Comparison of Wireless Electrocardiographic Monitoring and Standard ECG in Dogs

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Abstract – **Electrocardiographic (ECG) data obtained by a wireless body electrode attached to the skin and connected to a smart device via low power Bluetooth technology were compared with a standard ECG in 8 dogs. The ECG data were gained from dogs with suspected arrhythmias due to cardiac or systemic diseases. A 2-minute standard ECG has been compared to a 15-minute recording obtained with wireless body electrodes. It has been established that this wireless electrocardiographic monitoring is a sensitive and specific method for identification of heart rates, duration of ECG waves and arrhythmia. When compared to a standard ECG, equivalent results were obtained for the heart rate and duration of different waves. Due to longer recording time the wireless device was more sensitive for documenting arrhythmias. With the wireless body electrodes, the ECG data were obtained while the dogs were lying down, standing or walking. The wireless electrode proved to be reliable and simple to use. This device enables a good option of long-term monitoring of canine cardiac rhythm in real-world environment.**

I. Introduction

In veterinary medicine the standard electrocardiogram (ECG) is used in every day practice to document many cardiac diagnoses, especially arrhythmias [1]. With the development of electronics over the past several years, many new approaches have been proposed to replace conventional methods of ECG monitoring [2 - 23]. Wireless ECG monitoring that allows a long-term evaluation is more suitable, since in veterinary hospitals many dogs have heart rhythm disturbances that may only occur intermittently. In addition to the long-term measurements wireless ECG is easier to use and more comfortable to wear. Electrodes are suitably small, attached directly to the skin with a patch carrier and waterproof [1, 6]. Dogs are often disrupted by wires, which prevent them from moving and this causes additional stress that can lead to misinterpretation of results and inadequate diagnosis. Furthermore, the characteristics of ECG signals are highly dependent on the patient's physical activity; it is therefore very important to monitor ECG during physical activity, also [4].

The wireless ECG monitor is a very promising method by which diagnostic accuracy of the ECG measurements could be obtained. The main goal of our measurements was to compare a standard ECG with the wireless ECG monitoring to determine the usefulness of the latter in canine electrocardiography.

II. Presentation

A. *Materials and Methods*

Wireless ECG sensor consisted of an electronic module with battery and two self-adhesive electrodes with a distance of 9 cm (Fig. 1). If necessary to prevent detachment, the ECG sensor was bandaged.

The ECG sensor recorded one bipolar lead. Wireless communication with the sensor via low power Bluetooth technology allowed the display of the ECG signal on a smart device. This device records real-time data from the electrodes and has already been described in the literature [2, 16, 23]. Evaluation of the ECG recordings was performed with NevroEKG software (Jožef Stefan Institute, Clinical Centre Ljubljana). The software can also extract the respiration rate based on the amplitude changes of QRS complexes [15].

The ECG data were obtained from 8 hospitalized dogs with suspected arrhythmias due to cardiac or systemic disease (5 and 3 dogs, respectively). The diagnoses of the dogs with cardiac disease were myxomatous mitral valve disease, tricuspid valve disease, pericarditis, pericardial effusion, and dilated cardiomyopathy (DCM). The systemic diseases included electrolyte disturbances, gastric dilatation and volvulus (GDV), pyelonephritis, and splenic tumor. During measurements, animals were lying in cages or moving freely in the room. The duration of wireless recording of the cardiac rhythm was 15 to 30 minutes.

All data were compared to the recordings with the 9-lead ECG, which included 6 limb leads and 3 precordial leads (V1, V2, V4) (Fig. 2).

Fig. 1: Wireless body ECG sensor placed on the left side of the thorax, negative electrode near atria and positive electrode at the apex of the left ventricle.

