Autonomic Nervous System

Theoretical foundations and instructions for conducting practical exercises carried out during the course

List of practical exercises

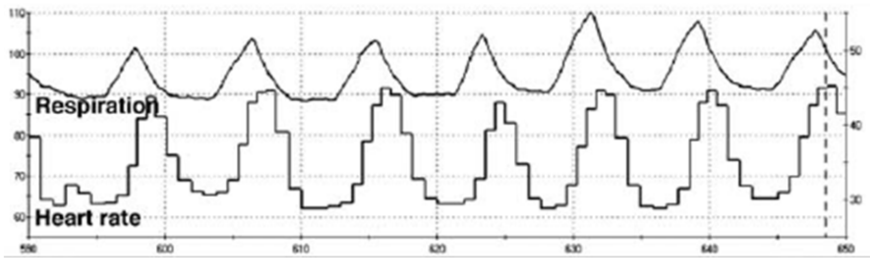
1. Deep (controlled) breath test
2. Cold pressor test (ice-water test)
3. Martinet's orthostatic test
4. Isometric muscle contraction test
5. The Valsalva test (manoeuvre)

Note: At the end of the instructions, you will find a table which must be filled in to complete the exercise.

Deep (controlled) breath test

Aim of the test: To evaluate the vagus nerve impact on the heart function, based on the inspiration-to-expiration difference in heart rate (*HR*).

Introduction: Heart rate increases during inspiration and decreases during expiration. Such coupling of the respiratory and circulatory systems is referred to as *respiratory sinus arrhythmia* (RSA). It has been experimentally shown that RSA improves the gas exchange in the lungs.



Simultaneous record of respiration (airflow, above) and HR (below).

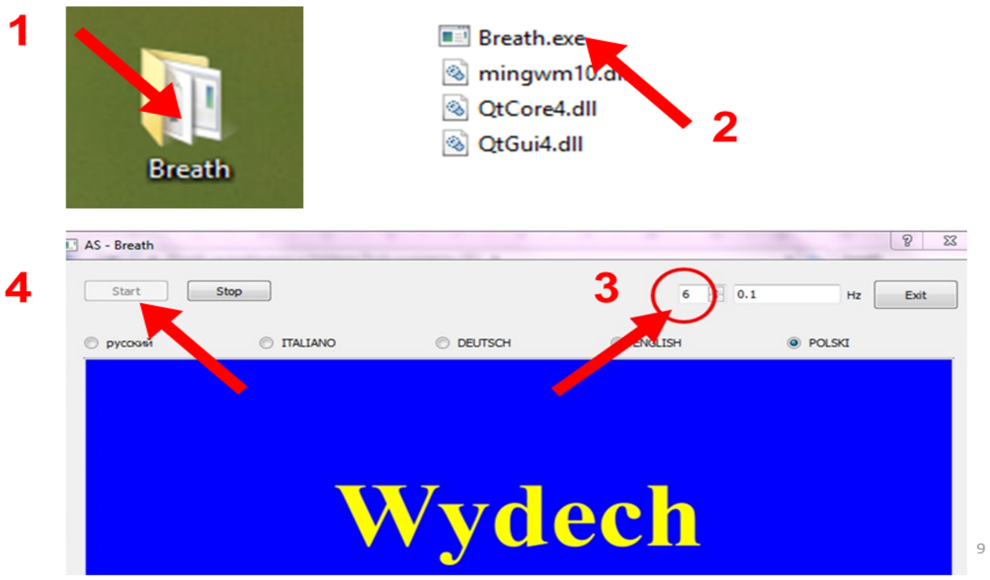
RSA is mainly triggered by the changes in the activity of the cardiac fibers of the vagus nerve. The vagus nerve activity is low during inspiration, but it increases during expiration. On this basis, RSA is treated as a marker of the activity of the parasympathetic branch of the ANS in control of the heart function. RSA decreases with age. Low RSA values are also observed in diseases which are accompanied by impaired autonomic balance, such as coronary heart disease or diabetes.

