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Prevalence and Risk Factors for Cardiac Diseases in a Hospital-Based Population of 3,434 Horses (1994–2011)

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Background: Risk factors for cardiac diseases in horses have not been explored in a large population of animals.

Objectives: To describe risk factors for various cardiac diseases in a hospital-based population of horses.

Animals: Files of 3,434 horses admitted at the Internal Medicine Department of the Liege Equine Teaching Hospital between 1994 and 2011 were reviewed and of those, 284 were categorized as having moderate-to-severe cardiac disease.

Methods: Observational study. After calculating prevalence for each cardiac disease, we tested whether breed (chi-square test) or sex, age, body weight (BW), and other cardiac diseases (logistic regressions) were risk factors ($p < .05$ significant).

Results: Mitral regurgitation (MR, 4.4%), atrial fibrillation (AF, 2.3%), aortic regurgitation (AR, 2.1%), and tricuspid regurgitation (TR, 1.7%) were the most common cardiac abnormalities detected. Determinants were male sex and increasing age for AR (OR = 2.03, CI = 1.07–4.94), racehorses breed and middle-age for TR (OR = 4.36; CI = 1.10–17.24), and high BW for AF (OR = 3.54; CI = 1.67–7.49). MR was the most common valvular disease associated with AF, clinically important ventricular arrhythmia, pulmonary regurgitation (PR), and congestive heart failure (CHF). TR was also associated with AF, PR, and CHF; AR was not associated with CHF.

Conclusions and Clinical Importance: Several previously suspected risk factors for a variety of equine cardiac diseases are statistically confirmed and other risk factors are highlighted in the studied hospital-based population. These observations should be taken into account in health and sport's monitoring of horses presenting predisposing factors.

Key words: Cardiac arrhythmia; Epidemiology; Equine; Valvulopathy.

Cardiac clinical abnormalities including murmurs and arrhythmias are relatively common in horses whereas the prevalence of clinically important cardiac diseases is low.[1,2] Indeed, most cardiac murmurs and arrhythmias are physiologic in horses.[3–8] However, investigation of these with ECG and Doppler echocardiography is recommended as even mild cardiac abnormalities might lead to important cardiac disease and cause poor performance in sport horses.[1,9,10]

Clinically important cardiac murmurs in horses are mostly caused by degenerative valvular regurgitation, infective valvular lesions, or congenital heart disease.[11–13] Valvular regurgitations are commonly reported by auscultation and on echocardiography in horses. Mitral and aortic regurgitations (MR and AR, respectively) are the most frequently reported,[14] except in trained racehorses, in which tricuspid regurgitation (TR) is most frequently reported.[6,15,16] These valvular regurgitations occur in thoroughbreds and trotters,[17–20] but they have not been explored in other breeds.

Abbreviations:

AF	atrial fibrillation
AR	aortic regurgitation
AUC	area under curve
CHF	congestive heart failure
CI	confidence interval
MR	mitral regurgitation
OR	odds ratio
PR	pulmonary regurgitation
ROC curve	receiver operating characteristic curve
TR	tricuspid regurgitation
VA	clinically important ventricular arrhythmia including ventricular tachycardia and frequent ventricular premature complexes (≥2/min at rest)
VSD	ventricular septal defect

Ventricular septal defect (VSD) is the most frequently reported congenital heart diseases in horses.[12,21,22]

Atrial fibrillation (AF) is an arrhythmia frequently associated with clinical signs in horses and is one of the first cardiac causes of poor performance in racehorses.[9,23] AF can appear secondary to mitral regurgitation with atrial dilatation and congestive heart failure (CHF)[2,11,13,24] but can also be called paroxysmal, occurring during or just after an exercise of maximal intensity without any other cardiac disease.[9,25] Clinically important ventricular and supraventricular tachydysrhythmias are less frequently described and their prevalence is unknown in horses.[1,26]

No extensive epidemiologic study of equine cardiac diseases has been performed in a hospital-based mixed population. The aim of this study was to describe the prevalence of the most frequently described cardiac diseases (MR, AR, TR, pulmonary regurgitation [PR],

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AF, clinically important ventricular arrhythmia [VA], VSD, and CHF) in a hospital-based population and to identify any breed, age, sex, or body weight (BW) predispositions for these cardiac diseases.

