**Auscultation:** Simply listening caudal to the triceps just above the point of the elbow in only one location usually does not provide the optimal auscultation of the equine heart. It can be difficult to identify specific intercostal spaces under the mass of the triceps muscle. In addition, the height relative to the olecranon or point of the shoulder may be affected by the horse’s stance. Therefore, some clinicians feel murmurs are best identified in relation to the apex beat rather than specific anatomical location (i.e., valves or intercostal spaces). The apex beat is in the proximity of the 5th intercostal space (the natural girth location) dorsal to the point of the olecranon. It is identified as the PMI of S1. Frequently, the heartbeat is palpable through the chest wall at the site of the apex beat. In addition, listening in only one location will likely result in the practitioner missing murmurs and/or arrhythmias. It is important to move your stethoscope cranially and dorsally from the apex to appreciate the heart base and remembering to listen on both the left and the right sides of the horse. Consider ausculting not only the apex and base of the heart but try to be conscious of listening over the areas of all four heart sounds and all valves. A common error the author notices in neophyte and seasoned veterinarians alike is only listening for 10-15 seconds in one location to simply, “get a heart rate”. Murmurs and arrhythmias are commonly missed in this way and the author recommends ausculting for at least 1-2 minutes.

**Heart sounds:** Unlike in small animal species, it can be completely normal and frequent to hear all four heart sounds in equids. It is important to consider each heart sound and to gain a familiarity with what is occurring during the cardiac cycle in relation to each of the four heart sounds. S1 occurs at the onset of systole and sounds lower in frequency than S2. It is the “lub” sound of “lub-dub”. The S1 heart sound is created due to: closure of the A/V valves, contraction of the ventricles, opening of the P/A valves, ejection of blood into the aorta and MPA. It is best heard at the apex beat ~ ICS 5 (mitral valve area) and the heartbeat is frequently palpable at this location. The ECG timing corresponds to QRS complex.

The heart sound termed S2 is higher in frequency (i.e, the “dub” of “lub-dub”). It occurs at the end of systole due to: blood deceleration in the MPA and aorta, and the P/A valves closing. It is heard best at heart the heart base, cranial and dorsal to apex beat (Aortic valve region). It corresponds to the to the end of the T wave on the ECG.

Heart sounds S3 and S4 may be ausculted in horses without pathology, due to the huge size of the cardiac chambers. S3 is commonly heard in young fit horses and is due to: ventricular filling (diastole), and the abrupt tensing of ventricular walls in early diastole. It is best heard at the left heart apex. This sound may be reflective of ventricular dilation with a systolic murmur, however does not always denote pathology. S4 is best heard at the left heart base, distinguishing it from S3. It occurs due to the end of atrial contraction as the last blood moves into ventricle, also known as ‘atrial kick’. It occurs due to the transient closure of the AV valves and corresponds to the P wave of the ECG. It may be heard as an isolated sound during asystole or be associated with 2° AV block.
Description of Murmurs: It is helpful when considering a murmur to quantify and qualify it using several descriptive categories. By convention, the point of maximal intensity (PMI), timing in the cardiac cycle (systole, diastole, continuous), duration in cardiac cycle (early, mid, late, holo-, pan-), intensity (Grade: I-VI), shape, quality, radiation of murmur are descriptors used to define the location and extent of the murmur. Having a systematic approach to murmurs such as this will help the practitioner: 1) decide the most likely reason for the murmur, 2) recognize it’s potential significance to the horse and owner, 3) clarify whether further diagnostics are prudent, and 4) facilitate communication with colleagues.

It is important to grasp not only that a murmur is heard but to narrow down where it is heard the loudest, called “point of maximal intensity” (PMI). The mitral valve is ausculted at the left 5th ICS, dorsal to elbow under triceps. The aortic valve is heard at the left 4th ICS, at the point of the shoulder. The pulmonic valve is located at the left 3rd ICS, rostral above the mitral valve and the tricuspid valve is ausculted on the right at the 4th ICS, ½ way between the elbow and shoulder.

It is also helpful to define the timing of the murmur in the cardiac cycle (i.e., systolic, diastolic or continuous). If you have trouble differentiating systole versus diastole, remember, diastole is longer occurs between S2-S1 and may contain S3 and S4 heart sounds. Also, palpating the facial artery while listening for the murmur will help you define the phase, as the pulse occurs during systole. Other descriptors used include pan- (throughout the cycle, obscuring the S1 and S2), holo- (between the heart sounds but S1 and S2 clearly audible), early, mid or late. In general, longer duration murmurs are more likely to carry significance (pansystolic or diastolic) than murmurs not present throughout cycle.

