МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ
БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ
1-я КАФЕДРА ВНУТРЕННИХ БОЛЕЗНЕЙ

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МЕТОДИКА ПРОВЕДЕНИЯ НЕКОТОРЫХ ИНСТРУМЕНТАЛЬНЫХ ДИАГНОСТИЧЕСКИХ И ЛЕЧЕБНЫХ МАНИПУЛЯЦИЙ В РАМКАХ ВРАЧЕБНОЙ КЛИНИЧЕСКОЙ ПРОИЗВОДСТВЕННОЙ ПРАКТИКИ ПО ТЕРАПИИ

THE METHOD OF CARRYING OUT SOME INSTRUMENTAL DIAGNOSTIC AND THERAPEUTIC MANIPULATIONS WITHIN THE FRAMEWORK OF MEDICAL CLINICAL PRACTICE IN THERAPY

Учебно-методическое пособие

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Определены цели и задачи производственной практики, порядок и место ее прохождения, примерное распределение рабочего времени студента, перечень практических навыков и умений, подлежащих освоению или закреплению во время практики.

Предназначено для студентов 5-го курса медицинского факультета иностранных учащихся, обучающихся по специальности «Лечебное дело» на английском языке, проходящих летнюю производственную практику «Врачебная клиническая производственная практика по терапии».

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INTRODUCTION

Medical clinical practice of the 5-th year students studying in the specialty «General Medicine» as an assistant to the inpatient general practitioner is carried out in accordance with the curriculum after the end of the spring examination session of the 8-th semester in the therapeutic departments of the city and central regional hospitals of the Republic.

The purpose of the medical clinical practice is to test and consolidate the knowledge gained by students during the study the main clinical disciplines, to further deepen and improve the practical skills and abilities acquired in the clinics of the university, to familiarize students with the organization of therapeutic care for the population, the working conditions of a hospital physician, with the principles of anti-epidemic work.

Multidisciplinary city or central district hospitals with a well-organized system for providing qualified medical care in the main medical specialties are used as practice bases. The duration of the practice is 2 weeks (12 working days). The practical work of students in the department consists of a daily 6-hour shift in a hospital and 2 evening shifts.

During the medical clinical practice, students follow the rules of the internal labor regulations of the medical institution.

The objectives of the medical clinical practice in therapy: to gain an understanding of the organization and principles of work of the hospital therapeutic service, to consolidate the previously acquired in the learning process and to master new practical skills and abilities in the diagnosis and treatment of internal diseases, including basics of emergency medical care

CARDIOLOGY

ELECTROCARDIOGRAPHY

Basics of electrocardiography

The electrocardiograph records the total electrical activity of the heart, or more precisely, the difference in electrical potentials (voltage) between 2 points.

Pathogenesis of the action potential. At rest, myocardial cells are negatively charged from the inside, and positively from the outside, while a straight line (isoline) is recorded on the ECG tape. When an electrical impulse (excitation) arises and propagates in the conducting system of the heart, the cell membranes pass from a state of rest to an excited state, changing the polarity to the opposite (depolarization). In this case, the membrane becomes positive from the inside, and negative from the outside due to the opening of a number of ion channels and the mutual movement of Na^+, Ca^{2+} and K^+ ions from and to the cell. After depolarization, the cells restore their original polarity (repolarization). The electrical impulse consequently spreads through the parts of the heart, causing depolarization of myocardial cells. A potential difference arises. When all cells are depolarized or repolarized, there is no potential difference. The electrocardiogram (ECG) records the total potential difference from all myocardial cells, or, as it is called, the electromotive force of the heart (EMF of the heart).

RECORDING ELECTROCARDIOGRAM

Patient position during recording. The patient is placed horizontally on his back, the wrists, legs and chest are exposed. If the patient has severe shortness of breath and cannot lie down, the ECG is recorded in the sitting position (Fig. 1).

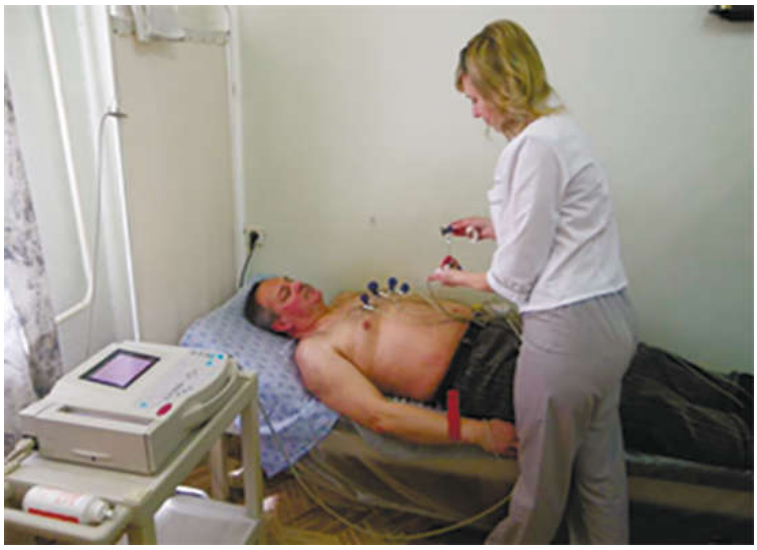


Fig. 1. Recording the ECG

The ECG electrodes. Electrical activity going through the heart can be measured by external (skin) electrodes. The electrocardiogram (ECG) registers these activities from electrodes, which have been attached onto different places on the body. In total, twelve leads are calculated using ten electrodes.

The ten electrodes are:

The four extremity electrodes:

– LA — left arm;

– RA — right arm;

– N — neutral, on the right leg (= electrical earth, or point zero, to which the electrical current is measured);

– F — foot, on the left leg.

It makes no difference whether the electrodes are attached proximal or distal on the extremities (Fig. 2). However, it is best to be uniform in this. (eg. do not attach an electrode on the left shoulder and one on the right wrist).

The six chest electrodes:

– V1 — placed in the 4th intercostal space, right of the sternum

– V2 — placed in the 4th intercostal space, left of the sternum

– V3 — placed between V2 and V4

– V4 — placed 5th intercostal space in the nipple line. Official recommendations are to place V4 under the breast in women.

– V5 — placed between V4 and V6

– V6 — placed in the midaxillary line on the same height as V4 (horizontal line from V4, so not necessarily in the 5th intercostal space) (Fig. 3).

With the use of these 10 electrodes, 12 leads can be derived. There are 6 extremity leads and 6 precordial leads.

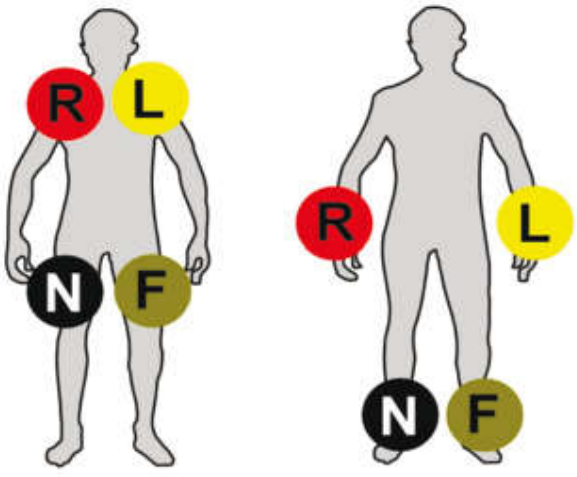


Fig. 2. The limb leads

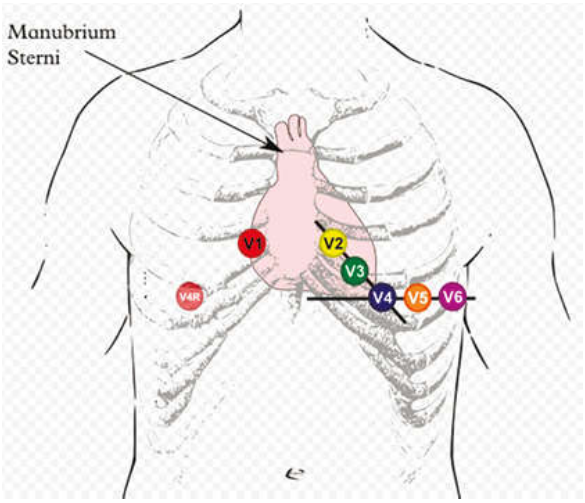


Fig. 3. The chest leads

The extremity leads are:

– I from the right to the left arm;
– II from the right arm to the left leg;
– III from the left arm to the left leg.

An easy rule to remember: lead I + lead III = lead II This is done with the use of the height or depth, independent of the wave (QRS, P of T). Example: if in lead I, the QrS complex is 3 mm in height and in lead III 9mm, the height of the QRS-complex in lead II is 12 mm.

Other extremity leads are:

– AVL points to the left arm;
– AVR points to the right arm;
– AVF points to the feet.

The capital A stands for «augmented» and V for «voltage». (aVR + aVL + + aVF = 0)

The Chest Leads. The precordial, or chest leads, (V1,V2,V3,V4,V5 and V6) «observe» the depolarization wave in the frontal plane.

Example: V1 is close to the right ventricle and the right atrium. Signals in these areas of the heart have the largest signal in this lead. V6 is the closest to the lateral wall of the left ventricle.

Normal ECG

A normal ECG contains waves, intervals, segments and one complex, as defined below (Fig. 4).

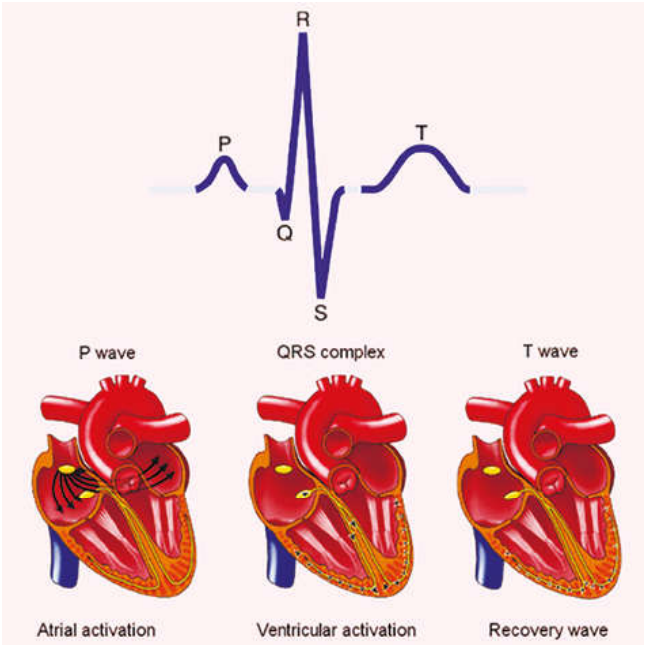


Fig. 4. The origin of the different waves on the ECG

Wave: A positive or negative deflection from baseline that indicates a specific electrical event. The waves on an ECG include the P wave, Q wave, R wave, S wave, T wave and U wave.

Interval: The time between two specific ECG events. The intervals commonly measured on an ECG include the PR interval, QRS interval (also called QRS duration), QT interval and RR interval.

Segment: The length between two specific points on an ECG that are supposed to be at the baseline amplitude (not negative or positive). The segments on an ECG include the PR segment, ST segment and TP segment.

Complex: The combination of multiple waves grouped together. The only main complex on an ECG is the QRS complex.

Point: There is only one point on an ECG termed the J point, which is where the QRS complex ends and the ST segment begins.

The P wave indicates atrial depolarization. The P wave occurs when the sinus node, also known as the sinoatrial node, creates an action potential that depolarizes the atria.

The P wave should be upright in lead II if the action potential is originating from the SA node. In this setting, the ECG is said to demonstrate a normal sinus rhythm, or NSR (Fig. 5). As long as the atrial depolarization is able to spread through the atrioventricular, or AV, node to the ventricles, each P wave should be followed by a QRS complex.

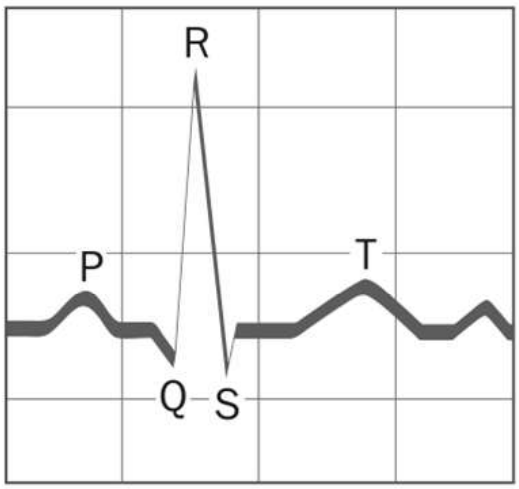


Fig. 5. The normal sinus rhythm

Atrial enlargements can widen the P wave or increase the P wave amplitude. Ectopic atrial rhythms can alter the normal morphology of the P waves. There are many heart rhythms in which the P waves are not able to be identified, including atrial fibrillation and sometimes junctional rhythms. At times, the P waves can

be buried at the end of the QRS complex, causing a «short RP» scenario, as seen in atrioventricular reentrant tachycardia.

The Q wave is the first downward deflection after the P wave and the first element in the QRS complex. When the first deflection of the QRS complex is upright, then no Q wave is present. The normal individual will have a small Q wave in many, but not all, ECG leads. Abnormalities of the Q waves are mostly indicative of myocardial infarction. The terms «Q wave myocardial infarction» and «non-Q wave myocardial infarction» are earlier designations of different types of MIs ultimately resulting in, respectively, Q wave development or the absence of Q wave development.

The R wave is the first upward deflection after the P wave and part of the QRS complex. The R wave morphology itself is not of great clinical importance but can vary at times. The R wave should be small in lead V1. Throughout the precordial leads (V1–V6), the R wave becomes larger — to the point that the R wave is larger than the S wave in lead V4. The S wave then becomes quite small in lead V6; this is called «normal R wave progression». When the R wave remains small in leads V3 to V4 — that is, smaller than the S wave — the term «poor R wave progression» is used. Both types of wave progression are depicted below (Fig. 6).

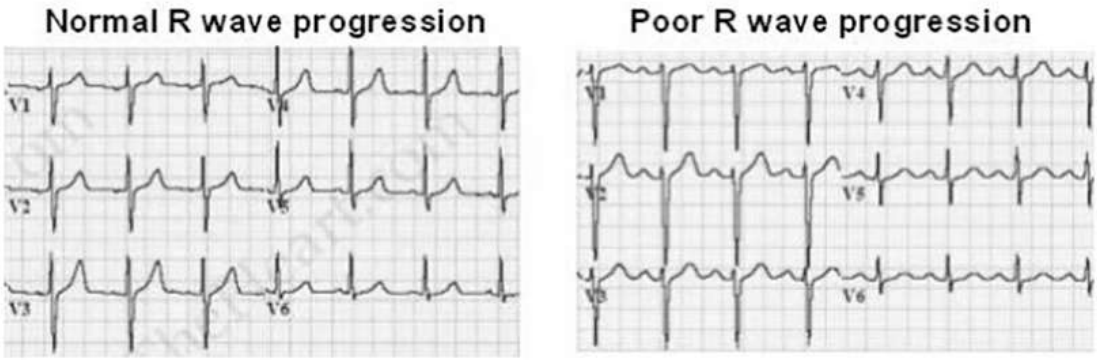


Fig. 6. Normal and poor R wave progression

Recall that the R wave is usually quite small in lead V1; if the R wave is large in V1 — that is, greater in amplitude than the S wave — significant pathology may be present.

The causes for a R/S wave ratio greater than 1 in lead V1 include right bundle branch block, Wolff-Parkinson-White syndrome, an acute posterior myocardial infarction, right ventricular hypertrophy and isolated posterior wall hypertrophy, which can occur in Duchenne muscular dystrophy. If a right bundle branch block is present, there may be two R waves, resulting in the classic «bunny ear» appearance of the QRS complex. In this setting, the second R wave is termed «R» or «R prime».

The S wave is the first downward deflection of the QRS complex that occurs after the R wave. However, a S wave may not be present in all ECG leads in a

given patient. In the normal ECG, there is a large S wave in V1 that progressively becomes smaller, to the point that almost no S wave is present in V6. A large slurred S wave is seen in leads I and V6 in the setting of a right bundle branch block.

The presence or absence of the S wave does not bear major clinical significance. Rarely is the morphology of the S wave discussed.

In the setting of a pulmonary embolism, a large S wave may be present in lead I — part of the S1Q3T3 pattern seen in this disease state. At times, the morphology of the S wave is examined to determine if ventricular tachycardia or supraventricular tachycardia with aberrancy is present.

The T wave occurs after the QRS complex and is a result of ventricular repolarization. T waves should be upright in most leads; the exceptions are aVR and V1. Further, T waves should be asymmetric in nature. The second portion of the T wave should have a steeper decline when compared with the incline of the first portion. If the T wave appears symmetric, cardiac pathology such as ischemia may be present (Fig. 7).