Materials and Methods

Animals

Clinical data were reviewed for all horses aged 2 years and over that were admitted to the Internal Medicine Department of the Equine Teaching Clinic of Liege between August 26, 1994 and December 31, 2011. If an animal was admitted more than once during this period, only the initial file was used. Breed, sex, age, BW, realization of a cardiac examination (echocardiography and ECG), and final diagnosis were recorded for each animal.

ECG and Doppler Echocardiographic Methods

Echocardiography and ECG were performed in all cases that were referred for an abnormal cardiac auscultation by their veterinarian. Moreover, in horses admitted for other reason than cardiac investigation, a thorough cardiac examination was performed whenever a cardiac murmur with grade ≥3/6, a cardiac arrhythmia, or clinical signs suggestive of cardiac disease (unexplained tachycardia or tachypnea, increased jugular distension or pulsation, ventral or pulmonary edema, exercise intolerance, and syncope) were detected.[1,2,13] Horses that presented one or more of these clinical signs but had no echocardiography performed were excluded from the study. Thus, remaining horses without cardiac ancillary test were considered to have no clinically important cardiac abnormality. Two groups of horses were defined: cardiac horses that presented moderate or severe cardiac abnormalities on echocardiography or ECG and control horses that had no ancillary cardiac testing performed or were considered free of cardiac disease based on these tests.

All cardiac horses underwent a standard Doppler echocardiographic protocol as previously described[27,28] and 2 different ultrasound systems were used depending on examination date.[ab] Using color-flow Doppler echocardiography, severity of regurgitations was graded as mild, moderate, or severe as previously described.[10] A final diagnosis of MR, TR, AR, or PR was recorded only if the respective regurgitation was moderate or severe, whereas horses with only mild regurgitation were included in controls. Diagnosis of VSD was based on 2D echocardiography and Doppler examination. A diagnosis of CHF was retained if the horse presented suggestive clinical signs (ie, tachycardia, increased jugular distension or pulsation, and ventral or pulmonary edema) and signs of volume overload on echocardiography (ie, cardiac chambers dilatation, hypo- or hyper-motility of cardiac walls, decreased fractional shortening and ejection fraction, and pulmonary artery dilatation).[1,2]

Modified base-apex ECG recordings were performed simultaneously with Doppler echocardiography or using an ECG Holter monitor or a standard ECG monitor.[c,d] Cardiac arrhythmias were evaluated on ECG at rest for duration of at least 5 minutes. AF cases and horses with clinically important VA including ventricular tachycardia and frequent ventricular premature complexes (≥2/min at rest) were recorded in the final diagnosis list. On the contrary, horses showing second degree atrioventricular blocks, sinus arrhythmia, sinus bradycardia, or sinoatrial block which disappeared during exercise were considered to have physiologic cardiac abnormalities,[1] and were not recorded in the final diagnosis list.

Statistical Analyses

All statistical analyses were performed using statistical software.[e] First, a formal analysis was performed to identify possible bias because of improvement of the echocardiographic resolution and technique over the 17 years duration of the study. Studied period was divided into tertiles and the prevalence of each valvular disease during the first tertile (from 1994 to 1999) was compared to its prevalence during the last tertile (from 2006 to 2011) using a chi-square test.

Mean age, mean BW, sex, and breed distribution, number of horses submitted to cardiac ancillary testing, and prevalence of MR, TR, AR, PR, AF, VA, VSD, and CHF were calculated for the studied population. Twenty-eight different breeds were recorded and classified into 5 groups: draft type horses, ponies, thoroughbreds, trotters, and warmbloods. The animal's sex was categorized as either stallion, mare, or gelding.

