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THE EQUINE HEART: Diagnosing disease – physical examination, electrocardiography and echocardiography

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INTRODUCTION
The physical examination is still the most important portion of the diagnostic work-up in the sick horse. Defining which system(s) is affected is essential, although not always easy, when clinical signs are subtle.

TAKE A GOOD HISTORY
• Signalment – age, breed and sex are very useful !!
• contact with other horses
• herd health – are the other paddock mates clinically normal ?
• vaccination status
• performance changes – “grumpy”, decreased function, collapse
• trauma – fractured ribs & myocardial damage, fractures ribs and lung parenchymal damage, diaphragmatic hernia
• other illness – is it related ? (eg. Mild respiratory signs, a few weeks later febrile and cardiac murmur and high fibrinogen and very high WCC, then it might be due to endocarditis)
• feed changes, feed source (cattle feed preparation before equine – ionophores in feed by mistake)
• changes in appetite and water intake – does the client really know ? (i.e. paddock situation)
• toxic plants in your area
• urinating – does the owner/trainer really know – i.e. paddock versus stabled
• medications by the owner – eg. NSAIDS – how many different ones have been administered? [eg. Phenylbutasone & Finadyne® (Flunixin meglumine)]

EVALUATION OF THE PATIENT FROM A DISTANCE

The first thing to notice is whether the horse is bright, alert and willing to move around freely, or whether it has obtunded mentation (i.e. dull).

Then record the condition score of the horse, as this may help determine whether there is underlying chronicity to the disease state. Horses with chronic inflammation, due to many conditions including valvular endocarditis, pulmonary or abdominal abscessation, pneumonia or primary or metastatic neoplasia, may have weight loss or diminished average daily gain (i.e. young horses). Weight loss due to neoplasia in horses may also be compounded by cancer cachexia - part of the paraneoplastic syndrome.

After estimating the body-weight of the patient, one should note the head and neck posture of the patient. The head, ventrum, and extremities should not have any oedema. The abdominal silhouette and the distal limbs should be examined to see if ascites or oedema is present, in case of cardiac disease, hypoproteinaemia and vasculitis etc..
Diagnosis of cardiac disease in the horse can be difficult. Understanding normal cardiovascular physiology is important, because it can make our job easier.

- In the horse it is easy to appreciate the first (S1) and second (S2) cardiac sounds, but it can also be normal to auscult the third (S3) and fourth (S4) heart sounds, which differs markedly from the situation in small animal cardiology. It may also be possible in the horse to hear split sounds for S1 and S2. All of these possibilities (theoretically it’s possible to hear 6 sounds – very rare !!) can be physiological and should not always be interpreted as abnormalities, especially in the absence of clinical signs.

- In the horse, S4-S1-S2-S3 have been described as sounding like du-LUBB-DUPP-boo respectively, although sometimes it is only possible to appreciate S1-S2 as LUBB-DUPP, and if they are split leLUBB (split S1) and deDUPP (split S2).

THE CARDIAC EXAMINATION IN MORE DETAIL

- First check the mucous membranes (mm) [for colour and capillary refill time (crt)]. Mucous membranes should be pink and moist with a capillary refill time less than 2-2.5 seconds. If mucous membranes are injected or pale, icteric, cyanotic or have petechial hemorrhages further testing should be considered to enhance documentation of these abnormalities. If cyanosis (i.e. bluish discoloration of the membranes/skin due to an increased concentration of reduced hemoglobin in the circulation) is present, then the PaO$_2$ is usually < 40 to 50 mmHg. Consequently visible cyanosis will only be present if the hemoglobin level in the blood is sufficient, whereas in cases of anaemia, despite concomitant desaturation, visible cyanosis will not be present. Severe respiratory or cardiac disease may potentiate this.

- Then, check the HEART RATE and respiration rate quickly before the horse is upset. The heart rate of the adult horse should be between 26 to 44 beats per minute. Get the facial pulse/digital pulse at the same time as the heart rate so you can check that there are no pulse deficits. There should be no pulse deficits (even when there is an arrhythmia).

