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ASSESSMENT OF CARDIAC MURMURS

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Introduction
Cardiac murmurs are extremely common, occurring in 65-80% of athletic horse breeds. While cardiac murmurs can be associated with poor performance or even occasionally heart failure, most cardiac murmurs are detected when the heart is examined as part of a general physical examination, for example in a pre-purchase setting or prior to anaesthesia. In this situation, the clinician must decide whether the cardiac murmur is indicative of serious cardiac disease, mild sub-clinical cardiac disease or due to physiological processes. In addition, if cardiac disease is detected, it is necessary to decide whether this is likely to be progressive or non-progressive. With careful examination it is possible to characterize murmurs, determine the list of differential diagnoses and identify those horses that require further investigation before a prognosis can be offered. Echocardiography is extremely useful in assessing the structure of the heart and in identifying changes to the chamber dimensions and function that may provide an insight on the impact of the heart disease. Electrocardiography allows concurrent cardiac rhythm disturbances to be documented but, in horses, provides little information on cardiac chamber size.

Characterizing Murmurs
Cardiac murmurs are prolonged sounds occurring during periods of the cardiac cycle that are usually silent. Murmurs arise when normal laminar flow is disrupted. The criteria used to describe murmurs are its timing [fig 1], location (point of maximal intensity [fig 2] and direction of radiation) and quality (intensity [table 1] and shape [fig 3]). If all five characteristics of a murmur are considered carefully, the clinician is usually able to formulate a differential diagnosis and differentiate murmurs which are physiological (functional) from those which indicate that there is cardiac pathology and justify further diagnostic evaluation.

Fig. 1. The timing of murmurs is determined within the cardiac cycle.
Fig. 2. The point of maximal intensity corresponds to the valve area over which the murmur is loudest.

Table 1. Definitions of murmur intensity grades.

<table>
<thead>
<tr>
<th>Intensity Grade</th>
<th>Definition</th>
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<tbody>
<tr>
<td>1</td>
<td>A soft murmur audible only after careful auscultation in a localized area of the thorax</td>
</tr>
<tr>
<td>2</td>
<td>A soft murmur which is clearly audible after a few seconds auscultation</td>
</tr>
<tr>
<td>3</td>
<td>A moderately loud murmur that is immediately audible</td>
</tr>
<tr>
<td>4</td>
<td>A loud murmur that is immediately audible over a wide area of the thorax with no precordial thrill</td>
</tr>
<tr>
<td>5</td>
<td>The loudest murmur that becomes inaudible when the stethoscope is removed from direct contact with the thorax, always accompanied by a precordial thrill</td>
</tr>
<tr>
<td>6</td>
<td>A loud murmur that can still be heard when the stethoscope is removed from direct contact with the thoracic wall, always accompanied by a precordial thrill</td>
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Fig 3. Terms used to describe the quality or shape of murmurs
Causes of Murmurs

Physiological Murmurs
Physiological (functional) murmurs are present where there is no cardiac pathology, particularly associated with left ventricular ejection. Whilst often found in normal horses, they also occur if blood viscosity is lowered in anemia or hypoproteinemia. However, because cardiac murmurs can accompany congenital cardiac disease or valvular insufficiency, it is important that physiological (functional) murmurs are distinguished from pathological murmurs. Physiological murmurs are quieter (grade 3 or less), soft and localized, do not have precordial thrills and do not obscure the heart sounds. Functional murmurs in systole caused by ventricular ejection are localized to the heart base in the third or fourth intercostal space; they are usually grade 3 or less and have a soft, blowing quality. Functional diastolic murmurs occur in early or mid diastole, they are frequently musical or squeaky, and are auscultated over the left heart base or left AV valve area.