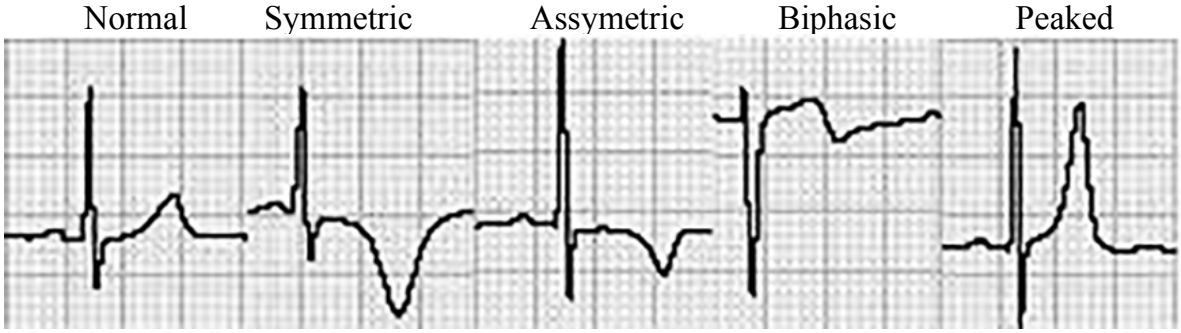


Fig. 7. Abnormal T wave patterns

Many abnormal T wave patterns exist, these include hyperkalemia, Wellens' syndrome, left ventricular hypertrophy with repolarization abnormalities, pericarditis (stage III), arrhythmogenic right ventricular dysplasia, and hyperacute T waves during myocardial infarction.

The PQ interval starts at the beginning of the atrial contraction and ends at the beginning of the ventricular contraction.

The PQ interval (sometimes referred to as the PR interval as a Q wave is not always present) indicates how fast the action potential is transmitted through the AV node (atrioventricular) from the atria to the ventricles. Measurement should start at the beginning of the P wave and end at the beginning of the QRS segment.

The normal PQ interval is between 0.12 and 0.20 seconds.

A prolonged PQ interval is a sign of a degradation of the conduction system or increased vagal tone (Bezold-Jarisch reflex), or it can be pharmacologically induced.

This is called 1st, 2nd or 3rd degree AV block.

A short PQ interval can be seen in the WPW syndrome in which faster-than-normal conduction exists between the atria and the ventricles.

The QRS duration indicates how fast the ventricles depolarize. The normal QRS is < 0.10 seconds

The ventricles depolarize normally within 0.10 seconds. When this is longer than 110 miliseconds, this is a conduction delay. Possible causes of a QRS duration > 110 miliseconds include:

- Left bundle branch block;
- Right bundle branch block;
- Electrolyte Disorders;
- Idioventricular rhythm and paced rhythm.

For the diagnosis of LBBB or RBBB QRS duration must be >120 ms.

The normal QTc (corrected) interval. The QT interval indicates how fast the ventricles are repolarized, becoming ready for a new cycle. The normal value for QTc is: *below 450ms for men and below 460ms for women*. If QTc is < 340 ms short QT syndrome can be considered.

The QT interval comprises the QRS-complex, the ST-segment, and the T-wave. One difficultly of QT interpretation is that the QT interval gets shorter as the heart rate increases. This problem can be solved by correcting the QT time for heart rate using the Bazett formula:

$$QTc = \frac{QT}{\sqrt{RR\ interval\ (sec)}}$$

Thus at a heart rate of 60 bpm, the RR interval is 1 second and the QTc equals QT/1. The QTc calculator can be used to easily calculate QTc from the QT and the heart rate or RR interval.

On modern ECG machines, the QTc is given. However, the machines are not always capable of making the correct determination of the end of the T wave. Therefore, it is important to check the QT time manually.

The ST segment is the portion of the ECG from the end of the QRS complex to the beginning of the T wave. The ST segment normally remains isoelectric, thus ST segment depression or ST segment elevation can indicate cardiac pathology.

The ST segment is scrutinized on the ECG for the detection of myocardial ischemia. This can be done in the setting of either exercise or pharmacologic stress testing.

Determining Axis. The axis of the ECG is the major direction of the overall electrical activity of the heart. It can be normal, leftward (left axis deviation, or LAD), rightward (right axis deviation, or RAD) or indeterminate (northwest axis). The QRS axis is the most important to determine. However, the P wave or T wave axis can also be measured.

To determine the QRS axis, the limb leads (not the precordial leads) need to be examined.

Normal QRS Axis. If the QRS complex is upright (positive) in both lead I and lead aVF, then the axis is normal (Fig. 8).

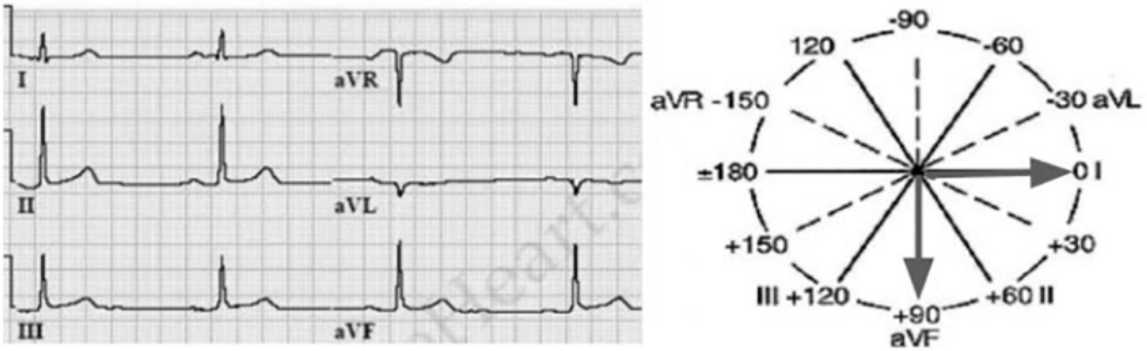


Fig. 8. Normal QRS Axis: positive in lead I and aVF

Left Axis Deviation. If the QRS is upright in lead I (positive) and downward in lead aVF (negative), then the axis is between 0 and –90 degrees (Fig. 9).

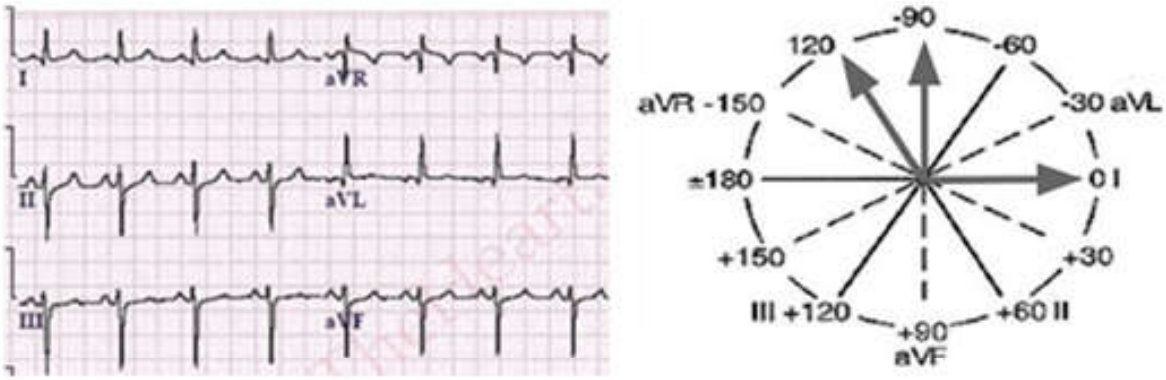


Fig. 9. Left Axis Deviation: positive in lead I, negative in lead aVF and lead II

Right Axis Deviation. If the QRS is predominantly negative in lead I and positive in lead aVF, then the axis is rightward (right axis deviation) (Fig. 10).

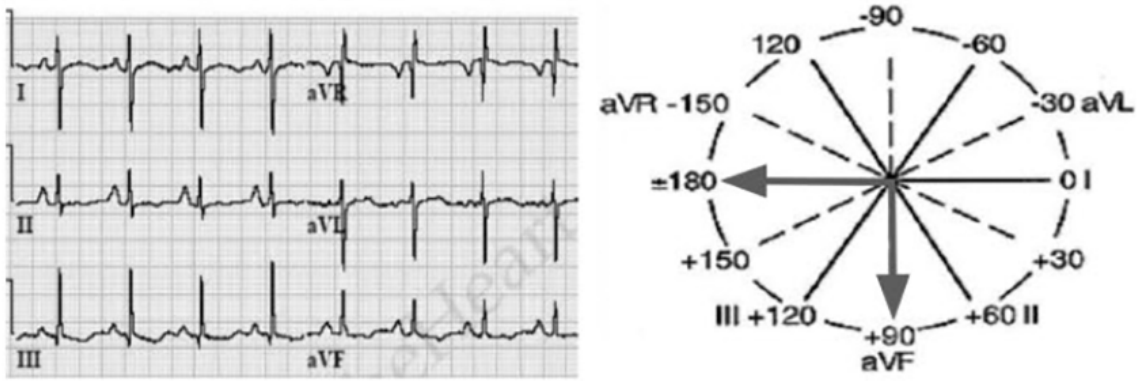


Fig. 10. Right Axis Deviation: negative in lead I and positive in lead aVF

Indeterminate Axis. If the QRS is downward (negative) in lead I and downward (negative) in lead aVF, then the axis is indeterminate and sometimes referred to as «northwestern axis». This finding is uncommon and usually from ventricular rhythms; however, it can also be from paced rhythms, lead misplacement and certain congenital heart diseases (Fig. 11).

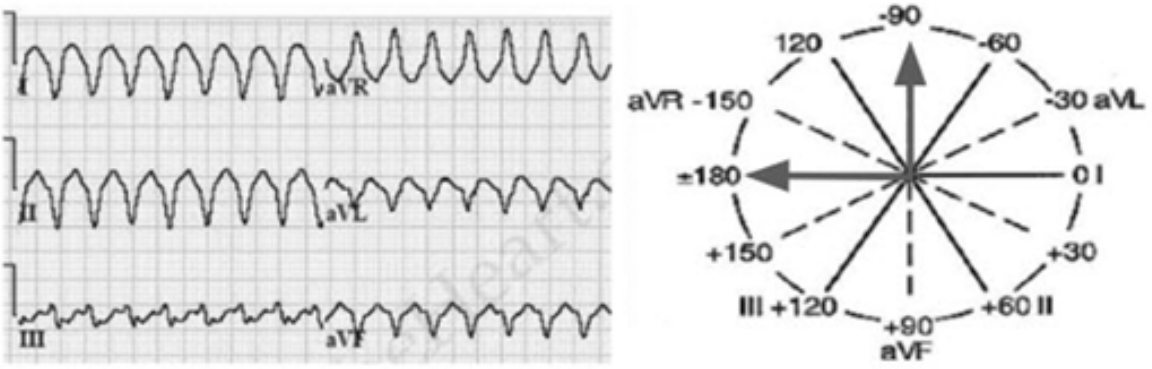


Fig. 11. Indeterminate Axis: negative in lead I and negative in lead aVF

Decoding electrocardiogram:

1. Source of heart rhythm.
2. Regularity of rhythm (regular or not).
3. Heart rate (HR).
4. Position of the electrical axis of the heart.
5. Intervals reflecting conductance (PQ, QRS, QT duration).
6. Description of the P wave.
7. Description of the QRS complex.
8. Description of ST segments and T wave.
9. Rhythm disturbances (arrhythmias).
10. The conclusion should reflect the presence of 4 syndromes: hypertrophy and/or overload of the ventricles and atria, myocardial damage (ischemia, dystrophy, necrosis, scars), rhythm disturbances, conduction disturbances.

Ambulatory electrocardiogram monitoring

Ambulatory electrocardiogram (AECG) monitoring allows the noninvasive evaluation of a suspected arrhythmia during normal daily activities. It aids in the diagnosis, documentation of frequency, severity, and correlation of an arrhythmia with symptoms such as palpitations, lightheadedness, or overt syncope. AECG monitoring can be extremely helpful in excluding an arrhythmia as a cause for a patient's symptoms if there is no associated event during monitoring. AECG can also be used to assess antiarrhythmic drug response in patients with defined

arrhythmias. Occasionally AECG is also used in other situations. The current major indications for AECG monitoring:

Class I (Recommended).

Patients with unexplained syncope, near syncope, or episodic dizziness in whom the cause is not obvious.

Patients with unexplained recurrent palpitations.

To assess antiarrhythmic drug response in individuals with well-characterized arrhythmias.

To aid in the evaluation of pacemaker and ICD function and guide pharmacologic therapy in patients receiving frequent ICD therapy.

Class IIa (Weight of Evidence/Opinion Is in Favor of Usefulness/ Efficacy).

To detect proarrhythmic responses in patients receiving antiarrhythmic therapy.

Patients with suspected variant angina.

Class IIb (Usefulness/Efficacy Is Less Well Established by Evidence/ Opinion).

Patients with episodic shortness of breath, chest pain, or fatigue that is not otherwise explained.

Patients with symptoms such as syncope, near syncope, episodic dizziness, or palpitation in whom a probable cause other than an arrhythmia has been identified but in whom symptoms persist despite treatment.

To assess rate control during atrial fibrillation.

Evaluation of patients with chest pain who cannot exercise.

Preoperative evaluation for vascular surgery of patients who cannot exercise.

Patients with known coronary artery disease and atypical chest pain syndrome.

To assess risk in asymptomatic patients who have heart failure or idiopathic hypertrophic cardiomyopathy or in post–myocardial infarction patients with ejection fraction less than 40 %.

Patients with neurologic events when transient atrial fibrillation or flutter is suspected.

The major types of AECG monitoring include Holter monitoring, event monitoring, ambulatory telemetry, patch monitoring, and monitoring with an implantable loop recorder (ILR). The type and duration of monitoring depend on the frequency and severity of symptoms. Most modern devices are capable of the transtelephonic transmission of ECG data during or after a detected arrhythmia. Each system has advantages and disadvantages; selection must be tailored to the individual. With any system, however, patients must record in some fashion (e. g., diary, electronically) symptoms and activities during the monitored period (Fig. 12 *a*, *b*).

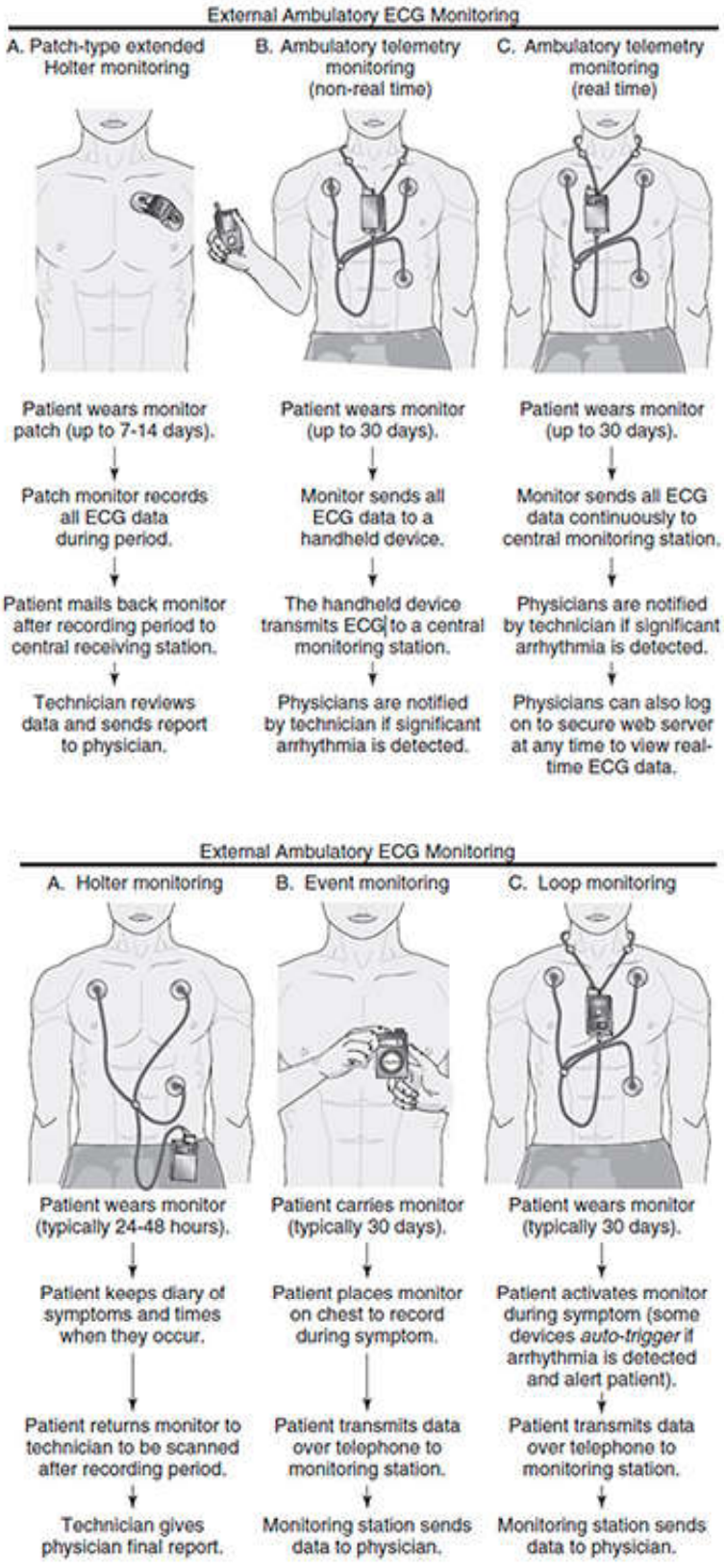


Fig. 12. Types of AECG monitors currently available in clinical practice

Holter monitors: A Holter monitor constantly monitors and records 2 to 3 channels of ECG data for 24 to 48 hours. It is ideal for patients with episodes that occur daily.

