Hypertensive cardiomyopathy is the myocardial component of HHD and is characterized by left ventricular hypertrophy and fibrosis. Hypertensive heart disease is the group of functional and structural cardiac abnormalities described in humans and veterinary species as a consequence of the adaptations to increased blood pressure. Hypertensive heart disease involves mechanical, neurohormonal, and cytokine alterations, including compensatory hypertrophy of the left ventricle, increased wall thickness, and ventricular mass. The interventricular septum was thickened at end diastole (n = 5) and in peak systole (4). The left ventricular internal diameter was small at end diastole (n = 4) and in peak systole (3). The left ventricular free wall was thickened at end diastole (n = 3) and in peak systole (4). No associations between blood pressure and variables consistent with hypertrophy were detected. All horses were euthanized because of the grave prognosis of the primary diseases. All 3 horses that underwent postmortem evaluation had cardiovascular abnormalities.

Conclusions and Clinical Relevance—Hypertensive cardiomyopathy should be considered as a comorbid diagnosis in horses with laminitis or chronic renal failure. Information about the development, progression, reversibility, importance of early detection, and long-term sequelae of this condition is needed. (J Am Vet Med Assoc 2013;243:126–130)

**Abbreviations**

FS  Fractional shortening  
HC  Hypertensive cardiomyopathy  
HHD  Hypertensive heart disease  
HR  Heart rate  
IQR  Interquartile range  
IVSd  Interventricular septal thickness at end diastole  
IVSs  Interventricular septal thickness at peak systole  
LVPWd  Left ventricular free wall thickness at end diastole  
LVId  Left ventricular internal diameter at end diastole  
LVIDs  Left ventricular internal diameter at peak systole  
LVM  Left ventricular mass  
MWT  Mean wall thickness  
NIBP  Noninvasive blood pressure (ie, blood pressure measured noninvasively)  
RWT  Relative wall thickness

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thickness without ventricular dilation). However, to the best of our knowledge, this genetic disease has not been described in horses. Volume depletion has been found in multiple species, including horses, to cause pseudohypertrophy, an echocardiographic pattern that mimics concentric hypertrophy, and in which the LVM remains within reference range. Equine valvular disease or primary cardiomyopathies most frequently cause eccentric hypertrophy (increase in size with dilation of the affected chamber as opposed to increase in the wall thickness), easily distinguishable echocardiographically from the pattern seen in HC, hypertrophic cardiomyopathy, or pseudohypertrophy. Left ventricular hypertrophy secondary to systemic hypertension has been detected at postmortem examination in ponies with laminitis, but the clinical findings and echocardiographic findings of HHD in horses have not been described. Chronic renal disease is a common cause of HHD and myocardial hypertrophy in many species; however, it has not been reported in horses in peer-reviewed literature.

The purpose of the study reported here was to describe the demographics, history, clinical findings, echocardiographic appearance, prognosis, and pathological findings associated with left ventricular hypertrophy and hypertension in horses. The hypothesis was that myocardial hypertrophy occurs in hypertensive horses associated with chronic renal failure and chronic pain and that horses with laminitis are overrepresented.

Materials and Methods

Case selection—Records of horses presented to a referral practice for cardiac evaluation between 1995 and 2011 with systemic hypertension (systolic and mean NIBP > 144 and 116 mm Hg, respectively) and echocardiographically evident left ventricular hypertrophy were studied retrospectively.

Medical records review—Information retrieved included demographic variables (age, sex, breed, and weight), primary diagnosis, reason for cardiac evaluation, maximal NIBP (mean of 3 consecutive measurements of systolic, diastolic, and mean blood pressures), HR at the time of cardiac examination, presence of arrhythmias, cardiac troponin I, presence of clinical dehydration, fluid therapy administration, standard echocardiographic variables measured via transthoracic 2-D and M-mode echocardiography, outcome, necropsy results, and cardiovascular histopathologic findings. M-mode echocardiographic variables were obtained from standard right parasternal short axis views of the left ventricle under the chordal attachments and included LVIDd, LVIDs, IVSd, IVSs, LVFWd, and left ventricular free wall thicknesses at peak systole. Two-dimensional measurements included pulmonary artery diameter and aortic root diameter from right parasternal windows and left atrial size from a standard left parasternal window. The mean of the measurements available in the records (multiple measurements were routinely obtained for each variable) was used in the analysis. The presence of substantial regurgitant jets detected with color flow Doppler echocardiography was also recorded. Calculated values included FS, MWT, RWT, and LVM obtained from the following formulas:

\[
FS = \frac{LVIDd - LVIDs}{LVIDd}
\]

\[
MWT = \frac{LVFWd + IVSd}{2}
\]

\[
RWT = \frac{LVFWd + IVSd}{LVIDd}
\]

\[
LVM = 1.04 \left(\left(\frac{LVIDd + LVFWd + IVSd}{LVIDd}\right)^3 - LVIDd^3\right) - 13.6
\]

Statistical analysis—The raw echocardiographic variables were compared with the most appropriate reference range for each individual on the basis of breed.
and size. The calculated values were compared with the reference values reported in a population of horses of mixed breeds and not in training. Descriptive statistics were calculated for age, NIBP, HR, and the echocardiographic variables as described. Results were reported as medians, IQR, and ranges. Associations between blood pressure (systolic and mean) and each echocardiographic variable indicative of cardiac hypertrophy (interventricular septal thickness, left ventricular internal diameter, free wall thickness, MWT, RWT, and LVM) were detected.

