HUMAN PHYSIOLOGY WORKBOOK

DEPARTAMENT DE FISIOLOGIA

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FIRST SESSION
ACTION POTENTIAL: COMPUTER-SIMULATED MODEL

The aim of this practical session is to reinforce some of the theoretical knowledge on action potential and the factors related to it using a web application based on the Hodgkin-Huxley model, which simulates stimulation of the squid giant axon.

The session consists of obtaining an intensity-time curve (ITC) based on the pre-set times of the various stimuli, which are shown at the end of this document. With the help of the web application, students must determine the minimum intensity (expressed with integers) that triggers an action potential for each time value. As this minimum intensity depends on the duration of the electrical stimulus applied, these steps will need to be repeated for each pre-set time. Once the ITC is obtained, other electrophysiological parameters, such as chronaxie and rheobase, will be determined. Also, in pairs, students must design an experimental protocol, using the web application, to determine the refractory periods.

Link for web application:
https://www.uv.es/madomaua/p1.html

After accessing the web application, we follow the instructions given.
We begin with a membrane potential value of -80 mV. This value will be kept constant throughout the practice session.
The application enables users to change data relating to

- the intensity and duration of two successive and independent stimuli, and
- the time interval (or separation) between the two stimuli.

To obtain the ITC, we use only the first stimulus so we give a value of zero to the intensity or duration of the second stimulus. Once we have obtained the minimum intensities at the pre-set times that trigger an action potential, the data (the points obtained) will be transferred to the coordinate axes (x-axis and y-axis) on the results sheet and, after joining the points, the ITC will be represented. Then, we calculate the rheobase and chronaxie parameters.

To determine the absolute refractory period (ARP) and relative refractory period (RRP), we use both stimuli and vary the interval between them.

The results of the stimulation simulation are represented by two graphs in the screen as follows:

1. The graph in the upper part of the screen represents the variations in cell membrane voltage.

2. The graph at the bottom part of the screen represents the variations of the conductance to sodium (sharper) and potassium.

The characteristics of the stimuli we apply (duration, intensity, and the interval between them) appear at the bottom of the screen. The first stimulus is represented by #1 and the second stimulus is represented by #2. Both stimuli are represented as rectangular bars in maroon.

This link may help you understand the concepts of rheobase and chronaxie:
https://youtu.be/soItBpi3oQk

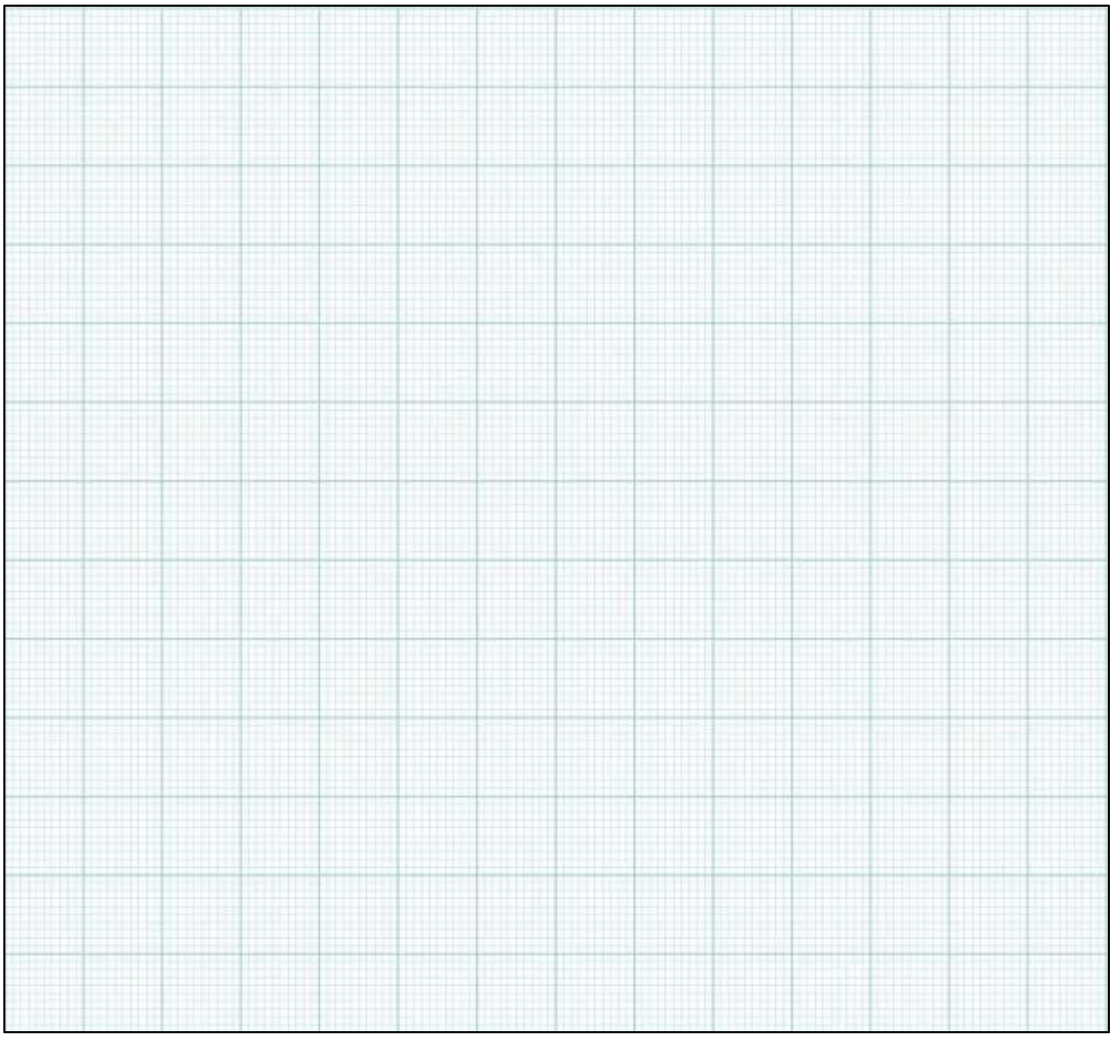
RHEOBASE:

CHRONAXIE:

ABSOLUTE REFRACTARY PERIOD:

RELATIVE (OR TOTAL) REFRACTARY PERIOD:

Duration (Pre-set time) (ms)	Intensity (mA)
0.06	
0.12	
0.25	
0.50	
1.00	
1.50	
2.00	
6.00	
8.00	
15.00	



SECOND SESSION
ANALYSIS OF SENSORY FUNCTION

In this and the next practice session we will conduct an examination of the Nervous System. We have divided this examination into two parts: sensory (current session) and motor function (next session). The aim is to assess the subjective and objective manifestations produced by certain stimuli in a presumably healthy person. Students will then be better prepared to correctly interpret the altered response they will study in later subjects related to pathology.

Practical content: tactile, stereognostic, proprioceptive and pain sensitivity are explored. To make best use of this practice session, students should previously have reviewed in particular the following points: the general physiology of sensitivity; tactile, proprioceptive, painful and thermal mechanoreceptive sensitivity.

Materials required and method. We will use sharp objects, a brush, a tuning fork and an algesimeter. We will begin by exploring **tactile sensitivity** using a brush and a sharp object. We will also explore **sterognosia**, which is the faculty that enables recognition of an object by means of palpation without use of other senses. We will explore how we adapt to touch, which depends on the **receptor potential**. Tactile sensitivity can be **epicritical**, which is defined as being able to discriminate between two points and depends on the receptor field, or **protopathic**.

We will then explore **proprioceptive sensitivity** by vibrating the tuning fork on a bony protrusion such as the ankles. We can also place a part of the body in a certain position which the person being tested must identify with their eyes closed. We will also perform the Romberg test (i.e. check the maintenance of posture with feet together and eyes closed). The Romberg test is negative if posture is maintained correctly.

Finally, we will use the algesimeter to explore **pain sensitivity**.

It is important to remember that in every exploration performed you must compare the sensitivities of symmetrical points on the body. The practice session will be conducted in pairs and each student will write down their results on the results sheet.

In the next practice session, we will continue with the motor examination of the Nervous System. You can learn how to do a complete examination of the Nervous System from the following links:

Part 1: https://youtu.be/OtwpMf06-eM
Part 2: https://youtu.be/kPJySCXgji8
Part 3: https://youtu.be/OPGRXnmiPqE

SURNAME AND FIRST NAME: ____

LIGHT TOUCH (displacement of a hair):

	1	2	3	4	5	Average
Location error (mm.)						

TOUCH (Object on a finger):
Duration of sensation _____________________________ seconds.

ADAPTATION TO TOUCH:

Test	1	2	3	4	5	6	7	8	9	10	Mistakes
Yes											
No											

LOCATION OF TOUCH:

	Test	ZONE					
		FINGER	HAND	ARM	BACK	FACE	OTHER
Location error (mm)	1						
	2						
	3						
	4						
	5						
	Average						

DISCRIMINATION BETWEEN TWO POINTS:

	Test	ZONE					
		FINGER	HAND	ARM	BACK	FACE	OTHER
Minimum distance for discrimination (mm)	1						
	2						
	3						
	4						
	5						
	Average						

Romberg test:

THIRD SESSION
ANALYSIS OF MOTOR FUNCTION

In this session we will conduct an examination of motor function and determine the physiological response. We will work in pairs to assess the manifestations of certain stimuli in a presumably healthy person. We will analyse muscle tone, strength, motor coordination, tendon and skin reflexes, and gait.

MATERIALS REQUIRED

1. Reflex hammer.
2. Dynamometer (hand grip).
3. Nail or pin.
4. Clinical examination bed or stretcher.

METHOD

First, we will study **MUSCULAR TONE** by inspecting muscle mass and the disposition of the limbs and by checking the existence of symmetries. We will then proceed to palpate in order to detect muscle consistency. When doing so, it is useful to compare symmetrical muscle groups. Passive mobilization will enable us to check physiological resistance to movement and the absence of abnormal resistance (stiffness, spasticity and hypotonia). Here it is worth mentioning the **Stewart-Holmes manoeuvre**, which involves holding the subject’s forearm while they flex it against our resistance. If we suddenly remove this resistance, the subject should control the flexion movement in a physiological situation. This control does not occur when there is muscular hypotonia.