Event monitors: An event monitor constantly monitors 2 to 3 channels of ECG data for 30 to 60 days. However, it will record events only when the patient experiences a symptom and presses a button that triggers the event monitor to store ECG data 1 to 4 minutes before and 1 to 2 minutes after the event. Some event monitors will also store arrhythmias detected by the monitor itself, based on preprogrammed parameters. An event monitor is appropriate for patients with episodes that occur weekly or monthly.

Ambulatory real-time cardiac monitors: Ambulatory real-time cardiac monitoring has various names. It has been called ambulatory telemetry, real-time continuous cardiac monitoring, and mobile cardiac telemetry (MCOT). Ambulatory telemetry is a monitoring system that continuously records a 1- to 3-lead strip for 14 to 30 days. Depending on the vendor, the ECG data are either stored for offline interpretation or instantaneously transmitted for interpretation by a monitoring technician. In cases where the rhythm is monitored by a technician in real time, the patient or physician can be contacted immediately after an arrhythmia has been detected, thus minimizing delays in treatment. No patient action is necessary for an arrhythmia to be stored and patient compliance can easily be assessed. These features facilitate the detection of silent or asymptomatic arrhythmias.

Adhesive patch electrocardiographic monitors: Adhesive patch monitors self-adhere to the chest wall and are worn continuously for several weeks. Advantages include the patient's ability to wear the device continuously and not have to connect and disconnect wire leads. Currently available devices provide only a single ECG channel.

Implantable loop recorders: An ILR is an invasive monitoring device that allows long-term monitoring and recording of a single ECG channel for over a year. Like an event monitor, it records events based on the patient's symptoms or automatically based on heart rate. It is best reserved for patients with more infrequent episodes occurring more than 1 month apart. An ILR is placed subcutaneously below the left shoulder or overlying the fourth anterior intercostal spaces. Previous devices required a small surgical incision for placement. The more recent, smaller version of the device is placed via an incision smaller than 1 cm and a syringe-like device. As discussed above, it monitors bipolar ECG signals continuously for up to a year or more. The patient can use a magnetic activator held over the device to trigger an event at the time of symptoms. In addition, the device automatically records episodes of bradycardia and tachycardia. The older device is then interrogated with an external programmer and recorded events reviewed in a similar manner to a permanent pacemaker. The newer device wirelessly connects to

a patient monitor. After a diagnosis is obtained, the device is surgically extracted. In patients with unexplained syncope, an ILR yields a diagnosis in more than 90% of cases after 1 year.

24-Hour ambulatory blood pressure monitoring

Ambulatory Blood Pressure Monitoring (ABPM) is a diagnostic test to determine the presence of hypertension by taking measurements during normal daily activities, over a span of 24 consecutive hours. The instrument used is a portable blood pressure machine worn as a belt, with the cuff being attached around the upper arm. All types of daily activities, including sleep, may be normally carried out while wearing this device (Fig. 13).

Fig. 13. Ambulatory Blood Pressure Monitoring

Indications for 24-hour ambulatory blood pressure monitoring:

1. Diagnosis of arterial hypertension (AH):

– borderline AH;

– phenomenon of the «white coat hypertension»;

– examination of hypertensive patients in combination with ischemic heart disease, heart failure, left ventricular myocardial hypertrophy, cerebrovascular diseases, disorders of carbohydrate and lipid metabolism, sleep apnea syndrome;

– examination of young people with unfavorable heredity for hypertension.

2. Diagnosis of arterial hypotension:

– examination of patients with chronic constitutional and orthostatic hypotension;

– examination of patients with impaired postural and dynamic blood pressure control;

– syncope of unclear cause.

3. Control of therapy:

– assessment of the effectiveness and safety of pharmacotherapy (detection of episodes of hyper- or hypotension);

– assessment of drug resistance and selection of the optimal treatment regimen in such patients;

– study of the individual circadian rhythm of blood pressure during chronotherapy.

Indicators of 24-hour ambulatory blood pressure monitoring:

– mean blood pressure: daytime, nighttime, daily;

– pressure load: percentage of measurements exceeding normal values;

– BP variability — the amplitude of BP fluctuations during the day;

– the degree of nighttime decrease in blood pressure;

– the degree and speed of the morning increase in blood pressure.

Indicators of 24-hour blood pressure monitoring are presented in table 1, 2.

Table 1

Mean values of daily blood pressure monitoring (BPsyst / BPdiast)
(E. O'Brien and J. Staessen, 1998)

Period	Decreased BP	Normal BP	Borderline BP	Increased BP
Day	< 100/60	< 135/85	135–140/85–90	> 140/90
Night	< 85/45	< 120/70	120–125/70–75	> 125/75
24-hours	< 85/50	< 130/80	130–135/80–85	> 135/85

Table 2

Indicators of pressure load (PL)

Period	Normal PL	Borderline PL	Increased PL
Day	< 15	15–25	> 25
Night	< 15	15–25	> 15
24-hours	< 15	15–25	> 25

Cardiac stress tests

Cardiac stress test (also referred to as a cardiac diagnostic test, cardiopulmonary exercise test) is a cardiological test that measures the heart's ability to respond to external stress in a controlled clinical environment. The stress response is induced by exercise or by intravenous pharmacological stimulation.

Cardiac stress tests compare the coronary circulation while the patient is at rest with the same patient's circulation during maximum cardiac exertion, showing any abnormal blood flow to the myocardium.

Indications for cardiac stress tests

1. Diagnosis of ischemic heart disease:

– detection of ischemic ECG changes in case of suspected angina pectoris and determination of the functional class (FC) in persons with typical angina pectoris or atypical pain syndrome provoked by physical exertion;

– assessment of drug treatment for stable angina pectoris;

– patients before coronary angiography (in the absence of contraindications);

– assessment of the effectiveness of revascularization: balloon angioplasty, coronary artery bypass grafting;

– early diagnosis of coronary artery disease in asymptomatic patients with multiple risk factors (smoking, hypertension, hypercholesterolemia, etc.).

2. Examination after myocardial infarction:

– assessment of the prognosis in the early post-infarction period;

– control of rehabilitation measures in the post-infarction period according to the dynamics of tolerance to physical activity at the stationary, sanatorium and outpatient stages of rehabilitation.

3. Assessment of coronary reserve and exercise tolerance to determine the ability to work or the degree of risk:

– in healthy individuals (athletes, public transport drivers, pilots);

– in persons with non-coronary cardiac pathology: heart defects, myocardial dystrophy, postmyocarditis cardiosclerosis, hypertension;

– in persons with extracardiac pathology to study the functional capabilities of the cardiovascular system.

Contraindications for cardiac stress tests:

– myocardial infarction with remoteness < 7 days;

– all types of unstable angina pectoris;

– severe chronic heart failure (NYHA FC 3–4) and respiratory failure;

– AH with BP > 200/120 mm Hg;

– tachyarrhythmias of the heart and blockade (complete left bundle branch block and II degree atrioventricular block), with the exception of a single extrasystole or I degree atrioventricular block;

– vascular diseases of the lower extremities (thrombophlebitis, intermittent claudication);

– pulmonary embolism;

– acute infectious diseases with fever;

– lesions of the musculoskeletal system;

– a history of acute cerebrovascular accident;

– ECG changes at rest (ST decrease from the isoline > 1 mm).

Bicycle ergometer

The stress test is carried out according to the international guideline (Fig. 14). Electrodes and a cuff are attached to the patient's body for continuous recording of ECG and blood pressure before exercise, during exercise and during the recovery period. The patient pedals at a certain speed. Every 3 min, the pedaling resistance increases, and the pedaling rate remains constant. The study is stopped when a certain heart rate is reached (submaximal frequency for each age group), due to changes in the ECG, pain or fatigue of the patient.

Fig. 14. Bicycle ergometer

ECG recording is carried out in dynamics, on the background of a stepwise increasing of physical activity performed on a bicycle ergometer. Developed power strongly depends on the function of the left ventricle, the severity of coronary artery disease. Under the influence of physical activity, the work of the myocardium and its need for oxygen gradually increase. Height oxygen demand is directly proportional to heart rate (a more significant factor used to assess the intensity of physical activity) and BPsyst. Physical activity is regarded as sufficient if ≥ 85 % of the patient's maximum heart rate for a given age is reached (heart rate = 220 – age).

Under physical activity, it is possible to identify:

– transient myocardial ischemia — a decrease in the ST interval > 2 mm (coronary pain may also appear);

– chronotropic insufficiency (impossibility of reaching 85 % of the maximum proper heart rate);

– the rate of normalization of heart rate — the difference in heart rate during the period of maximum physical activity and 1 min after the termination of the test (value < 12/min is not normal and is associated with poor patient survival).

With a positive bicycle ergometer test, stenosing atherosclerosis of the coronary artery is observed in 80 % of patients.

Positive bicycle ergometer test criteria:

– the appearance of clinical symptoms (anginal attack or obvious shortness of breath, suffocation or fatigue and a decrease in blood pressure) during the test or during the recovery period;

– ischemic oblique displacement of the ST segment downward or upward by 1–2 mm or more (ST displacement> 1 mm is interpreted as unconditioned ischemia, and > 2 mm — as sharp ischemia).

Predictors of high risk of death according to bicycle ergometer test:

– early (≤ 3 min) positive test result;
– ST decrease persists for ≥ 3 min after termination of the test;
– downward sloping and negative ST spacing;
– ischemia during the period of free work of the heart (heart rate ≤ 120/min);
– no increase in blood pressure or its decrease during the test;
– the appearance of severe ventricular arrhythmia at heart rate ≤ 120/min.

Treadmill test

Before the examination, electrodes are applied to the patient's body. With its help, an electrocardiogram is recorded, which is displayed on the monitor in real time. During the test, the patient walks along a moving path (treadmill). At each stage of the test, the speed of movement and the angle of ascent of the treadmill will change (it will move faster and «uphill»). The duration of each stage is 3 min (Fig. 15).

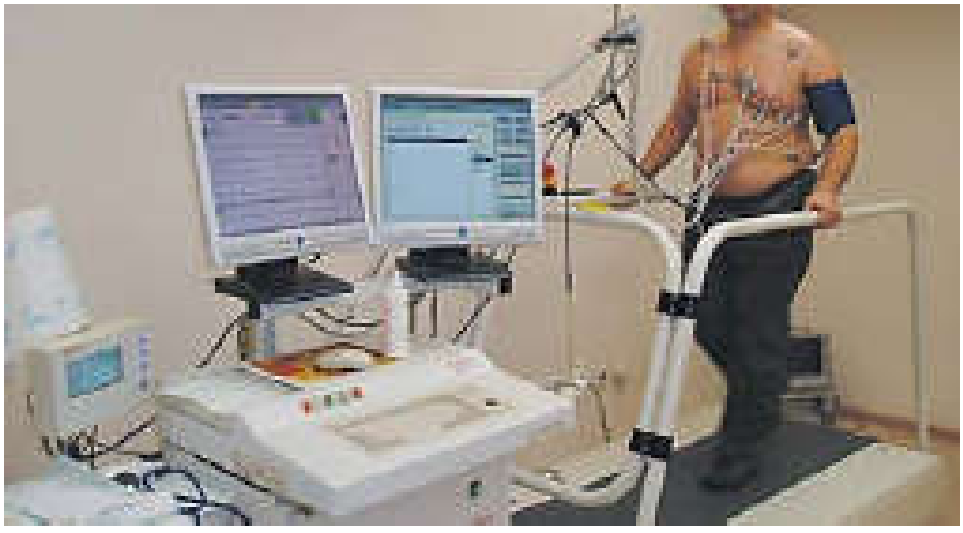


Fig. 15. Treadmill test

The test is terminated in the following cases:

– achievement of electrocardiographic criteria for termination of the test (determined by the doctor);

– the appearance of complaints in the patient, indicating myocardial ischemia;

– achievement of a certain heart rate, determined individually for each patient.

The criteria for a positive sample are similar to those for positive bicycle ergometer test.

Stress tests not related to physical activity

Transesophageal electrical stimulation of the left atrium is safer than bicycle ergometer test. The patient is imposed a stepwise increase in heart rate (100 → 110 → 120, etc., up to 160/min), that is, an increase in myocardial oxygen demand, which provokes its ischemia.

Pharmacological tests are usually performed in patients who are unable to perform physical activity due to musculoskeletal system damage, with adenosine, which causes spasm of the microcirculation vessels, facilitating the detection of narrowing of the coronary artery (causing uneven blood flow in the myocardium), which does not allow increasing the volume of blood flow in it (in the case of a significant narrowing of the artery, ischemic steal occurs), or (more often) dipyridamole (intravenously 0.75 mg/kg for 5 min), which inhibits the uptake of adenosine by cells, has the same effect as adenosine, but with a slower onset and longer duration of action (20–30 min). Dipyridamole causes tachycardia, a more prolonged spasm of the coronary artery and the phenomenon of coronary steal, provoking an anginal attack.

Visualizing stress tests

Stress echocardiography. The echocardiography is performed both before and after the exercise so that structural differences can be compared. A resting echocardiogram is obtained prior to stress. The images obtained are similar to the ones obtained during a full surface echocardiogram, commonly referred to as transthoracic echocardiogram. The patient is subjected to stress in the form of exercise or chemically (usually dobutamine). After the target heart rate is achieved, «stress» echocardiogram images are obtained. The two echocardiogram images are then compared to assess for any abnormalities in wall motion of the heart. This is used to detect obstructive coronary artery disease.

Nuclear stress test. The best known example of a nuclear stress test is myocardial perfusion imaging. Typically, a radiotracer (Tc-99 sestamibi, Myoview or thallous chloride 201) may be injected during the test. After a suitable waiting period to ensure proper distribution of the radiotracer, scans are acquired

with a gamma camera to capture images of the blood flow. Scans acquired before and after exercise are examined to assess the state of the coronary arteries of the patient. Showing the relative amounts of radioisotope within the heart muscle, the nuclear stress tests more accurately identify regional areas of reduced blood flow.

The typical dose of radiation received during this procedure can range from 9.4 millisieverts to 40.7 millisieverts.

Cardiopulmonary exercise test (Fig. 16). Carrying out a test with physical activity while analyzing oxygen consumption. Oxygen consumption increases during exercise, but only up to a certain power level. At critical power, the reserve capabilities of the cardiorespiratory system are exhausted and oxygen consumption no longer increases even with an increase in the load power. Aerobic metabolism becomes anaerobic. The degree of decrease in this threshold is one of the most reliable indicators of a person's physical performance.

Fig. 16. Cardiopulmonary exercise test

Indications:

1. Evaluation of Exercise Intolerance.
2. Unexplained Dyspnea.
3. Evaluation of Patients with Cardiovascular Disease.
4. Evaluation of Patients with Respiratory Disease:

– Chronic Obstructive Pulmonary Disease (COPD);
– Interstitial Lung Disease (ILD);
– Chronic Pulmonary Vascular Disease (PVD);
– Cystic Fibrosis;
– Exercise-Induced bronchospasm (EIB).

5. Preoperative Evaluation:

– Preoperative Evaluation for Lung Cancer Resectional Surgery;
– Lung Volume Reduction Surgery (LVRS);
– Evaluation for Lung or Heart-Lung Transplantation;
– Preoperative Evaluation of Other Procedures;

6. Exercise Prescription for Pulmonary Rehabilitation.
7. Evaluation of Impairment/Disability.

Echocardiography

It is a type of medical imaging of the heart, using standard ultrasound or Doppler ultrasound.

Echocardiography has become routinely used in the diagnosis, management, and follow-up of patients with any suspected or known heart diseases. It is one of the most widely used diagnostic tests in cardiology. It can provide a wealth of helpful information, including the size and shape of the heart, pumping capacity, and the location and extent of any tissue damage. An echocardiogram can also give physicians other estimates of heart function, such as a calculation of the cardiac output, ejection fraction, and diastolic function (Fig. 17, 18).

