SOUND RECORDING AND DIGITAL PHONOCARDIOGRAPHY OF CARDIAC MURMURS IN DOGS BY USING A SENSOR-BASED ELECTRONIC STETHOSCOPE

Károly VÖRÖS1*, Ingo NOLTE1, Stephan HUNGERBÜHLER1, Jenő REICZIGEL3, Jan P. EHLERS2, Guy TATER1, Reinhard MISCHKE1, Tanja ZIMMERING1 and Matthias SCHNEIDER4

1Small Animal Clinic and 2E-Learning Consultant, University of Veterinary Medicine Hanover, Bünteweg 9, D-30559 Hanover, Germany; 3Department of Biomathematics and Informatics, Faculty of Veterinary Science, Szent István University, Budapest, Hungary; 4Small Animal Clinic, Veterinary Faculty, Justus-Liebig University Giessen, Giessen, Germany

(Received 16 September 2010; accepted 7 October 2010)

The goals of this study were to present a technique of digitalised sound recordings and phonocardiograms (dPCGs), and to analyse its diagnostic capabilities. Heart sounds of 20 dogs were auscultated in vivo (on-line) and recorded with dPCGs by two authors using a Welch Allyn Meditron Stethoscope System. Sound recordings were auscultated off-line and blindly by four different observers having various auscultatory experiences, then listened to while viewing dPCGs. The results were compared to echocardiographic diagnoses. There was a significant agreement (p < 0.001) between on-line and off-line auscultatory findings regarding the four observers, ranging from 45% to 75% (weighted kappa values: 0.72 to 0.87). The best agreement was achieved by Observer 1 having the highest experience. Significant differences (p < 0.05) were found between Observer 1 and Observer 4 (with the lowest experience) in judging the quality of the murmurs during the off-line and blind auscultation. However, there were only minimal differences (95% to 100% agreements) in dPCG analyses among the four observers regarding intensity and quality of the murmurs while simultaneously listening to and viewing the dPCGs. Significant correlations were found between the traditional ‘0 to 6 scale’ and a new ‘0 to 3 scale’ murmur intensity gradings by all observers (correlation coefficients 0.640 to 0.908; p < 0.01 to p < 0.001). Analysis of dPCGs might be a valuable, additional tool helping with the diagnosis of canine cardiac murmurs, especially for those with less cardiological experience.

Key words: Heart, auscultation, digital phonocardiography, canine

*Corresponding author; Present address: Department and Clinic of Internal Medicine, Faculty of Veterinary Science, Szent István University, István u. 2, H-1078 Budapest, Hungary; E-mail: Voros.Karoly@aotk.szie.hu; Phone: 0036 (1) 478-4132; Fax: 0036 (1) 478-4137
Heart diseases often coincide with cardiac murmurs in dogs, and auscultation is the most important part of the physical examination, providing important diagnostic clues *per se* as well as helping with indications for further examinations. By the development of sophisticated diagnostic methods such as radiography, echocardiography and even computer tomography introduced into cardiology, the importance of cardiac auscultation has been questioned in human medical papers and the relevant knowledge about interpreting auscultatory findings seems to have regrettably decreased. On the other hand, several authors emphasise the importance of auscultation as being still important even in the age of modern diagnostic tools (Roldan et al., 1996; Tavel, 1996; Tavel, 2006; Murphy, 2008). Recently, new types of electronic stethoscopes have been introduced into human cardiology, and there are also a few publications on their application in veterinary clinical research (Tavel, 2006; Höglund et al., 2007; Rezakhani and Zarifi, 2007; Ljungvall et al., 2009).

Traditional (or conventional) phonocardiography gives the possibility to graphically record and analyse cardiac sounds. This technique includes a conventional ECG machine equipped with a mechanical microphone to record the sounds as vibrations of the thorax. The sounds are then converted into electronic signals in an analogue way, and recorded on the paper of the ECG machine or on an ECG monitor, usually together with a lead II ECG signal for timing. Despite the diagnostic capabilities of this modality, phonocardiography was hardly used in the last decades in small animal cardiology, although there are some scientific papers that rely upon that technique (Pedersen et al., 1999; Höglund et al., 2004). The recent underplaying of traditional phonocardiography is not only because echocardiography offers a more powerful means for cardiological diagnosis, but also because traditional phonocardiography is a rather cumbersome method with potentials of technical problems often causing artefacts and poor quality recordings.