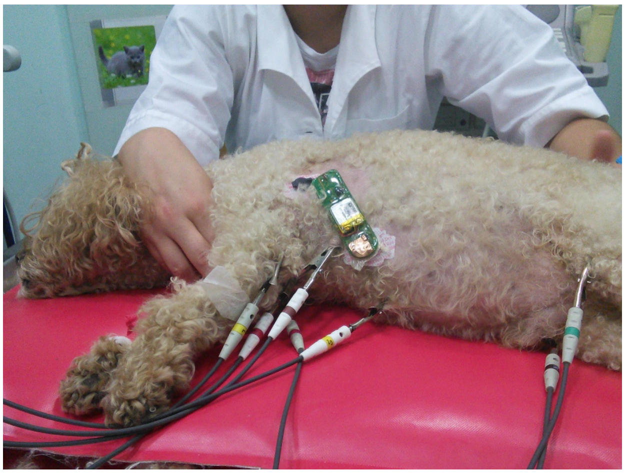

Fig. 2: Simultaneous recording of the 9-lead and wireless ECG.

B. *Results*

In eight patients, heart rate and rhythm from the wireless ECG data were compared with the data from the standard ECG.

Six dogs were placed in cages during the measurements and could not move away from the smart device. Two dogs were moving freely in the room. Not many movement artifacts or loss of the signal were noticed. When skin under the sensor was folded, the ECG waves were small, because the distance between electrodes was shorter. When the negative electrode was placed at the left base of the heart, i.e. near atria, the P wave was clearly seen. This position also caused more artifacts due to the moving of the animal's left front leg moving.

Instantaneous and average heart rates measured with the two devices were identical in all cases.

In four dogs (50%) the results of the wireless ECG data were equivalent to the results of standard ECG for detection of type of arrhythmia. Ventricular tachycardia, ventricular premature complexes (VPCs), sinus tachycardia, and normal sinus rhythm were all detected with both ECG devices.

In three dogs (37.5%) the extended ECG monitoring time increased the diagnostic yield of arrhythmias, the wireless device detected more arrhythmia than the standard ECG. The patient diagnosed with a DCM had a normal sinus rhythm on the standard ECG. However, the wireless sensor detected several VPCs (Fig. 3). In both recordings, P waves were clearly seen. In the patient, diagnosed with a splenic tumor, sinus bradycardia was detected in both measurements, but an episode of idioventricular rhythm and frequent VPCs were observed additionally with the wireless sensor (Fig. 4). The patient with tricuspid regurgitation and pleural effusion had atrial fibrillation on the standard ECG. The wireless sensor documented atrial fibrillation with several VPCs and a short asystole (Fig. 5 and Fig. 6).

In one case (12.5%), which was a patient monitored after surgery of GDV, the recording of the wireless device was diagnostically less useful than in other cases due to respiratory artifact caused by panting. In the recording T waves could not be followed, but arrhythmia and QRS intervals could still be observed.

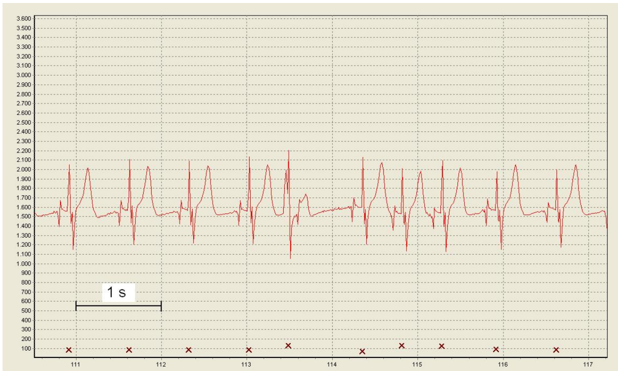

Fig. 3: Display of the recording with NevroEKG software of a dog, heart rate is 85 beats/min, P waves are seen and the 5th beat is a ventricular premature complex (VPC).