To explore **MUSCLE STRENGTH**, the patient must perform movements involving different muscle groups and we must check that the movements are symmetrical (by comparing the right and left parts of the body). We test the **Barré manoeuvre for the upper limb** by asking the patient to place both their upper limbs in antepulsion to determine whether both limbs reach the same level. The subject being examined must close their eyes. The same manoeuvre for the lower limb is performed with the patient lying "face down" and asking them to bend their knees at a 45° angle: this is the **Barré manoeuvre for the lower limb**. Another manoeuvre for assessing the global muscle strength of the lower limb is the **Mingazzini manoeuvre**, in which the patient lying down (in the supine position) is asked to flex their thigh and leg at roughly 90° and we observe whether there is a descent of one limb with respect to the other.

It may also be useful to give the hand dynamometer (hand grip) to the subject, ask them to close their hand with maximum force, tell them to repeat the operation with their other hand, and then compare the levels achieved with both limbs.

COORDINATION is analysed using tests such as “finger-nose”, “heel-knee”, or rapid alternating movements of the hands (pronation-supination). All these tests assess correct execution of the movement and achievement of the objective (absence of tremor, resolution in the execution, non-hesitant attitude, and absence of dysmetria).

Finger-nose test: the subject must touch the tip of their nose with their index finger and with their eyes closed.

Heel-knee test: the subject must bring the heel of their opposite foot to their knee.

The following should be explored when examining **REFLEXES**:

1. Tendinoperiosteal medullary reflexes, also known as muscular and deep (**myotatic**) reflexes
2. **Cutaneous** reflexes (superficial)

Each of these reflexes will be examined on both sides to check similarity. We will also explore the existence and/or disappearance of the reflex as well as the absence of weakness or the exaggeration of the reflex. The functional integrity of the reflex will indicate the functional normality of the structures in which it is integrated.

Below is a form (of which there are several) for the exploration of each reflex and its physiological response.

1. Myotatic reflexes

a. Ankle reflex: With the person “on all fours” on a stretcher and with the feet protruding from the stretcher, the Achilles tendon is tapped lightly with the reflex hammer. The normal response is plantar flexion of the foot due to contraction of the calf muscles (which in this case are the pre-stretched muscles).

b. Patellar reflex (quadriceps tendon): with the subject seated and letting the legs hang, tap on the quadriceps tendon. The normal response is extension of the knee due to contraction of the quadriceps.

c. Bicipital reflex: with the subject resting their arm on the examiner, the examiner covers the biceps tendon with their thumb at the level of the elbow flexion and taps their thumbnail with the reflex hammer. The normal response is flexion of the elbow.

d. Tricipital reflex: with the subject resting their arm on the examiner, the examiner taps the triceps tendon. The normal response is extension of the elbow.

e. Brachioradialis reflex: with the subject resting their forearm on the examiner, the examiner taps the radial styloid process. The normal response is flexion of the hand.

The reflexes described above are integrated in the spinal cord.

2. Cutaneous reflexes:

a. Cutaneous-plantar reflex: with the subject barefoot and lying down, a pointed object is slid slowly over the outside of their foot sole. The normal response is plantar flexion of the toes. In children up to 2 years of age, the response is dorsal flexion of the toes (Babinski's sign). The normal skin-plantar reflex indicates integrity of the pyramidal pathway.

b. Cutaneous-abdominal reflex: with the subject lying down with their abdomen uncovered, a pointed object is slid down the side of their abdomen towards the middle of their abdomen. The normal response is contraction of the abdominal muscles and displacement of the umbilicus towards that side. This normal response shows the integrity of the pyramidal pathway.

These reflexes are integrated in the cerebral cortex.

Finally, as a component of the motor function examination, we should also analyse the subject's correct execution of **GAIT** by asking them to walk slowly. We should observe the correct route we indicated to the patient and analyse the movements of the lower limbs (needed for walking) and the upper limbs (movements associated with walking that should appear in physiological walking), and verify their normality. Normal gait is performed if all the structures related to it (pyramidal system, basal ganglia, cerebellum, vestibular apparatus, sight, medulla, peripheral nerves, structures of the locomotor apparatus, etc.) are functionally intact.

RESULTS SHEET:

Name and surname:

MUSCULAR TONE

RIGHT	Leg	Thigh	Arm	Forearm
Inspection				
Palpation				
Passive mobilization				

LEFT	Leg	Thigh	Arm	Forearm
Inspection				
Palpation				
Passive mobilization				

Assess relatively between 1 and 5

Stewart--Holmes (displacement in cm) ....

Stewart--Holmes (displacement in cm) ....