Physiological mechanisms triggering the RSA have not been fully explained. Stimulation of central inspiratory neurons has an inhibitory effect (by the cholinergic synapse) on cardiac vagal neurons in the ambiguous and dorsal nucleus (central mechanism of the RSA formation). In addition, peripheral mechanisms may also contribute to the formation of RSA, including the pulmonary mechanoreceptor reflex and the arterial baroreceptor reflex.

Test procedure: In general terms, evaluation of RSA consists in determining the mean difference between HR during inspiration vs. expiration. The breathing pattern (e.g. breathing frequency) may potentially modulate the RSA magnitude. For this reason, in the course of the test, the patient breathes according to the imposed, standard rhythm - 6 breaths/min [breathing rhythm is displayed on the computer screen].

Equipment and accessories needed: (1) ECG, (2) a watch or stopwatch, (3) *Breath* software to determine the rhythm of breathing, (4) a marker pen.

1. Ask the patient to lie down on the couch with his/her face up.
2. Connect the ECG.
3. The examined person should remain in a lying position for at least 5 minutes (this time helps to stabilise the hemodynamic parameters).
4. Start the *Breath* application. Remember to select the frequency of 6 breaths per minute (figure below).



5. Ask the patient to breathe according to the rhythm displayed on the screen. Duration of breathing according to the imposed rhythm: approx. 2 minutes. During this time, it is essential to watch the chest movement of the patient and on that basis mark the beginning of each inspiration and expiration on the ECG printout with a marker pen (e.g. a vertical line and the letter "I" for *inspiration* and "E" for *expiration*).

Note: Following the respiratory rhythm displayed on the screen is a demanding task. Before the actual 2-minute ECG recording is started, it is necessary to make sure that the patient has understood the command and that he/she breathes normally, according to the instructions.

Data analysis and interpretation of the result: Locate all R-waves in the selected lead (usually II) of the analysed part of the ECG recording. Then count the squares between the successive R-waves and use the following equation (this method provides the HR value for each RR interval, see figure below):

at the ECG recording speed = 50 mm/s

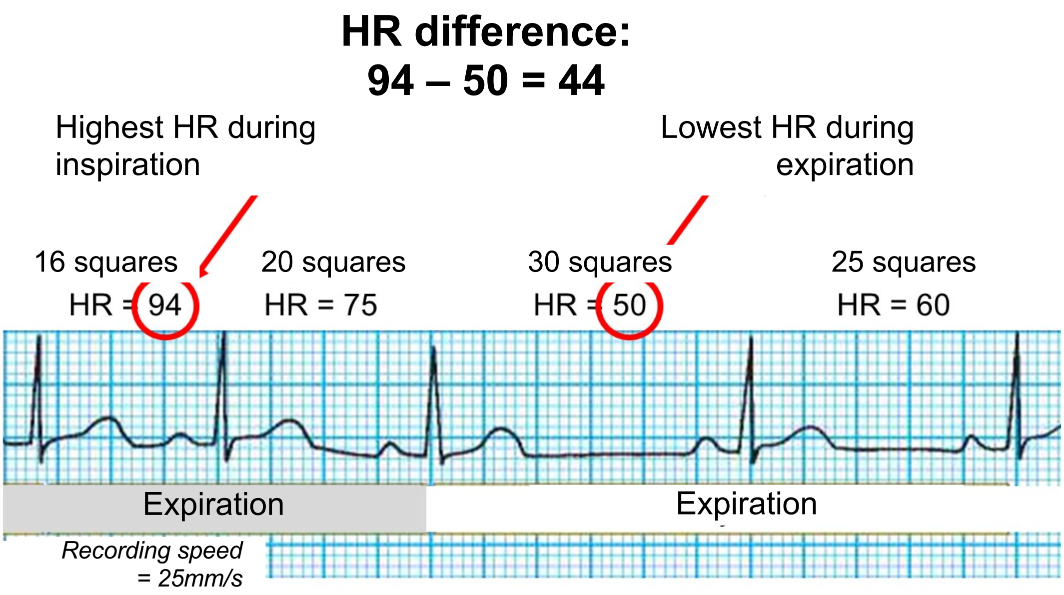
HR = (60 x 50) / number of squares

at the ECG recording speed = 25 mm/s

HR = (60 x 25) / number of squares

Then, for each pair - inspiration and expiration - calculate the difference between the highest HR during inspiration and the lowest HR during expiration (the calculation scheme has been summarised in the figure below).