With the use of sensor-based, electronic stethoscopes, cardiac sounds can be recorded, stored, and analysed on a computer. By visually displaying the sounds together with synchronous electrocardiograms as digital (digitalised) phonocardiograms (dPCGs), it is possible to accurately measure time intervals, to characterise the sounds regarding their shape and timing, and to clearly display low-frequency sounds. In addition to the traditional phonocardiogram formats, different types of sound spectral analysis can also be applied (Tavel and Katz, 2005; Tavel, 2006). Few scientific veterinary papers have been published on spectral analysis of digitalised cardiac sounds in canine cardiac diseases (Höglund et al., 2007; Ljungvall et al., 2009). However, to the best of our knowledge there are no veterinary reports on the use of digital phonocardiography for clinical applications, although the technical and diagnostic aspects for animals, including dogs, might be quite different from the human situations.

The goals of this prospective study were to provide a technique of digitalised sound recordings and dPCGs, and to analyse the diagnostic capabilities of digital phonocardiography in typically occurring canine heart murmurs.
Materials and methods

Dogs

A total of 20 canine patients with obvious cardiac murmurs or with suspected murmurs, referred to the Small Animal Clinic, University of Veterinary Medicine Hanover (SAC-H), were used for the study. The dogs were randomly selected from consecutive patients by the internists working either at the ambulatory or at the hospital units of SAC-H. Selections were based on history, physical examination findings as well as on 6-channel ECGs and standard thoracic radiography. The procedures implemented in this study were compliant with the Animal Protection Committee of the University of Veterinary Medicine Hanover. An informed owner consent was obtained.

Study design

A detailed physical examination of the cardiovascular system including *in vivo* (i.e. on-line) cardiac auscultation was done on the selected dogs by two of the authors (KV and GT). Echocardiographic examinations were then performed by SH, KV, and GT whilst digitalised cardiac sounds were recorded by KV and GT. Off-line, post-processing analyses of the digitalised heart sounds and digital phonocardiograms were made independently (i.e. not knowing the results of on-line auscultation and echocardiography) by four different authors, i.e. by Observer 1, a diplomate of the European College of Veterinary Internal Medicine, Companion Animals (ECVIM-CA) as a board-certified cardiologist, by Observer 2 and Observer 3, both diplomates of ECVIM-CA, and by Observer 4, a resident of ECVIM-CA. Observer 1 had a high, Observers 2 and 3 a medium, and Observer 4 a low degree of experience in cardiac auscultation.

Methods

*Conventional cardiac auscultation.* Conventional auscultation of the heart of patients (on-line auscultation) was first performed with conventional stethoscopes. Timing, intensity (loudness), location, quality and pitch of cardiac murmurs were characterised as described by Kwart and Häggström (2002), just as the grading of murmur intensity and the application of conventional veterinary classification (1 to 6 scale), as shown in Table 1.

*Digital auscultation and phonocardiography.* An electronic sensor-based stethoscope was used both for auscultation and sound recordings (Welch Allyn Meditron Master Elite Stethoscope and Analyser System, Welch Allyn Corp., Skaneateles Falls, NY, USA). The electronic stethoscope was connected with an A/D (analogue/digital) converter provided by the manufacturer together with its analysis software program. Cardiac sounds and the ECG signals were digitalised and recorded by this software, on a commercial personal computer operating un-
der Windows XP (Höglund, et al. 2007; Germanakis et al., 2008). Cardiac sounds were stored and later visualised as phonocardiograms, simultaneously with the recorded ECG signals (Figs 1 and 2). The heart sounds were replayed and auscultated with commercially available, good-quality headphones having a frequency range of 15,000–22,000 Hz (sensitivity: 100 dB, impedance: 32 Ohm, maximum power input: 500 mV, Philips Stereo Headphones, type SHP 2500 Philips, Eindhoven, The Netherlands).

The original recordings were filtered using the supplied software to filter out or dampen respiratory sounds or artefacts as suggested (Kvart and Häggeström, 2002). The recorded and processed cardiac sounds of 15 sec duration were listened off-line and blindly (i.e. not knowing about any other findings of the patients and not seeing the dPCGs) by Observers 1, 2, 3 and 4 independently, to describe the following parameters: existence, intensity, and quality of the murmur (Belmont and Mattioli, 2003; Germanakis et al., 2008; Mahnke et al., 2008).