Valvular Regurgitation.
Valvular disease in horses can be due to degenerative or inflammatory processes, and inflammation of the valve can be further sub-divided into non-septic or septic inflammation, the latter being better known as bacterial endocarditis. In all instances, the disease typically leads to regurgitation (leaking). It is important to appreciate that since a valve can only leak at a time in the cardiac cycle when it should be closed, if a murmur can be localized to one valve area and its timing determined, the clinician can often distinguish regurgitation from sounds associated with forward flow (physiological murmurs) fairly easily. It has now been well-documented that valvular regurgitation occurs in the absence of valvular pathology [1]; this is described as physiological regurgitation and may or may not be associated with soft murmurs. Physiological regurgitation has no clinical significance.

Congenital defects
Congenital defects occur less commonly than the other causes of murmurs; typically they are very loud and are often accompanied by precordial thrills. Simple defects, such as the ventricular septal defect are often well-tolerated and may not be detected until the animal is mature (see below) whereas with complex congenital cardiac defects, the foal may present fairly early in life and the murmur will be accompanied by other signs of cardiovascular compromise.

Differential Diagnoses for specific murmurs

Systolic murmurs loudest on the left side
The two most common causes of systolic murmurs loudest on the left side are flow murmurs associated with the semi-lunar valves (usually aortic) and mitral (left atrioventricular) valvular insufficiency.

Mitrail Insufficiency
Murmurs of mitral insufficiency are present in around 3.5% of the general horse population [2]. However, it is the most frequent form of valvular insufficiency referred for further investigation and is more likely to be associated with signs of poor performance: 35% of horses presented to the author for investigation of valvular insufficiency have mitral insufficiency and in 50% of these there is a history of poor performance. Mitral insufficiency is the second commonest location for valvular pathology, but it is the most likely form of insufficiency to lead to congestive heart failure or sudden death due to pulmonary rupture [3-5]. More often, horses with mitral valve disease develop atrial fibrillation that is refractory to treatment with quinidine sulphate, thus ending their competitive careers [6]. Horses with severe mitral insufficiency also have a high incidence of ventricular arrhythmias [3]. Because of these potentially serious sequelae, investigation of horses with murmurs of mitral insufficiency is warranted more frequently.
The murmur of mitral insufficiency is holo- or pan-systolic, typically band shaped and is loudest over the left fifth intercostal space, radiating caudodorsally if it is severe. The grade of the murmur does not necessarily relate to the severity of the disease, and it may reflect the direction of the regurgitant jet, frequently being louder if the jet is orientated towards the chest wall. Flow mapping can underestimate the severity of mitral regurgitation, because it is difficult to align the ultrasound beam parallel to the direction of regurgitant flow. Therefore, care must be taken if a small jet is detected in a horse with other signs of severe mitral insufficiency, such as left atrial enlargement or left ventricular volume overload.

Echocardiography is an important tool with which to investigate mitral valvular regurgitation. Mitral valve prolapse is a fairly common finding [1], often associated with a mid-systolic murmur. If there is no or minimal regurgitation, the prognosis appears to be good. Extensive nodular changes on the valve, ruptured chordae tendineae and flail cusp indicate more severe pathology [3]. The dimensions of the left ventricle, left atrium and pulmonary artery should be carefully evaluated. A good prognosis can be offered if the regurgitant jet is small, there are no valvular structural changes and no cardiac enlargement. Pulmonary artery dilatation is a poor prognostic sign [3], and care should be taken not to underestimate the importance of mitral insufficiency in horses with large regurgitant jets and minimal atrial enlargement, because this may indicate an acute onset which may continue to progress.

Myocardial disease may accompany mitral insufficiency [3]. If this has led to severe dilatation, the prognosis is poor. These horses should be evaluated during high-speed treadmill work to determine their exercise tolerance and ensure that exercise-induced arrhythmias are absent. With mild to moderate ventricular dilatation, the horse may experience reduced performance but be able to perform light work.

**Systolic murmurs loudest on the right side.**

The two most common systolic murmurs on the right side are due to tricuspid (right atrioventricular) valvular regurgitation.