Calculate the arithmetic average of all inspiration-to-expiration HR differences. The correct average is ≥15 beats/min, limit values: 11-14 beats/min; while values of ≤10 beats/min are considered abnormal.



Cold pressor test (ice-water test)

Introduction and purpose of the test: immersing the hand or foot in cold water (the so-called cold pressor test - *CPT*) stimulates the sympathetic branch of the ANS, which in turn triggers a series of cardiovascular reactions. On this basis, CPT was used for assessing the influence of the sympathetic branch of the ANS on the functioning of the cardiovascular system (including the diagnosis of damage to the efferent sympathetic pathways). The clinical utility of CPT has been considered, for example as a risk factor for the development of hypertension. Exceptionally strong pressor responses are recorded in hyperthyroidism and hypertension, while the pressor response tends to be reduced in orthostatic hypotension.

Immersing one's hand or foot in water at about 4°C stimulates the thermoreceptors and nociceptors (pain receptors) in the skin, resulting in increased sympathetic activity, which leads to vasoconstriction, increased heart rate and increased cardiac contractility. These changes contribute to the increase in blood pressure.

Test procedure

Equipment and accessories needed: (1) a manual blood pressure monitor with a stethoscope or an automatic blood pressure monitor, (2) a bowl of water at ca. 4°C, (3) a watch or stopwatch.

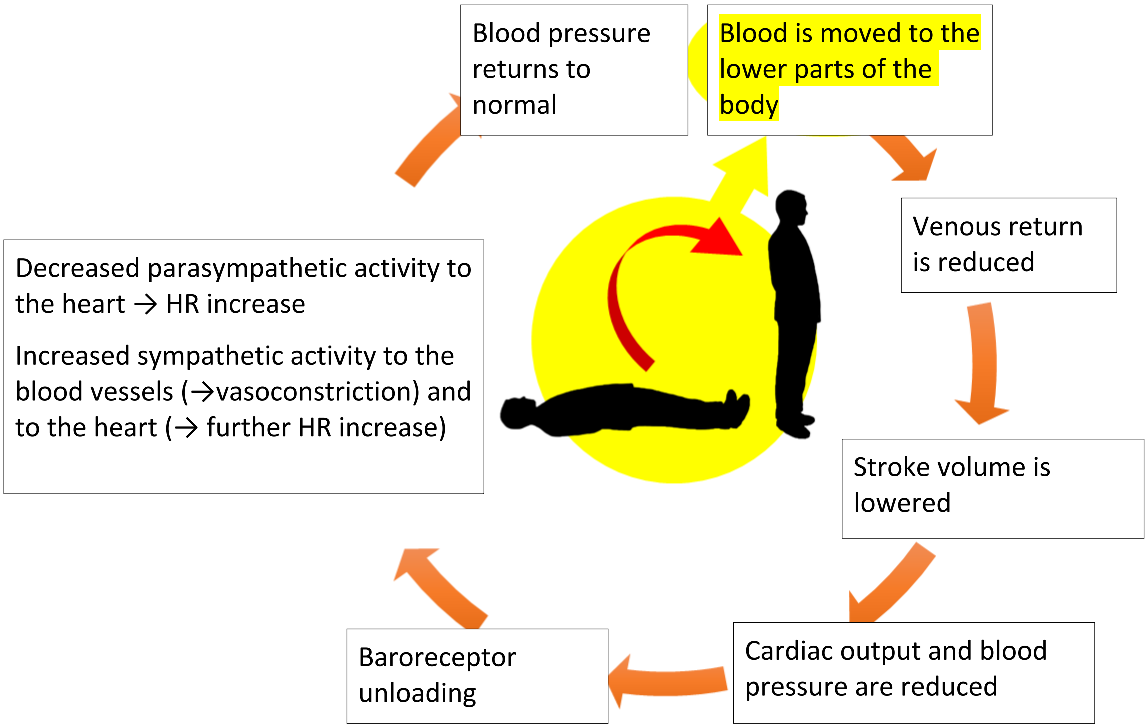
1. Ask the patient to lie down on the couch with his/her face up.
2. Place the blood pressure cuff on the hand which will not be immersed in water.
3. The examined person should remain in a lying position for at least 10 minutes (resting record). During this time, take 2-3 measurements of blood pressure and heart rate (e.g. 3, 6, and 9 minutes into the test). Note the values down on the test record sheet.
4. Ask the patient to immerse their hand (up to the wrist) in the water. Measure blood pressure and heart rate 30 sec, 1 min, 1:30 min and 2 min after the hand is immersed. Note the values down on the test record sheet. **Note:** *Discrepancies exist in literature data concerning the duration of the immersion phase. In some papers, the immersion phase is one minute. When the test becomes too painful, the patient should inform the supervisor of the test and immediately remove their hand from the water before 2 minutes have elapsed*.
5. Ask the patient to remove their hand from the water. Measure the blood pressure and heart rate 30 sec after the hand is removed from the water, and again in 30-second intervals until the blood pressure and heart rate return to the baseline (resting) values, but at least until 3 minutes after the hand is removed from the water. Note the values down on the test record sheet.

