Chapter :

Semiology of the Cardiovascular System

In Carnivores and Equids

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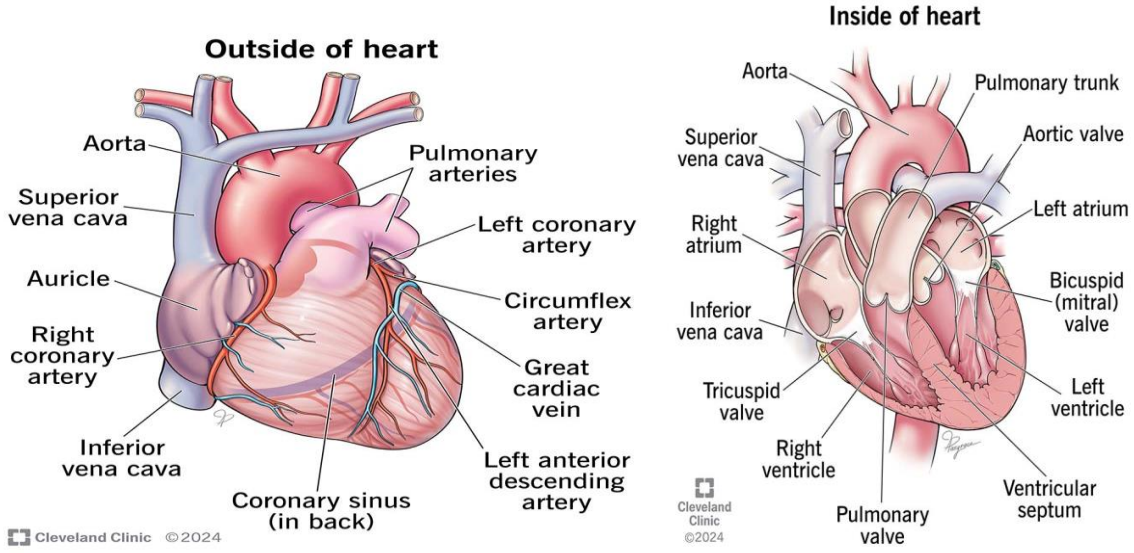
3rd Year Veterinary Medicine

1. Anatomical and Physiological Review of the Heart

The heart is a hollow organ divided into four chambers by two septa: a complete longitudinal septum, the cardiac septum, which divides the heart into left and right hearts, and an incomplete transverse septum that divides the heart into atria and ventricles, communicating through openings in the transverse wall called the atrioventricular ostia. Through an extensive arteriovenous vascular network, the cardiac pump enables irrigation and drainage of all tissues in the body.

The heart is located in the middle mediastinum, surrounded by its own serous membrane, the pericardium, which is itself surrounded by the lungs. The cardiac area projects onto the thorax between the 3rd and 6th ribs. The right heart is positioned anteriorly, while the left heart is posterior. It is displaced from the median axis by 4/7 toward the left. The cardiac axis is oblique in a ventro-caudal direction and from right to left. Therefore, the heart is closer to the left thoracic wall than the right. The caudal border of the heart forms an angle of 30 to 40 degrees with the sternal axis.



1.1 Heart Wall Layers (Tunics)

The heart is composed of three layers:

Endocardium

This is the innermost layer, continuous with the endothelium of veins and arteries. It lines all internal walls of the atria and ventricles, as well as the surface of the valves. It consists of an endothelium resting on a subendothelial layer composed of loose connective tissue, elastic fibers, and smooth muscle cells. Between the myocardium and endocardium lies a subendocardial zone. This is a connective-adipose zone containing vessels, myelinated nerve fibers, and cardionector cells.

Myocardium

This is the cardiac muscle. It consists of two types of muscle cells: myocardial cells and nodal tissue cells or cardionector cells, all resting on connective tissue structures. The ordinary myocardium is striated muscle identical to skeletal striated muscle, ensuring mechanical activity. The nodal tissue, however, is specific cardiac muscle tissue. It has the capacity for self-stimulation: it constitutes the automatic tissue of the heart (commands and coordinates the various structures involved in the cardiac cycle).

Epicardium

This is the outermost layer, lining the external surface of the heart. It is a very thin fibrous layer corresponding to one of the pericardial leaflets.

1.2 Pericardium

The pericardium is an envelope enclosing the heart and proximal portions of the pulmonary trunk, aorta, and terminations of the vena cavae and pulmonary veins, suspending the heart within the mediastinum. It has several important functions:

- Anatomical fixation of the heart
- Mechanical protection of the heart
- Limitation of cardiac dilation
- Barrier against inflammation
- Lubrication as well as hemodynamic role

1.3 Blood Vessels

Within the thoracic cavity, various blood vessels are present, the most important of which are:

- The aorta, which originates from the left ventricle in a ventral position relative to the base of the heart. It takes a cranio-dorsal orientation then curves into an aortic arch, before positioning itself ventrally to the vertebral column at the level of the 6th or 7th thoracic vertebra, then continues caudally along the ventral surface of the vertebral bodies, slightly to the left of the median plane. It then passes through the diaphragm at the aortic hiatus.
- The pulmonary trunk, arising from the right ventricle, originates from the left side of the individual, cranially, with a backward curve that brings it ventrally and caudally to the aorta: it has a cranial convexity. It then divides into two pulmonary arteries: the right and left pulmonary arteries going to the right and left lungs. Each of these arteries enters at the hilum of the lung then branches following the lobar divisions of the lung.
- The caudal vena cava passes through the diaphragm at the caval hiatus and then enters the thoracic cavity. It subsequently joins the heart in the right hemithorax.
- The cranial vena cava enters the thorax.

1.4 Left Heart

The myocardium of the left heart is more developed than that of the right heart. It ensures systemic or general circulation. The pulmonary vein supplies the left atrium; the atrioventricular valve is called the mitral valve. From the left ventricle arises the aorta, separated from it (from the ventricle) by the aortic semilunar valve.