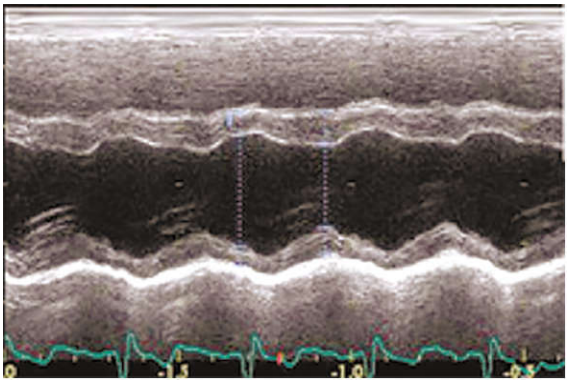


Fig. 17. Echocardiography in M-mode

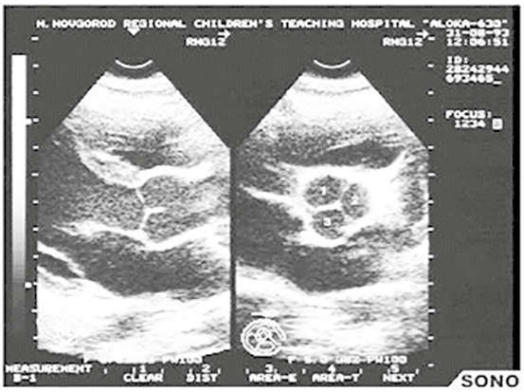


Fig. 18. Echocardiography in B-mode

Echocardiography is an important tool in assessing wall motion abnormality in patients with suspected cardiac disease. It is a tool which helps in reaching an early diagnosis of myocardial infarction showing regional wall motion abnormality of the heart. Also, it is important in treatment and followup in patients with heart failure, by assessing ejection fraction.

Echocardiography can help detect cardiomyopathies, such as hypertrophic cardiomyopathy, dilated cardiomyopathy, and many others.

Not only can an echocardiogram create ultrasound images of heart structures, but it can also produce accurate assessment of the blood flowing through the heart by Doppler echocardiography, using pulsed- or continuous-wave Doppler ultrasound

(Fig. 19). This allows assessment of both normal and abnormal blood flow through the heart. Color Doppler, as well as spectral Doppler, is used to visualize any abnormal communications between the left and right sides of the heart, valvular regurgitation or valvular stenosis. The Doppler technique can also be used for tissue motion and velocity measurement, by tissue Doppler echocardiography.

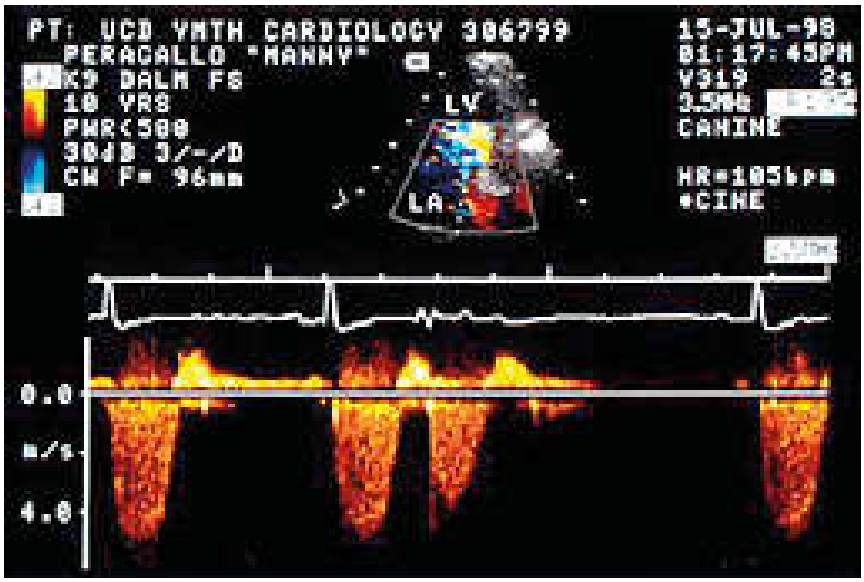


Fig. 19. Doppler ultrasound

The main echocardiographic parameters are presented in the table 3.

Table 3

Average values of the main hemodynamic echocardiography parameters

Hemodynamic parameters	**M-mode**	**2D echocardiogram**		
		Area-length method (apical view)		**Simpson's method of discs**
		4-chamber	**2-chamber**	
Left Ventricular End-Diastolic Diameter (mm)	38–56			
Left Ventricular End-Systolic Diameter (mm)	22–38			
Interventricular septal wall thickness (mm)	7–10			
Posterior wall thickness (mm)	8–11			
Male LV mass (g)	135–182			
Female LV mass (g)	95–141			
Left ventricular myocardial mass index	70–95			
Right Ventricular End-diastolic dimension (mm)	20–28 (base), 15–22 (mean)	S = 11–28 mm^2	–	–

End of the table 3

Hemodynamic parameters	M-mode	2D echocardiogram		
		Area-length method (apical view)		Simpson's method of discs
		4-chamber	2-chamber	
LV end-diastolic volume, male, (ml)	110–145	112	130	111
LV end-diastolic volume, female, (ml)		89	92	80
LV end-systolic volume, male, (ml)	45–75	45	52	45
LV end- systolic volume, female, (ml)		36	39	35
Stroke volume, male (ml)	60–80	68	78	67
Stroke volume, female (ml)		54	56	48
Stroke index (ml/m2)	25–34	30–38	31–44	27–38
LV ejection fraction (%)	55–65			
Left ventricular minute volume (l/min)	3,5–4,5			
Systolic index (l/min/m2)	2,2–2,7			
Left atrium in men	19–33 mm	41 ml	50 ml	41 ml
Left atrium in women		34 ml	36 ml	32 ml
Right atrium (mm)	27–38			

Modern devices provide additional opportunities for new diagnostic technologies:

- tissue doppler;
- 3D and 4D modeling;
- echocardiography with contrast.

Coronary angiography

Coronary angiography is an X-ray examination of the coronary vessels using contrast. This study is the «gold standard» in the diagnosis of ischemic heart diseases. Coronary angiography can be performed urgently or routine, depending on the clinical situation and the patient's condition.

Technically, coronary angiography is performed as follows: under local anesthesia, a catheter is passed through the femoral or brachial artery to the orifice of the coronary arteries. Further, a radiopaque substance is injected in the coronary vessels through a catheter. On the angiograph screen, the movement of the radiopaque substance is recorded with the blood flow along the coronary vessels. The image is displayed on a special screen, and also saved on a hard disk (Fig. 20). Based on the results of the study, a decision is made on further treatment.

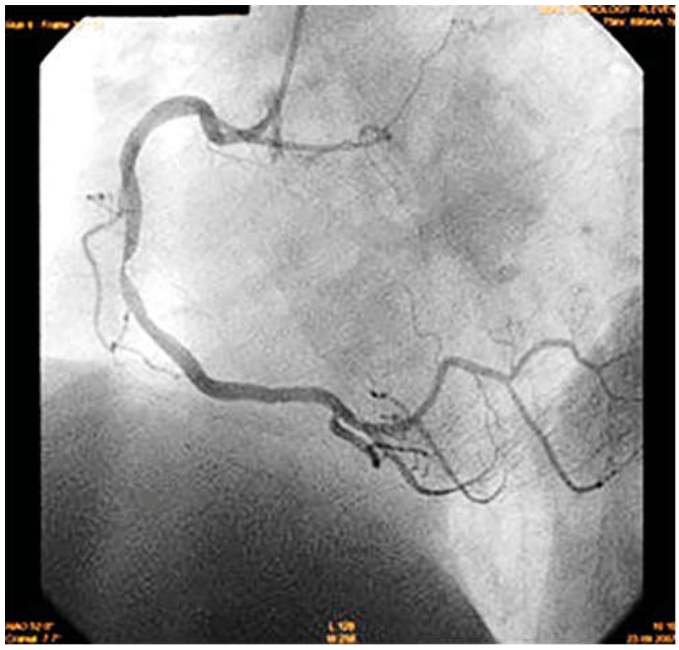


Fig. 20. Image obtained with coronary angiography

Routine coronary angiography

Indications for routine coronary angiography in patients with an diagnosed or suspected ischemic heart disease:

1. Functional class III or IV of angina pectoris according to the Canadian classification in patients receiving drug therapy.

2. High-risk criteria for non-invasive testing, regardless of the severity of angina.

3. Patients who have undergone resuscitation for sudden cardiac death or who have episodes of prolonged (> 30 s) paroxysmal monomorphic ventricular tachycardia or unstable (< 30 s) paroxysmal polymorphic ventricular tachycardia.

4. Patients whose professional activities are related to ensuring the safety of others (airplane pilots, drivers, etc.), whose results of stress tests indicate pathology, but there are no high-risk criteria, or patients with multiple clinical manifestations suggesting a high risk.

5. Patients with proven or suspected coronary artery disease who do not have the ability to stratify risk due to physical inability or due to concomitant diseases.

6. Patients with re-hospitalization for atypical chest pain who have changes in non-invasive tests.

7. In cases when the data of non-invasive tests are insufficient for differential diagnosis in patients with atypical pain syndrome and risk factors for cardiovascular diseases (diabetes mellitus, hypertension, smoking, etc.).

8. Before operations on the heart valves after 40 years old.

Urgent coronary angiography

Urgent coronary angiography is performed in acute conditions such as unstable angina pectoris or myocardial infarction. The urgency of coronary angiography depends on the type of acute coronary syndrome and the clinical situation.

In acute coronary syndrome without ST segment elevation (unstable angina pectoris and myocardial infarction without ST segment elevation) the risk of an unfavorable outcome is determined. The urgency of the intervention is determined based on the results of the risk assessment.

Indications for coronary angiography in acute coronary syndrome without ST-segment elevation:

1) immediate percutaneous coronary intervention (< 2 h) — at very high risk:
– acute heart failure (pulmonary edema, cardiogenic shock);
– persisting or recurrent ischemia;
– life-threatening heart rhythm disturbances or cardiac arrest;
2) early percutaneous coronary intervention (< 24 h) — at high risk:
– rise / fall of troponins (myocardial infarction);
– recurrent ST-T deviation, especially with transient ST elevations;
– high risk on the GRACE scale > 140;
3) routine invasive strategy (< 72 h) — at moderate risk:
– diabetes;
– chronic kidney disease (glomerular filtration rate < 60);
– congestive chronic heart failure or ejection fraction < 45 %;
– early postinfarction angina pectoris;
– a history of coronary artery bypass grafting or percutaneous coronary intervention;
– risk on the GRACE scale > 109 and < 140;
4) in the absence of risk factors (risk on the GRACE scale < 90) — non-invasive assessment of coronary blood flow to determine the need for coronary angiography.

Coronary angiography followed by stenting of the infarction-associated artery in ST-elevation myocardial infarction is the preferred method of reperfusion. If technically feasible, it should be preferred to thrombolytic therapy.

Indications for coronary angiography in acute coronary syndrome with ST-segment elevation:

– ischemic chest pain > 30 min, not relieved by nitroglycerin;
– ST segment elevation > 1 mm in two or more leads or the appearance of a left bundle branch block;
– duration of symptoms < 12 hours from the onset of symptoms;
– persistent or recurrent symptoms and ECG changes in the period > 12 hours;
– early postinfarction angina pectoris.

PULMONOLOGY

Chest X-ray examination

Indications for chest X-ray:

1) annual screening (fluorography);

2) X-ray diagnosis:

– tuberculosis;

– pneumonia;

– pleurisy;

– atelectasis;

– pneumo — or a hydrothorax;

– traumatic injuries of the chest;

3) monitoring the treatment effectiveness of pulmonary diseases.

Steps of examination

Metal jewelry and synthetic clothing should be removed before the examination. Long hair must be pinned up. The patient is placed on a special stand. It is necessary to press tight the chest to the photofluorograph screen, put the chin on a special stand for it. The picture is taken while inhaling and holding your breath.

On x-ray check the following:

1. Check patient details (first name, surname, date of birth).

2. Check orientation, position and side description (left, right, erect, ap, pa, supine, prone).

3. Check additional information (inspiration, expiration).

4. Check for rotation (measure the distance from the medial end of each clavicle to the spinous process of the vertebra at the same level, which should be equal).

5. Check adequacy of inspiration (nine pairs of ribs should be seen posteriorly in order to consider a chest x-ray adequate in terms of inspiration).

6. Check penetration (one should barely see the thoracic vertebrae behind the heart).

7. Check exposure (one needs to be able to identify both costophrenic angles and lung apices).

Specific radiological check-list

A – Airway.

1. Ensure trachea is visible and in midline:

– trachea gets pushed away from abnormality, eg pleural effusion or tension pneumothorax;

– trachea gets pulled towards abnormality, eg atelectasis;

– trachea normally narrows at the vocal cords;

– view the carina, angle should be between 60–100 degrees;

– beware of things that may increase this angle, eg left atrial enlargement, lymph node enlargement and left upper lobe atelectasis;

– follow out both main stem bronchi;

– check for tubes, pacemaker, wires, lines foreign bodies etc.;

– if an endotracheal tube is in place, check the positioning, the distal tip of the tube should be 3-4cm above the carina.

2. Check for a widened mediastinum:

– mass lesions (eg tumour, lymph nodes) (Fig 21, *a*);

– inflammation (eg mediastinitis, granulomatous inflammation);

– trauma and dissection (eg haematoma, aneurysm of the major mediastinal vessels).

B – Bones:

1. Check for fractures, dislocation, subluxation, osteoblastic or osteolytic lesions in clavicles, ribs, thoracic

2. Spine and humerus including osteoarthritic changes

3. At this time also check the soft tissues for subcutaneous air, foreign bodies and surgical clips

4. Caution with nipple shadows, which may mimic intrapulmonary nodules (compare side to side, if on both sides the «nodules» in question are in the same position, then they are likely to be due to nipple shadows)

C – Cardiac:

1. Check heart size and heart borders

– Appropriate or blunted

– Thin rim of air around the heart, think of pneumomediastinum

2. Check aorta (Widening, tortuosity, calcification).

3. Check heart valves (Calcification, valve replacements).

4. Check superior vena cava, inferior vena cava, azygos vein (Widening, tortuosity).

D – Diaphragm:

1. Right hemidiaphragm

– should be higher than the left

– if much higher, think of effusion, lobar collapse, diaphragmatic paralysis

– if you cannot see parts of the diaphragm, consider infiltrate or effusion

2. If film is taken in erect or upright position you may see free air under the diaphragm if intra-abdominal perforation is present.

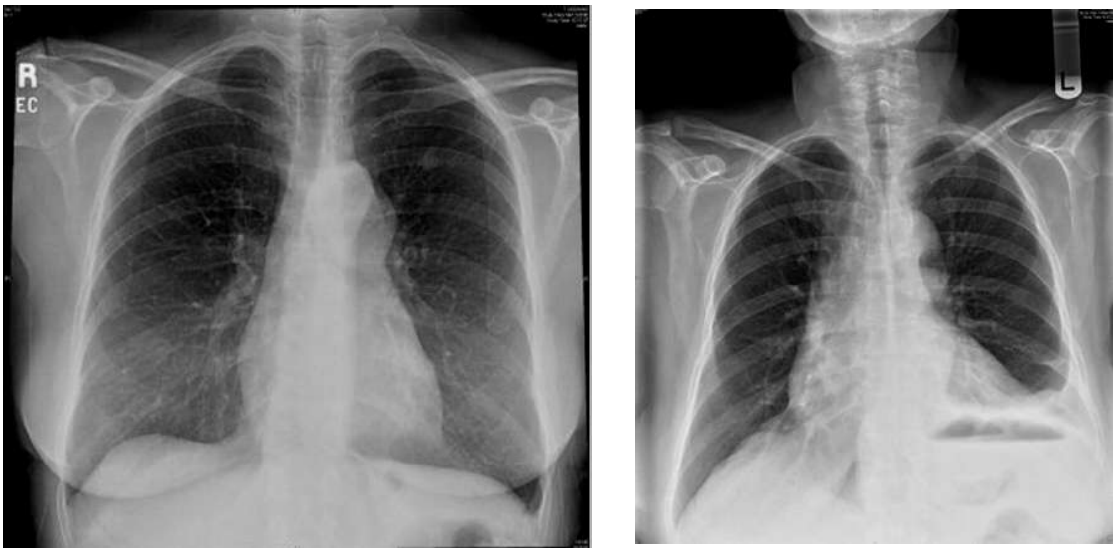
E – Effusion

1. Effusions:

– look for blunting of the costophrenic angle (Fig 21, *b*)

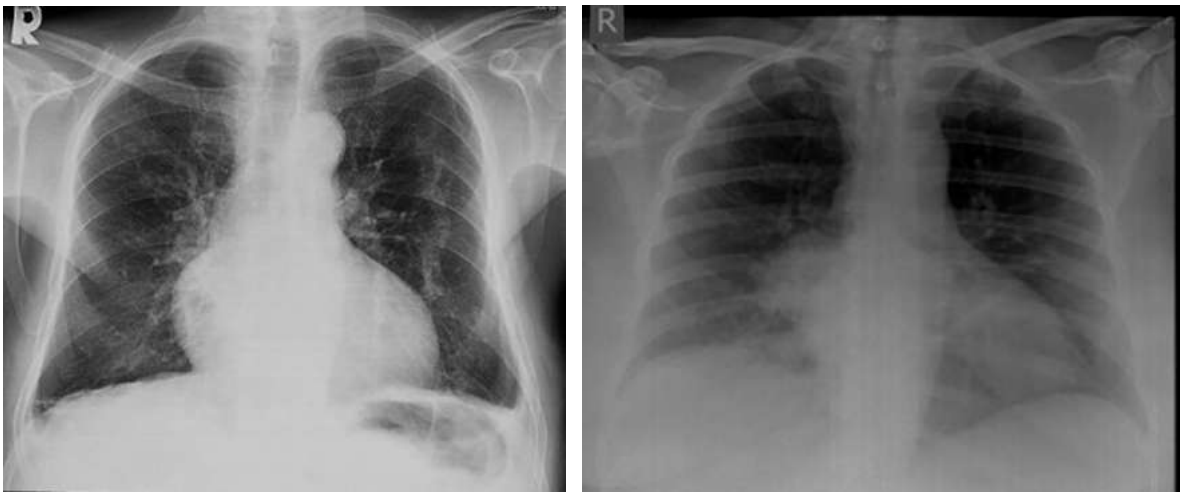
– identify the major fissures, if you can see them more obvious than usual, then this could mean that fluid is tracking along the fissure.