Interpretation of the results: The normal response is a systolic blood pressure increase of 15-20 mmHg and a diastolic blood pressure increase of 10-15 mmHg, persisting for up to 3 minutes after the hand is removed from the water. A systolic blood pressure increase of 25 mmHg and more or a diastolic blood pressure increase of 20 mmHg and more are considered abnormal.

Martinet's orthostatic test

Introduction and purpose of the test: The orthostatic test serves to evaluate the cardiovascular response (controlled by the autonomic nervous system) to a rapid change in body position from lying to standing. A normal response involves a slight decrease in blood pressure (a systolic blood pressure decrease no greater than 10 mmHg, a diastolic blood pressure decrease no greater than 5 mmHg) and an increase in heart rate by 5-20 beats/min. The changes in blood pressure persist for ca. 19 seconds. An abnormal response in the form of significant and persisting blood pressure decrease (orthostatic hypotension) is associated with insufficient activity of sympathetic vasoconstrictor neurons (e.g. as a result of damage to the autonomic nervous system or the use of antihypertensive drugs).

The change in body position results in a significant volume of blood being moved to the lower body, a decrease in blood pressure and, consequently, the unloading of aortic baroreceptors. The response by the ANS involves the inhibition of parasympathetic activity to the heart and an increase in sympathetic activity to the heart and blood vessels. The result is an increased heart rate and a vasoconstriction of blood vessels, which translates into an increase in blood pressure (temporarily even above the baseline values; this in turn secondarily triggers the baroreceptor reflex, subsequently leading to a reduced heart rate). The test provides information on: (1) the parasympathetic regulation of the heart and baroreceptor sensitivity (the length of RR intervals during unloading and stimulation of the baroreceptors is compared) and (2) the activity of the sympathetic branch (analysis of changes in blood pressure).



Test procedure

Equipment and accessories needed: (1) ECG, (2) manual blood pressure monitor with a stethoscope or an automatic blood pressure monitor, (3) a watch or stopwatch, (4) marker pen.

1. Ask the patient to lie down on the couch with his/her face up.
2. Connect the ECG.
3. The examined person should remain in a lying position for at least 15-20 minutes (resting record). During this time, take 2-3 measurements of blood pressure and heart rate (e.g. 5, 10 and 15 minutes into the test). Note the values down on the test record sheet.
4. Measure blood pressure and heart rate immediately before assuming a vertical position. Next, ask the patient to get up from the couch as quickly as possible and stand in a relatively still position (extra movement may cause artefacts in the ECG record). Mark the point at which the patient gets up on the ECG printout. Measure blood pressure and heart rate immediately upon assuming a vertical position. Note the values down on the test record sheet.
5. Measure blood pressure and heart rate 1, 2 and 3 minutes after the patient stands up. Continue the measurements at 1-minute intervals until the parameters return to the baseline values. Note the values down on the test record sheet.