- The heart rate provides valuable information about the horse’s demeanor, stimuli to sympathetic innervation and the state of the cardiac system. If the horse is in pain for any reason (eg. pleuropneumonia, colic, laceration) tachycardia is frequently present. It is important to judge: (1) the severity of the tachycardia and (2) whether the tachycardia is significant and related to other clinical signs, consistent with either primary respiratory disease or other system involvement (eg. mucopurulent nasal discharge, fever and coughing in cases of pneumonia versus pulse deficits, abnormal jugular pulsation and weight loss in cardiac failure or abdominal pain and absence of borborygmi in horse with colic). i.e. THINK ABOUT THE FOLLOWING CAUSES OF TACHYCARDIA: PAIN, FEVER, ENDOTOXAEMIA, HYPOVOLAEMIA, HYPOXIA, ANAEMIA (usually only when severe)

- If the heart sounds are abnormal, come back and ensure both left and right sides are ausculted, and have someone hold the nares off (i.e. stop airflow for 5 to 20 seconds), so respiratory sounds are obliterated (but recognize this is going to annoy many horses, so perform other less annoying parts of your exam first).

PULSE -Also try to get a feel for the pulse in terms of how easy it is to palpate [i.e. is it hyperkinetic (“bounding”) or is it weak ?] eg. If you have just diagnosed or are monitoring an aortic insufficiency case it is very important to know whether the pulse is bounding or changing. If this is changing and the pulse is becoming more hyperkinetic (i.e. bounding), this is a poor
prognostic indicator. I would like to check the horse at this time with telemetric electrocardiogram (ECG) for intermittent ventricular premature contractions (VPCs) – if more than one per hour is present on the ECG, then once again the prognosis decreases.

- If the **pulse is weak**, it suggests:
  - poor cardiac contractility (eg. myocardial damage – such as ionophore toxicity or viral/bacterial damage etc.) - might prompt you to do and echocardiogram &/or get a troponin (cTnI) measurement
  - poor ventricular filling or ejection (lots of cardiac diseases including cardiac arrhythmias and insufficient valves)
  - hypovolaemia and endotoxaemia.

**JUGULAR PULSE & FILLING**- With the horse’s head in neutral carriage, it is normal for a jugular pulse to extend from the level of the thoracic inlet up to a point that is approximately 1/3 of the way up the neck. A jugular pulse extending beyond this point is indicative of cardiac disease (and cranial mediastinal masses). A normal jugular vein should fill within two to three seconds after being occluded, and immediately disappear once that pressure is relieved. A non-distended jugular vein is normally not palpable. There is usually increased central venous pressure in horses with right sided heart failure, so there is venous engorgement and therefore an engorged jugular vein.

**ARRHYTHMIAS** are very important to assess and one must decide whether they are “regularly irregular” or “irregularly irregular”, and at what heart rate they are present (i.e. do they disappear with exercise and a higher heart rate, when vagal tone is abolished ?), and what the heart rate is during the arrhythmia (i.e. brady, normal, tachy).

- When arrhythmias occur there may be an underlying cardiac problem, electrolyte or acid-base abnormalities or they may be idiosyncratic (note: the very fit horse can be a problem sometimes, as arrhythmias occur as parasympathetic tone increases so quickly as exercise stops). See later pages on specific arrhythmias.

**MURMURS:** If a murmur has been ausculted, try to gauge whether it is physiologic or pathologic. Physiologic murmurs may vary in intensity with changing heart rates (eg. exercise), are generally sporadic in their occurrence, are often subtle, and may tend to have a focal point of maximal intensity (PMI). Conversely persistent or prominent murmurs are often pathological and may be ausculted over a more diffuse field.

Murmurs are classified according to:

a) **timing/duration**
b) **character**
c) **intensity**
d) **location** (point of maximal intensity).

