Ministry of Health of Ukraine
Kharkiv National Medical University

STUDY OF ARTERIAL PULSE AND BLOOD PRESSURE

Methodical instructions for students

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STUDY OF ARTERIAL PULSE

Pulse [L, *pulsare,* to beat] is the regular, recurrent expansion and contraction of an artery produced by waves of pressure caused by the ejection of blood from the left ventricle of the heart as it contracts. The phenomenon is easily detected on superficial arteries, such as the radial, brachial, carotid, and femoral arteries, and corresponds to each beat of the heart.

Palpation of the pulse. Technique. Pulse is commonly studied on the radial artery between the styloid process of the radial bone and the tendon of the internal radial muscle.

The carotid pulse is best examined with the sternocleidomastoid muscle relaxed and with the head rotated slightly toward the examiner. Palpate the carotid pulse with the patient lying on a bed or couch. Never compress both carotids simultaneously. Use the left thumb for the right carotid and vise versa. Place the tip of the thumb between the larynx and the anterior border of the sternocleidomastoid muscle. Press the thumb gently backwards to feel the pulse. In palpating the brachial arterial pulse, the examiner can support the subject's relaxed elbow with the arm while compressing the brachial pulse with the thumb with the fingers cupped round the back of the elbow. Feel just medial to the tendon of the biceps muscle to detect the pulse.

The usual technique is to compress the artery with the fingers until the maximum pulse is sensed. Varying degrees of pressure should then be applied while concentrating on the separate phases of the pulse wave.

This method is used for assessing the following characteristics of the pulse: symmetry, rhythm, rate, correlation of the pulse and heart rate, tension, filling (volume), size, speed, and pulse waves shape (Tab. 1).

Tab. 1. Examination of the arterial pulse

Examination sequence	Factors that cause pulse characteristics	Norm	Pathology
Symmetry on the pair arteries	Degree of arteries filling	Symmetric	Asymmetrical *p. differens*
Rhythm	Cardiac activity	Rhythmic *p. regularis*	Arrhythmic *p. irregularis*
Rate (PR)	Heart rate (HR)	60-80 beats per minute (b.p.m.)	Frequent – *p. frequens,* Rare - *p. rarus*
Correlation between PR and HR	Contractile ability of the heart	HR = PR	HR>PR – pulse deficit *p. dificiens*

Tension	BP level in the greater circulation	Sufficient tension	Soft (BP low) – *p. mollis* Firm (BP high) – *p. durus*
Volume	Volume of circulating blood	Sufficient volume	Large volume – *p. plenus* Empty or low volume – *p. vacuus*
Size	Stroke volume, arteries filling	Moderate size	Large – *p. magnus* High – *p. altus* Small – *p. parvus* Thready – *p. filiformis*
Speed	Speed of pressure changes in the arteries	Moderate speed	Fast – *p. celer* Slow – *p. tardus*
Shape	Stroke volume, velosity of the BP changes during systole and diastole	Moderate size and velosity, uniform – *p. aequalis*	Fast (*p. celer)* and high (*p. altus)* Slow (*p. tardus*) and small (*p. parvus*) Nonuniform–*p. inaequalis* Variable – *p. alternans*

Normal findings. Pulse is symmetrical (pulsus differens is absent), rhythmic, pulse rate is between 60-80 beats per minute, pulse deficit is absent, pulse is of sufficient pressure and volume, of moderate speed and size.

Symmetry. The pulse should be taken in definite order. As the pulse may be different on different arms, you should first palpate simultaneously on both radial arteries. Apply four fingers over radial pulse at the wrists. Use the pulp of the fingers to assess the symmetry of the pulse. If the pulse waves are equal on both hands, you continue palpation on either hand. If the pulse waves are different, further study should be carried on that arm where the pulse waves are more pronounced.

The pulse waves on the both hands normally should be equal. If the pulse waves on the one hand are smaller or lag in time is said to be *pulsus differens* is present. It occurs in compression of corresponding artery (peripheral, brachial, or subclavian arteries) or by scar, tumor, enlarged lymph node, or by inflammatory infiltration. Pulsus differens may also be caused by compression of large arteries by aortic aneurism, mediastinal tumor, retrosternal goiter, or by markedly enlarged left atrium.