Grading of the intensity of murmurs was based on the Levine system with grades 1 to 6 as described earlier (Freeman and Levine, 1933; Levine, 1933) and shown in Table 1. To ensure a possibly consequent grading by the different observers, all observers listened to a collection of selected, digitalised murmurs from 0 to 6 grades before starting the study. This grading collection and some typical canine heart murmurs are available under a website (www.multiermedia.de/heartsounds.html) of the University of Veterinary Medicine Hanover. The quality of the murmurs was classified into three categories: murmurs of plateau configuration were regarded as regurgitant murmurs, those of crescendo-decrescendo configuration as ejection murmurs, and any different types as other murmurs (Pedersen et al., 1999; Belmont and Mattioli, 2003; Germanakis et al., 2008). During this blind, off-line auscultation, the intensity of the cardiac murmurs was also graded by applying a new human system with grades 1 to 3 as published by Keren et al. (2005). This classification uses the heart sounds as an internal sound reference, where the intensity of the murmur is compared to S1 and S2 of the given patient as shown in Table 1.

After a 24-hour-long ‘wash-out’ period, Observers 1, 2, 3 and 4 were allowed to learn the individual data of the patients (breed, age, sex, body weight) as well as the location of the recording (point of maximal intensity), and they analysed the sounds off-line by listening to and viewing the dPCGs simultaneously, together with their ECGs (Germanakis et al., 2008; Mahnke et al., 2008). An arbitrary cut-off value of 0.1 dB was set to define accidental baseline undulations and to separate these from murmurs on the dPCGs. As only Observer 1 had previous experience with analysing traditional phonocardiograms, a brief education was provided for Observers 2, 3 and 4, showing and explaining some typical dPCGs of canine heart murmurs. The same parameters were analysed and described by Observers 1, 2, 3 and 4 as during the blind, off-line auscultation (see above). Possible differential diagnoses were then chosen by the observers based

*Acta Veterinaria Hungarica 59, 2011*
on the murmur characteristics and locations (point of maximal intensity) from a list of considerable cardiac diseases as given by Bonagura and Berkewitt (1991).

**Echocardiography.** Echocardiographic examinations were performed with an ultrasound system applying 3.5–7.0 MHz electronic sector transducers depending on the dog’s size (Vivid 7 GE, General Electrics Health Care, Milwau-kee, Wisconsin, USA). Standard M-mode, two-dimensional and Doppler echocardiography were performed as described (Kienle and Thomas, 2002). Echocardiographic diagnoses including the severity of valvular cardiac diseases as well as intracardiac shunts were based on established criteria (Pedersen et al., 1999; Kienle and Thomas, 2002; Brown and Gaillot, 2008).

The results of the off-line auscultatory findings and those of the dPCG analyses regarding murmur intensity and quality were compared to the echocardiographic diagnoses as described previously (Roldan et al., 1996; Belmont and Mattioli, 2003).

**Statistical analysis**

The results were evaluated using R, a freely available statistical programme (R Development Core Team, 2006). The results of Observers 1 to 4 regarding the diagnostic accuracy of blind, off-line auscultation were compared with the results of the on-line auscultatory findings applying Fisher’s exact test (Agresti, 1990). To evaluate the actual agreement beyond the agreement occurring by chance, Cohen’s weighted kappa analysis was performed (Cohen, 1960; Altman, 1991; Höglund et al., 2004). The results of Observers 1 to 4 regarding the diagnostic accuracy of blind, off-line auscultation of the recorded cardiac sounds were compared with the results of final echocardiographic diagnoses to define the true presence of the murmur by Fisher’s exact test and by Cohen’s weighted kappa analysis (Roldan et al., 1996; Belmont and Mattioli, 2003). The number of correct diagnoses made by Observers 2, 3 and 4 was compared to those made by Observer 1 (as the most experienced observer) using Fisher’s exact test. The same comparisons were made between dPCG analyses and the final echocardiographic diagnoses. Results of blind, off-line auscultation of Observers 1 to 4 regarding the grading and quality of the murmurs were compared to their own results when analysing the dPCGs with Fisher’s exact test. Differential diagnoses of the cardiac murmurs made by Observers 1 to 4 based on the data of the history, signalment, point of maximal intensity, and dPCG analyses were compared with the final echocardiographic diagnoses using Fisher’s exact test. Murmur gradings made during blind, off-line auscultation and using the 1 to 6 scale system were statistically compared to the gradings gained by applying the 1 to 3 scale system of the intracardiac reference sounds. Correlations between the grades assigned with these two grading systems by Observers 1 to 4 were quantified by Spearman’s rank correlation (Hollander and Wolfe, 1973). All analyses were performed using a level of significance at a p value of ≤ 0.05.