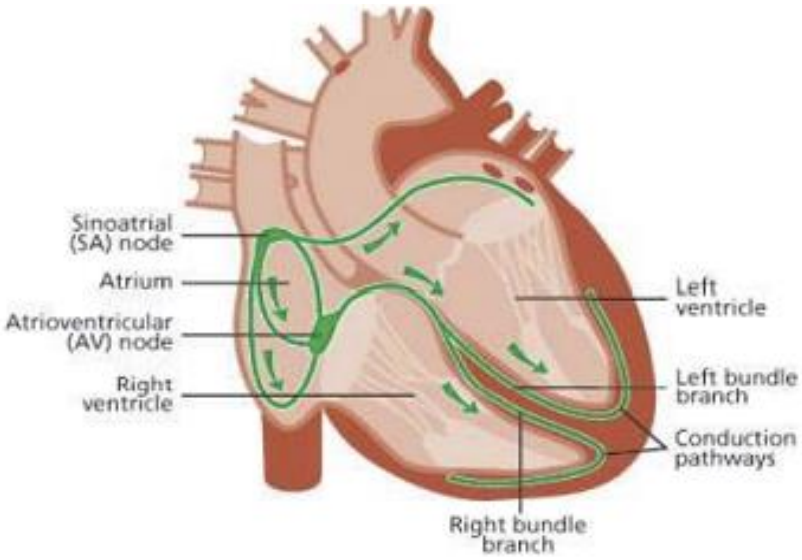
1.5 Right Heart

It ensures the small circulation or pulmonary circulation. Blood arrives at the right heart in the atrium via the cranial and caudal vena cavae, then passes through the right atrioventricular valve or tricuspid valve and exits through the pulmonary trunk, from which it is separated by the pulmonary semilunar valve. The azygos vein empties directly into the right atrium.

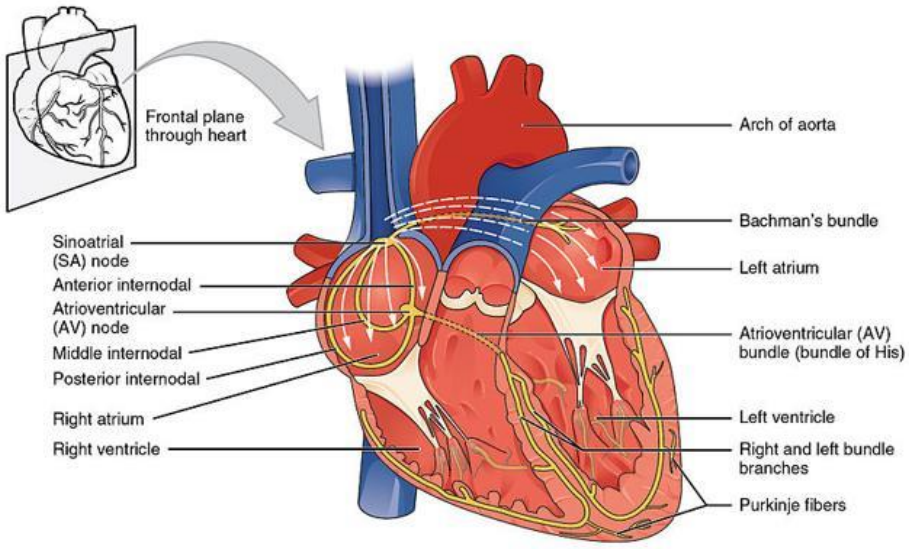
1.6 Nodal Tissue

It consists of muscle fibers with particular electrical activity. It forms two essential poles:

- The Keith and Flack node or sinoatrial node; it is located in the right atrium near the opening of the anterior vena cava.
- The Aschoff-Tawara node or atrioventricular node; it sits at the base of the interatrial septum.
- The atrioventricular node is extended toward the apex by a nodal cord called the bundle of His. It travels through the membranous portion of the interventricular septum as a single cord and divides into two right and left branches in the muscular portion of the septum. At the cardiac apex, these branches become finer and branch out as they ascend toward the base of the heart, forming the Purkinje network.



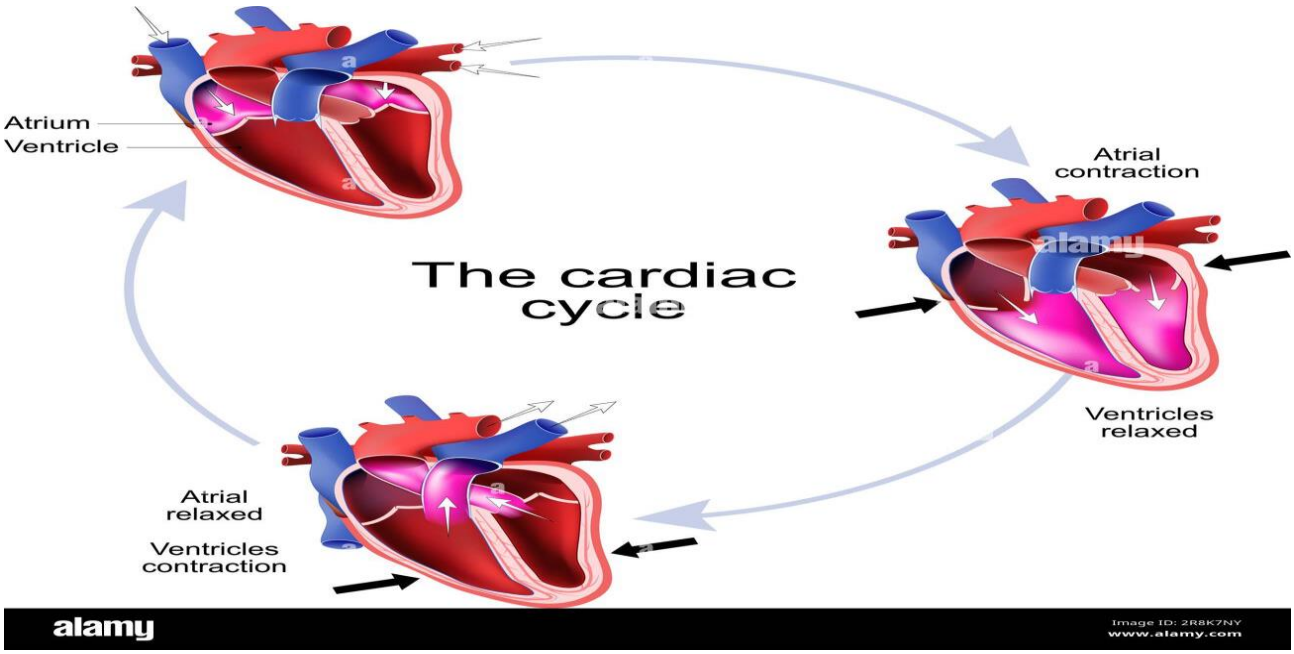
The fibers of the nodal tissue have an unstable resting potential and are capable of spontaneously depolarizing and reaching the threshold excitation potential, which has an action potential value. It is these characteristics that give the heart its automaticity. However, if each nodal center depolarized spontaneously and independently, cardiac contractions would be anarchic.