Frequencies of breed and sex (chi-square tests) and the averages of age and body weight (unpaired *t*-tests) of horses with or without echocardiography, with and without cardiac diseases (controls versus cardiacs), and with or without each specific cardiac disease (controls versus each disease) were compared. Next, unconditional logistic regressions (GENMOD procedure) within each breed group were performed to test the relationships between occurrence of a cardiac disease and its potential risk factors (sex, age, BW, and another cardiac disease). In the logistic regressions, age was arbitrarily grouped into 4 classes: young horses (2–5 years), middle-aged horses (5–15 years), old horses (15–25 years), and geriatric horses (more than 25 years). Similarly, BW was arbitrarily divided into 3 classes: light horses (less than 400 kg), medium-weight horses (400–550 kg), and heavy horses (more than 550 kg). Adjusted odds ratio (OR) and their confidence intervals (CI) were obtained for each cardiac disease and within each breed class. Finally, for each statistically significant risk factor, its sensitivity and specificity in identifying the occurrence of a cardiac disease were computed. The corresponding receiver operating characteristic (ROC) curves and areas under the ROC curves (AUC) were constructed and evaluated according to previous guidelines,[29] and the Youden indexes (J) were calculated to fix the cutoff value where sum of sensitivity and specificity were maximum.[30]

For all statistical tests, a *p*-value of less than .05 was considered significant.

Results

From a total of 3,991 examined files, 3,434 horses were included in the study, whereas the remaining 557 horses were excluded because of too much data missing in their file or because the cases did not have echocardiography or ECG of a clinically important cardiac arrhythmia, a grade 3 or higher cardiac murmur, or clinical signs compatible with CHF. None of the valvular regurgitations presented a significantly different prevalence between the first and the last tertile of the studied period.

Of the 3,434 horses, 492 underwent echocardiography and ECG, and 284 had important cardiac disease. Mean age, BW, and distribution of sex and breed in the total studied population and within the cases presenting each of the studied cardiac diseases are summarized in Table 1. In the studied population, the most frequently observed cardiac abnormalities were mitral regurgitation (4.4%), atrial fibrillation (2.3%), aortic regurgitation (2.1%), and tricuspid regurgitation

Table 1. Prevalence of various cardiac diseases and descriptive data in 3,434 horses referred at the Internal Medicine Department of the Equine Teaching Hospital of Liege between 1994 and 2011.

				Sex			Breeds				
	Total (n = 3,434)	Age Mean ± SD (years)	BW Mean ± SD (kg)	M (n = 1,600)	G (n = 1,438)	S (n = 371)	WB (n = 2,382)	Trotters (n = 153)	TB (n = 206)	Ponies (n = 527)	Draft Horses (n = 166)
Echo/ECG not performed	2,942	10.7 ± 6.2	484 ± 136	1,437	1,194	286	1,996	109	173	503	161
Echo/ECG performed	492	10.1 ± 6.3	539 ± 93[a]	163	244	85	386	44	33	24	5
Controls	3,150	10.5 ± 6.2	487 ± 134	1,510	1,296	319	2,150	130	190	518	162
Cardiac	284	11.2 ± 6.7	543 ± 92[a]	90	142	52	232	23	16	9	4
MR	151	11.1 ± 6.8	543 ± 86[a]	54	73	25	134[b]	9[b]	3	4	2
AR	75	15.3 ± 7.5[a]	516 ± 99	19	40	16	62[b]	2	7[b]	2	2
TR	60	9.5 ± 6.2	553 ± 85[a]	23	24	13	44	7[b]	8[b]	0	1
PR	39	11.5 ± 6.2	519 ± 98	13	20	6	33	0	2	3	1
AF	79	11.6 ± 6.1	580 ± 88[a]	31	36	12	68[b]	9[b]	1	0	1
VA	25	11.8 ± 5.7	540 ± 80[a]	7	16	2	22	1	0	2	0
VSD	12	9.5 ± 7.8	474 ± 120	3	7	2	8	1	1	2	0
CHF	29	13.0 ± 7.2[a]	555 ± 84[a]	14	12	3	28[b]	0	1	0	0

AF, atrial fibrillation; AR, moderate or severe aortic regurgitation; BW, body weight; CHF, congestive heart failure; Cardiac, cases with one or more important cardiac disease; Control, cases without important cardiac diseases; Echo/ECG performed and not performed, horses submitted or not to an echocardiographic and ECG examination; G, geldings; M, mares; MR, moderate or severe mitral regurgitation; PR, moderate or severe pulmonary regurgitation; S, stallions; SD, standard deviation; TB, thoroughbreds; TR, moderate or severe tricuspid regurgitation; VSD, ventricular septal defect; VA, Clinically important ventricular arrhythmia including ventricular tachycardia and frequent ventricular premature complexes (≥2/min at rest); WB, warmbloods.