MUSCLE STRENGTH

	Right	Left
Hand grip		

	Unevenness in cm
BARRÉ upper limb	
BARRÉ lower limb	
MINGAZZINI	

COORDINATION

Right									**Average**
Finger -nose									
Heel-knee									

Left									**Average**
Finger -nose									
Heel-knee									

In these tests indicate the error in cm.

MYOTATIC REFLEXES

	Right					
Displacement in cm	**Test**	**Ankle**	**Patellar**	**Bicipital**	**Tricipital**	**Brachioradialis**
	1					
	2					
	3					
	4					
	5					
	Average					

	Left					
Displacement in cm	**Test**	**Ankle**	**Patellar**	**Bicipital**	**Tricipital**	**Brachioradialis**
	1					
	2					
	3					
	4					
	5					
	Average					

CUTANEOUS REFLEXES

Right									**Average**
Plantar									
Abdominal									

Left									**Average**
Plantar									
Abdominal									

In these tests indicate the error in cm.

GAIT: Indicate any alterations observed.

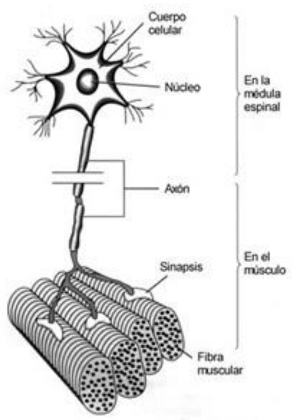
FOURTH SESSION
ELECTROMYOGRAPHY

1. OBJECTIVE

The aim of this session is to learn how to measure the electrical activity of skeletal muscles by using an electromyograph.

2. ELECTROMYOGRAPHY (EMG)

Unlike electrocardiography or electroencephalography, electromyography (EMG) is not a single diagnostic test but comprises several different tests. We can perform needle EMG and electroneurography or nerve conduction study. Needle EMG records voluntarily evoked potentials in the muscle and electroneurography or nerve conduction study
recorded muscle evoked potentials after nerve stimulation



In this session, we will perform a needle EMG in the biceps and triceps. To avoid punctures, we will use surface electrodes.

Remember that a Motor Unit is the set of one motor neuron with its axon and axon branches and all the muscle fibres that the motor neuron innervates. When muscle contraction is minimal, few motor units are activated. However, when the force of the contraction increases, more motor units are activated.

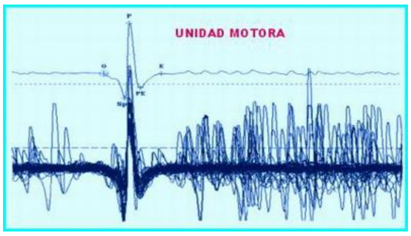
To perform the needle EMG, the needle electrode is inserted into the muscle and the activity of the muscle is first recorded at rest and then after minimal activity. The degree of contraction is increased until it reaches a maximum. What we see in the recording are the so-called motor unit potentials (MUP). We distinguish MUPs from others present in the same recording by their morphological characteristics. In physiological conditions, a given MUP must always have the same amplitude, duration and phases. The shape of the MUP depends on the composition of the motor unit, which includes factors such as the number of muscle fibres and the metabolic type of those muscle fibres. All these factors affect the shape of the MUP which is the same for a given MUP.

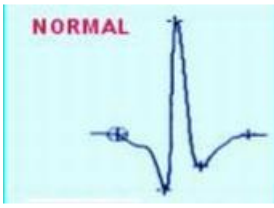
When more motor units begin to be recruited, we no longer see individual MUPs but overlapping spikes. This results in the appearance of the four patterns described below.

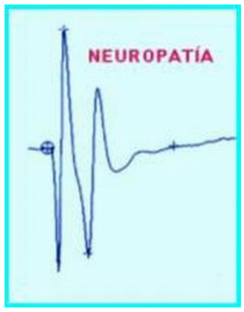
An electrically silent pattern occurs when the muscle is at rest, i.e. there is no MUP. In a clinical examination, when the patient is asked to begin contracting, the so-called simple pattern appears, which contains the appearance of one MUP. If the computer programme transforms this MUP into sound, gunshots are heard each time a motor unit is recruited. If the patient progressively exerts more force, more motor units are recruited. This leads to the so-called intermediate or mixed pattern until finally an interferential pattern is obtained in which the muscle's electrical activity is maximum.

If the patient has myopathy, an early recruitment will appear when force is first exerted because an alteration in the muscle fibres will occur and the interferential pattern will appear with less intense effort. Also, MUP amplitude will be lower due to damage in the fibres. In this case, a **myopathic pattern** appears.

If the patient has neuropathy, which implies a loss of axons, the pattern will have a larger amplitude and a lower density, i.e. it would not become interferential with maximal effort. In neuropathies, the well-functioning motor units become larger, which compensates for the loss of motor units, Therefore, the new motor neuron has many more fibres, which explains the pattern of greater amplitude. The patient cannot recruit more motor units because they do not have them, and a **neurogenic pattern** appears.