Anterior view of frontal section

There is a hierarchy within the nodal formations. In dogs as in all mammals, it is the sinoatrial node that ensures the conductor functions. The depolarization wave originates in the sinoatrial node and propagates through this tissue: it reaches the atria, the atrioventricular node, the two branches of the bundle of His, and finally the Purkinje network. This wave triggers contractions of the different cardiac chambers and thus creates blood flow.

1.7 Cardiac Cycle



Blood flow follows the laws of fluid dynamics, always moving in the direction of lower pressures. It proceeds as follows:

0. Atrial systole drives blood from the atria into the ventricles through the opening of the atrioventricular valves.
1. Ventricular systole occurs simultaneously with atrial relaxation. The increase in intraventricular pressure causes closure of the atrioventricular valves. Two phases are distinguished during ventricular systole:

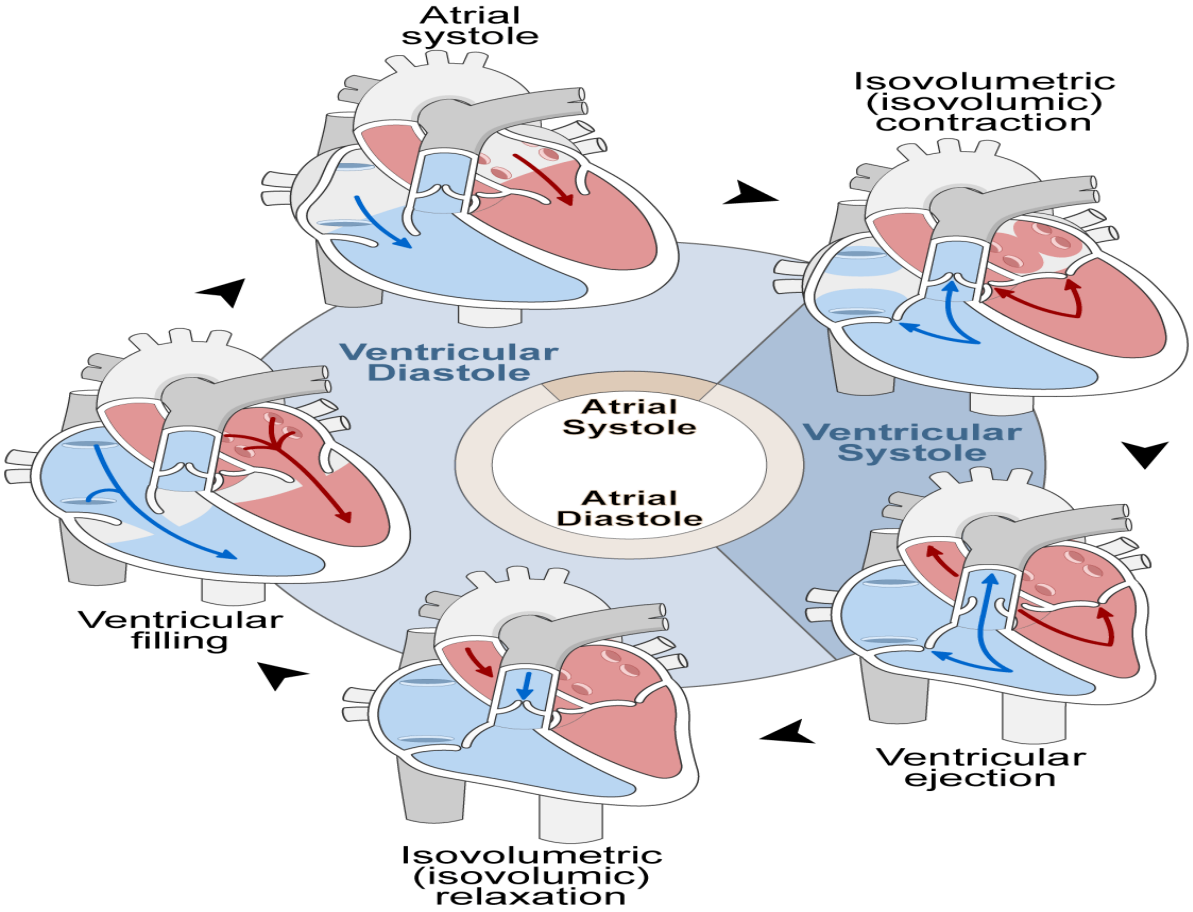
The isovolumetric contraction; this is the pre-ejection phase during which, with the valves closed, the muscle fibers cannot shorten due to the ventricular liquid content. Ventricular pressure then increases until it exceeds the downstream arterial pressure.

Ventricular ejection; the semilunar valves open passively under pressure and the muscle fibers contract. This phase occurs in an isobaric manner. However, ventricular blood is not completely ejected; a post-systolic residue remains.