2. Check out the pleura (Thickening, loculations, calcifications and pneumothorax (Fig 22, *a*)).



a ***b***

Fig. 21. Chest X-ray:
a — left mid mediastinal/paraaortic tumour and left upper lobe satellite lesion; *b* — Left basal pleural effusion and consolidation



a ***b***

Fig. 22. Chest X-ray:
a — pleural calcifications and adhesions due to asbestos exposure; *b* — right middle lobe pneumonia

F – Fields (Lungfields):

1. Check for infiltrates (Fig 22, *b*):

– identify the location of infiltrates by use of known radiological phenomena, eg loss of heart borders or of the contour of the diaphragm;

– remember that right middle lobe abuts the heart, but the right lower lobe does not;

– the lingula abuts the left side of the heart.

2. Identify the pattern of infiltration:

– interstitial pattern (reticular) versus alveolar (patchy or nodular) pattern;

– lobar collapse;

– look for air bronchograms, tram tracking, nodules, Kerley B lines;

– pay attention to the apices;

3. Check for granulomas, tumour and pneumothorax.

G – Gastric Air Bubble:

1. Check correct position.
2. Beware of hiatus hernia.
3. Look for fee air.
4. Look for bowel loops between diaphragm and liver.

H – Hilum:

1. Check the position and size bilaterally.
2. Enlarged lymph nodes.
3. Calcified nodules.
4. Mass lesions.
5. Pulmonary arteries, if greater than 1.5cm think about possible causes of enlargement.

Bronchoscopy

A bronchoscopy is a procedure that allows a doctor to examine the inside of the lungs, including the bronchi, which are the main pathways into the lungs. The bronchoscope can be flexible or rigid. A flexible scope is almost always used. It is a tube less than one centimeter wide and about 60 centimeters long. In rare cases, a rigid bronchoscope is used (Fig. 23).

Indications for a bronchoscopy:

– follow up on a scan that has indicated a lung infection or tumor, or a collapsed lung;

– determine why someone is coughing up blood;

– find the cause of a chronic cough;

– discover the reason for shortness of breath;

– look for blockages in the airways;

– check for lung rejection, following a transplant;

– assess damage after someone has inhaled chemicals or toxic gases;
– take a biopsy;
– removing fluid, mucus plugs, or foreign objects in the airways;
– widening a blocked or narrowed airway;
– treating cancer;
– draining an abscess.

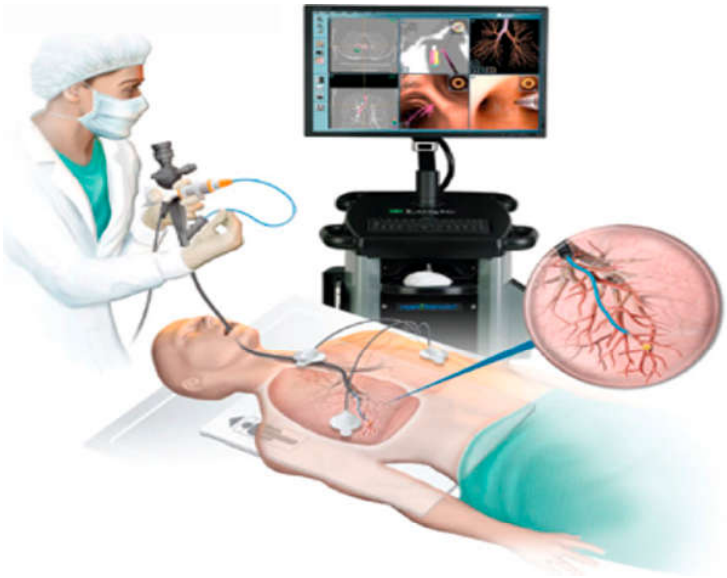


Fig. 23. Bronchoscopy

Preparing for a bronchoscopy

In a critically ill patient who has a breathing tube, feedings are stopped hours before the procedure to assure that the stomach is empty. The patient is given a small amount of medicine (a sedative) that causes sleepiness. If a patient is having a bronchoscopy as an outpatient or as a non-critically ill inpatient, he will be told not to eat after midnight the night before (or about 8 hours before) the procedure. A patient will also receive instructions about taking his regular medicines, not smoking and removing any dentures before the procedure.

Procedure

Most people are awake during a bronchoscopy. Before the procedure, a doctor sprays a local anesthetic into the nose and throat to numb the area. Many people also take a sedative to help them relax. Doctors only recommend a general anesthetic in rare cases, when they will be using a rigid bronchoscope. Once the anesthetic takes effect, the doctor will usually insert a flexible bronchoscope tube through the nose and throat and into the bronchi. As the tube moves into the lungs, a person may feel a pressing or tugging sensation. Some people initially cough or gag, but this usually subsides quickly. A doctor may administer oxygen throughout

the procedure may to aid breathing. The bronchoscope's light and camera help the doctor to see the airways clearly, even around bends. If a doctor needs to insert a stent or take a biopsy, they can pass brushes, needles, and other instruments through a channel in the bronchoscope. A stent is a small tube that helps to keep blocked or narrow airways open.

A doctor sometimes sprays a saline solution through the airways, in a process called bronchial washing, or lavage, to collect cells and fluids. The doctor will later examine them under a microscope. During the bronchoscopy, a doctor may take an ultrasound, to get a clearer picture of the lymph nodes and tissues in and around the bronchi. Once they are finished checking the airways, the doctor will remove the bronchoscope. The procedure usually takes 20–30 minutes, although times can vary, depending on the number of examinations and the underlying issue.

Recovery time

A bronchoscopy is a relatively quick and painless procedure. Afterward, a person will need to remain at the hospital for a few hours until the medications wear off. Blood pressure and breathing are monitored during this time to check for complications. The ability to cough, called the cough reflex, should return within 2 hours. After this, it is safe to eat and drink again. After taking a sedative, a person should avoid driving, operating machinery, and drinking alcohol for 24 hours. Most people can return to regular activities after 24 hours, but it is normal to have a sore throat and hoarseness for a few days.

Thoracocentesis

Thoracentesis (thoracocentesis) is a core procedural skill for hospitalists, critical care physicians, and emergency physicians. With proper training in both thoracentesis itself and the use of bedside ultrasonography, providers can perform this procedure safely and successfully.

Indications

Thoracentesis is indicated for the symptomatic treatment of large pleural effusions (Fig. 24) or for treatment of empyemas. It is also indicated for pleural effusions of any size that require diagnostic analysis.

Contraindications

There are no absolute contraindications for thoracentesis. Relative contraindications include the following:

- uncorrected bleeding diathesis;
- chest wall cellulitis at the site of puncture.

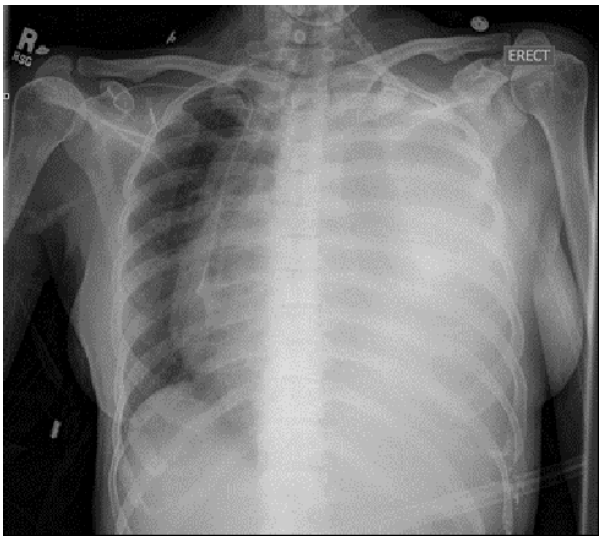


Fig. 24. Image of a 48-year-old woman with cancer and large left pleural effusion (2.5 liters were removed). The patient was tachypneic, hypoxic, and reported pleuritic chest pain

Complications

Major complications include the following:
- pneumothorax (11 %);
- hemothorax (0.8 %);
- laceration of the liver or spleen (0.8 %);
- diaphragmatic injury;
- empyema;
- tumor seeding.

Minor complications include the following:
- pain (22 %);
- dry tap (13 %);
- cough (11 %);
- subcutaneous hematoma (2 %);
- subcutaneous seroma (0.8 %);
- vasovagal syncope.

Patient Education and Consent

Before thoracentesis, it is important to pay attention to the consent process and provide a focused set of risks and complications, so that the patient is not surprised if he or she experiences adverse effects.

Consent should be obtained from the patient or family member. The reason the procedure is being performed (suspected diagnosis); the risk, benefits, and alternatives of the procedure; the risks and benefits of the alternative procedure; and the risk and benefits of not undergoing the procedure. Allow the patient the opportunity to ask any questions and address any concerns they may have. Make

sure that they have an understanding about the procedure so they can make an informed decision.

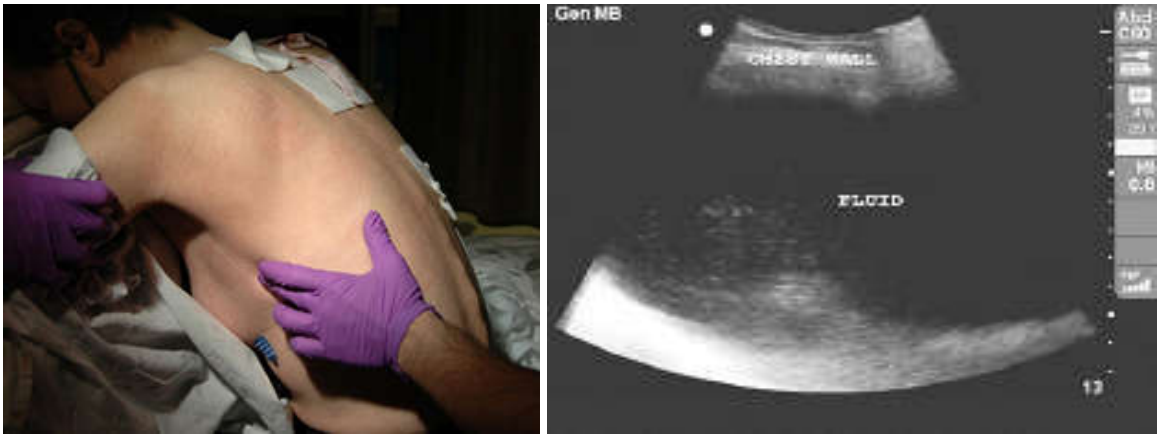
Patient Preparation

Patient preparation includes adequate anesthesia and proper positioning.

Anesthesia. In addition to local anesthesia, mild sedation may also be considered. IV midazolam or lorazepam can attenuate the anxiety that may be associated with any invasive procedure. Analgesia is critically important, in that pain is the most common complication of thoracentesis. Local anesthesia is achieved with generous local infiltration of lidocaine.

The skin, subcutaneous tissue, rib periosteum, intercostal muscle, and parietal pleura should all be well infiltrated with local anesthetic. It is particularly important to anesthetize the deep part of the intercostal muscle and the parietal pleura because puncture of these tissues generates the most pain. Pleural fluid is often obtained via aspiration during anesthetic infiltration of these deeper structures; this helps confirm proper needle location.

Positioning. Patients who are alert and cooperative are most comfortable in a seated position, leaning slightly forward and resting the head on the arms or hands or on a pillow, which is placed on an adjustable bedside table (Fig. 25). This position facilitates access to the posterior axillary space, which is the most dependent part of the thorax. Unstable patients and those who are unable to sit up may be supine for the procedure.



a ***b***

Fig. 25. Step I:
a — easy access to the 7–9 rib space along the posterior axillary line; *b* — ultrasound image using curvilinear probe. Image shows chest wall and large volume of pleural fluid

The patient is moved to the extreme side of the bed, the ipsilateral hand is placed behind the head, and a towel roll is placed under the contralateral shoulder. This measure facilitates dependent drainage and provides good access to the posterior axillary space.

Bedside ultrasonography

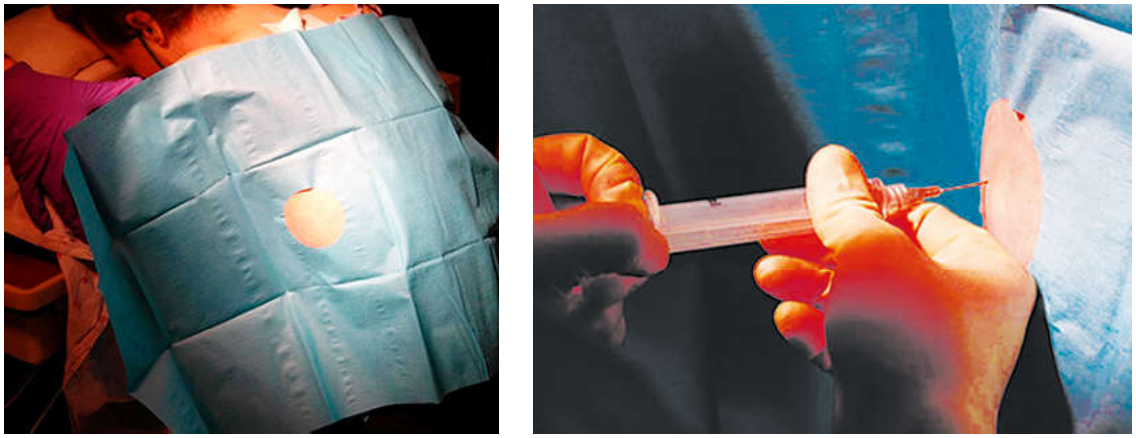
After the patient has been positioned, ultrasonography is performed to confirm the pleural effusion, assess its size, look for loculations, and determine the optimal puncture site. Either a curvilinear transducer (2–5 MHz) or a high-frequency linear transducer (7.5–1 MHz) may be used. The diaphragm is brightly echogenic and should be clearly identified. Its exact location throughout the respiratory cycle should be determined. It is important to select a rib interspace into which the diaphragm does not rise up at end-exhalation.

The optimal puncture site may be determined by searching for the largest pocket of fluid superficial to the lung and by identifying the respiratory path of the diaphragm. Traditionally, this is between the seventh and ninth rib spaces and between the posterior axillary line and the midline. Bedside ultrasonography can confirm the optimal puncture site, which is then marked.

Preparation of puncture site

Standard aseptic technique is used for the remaining steps of the procedure. Sterile probe covers are available and should be used if thoracentesis is performed under real-time ultrasonographic guidance.

A wide area is cleaned with an antiseptic bacteriostatic solution. Chlorhexidine solution is preferred for preparing the skin; it dries faster and is far more effective than povidone-iodine solution. A sterile drape is placed over the puncture site, and sterile towels are used to establish a large sterile field within which to work (Fig. 26).



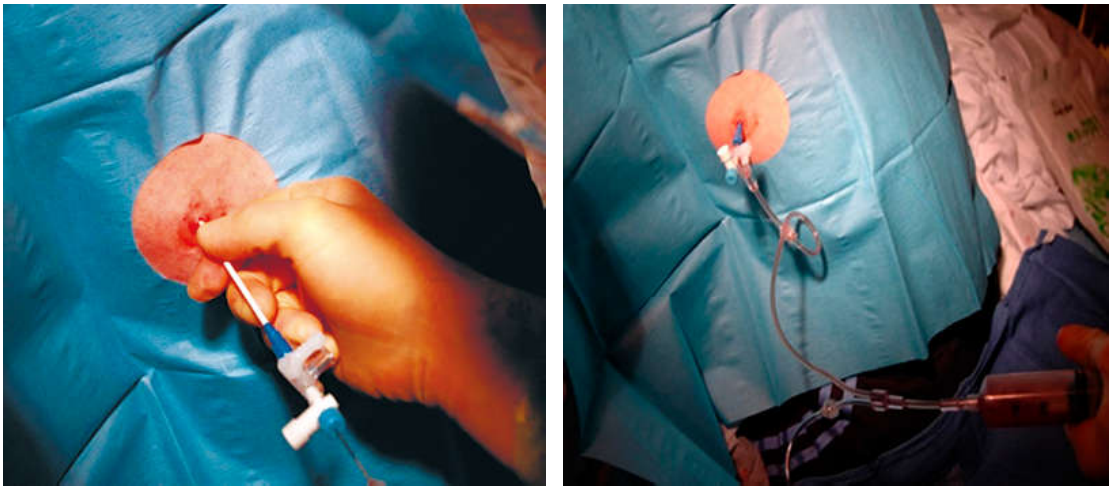
a ***b***

Fig. 26. Step II:
a — sterile drape with fenestration and adhesive strip placed over puncture site, with sterile towels draping a large work area; *b* — administering anesthesia to the skin, subcutaneous tissue, rib periosteum, intercostal muscle, and parietal pleura

The skin, subcutaneous tissue, rib periosteum, intercostal muscles, and parietal pleura should be well infiltrated with anesthetic (lidocaine 1–2 %). Infiltration can also be guided by real-time ultrasonography using a high-frequency linear transducer (7.5–10 MHz).