Needle EMG enables the examiner to

1) distinguish between CNS and PNS lesions, and

2) in neuromuscular pathology, to locate and quantify different types of lesions accurately and precisely. Specifically, the lesions are

(a) lesions of the motor neuron of the anterior horn (motor neuronopathies) and the neurons of the posterior spinal ganglion (sensory neuronopathies),

(b) lesions of motor or sensory roots (radiculopathies), plexuses (plexopathies) and nerve trunks (truncal lesions),

(c) disorders of neuromuscular transmission, including presynaptic and postsynaptic disorders,

(d) primary skeletal muscle disorders (myopathies).

In clinical practice, nerve conduction studies are performed by stimulating a nerve. These studies provide information about the patient's pathology (muscular or nervous), demyelination of the nerve or axon loss.

3. PREPARING THE EXPERIMENT

MATERIALS:

- PowerLab system connected to a computer
- Bio Amp Cable

- 4 recording electrodes
- Velcro® wrist strap for earthing
- 4 weights, each of 2 kg

PREPARING THE SUBJECT:

- Remove the subject’s wristbands or wristwatch.
- Fasten the Velcro® wrist strap tightly around the subject’s wrist (the lint should be in contact with the skin) and connect the terminal to ground
- Clean the skin on the biceps with alcohol. Make two small crosses on the muscle belly along the major axis of the arm 2 to 5 cm apart.
- Connect the terminals of the two electrodes to the two holes of channel 2 (CH1) of the Bio Amp cable (polarity is not important).

4. EXERCISES

4.1. Isotonic contraction

Objective:

To contract the muscle voluntarily in an isotonic manner and analyse the corresponding EMG.

Procedure:

- Ask the subject to sit in a relaxed position, with their elbow resting on the table, their arm forming a 90˚ angle and their eyes facing the palm of their hand. Then ask them to use their other hand to hold the wrist on their recording arm (in the resting position).
- Choose the command “Bio Amp...” from the drop-down menu of channel 3 (biceps) function.
- Ask the subject to intensively contract their biceps by trying to flex the arm being recorded, while the other arm opposes this movement.
- Adjust the range value (“Range”) in the Bio Amplifier dialog box so that the maximum electrical response occupies half or two thirds of the full scale. Press OK.
- Return the arm to the resting position.
- Press “Start” to begin the recording.
- Ask the subject to perform an intense biceps contraction by flexing the arm being recorded until their fist reaches their shoulder.
- Press “Stop” to stop the recording.
- Analyse the complete recording.

4.2. Isometric contraction

Objective:

To perform voluntary isometric muscle contraction with increasing load and analyse the corresponding EMG.

Procedure:

- Ask the subject to sit in a relaxed position with their arm extended on the table (in the resting position).
- Press “Start” to begin the recording.
- Ask the subject to stand, with their elbow at a 90˚ angle and the palm of their hand facing upwards (in the counter-gravity lifting position).
- After a few seconds, place a 2 kg weight in their hand and record for 4-5 sec. Repeat the process by adding 2 kg weights up to a total of 8 kg.
- Press “Stop” to stop the recording.
- Obtain recordings of 2-second sequences. Enlarge the image with the ‘zoom’ function and analyse the recordings from the beginning (at rest) and for each load.

4.3. Antagonist muscles

Objective:

To examine the EMG of antagonist muscles and analyse the phenomenon of coactivation.

Procedure:

- Place electrodes on the triceps of the subject being examined (connected to channel 2, CH2, of the Bio Amp cable).
- Display and activate channels 2 and 4 on the screen.
- Ask the subject to sit in a relaxed position, with their elbow resting on the table, their arm forming a 90˚ angle and their eyes facing the palm of their hand. Ask them to use their other hand to hold the wrist of the arm being recorded (in the resting position).
- Press “Start” to begin the recording.
- Ask the subject to contract their biceps and triceps vigorously by alternately flexing and extending their arm. Repeat the exercise while holding a 2 kg weight.
- Record for 3 or 4 flexion-extension cycles.
- Press “Stop” to stop the recording.
- Analyse the complete recording.

4.4. Myotatic reflex

This technique enables us to observe the electrical activation that causes muscle contraction in the myotatic reflex. To use this technique we can place the electrodes on the quadriceps in the same way as was explained above for the biceps or triceps. If we gently tap the patellar tendon, we will observe a reflex contraction of the quadriceps and the electromyograph will record the muscle’s previous electrical activity. As we explained in the third practical session, we can also perform this reflex in the biceps and triceps.

5. ANALYSIS AND DISCUSSION OF THE RESULTS

1. Observe and compare the variations in electrical activity with the progression of isotonic and isometric contractions.

2. Observe the activation of the antagonistic muscles in relation to flexion-extension: predominant activation and coactivation.

6. CLINICAL EXAMPLES

Note that the EMG has no sound. A sound (not real) provided by the software helps us with the diagnosis. Faster frequencies emit higher pitched sounds and slower frequencies emit lower pitched sounds.

Video 2: MINIATURE MOTOR PLATE POTENTIAL

In this video we see the recording from the moment we begin inserting the needle into the muscle. We can see that the baseline goes from being straight to having irregularities. This is because as the needle is introduced, it moves closer to the motor plate. It represents the miniature potentials, which are the potentials that occur in the motor plate due to the acetylcholine that remains after the action of acetylcholinesterase.