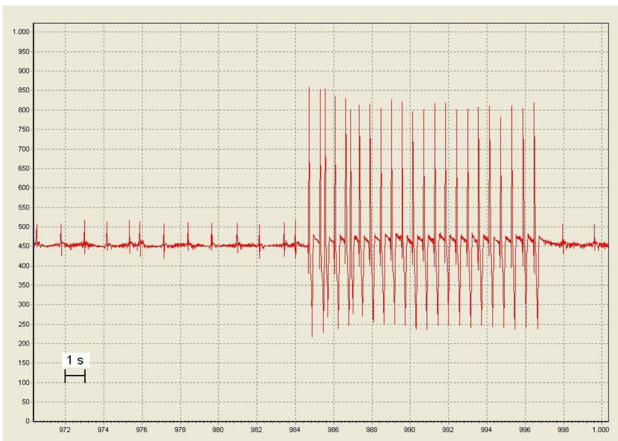

Fig. 4: Display of the recording with NevroEKG software, sinus bradycardia rate was 52 beats/min before and after idioventricular rhythm with the rate of 112 beats/min.

Fig. 5: Display of the recording with NevroEKG software, heart rate 140 beats/min, atrial fibrillation with four ventricular beats.

Fig. 6: Display of the recording with NevroEKG software, four ventricular beats of a rate 140/min, asystole, one atrial beat and three ventricular beats.

C. Discussion

There is an increasing demand by veterinarians and dog owners to continuously monitor dogs' vital signs, including ECG. In some breeds with high risk of cardiomyopathies (Boxers and Dobermans for example), the arrhythmias can be early indicators of an occult disease and can cause sudden death [2, 24]. Therefore the ECG sensor could be a useful tool for early detection and diagnostics. In veterinary medicine there are reports of other wearable sensors for monitoring the vital signs, but these devices are more invasive or have wires attached to the body [5, 19].

In our series of patients, the wireless ECG monitoring proved to have many advantages in monitoring heart rate and rhythm over standard short-time ECG recording. One major advantage is unlimited length of recordings that can be reviewed subsequently. Another advantage is a long autonomy due to wearable comfort, and a long battery life of the sensor. Additionally, it can be used also in a moving patient. These advantages have been reported previously [2, 6, 8, 9, 11]. The system used in this report has no wires, smaller number of electrodes, and the ability to synthesize the multi-lead ECG [20, 21, 23]. The NevroEKG software enables quick and easy analysis of instantaneous heart rate and rhythm, as well as average heart rate during sampled periods. Additionally, the NevroEKG enables good overview of the recording so that any changes of the rhythm, heart rate or duration of the waves can be promptly noticed, even if the arrhythmias are intermittent [2, 16]. A small-sized wireless sensor enables its use in various breeds of dogs. Due to longer recording time the wireless device was more sensitive for documenting arrhythmias in 37.5% of the dogs in our study. A higher diagnostic yield with prolonged duration monitoring for detection of arrhythmia events has been reported previously [8, 10, 12, 24]. All arrhythmias documented with standard ECG were also documented with wireless sensor. Instantaneous and average heart rates measured with the two devices were identical in all cases. High diagnostic accuracy of the wireless devices has been noted in previous studies, as well [6, 8 - 14, 18].

There were problems encountered in the wireless ECG monitoring, also. For example, ECG signal changes with the position of the body, and in case of rapid movements of the thorax (jumping, running, panting, etc.) the evaluation of the ECG signal can be more difficult due to multitude of artifacts and changes in the shape and size of the signal. Of course, excessive motion artifacts are also common in ECG monitoring with Holter and Event monitors, which are currently used for long-term monitoring in veterinary medicine [25, 26]. Another problem were electrode patches, which did not attach firmly. The firmness of the attachment depended on the quality of the electrode patches and on the thoroughness of shaving the hair and dry-cleaning of the skin. Bandaging the sensor decreased the number of the artifacts due to detachment and excessive motion. Bandaging and special coats are used to prevent detachment and excessive motion in Holter and Event monitors, as well.

Our pilot study proved that wireless ECG monitoring can give satisfactory ECG recordings regardless of the position, motion or size of the dog.

III. CONCLUSIONS

The wireless electrocardiographic monitoring described in this paper is highly reliable, simple to use, reusable, lightweight, small and comfortable to wear. It can be used during physical activities and offers long-term monitoring, therefore enhancing diagnostic yield. Such devices could become an important tool for clinical use in veterinary medicine.

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