Insertion of device or catheter and drainage of effusion

If a commercially available device or a large intravenous catheter is being used, the skin should be nicked with a No. 11 scalpel blade to reduce drag as the catheter is advanced through the skin. With aspiration initiated, the device is advanced over the superior aspect of the rib until pleural fluid is obtained. The neurovascular bundle is located at the inferior border of the rib and should be avoided. Most commercial devices have a marker at 5 cm. At this depth, the hemithorax is usually entered, and the needle need not need be advanced any further. The catheter is then fed over the needle introducer. In most cases, it can be fed all the way to the hub. With either a syringe pump or a vacuum bottle, the pleural effusion is drained until the desired volume has been removed for symptomatic relief or diagnostic analysis (Fig. 27).



a ***b***

Fig. 27. Step III:
a — feeding the catheter over the needle introducer; *b* — use the manual syringe pump method or a vacuum bottle

Completion of procedure

The catheter or needle is carefully removed, and the wound is dressed. If there is any doubt, pleural fluid should be sent for diagnostic analysis; in practice, diagnostic analysis is almost always necessary. The patient is repositioned as appropriate for his or her comfort and respiratory status.

Finally, a procedure note is written, commenting specifically on the descriptive characteristics of the pleural fluid.

Needle aspiration of primary spontaneous pneumothorax

Needle aspiration is appropriate for patients with a first episode of primary spontaneous pneumothorax. Patients should have no evidence of underlying lung disease but should have either shortness of breath or a pneumothorax with a rim of air measuring at least 2 cm when assessed at the level of the hilum.

Contraindications. Needle aspiration is contraindicated when a patient has traumatic pneumothorax, pneumothorax in each lung, tension pneumothorax, hemodynamic instability, underlying pulmonary disease, a history of recurrent pneumothorax, or a bleeding disorder. An age older than 50 years is a relative contraindication, because the procedure is less likely to be successful in patients in this age group.

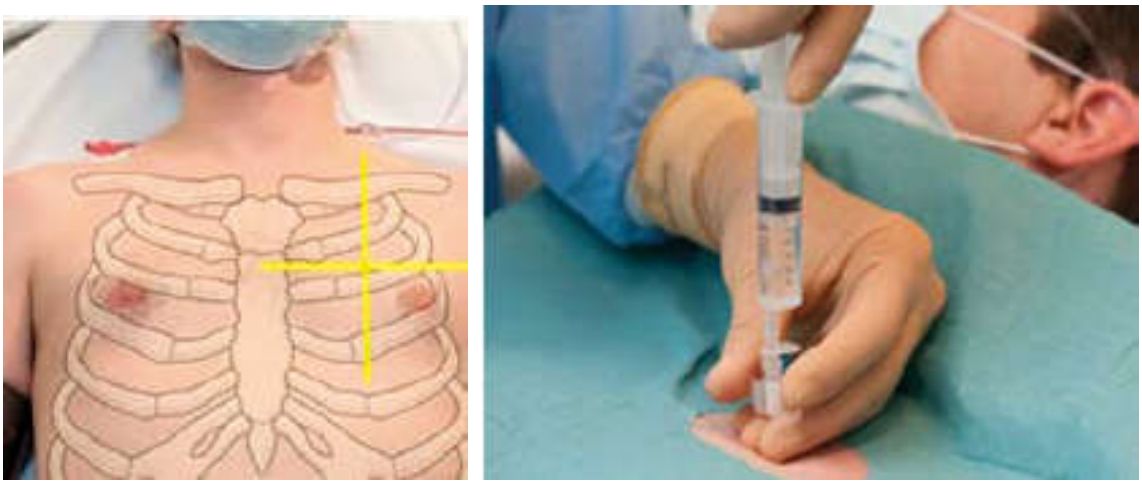
Equipment. The procedure requires a 16-gauge or 18-gauge over-the-needle catheter, tubing with a threeway stopcock, and a 50-ml or 60-ml syringe. To administer a local anesthetic agent, you will need 1% or 2% lidocaine, a 10-ml syringe, and one small-gauge needle (size 25); for anesthetizing deeper layers of tissue, you will also need one larger-gauge needle (size 22). You will also need sterile gloves, a protective or sterile gown, a face mask, chlorhexidine or another antiseptic solution, a sterile preparation kit, and sterile drapes.

Patient Preparation. To prepare the patient, explain the procedure, confirm the patient's identity, and obtain written informed consent. You should also verify the absence of contraindications, confirm that the patient has no allergy to lidocaine, and verify whether the pneumothorax is on the right or the left side. Place the patient in a semisupine position (with the torso at an angle of 30 to 45 degrees) to allow the air to collect at the apex of the lung. Administer oxygen and monitor the oxygen saturation of the arterial blood with pulse oximetry. Heart rate and blood pressure should also be monitored, and an intravenous catheter should be in place. The patient should be provided with a face mask.

Locating Landmarks. The preferred location for placement of a needle for aspiration of pneumothorax is the second intercostal space at the midclavicular line, on the side with the pneumothorax. Begin by locating the second and third ribs. The second rib can be felt just below the collar bone. The second intercostal space is the area between the second and third ribs. Next, identify the middle of the clavicle and the midclavicular line. The intersection of the midclavicular line and the second intercostal space is the correct place to insert the needle for aspiration of pneumothorax (Fig. 28, *a*). A skinmarking pen can be used to mark the insertion site.

Procedure. Put on the face mask, the protective or sterile gown, and the sterile gloves. Use chlorhexidine or another antiseptic solution to clean the patient's skin, and then position the sterile drape. Aspirate lidocaine into the 10-ml syringe. Using the 25-gauge needle, inject a wheal of lidocaine at the superior edge of the third rib, at the midclavicular line. Switch to a 22-gauge needle and anesthetize the deeper tissue layers by inserting the needle perpendicular to the skin. Always aspirate the

site before injecting the anesthetic, to make sure the needle has not entered a blood vessel. With the needle positioned just over the top of the third rib, advance it in the direction of the pleural space. Placing the needle just above the third rib will prevent injuries to the intercostal vessels and nerves, which lie just below the rib. Once you have inserted the needle through the intercostal space, continue to aspirate slightly. When you penetrate the pleural space, air bubbles will appear as you aspirate (Fig. 28, *b*).



a ***b***

Fig. 28. Step I:
a — site of Needle Insertion; *b* — confirmation of Penetration of Pleural Space

Before you remove the needle, note the depth of the penetration. You will use the depth as a reference point when you insert the over-the-needle catheter. Connect the over-the-needle catheter to the 10-ml lidocaine syringe, which should be partially filled with the remainder of the local anesthetic. Using the same landmarks that you used for the local anesthetic, slowly advance the needle in the direction of the pleural space while continuing to aspirate with the syringe. Again, when the needle penetrates the pleural space, air bubbles will appear in the syringe. At this time, advance the needle by a few more millimeters to allow the catheter tip to fully penetrate the pleural space. Remove both the catheter needle and the 10-ml syringe as the patient exhales or coughs. Quickly obstruct the opening of the catheter with your finger to prevent the entry of additional air into the pleural space. Attach the tubing with the three-way stopcock to the catheter, and use the 50-ml or 60-ml syringe to gently aspirate the air from the pleural space (Fig. 29).

Fig. 29. Aspiration of air from a pneumothorax

Manipulation of the three-way stopcock requires close attention, since any opening to the ambient air can lead to air entrapment in the pleural space and failure of the procedure. When manipulating the stopcock, be sure that the pleural space is never open to the environment. Return the air through the side port into the ambient air and measure the volume of the air that is aspirated by counting the number of syringes you evacuate. The evacuation of more than 2.5 liters is an indication that there may be an air leak, and the procedure should be stopped. Continue manual aspiration until you cannot aspirate any more air. Remove the catheter and put a sterile dressing on the site of insertion. A postprocedural chest radiograph should be obtained with the patient in an upright position. When needle aspiration is successful, the patient's symptoms will improve, and only minimal residual pneumothorax — or no pneumothorax — should be present on the chest film. Most patients are ready for discharge 6 hours after the procedure, provided that a second postprocedural chest radiograph shows no recurrence of the pneumothorax. The time of patient discharge will vary according to the institution.

Complications. Complications from needle aspiration of primary spontaneous pneumothorax may include localized subcutaneous emphysema, infection, lung laceration, air embolism, or bleeding. You can minimize the risk of bleeding by placing the catheter at the intercostal space just above the third rib, thereby preventing injuries to the intercostal vessels. Technical failure may occur if you cannot reach the pleural space — if the catheter is too short, for instance. This problem most often arises in patients who are very muscular or obese. Aspiration of more than 2.5 liters of air may indicate the presence of a persistent air leak, for which the placement of a chest tube should be considered.

SPIROMETRY

Spirometry is the term given to the basic lung function tests that measure the air that is expired and inspired. There are three basic related measurements: volume, time and flow. Spirometry is objective, noninvasive, sensitive to early change and reproducible. With the availability of portable meters it can be performed almost anywhere and, with the right training, it can be performed by anybody. It is performed to detect the presence or absence of lung disease, quantify lung impairment, monitor the effects of occupational/environmental exposures and determine the effects of medications.

The measures

Spirometric measures include the following:

1. Forced expiratory volume in 1 s (FEV_1), the volume of air that can forcibly be blown out in first 1 second, after full inspiration.

2. Forced vital capacity (FVC), the maximum amount of air that can be exhaled when blowing out as fast as possible.

3. FEV_1/FVC ratio.

4. Peak expiratory flow (PEF), the maximal flow that can be exhaled when blowing out at a steady rate.

5. Forced expiratory flow, also known as mid-expiratory flow; the rates at 25%, 50% and 75% FVC are given.

6. Inspiratory vital capacity (IVC), the maximum amount of air that can be inhaled after a full expiration.

Performing spirometry. Prior to performing spirometry, the patient's identification should be checked, their height without shoes or boots and weight measured (if scales are available, as this is not used in prediction equations but is useful to know, as volume may be restricted in obese patients), and their age, sex and race recorded (table 4).

Table 4

Checklist of factors that the patient should avoid prior to spirometry

Activity	**Length of time to stop before spirometry**
Drinking alcohol	4 h
Eating a large meal	2 h
Vigorous exercise	30 min
Smoking	1 h
Medication use	Document treatment and when last taken
For reversibility testing	
Taking short-acting bronchodilators	6 h
Taking long-acting bronchodilators (including combination inhalers) or twice-daily preparations	24 h
Taking tiotropium or once-daily preparations	48 h

Contraindications

If any of the following have occurred recently, then it may be better to wait until the patient has fully recovered before carrying out spirometry.

1. Haemoptysis of unknown origin
2. Pneumothorax
3. Unstable cardiovascular status, recent myocardial infarction or pulmonary embolism
4. Thoracic, abdominal or cerebral aneurysms
5. Recent eye surgery
6. Acute disorders affecting test performance, such as nausea or vomiting
7. Recent thoracic or abdominal surgical procedures

Patient positioning

Correct measurement posture is as follows:

1. Sit upright: there should be no difference in the amount of air the patient can exhale from a sitting position compared to a standing position as long as they are sitting up straight and there are no restrictions.

2. Feet flat on floor with legs uncrossed: no use of abdominal muscles for leg position.

3. Loosen tight-fitting clothing: if clothing is too tight, this can give restrictive pictures on spirometry (give lower volumes than are true).

4. Dentures normally left in: it is best to have some structure to the mouth area unless dentures are very loose.

5. Use a chair with arms: when exhaling maximally, patients can become light-headed and possibly sway or faint.

Technique

There are a number of different techniques for performing spirometry.

1. Before performing the forced expiration, tidal (normal) breaths can be taken first, then a deep breath taken in while still using the mouthpiece, followed by a further quick, full inspiration.

2. Alternatively, a deep breath can be taken in then the mouth placed tightly around the mouthpiece before a full expiration is performed.

3. The patient can be asked to completely empty their lungs then take in a quick full inspiration, followed by a full expiration.

The latter technique can be useful in patients who may achieve a larger inspiration following expiration.

1. For FVC and FEV1, the patient takes a deep breath in, as large as possible, and blows out as hard and as fast as possible and keeps going until there is no air left.

2. PEF is obtained from the FEV1 and FVC manoeuvre.

3. For VC, the patient takes a deep breath in, as large as possible, and blows steadily for as long as possible until there is no air left. Nose clips are essential for VC as air can leak out due to the low flow.

4. The IVC manoeuvre is performed at the end of FVC/VC (depending on what type of equipment is used) by taking a deep, fast breath back in after breathing all the way out.

Encouragement makes a big difference, so don’t be afraid to raise your voice to encourage the patient, particularly near the end of the manoeuvre. The patient needs to keep blowing until no more air comes out and the volume–time trace reaches a plateau with <50 mL being exhaled in 2 s. Some patients, particularly those with obstructive disease, may find it difficult to exhale completely on a forced manoeuvre. A relaxed VC may produce better results in this case.

Reversibility testing

Reversibility testing is usually performed for the diagnosis of asthma. Spirometry is performed, after which a bronchodilator is given that can either be a short-acting b-agonist or other agents, such as anticholinergics. For the former, 4 × 100 mg salbutamol are recommended via a spacer device and 15 min is given before retesting, and for the latter, 4 × 40 mg ipratropium bromide is recommended, leaving 30 min before retesting. The combined ATS/ ERS Task Force recommends that there should be at least a 12 % from baseline and 200 mL improvement in FEV1. The British Thoracic Society (BTS)/Association of Respiratory Technicians and Physiologists (ARTP) guidelines suggest >160 mL for FEV1 and > 330 mL for FVC. These measures of reversibility show that the change is outside the 95 % confidence limits for repeat spirometry without any bronchodilator and do not relate to diagnosis or usefulness of the drug in everyday use. Reversibility is the defining characteristic of asthma and it separates asthma from other causes of airflow obstruction. An increase of ≥400 mL in FEV1 post-bronchodilator is strongly suggestive of asthma in adults, but a lack of reversibility does not exclude asthma.

Equipment

A number of spirometers are available, ranging from desktop portable devices to large, less portable versions. Most measure flow directly using pneumotachographs, turbines or other technology and calculate volume, but the wedge bellows spirometer measures volume directly and calculates flow. The choice of equipment depends on your service needs. Larger equipment tends to be more stable, but there are now some very usable hand-held devices that store flow–volume loops, have built-in quality control and measure all spirometric indices. Some of these have printing capacity as well, whereas others require attachment to a computer for this (Fig. 30).

Fig. 30. Performing spirometry

Interpreting spirometry

Normal lung function. Results obtained from lung function tests have no meaning unless they are compared against reference values or predicted values. There are a number of reference values available that have been equated in slightly different ways, but for studies comparing different European communities, the equations from the European Community for Coal and Steel (ECCS) are often used. Reference values are derived from reference equations that contain data from population surveys. The population in the survey is ideally very large, and data is gathered about the subjects' height, weight, age, sex, ethnic origin, smoking habits, environment, working conditions and physical fitness. The current ECCS equations are linear in nature but in reality, lung function change is a nonlinear process. Reference values given can, therefore, be unrepresentative of the person being tested in some situations. There will be new equations available in the near future which should overcome these issues. In adults, age, height, sex and race are the main determinants of the reference values for spirometric measurement. Fig. 31 shows an example of a normal flow–volume loop.

