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Concepts in canine cardiology
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Heart anatomic and physiologic background

In order to understand how the heart works, it is essential to know all of its anatomical structures. Longitudinally, it is divided in right and left sides. In each part, there is one atrium, one ventricle and two valves. Valves found between atria and ventricles are named tricuspid (in the right side) and mitral (in the left side). Each of these valves has several parts: (1) the leaflets that make the valve itself, (2) tendinous cords which role is to hold them, (3) papillary muscles that are the connection between the heart muscle and the tendinous cords, and (4) the valve ring. On the other hand, the semilunar valves are found at the ventriculi exit. The right side one is named pulmonary valve, and the one in the left side is named aortic valve. Normally, blood arrives to the heart through cranial vena cava and caudal vena cava entering the right atrium. From there, it moves to the tricuspid valve, into the right ventricle and to the lungs through the pulmonary artery, in order to be oxygenated. Then, the blood flow goes back to the heart through pulmonary veins, but this time entering the left atrium, through the mitral valve, the left ventricle and going out through the aorta into the system circulation (Figure 1).

The heart movement has two stages that define a beat: systole or contraction phase, and diastole or relaxation and filling phase. The blood flows that circulate through both sides move in a simultaneous way. During the systole, ventricles contract and pump blood into the lungs (right side) and the general circulation (left side). In this moment, atrium-ventricular valves must remain closed in order to prevent blood from move back into the atria, and pulmonary and aorta valves must open to allow the blood ejection. During the ventricular systole, the atria fill of blood at the same time. Then, once ended the systolic phase, the heart relaxes and gets ready for the following beat (diastole phase). Now, tricuspid and mitral valves must open to allow the blood to move from atria into ventricles, and semilunar leaflets must remain closed. Once the ventricles are filled enough, atrium-ventricular valves are closed and the heart is already prepared for the following systole.

Physical examination

We must record in the clinical history the animal data (age, breed, sex, previous diseases, result of tests performed, treatments administered, doses and response to them, vaccinations, familiar history, surgeries, etc). Signs more often observed in patients with cardiovascular disorders are dyspnea, cough, exercise intolerance, syncopes, edema,… At physical examination, the conscience level, the animal position, the nutritional condition and the presence of abnormal sounds essentially with regard to respiration must be assessed, as well as the respiratory pattern, frequency (normal between 10 and 30 rpm) and rhythm. At pulmonary auscultation, the different lung areas and the presence of crepitating must be evaluated. The femoral pulse is evaluated on the internal side of the thigh bilaterally. It must be symmetrical, regular and synchronized with the heart beat shock of apex. Both oral and conjunctive mucose membranes must be evaluated, as well as the preputial or vulva mucose. The mucose membranes color may be
normal (pink), pallid, icteric (yellowish) or cyanotic (bluish). The filling time must be below 2 seconds under normal conditions.

Heart auscultation must be carried out following an ordered and routine technique. The four heart valvular focus must be auscultated: the pulmonary focus in the third left intercostal space at costochondral union level; the mitral focus in the fifth left intercostal space in the area of apex shock; the aortic focus in the left fourth intercostal space at the scapulo-humeral joint level and the tricuspid focus in the fourth right intercostal space at the costochondral union level. When a murmur is identified, the valvular focus where it is more intensely auscultated must be recorded. Also, arrhythmias like tachycardias, bradycardias or premature beats followed by a stop of variable length can also be identified.

**Basic electrocardiography**

The electrocardiography consists of the recording and study of the electric activity generated by the heart, and by placing four skin electrodes that transfer electric information to the electrocardiograph (Figure 2A). The main clinical indications of the ECG include: (1) differential diagnostic of the various arrhythmias auscultated, (2) try to identify a potential cause of syncope, and (3) to control the effectiveness of the drugs administered to our patient. The ECG can be performed with the patient in lateral recumbent or standing. It is important to have the animal as calmed as possible, so that the position is not an excessively important fact. Skin electrodes must be placed on the patient as follows: Yellow (left fore limb), Red (right fore limb), Green (left hind limb) and Black (right hind limb). They must be impregnated with gel or alcohol in order to achieve good contact and transmission.

Interpretation of the ECG is much easier when a routine and ordered protocol is followed. The following steps must be followed: (1) calculation of the heart frequency, (2) rhythm evaluation, (3) waves P identification, (4) QRS complexes morphology evaluation, (5) confirmation of interrelation between P waves and QRS complexes, and (6) differentiation between extrasystole and escape beat.

The ECG is basically used to determine the type of arrhythmia of our patient, being defined as alterations of: (1) frequency, regularity or the place of origin of the heart stimulus, (2) interruptions in the stimulus conduction, and (3) alterations in the activation sequence of atria and ventricles.