Rhythm. Pulse rhythm is reflection of the heart rhythm. The normal rhythm of the heart is called sinus rhythm because it originates from the sinoatrial node. Normally pulse is rhythmic or regular. When the pulse is irregular, it is important to identify the nature of the irregularity and to determine whether it is present all-time or only intermittently.

Sinus rhythm is seldom completely regular, because the heart speeds up during inspiration. This sinus arrhythmia is most obvious in children, young people and athletes.

An occasional irregularity is commonly caused by ectopic beats or extrasystoles, which can be atrial or ventricular in origin.

Atrial fibrillation causes a totally random heart rhythm leading to a pulse, which is irregular in both timing and volume. This is often described as an 'irregularly irregular' rhythm.

Arrhythmic pulse can also be caused by atrial flutter with variable response and atrioventricular block (AV block).

The most common causes of an irregular pulse are as follows:

- Sinus arrhythmia
- Atrial extrasystoles;
- Ventricular extrasystole;
- Atrial fibrillation;
- Atrial flutter with variable response;
- Atrioventricular block.

Pulse rate. A normal resting pulse rate is from 60 to 80 beats per minute in an adult. If the pulse is regular, count the pulse for 15 seconds and multiply by four to obtain pulse rate in beats per minute. If the pulse is irregular, you should count the pulse rate not less than 1 minute.

In accelerated heart rate to more than 90 beats per minute – *tachycardia*, the pulse rate increases accordingly so-called – *p. tachus* or *p. frequens*.

Frequent pulse can occur in healthy persons in physical and emotional exertion, in coffee, strong tee, alcohol, hot food and drinks, pepper, garlic intake, and smoking.

Compensatory tachycardia arises in heart failure, hypotension, anemia, bleeding, collapse, traumatic and postoperative shock, and in neurosis. Tachycardia is also frequent symptom of myocarditis and heart defects.

In infectious diseases, in elevation of temperature at 1˚ pulse rate accelerates at 10 beats, except meningitis and typhoid fever. Some medication (sympathomimetics, vasodilators) can also cause acceleration of the pulse rate.

The causes of pulse rate acceleration are shown in Table 2.

Tab. 2. Causes of frequent pulse

Tachycardia, HR>90/min – ***pulsus freguens*** or ***pulsus tachus***	
Sinus tachycardia	Arrhythmia
Physiological:	Atrial fibrillation
Exercise	Atrial flutter
Excitement/anxiety	Supraventricular tachycardia
Coffee	Ventricular tachycardia
Strong tee	
Alcohol	
Smoking	
Pepper, garlic	
During inspiration	
Compensatory:	
Heart failure	
Myocarditis	
Heart defects	
Hypotension	
Anemia	
Bleeding	
Collapse, shock	
Neurosis	
Infections, intoxication	
Fever	
Tuberculosis	
Hyperthyroidism	
Tumor	
Medication	
Sympathomimetics	
Vasodilators	

Bradycardia is defined as heart rate of < 60 beats per minute, in such case *p. rarus* or *p. bradus* is found. An important cause of bradycardia is complete heart block (3 rd degree atriventricular block) when the heart rhythm is regular and the rate is often less than 40 b.p.m. This may be intermittent and cause the patient to lose consciousness (Adams-Stokes attacks). The most common causes of bradycardia are listed in Tab. 3.

Tab. 3. Causes of rare pulse

Bradycardia, HR<60/min – ***pulsus rarus*** or ***pulsus bradus***	
Sinus bradycardia	Arrhythmia
Physiological	Sick sinus syndrome
Congenital bradycardia	Second degree AV block
Sleep	Third degree AV block
Lying posture	
After food intake	
During expiration	
Athletic training	
Increased vagus tone	
Pathological	
Jaundice	
Meningitis	
Cerebral tumor, edema	
Cerebral hemorrhage	
Hypertension	
Hypothyroidism	
By reflex in irritation of the peritoneum	
Appendicitis	
Cholecystitis	
Peptic ulcer disease	
Medication	
Beta-blockers	
Digoxin	
Verapamil, diltiazem	

Pulse deficit is difference between the actual heart rate and the rate palpable at the radial pulse. You should calculate heart rate, for example 85 beats per minute, then pulse rate – 75 beats per minute. 85-75=10. Pulse deficit is 10 beats per minute.