2. Ventricular diastole corresponds to relaxation of the ventricles. The downstream arterial pressure becomes lower than that of the ventricles, causing closure of the semilunar valves. Two phases are distinguished:

Isovolumetric relaxation; endoventricular pressure rapidly decreases at constant volume since the valves are closed, then becomes lower than that in the atria. The atrioventricular valves open passively.

Biphasic ventricular filling is first passive. Atrial systole constitutes the active phase. The cycle is thus closed.



1.8 Cardiac Innervation

1.8.1 Parasympathetic Nervous System

Cardiac parasympathetic innervation is provided by the vagus nerve (cranial nerve X). This nerve travels from the brainstem to the thoracic and abdominal organs. For its cardiac portion, the left vagus nerve sends its branches to the atrioventricular node while the right vagus nerve terminates at the sinoatrial node. Control of cardiac parasympathetic innervation is carried out in the brainstem at the parasympathetic nuclei of the vagus nerve. Dogs and cats are species described as vagotonic: at the cardiac level, parasympathetic tone is predominant over sympathetic tone.

Effects of the parasympathetic nervous system:

The parasympathetic system is cardio-moderator; it has depressor effects on cardiac function. Stimulation of the vagus nerve produces effects:

- On the sinoatrial node by decreasing heart rate
- On the atrioventricular node by decreasing conduction velocity
- On cardiac muscle tissue by inhibiting the sympathetic nervous system

A decrease in blood pressure is also observed.

1.8.2 Sympathetic Nervous System

The heart receives innervation from the cervical cardiac nerves and thoracic cardiac nerves. Control of cardiac sympathetic innervation is provided by the medullary sympathetic centers, in the intermediolateral nucleus of thoracic spinal cord segments 1 to 5.

Effects of the sympathetic nervous system:

The sympathetic system is cardio-accelerator. During its stimulation, an increase in cardiac output is observed. However, in case of excessive stimulation and excessively high heart rate, cardiac output drops because diastolic time is too short to allow proper cardiac filling.

In total, the sympathetic nervous system acts:

- On the sinoatrial node by increasing heart rate
- On the atrioventricular node by increasing conduction velocity
- On all cells by increasing contraction intensity

1.9 Sinus Rhythm

Physiologically, it is the cells of the sinoatrial node that command the cardiac rhythm called sinus rhythm for this reason. The frequency of this rhythm is constantly modulated according to the body's needs by neurohumoral regulation (acceleration

under the effect of the sympathetic system and catecholamines, slowing under the effect of the parasympathetic system).

1.10 Conduction

The action potentials generated by the nodal tissue are conducted at high speed to the cells of the myocardium. Physiologically, the rhythm originating in the sinoatrial node activates the auricular myocardium then reaches the auriculoventricular node and the trunk of the bundle of His. This activity then spreads to the right and left branches of the bundle of His, the Purkinje cells, and finally the cells of the ventricular myocardium. The interventricular septum is depolarized first from left to right, then the ventricles from endocardium to epicardium.

2. Clinical Examination

2.1 History and Anamnesis

2.1.1 Age

In cardiovascular pathologies, age is very important to determine.

Example: Congenital cardiovascular pathologies such as mitral dysplasia (in dogs), tricuspid dysplasia (in dogs), etc., are characteristic of young age in dogs.

2.1.2 Breed

Certain cardiac pathologies have a higher incidence in certain breeds, such as atrial fibrillation in heavy horse breeds and certain cardiomyopathies in the Doberman breed.

2.1.3 Use

In the case of examining a sport animal (dog and horse), it is important to look for the presence of exercise intolerance, and to differentiate this exercise intolerance from a possible genetic deficit in sporting abilities of the animal or lack of training, which is not always easy.

In cases where a standardized exercise test (horse) would be performed, it is important to ask the owner about the animal's training status in order to correctly interpret the test results.

2.1.4 History of the Disease

It will be very important to determine whether the problem was of gradual or sudden onset, whether the problem occurs constantly or only under certain conditions, and to determine the duration of problem onset. Symptoms that may suggest a cardiovascular problem are as follows: depression, exercise intolerance, weight loss, lethargy, peripheral edema, abdominal distension (large belly), fever, changes in mental state (syncope with exercise), anorexia or dysorexia, diarrhea, polydipsia, cough, nasal discharge, dyspnea at rest and/or with exercise.

2.2 Cardiovascular System Examination

Most steps of the clinical examination of the cardiovascular system are integral parts of the general examination.

2.2.1 Distant Examination

During the general inspection of the animal at a distance as part of the general examination, a number of points are particularly important in evaluating the cardiovascular system:

- Mental state: A change in mental state can help identify a systemic pathology that could manifest as a cardiovascular pathology.
- Body condition of the animal; obesity is a risk factor for many cardiac conditions.
- Position: The animal may show pain during certain movements (standing up - lying down). During cardiac involvement, the animal may show signs of respiratory distress such as orthopnea, expiratory grunt, etc.
- Presence of edema or ascites: The preferred sites of peripheral edema formation following congestive heart failure are: the sub-sternal and sub-ventral regions, possibly accompanied by preputial edema (male) and/or the distal portion of the limbs.
- State of filling of the return veins, particularly the jugular veins.
- Venous pulse: In large animals, evaluation of the venous pulse should be done at the base of the heart; the venous pulse, if physiological, should not rise more than 10 cm above the base of the heart. Otherwise, it will be considered pathological.

When the animal is examined with its head down, as for example when grazing (horse), the presence of a venous pulse along the entire length of the neck may be completely normal since in this position the head is below the level of the right atrium.

2.2.2 Evaluation of Peripheral Circulation

2.2.2.1 Mucous Membrane Inspection

Healthy mucous membranes have a pink coloration, giving an idea of tissue oxygenation and peripheral perfusion. The mucous membranes that should be evaluated are the oral, nasal, and ocular mucous membranes, penile mucosa in males and vulvar mucosa in females:

- Pallor may be a sign of anemia or vasoconstriction

- Intense red color indicates congestion
- Blue-gray color is a sign of cyanosis (tissue hypoxia), manifested in animals in severe shock, with significant cardiac anomaly, or in young animals in case of severe pulmonary ventilation deficit

A change in mucous membrane color will only be observed in cases of severely compromised peripheral perfusion or very altered gas exchange.