**Holter record**

The Holter is an ambulatory electrocardiography system that consists of a portable non invasive device that records the heart electric activity in a continuous way for 24-48 hours. This a very useful tool that allows to overcome some of the electrocardiograph limitations, since the ECG obtained for a 5 minutes period is not representative of the heart electric activity of the complete day, because rhythms may occur intermittently at any moment.

The holter is indicated to (1) diagnose the cause of syncopeces and episodes of weakness, (2) to evaluate the arrhythmia seriousness, (3) to monitor the efficacy of the antiarrrhythmic therapy, and (4) to detect patients with predisposition to suffer from heart diseases. Throughout the record, the patient must be in its usual environment, performing the activities he would do in a routine way. The device uses to be placed in the interscapular area and hold and protected by dressing. Once the record is completed, the device must be removed and data are unloaded to a computer in order to be read.
In order to interpret correctly the record, it is essential to have got a list of the activities the dog has performed in each moment, especially if during the test weakness, lethargy or syncope has occurred. If bradycardia appears, it is interpreted differently if the dog was sleeping than if it was making a moderate physical activity. In the first case, it would no be very important, whereas in the second case it could be due to problems in the sinoatrial node or in the electric conduction, so that its heart could not cover the needs required for such activity.

Heart radiology

In all radiographies, the air is black, the bones are white and the organs and soft tissues are grey. There are three positions of the patient to evaluate appropriately the thorax radiographies: (1) laterolateral, dorsoventral and ventrodorsal. It is very important to carry out the shot at maximum inspiration, in order to obtain lungs with the maximum degree of insufflation and to evaluate objectively the presence of lesions in lung areas. The radiography must be evaluated in a routine, ordered and complete way. Starting from a correct position and a good radiographic contrast, the first structures to be evaluated are the thorax cage (column, sternum, ribs and diaphragm); then, the heart silhouette and large vessels, the mediastinum, the trachea size and location, and finally the lung areas.

Since a radiological point of view, a good radiography allows to evaluate the presence of: (1) position, size and silhouette of the heart, (2) to identify signs of heart failure, and (3) to evidence thorax extracardiac diseases that could be associated to the clinical presentation of our patient. Taking into account the heart silhouette variations among breeds, the most objective method to detect the presence of cardiomegaly is the vertebral heart score (V.H.S), also named “Buchanan index” (Figure 2B). It is calculated by measuring the distance between the carina and the heart apex, and then, the largest perpendicular distance to the anterior axis from the ventral part of the caudal vena cava to the cranial edge of the heart silhouette. Both measures are moved to the spinal column taking as starting point the cranial edge of the fourth thoracic vertebra. The number of vertebral bodies occupied by each of both measures is counted, and both values are summed. The heart size is considered as normal if the sum is below 9.7 +/- 0.5 vertebral bodies in dogs. For the evaluation of alterations in each heart chamber and large vessels, the “Watch Method” can be used, which consists of dividing the heart silhouette area in timeslots that determine the various structures (Figures 2C and 2D).

Sometimes, in patients with congestive heart failure, it can be observed the presence of pulmonary edema, pulmonary venous congestion and/or pleural effusion. In dogs, cardiogenic pulmonary edema indicates left congestive failure usually due to mitral valve failure, whereas the pleural effusion, when cardiogenic, is due to right congestive failure. In dogs, the pulmonary edema is identified as diffuse infiltrate in the perihilar area, in the caudodorsal pulmonary areas caudally to the left atrium in the laterolateral view. The pleural space corresponds to the area located between the lung and the costal wall. The pleural effusion is the accumulation of fluid in this space. Total or partial loss of the heart silhouette and the diaphragm is observed, as well as separation of pulmonary edges with regard to the thorax wall and vertebrae, interlobe fissures and trachea elevation in the laterolateral view.

Ultrasonography: patient preparation and positioning

Ultrasonography allows to evaluate valve lesions, the heart chambers size, the myocardial function, the presence of pericardial effusions and to diagnose the
various congenital cardiomiopathies. It is indicated when clinical signs (cough, exercise intolerance, arrhythmias, pulmonary edema, cardiac dilatation observed radiologically, cyanosis, lethargy, abnormal femoral pulse, murmurs, syncope, …) suggest the presence of cardiac disease. In order to carry out a good ultrasonography study, it is usually necessary to clip both sides of the area where the highest intensity of the heart beat is detected. Also, it is necessary to clip a little part of hair caudally to the last rib, close to the ventral zone in the left side. Sometimes, the clipper can be avoided by moisturizing the hair with water and soap. Once the patient positioned on the ultrasonography table, it is essential to restrain it appropriately. It must be positioned laterally by extending the fore limbs and preventing him from sitting up.


References