The most common causes of pulse deficit are extrasystoles and atrial fibrillation. Frequently the pulse waves produced by ectopic beat are too weak to be felt at the wrist. In atrial fibrillation, the delay between some ventricular contractions may too short to allow proper filling, leading to a reduced stroke volume and an impalpable pulse. This may produce a considerable pulse deficit.

Pulse tension is defined as the force that should be applied to compress pulsating artery completely. Pulse tension depends on blood pressure level. If

blood pressure level is normal, a moderate force is applied to compress the radial artery, and pulse is said to be of moderate tension.

According to the pulse tension you can estimate indirectly BP level: in high BP the pulse is firm – *p. durus*, in low BP the pulse is soft – *p.mollis*.

Pulse volume depends on the arteries filling by blood. The full pulse – *p. plenus*, and empty pulse – *p. vacuus* are differentiated.

The full pulse *(p. plenus)* is found in the normal stroke volume, when the arteries are sufficiently filled with blood.

A large volume pulse may be due to aortic regurgitation or vasodilatation. Exercise, emotion, heat and pregnancy are physiological factors causing vasodilatation, which is also, occurs with fever, thyrotoxicosis, anemia, or drug therapy.

In decreased pulse volume, the pulse is said to be empty - *p. vacuus*. The low volume pulse is found in patients with decreased circulating blood volume (bleeding, vomiting, diarrhea, profuse sweating), re-distribution of blood in circulatory system – collapse, and in patients with reduced stroke volume due to heart failure or peripheral vascular diseases.

Pulse size implies its tension and volume. The pulse of large volume and tension is defined as large pulse – *p. magnus.* The pulse of small volume and tension is called small pulse – *p.parvus*. Considerably weak pulse is called thready or *p. filiformis*. It found in shock, acute heat failure, and profuse bleeding.

BLOOD PRESSURE MEASUREMENT

Blood pressure (BP) is a hemodynamic variable dependent on cardiac output and total peripheral resistance.

Blood pressure is generally measured by the indirect method, using a mercury sphygmomanometer. N. Korotkoff proposed this method in 1905. In 1953 World Health Organization (WHO) introduced the Korotkoff's method as a classical world standard for measure BP.

Semi-automatic and automatic devices for blood pressure measurement at home and for prolonged (24 h and longer) ambulatory blood pressure monitoring are now available. It should be stressed that all of these devices should be tested for accuracy and reliability against standard methods according to strict protocol. Ambulatory blood pressure monitoring is an interesting research technique, which is used to investigate blood pressure variability, behavioral influences on arterial pressure and the time-course of the effects on antihypertensive therapy. It is also used, as are home blood pressure readings, to provide a supplementary source of information for diagnostic and therapeutic decisions.

Attention to detail is needed for accurate blood pressure measurement. It is important to use the correct size of cuff. A cuff for adults must have a bladder 13-15 cm wide and 30-35 cm long so as to encircle the average arm. Larger cuff are needed for fat arms and smaller cuffs for children.

Examination sequence

- Before measurement commences the patient should be seated for several minutes in a quiet room.
- The chair should provide comfortable back support.
- The arm muscles should be relaxed.
- Support the arm comfortably with cubital fossa at about heart level (fourth intercostal space).
- Apply a cuff of suitable size to the exposed upper arm. Care should be taken to avoid tight sleeves.
- Identify brachial pulse.
- Inflate the cuff rapidly until the manometer reading is about 30 mmHg above the level at which pulse disappears.
- Deflate the cuff slowly at approximately 2 mmHg until regular heart sounds (called Korotkoff sounds) can be just heard. This is the systolic blood pressure (SBP).
- Continue to deflate the cuff slowly until the sounds disappear – diastolic blood pressure (DBP).

Blood pressure may also be measured with the subject supine and standing, and in each position the arm should be supported at the heart level.

Normal findings

The pressure at which the sounds are first heard is the *systolic blood pressure* (phase I).

The pressure at which the sounds disappear is *diastolic blood pressure* (phase V). Phase V may not be heard (the sounds not disappears), the phase IV (muffling of sounds) is taken as diastolic blood pressure in these cases.

The difference between SBP and DBP is defined as *pulse pressure*. Normally pulse pressure is 40-50 mmHg.