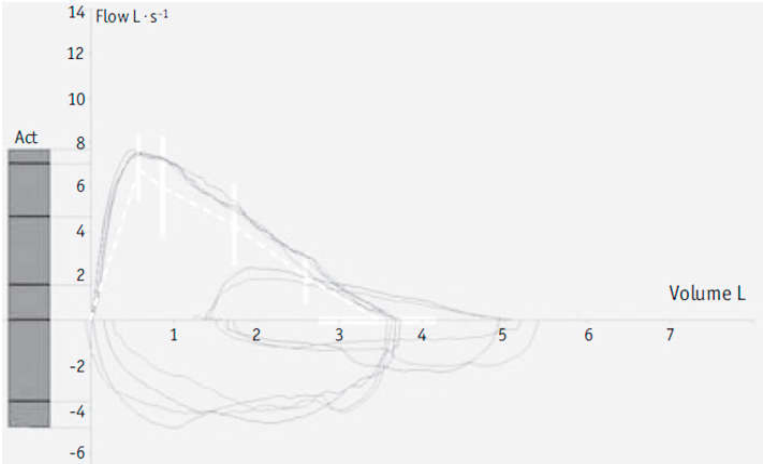


Fig. 31. Flow–volume loop of a normal subject. Forced expiratory volume in 1 s (FEV1): 105 % predicted; forced vital capacity (FVC): 103 % pred; FEV1/FVC ratio: 89 %. The plot shows the predicted flow–volume loop (-----) and predicted ranges for the peak and mid-expiratory flow rates and the FVC

Obstruction is characterised by airflow limitation; there is a decreased airway calibre through either smooth muscle contraction, inflammation, mucus plugging or airway collapse in emphysema.

Obstruction is characterised by:

- reduced FEV1;
- normal (or reduced) VC;
- normal or reduced FVC;
- reduced FEV1/FVC ratio; and
- concave flow–volume loop (Fig. 32).

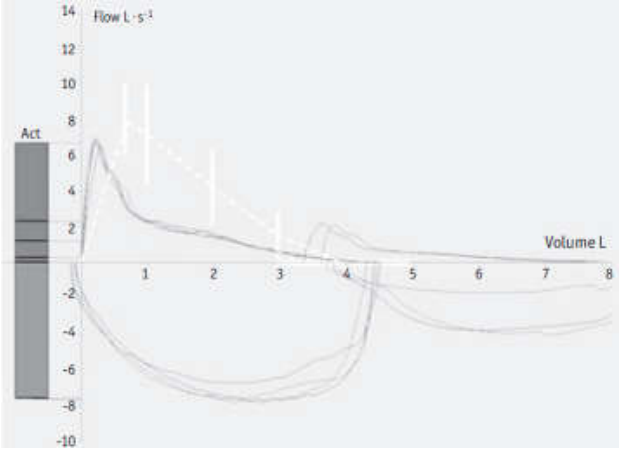


Fig. 32. Moderate airflow limitation in a subject with asthma. Forced expiratory volume in 1 s (FEV1): 73% predicted; forced vital capacity (FVC): 109% pred; FEV1/FVC ratio: 53%

Asthma is an obstructive disease but because it is reversible, spirometry may be normal when the person is not experiencing an exacerbation. Chronic obstructive pulmonary disease is also an obstructive disorder but tends not to be reversible in most cases.

Restriction. Restrictive disorders are characterised by a loss in lung volume and are much rarer. This occurs in pulmonary fibrosis, pleural disease, chest wall disorders (kyphoscoliosis), neuromuscular disorders, pneumonectomy, pulmonary oedema and obesity, to name a few. Many so-called restrictive spirometry traces are due to failure to reach the end of expiration, falsely reducing FVC.

Restriction is characterised by:

– reduced FVC;
– normal-to-high FEV1/FVC ratio;
– normal looking shape on spirometry trace (Fig. 33);
– possibly a relatively high PEF.

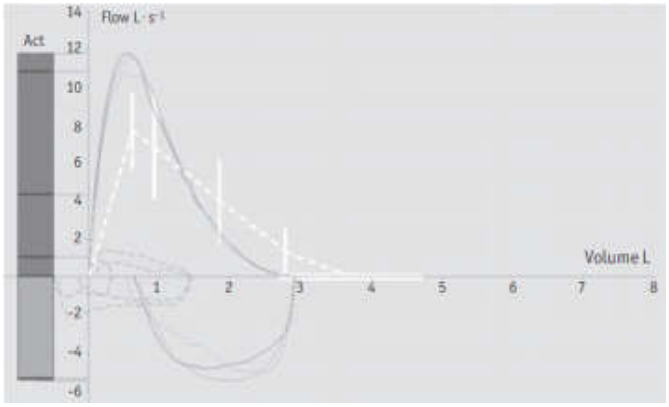


Fig. 33. Example of a typical restrictive defect. Forced expiratory volume in 1 s (FEV1): 82 % predicted; forced vital capacity (FVC): 85 % pred; FEV1/FVC: 84 %; peak expiratory flow: 157 % pred

Mixed patterns. If a person is a heavy smoker and has a fibrotic disease, for example, they may show a mixed picture on spirometry, which is harder to interpret. Further lung function tests may be useful in these cases to analyse static lung volumes (total lung capacity, functional residual capacity and reserve volume) and gas transfer (transfer factor of the lung for carbon monoxide).

GASTROENTEROLOGY

Gastric lavage

Gastric lavage is a method of gastrointestinal decontamination, performed in the setting of an acute poisoning by ingestion, to decrease the absorption of substances in the stomach. This technique was first described in 1812 and has been used for nearly 200 years. It was repopularized in the 1950s and 1960s and thrived during the heyday of the «tricyclic era» of the 1970s and 1980s.

Gastric lavage may be considered for immediate stomach emptying within 1 hour for an ingestion determined to be potentially serious or life-threatening or where antidotal or other supportive modalities are unavailable or inadequate.

Indications for performing a gastric lavage:

Acute presentation (within 1 hour) and:

1. Evident or high risk of morbidity or mortality

Beta-blockers, heterocyclic antidepressants, calcium channel blockers, iron, chloroquine, paraquat, colchicine, salicylates, cyanide, selenious acid, heavy metals.

2. Poor absorption by activated charcoal

Heavy metals, iron, lithium, toxic alcohols.

3. Evidence of formed concretion

Enteric-coated preparations, iron, phenothiazines, salicylates.

4. Ineffective or no antidotal therapy available

Cellular poisons (e.g., colchicine), paraquat, selenious acid.

Contraindications. An absolute contraindication to gastric lavage is in a patient with a depressed level of consciousness who cannot protect their airway. Gastric lavage should not be performed in combative patients, patients at high risk of seizures, and in those who may be expected to deteriorate rapidly. Intubating a patient solely for the purpose of gastric lavage is not recommended. Gastric lavage is contraindicated in caustic ingestions. Local mucosal damage amplifies the risk for traumatic perforation. Gastric lavage should not be performed to retrieve large pills, large foreign bodies, or sharp foreign bodies. It is relatively contraindicated in hydrocarbon ingestions, especially where there is high pulmonary aspiration potential. Significantly abnormal upper airway or upper gastrointestinal anatomy (e. g., anomalies, strictures, or a fresh interposition graft) may restrict the use of gastric lavage. Gastric lavage is contraindicated in the vomiting patient due to the

risk of aspiration and perforation. Vomiting is common after many overdoses and may itself serve as a «natural» decontamination measure. Multiple episodes of emesis may clear the majority of a toxicant from the stomach and obviate the need for gastric lavage. Vomiting in the setting of caustic ingestions can cause further harm by reexposing the gastrointestinal mucosa to the caustic substance. Attempts at gastric intubation in the setting of an actively vomiting patient are likely to be met with minimal success and may cause injury.

Equipment:

- Pulse oximeter;
- Cardiac monitor;
- Noninvasive blood pressure monitor;
- Protective clothing;
- Bite block;
- Oral airway;
- Endotracheal tube and intubation equipment;
- Endotracheal tube stabilizer;
- Emesis basin;
- Suction source, tubing, and Yankauer suction catheter;
- Orogastric tube 36 to 50 French for adults or 24 to 34 French for children;
- Large bulb suction device or 50 mL Toomey syringe;
- Warm water or normal saline for adults;
- Warm normal saline for children;
- Water-soluble lubricant;
- Activated charcoal (optional);
- Resuscitative equipment.

Patient preparation. Explain the indications, details of the procedure, risks and benefits, and alternatives with the patient and/or their representative. Informed consent should be obtained when possible. Place the patient in the left lateral decubitus position and in 15° to 20° of Trendelenburg. This position is intended to maximize gastric emptying. The supine and lateral decubitus positions are associated with a higher risk of pulmonary aspiration in comatose and mechanically ventilated patients. Most gastric lavages can be performed safely and effectively with the conscious patient placed in the semi-upright position. The use of a topical anesthetic spray into the oropharynx may decrease the patient's gag reflex and allow easier passage of the orogastric tube. This can also increase the risk of aspiration. It is recommended that a cardiac monitor, noninvasive blood pressure cuff, and pulse oximeter be placed on the patient prior to performing the lavage.

Technique. Measure the length of the orogastric lavage tube to be inserted (Fig. 34, *a*). The length should be marked with a permanent marker or a piece of surgical tape. Liberally lubricate the tip of the lavage tube. Place a bite block into the patient's mouth if they are conscious. A bite block or oral airway may

preclude biting of the tube by an uncooperative or stuporous patient. Gently insert the lavage tube into the patient's mouth and direct it into the hypopharynx. Flexion of the patient's neck may facilitate passage of the tube into the esophagus and avoid endotracheal insertion.

a ***b***

Fig. 34. Gastric lavage:
a — the length is determined by the distance from the xiphoid process to the tip of the nose to the earlobe; *b* — example of a closed lavage pump system

Conscious and cooperative patients may be asked to swallow water through a straw or their saliva to facilitate passage of the tube. Stridor, cough, or cyanosis indicates that the lavage tube is in the airway and should prompt removal of the tube. Significant resistance is occasionally met in the hypopharynx. Apply gentle pressure to the tube while instructing the patient to swallow allows passage through the upper esophageal sphincter. The tube should not be forced, as misplacement may damage the larynx or perforate the pyriform sinus. Slowly advance the tube to the premeasured depth. Confirmation of intragastric tube placement must precede instillation of any fluid through the tube. Proper placement should be confirmed by aspiration of gastric contents, auscultation of insufflated air over the epigastrium, and/or radiography. Gastric irrigation should be preceded by aspiration of available gastric contents. The initial aspirate may be sent for toxicologic assay.

Perform the gastric lavage. Instill normal saline or tap water through the lavage tube. The lavage fluid should ideally be warmed to body temperature. This is often not practical, and room temperature lavage fluid is satisfactory. Instill aliquots of 10 to 15 mL/kg to a maximum of 300 mL of the irrigant solution. Instillation of larger volumes may result in vomiting, pulmonary aspiration,

and the passage of gastric contents past the pyloric sphincter where subsequent absorption may occur. Lavage aliquots may be instilled by placing a funnel in the free end of the lavage tube and allowing gravity instillation, or they may be infused with a Toomey syringe. Remove the lavage fluid after a brief (i.e., 1 to 2 minutes) equilibration period by either gravity drainage into an emesis basin or aspiration (e. g., a syringe or suction bulb). Repeat the lavage process until 2 to 3 L of irrigant has been used in the adult or the lavage fluid is free of particulate matter and pill fragments. Alternatively, closed systems are available for both instilling and suctioning lavage fluids through a common tube (Fig. 34, *b*).

Activated charcoal may be administered, if desired, through the lavage tube before it is removed. A dose of 1 gm/kg of body weight is typically given initially, either in a premixed slurry or diluted in normal saline or tap water (e. g., 30 gm charcoal per 240 mL of diluent).

Remove the lavage tube. It is recommended to wear gloves, a mask with an eye shield, and a gown to prevent being contaminated during the removal. Place towels or pads over the patient's neck and chest. Have an emesis basin, tissues, and Yankauer suction immediately available. Disconnect the lavage tube from its proximal attachment. Fold over the proximal end of the lavage tube and hold it tightly. Ask the patient to slightly flex their neck, breath in, and hold it. Place a drape or towel around the lavage tube as it is exiting the patient's mouth. Firmly squeeze the drape around the lavage tube. Briskly withdraw the lavage tube through the drape. The drape will contain all the secretions and bodily fluids and prevent them from splashing on the patient or the physician. Discard the lavage tube and the drape. Further gastric access, when needed, should be provided by the subsequent placement of a smaller-bore nasogastric tube.

The complications associated with gastric lavage can be minimized by careful patient selection and technique. Placement of the lavage tube can result in mucosal injury, bleeding, esophageal perforation, gastric perforation, or endotracheal placement. Monitor the patient for cardiac arrhythmias, hypoxemia, and tachycardia. No more than 10 mL/kg or 300 mL aliquots of lavage fluid should be used to prevent vomiting, aspiration, or pushing of gastric contents into the small bowel. The impaction of a lavage tube may prevent its removal. Do not use force to remove the lavage tube, as this may injure or rupture the stomach or esophagus. Evaluate the tube using fluoroscopy or plain radiographs. A lavage tube that is kinked or knotted will require endoscopically aided or surgical removal.

Gastric lavage with large volumes of cold fluid can result in hypothermia. Warmed lavage fluid should be used if available, although this is somewhat controversial. Warm lavage fluid may dissolve more of the toxicant and allow rapid access of gastric contents past the pylorus to be absorbed into the systemic circulation. Electrolyte abnormalities may result, especially in children, if the lavage fluid is hypotonic (i. e., tap water). The use of normal saline for gastric lavage is recommended.

Paracentesis

Ascites is an abnormal accumulation of fluid in the abdominal cavity. It has important implications diagnostically, prognostically, and therapeutically. Cirrhosis of the liver is usually related to alcoholism and accounts for 75 % of cases of ascites. Malignancy accounts for an additional 10–12 % and cardiac failure for another 5 %. The remaining cases have a variety of etiologies. The physical examination is not very reliable when it comes to detecting ascites, making paracentesis and ultrasound (US) important clinical tools.

Peritoneal aspiration of ascitic fluid or paracentesis was first described in the early twentieth century. Paracentesis fell out of favor in the 1950s with the introduction of diuretics and the fear of procedure-related complications and was replaced by medical management. Large-bore needles were being used at that time, and complication rates were significant. Clinical studies published in the late 1980s demonstrated that performing a paracentesis was a safe procedure. A paracentesis is now common in Emergency Departments.

Indications. A paracentesis can be performed for diagnostic or therapeutic purposes. A paracentesis or «abdominal tap» is warranted in a patient with new-onset ascites to establish the etiology of the fluid. A patient with a history of ascites may need the procedure if they have associated signs and symptoms suggestive of infection (e. g., abdominal pain, dyspnea, fever, encephalopathy, peripheral leukocytosis, or renal impairment). A paracentesis can be performed therapeutically if medical management with diuretics has not been successful. A paracentesis may be therapeutic in patients with cardiorespiratory or gastrointestinal manifestations secondary to tense ascites. It is most commonly performed when an intraperitoneal infection is suspected. Clinical guidelines recommend that patients with new-onset ascites admitted to the hospital undergo a paracentesis regardless of whether they have symptoms of spontaneous bacterial peritonitis. Paracentesis has been used to aid in the diagnosis of intestine perforation, hemoperitoneum due to trauma, and ruptured ectopic pregnancy. More accurate diagnostic procedures should be used rather than a paracentesis for these conditions if they are available. Paracentesis is used to manage some patients with hepatorenal syndrome in conjunction with the consultant.

Contraindications. There are no absolute contraindications to performing a paracentesis. The relative contraindications include abdominal wall cellulitis, coagulopathy, current intestine obstruction, history of abdominal surgery, pregnancy, or thrombocytopenia.

Equipment:

- Protective eyewear;
- Sterile gloves and gown;
- Cap and mask;
- Povidone iodine or chlorhexidine solution;
- Sterile 4 × 4 gauze;

– Sterile drape;
– Local anesthetic solution with epinephrine;
– 25 or 27 gauge needle to anesthetize the skin;
– Large syringe(s) for fluid collection (20 to 60 mL);
– Intravenous tubing or blood collection tubing if vacuum bottles are being used;
– Collection bottles (vacuum) or collection bag;
– Adhesive dressing;
– Three-way stopcock;
– Blood collection tubes for white blood cell count, electrolytes, albumin, pH, etc.;
– Blood culture bottles (aerobic and anaerobic);
– Sterile specimen container for cytology (optional);
– US machine;
– US transducer, 3.5 to 5 MHz curvilinear and 8 to 12 MHz linear;
– Sterile US gel;
– Sterile US transducer cover.

Commercially available paracentesis kits are available (Fig. 35). These contain all the required equipment except the collection bottles.