**Tricuspid Insufficiency**

Pathological changes in the tricuspid valve are uncommon, conversely tricuspid insufficiency is frequently encountered, particularly in performance horses [2]. In one survey of 545 horses, the overall incidence was 9% but the incidence in Thoroughbred racehorses was 16.4%. In the author’s clinical population, Thoroughbreds are at an increased risk of having tricuspid insufficiency compared to other breeds: 22% of Thoroughbreds presented for investigation of valvular insufficiency had tricuspid insufficiency, whereas there was an incidence of 8% in mixed pleasure horses and 5% in ponies (risk ratio 2.84, 1.24–6.45, $P<0.01$). Murmurs of tricuspid insufficiency are also often found in Standardbreds. It has been proposed that the insufficiency is caused by geometric changes in the ventricle in response to hypertrophy [2] but prospective studies have not yet been performed to substantiate this theory. Similarly, the tricuspid valve is a common site for physiological regurgitation [1,7]. Tricuspid insufficiency is rarely related to clinical signs such as poor performance in performance animals, but if it is encountered in breeds in which it is less common, it may warrant further investigation. Occasionally, lesions such as rupture of a chorda tendinea, bacterial endocarditis and severe degenerative valve disease are encountered. Valvular prolapse is seen commonly.

The severity of tricuspid insufficiency can be semiquantitated with Doppler echocardiography fairly easily. Signs of right ventricular volume overload include dilatation of the right ventricle, rounding of its apex so that the heart appears to have a double apex, and paradoxical septal motion. Horses with normal valve structure or valvular prolapse, moderate regurgitation and no signs of right ventricular volume overload generally have a good prognosis for continued performance. Tricuspid insufficiency does not appear to predispose to the development of atrial fibrillation unless it is severe [6].
**Ventricular Septal Defect**

The ventricular septal defect (VSD) is the commonest congenital cardiac defect in horses [8]. VSDs are also frequently a component of complex defects. VSDs have been documented in a wide variety of breeds. The lesion is particularly common in Welsh Mountain ponies. VSDs are usually located in the membranous (non-muscular) portion of the septum in the left ventricular outflow tract (subaortic) immediately below the right coronary cusp of the aortic valve and the tricuspid [8]. Less commonly, defects are found in the perimembranous or muscular portions where there may be single, multiple or fenestrated defects or in the membranous septum in the right ventricular outflow tract (subpulmonic) [8]. In the left ventricular outflow tract, larger defects can lead to moderate to severe aortic insufficiency as the cusps of the aortic valve are sucked into the defect and, ultimately, may rupture [8]. The shunt direction is usually left to right with simple VSDs.

The VSD is usually associated with at least two murmurs. The shunt itself causes a loud, pansystolic band-shaped or coarse murmur with its point of maximal intensity over the right fourth intercostal space. There is often also a murmur of relative pulmonic stenosis [8]. The right ventricular tract is anatomically normal but, because of the increased volume of blood leaving the right ventricle, a loud holosystolic crescendo–decrescendo murmur is auscultated over the pulmonic valve area in the left third intercostal space. This murmur of relative pulmonic stenosis is typically at least one grade less than the VSD murmur. If there is concurrent aortic insufficiency, a holodiastolic decrescendo murmur will be present over the aortic valve area in the left fourth intercostal space.

The integrity of the septum is assessed with two-dimensional echocardiography [8]. A membranous VSD is typically best visualised in an image of the left ventricular outflow tract. The defect should be measured in two mutually perpendicular planes to determine its maximal diameter [8]. Colour flow Doppler echocardiography demonstrates the intracardiac shunt and is particularly helpful in identifying small VSDs. Continuous wave Doppler echocardiography is used to document the maximal velocity of the intracardiac shunt. The maximal shunt velocity reflects the pressure difference between the left and right ventricles. If the right ventricular pressure rises, the pressure difference will fall and therefore the shunt velocity will be low. The echocardiogram should also be assessed for signs of left ventricular volume overload, dilatation of the left ventricle, rounding of the apex, right ventricular hypertrophy and dilatation, and concurrent valvular insufficiency.