2.2.2.2 Capillary Refill Time

Capillary refill time is a very reliable clinical sign for evaluating peripheral circulation: prolonged capillary refill time indicates decreased peripheral perfusion. It should normally be less than 2 seconds. It is measured by pressing on the oral mucosa.

2.2.2.3 Temperature of Extremities

The temperature of the extremities is evaluated at the level of the ears, nostrils, base of the tail, and digital extremities. Decreased temperature of the extremities indicates reduced peripheral perfusion. This sign is particularly important during cardiovascular dysfunction.

2.2.2.4 Pulse Evaluation

The pulse is the reflection of systolic effectiveness. In carnivores, palpation of the femoral artery allows estimation of the pulse, which should be strong; a strong pulse reflects good blood volume, while a weak (thread) pulse reflects hypovolemia (dehydration, hemorrhage, etc.). One feels regularity, strength, and concordance with the precordial thrust.

In the horse, the pulse is easily palpable at the facial artery, difficultly palpable on the brachial artery (deep artery of the medial surface of the forelimbs). Rectal palpation of the quadrifurcation of the aorta, the cranial mesenteric artery, and the internal iliac arteries can also be useful for evaluating the peripheral pulse, particularly in cases of aortic thrombosis.

The frequency, rhythm, amplitude, and regularity of the pulse will be evaluated:

- Frequency is particularly important to evaluate since most cardiovascular pathologies will manifest with tachycardia. It is measured over 15 seconds. The

dog has a frequency of 60 to 180 beats/minute (depending on size, nervous state); in the cat, the norm is between 100 and 240 bpm. In the horse, the normal heart rate is 24 to 40 bpm in adults and 70 to 100 bpm in young foals.

- The rhythm of the pulse is also important to consider since an arrhythmia may reflect primary or secondary cardiac dysfunction.
- Pulse amplitude constitutes a subjective but very important guide for evaluating the cardiovascular system. Pulse amplitude depends on vessel size, distance from the heart, and finally pulse pressure. Increased pulse amplitude (bounding pulse) is frequently encountered in aortic insufficiency in horses and is indeed one of the best prognostic factors in this pathology. However, decreased pulse amplitude results from reduced pulse pressure. Finally, variable pulse amplitude from one heartbeat to another may be indicative of atrial fibrillation.

2.2.2.5 Evaluation of Venous Circulation

The appearance of the jugular veins also attests to cardiac function: if they are swollen and turgid, this indicates right heart failure, where blood accumulates.

Compression of the jugulars at mid-height of the neck allows evaluation upstream of their filling speed, allowing evaluation of vascular hydration status, and downstream, the emptying speed, allowing evaluation of the quality of venous return to the heart.

2.2.3 Palpation of the Precordial Thrust

During its contraction, the heart exerts pressure on the thoracic wall called the precordial thrust. This can be felt in most animals by placing the hand on the left thorax in the cardiac region, that is, at the 4th and 5th intercostal space in the lower third of the thorax.

The ease with which the precordial thrust can be perceived is influenced by thoracic conformation, thickness of the thoracic wall, and amount of subcutaneous fat. In most animals, the precordial thrust is difficult to detect on the right thorax.

The diagnostic value of precordial thrust palpation is limited in large animals. If it is palpable over a larger area than normal, this may suggest cardiac dilation.

Very significant blood flow turbulence in the heart or great vessels may possibly be detected by palpation, appearing as a thrill or vibrations, which is generally the case with a severe anomaly (associated with a heart murmur). In young animals with congenital cardiac anomalies, a thrill associated with the heart murmur is frequently palpated.

Finally, thoracic palpation may possibly allow detection of pain in the cardiac region, as for example in cases of traumatic pericarditis.

2.2.4 Thoracic Percussion

Percussion is reserved for large animals. It can be performed either by percussing the thorax directly with the fingers or by placing one hand with the palm against the thorax and tapping with the fingers of the other hand on the back of the hand. A dull resonance may reveal thoracic effusion, cardiomegaly, thoracic mass, etc.

2.2.5 Respiratory Examination

Most cardiac pathologies concern the left heart. When these pathologies evolve into congestive heart failure, hypertension progressively develops in the pulmonary vascular network.

Hypertension in the pulmonary network most often evolves into interstitial edema rather than pulmonary edema, except at an advanced stage of the pathology, which is generally a sign of terminal evolution.

Interstitial edema is often difficult to detect clinically, accompanied by increased amplitude of respiratory movements especially marked after exercise.

Alveolar edema, when it occurs, is clinically detectable by tachycardia, polypnea, increased amplitude of respiratory movements, cough, and mixed dyspnea. Pulmonary auscultation reveals inspiratory and expiratory crackles. If pulmonary edema is very extensive, foam may appear at the nostrils.

2.2.6 Auscultation

2.2.6.1 Acoustic Concepts

The mechanical action of the heart creates vibrations. Propagated, they are the origin of heart sounds; their methodical listening constitutes cardiac auscultation.

A sound is characterized by three measurable properties:

- Intensity (amplitude), measured in decibels, depends on the importance of the air mass displaced by the wave.
- Frequency (pitch) is determined by the number of vibrations per second. The human ear hears acoustic vibrations in air from 20 Hertz (low sounds) to 20,000 Hz (high sounds) with an optimal zone between 1000 to 3500 Hz. Below 20 Hz, we speak of infrasound; above 20,000 Hz, we speak of ultrasound.

Canine, feline, and equine heart sounds have a frequency varying from 20 to 500 Hz or even 1000 Hz. A large part of heart sounds is below the threshold of audibility, which limits the information provided by auscultation.

- The duration of the sound allows recognition of two types of sounds from the heart: short-duration sounds or heart sounds and long-duration sounds or murmurs. Physiological murmurs are often heard in horses and puppies.