Video 6: NORMAL RECRUITMENT

First, we see a single MUP and when the patient exerts more force this single MUP appears with an increased firing frequency. When the force intensity reaches a certain threshold the second motor unit is recruited.

Video 20: CRAMP (ramp)

We see how the cramp starts and then fades away.

Video 21: CRAMP

We see a patient with familial congenital cramp with increasing intensity.

Video 24: TREMBLOR

We see a patient with Parkinson's disease with the typical outbreaks of electrical activity and intervals of silence.

Video 9: FIBRILLATION

An example of fibrillation is denervation, where the muscle fibre loses contact with the axon. A common characteristic is that the frequency is regular.

Video 29: DECREASE IN RECRUITMENT

We see a patient in whom there is a loss of recruitment while the same MUP is seen to increase in frequency when trying to exert more force but no more motor units are recruited. There is a loss of motor units.

Video 30: INCREASE IN RECRUITMENT

Many motor units are recruited but the force is low. This happens with myopathy.

View the video in this link to see how to perform a needle EMG:
https://youtu.be/5P2fIOU1wRM

FIFTH SESSION
BLOOD PRESSURE AND CARDIAC AUSCULTATION

Objectives:

1) To study the components of the phonendoscope and sphygmomanometer and learn how to use these instruments correctly.
2) To learn the techniques of cardiac auscultation and how to take blood pressure.
3) To interpret the data obtained.
4) To know the focal points of valvular auscultation or the areas of preferential expression for each sound.
5) To recognise each physiological heart sound.

Content: To perform a cardiac auscultation, record blood pressure, and analyse the data obtained.

RECORDING BLOOD PRESSURE (BP)

INTRODUCTION

Two types of methods exist for determining BP:

- Those in which we insert a needle into the arterial compartment or cardiac cavity to determine the pressure (direct or crude methods).

- Those in which the arterial compartment is not invaded and BP is obtained indirectly (indirect or bloodless methods).

DIRECT METHODS

To directly measure blood pressure in an artery or cardiac cavity, an open, non-distensible tube filled with liquid (usually 0.9% NaCl) must be inserted into the region to be studied. This transmits the pressure to a recording device such as a mercury manometer or an electronic pressure transducer.

These techniques are used only for experimental purposes, for certain diagnostic tests, or during surgery.

INDIRECT METHODS

The most common indirect method is sphygmomanometry and the instrument used for this purpose is a sphygmomanometer. This consists of a flattened, inflatable rubber bag covered with a non-distensible fabric, called a cuff. The cavity of the bag is connected to the manometer (the pressure reading clock) and to a hand bulb or small pump by means of a rubber tube. In this way the bag can be inflated to the desired pressure. A small valve between the bulb and the bag allows the air to escape and the pressure to be reduced as needed.

Technique

The patient must be relaxed and be sitting or lying comfortably to allow them time to recover from emotional stress or physical exertion. Their arm should be at the level of the heart and be bare so as to prevent their clothing from compressing their arm. The cuff should be placed tightly on the arm about three centimetres above the bend of the elbow, while taking care that the air chamber mainly occupies the inner part where the humeral artery runs.

Palpatory method

The cuff is inflated until the radial pulse, which is palpated with the left hand, disappears, and is then slowly emptied (2 mmHg/s) so that when the pulse reappears, it corresponds approximately to the systolic or peak pressure. As the cuff continues to slowly deflate, the pulse acquires a bounding pulse quality until it suddenly acquires a normal quality that corresponds approximately to the diastolic or minimum pressure.

Auscultatory method

The cuff is inflated until the needle on the manometer is 15-20 mmHg above the pressure value at which the radial pulse disappears. The cuff is then slowly deflated while the stethoscope is on the humeral artery at the elbow flexure. The systolic pressure corresponds approximately to the value at which the first sound is heard, while the diastolic pressure corresponds approximately to the value at which the last sound is heard. These sounds are called **Korotkoff sounds** and are due to the passage of blood from a laminar to a turbulent regime due to variation in the vessel diameter. When the cuff pressure is higher than the arterial systolic pressure, the artery remains closed and there is no turbulence and therefore no sound. When the systolic pressure is greater than the pressure inside the cuff, the blood passing through the humeral artery runs in a turbulent regime, which is audible (Korotkoff sounds). As the cuff empties, these sounds are replaced by a murmur before they fade away a few millimetres of mercury below. This is because the diastolic blood pressure is higher than the pressure inside the cuff. Some authors consider that the diastolic pressure corresponds to the moment when the tones turn off, while others consider that it corresponds to when they disappear. To avoid discrepancies, if there is a big difference between the two points (since sometimes the pulses do not disappear), both values should be noted (e.g. 150/100/85).

If the humeral beats are difficult to hear, which is often the case, the cuff should be completely deflated, the arm should be raised to vertical to drain venous blood and aided by repeated opening and contraction of the hand. The blood pressure should then be measured again. This manoeuvre produces excellent results.

