 90 to 97 mm Hg
- ❖ P(A-a)O2 = 0 to 10 mm Hg
- ❖ PaO2 < 60 mmHg …. Hypoxemia….Hypoxia

INCREASED PaCO2

- ❖ Respiratory center disorder
- ❖ Spinal cord diseases
- ❖ Chest wall disease

SYSTEMATIC ANALYSIS

- ❖ Whether the reading is correct?
- ❖ Acidosis or alkalosis?
- ❖ Metabolic or respiratory?
- ❖ Simple or mixed?
- ❖ Acute or chronic?
- ❖ Compensated/partially compensated/uncompensated

LOOK AT pH

- If pH is less than 7.35, there is acidosis
- If the pH is more than 7.45, there is alkalosis
- If the pH is 7.35 to 7.45, there is
  - Either a combined acid base disorder
  - There is no acid base disorder

– There is complete compensation for the acid base disorder

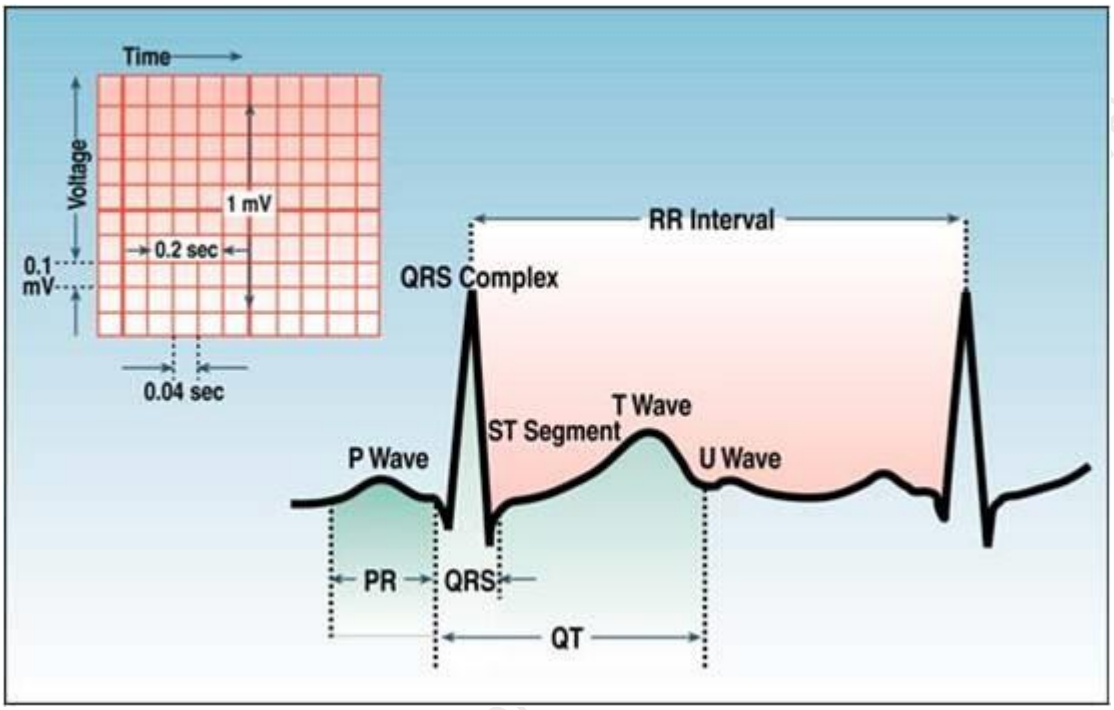
LOOK AT THE PaCO2

- If the PaCO2 is increased with decreased pH, there is respiratory acidosis
- If the PaCO2 is decreased with a decreased pH, there is metabolic acidosis
- If the PaCO2 is decreased with increased pH, there is respiratory alkalosis
- If the PaCO2 is increased with increased pH, there is metabolic alkalosis

PH	PaCO2	HCO3	ALKALOSIS/ ACIDOSIS	RESPIRATORY/ METABOLIC	COMPENSATED/ UNCOMPENSATED
↓	↑	↑	ACIDOSIS	RESPIRATORY	UNCOMPENSATED
N	↑	↑↑	ACIDOSIS	RESPIRATORY	COMPENSATED
↓	↓	↓	ACIDOSIS	METABOLIC	UNCOMPENSATED
N	↓↓	↓	ACIDOSIS	METABOLIC	COMPENSATED
↑	↓	↓	ALKALOSIS	RESPIRATORY	UNCOMPENSATED
N	↓	↓↓	ALKALOSIS	RESPIRATORY	COMPENSATED
↑	↑	↑	ALKALOSIS	METABOLIC	UNCOMPENSATED
	↑↑	↑	ALKALOSIS	METABOLIC	COMPENSATED