The prognosis in VSD depends on the size and location of the defect and the maximal velocity of the shunt. Horses with small defects in the left ventricular outflow tract can have a useful career. All horses which had a successful career had membranous or perimembranous VSDs with a maximal diameter of less than 2.8cm in one study [8]. Seven of 11 horses with a shunt velocity greater than 4m/s performed successfully at maximal types of competition, while the remainder were successful at lower levels of activity such as showing or hunting [8]. In smaller breeds of horses and ponies, it may be helpful to compare the size of the VSD with the diameter of the aortic root. VSDs which are less than one-third of the aortic root are likely to be restrictive and therefore carry a more favourable prognosis [9]. Horses with muscular VSD, additional lesions such as severe aortic insufficiency or in which the VSD is part of a more complex cardiac defect have a poor prognosis [8]. Therefore, the echocardiogram should be evaluated carefully to provide accurate prognostic information.

**Diastolic Murmurs on the left and/or right side**

The two main differential diagnoses for diastolic murmurs are physiological murmurs associated with ventricular filling and aortic valvular regurgitation. Pulmonic valvular regurgitation occurs very rarely.
Aortic Valvular Regurgitation

The aortic valve is the commonest site for valvular pathology, particularly in the middle-aged and older horse [10]. Degenerative lesions consisting of nodular or, less commonly, generalised fibrous thickenings are seen most often on the left coronary cusp, although any or all of the three cusps may be affected [10]. Bacterial endocarditis can affect the aortic valve [10]. All forms of congenital valvular lesions are extremely uncommon in isolation but congenital malformations have been reported in the aortic valve [11, 12]. Severe aortic insufficiency can accompany ventricular septal defects, when the presence of the defect immediately beneath the aortic root leads to instability and, in some cases, rupture of the aortic valve (see above).

The murmur of aortic insufficiency is typically pan, holo or early diastolic decrescendo and has its point of maximal intensity over the aortic valve in the left fifth intercostal space and radiates variable distances ventrally towards the heart base. It may be musical in quality, and in some horses it has a bizarre ‘creaking’ quality, which may be due to vibrations of cardiac structures, such as the mitral valve and the ventricular septum, rather than turbulent blood flow itself.

The best clinical guide to severity of regurgitation is the quality of the arterial pulses, rather than the grade of the murmur. Horses with moderate aortic insufficiency have reduced diastolic pressure and in those with severe aortic insufficiency and left ventricular volume overload, the systolic pressure and difference between the systolic and diastolic pressures increase, so that the pulses become increasingly hyperkinetic. In middle-aged horses, slowly progressive aortic insufficiency is common and well tolerated. Aged horses should be investigated if they are to continue to be used for riding, and aortic insufficiency may be more important if it is detected in a young animal.

Colour flow Doppler echocardiography can readily demonstrate the area occupied by the regurgitant jet. Doppler echocardiography can also be used to assess pressure gradients which arise as a result of aortic insufficiency. The two-dimensional and M-mode echocardiographic features of aortic insufficiency have been described previously [13]. Prolapse of the non-coronary cusp is a common finding and is rarely associated with severe regurgitation [1]. In the typical, degenerative disease seen in older horses, echogenic foci, representing degenerative nodules, are commonly localised to the left coronary cusp. Generalised thickening of the aortic valve, and flail cusp, indicate more extensive pathology. Dilatation of the aortic root, diastolic vibrations of the mitral valve and septum, and premature closure of the mitral valve, are seen with moderate to severe aortic insufficiency but are not necessarily relate to severity [13]. The vibrations arise as a consequence of the turbulence created in the left ventricular outflow tract by the regurgitant jet.

Both two-dimensional and M-mode echocardiograms are useful in assessing the degree of left volume overload. Left ventricular volume overload is diagnosed if the left ventricular diameter is increased, the apex of the ventricle takes on a globoid shape and the ventricle is hyperkinetic.

In the author’s clinical population, there is an apparent association between aortic insufficiency and ventricular arrhythmias: horses with aortic insufficiency are more likely to have ventricular arrhythmias compared to horses with other forms of valvular insufficiency (risk ratio 1.87, 1.05–3.31, $P = 0.035$). Therefore, ambulatory and exercising electrocardiography are recommended as part of the diagnostic work-up in cases of aortic insufficiency, particularly in horses with moderate to severe arrhythmias which are being used for riding purpose.