2.2.6.2 Heart Sounds

There are potentially 4 heart sounds called S1, S2, S3, and S4; 2 of them (S1, S2) are found in all species. Sound S4 is frequently heard in horses as the first sound perceived in a new cardiac cycle.

First Sound (S1): The first sound (S1) is low-pitched, dull, prolonged with a frequency varying from 50 to 400 Hz; it lasts 0.08 to 0.1 second and appears 0.04 second after the Q wave of the electrocardiogram. It is the loudest of the four heart sounds in carnivores, while in horses it is less intense than S2. It is expressed orally as: BOUM, TOUM in French, LUB in English-speaking countries, or BUH in German. It is contemporary with the apical thrust.

The first sound (S1) is heard at the beginning of ventricular systole (isovolumetric contraction). It occurs when ventricular pressure is higher than atrial pressure, therefore at the closure of the atrioventricular valves. It corresponds to the summation of several vibratory phenomena:

- Closure of the mitral and tricuspid valves or more exactly (vibrations of valvular origin)
- Tensing of the ventricular walls (vibrations of muscular origin)
- Opening of the semilunar valves and ejection of the blood mass toward the great vessels (vibrations of vascular origin)

Second Sound (S2): It is shorter than the first sound: it lasts 0.05 to 0.06 second and occurs at the end of the T wave of the electrocardiogram, that is, at the end of ventricular systole. It is a short, sharp sound with a frequency of 100 to 200 Hz, optimally heard in the aortic and pulmonary auscultation areas.

The second sound (S2) occurs at the beginning of ventricular diastole, that is, when the ventricle begins to relax and intraventricular pressure becomes lower than that in the arterial trunk. It corresponds to the closure of the aortic and pulmonary semilunar valves and the vibratory phenomenon produced by the blood column.

S2 has indirect origin from closure of the semilunar valves with 2 components:

- An aortic component (A2)
- A pulmonary component (P2)

It is generally difficult to hear the two components of S2 separately except sometimes during respiratory arrhythmia in dogs: the time interval between A2 and P2 increases (more than 30 msec) with each inspiration allowing identification of the splitting. The widening between A2 and P2 is due to the fact that venous return increases during inspiration, lengthening the systolic ejection time of the right heart and causing delayed closure of the pulmonary valves. In healthy horses, splitting of S2 is not heard.

Third Sound (S3): It is normally never audible in dogs (considered pathological in dogs) and rarely in cats. It may be audible in horses. It occurs during the long silence. When it becomes audible, the rhythm of the cardiac cycle becomes analogous to the rhythm of a galloping horse. This third sound is therefore called the gallop sound.

Fourth Sound (S4): It is normally never audible in dogs and rarely in cats. It is considered pathological in dogs and cats but is very frequently heard in horses when the heart rate is low. It occurs during the long silence. Like S3, when it becomes audible, the rhythm of the cardiac cycle is called a gallop sound.

2.2.6.3 Variation in Heart Sounds

Heart sounds are decreased by obesity, emphysema, pleural and pericardial effusions, thoracic masses and diaphragmatic hernias, when cardiac contractility is diminished or when an obstacle prevents the heart from having high output. Heart sounds are increased by young age, thinness, elevated heart rate, anemia or fever, etc.

2.2.6.4 Heart Murmurs

These are superimposed noises characterized by their spatial location (apical/basal, right/left), their temporal location (systolic, diastolic, continuous), and their grade, which allows their follow-up over time.

Heart murmurs are sounds of longer duration than the normal sounds already described. They are due to vibrations induced by turbulent blood flow passing through stenotic or narrowed orifices. Blood follows the laws of hydrodynamics; it obeys the Reynolds formula:

Reynolds Number = 2 x r x d x v / n

v: velocity; r: conduit diameter; n: viscosity.

Audible turbulence appears when this number takes a value greater than 2300. Blood fluid has constant density, so its turbulence will depend on the 3 other factors.

Murmurs are mechanical anomalies of the heart: their exploration requires echocardiography. They have various causes:

- Valve closure insufficiencies
- Caliber reductions of passages used by blood or stenoses
- Abnormal communications between the various chambers of the heart
- Variations in blood velocity and viscosity

A number of characteristics allow knowledge of the etiology of the murmur heard on auscultation:

- Its duration and place in the chronology of the cardiac cycle (systolic, diastolic, continuous, etc.)
- Its anatomical location (heard mainly on the left apical area, etc.)
- Its intensity (grade from 1 to 6 on a scale of 6): The strength of a murmur is characterized by a grade from 1 to 6:

Grade I: Very faint, requires great auditory attention

Grade II: Faint, but immediately heard

Grade III: Moderate (most hemodynamically significant murmurs are grade III)