ECG

The standard 12-lead electrocardiogram is a representation of the heart's electrical activity recorded from electrodes on the body surface



- P wave: the sequential activation (depolarization) of the right and left atria
- QRS complex: right and left ventricular depolarization
- T wave: ventricular repolarization
- U wave: repolarization of papillary muscles
- PR interval: time interval from onset of atrial depolarization (P wave) to onset of ventricular depolarization (QRS complex)
- QRS duration: duration of ventricular muscle depolarization
- QT interval: duration of ventricular depolarization and repolarization
- RR interval: duration of ventricular cardiac cycle (an indicator of ventricular rate)
- PP interval: duration of atrial cycle (an indicator of atrial rate)

Orientation of the 12 Lead ECG

It is important to remember that the 12-lead ECG provides spatial information about the heart's electrical activity in 3 approximately orthogonal directions:

- Right ⇔ Left
- Superior ⇔ Inferior
- Anterior ⇔ Posterior

Each of the 12 leads represents a particular orientation in space, as indicated below (RA = right arm; LA = left arm, LL = left foot):

Bipolar limb leads (frontal plane):

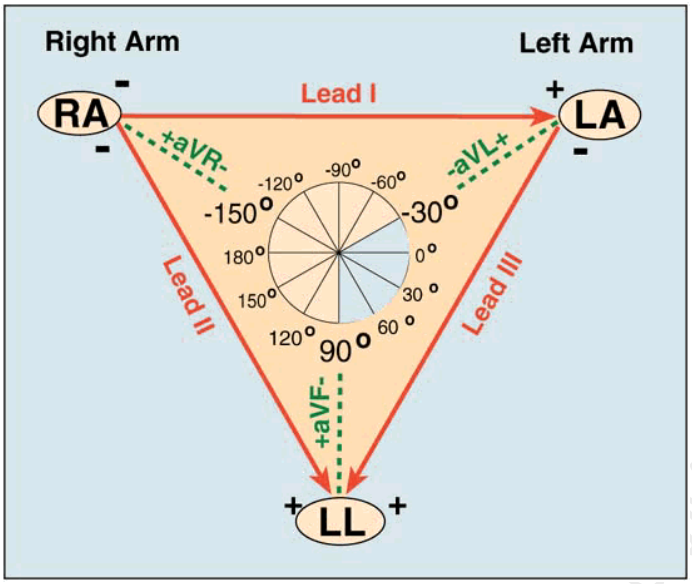
- Lead I: RA (-) to LA (+) (Right Left, or lateral)
- Lead II: RA (-) to LL (+) (Superior Inferior)
- Lead III: LA (-) to LL (+) (Superior Inferior)