- **a) Timing** of the murmur refers to the point in the cardiac cycle in which the murmur occurs. **Pan**- means obscuring the heart sounds, so it starts at the beginning of S1 and goes to the end of S2; **holo**- means that the murmur begins/ends immediately after/before the heart sounds, systolic means between S1 and S2, and diastolic means between S2 and S1. Thus, a pansystolic murmur is one that obscures S1 and S2. A holosystolic murmur is present from the end of S1 to the beginning of S2. Likewise, a holodiastolic murmur is ausculted from the end of S2 to the beginning of S1. Murmurs can also be described as occurring early, midway through, or late in systole or diastole.
b) **Character** of the murmur refers to the qualities of intensity and pitch. Changes in intensity result from various pressure gradients and velocity of flow. Pitch can range from musical to harsh and sonorous. Both intensity and pitch can vary from beat to beat or can change with varying heart rates.

c) **Murmur intensity** is divided into six levels.
- Grade I: Murmur barely audible. Discernable only after careful auscultation over a focal area.
- Grade II: Low intensity murmur. Heard immediately to a few seconds after the stethoscope is placed over the point of maximal impulse of the murmur. Softer than the first heart sound (S1).
- Grade III: Loud murmur that is immediately audible. May be heard over a wide area of the chest. Equally as loud as S1.
- Grade IV: A prominent, widespread murmur that is louder than S1 and may be heard over a wide area of the chest.
- Grade V: A prominent murmur (the loudest that becomes inaudible when the stethoscope is removed) with a palpable thrill.
- Grade VI: A loud murmur with accompanying thrill that can be ausculted with the stethoscope off the chest wall.

d) **Location of the point of maximal intensity (PMI)** of the murmur can be helpful in associating the sound with a particular valve.

**PERFORMING AN ECG IN A HORSE**
The ecg is important to establish the origin of an arrhythmia. It is also important to remember that the depolarization process differs from humans and small animals because there is an extremely widespread distribution of the Purkinje network, so ventricular activation occurs from multiple sites (and there is a lack of wavefront formation in horses). The duration of the QRS complex does not depend on the spread of wavefront (ie. very different from small animals and humans) across the ventricles, and is not necessarily related to size!

- Different countries may have ecg machine with leads of varying colours
- Most commonly:
  - Black – LF - positive
  - White – RF - negative
  - Red – LH
  - Green – RH

- **BASE-APEX ECG** is the simplest way to examine the rhythm:
  - Frequently:
    - black – ie positive at left heart
    - white – ie negative at left jugular furrow (~ 1/3 way up)
    - ground eg. (green) – can be at withers
  - Otherwise you may use:
    - red lead at left heart (red – think colour of blood)
    - white lead at left withers (white - think “w” for withers)
    - black lead: left jugular groove
Heart Scores calculated from an ECG are of minimal use [we have echocardiography now if we want to look at myocardial mass and chamber size, as well as fractional shortening (contraction of the myocardial muscle)]. ECGs provide very little or no information about ventricle size!

Diagnosis of Heart Strain based on an ECG is extremely dubious, try not to let trainers push you into doing this. Don’t make too much of T-wave changes! If you think there is a cardiac problem, then diagnose it properly [i.e. try physical exam, ekg to check for arrhythmias, echocardiogram (explain that there may be the need for referral for safety reasons)]

**EVALUATION OF THE PATIENT AT AND AFTER EXERCISE**
As previously mentioned evaluation of the horse at and after exercise can provide veterinarians with significant information. In the field this is often an under-utilized diagnostic modality for horses with mild or subclinical respiratory, cardiac and even neurological/muscular complaints. If the horse has a history of poor performance and even collapse, then exercise and telemetric electrocardiogram (ECG) is a fantastic tool. I would prefer to have examined the horse at rest first, including physical examination, blood work including biochemical profile and complete blood count and even arterial blood gas and troponin levels. Then at rest, I would like to perform a resting ECG and resting echocardiogram before undertaking further testing at exercise, especially high speed or exercise befitting the horse’s fitness and intended work. Obviously, if the horse has collapsed then one needs to be very sure of its cardiac status before putting it on the treadmill for a high speed standardized exercise test.