Blood pressure varies with excitement, stress and environment. Repeated measurements are required before a patient should be identified as hypertensive. SBP and DBP should be measured at least twice over a period of no less than 3 min; both should be recorded and the mean value for both should be used. It is also recommended that, on the first visit, the blood pressure should be measured on both arms. Measurement with the subject in the standing position should also be performed when postural hypotension is suspected and in the elderly, in whom this condition may be more common.

In some patient blood pressure is elevated in the presence of a doctor but falls when the subject leaves the medical environment – so-called ‘white-coat

hypertension' or 'effect'. Measurement by trained non-medical staff may reduce white-coat effect. Ambulatory blood pressure monitoring helps to distinguished these patients from those with true sustained hypertension.

Common abnormalities

Hypertension

Hypertension is an increase in total peripheral resistance due to arterioral vasoconstriction and wall thickening, leading to raised systemic pressure. According to World Health Organization and International Society of Hypertension (WHO/ISH) definition in 1999 hypertension exists when in an adults SBP is 140 mmHg and more, and DBP is 90 mmHg and more. Two classifications of hypertension by blood pressure level (Tab. 3) and by extent of organ damage (Tab. 4) were published by WHO/ISH and have not been changed since.

Tab. 3. Classification of hypertension by blood pressure level (WHO/ISH, 1999).

	SBP (mmHg)	**DBP** (mmHg)
Optimal	< 120	< 80
Normotension	< 130	< 85
High normal	130-139	85-89
Hypertension:		
I grade (mild hypertension)	140-159	90-99
Subgroup: Borderline	140-149	90-94
II grade (moderate hypertension)	160-179	100-109
III grade (severe hypertension)	≥ 180	≥110
Isolated systolic hypertension	≥ 140	≤ 90
Subgroup: Borderline	140-149	< 90

Tab. 4. Classification of hypertension by extent of organ damage

Stage I	*No objective signs of organic changes*
Stage II	*At least one of the following signs of organ involvement without symptoms or dysfunction* Left ventricular hypertrophy (radiogram, electrocardiogram, echocardiogram) Generalized and focal narrowing of the retinal arteries Proteinuria and/or slight elevation of plasma creatinine concentration (1.2-2.0 mg/dl or to 177 mmol/l Ultrasound or radiological evidence of atherosclerotic plaque (carotid arteries, aorta, iliac and femoral arteries)

Stage III	*Both symptoms and signs have appeared as result of organ damage*. These include: Heart Myocardial infarction Heart failure Brain Stroke Transient ischaemic attack Hypertensive encephalopathy Vascular demension Optic fundi Retinal hemorrhages and exudates with or without papilloedema Kidney Plasma creatinine concentration > 2.0 mg/dl or > 177 mmol/l Vessels Dissecting aneurysm Symptomatic arterial occlusive disease

Hypertension may be essential or primary and secondary. The causes of secondary hypertension are outlined in Table 5.

Tab. 5. Clasification of secondary hypertension

I. Renal
1. Damage of renal parenchyma and tissue: o glomerulonephritis (acute and chronic) o pyelonephritis (chrronic) o diabetic glomerulosclerosis o nephrolithiasis o polycystic kidney disease o hypo- or dysplasia of kidney o renal tuberculosis o renal tumor o renin-secreting renal tumor o renal transplantation o chronic renal failure o rheumatoid arthritis o systemic lupus erythematosus o scleroderma

2. Renovascular (vasorenal): o fibromuscular dysplasia and hypertrophy o aortitis o atherosclerotic damage of renal arteries o congenital renal artery disease
II. Hemodynamic
1. Coarctation of the aorta 2. Hypertension in aortic atherosclerosis 3. Arterio-venous fistula (arterial shunt), various congenital defects 4. Hyperkinetic syndrome (aortic regurgitation, congestive heart failure) 5. Complete AV block 6. Cor pulmonale
III. Endocrine
1. Phaeochromocytoma 2. Primary aldosteronism 3. Cushing's symdrome 4. Hyperthyroidism 5. Hyperparathyroidism 6. Acromegaly 7. Adrenogenital syndrome 8. Primary renin hyperproduction 9. Endotelin-secreting tumors
IV. Neurogenic
1. Cerebral tumor 2. Cysts after stroke 3. Meningitis, traumatic encephalitis, diencephal syndrome 4. Carbon dioxide retention (pulmonary emphysema, bronchial asthma, pneumosclerosis, sleep apnoe syndrome)
V. Blood system disease
1. Polycythemia rubra vera
VI. Exogenic
1. Fluorine and chlorine poisoning 2. Drug-induced problems: estrogens, cyclosporin, oral corticosteroids (systemic or topical), oral contraceptives, narcotics.