[a]Mean age or mean BW significantly higher than mean age or mean BW of control cases (unpaired *t*-test, $p < .05$ significant).

[b]Breeds presenting a significantly higher representation with the cardiac disease compared to the breed distribution of control cases (chi-square test, $p < .05$ significant).

(1.7%). Warmbloods were the predominant breed. The mean BW was significantly higher in the horses submitted to echocardiography/ECG and in the cardiac animals than in horses not submitted to echocardiography/ECG and in the control animals, respectively. The mean BW was significantly higher in horses with MR, TR, AF, VA, and CHF than in the control group. Compared to the breed distribution of controls, warmbloods presented significantly higher prevalence of MR, AR, AF, and CHF, trotters presented significantly higher prevalence of MR, TR, and AF, and thoroughbreds presented a significantly higher prevalence of AR and TR.

Because of the very unequal distribution of horses of different breeds (warmbloods overrepresented) and the limited number of VA, VSD, and CHF cases, calculation of adjusted OR and CI were only possible for warmbloods (Tables 2 and 3). Sex was a significant risk factor only for AR, with a significantly higher OR in stallions than in geldings and mares. Age was a significant risk factor for AR and TR: older horses were predisposed to AR, whereas horses aged less than 15 years old were more frequently affected by TR. Body weight was a significant risk factor for PR and AF: horses heavier than 550 kg were significantly less at risk of developing PR, but more at risk of developing AF. Moreover, cardiac diseases were often present simultaneously in the same horse: 85 of the 232 cardiac warmbloods presented several simultaneous cardiac diseases and many relationships between these diseases were significant (Table 3). Two ROC curves were constructed from these statistical data: one showing age as risk factor for the occurrence of AR (Fig 1) and the second, BW as risk factor for occurrence of AF (Fig 2). For the 2 ROC curves, AUC was calculated and were considered as low to moderate. Using calculation of J, cutoff values for which sensitivity and specificity were maximum corresponded to age 13.5 years for the risk of developing AR and to 542 kg BW for the risk of developing AF.

Discussion

The prevalence of the different cardiac abnormalities in the studied population is in accordance with the literature, as MR, AF, AR, TR are commonly reported whereas PR, VA, VSD, and CHF are less frequently reported.[5,10,15] Moreover, several previously suspected risks factors for cardiac diseases were confirmed statistically in this hospital-based population. MR was the most common valvular disease associated with AF, clinically important VA, PR, and CHF; TR was also associated with AF, PR and CHF; AR was not associated with CHF. Similar observation could be suspected in a larger randomized population.

MR was the most frequent cardiac disease in our study with a prevalence of 4.4%. This prevalence is slightly higher than those reported in previous studies performed in a mixed equine population (2.9–3.5%)[14,15] and in a trotter population (3.1%),[16] but it is slightly less than the maximum prevalence reported in young trained thoroughbred racehorses (6%).[5] Furthermore, in the present study, warmbloods and trotters were more strongly associated with MR than other breeds, including thoroughbreds. This result could be explained by the fact that thoroughbreds of the studied population were older (9.5 ± 5.5 years) than in previous studies[5,15]; they had finished their racing career and were generally untrained. Another reason could be because of the effect of BW as mean BW of warmbloods and trotters was higher than that of thoroughbreds. Indeed, mild MR has previously been

Table 2. Adjusted odds ratio and confidence intervals of sex, age, and body weight as risk factors of developing valvular regurgitations, atrial fibrillation, and congestive heart failure calculated in a population of 2,382 warmbloods referred at the Internal Medicine Department of the Equine Teaching Hospital of Liege between 1994 and 2011.