Murmurs are graded on a scale of 1-5 or 1-6. The author uses the following scale: Grade I: very soft, localized murmur, requires careful auscultation; Grade II: Quiet, focal, readily heard @ PMI; Grade III: readily heard, radiate; Grade IV: fairly loud relative to S1 & S2, radiate, +/- precordial thrill; Grade V: Loud, radiate, palpable thrill and Grade VI: Loud, heard with stethoscope off chest wall.
It is also helpful to consider the shape and quality of the murmur (i.e., whether it is plateau or band-shaped versus crescendo, decrescendo or a combination). This may help elucidate the cause of the murmur, as MR and TR tend to be band-shaped while prolapsed MV more often is crescendo in sound. A soft, harsh or coarse sound is likely consistent with MR or TR whereas harmonic or musical sounds are generated by a vibrating structure such as a ruptured chordae tendinae or a fenestrated leaflet. The author also finds it helpful to consider what the valves are doing during systole versus diastole to help determine if the cause of the murmur is due to stenosis or insufficiency. During systole the mitral and tricuspid valves are CLOSED while the pulmonic and aortic valves are OPEN. In contrast, during diastole mitral and tricuspid valves are OPEN and the pulmonic and aortic valves are CLOSED. For example, either a mitral / tricuspid valve stenosis or a pulmonic / aortic insufficiency causes a diastolic murmur. Combine this information with the location of PMI to narrow down which valve may be involved.

Ultimately, the practitioner must synthesize all of the information regarding the murmur and considers what lesions are common for the signalment. Stenosis of any heart valve is rare; whereas insufficiency of heart valves is more common. Mitral insufficiency is the most common etiology for murmurs noted in middle-aged horses with aortic insufficiency being second and tricuspid insufficiencies a distant third. Mitral insufficiencies generally progress slowly over years, if at all but are most likely to affect performance and can result in left heart failure. Tricuspid valve insufficiency is rare, is best tolerated by horses and is often an incidental finding that does not affect performance, unless severe. Pulmonic insufficiency is quite, but may be difficult to discern from aortic insufficiency on auscultation, due to close proximity of the valves and the challenge of advancing the stethoscope cranially under the triceps muscle. Aortic Insufficiencies are usually due to acquired degeneration of the valve in mid to older horses and aortic stenosis is rare. Aortic valve lesions are diastolic murmurs with a decrescendo sound coined “dive-bomber” sound, decrescendo. These lesions are often misinterpreted as systolic by students and vets and thus may be misclassified as MR or a more subtle secondary murmur of mitral insufficiency is often missed. Note: the intensity of a murmur is NOT an indication of severity of lesion! Often smaller lesions are louder in intensity. Some other key points to keep in mind include: loud murmurs don’t necessarily mean serious conditions; not all murmurs are associated with a cardiac defect; and not all murmurs associated with a cardiac defect are significant.

**Diagnostic evaluation:** Critical auscultation is important in determining the next step and whether additional diagnostics are indicated. The primary tools practitioners have available to aid in determining the significance of a murmur or arrhythmia include: electrocardiography (ECG), echocardiography, exercising or 24hr electrocardiography (radiotelemetry and Holter monitoring), cardiac troponin I, intracardiac pressure monitoring, and radiography. Some referral hospitals are now equipped with biphasic electrical defibrillators and the capability to perform electro-cardioversion.

**ECG:** It is extremely valuable to be able to monitor how an arrhythmia alters with changing levels of exercise in the horse. Many normal horses have an arrhythmia at rest, which is abolished by exercise. However, highly significant arrhythmias, which are only seen under exercise at high heart rates, require an ECG in order to be detected and an appropriate diagnosis made. These arrhythmias are often presented because the horse owner reports that the horse is
showing poor athletic performance. By convention, base-apex leads are often used in electrocardiograms in horses because it aligns the electrical leads relatively parallel to the electrical axis of the heart providing greater deflection of the waveforms generated compared to standard lead configurations. Electrodes should be placed as follows and recorded in Lead 1. Right arm (-) - is attached to the skin at the dorsum of the base of the neck just cranial to the scapula and withers or over jugular furrow (2/3 way down). The left arm (+) - is attached on the left apex by attaching to chest wall just caudal to the point of the elbow (about the 5th/6th ICS) and the ground - is attached anywhere in standing horse. Any arrhythmia other than second degree AV block should be pursued with electrocardiogram.

In addition to standard resting ECG recordings, ambulatory and exercising ECG studies are often indicated to confirm the presence or absence of arrhythmias and to determine the significance of an arrhythmia. The goal of exercising ECG is to determine if the CVS is the rate-limiting step causing poor or decreased performance. This should be evaluated in addition to thorough respiratory and soundness examinations. While echocardiography should be included in ones exercising cardiovascular workup to rule out overt pathology, some functional abnormalities may only manifest at exercise.