*Acta Veterinaria Hungarica 59, 2011*
<table>
<thead>
<tr>
<th>Grade</th>
<th>Conventional veterinary classification (Kvart and Häggström, 2002)</th>
<th>Original Levine system (Freeman and Levine, 1933)</th>
<th>Grade</th>
<th>Heart sounds as internal reference system (Keren et al., 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low-intensity murmur, heard only in a quiet environment after careful auscultation over a localised cardiac area</td>
<td>Faintest bruit that can be definitely heard; must have appreciable duration after the first heart sound</td>
<td>1</td>
<td>Clearly softer than the heart sounds</td>
</tr>
<tr>
<td>2</td>
<td>Low-intensity murmur, heard immediately when auscultating over the point of maximal intensity</td>
<td>Slight murmur</td>
<td>2</td>
<td>Approximately equal in intensity to the heart sounds</td>
</tr>
<tr>
<td>3</td>
<td>Moderate-intensity murmur</td>
<td>Moderate-intensity murmur</td>
<td>3</td>
<td>Clearly louder than the heart sounds</td>
</tr>
<tr>
<td>4</td>
<td>High-intensity murmur, heard over several areas but without a palpable precordial thrill</td>
<td>Loud murmur</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>High-intensity murmur with a palpable precordial thrill</td>
<td>Very loud murmur</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>High-intensity murmur with a palpable precordial thrill, heard even when the stethoscope is lifted slightly away from the thoracic wall</td>
<td>Loudest murmur</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The numerical grades of columns 2 and 3 are equal to each other, whilst those in the last column to the right are not equal to the other two systems.
Fig. 1. Digital phonocardiogram (dPCG) of a healthy Beagle with simultaneous electrocardiogram, done over the left apex. S1: first heart sound, S2: second heart sound
Fig. 2. Digital phonocardiogram (dPCG) of a Basset Hound with simultaneous electrocardiogram done over the left heart base, demonstrating a holosystolic, ejection (crescendo-decrescendo) murmur which starts at the first heart sound (S1) and ends at the second heart sound (S2). An early diastolic murmur can also be seen. Echocardiography demonstrated moderate pulmonary stenosis and mild (clinically non-significant) pulmonary insufficiency.
Results