Note: *Remember to secure the patient during and after assuming a vertical position. Make sure to prevent the ECG cables from falling out or the ECG apparatus from tipping over during the process.*

Data analysis and interpretation of the results

The results of the Marinet's orthostatic test include:

1. The ratio of the longest RR interval at beat 30 to the shortest RR interval at beat 15 after actively assuming a vertical position (the so-called **30:15 ratio**). The correct value of the 30:15 ratio is >1.18 for people aged 15-19, >1.117 for people aged 20-24, 1.15 for people aged 25-29. The 30:15 ratio reflects the difference between baroreceptor unloading and a strong baroreceptor stimulation and is considered as a **marker of the parasympathetic regulation of the heart rate**.

2. A correct decrease in systolic blood pressure upon actively assuming a vertical position should be no greater than 10 mmHg. The limit values are 11-29 mmHg, while a systolic blood pressure decrease of ≥30 mmHg is considered abnormal. The evaluation of changes in blood pressure upon assuming a vertical position is considered as a **marker of sympathetic activity**.

Classification of orthostatic dysregulation:

1. **Orthostatic hypotension:** a decrease in systolic blood pressure by ≥20 mmHg or diastolic blood pressure by ≥10 mmHg within 3 minutes of assuming a vertical position.
2. **Postural tachycardia syndrome:** heart rate accelerated by ≥30 beats/min in comparison with the resting value or to >120 beats/min with no blood pressure drop.
3. **Neurocardiogenic syncope:** a sudden drop in systolic blood pressure by ≥50 mmHg after a long time spent in a standing position, often also bradycardia and asystole).

Isometric muscle contraction test

Introduction and purpose of the study: Isometric muscle contraction causes blood pressure to increase, mainly due to increased sympathetic activity.

Test procedure

Equipment and accessories needed: (1) a manual blood pressure monitor with a stethoscope or an automatic blood pressure monitor, (2) dynamometer, (3) a watch or stopwatch.

1. The patient remains in a sitting position. Measure and note down the resting blood pressure value.
2. In order to determine the maximum grip strength, ask the patient to squeeze the dynamometer thrice. Calculate the average result and then calculate 30% of the average.
3. Ask the patient to squeeze the dynamometer at 30% of the maximum strength and maintain the grip for as long as possible (up to 5 minutes). Measure the pressure at 1-minute intervals. Note down the results.

Interpretation of the results: A diastolic blood pressure increase of at least 16 mmHg is regarded as correct.

The Valsalva test (manoeuvre)

Introduction and purpose of the test: Forced expiration for ca. 15 seconds with the glottis closed is called the Valsalva test (manoeuvre) and is commonly used to assess the performance of autonomic regulation in the cardiovascular system. The Valsalva manoeuvre leads to a short-term drop in blood pressure, and the compensatory responses to restore the correct blood pressure are mainly mediated by the arterial baroreceptor reflex. On this basis, the Valsalva manoeuvre is considered to be one of the methods to assess the sensitivity of arterial baroreceptors.

Hemodynamic responses during the Valsalva test occur according to a pattern (figure below):

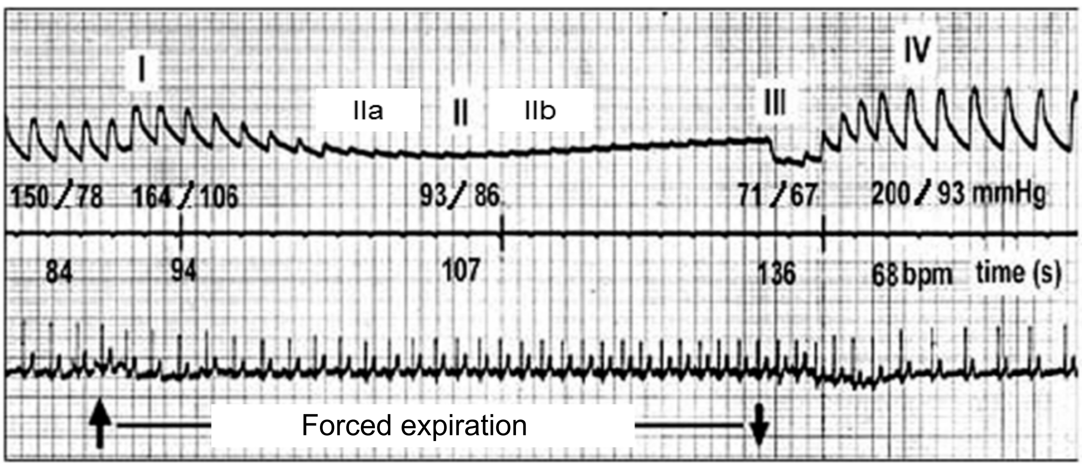
Phase 1: Forced expiration causes elevated pressure in the chest and a short-term increase in blood pressure.