The auscultatory method can produce various errors. For example, after reaching the systolic level and continuing to deflate the cuff, there may be an auscultatory discontinuity or auscultatory interval (also called the well phenomenon) after which the beats are heard again. This interval may be erroneously interpreted as corresponding to the systolic level, which is higher. This error can be avoided by not starting to deflate the cuff until it is certain by palpation that the radial pulse has disappeared. Palpation also prevents an error from occurring in the opposite direction, i.e. that a transmission of arterial sounds from the proximal part of the cuff, as sometimes occurs, is interpreted as a manifestation of systolic pressure, which is actually lower.

Other errors are caused by keeping the cuff inflated for too long or not deflating it completely. Further errors may be due to the patient's state of anxiety or to the patient not being at rest.

<u>Other indirect methods</u>

Other methods based on using the occlusive cuff use various sensors to detect sounds, pulsations or blood flow under the pneumatic cuff. These methods include:

- the Blush method,
- pulse detectors,
- microphones, and
- ultrasound (the Doppler effect).

View the video in this link to see how to measure blood pressure:
https://youtu.be/SEiTWsqslQ8

CARDIAC AUSCULTATION

Traditionally, four foci of cardiac auscultation have been considered. Since the first and second heart sounds, which are normally audible with the stethoscope, have obvious and important valvular components, there are points or foci on the anterior chest wall where the valve sound caused by the valve whose focus we are auscultating is heard most intensely. This does not mean that at each focus of auscultation only the sound caused by a single valve is heard but that this sound is heard the most intensely. These points do not represent foci or areas of the heart valves with exact anatomical projection.

The auscultation foci are:

1) the mitral focus, which is located at the intersection of the left midclavicular line with the fourth left intercostal space. This is the area of the apexial beat or tip shock.

2) the aortic focus, which is located at the intersection of the second right intercostal space and the parasternal line on the same side. There is also the so-called accessory or secondary aortic focus (Erb’s zone), which is located at the intersection of the third left intercostal space and the parasternal line on the same side.

3) the tricuspid focus, which is located in the xiphoid appendix or sixth right chondrocostal joint.

4) the pulmonary focus, which is located at the intersection of the second left intercostal space and the parasternal line on the same side.

However, other auscultation zones have also been described in the literature. Luisiada, for example, established the following auscultation zones: the ventricular (right and left), the atrial (left and right), the aortic (root and descending thoracic) and the pulmonary. These zones are described in various textbooks.

MATERIALS REQUIRED:
1) Clinical examination bed
2) Sheet
3) Flexible binaural stethoscope or phonendoscope

Below is a brief description of the stethoscope.
Components of the stethoscope:

<u>Earpieces</u>: these must be of such a design and material that they can be inserted into the ear canals so that we hear only the sound of auscultation.

<u>Tubes:</u> these should be flexible, approximately 25 cm long, and with an inner diameter of roughly 0.32 cm.

Bell: this part of the stethoscope allows for better hearing at the lowest frequencies.

Diaphragm: this is a semi-rigid membrane that allows for better auscultation of high-frequency sounds.

Although there are many types of stethoscope, the one normally used in clinical practice for both cardiac and respiratory auscultation is the flexible biauricular stethoscope we have just described. The use of modified rigid stethoscopes is currently limited to the gynaecological clinic.

TECHNIQUE:

The patient should be lying on their back and be in slightly raised position. However, to make certain sounds more evident, other positions may be adopted, including right lateral decubitus, left lateral decubitus, and seated with body leaning forward, etc.

With the patient as calm and relaxed as possible and having adopted the most suitable position, we perform cardiac auscultation at each focus mentioned above. We recommend that the auscultation should be performed in the following order:

1) Auscultate with the diaphragm and then the bell, or vice versa, at a focus while paying attention to both heart sounds.

2) Repeat the procedure for the other auscultation foci.

3) Repeat the examination in respiratory apnoea (inspiratory and expiratory) in order to detect split sounds.

4) Perform auscultation after physical exercise to more clearly recognise sounds due to cardiac activity, which are more evident with this manoeuvre (the intensity of the sounds is greater).

SIXTH SESSION
RESPIRATORY SYSTEM EXPLORATION

Objectives: To recognise physiological respiratory sounds of auscultation in different auscultation areas. To learn how to use the spirometer to determine lung volumes and capacities while analysing the morphology of the tracings obtained. To provide the physiological basis for interpreting pathology in subsequent studies.

Content: In a presumably healthy person we will: 1) use a phonendoscope to perform an auscultation of normal sounds at various auscultation zones and analyse the characteristics of each one, and 2) use a spirogram to measure the various parameters (tidal, inspiratory and expiratory reserve volumes, maximum expiratory volume per second (FEV1), vital capacity, and ventilatory frequency).

PULMONARY AUSCULTATION

MATERIALS REQUIRED:
1) Clinical examination bed
2) Sheet
3) Flexible binaural stethoscope or phonendoscope

TECHNIQUE:

The subject should be bare-chested and seated while leaning slightly forward with their arms crossed and their elbows resting on their knees or in the orthostatic position. They should be instructed to ventilate normally, i.e. as they normally do, without forcing inspiration or expiration unless these manoeuvres are required.