Several breeds were represented in this study. Their mean age was 5.3 ± 4.3 years, ranging from 0.2 to 12.0 years, and their body weight was 17.0 ± 14.9 kg, ranging from 2.0 to 64.5 kg, respectively. Three dogs had no cardiac murmurs during the on-line auscultation. No echocardiographic signs of cardiac diseases coinciding with heart murmurs were seen in these three dogs. Their ECG diagnoses included a 2nd degree atrioventricular block, isolated premature ventricular beats, and isolated premature atrial beats, respectively. Altogether 17 dogs had cardiac murmurs during the on-line auscultation (16 systolic murmurs and one systolic-diastolic machinery murmur). These patients demonstrated the following echocardiographic diagnoses: 7 mild and 2 severe mitral valve insufficiencies typical of degenerative mitral valve disease (one of them with mild, nonsignificant tricuspid regurgitation), 1 moderate and 2 severe pulmonary stenoses (all with mild, non-significant pulmonary insufficiency), 1 severe sub-valvular aortic stenosis, 2 restrictive ventricular septal defects (both with mild, non-significant mitral regurgitation), 1 restrictive ventricular septal defect with severe aortic stenosis, and 1 patent ductus arteriosus with mild mitral regurgitation. Of the 17 dogs with audible murmurs during the on-line auscultation, 1 case was graded as 1/6, 1 as 2/6, 6 as 3/6, 3 as 4/6, 5 as 5/6, and 1 as 6/6 using the conventional veterinary grading scale shown in Table 1. Digitalised sound recordings and dPCGs of good quality were recorded in all cases with the described method (Figs 1 and 2). Table 2 shows the agreements between the on-line and the independent, blind, off-line auscultatory findings of four observers in grading the heart murmurs of the 20 dogs. There was a highly significant agreement (p < 0.001) among the on-line auscultatory findings and the blind, off-line auscultation by all (1 to 4) observers ranging from 45% to 75% and with weighted kappa values from 0.72 to 0.87, respectively. The best agreement was achieved by Observer 1, having the highest experience in cardiac auscultation. The agreements among the blind, off-line auscultatory findings as well as dPCG analyses when compared to the final echocardiographic diagnoses are listed in Table 3. The best results were produced by Observer 1 both when grading (95% agreement) and when estimating the quality of the murmurs (85% agreement). Significant differences (p < 0.05) were found between Observer 1 (with the highest experience) and Observer 4 (with the lowest experience) in judging the quality of the murmurs during blind, off-line auscultation. Regarding dPCG analyses, there were only minimal differences (95% to 100% agreements) among the four observers when grading the intensity and analysing the quality of the murmurs. Significant differences were found when the number of correct diagnoses of blind, off-line auscultation was compared to dPCG analyses made by Observer 3 (p < 0.01) and by Observer 4 (p < 0.001) regarding the quality of the murmurs. Based on dPCG analyses, differential diagnoses of the murmurs were in accor-
dance with the final echocardiographic diagnoses made by Observers 1 to 3 in 100% and with those made by Observer 4 in 95% of the cases.

Table 2
Agreements between the on-line and blind, off-line auscultatory findings of four observers in grading the heart murmurs of 20 dogs

<table>
<thead>
<tr>
<th>Observer No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agreement (%)</td>
<td>75</td>
<td>60</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Kappa</td>
<td>0.87</td>
<td>0.79</td>
<td>0.72</td>
<td>0.72</td>
</tr>
<tr>
<td>Strength of agreement</td>
<td>very good</td>
<td>good</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>P value</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*On-line (in vivo) auscultations were done by different authors (KV and GT) independently of the four observers performing the off-line auscultations and dPCG analyses. Heart murmurs were graded from 0 to 6 as shown in Table 1. Höglund et al. (2004), Altman (1991)

Table 3
Agreements among the blind, off-line auscultatory findings together with dPCG analyses of four observers and the final echocardiographic diagnoses in the grade and quality of heart murmurs in 20 dogs

<table>
<thead>
<tr>
<th>Observer No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital, off-line auscultation (%)</td>
<td>95</td>
<td>85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>95</td>
<td>80</td>
</tr>
<tr>
<td>dPCG (digital phonocardiography) (%)</td>
<td>100</td>
<td>100</td>
<td>95</td>
<td>100</td>
</tr>
</tbody>
</table>

*On-line (in vivo) auscultations were performed by different authors (KV and GT) independently of the four observers doing the off-line auscultations and dPCG analyses. Heart murmurs were graded from 0 to 6 as shown in Table 1. Agreement between grading/quality of the murmur stated by blind, off-line auscultation by Observers 1 to 4 and final echocardiographic diagnoses. Agreement between grading/quality of the murmur stated by off-line auscultatory findings together with dPCG analyses made by Observers 1 to 4 and the final echocardiographic diagnoses. p < 0.05: Level of significance regarding the percent of correct blind, off-line auscultatory diagnoses when the results of Observer 1 were compared with those of Observers 2, 3 and 4, respectively. p < 0.01 and p < 0.001: Levels of significance between the percent of correct diagnoses achieved with blind, off-line auscultation vs. dPCG analyses by the same observer

The correlations between heart murmur gradings of the ‘0 to 6 scale’ and the ‘0 to 3 scale’ are demonstrated in Table 4. Strong and highly significant correlations were found between the results of Observers 1 to 3 (correlation coefficients ranging from 0.874 to 0.908, p < 0.001) and a weaker but still significant correlation (0.640, p < 0.01) was seen between the results of Observer 4.