Risk Factors	MR OR (95% CI)	AR OR (95% CI)	TR OR (95% CI)	PR OR (95% CI)	AF OR (95% CI)	CHF OR (95% CI)
Sex						
M versus G	0.72 (0.47–1.12)	0.56 (0.29–1.09)	1.91 (0.76–4.78)	0.52 (0.17–1.57)	0.85 (0.45–1.58)	1.05 (0.31–3.57)
S versus G	1.42 (0.78–2.58)	2.30 (1.07–4.94)[a]	2.88 (0.86–9.64)	0.67 (0.13–3.41)	1.18 (0.44–3.12)	0.27 (0.02–4.52)
Age						
5–15 years versus 2–5 years	0.64 (0.38–1.05)	2.81 (0.99–7.97)[a]	1.36 (0.47–3.90)	1.03 (0.28–3.76)	2.06 (0.80–5.28)	0.53 (0.09–3.03)
5–15 years versus 15–25 years	0.67 (0.40–1.13)	0.34 (0.18–0.63)[a]	4.36 (1.10–17.24)[a]	4.41 (0.92–21.18)	0.53 (0.27–1.03)	0.54 (0.12–2.42)
5–15 years versus >25 years	0.38 (0.12–1.15)	0.20 (0.06–0.63)[a]	2.03 (0.18–22.52)	2.87 (0.14–60.42)	2.73 (0.17–44.03)	0.65 (0.03–12.45)
BW						
400–550 kg versus <400 kg	2.85 (0.65–12.43)	0.51 (0.14–1.94)	2.21 (0.09–51.72)	0.55 (0.06–5.30)	4.40 (0.31–63.07)	2.40 (0.04–137.22)
>550 kg versus 400–550 kg	1.56 (0.94–2.58)	2.00 (0.95–4.22)	1.77 (0.62–5.03)	0.19 (0.04–0.82)[a]	3.54 (1.67–7.49)[a]	1.84 (0.36–9.45)

See Table 1 for legends. CI, confidence intervals; OR, Odds ratio adjusted for all the effects of the model (sex, age, BW, MR, AR, TR, PR, AF, CHF) except the one analyzed.

[a]Values statistically significant (chi-square test, $p < .05$).

Table 3. Adjusted odds ratio and confidence intervals of the presence of a cardiac disease as risk factor of developing valvular regurgitations, atrial fibrillation, ventricular arrhythmia, and congestive heart failure calculated in a population of 2,382 warmbloods referred at the Internal Medicine Department of the Equine Teaching Hospital of Liege between 1994 and 2011.

Risk factors	MR OR (95% CI)	AR OR (95% CI)	TR OR (95% CI)	PR OR (95% CI)	AF OR (95% CI)	VA OR (95% CI)	CHF OR (95% CI)
MR	X	7.33 (3.63–14.80)[a]	16.11 (6.86–37.83)[a]	3.74 (1.07–13.08)[a]	8.44 (4.36–16.37)[a]	5.97 (1.84–19.39)[a]	12.66 (3.20–50.11)[a]
AR	7.58 (3.82–15.04)[a]	X	0.45 (0.11–1.88)	26.99 (7.70–94.68)[a]	1.20 (0.42–3.45)	0.93 (0.17–5.06)	3.65 (0.88–15.10)
TR	11.68 (4.88–27.94)[a]	0.47 (0.12–1.84)	X	25.48 (7.04–92.18)[a]	6.73 (2.59–17.45)[a]	2.58 (0.49–13.62)	5.25 (1.33–20.73)[a]
PR	2.76 (0.95–8.02)	20.74 (6.25–68.81)[a]	33.09 (9.68–113.18)[a]	X	9.64 (3.12–29.84)[a]	1.82 (0.26–12.50)	5.56 (1.27–24.43)[a]
AF	7.53 (3.87–14.65)[a]	0.96 (0.33–2.75)	9.22 (3.43–24.81)[a]	12.66 (1.31–3.77)[a]	X	1.13 (0.20–6.27)	15.17 (4.22–54.45)[a]
VA	6.16 (1.94–19.61)[a]	1.50 (0.29–7.82)	2.89 (0.19–17.17)	1.17 (0.14–9.85)	1.32 (0.25–6.91)	X	2.11 (0.20–22.27)
VSD	0.22 (0.02–2.39)	9.36 (1.27–68.91)[a]	77.50 (12.65–474.93)[a]	2.08 (0.16–26.31)	1.88 (0.19–18.92)	NC	NC

See Tables 1 and 2 for legends. NC, not calculable because of too few data.
[a]Values statistically significant (chi-square test, $p < .05$).