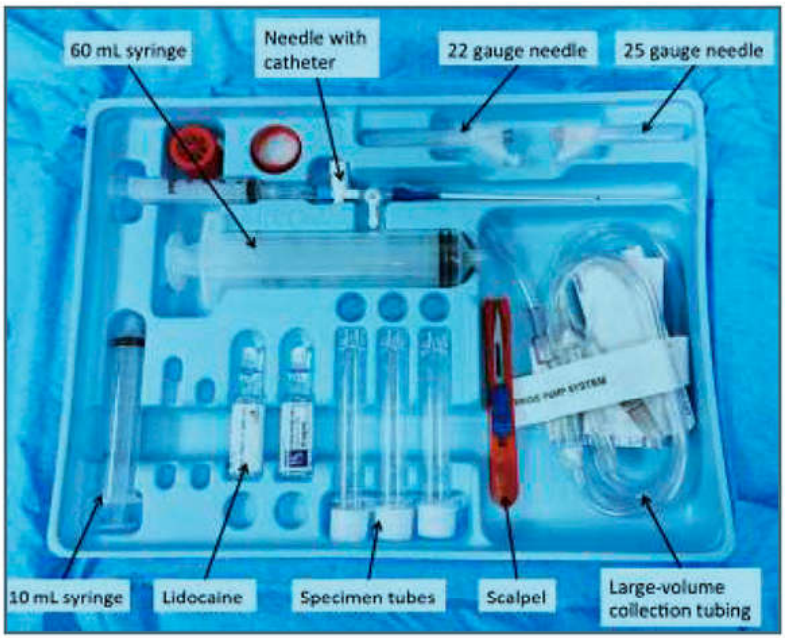


Fig. 35. Commercially available paracentesis kit

Patient preparation. Explain the procedure, its risks, and its benefits to the patient and/or their representative. Obtain an informed consent for the procedure. The patient's bladder should be empty. Use a US machine to check for a full bladder or place a Foley catheter to decompress the bladder if the patient is unable to

urinate voluntarily. Placement of a nasogastric tube can be considered, although it is not routine. It prevents an iatrogenic perforation if the stomach is dilated or if a concomitant intestine obstruction is present. It is recommended if the blind technique is performed to avoid a perforation. There are two recommended areas of entry for the paracentesis needle (Fig. 36). The first site is in the midline and 2 cm below the umbilicus through the avascular linea alba. Alternatively, the region 4 to 5 cm superior and just medial to the anterior superior iliac spine in one of the lower quadrants may be used. This location should be lateral to the rectus abdominis muscle to avoid injury to the inferior epigastric artery, which runs vertically along the muscle sheath. Some physicians choose the right lower quadrant to avoid the sigmoid colon and spleen. Others choose the left lower quadrant to avoid the cecum and liver. Remember to exercise caution in the regions of caput medusa, prominent veins, veins, scarring, over an area of inflamed or infected skin to minimize complications. US-assisted paracentesis is recommended if a US machine is readily available. US can assist in identifying the ideal fluid pocket and hopefully avoid a «dry tap».

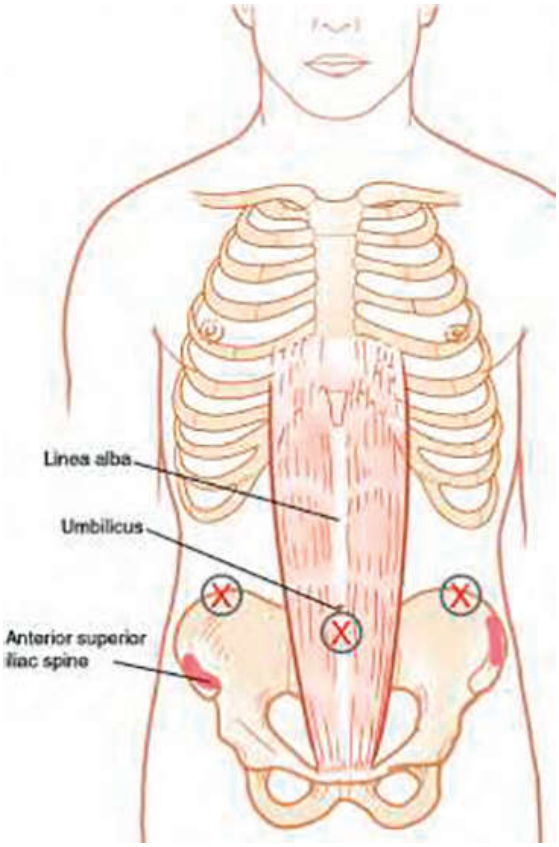


Fig. 36. Needle insertion sites to perform a paracentesis. The preferred site is in the midline and 2 cm below the umbilicus. Alternative sites are just medial and 4 to 5 cm above the anterior superior iliac spines

Place the patient sitting 45° upright for a midline approach. This positioning can be used for the right or left lower quadrant approach if there is ample ascites.

Lying in the right lateral decubitus position for a right lower quadrant approach or lying in the left lateral decubitus position for a left lower quadrant approach increases dependency of the ascites to a desirable quadrant while displacing the intestine superiorly. Another position one might consider is having the patient assume a hand-knee or «crawling» position. This position is awkward for the physician performing the procedure. Remember that the fluid will pool in dependent areas and the intestine will float on top of it, barring any adhesions or masses. Prepare the patient. Clean the skin around the chosen puncture site of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. Apply sterile drapes to delineate a sterile field. Don a cap, mask, sterile gloves, and sterile gown. Perform the paracentesis using strict sterile technique. Inject 2 to 5 mL of local anesthetic solution subcutaneously and along the needle insertion tract. Allow 3 to 5 minutes for the local anesthetic to take effect.

Technique. *Z-track technique*. A «Z-track» is used to decrease the possibility of an ascitic fluid leak, especially in patients with tense ascites (Fig. 37). This is the preferred method for inserting the needle. This technique should be followed when using the other techniques described below. Apply traction on the skin 2 cm cephalad or caudad to the needle insertion site so that the skin is pulled taut when the needle enters the peritoneum (Fig. 37, *a*, *b*). The skin will return to its normal position when the tension is released and seals off the pathway of the paracentesis needle.

Apply an 18 to 22 gauge, 3½ inch needle or spinal needle to a 60 mL syringe. Slowly insert and advance the needle perpendicular to the skin (Fig. 37, *a*) or at 45° to the skin and aimed caudally (Fig. 37, *b*). Apply negative pressure to the syringe as it is being advanced. A loss of resistance will be felt as the needle enters the peritoneal cavity. Stop advancing the needle when ascitic fluid enters the syringe. Continue to aspirate until the syringe is one-half to three-fourths filled with fluid. Depending on the size of syringe, consider using a three-way stopcock so syringes can be removed as they are filled. The omentum, a loop of intestine, peritoneal fat, or other tissue may be occluding the needle tip if ascitic fluid suddenly stops flowing into the syringe. Release the plunger of the syringe. Reattempt to aspirate. Inject 1 to 2 mL of ascitic fluid back into the peritoneal cavity if fluid still will not flow and then reattempt to aspirate. Reposition the needle if ascitic fluid still does not flow into the syringe.

Never reposition the needle while the sharp tip is within the peritoneal cavity. The needle can lacerate a blood vessel, the intestine, or the omentum. Withdraw the needle to the dermis, reposition it, and then readvance it into the peritoneal cavity. The Caldwell needle appears to be superior to a conventional angiocatheter needle when it comes to problems with fluid return. The Caldwell needle's unique design with fenestrations on the side is believed to allow for continued flow despite occlusion of the needle tip.

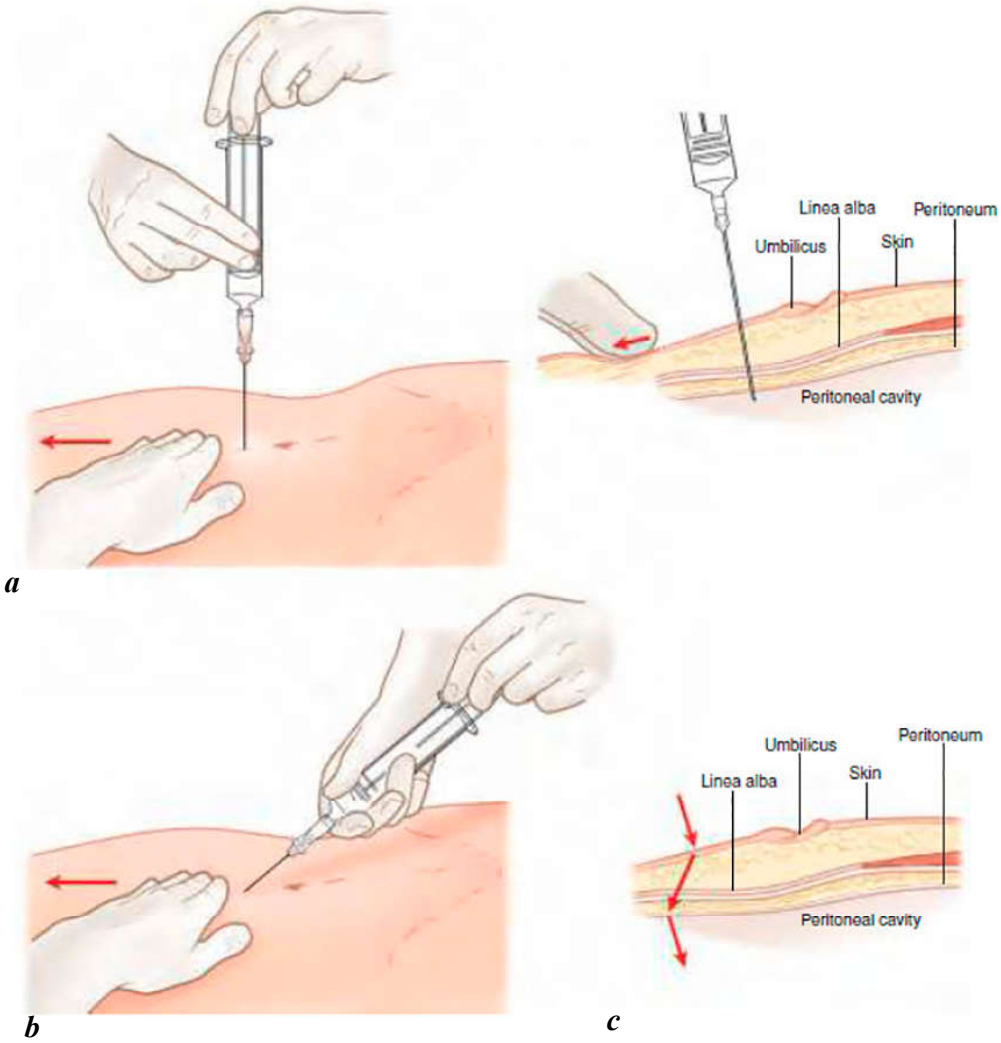


Fig. 37. The Z-track:
a — the needle is inserted perpendicular to the skin while the skin is pulled taut; *b* — alternatively, the needle can be inserted at 45° to the skin and aimed caudally; *c* — the resultant Z-track (arrows)

Note the color and clarity of the ascitic fluid. Aspirate 30 to 50 mL if the procedure is being performed for diagnostic purposes. Withdraw the needle after obtaining the ascitic fluid. Immediately place the fluid into the appropriate collection tubes and culture bottles. Hold the needle or catheter securely and remove the syringe if the reason for the paracentesis is therapeutic and there is a large collection of fluid that must be drained. An assistant can place the sample into laboratory containers. Connect the needle or catheter to intravenous tubing. Connect the other end of the intravenous tubing to a suction bottle or bag to drain off the desired amount of ascitic fluid. Remove the needle or catheter once the procedure has been completed. Removal results in the formation of the Z-track so that ascitic fluid will not leak from the skin (Fig. 37, *c*). Apply a bandage to the skin

puncture site. Consider a compression dressing with an occlusive bandage if fluid is oozing from the puncture site.

Complications. Complications from abdominal paracentesis are infrequent. Known complications include abdominal wall hematoma, intestine perforation, hemoperitoneum, infection, persistent ascitic fluid leak, shearing of the peritoneal catheter, and systemic hemodynamic compromise.

Ascitic fluid analysis. Normal ascitic fluid should appear clear with a yellow color. Increased turbidity may suggest infection, elevated triglyceride levels, or other particulate matter. Sanguineous fluid is present in patients with malignancy, intraperitoneal bleeding from the intraabdominal organs (i. e., iatrogenically or spontaneously introduced), or tuberculous peritonitis. The appearance of the ascitic fluid is not sensitive for detecting SBP and cannot be used as a screening tool.

The specific analytical tests ordered on ascitic fluid should reflect the physician's clinical suspicion. Simple analysis of fluid with an albumin concentration, cell count and differential, and routine cultures are all that is necessary in patients with uncomplicated cirrhosis. These initial tests can be supplemented depending on clinical suspicion. An ascitic fluid pH < 7.35 and a blood-ascitic fluid pH gradient ≥ 0.10 can aid in the diagnosis of SBP. Amylase, bilirubin, glucose, lactate dehydrogenase, total protein, and triglycerides are not helpful except in select circumstances and are not warranted on a routine basis. The serum-ascites albumin gradient is approximately 97% accurate in indicating portal hypertension. The gradient is calculated by subtracting the ascitic fluid albumin concentration from the simultaneously measured serum albumin concentration. A gradient of ≥ 1.1 gm/dL suggests portal hypertension as the etiology of the ascites (Table 5). A gradient of < 1.1 gm/dL suggests that the patient does not have portal hypertension and that the ascites has some other etiology (Table 5). A dipstick for glucose, pH, and protein can be used to differentiate an exudate from a transudate. This method uses a hard to remember equation and requires the use of a calculator (k = 0.012protein – 0.012glucose – 3.329pH + 23.498).

Table 5

Classification of Ascites by the Serum to Ascites Albumin Concentration Gradient

High gradient (≥ 1.1 gm/dL)	Low gradient (< 1.1 gm/dL)
Alcoholic hepatitis	Nephrotic syndrome
Budd-Chiari syndrome	Pancreatic ascites
Cardiac ascites	Peritoneal carcinomatosis
Cirrhosis	Serositis in connective tissue disease
Fatty liver of pregnancy	Tuberculous peritonitis
Fulminant hepatic failure	
Massive liver metastases	
Mixed ascites	
Myxedema	
Portal vein thrombosis	
Venoocclusive disease	

Suspect peritoneal carcinomatosis and order cytology in patients with a history of breast cancer, colon cancer, gastric cancer, pancreatic cancer, or the suspicion of undiagnosed malignancy and ascites. Smear and cultures for mycobacteria are not sensitive. They should still be ordered when the suspicion for tuberculous peritonitis is high (e. g., patients who have immigrated from endemic areas or have an immunocompromised status).

Patients with uncomplicated ascites secondary to cirrhosis should have an ascitic fluid white blood cell (WBC) count < 500 cells/mm^3. The cells should be predominantly lymphocytes and mesothelial cells without clinical evidence of peritonitis. A polymorphonuclear (PMN) cell or neutrophil count of > 250 cells/mm^3 confirms SBP. The PMN count is obtained by multiplying the total WBC count by the percentage of PMNs in the differential. Subtract one neutrophil per 250 red cells/mm^3 to adjust for significant blood in a specimen (i. e., RBC > 10,000 cells/mm^3) from a traumatic tap. A Gram stain is not sensitive for SBP secondary to the low concentration of bacteria in ascites. Patients receiving continuous peritoneal dialysis can have SBP diagnosed with a WBC > 100 cells/mm 3.51 Culture all potentially infected ascitic fluid by directly inoculating blood culture bottles at the bedside.

SELF-CONTROL TESTS

1. A positive or negative deflection from baseline that indicates a specific electrical event on an ECG is _____ .

a) Interval; c) Segment;
b) Wave; d) Complex.

2. The time between two specific ECG events is _____ .

a) Complex; c) Segment;
b) Wave; d) Interval.

3. The length between two specific points on an ECG that are supposed to be at the baseline amplitude (not negative or positive) _____ .

a) Wave; c) Complex;
b) Interval; d) Segment.

4. The combination of multiple waves grouped together _____ .

a) Interval; c) Segment;
b) Wave; d) Complex.

5. _____ is a diagnostic test to determine the presence of hypertension by taking measurements during normal daily activities, over a span of 24 consecutive hours.

a) Ambulatory Blood Pressure Monitoring;
b) Echocardiography;
c) Cardiac stress tests;
d) Coronary angiography.

6. Stress test NOT related to physical activity:
a) Treadmill test;
b) Ambulatory Blood Pressure Monitoring;
c) Transesophageal electrical stimulation of the left atrium;
d) Coronary angiography.

7. Indications for a bronchoscopy:
a) Follow up on a scan that has indicated a lung infection or tumor, or a collapsed lung;
b) Symptomatic treatment of large pleural effusions;
c) Patients with new-onset ascites to establish the etiology of the fluid;
d) Gastrointestinal decontamination, performed in the setting of an acute poisoning by ingestion, to decrease the absorption of substances in the stomach.

8. _____ is the term given to the basic lung function tests that measure the air that is expired and inspired.
a) Bronchoscopy; c) Needle aspiration;
b) Spirometry; d) Treadmill test.

9. Asthma is an _____ disease but because it is reversible, spirometry may be normal when the person is not experiencing an exacerbation.
a) Obstructive; b) Restrictive; c) Mixed pattern.

10. _____ is a method of gastrointestinal decontamination, performed in the setting of an acute poisoning by ingestion, to decrease the absorption of substances in the stomach.
a) Needle aspiration; c) Bronchoscopy;
b) Spirometry; d) Gastric lavage.

Answers: **1** – b; **2** – d; **3** – d; **4** – d; **5** – a; **6** – c; **7** – a; **8** – b; **9** – a; **10** – d.

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Корнелюк Ирина Владимировна

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Учебно-методическое пособие

На английском языке

Ответственный за выпуск С. Е. Алексейчик
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