Acta Veterinaria Hungarica 59, 2011
Table 4

Correlations between heart murmur gradings made by the four observers on the ‘0 to 6 scale’ and the ‘0 to 3 scale’ during blind, off-line auscultation of 17 dogs

<table>
<thead>
<tr>
<th>Observer No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient</td>
<td>0.908</td>
<td>0.903</td>
<td>0.874</td>
<td>0.640</td>
</tr>
<tr>
<td>P value</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

Heart murmurs were graded from 0 to 6 as well as from 0 to 3 as shown in Table 1. *Only dogs with audible murmurs during the on-line auscultation are included in the table.

Discussion

Dogs included in the study represented various breeds with a relatively wide range of body weight and with different types of the most common cardiac murmurs allowing to test the applicability of the sound recording method. All dogs tolerated the procedure and good-quality recordings were made. Sound records and dPCGs can be filed to clinical records for later documentations, e.g. for possible legal cases and screening programs of congenital heart diseases. Later follow-up of potential changes in cardiac murmurs during the course of the diseases can also be performed. A further advantage of the method is that dPCGs allow repeated off-line analysis. Listening to cardiac sound recordings repeatedly, when teaching cardiac auscultation, increases auscultatory proficiency, and having typical examples for the grade and qualities of murmurs helps with their standardisation as it turned out also from our study (Tavel, 1996; Keren et al., 2005; Höglund et al., 2007).

When estimating the intensity and quality of heart murmurs, previous auscultatory experiences play an important role in both human and canine cases (Roldan, 1996; Pedersen et al., 1999; Belmont and Mattioli, 2003). This observation has been confirmed also in our study, demonstrated by the results of blind, off-line auscultations in Table 2 and Table 3, especially regarding the judgment of murmur quality. However, simultaneous listening to heart sounds and dPCG analyses, together with knowing the signalment and murmur location, significantly improved the diagnostic accuracy of all observers. This finding is similar to the results of previous human studies (Germanakis et al., 2008; Mahnke et al., 2008). The differences between blind, off-line auscultation and dPCG analysis regarding diagnostic capacities were especially obvious for the observers with less experience in cardiac auscultation. Correspondingly, there were only minimal differences among the observers regarding the findings of dPCG analyses. These results show that dPCG analysis might be a valuable tool helping with the cardiologic diagnosis, i.e. with compiling a list of possible differential diagnoses. In similar human studies, observers listening to and analysing dPCGs could have
reliably distinguished among patients with pathologically insignificant and significant murmurs and thus omitting or indicating further echocardiographic examinations. As such, gaining a second opinion from a far-distanced specialist is also possible by sending the recorded sounds via e-mail or within a network system (Dahl et al., 2002; Germanakis et al., 2008; Mahnke et al., 2008). Obviously, further sophisticated, additional methods, especially echocardiography, are necessary to achieve a definitive, *in vivo* diagnosis of cardiac diseases.

There have been some limitations of this study, such as the relatively small number of our cases, and the fact that our patients had only systolic murmurs and one machinery murmur. However, the most important and common murmurs of various intensities have been represented. Further studies might be needed on a more homogeneous population (e.g. on dogs belonging to one breed) as well as on a broader group of dogs with various types of heart murmurs to test the applicability and accuracy of the method described. Phonocardiography might gain some popularity again when applying the sound digitalisation method described in this paper. The positive correlations between the traditional 1 to 6 system and the new 1 to 3 internal sound reference system found in our study can only be considered as preliminary results. Further studies on a larger population with cardiac murmurs are warranted to define if the latter system can be used as an additional tool to complement the traditional one as proposed by Keren et al. (2005). For this purpose, spectral analysis of murmur and heart sound intensities would also be advisable, applying methods described previously (Tavel, 2006; Ljungvall et al., 2009).

**Acknowledgements**

Károly Vörös was supported by the German Academic Exchange Program (Deutscher Akademischer Austauschdienst, DAAD) during his stay at the Small Animal Clinic, University of Veterinary Medicine Hanover while performing the study. The authors express their thanks to their colleagues at this clinic who referred the patients to them for cardiological evaluation.

**References**


*Acta Veterinaria Hungarica 59, 2011*


Acta Veterinaria Hungarica 59, 2011