Theses of doctoral (PhD) dissertation

Digital phonocardiography in the diagnosis and education of canine cardiac arrhythmias

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1. Background and aims of the doctoral thesis

Cardiac auscultation is an important part of the physical examination in both human and veterinary medicine. Not only is it safe, cheap, and quick to perform, but it can also indicate other, more advanced diagnostic imaging methods, such as echocardiography, electrocardiography, and thoracic radiography. However, with the ever-increasing accessibility of these diagnostic imaging methods, both the clinical use and education of cardiac auscultation is on the decline. Another reason perceived behind this decline is the low sensitivity and specificity of conventional stethoscopes. Namely, both parameters depend greatly on experience, and the hearing capacity of the examiner, the latter decreasing with age. Electronic, sensory type stethoscopes have largely solved these limitations with the capability to filter and enhance selected frequency intervals. The ability to record and transfer the cardiac sounds to a computer allows further filtering and amplification with dedicated software. From the sound files, phonograms can be created (in this case digital phonocardiograms - DPCGs) providing the ability

to visualize heart sounds, adding further diagnostic value to auscultation. Some electronic stethoscopes also allow to record ECG-s simultaneously on DPCGs. Digital phonocardiograms can aid veterinarians in interpreting sounds phenomena and can be utilized in the education of veterinary students.

The following goals have led to the studies and for making up this dissertation.

1. The adaptation of the methodology developed to DPCG creation from canine heart murmurs to cardiac arrhythmias.
2. Comparing and reevaluation the available devices for DPCG creation as the range of accessible electronic stethoscopes have changed over time.
3. Documentation of the phonocardiographic appearance of the most common canine cardiac arrhythmias.
4. Determination of the role of digital phonocardiography in the education of canine cardiac murmurs and arrhythmias.

5. Expansion of the heart sound library made by our research group for canine cardiac murmurs with good quality DPCGs and synchronous ECGs of the most common arrhythmias of dogs.

2. New scientific results

2.1. The adaptation of the methodology developed to recording heart murmurs to cardiac arrhythmias

Our research group has previously demonstrated that the Welch Allyn Meditron electronic stethoscope provided good-quality digital phonocardiograms of canine cardiac murmurs which were helpful in their diagnosis. Based on our experiences with electronic stethoscopes and digital phonocardiography in the present study, these systems can help to detect and document canine arrhythmias, in the same way as cardiac murmurs.

2.2. Comparison of available electronic stethoscopes and reevaluation of previously used instruments

When comparing two devices, phonocardiograms recorded by the 3M Littmann 3200 stethoscope were less reliable for analyzing arrhythmias, because the artifacts produced with this stethoscope made it difficult to identify true arrhythmias without the presence of a synchronous ECG tracing. In addition, this stethoscope has a shorter

recording period (a maximum of 29 seconds), which could limit the detection of arrhythmias.

On the other hand, the 3M Littmann 3200 system seems to be easier to use due to its Bluetooth connection (<10 meters) to the computing device (computer and the relevant software). This fact can be an advantage for veterinarians in diagnosing cardiac murmurs and arrhythmias during their everyday clinical work.

For teaching and clinical research of heart murmurs and pathological arrhythmias, the Welch Allyn Meditron system is more suitable because of its capability of synchronous phonocardiographic and ECG recordings. The other advantage of this system is its reduced background noise due to noise filtering. This device, however, is greatly hindered by the large amount of short cables required for operation and making the creation of adequate quality recordings difficult in conscious patients.

2.3. Documentation of the phonocardiographic appearance of the most common canine cardiac arrhythmias

The digital phonocardiographic appearance of common canine cardiac arrhythmias and abnormal beats are demonstrated in Figure 1 and 2.
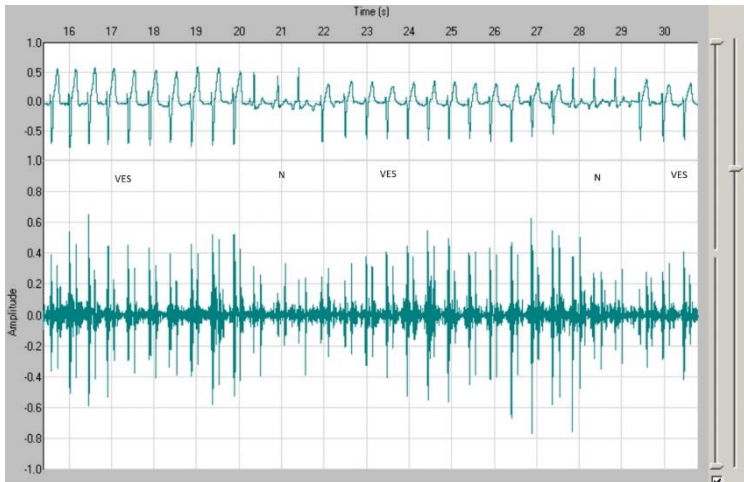

Figure 1. *DPCG and ECG recording of a dog with paroxysmal ventricular tachycardia.*

The run of ventricular extrasystoles with abnormal ECG complexes is marked with the text **VES** whereas normal beats are marked with **N**. Note the seemingly random and different amplitude of both S1 and S2 beats on the DPCG during the VES episodes, and the relatively constant S1 and S2 amplitudes on the normal segments. The changes in phonographic appearance of the heart sounds are in accordance with the ECG tracing.