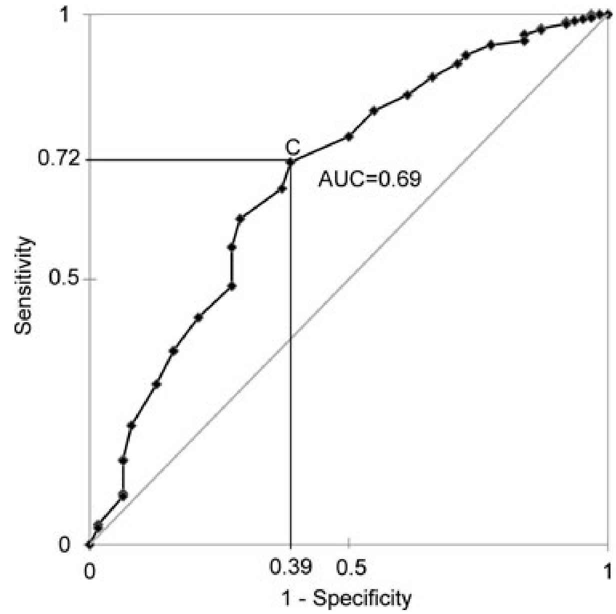

Fig 1. Receiver operating characteristic (ROC) curve of the effect of the age on the development of aortic regurgitation calculated in a population of 2,535 warmbloods referred at the Internal Medicine Department of the Equine Teaching Hospital of Liege between 1994 and 2011. AUC, Area under the ROC curve; C, dot corresponding to the higher value of the Youden's index (J = 0.334 for age = 13.5 years).

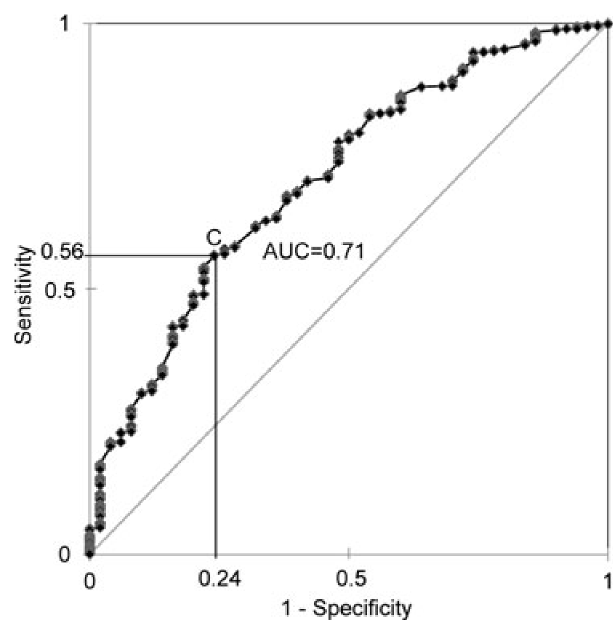

Fig 2. Receiver operating characteristic (ROC) curve of the effect of the body weight (BW) on the development of atrial fibrillation calculated in a population of 2,535 warmbloods referred at the Internal Medicine Department of the Equine Teaching Hospital of Liege between 1994 and 2011. AUC, Area under the ROC curve; C, dot corresponding to the higher value of the Youden's index (J = 0.324 for BW = 542 kg).

observed in large horses and in equine athletes with a good long-term prognosis[18,31] and, in clinical practice, larger horses are suspected to be predisposed to

developing MR. However, to the authors' knowledge, no study has tested this hypothesis statistically. In the present population, a *t*-test comparison between control horses and MR affected horses showed that horses with MR were heavier than control horses, but when considering warmbloods only, MR was not associated with BW.