**TIPS FOR ECHOCARDIOGRAPHIC EXAMINATION IN THE HORSE**
- Ideally use a low frequency (2-4 MHz) probe with a small footprint that can fit between the ribs.
- Clipping over the 3rd to 5th intercostal spaces (just behind the elbow and a strip of hair on the elbow, as skin moves as you press) on the right side and over a similar area on the left side is essential to obtain a good image.
- Alcohol and ultrasound gel is usually used for coupling. You may need to press harder into the skin to obtain good images than is needed for ultrasonography of other areas.
- The image is viewed on the monitor with the marker directed to the right of the screen – ensure you remember to do this manually if you do not have a cardiac programme, otherwise no textbook image will make sense to you!

The echocardiogram is usually performed in a standard sequence. You need to think of the clipped area as a clock, with the marker of the transducer at 12 o’clock, when the transducer head is held vertically. Then, the standard views are obtained by rotating the transducer between 1 o’clock (many long axis views) and 4 o’clock (most short axis views), and also by tilting the transducer caudally, cranially, dorsally and ventrally as needed. The transducer is not moved along the skin very much, most of the manipulations are just small movements.

**RIGHT SIDED VIEWS**
It helps greatly to have the right limb bearing weight but extended cranially.

**Long axis views, Tip: reference point of the transducer at 1 o’clock**
- **Right ventricular outflow tract (tricuspid and pulmonic valve)**
  Commence with the transducer just behind the right elbow (3rd-4th intercostal space) orientated at 1 clock. Direct the transducer cranially toward the left pectoral muscle. In this
view you should be able to see the tricuspid valve at the top of the screen and the pulmonic valve at the bottom left. The little black hole in the middle is the coronary artery.

**Aortic valve long axis view (tricuspid and aortic valve)**

Keeping the transducer at 1 o’clock, tilt the transducer slightly caudally to bring the aortic valve into view. The tricuspid is still seen at the top of the image, with the aortic valve beneath it, adjacent and to the right of the interventricular septum. You may need to rotate the transducer to 2 o’clock to extend the view of the aorta.

As most ventricular septal defects occur in the perimembranous, sub-aortic region, this is often the best view for imaging the defect. It will appear as a gap in the interventricular septum just adjacent to the aortic valve.

**Four chamber view (tricuspid and mitral valve)**

Again, keeping the transducer at 1 o’clock and directing further caudally, the mitral valve is brought into the image. You may need to direct the transducer slightly ventrally also.

**Colour flow Doppler:**

This is typically used in the right sided long axis views to further evaluate each of the valves and their competency. Regurgitation appears as a turbulent jet directed in the opposite direction to the anticipated flow when the valve is closed. It often helps to freeze the image and then rotate back slowly to gain more information about the timing and direction of regurgitation.

**Short axis views. Tip: reference point of the transducer at 4 o’clock**

**Left ventricle (for measuring the fractional shortening)**

From the four chamber view the transducer is rotated to 4 o’clock. The left ventricle appears as a triangular shape (Mushroom or Ram’s head). The ideal image for measuring fractional shortening is at the level of the papillary muscle just beneath the mitral valve. The values for the left ventricular dimension are obtained by switching to B mode. Measurements of the chamber in systole and diastole are then used to calculate fractional shortening. $FS = LVIDd - LVIDs / LVIDd$.

**Mitral valve**

With the transducer in the 4 o’clock position, the transducer is directed slightly dorsally to bring the view of the mitral valve in cross section. This appears similar to a ‘fish mouth’ as it is seen opening and closing. M mode may also be used to allow measurement of the mitral valve to septal separation (E-Sep). This is basically telling us how effectively the valve is opening during diastole.

**Aortic valve**

Again in the 4 o’clock position, the transducer is directed slightly more dorsally to section through the aortic valve. This appears similar to the “mercedes benz” sign. The left atrium is imaged on the far side of the aorta. A ratio of the aorta to left atrium may give some information about left atrial enlargement. Sometimes M mode may be used to measure the aortic diameter and left ventricular ejection time (length of time for which the valve is open). This gives information about systolic function of the left ventricle.
LEFT SIDED VIEWS

• Mitral valve long axis

The transducer is placed on the left 4th -5th intercostal space at approximately the level of the elbow (may be slightly dorsal). With the transducer at 11 - 12 o’clock an image of the mitral valve can be obtained. This view is used to measure the diameter of the left atrium when the valve is open (diastole).