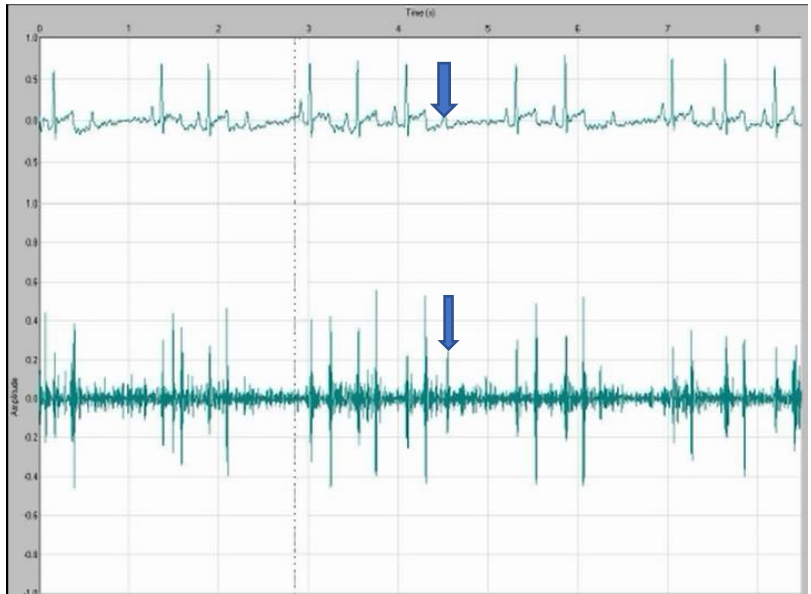Recording made by the Welch Allyn Meditron Electronic Stethoscope.

Figure 2. *DPCG and ECG recording of a dog with second-degree atrioventricular (AV) block.*

The condition is characterized by isolated P waves without consecutive QRS complexes when the impulse is not conducted from the atria to the ventricles. They can be isolated like in this image or occur in runs. One isolated P wave is marked with an arrow both on the ECG and on the phonocardiogram.

2.4. Evaluation the role of digital phonocardiography in the education of canine heart murmurs and arrhythmias

The participating students had similar knowledge (skill) levels at the beginning of this study, despite being selected from different years in training.

By the end of research, the two training groups' results significantly improved compared to the control group, who did not receive any training. This suggests that both teaching methods utilizing DPCGs (self-study website and online webinar) were effective.

We failed to observe a difference between the three groups in the changes of the scores. This finding seemingly contradicts the observations that both training groups had a higher post-training score than pre-training score, whereas the control group did not. The most plausible explanation is that our sample size was too small to detect a difference between groups but could detect a within-group change (which is a more powerful analysis method).

2.5. Summary of the new scientific results

1. Objective, quantifiable parameters have been established as the basis of comparing phonocardiograms and electrocardiograms created by different electronic stethoscopes. These parameters are the baseline deviation and the number of artifacts.

2. The methodology for recording normal heart sounds and murmurs previously developed by our research group is applicable to the recording good quality DPCGs of cardiac arrhythmias.

3. The digital phonographic appearances of common canine cardiac arrhythmias have been documented.

4. Educational materials utilizing DPCGs provide significant improvement in both the diagnosis of heart murmurs and arrhythmias. The improvement in the ability to identify arrhythmias via auscultation after training with DPCGs has not been demonstrated in veterinary medicine before this study.

5. The Heartsound Library constructed by our research group with canine cardiac murmurs has been expanded with DPCGs enhanced with synchronous ECGs and audio recordings of canine arrhythmias in the frame of the present study. The DPCG recordings demonstrated on this web site are annotated with key markers for better understanding, and they are freely accessible worldwide.

3. Publications the dissertation is based on

Balogh, M., Koch, F., Siver, L., Krima, A., Vörös, K.: Digital phonocardiography of cardiac arrhythmias in dogs–Preliminary experiences. Acta. Vet. Hung., 2021 *69.* 116-124.

Balogh, M., Rishniw, M., Vörös, K.: Remote teaching of canine cardiac auscultation using digital phonocardiograms. J. Vet. Med. Educ., 2022. DOI: 10.3138/jvme-2021-0097

Balogh, M., Vörös, K.: The role of cardiac auscultation and digital phonocardiography in the diagnosis and

education of canine heart diseases. Literature review and own experiences. Magy. Állatorvosok Lapja. 2022. *144*. 341-350.

4. Publications related to the topic of the dissertation

Balogh M.: Applying games technology to veterinary teaching. Vet Rec., 2014. *174*. 63-4.

Nolan, M.W., **Balogh, M.**, Waltman, S.S.: Teaching Tip: Virtual Oncology Clinic. J. Vet. Med. Educ., 2019. *46*. 367-371.

5. Presentations related to the topic of the dissertation

Balogh, M., Plisko, A.: What is the ideal case based learning method? – a review of student evaluations. Poster. INVEST 2014.

Balogh, M. Corbett, A.: High fidelity virtual patients in veterinary education: working with the VIN Virtual Clinic. VETVIP summerschool, 2014.

Balogh, M. Vörös, K. Ingo, N. Krima, A.: Kutyákban előforduló ritmuszavarok rögzítése és digitalizálása –

metodikai lehetőségek, előzetes tapasztalatok. MTA Áorv. Tud. Bizottsága, Akadémiai Beszámoló, Klinikumok Szekció, 2015.

Balogh, M., Müller, L.: Finding the straight line – computer simulation of complex biological systems in veterinary education. Workshop, VETED 2015.

Balogh, M., Seaman, N., Kittleson, M.D., Pion, P.D.: Simulating the management of congestive heart failure with the VIN Virtual Clinic. Poster Presentation, VETED 2016.

Balogh, M., Kittleson, M.D., Pion, P.D.: Assessing the impact of the VIN Virtual Clinic's Congestive Heart Failure Simulator on students. Poster Presentation, VETED 2017.