In the present study, AF had a prevalence of 2.3%, which is consistent with previously described prevalence of 0.3–2.4%.[23,25,32] This wide range of observed prevalence could be explained by study population characteristics and by the cause of the AF. Some previous studies were predominantly performed on racehorses and considered only lone or paroxysmal AF,[23,25] whereas in the present study, more cases developed AF secondary to underlying cardiac disease as AF was significantly associated with MR, TR, and PR. AF was also more frequently observed in warmbloods and trotters than in other breeds. Trotters were already described as more frequently affected by AF.[23,33] Concerning the suspected predisposition of warmbloods for AF, a reason could be an effect of BW rather than breed. Indeed, in the studied population, warmbloods were overrepresented and, when the breed effect was deleted analyzing only warmbloods, an effect of BW was still present. Calculation of the adjusted OR and CI in warmbloods showed that horses weighing more than 550 kg presented significantly more AF than middle-weight horses. Moreover, a ROC curve allowed setting 542 kg as the cutoff value above which the risk of AF increases. This cutoff value is higher than the mean BW of the studied population (492 ± 132 kg) and could indicate that heavier and larger horses could be more at risk of developing AF as their larger left atrium size could favor the re-entry mechanisms as previously suggested by others authors.[32,34] On the contrary, no significant age and sex effect have been observed in the present study, which did not confirm previous observations in racehorses.[23,25,32,33]

The prevalence of AR observed in the studied population (2.1%) was slightly lower than in previous studies,[14,15] but depends highly on study population characteristics.[1] Thoroughbreds and warmbloods presented AR more frequently than other breeds, but the thoroughbreds in this study population were older and not in race training (9.5 ± 5.5 years), unlike the trotters, which were younger (7.0 ± 6.2 years) and mostly still in training. Age differences could partly explain the different prevalence of AR in each breed. Indeed, as suggested by several previous studies[12,14] but never statistically demonstrated, the main risk factor in the present study for AR was age. Middle-aged horses were significantly more associated with AR than young but less than horses aged between 15 and 25 years and horses aged more than 25 years. A cutoff value of 13.5 years above which horses were at higher risk to develop AR, was calculated. The present study also showed that sex could be a predisposing factor in the studied population, with stallions presenting significantly more frequently AR compared to geldings. To the authors' knowledge, the predisposition of stallions to develop AR has not been previously reported, but aortic root diseases and especially aortic root rupture have been regularly reported in breeding stallions.[35,36] Aging and male sex have been demonstrated to be the clinical determinants of human AR,[37] and the same could be true in horses.

TR prevalence has already widely been described in thoroughbreds and trotters[6,15,16] and can reach 13% in national hunt thoroughbreds.[5] In the selected mixed population of the present study, TR prevalence was much lower (1.7%) but was significantly higher in trotters and thoroughbreds in which it reached 4.6 and 3.8%, respectively. This relatively low prevalence of TR could be because of the small number of horses in racing included in the studied population. In previous studies, mild TR was also included,[5,16] or diagnosis of TR was based on murmurs audible on auscultation,[6,15] noticeably increasing its prevalence compared to the present study in which only moderate and severe TR were included.

Results obtained for PR might be more questionable because of the definition of the inclusion criteria for controls. Indeed, the major problem to interpret PR prevalence was the common lack of a murmur associated with this disease; therefore, horses with moderate or severe PR might have been included as controls.[1,10] The prevalence of moderate or severe PR was very low (1%) and was not observed as an isolated finding in any of the studied animals. Therefore, it seems possible that horses without other regurgitation but with a substantial undetected PR were included in control horses. Risk factors for PR have been poorly studied, and this cardiac abnormality is in most cases considered to occur secondary to pulmonary hypertension.[13]

Prevalence of CHF was lower than 1% in the studied hospital-based population, but rose to 10% in horses presenting clinically important cardiac disease. Few data on the prevalence of CHF are available and only 1 study has reported 7.9% of death attributed to cardiac problems among a population of middle-aged and older horses.[14] In the present study, warmbloods were overrepresented with 28 of the 29 horses presenting CHF; this prevalence was significantly higher than in other breeds. Moreover, horses with CHF were older and heavier than control horses. In the literature, CHF has been reported in various horse breeds and in a wide age range,[2,13] including foals and yearlings, which were not included in the present study. Therefore, CHF associated with nonviable congenital cardiac defects were not studied. When studied within classes (logistic regressions), BW and age were not identified as risk factors for CHF. On the contrary, AF and all valvular regurgitations except AR were identified as risks factors for CHF. The results of this study were in agreement with previously suspected causes of CHF in horses and could indicate that AR could be the valvular regurgitation with the lowest risk for resulting in CHF.[2,13] In the studied population, MR was the most important cardiac disease as risk factor as it was associated with CHF but also with