**Results**

Five horses met the inclusion criteria, which was 0.26% of horses evaluated for cardiac disease during the study period. There were 3 geldings and 2 mares (3 Thoroughbred, 1 Thoroughbred cross, and 1 Paso Fino) with a median age of 18 years (IQR, 3 years; range, 13 to 24 years). Median weight was 386 kg (IQR, 127 kg; range, 327 to 613 kg). The primary diagnosis was chronic laminitis in 3 cases and chronic renal failure in 2. Persistent tachycardia, hypertension, chronic laminitis, or a combination of these prompted the cardiac evaluations. No horse was clinically dehydrated when echocardiography was performed. Simultaneous ECGs were performed in all horses during the echocardiographic examinations. No arrhythmias were reported; however, continuous or 12-lead ECGs were not performed. Cardiac troponin I plasma concentration was measured in 1 horse and was high (0.83 ng/mL [reference range, < 0.07 ng/mL]). Cardiac hypertrophy was detected in all horses (Figure 1). All horses were euthanized because of the grave prognosis of their primary disease. All 3 horses that underwent necropsy had macroscopic cardiac hypertrophy, and 2 had microscopic cardiovascular changes (arteriosclerosis, intimal degeneration, and cardiac lymphangiectasia were found in 1 horse each).

**Discussion**

Hypertensive cardiomyopathy is uncommon in horses and was uniformly associated with chronic renal failure or chronic laminitis. Renal hypertension is thought to be caused by volume overload, excessive activation of the renin angiotensin aldosterone system, and anemia. The relationship between hypertension and laminitis in horses has been known for decades. The pathophysiology of laminitis-induced hypertension may differ depending on the stage of the laminitis and the mechanism of the lamellar damage. Systemic hypertension has been proposed to occur during the development of laminitis or be the response to hemodynamic changes during acute laminitis. In the acute phases of laminitis, hypertension has been explained by increased sympathoadrenal outflow, renin activity, and aldosterone concentration caused by pain, dehydration,
and electrolyte changes. The mild hypertension seen in horses during the prelaminitic stages of equine metabolic syndrome may be caused by endothelial cell dysfunction. The hemodynamic changes associated with chronic pain and sympathetic system overstimulation may be the main factors in the hypertension seen in chronic laminitis.

Left ventricular hypertrophy is an adaptation or maladaptation to systemic hypertension easily recognizable in 2-D echocardiograms when the myocardial hypertrophy is moderate or severe, as seen in the horses reported here. Myocardial hypertrophy and diastolic dysfunction are the main echocardiographic changes reported in other species with HHD. Pressure overload does not appear to be the only mechanism that causes ventricular hypertrophy during hypertension. Renin angiotensin aldosterone system activation, insulin resistance, and catecholamine release play a direct role in the development of hypertensive myocardial hypertrophy in humans. The cardiac response to hypertension in humans has high individual variability and has been described as proportionate to the area under the lifetime blood pressure curve. The degree of left ventricular hypertrophy is not associated with blood pressure measurements in humans with HHD. Therefore, it is not surprising that no significant associations were found between the degree of left ventricular hypertrophy and the severity of hypertension in the horses reported here.

Myocardial fibrosis, a common finding in humans with hypertension, was not found echocardiographically or via postmortem examination of any of the horses reported here. Fibrosis could have been missed because of the retrospective nature of the study and the low sensitivity for detecting fibrous tissue on equine echocardiograms or routine necropsies. Subtle myocardial hypertrophy, fibrosis, or dysfunction occurs early during HHD and can be detected by use of more sophisticated imaging techniques such as tissue Doppler imaging, 2-D speckle tracking, echocardiography with integrated backscatter, cardiac MRI, molecular imaging, or measurement of procollagen-derived propeptides. Of all these tests, only tissue Doppler imaging and 2-D speckle tracking have been used in horses. Although potentially useful to detect diastolic dysfunction and subtle early changes associated with HHD in horses, the clinical usefulness of these techniques in horses with HC is unknown.