Horses with mild to moderate aortic insufficiency, which is slowly progressive and is not associated with ventricular arrhythmias, can be used successfully as riding horses for several years after the diagnosis is made. A poorer prognosis is warranted with acute-onset, severe aortic insufficiency and severe, advanced degenerative disease, particularly if the degree of left ventricular dilatation has caused dilatation of the mitral valve annulus and mitral insufficiency or if there are ventricular arrhythmias.
Decision Making in the Pre-purchase Exam setting.

As described above, the first step in rationale decision making is to attempt to characterize the murmur and narrow the causes down to a list of one or two possibilities. The age, intended use, state of training, intended career length of the animal can all influence the prevalence of the various causes of murmurs and impact on their significance. Factors such as insurance status and plans for re-sale may also influence the owners’ decision making in some cases. Clinicians have the option of advising a potential purchaser not to buy the horse, to buy the horse with a third option, of suggesting that further investigations are undertaken and echocardiography is usually the most logical next step although ECGs can be helpful in documenting concurrent arrhythmias. Horses that undergo further investigations are more likely to be judged suitable for purchase than not. Table 2 lists the various murmurs and guidelines for criteria that might prompt further investigations prior to making a decision to recommend purchase.

Table 2. Summary of decision making in the pre-purchase setting.

<table>
<thead>
<tr>
<th>Location and timing</th>
<th>Differentials</th>
<th>Characteristics causing concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic Flow murmur</td>
<td>If loud, prolonged or audible over a wide area, suspect that MI is present rather than a flow murmur</td>
<td></td>
</tr>
<tr>
<td>Mitral insufficiency</td>
<td>Grade 3 or louder</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-cordial thrill</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concurrent Arrhythmia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intended for use as top class Eventer with long career ahead.</td>
<td></td>
</tr>
<tr>
<td>Ventricular septal defect</td>
<td>A murmur on the left side will also be present</td>
<td></td>
</tr>
<tr>
<td>Right, systolic</td>
<td>Most often found in non-atheletic breeds or juveniles.</td>
<td></td>
</tr>
<tr>
<td>Tricuspid insufficiency</td>
<td>Grade 4 or louder</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-cordial thrill</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concurrent Arrhythmia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If found in a non-athelete (which is uncommon therefore VSD should be suspected)</td>
<td></td>
</tr>
<tr>
<td>Ventricular filling (physiological)</td>
<td>If loud, prolonged or audible over a wide area, suspect that AI is present rather than a flow murmur</td>
<td></td>
</tr>
<tr>
<td>Diastolic</td>
<td>Young horse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grade 4 or louder</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-cordial thrill</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concurrent Arrhythmia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Before arranging referral ensure prospective purchaser realizes this is a progressive lesion as this may be enough to put them off proceeding.</td>
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</tr>
</tbody>
</table>

When performing echocardiograms in horses in a pre-purchase setting, it is important that a systematic and detailed exam is undertaken. The cause of the murmur should be identified and in the case of mitral and tricuspid insufficiency, a favourable prognosis can be offered where there is no evidence of enlargement of the cardiac chambers, there are no visible valvular lesions and the jets of regurgitation are small. Ideally, an resting and exercising ECG should also be included as the present of a concurrent arrhythmia warrants a more cautious prognosis. Aortic insufficiency is seen less often in this particular clinical setting as it is a disease of the older horse population who are less likely to be subjected to pre-purchase examinations. Aortic insufficiency is invariably
progressive although many horses are useful in general riding activities with this disease. Aortic insufficiency is assessed by similar echocardiographic criteria.

Summary
Cardiac murmurs are commonly detected in situations where the clinician is required to determine if they are indicative of a cardiac disease that may impact on the horses performance or lifespan at some stage. Careful characterization allows a rationale decision of whether further investigation is necessary and if investigation is required it should usually include echocardiography and electrocardiography.

References