**Echocardiography:** While auscultation can lead the practitioner to identify the likely valve involved with a pathologic murmur, the extent of cardiac pathology can only be identified with echocardiography. This will give definitive answers regarding valve insufficiency or stenosis, size of the jet lesion, chamber enlargement, myocardial contractility and functioning. In addition, pathology such as ventral septal defects, ruptured chordae tendinae, pericarditis, cardiomegaly, and vegetative endocarditis can be readily diagnosed by echocardiography. Echocardiography is indicated under the following circumstances:

- Murmur grade ≥ 3-4/6
- Multiple murmurs
- Muffled heart sounds
- Signs of cardiac disease
- Any murmur accompanied by change in pulse quality
- Pathologic arrhythmia
- Fever of unknown origin (FUO)
- All aortic murmurs

Various modes including M-mode and B-mode give information regarding cardiac size and function. In addition, color Doppler allows elucidation of jet lesions helping to quantify the size, extent and direction of regurgitant blood flow. Pulse wave allow quantification of the size of the pressure differences created between two chambers, aiding in diagnosis and prognosis of a potential lesion.

Heart rate monitors, telemetry units and Holter monitors are useful for assessing fitness level or determining a cardiac explanation for poor performance. One limitation of all devises is that artifact may be created due to movement.
Heart rate monitors are useful for indicating maximal heart rate and correlating level of exercise. Some trainers use them for fitness monitoring either during workouts or to evaluated post-work. In the clinical setting they are most useful during treadmill analysis to ensure the horse is working at threshold level during airway evaluations. Heart rate monitors are limited in utility in that they do not give a read out of electrical activity of the heart and therefore cannot be used to evaluate arrhythmias.

Radiotelemetry is useful to evaluate ECG during exercise, either on the treadmill, lunge or under saddle, depending upon type of performance level necessary. Because a computer records the ECG signal, analysis is possible at a later time and can give information regarding cardiac rate and rhythm. Recently, smaller hand-held devices have been developed although often the technology is connected to a computer for analysis. Most have a range of about 100 meters, therefore are useful in treadmill situations or short-range field application. The advantage of radiotelemetry is that events can be seen in real-time, unlike the Holter monitor described next. Telemetry can be used like heart rate monitors during upper respiratory evaluations, but have the added benefit of recording dysrhythmias, if present.

Holter monitors record ECG signal for up to 24hrs of electrical activity. One limitation is once recording has begun, a real time read out is not possible, so evaluation of the entire period must be analyzed later. The events have occurred in the past and therefore there is limitation in the clinical setting to actually see a read out “while” an episode (for example syncope) is occurring. However, the devices are very portable and easily attached to the horse for stall or exercise activity.

Cardiac troponin I: The myocardium consists of myocardial cells within which the 3-unit cardiac troponin protein complex exists. This complex consists of cTnl, -T and –C. Cardiac troponins I and T are sensitive and specific biomarkers of myocardial damage and are easily measured in blood. They persist in the blood for several days after myocardial injury and are easily measured in blood. They persist in the blood for several days after myocardial injury. It is easy and non-invasive to obtain a sample (either serum or plasma may be used). When obtaining the sample, send on ice for preservation or stored at -70°C until analyzed. One caution is that normal athletes following exercise have elevations in troponin I secondary to cell leakage versus cell damage. It’s utility for exercise analysis is still being investigated and currently if used it is recommended to gather more than one sample (i.e., resting, 6 hrs post exercise and 24 hrs post exercise). There may be usefulness in employing these blood biomarkers in treadmill evaluations as well as during cardioversions for atrial fibrillation.

Electrocardioversion: Conventional treatment of equine atrial fibrillation (AF) involves administration of quinidine salts. Most uncomplicated cases respond to treatment, but pharmacologic cardioversion involves a range of adverse effects, and some horses are unable to tolerate medication. More recently transvenous electrical cardioversion (TVEC) has been investigated as an alternative treatment. The technique involves catheterization of the right atrium (RA) and pulmonary artery through the right jugular vein via specialized introducer and cardioversion catheters. One is placed in the left branch of the PA and a second is placed into the right atrium via pressure profiles and ultrasound guidance. Horses are then placed under general anesthesia and thoracic radiography confirms placement of electrodes. Biphasic, truncated exponential shock waves are delivered at incremental energies in synchrony with the QRS complex until cardioversion is achieved. Energy levels are usually initiated at 50J and may be increased up to 300J. Shocks are administered every 2 minutes until successful conversion.
Horses are then recovered from general anesthesia. McGurrin, K. reports 169/171 successful conversions of lone atrial fibrillation with this methodology at Ontario Veterinary College. Other veterinary referral hospitals including Colorado State University and The University of Pennsylvania currently offer access to this treatment modality.

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[www.vet.uga.edu/lam](http://www.vet.uga.edu/lam), Teaching, Large Animal Cardiology, Bartons heart sound self test.