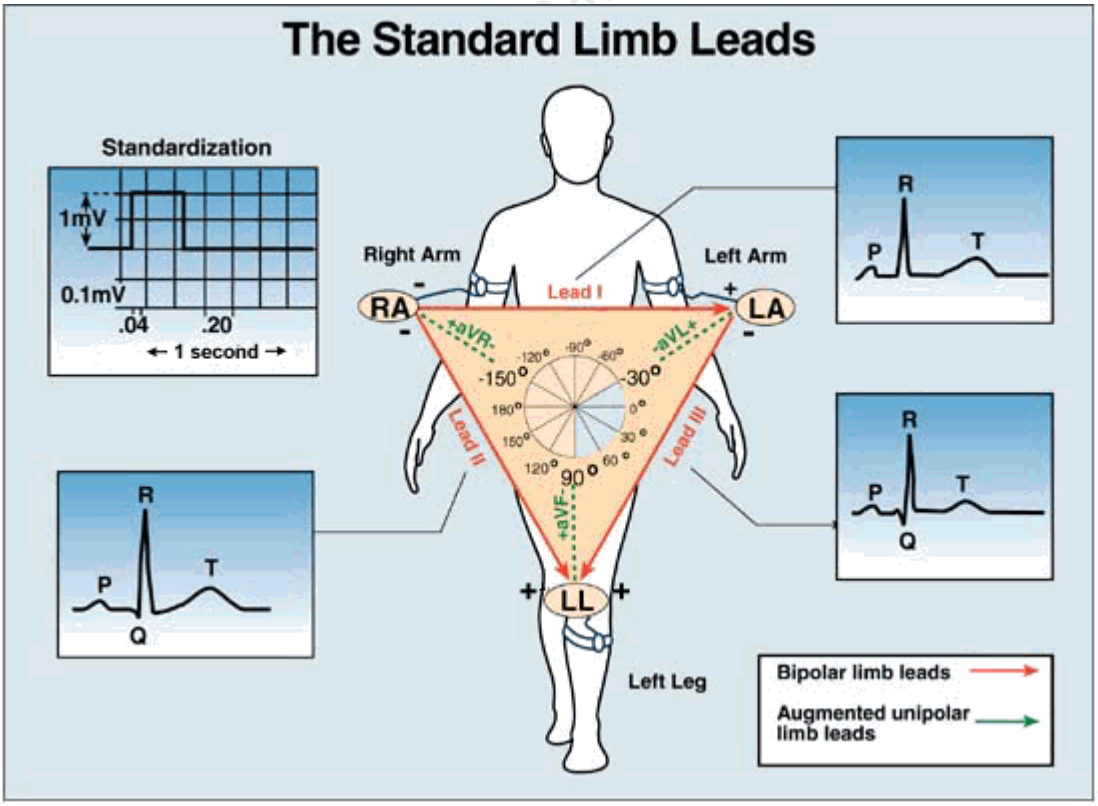
Augmented unipolar limb leads (frontal plane):

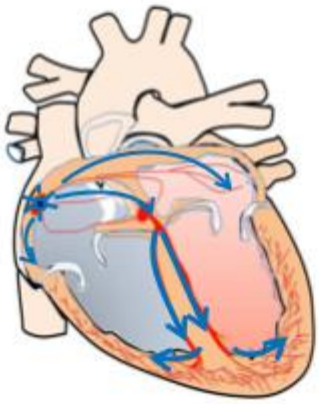
- Lead aVR: RA (+) to [LA & LL] (-) (Rightward)
- Lead aVL: LA (+) to [RA & LL] (-) (Leftward)
- Lead aVF: LL (+) to [RA & LA] (-) (Inferior)

Unipolar (+) chest leads (horizontal plane):

- Leads V1, V2, V3: (Posterior Anterior)
- Leads V4, V5, V6:(Right Left, or lateral)


Right Arm
Left Arm
RA
LA
LL
Lead I
Lead II
Lead III
+aVR-
-aVL+
+aVF-
-120°
-90°
-60°
-150°
-30°
180°
0°
150°
30°
120°
90°
60°


The Standard Limb Leads
Standardization
1mV
0.1mV
.04
.20
1 second
Right Arm
Left Arm
RA
LA
LL
Lead I
Lead II
Lead III
+aVR-
-aVL+
+aVF-
-120°
-90°
-60°
-150°
-30°
180°
0°
150°
30°
120°
90°
60°
R
P
T
Q
Left Leg
Bipolar limb leads
Augmented unipolar limb leads



Heart Rate in beats per min =

$$\frac{300}{\text{\# of Large squares in R-R interval}}$$

Or

$$\frac{1500}{\text{\# of small squares in R-R interval}}$$

Normal sinus rhythm

ECG OF SOME PATHOLOGICAL CONDITIONS

coarse Ventricular fibrillation

fine ventricular fibrillation

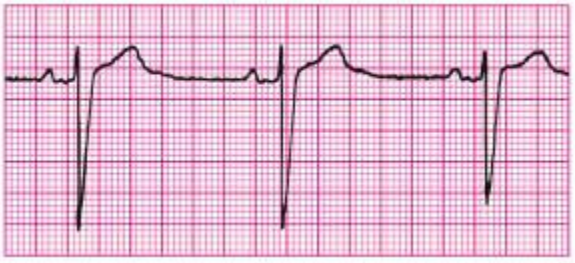
Sinus tachycardia

Tachycardia

Atrial flutter

Atrail fibrillation

ventricular tachycardia



Sinus bradycardia

First degree heart block

Second degree heart block type 1(mobitz type 2)

Secong degree block type 2 (mobitz type 1 or wenckback)

Third degree heart block