Grade IV: Loud, accompanied by a thrill on palpation

Grade V: Very loud, but requires a stethoscope to be audible

Grade VI: Audible without a stethoscope

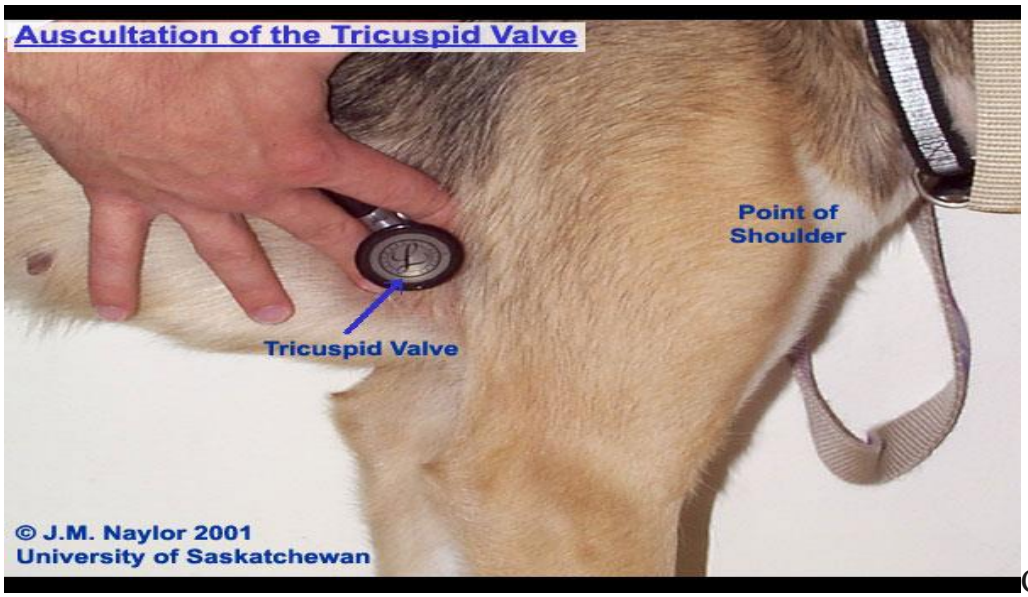
2.2.6.5 Cardiac Auscultation: Practical Aspects

The stethoscope (stethos: chest, skopein: to see) is the instrument necessary for auscultation. It consists of a terminal piece with two faces. One is equipped with a diaphragm and the other with a bell. The terminal piece is connected by tubing to earpieces. The bell of the stethoscope should allow transmission of low-frequency sounds (20-100 Hz) and the diaphragm, that of high-frequency sounds (100-1000 Hz). For correct auscultation, it is necessary to have:

- An adequate and properly placed stethoscope (earpieces)
- A prepared animal (calm)
- A quiet environment (avoid parasitic noises, etc.)
- Proper placement of the stethoscope on the different cardiac areas
- Perform a systematic exploration
- Good training; do not hesitate to spend several minutes auscultating

Auscultation Zones:

- On the left, the mitral valve zone ventrally, the aorta and pulmonary trunk zone dorsally
- On the right, the tricuspid zone, the right atrial zone, the right ventricular zone, the aorta and pulmonary trunk zone

- 

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3. Complementary Examinations

3.1 Electrocardiography

Electrocardiography is a procedure used for semiological purposes; it aims to record the electrical phenomena generated by the heart during its revolution (depolarization, repolarization), which allows identification of the chronology and topography of myocardial activity. The electrocardiogram (ECG) is its graphic translation. Indications for an ECG are:

- Rhythm disturbances
- Significant dyspnea
- Shock
- Syncope or convulsion
- Peri- and post-operative monitoring
- Treatment with anti-arrhythmics
- Electrolyte imbalances (hypokalemia)
- Cardiomegaly
- Exercise and sporting abilities (horse)

The ECG gives no indication of the mechanical properties of the myocardium, not exploring the totality of cardiac pathology (valves, endocardium, pericardium).

3.1.1 Presentation of a Typical Electrocardiographic Tracing

The first wave or auriculogram is called P, corresponding to depolarization of the atria, from activation originating at the sinoatrial node.

The second wave is a complex described by the letters QRS, being related to depolarization of the septum and ventricles (ventriculogram).

The third wave, T, translates ventricular repolarization (atrial repolarization being electrically masked by ventricular depolarization).

The PR segment corresponds to the time of passage of activation from the atrium to the atrioventricular node (AVN).

Whatever the position of the electrodes, the species and breed (especially canine breeds) being examined, one always finds a P wave, a QRS complex, and a T wave. However, the morphology, direction, and amplitude of the waves are very different, due to the depolarization patterns of the heart presenting specific particularities.

3.1.2 Reading the Tracing

The successive steps of tracing analysis are:

3. Determination of heart rate
4. Evaluation of cardiac rhythm: Inspection of the tracing, identification of P waves and QRS complexes, P-QRS concordance
5. Measurement of durations and amplitudes: P wave, PR interval, QRS complex, ST segment, T wave, QT interval
6. Determination of electrical axis: By approximation, one can estimate that the electrical axis is parallel to the orientation of the largest QRS complex deflection

3.1.3 Interpretation of the Tracing

To interpret an ECG tracing, one must take into account:

- Heart Rate: Number of heartbeats per unit of time (usually per minute)
- Sinus Rhythm: Normal cardiac rhythm, commanded by excitations originating in the sinoatrial node. A cardiac rhythm is said to be sinus on ECG if:

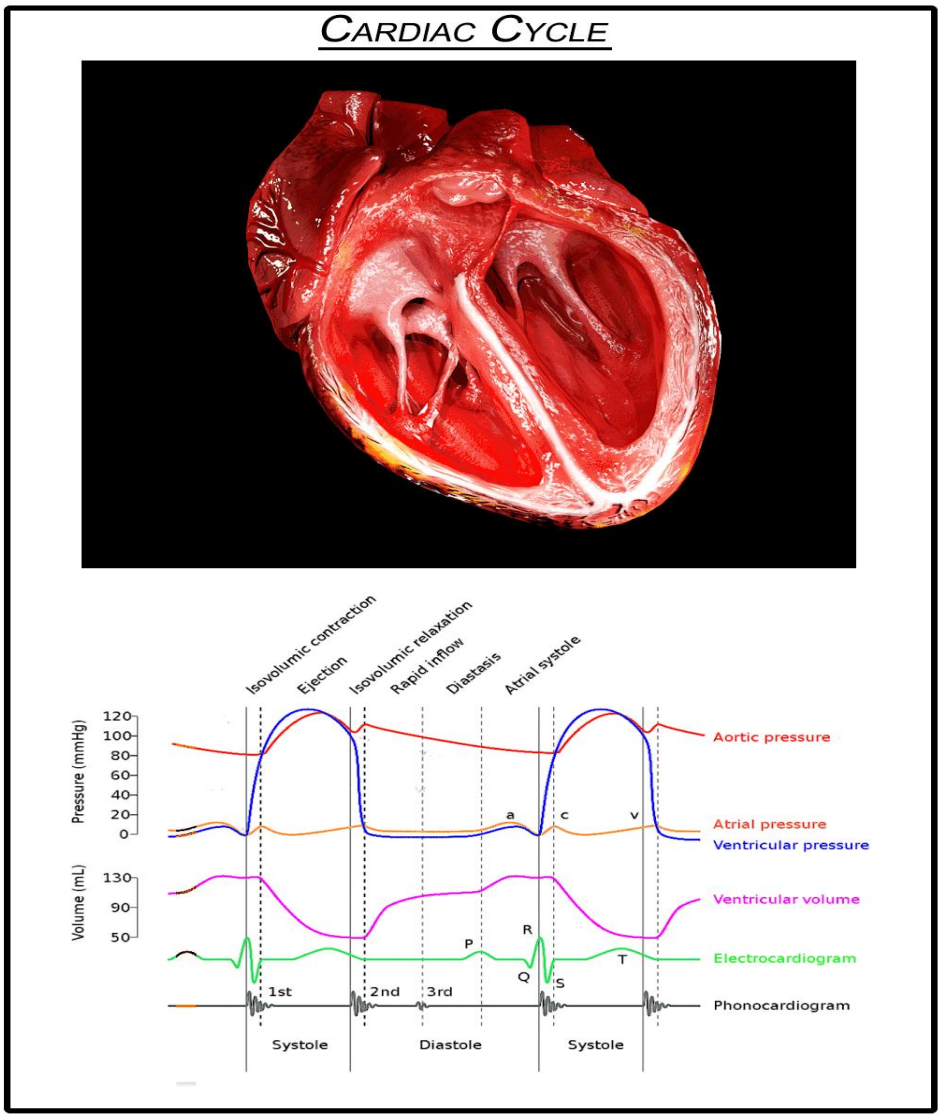
- Every P wave is followed by a QRS complex

- Every QRS complex is preceded by a P wave

- The PR interval is constant and less than 0.13s in dogs, 0.09s in cats

- The morphology of the P wave is normal and QRS is supraventricular

- Sinus Arrhythmia: Irregularity of cardiac rhythm linked to a disturbance in the cadence of excitations at the sinus itself



3.1.4 Cardiac Conduction Disorders

Heart Block: Rhythm disturbance characterized by the fact that the excitation wave does not propagate, or propagates with difficulty, in the cardiac conduction system.

Sinoatrial Block: Cardiac rhythm disturbance due, theoretically, to blocking of the excitation wave between the sinus and the atria.

Atrioventricular Block (AVB): Cardiac rhythm disturbance characterized by slowing or stopping of conduction of excitation between the atria and ventricles. They are classified into 3 main categories:

- First-degree AVB: Slowing of conduction, translating on ECG as prolongation of the PQ duration (greater than 0.13s)

- Second-degree AVB: Transmission of only certain atrial excitations to the ventricles, translating on ECG by the fact that not all P waves are followed by QRS
- Third-degree AVB: Permanent absence of atrioventricular conduction. No P wave is conducted; the ventricles will then contract secondarily to activation of an accessory junctional or ventricular pacemaker

Bundle Branch Block: Intraventricular cardiac block attributable to a lesion of one of the two branches of the bundle of His, preventing the motor excitation from normally reaching the concerned ventricle (conduction delay).

3.1.5 Cardiac Excitability Disorders

Atrial Flutter: Cardiac rhythm disturbance characterized by a series of atrial contractions succeeding rapidly without pause.

Fibrillation: Disordered trembling of cardiac muscle fibers, leading to inability of coordinated contractions of the concerned cardiac chambers.

Extrasystole (ES): Premature contraction of the heart, of ectopic origin, generally followed by a longer pause than the ordinary pause. They may be isolated or in salvos, atrial or ventricular depending on their site of appearance. We speak of monomorphic ES if they have the same morphology, polymorphic ES if their morphologies are different from each other.

3.2 Radiography of the Cardiovascular System

Thoracic radiography allows evaluation of the size and shape of the cardiac silhouette, as well as the consequences of heart failure.

3.2.1 Interpretation Principles

Analysis includes:

- The size of the cardiac silhouette
- The contours of the heart, particularly those of the 4 chambers, the great vessels, and the trachea
- Any anomalies of cardiac structure

Evaluation of the Cardiac Silhouette:

The cardiac silhouette can vary considerably in shape and size from one animal and breed to another. It is generally larger and rounder in small dogs with short or round chests, and visually smaller and more elongated in dogs with deep chests.

When evaluating the cardiac silhouette, it is essential to consider the breed of the dog being evaluated and ideally to compare with radiographs of a dog of the same breed judged normal. A clock face analogy system has been used for evaluation of the cardiac silhouette in dogs and cats. This system is more easily used on a ventrodorsal or dorsoventral view.

On the ventrodorsal view, the cardiac structures associated with the clock hours are as follows:

- 11-1 o'clock: Aortic trunk (TA)
- 1-2 o'clock: Pulmonary trunk (PT)
- 2-3 o'clock: Left atrial appendage (LAA)
- 3-6 o'clock: Left ventricle (LV)
- 6-9 o'clock: Right ventricle (RV)
- 9-11 o'clock: Right atrium (RA)

The method described by Buchanan uses a measurement index that compares the maximum length of the long and short axes of the heart to the thoracic vertebrae. Each axis is measured perpendicularly, then compared individually to the thoracic vertebrae, starting from the cranial surface of the T4 body. The number of vertebrae included in each measurement is calculated.

The sum of the 2 measurements should be between 9-10.5 in dogs (up to 11 in barrel-chested dogs), and 7-8 in cats. A normal index does not necessarily mean absence of cardiac pathology.

3.3 Echocardiography

Echocardiography is a complementary examination allowing confirmation or exclusion of the presence of dilated cardiomyopathy with certainty.

Echocardiography can evaluate ventricular function and the importance of chamber dilations for prognostic and therapeutic purposes. It also allows identification of sequelae following dilated cardiomyopathy such as valvular regurgitation, atrial thrombus, or pericardial effusion.