TR, PR, AF, and VA, probably because of enlargement of the left atrium, pulmonary hypertension, and cardiac decompensation, as already suggested.[2,11,13] TR was an important risk factor for AF and CHF.[2,33] On the other hand, AR was not a direct risk factor of CHF but was associated with MR most likely because of left ventricular enlargement.[1] As previously mentioned but never statistically verified,[21] VSD was a risk factor for TR and AR. This could be because of its usual location in the membranous portion of the septum in the left ventricular outflow tract.[21]

Some limitations of the present study should be underlined. Data used in this study have been collected over 17 years, and this time interval might have introduced bias as 2 different ultrasound systems were used and at least 5 different veterinarians performed echocardiography; however, case files were reviewed by the same person (HA). Only experienced echocardiographers performed the cardiac examinations, but grading of the severity of regurgitation can be subjective and the technique might vary between operators and between ultrasound systems.[38] For this reason, only moderate-to-severe regurgitations were considered as they were less likely to be under diagnosed as compared to slight valvular regurgitations, independently of time and of operator. To study this possible bias, a formal statistical analysis was performed to assess the time effect (chi-square test for each valvular disease): no significant difference was observed, suggesting that the proportion of cardiac cases related to the total population of horses was the same over this period even in the first tertile. Moreover, there was no significant effect of the different ultrasound systems as only the first machine was used during the first tertile and only the second machine was used during the last tertile.

Another important bias was the fact that the majority of control horses of this study were not submitted to echocardiography and ECG. Despite the absence of a grade 3 or higher cardiac murmur, the presence of moderate or severe valvular regurgitation could not be ruled out completely in these horses.[7] The likelihood that a control horse would have such regurgitation or cardiac arrhythmia is very low as all animals included in the study were submitted to a thorough clinical examination, including extensive cardiac auscultation. However, it cannot be fully ruled out that cardiac murmurs or arrhythmias were missed in cases that were classified as controls. Horses included in the study were all referred to the equine teaching clinic of the University of Liege. Therefore, none of them can be considered free of disease and the observed results in the studied population might not represent a population of normal horses. In this study, cardiac abnormalities were described more commonly in warmbloods, thoroughbreds and trotters than in draft horses and ponies; this could be a result of owners more readily demanding investigation of a possible cardiac problem in the overrepresented breeds as athletic performance is more often required.[9,16] Therefore, cardiac problems in draft horses and ponies might have been underestimated.

In conclusion, the prevalence of valvular regurgitations, AF, VA, VSD, and CHF observed in our hospital-based population were in accordance with previously described prevalence.[5,10,15] Various risk factors of these cardiac diseases were statistically demonstrated in the studied population: Aging and male sex appear to predispose to AR, middle-age appears to be a risk factor for TR, and AF was significantly more common in larger and heavier horses. Cutoff values above which horses were predisposed have been calculated for age for AR and BW for AF. Many horses of this selected population presented multiple concurrent cardiac abnormalities; therefore the risk of developing a cardiac abnormality in the presence of another could be high. In case of cardiac murmurs or cardiac arrhythmias and in the presence of demonstrated risk factors, ECG and Doppler echocardiography should be highly recommended to diagnose and to evaluate the severity of any cardiac abnormalities and to identify potential signs of evolution into CHF, including the presence of multiple cardiac diseases and enlargement of the cardiac chambers.

Footnotes

[a] Vingmed System Five, model SN293, with a 2.5 MHz phased array transducer GE SN1180 probe, General Electric Ultrasound, Zaventem, Belgium

[b] Vivid i, Software version 9.1.0, with a 1.5–3.6 MHz phased array transducer GE 3S-RS probe, General Electric Healthcare Europe GMBH, Diegem, Belgium

[c] Vista, Novacor, Rueil-Malmaison, France

[d] Model 8240K, Nihon Kohden Corporation, Tokyo, Japan

[e] Statistical Analysis System, version 9.1, SAS Institute Inc, Cary, NC

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