Hypotension

Arterial hypotension is defined as SBP < 100 mmHg and DBP < 60 mmHg. Hypotension can be physiological and pathological.

Physiological hypotension is caused commonly by constitutional and inherited factors. It occurs in asthenic persons, in athletes, and sometimes in healthy persons during usual exertion and is not accompanied by any complaints and pathological changes in the organism. Orthostatic hypotension (drop of BP in upright position) is typical for the subjects with constitutional hypotension. This BP liability can cause unconsciousness states in changes of body position, especially in the morning in getting out of bed, or in long standing.

Pathological hypotension can be the result of circulatory failure (of cardiac or peripheral origin) and endocrine pathology.

Hypotension due to altered circulation is divided into three forms:

1. Cardiogenic hypotension (myocardial infarction, heart failure, aortic stenosis, pulmonary vessels embolism);
2. Hypotension due to dilation of peripheral vessels (infections: pneumonia, peritonitis, septic processes; intoxication: antihypertensive drugs, barbiturates; anaphylactic reactions; hyper reflex mechanism: psychogenic hypotension);
3. Hypotension caused by decreased blood volume (dehydration, hemorrhage that leads to collapse, shock).

Arterial hypotension is found in such endocrine pathology as Addison's disease, and hypothyroidism.

According to course acute and chronic arterial hypotension is differentiated. *Acute* arterial hypotension (collapse, shock) occurs as a result of acute blood loss, poisoning by medicines and industrial toxins, in emotional stress (vasovagal syncope), sudden redistribution of the circulating blood volume (in rapid evacuation of ascitic fluid in paracentesis, or pleural fluid in thoracentesis). Acute vascular failure quite often complicates various infectious diseases: pneumonia, influenza, typhus, dysentery, etc.). Acute hypotension can be of reflex or pain origin (syncope in injections, collapse or shock in myocardial infarction), or in intense physical exertion.

Chronic pathological hypotension is divided into primary or essential (increased parasympathetic nervous system activity, dysfunction of vegetative centers of vasomotor regulation that lead to decreased peripheral vascular resistance) and secondary or symptomatic (professional allergy, chronic intoxications).

TEST CONTROL

1. What is it pulsus differens:

A. Difference between pulse rate and heart rate
B. Different pulse on both radial arteries
C. Escape of the separate pulse waves
D. Different volume of the pulse waves
E. Alternation of large and small pulse waves

2. A normal resting pulse rate in adult is:

A. 60-70 beats per minute
B. 60-80 beats per minute
C. 50-80 beats per minute
D. 65-85 beats per minute
E. 55-85 beats per minute

3. What is it tachycardia:

A. Large volume pulse
B. Heart rate more than 80 beats per minute
C. The full pulse – *p. plenus*
D. Heart rate less than 60 beats per minute
E. Heart rate more than 90 beats per minute

4. What is it bradycardia:

A. Heart rate more than 80 beats per minute
B. The full pulse – *p. plenus*
C. Large volume pulse
D. Heart rate less than 60 beats per minute
E. Heart rate more than 90 beats per minute

5. What is it pulse deficit:

A. Different pulse on both radial arteries
B. Difference between pulse rate and heart rate
C. Escape of the separate pulse waves
D. Different volume of the pulse waves
E. Alternation of large and small pulse waves

6. The pulse is firm (p. durus) in:

A. Hypotension
B. Aortic stenosis
C. Hypertension
D. Bleeding
E. Collapse

7. A large volume pulse is found in:

A. Aortic regurgitation
B. Collapse
C. Profuse vomiting
D. Profuse diarrhea
E. Aortic stenosis

8. Decreased volume pulse (p. vacuus) is found in:

A. Reduced stroke volume due to heart failure
B. Fever
C. Anemia
D. Thyrotoxicosis
E. Aortic regurgitation

9. Thready pulse (p. filiformis) is found in:

A. Anemia
B. Fever
C. Pregnancy
D. Shock
E. Aortic regurgitation

10. What is the name of device for blood pressure measurement:

A. Pneumotachometer
B. Oscillometer
C. Phlebomanometer
D. Sphygmomanometer
E. Phonocardiograph

11. Optimal blood pressure is defined as (WHO/ISH, 1999):

A. SBP 120-129 mmHg, DBP 80-84 mmHg
B. SBP ≥ 180 mmHg, DBP ≥ 110 mmHg
C. SBP < 120 mmHg, DBP < 80 mmHg
D. 140-159 mmHg, DBP 90-99 mmHg
E. 130-139 mmHg, DBP 80-85 mmHg