In the group of horses reported here, the primary disease was cause for euthanasia in all instances, suggesting that HC is associated with severe underlying disease. Because of the lack of long-term survivors, the sequelae, long-term complications, or reversibility of HC in horses could not be determined. Arrhythmias and sudden cardiac death are frequent complications of HHD in several species. Ventricular hypertrophy, fibrosis, increased myocardial oxygen demand, fluctuations in arterial pressure, and impaired coronary perfusion are the proposed arrhythmogenic factors. In the horses reported here, arrhythmias were not recognized; however, auscultation and simultaneous electrocardiography are unlikely to detect sporadic arrhythmias. Plasma cardiac troponin I concentration was measured in only 1 horse and was high. Cardiac troponin I is frequently within reference range or mildly increased in other species during HHD. It was not possible to draw conclusions regarding the presence of myocardial injury in these horses because of the paucity of data available. Continuous electrocardiography and cardiac troponin measurements should be obtained prospectively in a larger group of horses with HC, chronic laminitis, and chronic renal failure to assess the clinical importance of myocardial injury and arrhythmias in HC in horses.

Some degree of overlap in cardiac measurements and echocardiographic appearance exists between humans with athletic heart syndrome and those with diseases that cause myocardial hypertrophy such as HHD or hypertrophic cardiomyopathy. Comparison of the data in the present case series with those collected from equine athletes in other studies suggests that confusion caused by such overlap would be uncommon in horses. Relative wall thickness appears to be uniformly increased in horses with HC but not increased in equine athletes. Equine athletes develop a more proportionate left ventricular dilation with respect to the myocardial hypertrophy, and therefore RWT remains within reference range. Human athletes engaged in sports that require isometric exercises can potentially develop patterns of hypertrophy that resemble HHD. Studies in populations different from Thoroughbred and Standardbred racehorses would be necessary to determine whether other types of equine athletes develop different patterns of hypertrophy. However, the classic belief that the type of sport determines the pattern of hypertrophy has been challenged, and it seems unlikely that any common equestrian discipline mimics the isometric exercises that cause severe concentric hypertrophy in humans.

The echocardiographic appearance of the left ventricle of volume-depleted animals can resemble that of left ventricular hypertrophy. The clinical findings and blood pressure measurements of horses with HC should allow their differentiation from those with pseudohypertrophy. The LVM was increased in horses with HC that had true hypertrophy (vs pseudohypertrophy), and the values of RWT and MWT were higher than those reported in experimentally hypohydrated horses. Moreover, the systolic left ventricular measurements, which were altered in 4 horses in this series but within reference range in volume-depleted horses, would also help in this differentiation. Results of the present report suggested that systemic hypertension causes echocardiographically evident left ventricular hypertrophy in horses that can be differentiated from pseudohypertrophy by use of the calculated values of LVM or by detection of increased wall thicknesses during systole in horses in which the clinical appearance is not definitive. Establishing reference ranges would require the study of populations of more homogeneous groups divided by breed, body weight, use, and training status.

There were several limitations of the study because of the retrospective nature of this case series, the small number of cases, and the lack of long-term follow-up. Information about the development, progression,
reversibility, importance of early detection, and long-term sequelae of HC could not be obtained. Prospective study of horses with systemic hypertension at risk of developing HHD would be necessary to accomplish this. Blood pressure recordings were obtained from the medical records. These measurements were routinely obtained from the middle coccyeal artery by use of an automatic oscillometric monitor. The cuff-width-to-tail-circumference ratio was not controlled, and the recordings were not corrected for vertical distance from the tail to the heart base. Therefore, the absolute values of the NIBP recordings should be interpreted with caution. However, the blood pressure values obtained were markedly increased, compared with the reported reference range, and horses were classified as being hypertensive on the basis of ranges established from a large population of horses by use of an analogous method, making the information clinically useful. The echocardiographic measurements were obtained by different echocardiographers, and this fact introduces some interobserver variability. In some cases, additional measurements would have been needed to counteract intraobserver variability but could not be obtained because of the signs of pain observed during the examination. Although the formula used to calculate LVM has been reported to have low repeatability in horses, it has been used in equine studies to assess development of hypertrophy in response to training and has been correlated to postmortem measurements and oxygen consumption. The accuracy of this formula for use in horses with heart disease is uncertain, and therefore, the results of the LVM calculations in horses with clinical HHD should be interpreted with caution.

It may be that horses develop HC less frequently than other species because of the less common occurrence of hypertension. Conversely, limited awareness of the potential presence of cardiac disease in hypertensive horses may cause it to be under recognized. Because of the poor outcome of horses in this study and the association of HHD in other species with comorbidities that could affect horses’ health and riders’ safety, clinician attention to the possibility of horses developing this condition is warranted. Monitoring horses with or at risk of developing hypertension (eg, horses with laminitis, signs of chronic pain, chronic renal failure, or metabolic syndrome) may help determine the clinical relevance of this equine cardiomyopathy and identify interventions that could assist in the management of such cases.

References


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