Phase 2a: Elevated pressure in the chest hinders the venous return. The stroke volume and blood pressure are lowered.

Phase 2b: Unloading of baroreceptors and sympathetic stimulation lead to an accelerated heart rate, vasoconstriction and a slow increase in blood pressure.

Phase 3: The end of expiration causes a temporary drop in blood pressure due to a sudden decrease in chest pressure.

Phase 4: Increased venous return with the vessels constricted leads to a significant increase in blood pressure (above the baseline value).



Changes in blood pressure (above) and heart rate (ECG record with HR values, below) during the Valsalva manoeuvre.

Source: Junqueira (2008): Teaching cardiac autonomic function dynamics employing the Valsalva (Valsalva-Weber) maneuver. Advances in physiology education 32: 100-106.

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Test procedure: The patient remains in a sitting position. The nose is blocked with a clip. The patient's task is to perform a 15-second-long expiration under constant pressure (≥40 mmHg). The tests consist of three attempts separated by at least 3-minute breaks. The following should be noted down during each of the three attempts: (1) the peak HR during the attempt and (2) the lowest HR after the attempt (within a maximum of 60 seconds of concluding it).

Data analysis and interpretation of the result: The Valsalva test consists in evaluating the ratio of the peak HR during the attempt to the lowest HR thereafter (the so-called Valsalva ratio), corresponding to the difference between the state of baroreceptor unloading (Phase 2b) and the state of strong bioreceptor stimulation (Phase 4). The correct value of the Valsalva ratio is ≥1.21, the limit values are 1.11 to 1.20, while values of ≤1.10 are considered abnormal.

In addition, the evaluation of a Valsalva manoeuvre involves comparing the changes in blood pressure during the test with the pattern presented in the figure. Normally, all 4 phases can be distinguished in the blood pressure record. Phases 2a and/or 4 do not occur in sympathetic nervous system disorders.

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Deep (controlled) breath test:

Consecutive breathing cycles	HR during inspiration	HR during expiration	(HR during inspiration) minus (HR during expiration)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
Arithmetic average of the inspiration-to-expiration HR difference =			

Cold pressor test

	Systolic blood pressure	Diastolic blood pressure	HR
Resting record			
Measurement 1			
Measurement 2			
Average			
After dipping the hand			
30 sec			
1:00 min			
2:00 min			
After removing the hand from water			
30 sec			
1:00 min			
2:00 min			
3:00 min			

Martinet's orthostatic test

	Systolic blood pressure	**Diastolic blood pressure**	**HR**
Resting record			
Measurement 1			
Measurement 2			
Average			
Before assuming vertical position			
After assuming vertical position			
1:00 min			
2:00 min			
3:00 min			
4:00 min			
5:00 min			

	Systolic blood pressure	**Diastolic blood pressure**	**HR**
Time to return to baseline values	……………….. min.	……………….. min.	……………….. min.

30:15 Ratio =	$\dfrac{\textit{Longest RR around 30th heartbeat after getting up}}{\textit{Shortest RR around 15th heartbeat after getting up}}$	

Isometric muscle contraction test

	Systolic blood pressure	**Diastolic blood pressure**	**HR**
Resting record			
Measurement 1			
Measurement 2			
Average			
Length of exercise			
1:00 min			
2:00 min			
3:00 min			
4:00 min			
5:00 min			