12. Normal blood pressure is defined as (WHO/ISH, 1999):

A. SBP ≥ 140 mmHg, DBP ≥ 90 mmHg
B. SBP < 120 mmHg, DBP <80 mmHg
C. SBP 130-139 mmHg, DBP 85-89 mmHg
D. SBP 160-179 mmHg, DBP 100-109 mmHg
E. SBP 120-129 mm Hg, DBP 80-84 mmHg

13. High normal blood pressure is defined as (WHO/ISH, 1999):

A. SBP 130-139 mmHg, DBP 85-89 mmHg
B. SBP 120-129 mmHg, DBP 80-84 mmHg
C. SBP < 120 mmHg, DBP < 80 mmHg
D. SBP ≥ 180 mmHg, DBP ≥ 110 mmHg
E. SBP 140-159 mmHg, 90-99 mmHg

14. Hypertension in adults is defined as (WHO/ISH, 1999):

A. SBP 130-139 mmHg, DBP 85-89 mmHg
B. SBP 140-159 mmHg, DBP 90-99 mmHg
C. SBP 160-179 mmHg, DBP 100-109 mmHg
D. SBP ≥ 140 mmHg, DBP ≥ 90 mmHg
E. SBP ≥ 180 mmHg, DBP ≥ 110 mmHg

15. Grade 1 hypertension is defined as (WHO/ISH, 1999):

A. SBP ≥ 180 mmHg, DBP ≥ 110 mmHg
B. SBP 140-159 mmHg, DBP 90-99 mmHg
C. SBP 130-139 mmHg, DBP 85-89 mmHg
D. SBP 160-179 mmHg, DBP 100-109 mmHg
E. SBP ≥ 140 mmHg, DBP < 90 mmHg

16. Grade2 hypertension is defined as (WHO/ISH, 1999):

A. SBP 140-159 mmHg, DBP 90-99 mmHg
B. SBP 130-139 mmHg, DBP 85-89 mmHg
C. SBP ≥ 180 mmHg, DBP ≥ 110 mmHg
D. SBP ≥ 140 mmHg, DBP < 90 mmHg
E. SBP 160-179 mmHg, DBP 100-109 mmHg

17. Grade 3 hypertension is defined as (WHO/ISH, 1999):

A. SBP ≥ 180 mmHg, DBP ≥ 110 mmHg
B. SBP 140-159 mmHg, DBP 90-99 mmHg
C. SBP 130-139 mmHg, DBP 85-89 mmHg
D. SBP 160-179 mmHg, DBP 100-109 mmHg
E. SBP ≥ 140 mmHg, DBP < 90 mmHg

18. Isolated systolic hypertension is defined as (WHO/ISH, 1999):

A. SBP 140-159 mmHg, DBP 90-99 mmHg
B. SBP 130-139 mmHg, DBP 85-89 mmHg
C. SBP 160-179 mmHg, DBP 100-109 mmHg
D. SBP ≥ 140 mmHg, DBP < 90 mmHg
E. SBP ≥ 180 mmHg, DBP ≥ 110 mmHg

19. Hypotension is defined as:

A. SBP < 120 mmHg, DBP < 80 mmHg
B. SBP < 110 mmHg, DBP < 70 mmHg
C. SBP <100 mmHg, DBP < 60 mmHg,
D. SBP < 90 mmHg, DBP < 60 mmHg
E. SBP < 95 mmHg, DBP < 65 mmHg

20. Pulse pressure is defined as:

A. Maximum blood pressure level
B. Minimum blood pressure level
C. Difference between SBP and DBP levels
D. Venous pressure

E. Average SBP levels

Answers: 1B, 2B, 3E, 4D, 5B, 6C, 7C, 8A, 9D, 10D, 11C, 12C, 13A, 14D, 15B, 16E, 17A, 18D, 19C, 20C.

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