After the patient has adopted what we believe is the most suitable position and is as calm and relaxed as possible, we proceed to perform the pulmonary auscultation. We recommend the following order for this procedure:

1) Auscultate first with the diaphragm and then with the bell, or vice versa, at a certain point and pay attention to the sounds generated during both inspiration and expiration.

2) Auscultate a point in one lung field and then repeat with its counterpart in the other lung field.

By auscultation, we can distinguish the so-called normal respiratory sounds:

a) The normal respiratory sound (traditionally called the vesicular murmur), which is an almost exclusively inspiratory, soft, low-pitched sound. In general, it has two components: the inspiratory component (longer and more intense) is due to sudden distension of the pulmonary alveoli by the entry of air, while the expiratory component (shorter and less intense) represents the vestige of the inspiratory component of the tracheobronchial murmur. Areas of maximum intensity are the first two intercostal spaces, the scapulovertebral region, and the axillary regions.

b) The tracheal breath sound (traditionally called the tracheobronchial murmur) is intense, harsh, high-pitched, and audible in both phases of ventilation (though preferably expiratory) with a marked pause between the two phases. The source of the inspiratory component is the vibration of the tracheobronchial spurs by the passage of air through the glottis. The expiratory component is produced by the sound vibration caused by the passage of air from one bronchus to a larger bronchus.

View the video in this link to see a video prepared by our teaching staff on the subject of respiratory auscultation:

Respiratory auscultation:
https://youtu.be/WX9eheBejk4

SPIROMETRY

MATERIALS:

- Disposable mouthpieces
- Nasal forceps
- Spirometer

The oldest spirometer is the so-called gasometer, into which the subject exhaled after breathing in air. The gasometer is no longer in use today.

The Hutchinson spirometer then came into use. This comprises a light metal bell, perfectly balanced by counterweights, that is inverted over a tank of water. On inspiration, the individual takes air from inside the bell, and the bell descends. On exhalation, it is the other way round. The displacement of the bell, and therefore the gaseous volumes mobilised, can be read on a graduated scale.

Today’s electronic spirometers contain turbines and detect air volume and flow.

Two types of spirometry exist: slow spirometry, in which we record the volume of air moved but do not record the time it takes to perform the manoeuvre; and forced spirometry, in which we record both volume and time.
With spirometry, we obtain the following parameters:

- Tidal Volume - TV
- Inspiratory Reserve Volume - IRV
- Expiratory Reserve Volume - ERV
- Forced Expiratory Volume in the First Second - FEV1
- Respiratory Rate
- Tiffeneau Index
- Vital Capacity - VC

The following parameters cannot be measured by spirometry:

- Residual Volume - RV
- Total Pulmonary Functional Capacity - TPC

Procedure:

The patient should be as relaxed as possible and the nozzle should be fitted tightly between the lips (the nozzle should be individual and either prepared in the presence of the subject or left to be handled by the patient). When the clip is correctly positioned, the test can begin. The attitude of the examiner is fundamental to the success of the test. The examiner should give strict orders to the patient, warning them beforehand to expect such instructions.
To explain how to perform the test and interpret the results, UV teaching staff have made the following videos:

Simple spirometry:
https://youtu.be/vQdFOM1Nhdo

Forced spirometry:
https://youtu.be/1geCfx3r-9I

Important Concepts

LUNG VOLUMES

The TIDAL VOLUME (or lung ventilation volume) is the volume of air inhaled and exhaled in each normal breath. In the normal adult it is usually roughly 500 ml.

The INSPIRATORY RESERVE VOLUME is the volume of air that can be inhaled after a normal inspiration. In the normal adult it is roughly 2500-3000 ml.

The EXPIRATORY RESERVE VOLUME is the volume of air that can be exhaled after a normal expiration. In the normal adult it is roughly 1200 ml.

The RESIDUAL VOLUME is the volume of air remaining in the lungs after forced expiration. In the normal adult it is roughly 1200 ml (this volume cannot be measured by spirometry).

When added together, these four volumes equal the maximum volume of lung expansion.

The combination of two or more of these volumes provides the so-called lung capacities defined below.

LUNG CAPACITIES

Lung capacities are made up of two or more lung volumes.

VITAL CAPACITY is the inspiratory reserve volume plus the tidal volume plus the expiratory reserve volume:

VC = (IRV + TV + ERV) = approx. 4600 ml.

INSPIRATORY CAPACITY is the tidal volume plus the inspiratory reserve volume:

IC = (TV + IRV) is approx. 3500 ml.

TOTAL PULMONARY CAPACITY is the maximum volume the lungs can reach with the maximum inspiratory effort made by the lungs:

TPC = (TV + ERV + IRV + RV) = 5400-5800 ml.

RESIDUAL FUNCTIONAL CAPACITY is the amount of air remaining in the lungs at the end of a normal expiration.

RFC = (RV + ERV) = 2300 ml.

In women all these lung volumes and capacities are approximately 20-25% lower than in men.