Pferdeheilkunde – Equine Medicine 40 (2024) 2 (March/April) 149–153

DOI 10.21836/PEM20240207

Use of a novel smartphone based single-lead electrocardiogram device in clinical practice to evaluate heart rhythm in horses – a case series

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Summary: The surface electrocardiogram is the gold standard tool for the diagnosis of cardiac arrhythmias in horses. However, an electrocardiographic exam needs an electrocardiographic machine, cables and electrodes. Therefore, this diagnostic tool is not always available or practical in the field. Some handheld electrocardiographic devices that can transmit digitalised data have been reported in human and veterinary medicine in the last few years. The Ekuore ECG device, a novel smartphone tool, has recently shown an excellent agreement with standard base-apex electrocardiography in healthy horses. It obtained a standard electrocardiogram using traditional base-apex configuration when compared to previous smartphone devices. The aim of this case series is to report our clinical experience with the Ekuore device for heart rhythm analysis in horses referred for a cardiovascular examination. A total of 70 horses were evaluated for heart rhythm analysis using the Ekuore device. The single-lead bipolar Ekuore device allowed the diagnoses of physiological and pathological cardiac arrhythmias in all horses. One horse with atrial fibrillation was monitored by the referring veterinarian with the same device at home. In conclusion, we provide a first report on the use of the Ekuore device in clinical practice to evaluate heart rhythm in horses. The new smartphone electrocardiographic device can be more easily available in the field and might help clinicians to evaluate cardiac arrhythmias in horses.

Keywords: arrhythmias, cardiology, electrocardiography, heart, horse

Citation: Spitale D, Cicogna M, Porciello F, Colonnelli M, Caivano D (2024) Use of a novel smartphone based single-lead electrocardiogram device in clinical practice to evaluate heart rhythm in horses – a case series. Pferdehlk Equine Med 40, 149–153; DOI 10.21836/PEM20240207

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Submitted: October 30, 2023 | **Accepted:** February 6, 2024

Introduction

Electrocardiography allows a definitive diagnosis of any arrhythmia or investigation of unexplained tachycardia/bradycardia in horses.[1] An electrocardiographic (ECG) recording needs an ECG machine, cables and electrodes, but these are not always available or practical in the field. Some handheld ECG devices that can transmit digitalised data have been reported in human and veterinary medicine in the last few years.[2–6] These devices need to be positioned on the thorax in horses creating only a precordial reading and the interpretability of the electrical waves/complexes can be limited or different compared to a standard base-apex electrocardiogram.[7–10]

The single-lead Ekuore device has recently been compared with a reference ECG telemetry system in healthy horses and an excellent agreement was found between the two methods.[11] This smartphone device lets one obtain a standard electrocardiogram using traditional base-apex configuration with regard to previous smartphone devices.[11] However, no studies have evaluated the diagnostic utility of this device in the detection of cardiac arrhythmias in horses.

Therefore, the aim of this study is to report our clinical experience with the Ekuore device and assess its diagnostic usefulness for heart rhythm analysis in horses referred for a cardiovascular examination.

Materials and methods

Cardiovascular examinations were conducted in 60 horses at the Veterinary Teaching Hospital of Perugia University (Italy) and in 10 horses at their stables in central Italy between February 2022 and January 2023. Cardiovascular evaluation was requested for a cardiac arrhythmia or murmur.

The ECG recordings were performed in all horses by a single-lead, bipolar Ekuore ECG device and its tablet application (Chip Ideas Electronics SL, Valencia, Spain). All ECG tracings were acquired using a modified base-apex lead configuration, positioning the positive electrode attached in the right jugular groove near the thoracic inlet and the negative electrode attached on the left precordium (Figure 1).[8] Alcohol was applied to the skin before the placement of the electrodes to optimise the electrical contact. An ECG recording

was acquired for 2 min with a paper speed of 25 mm/s and an amplitude of 10 mm/mV for each horse; all ECG tracings were archived as PDFs in an iPad (Apple, Cupertino, CA, USA). The amplitude of the ECG tracings was modified (5 or 20 mm/s) before storage if the amplitude of complexes/waves was unsuitable for interpretation.

A stepwise approach was used to analyse all electrocardiograms recorded.[1] The heart rate was assessed counting the number of QRS complexes over 10 s multiplied by 6. The heart rate was classified into bradycardia (heart rate < 26 bpm), normal (heart rate 26 to ≤ 50 bpm) and tachycardia (heart rate > 50 bpm).[12] Each wave/complex duration and amplitude as well as the interval duration were calculated as the mean of three randomly selected heartbeats. The rhythm was classified as sinus (originating from the sinus node), supraventricular (stemming from the atria), atrioventricular (AV; deriving from node or junctional tissues) or ventricular (originating from the ventricle) rhythm.[12,13] The first-degree AV block was defined as a prolonged PQ interval (> 0.5 s) and a second-degree AV block as a P wave without the QRS complex.[12,13] The sinus block and sinus arrest were identified as a pause with a PP interval that is equal to (sinus block) or longer than (sinus arrest) two normal PP intervals.[12,13] A supraventricular premature beat was identified as a premature (shorter RR interval) QRS and T complex of normal morphology. The non-compensatory pause and P wave were eventually buried in the preceding T wave and were also considered for supraventricular complexes.[12,13] Atrial fibrillation was characterised by the absence of P waves, irregular RR intervals, normal QRS morphology and the presence of f waves.[12,13] The ventricular premature beat was defined as a premature QRS-T complex with a different configuration regarding the normal sinus QRS-T complex. A compensatory pause was also considered for ventricular premature complexes.[12,13]

Fig. 1 Modified base-apex placement of the Ekuore ECG electrodes. | *Modifizierte Basis-Apex-Platzierung der Ekuore-EKG-Elektroden.*

All ECG tracings were performed and interpreted by a single observer (DC, experienced cardiologist). We additionally obtained 10 ECG tracings recorded in one horse with atrial fibrillation by the referring veterinarian, who had been trained to use the smartphone ECG device at home. All ECG tracings were subjected to analysis for clinical rhythm diagnosis by another blinded observer (FP, experienced cardiologist) at the end of the study period. The percentage of agreement for two raters was used to calculate inter-rate reliability.

Results

The study population included horses of different breeds with a median age of 14 years (range 1–27 years) and median body weight of 446 kg (range 350–664 kg). The Ekuore device was tolerated well in all horses and ECG tracings were obtained in each horse included in the study. All ECG tracings were considered adequate for interpretation and allowed one to diagnose or exclude cardiac arrhythmias in all horses at rest.

The morphology of sinus P waves was bifid or single positive waves in ECG tracings; the morphology of QRS complexes was rS or S in all ECG tracings; and the T-waves morphology was variable (positive, negative or biphasic) (Figure 2). A regular sinus rhythm was recorded in 36 horses. A second-degree AV block was detected in 12 horses, sinus block/arrest in 9 horses, sinus tachycardia in 5 horses, atrial fibrillation in 7 horses and atrial premature complex in 1 horse. A first-degree AV block was also recorded in a horse with a second-degree AV block, three consecutively blocked P waves were recorded in a horse with a second-degree AV block, and ventricular premature complexes were recorded in one horse with atrial fibrillation.

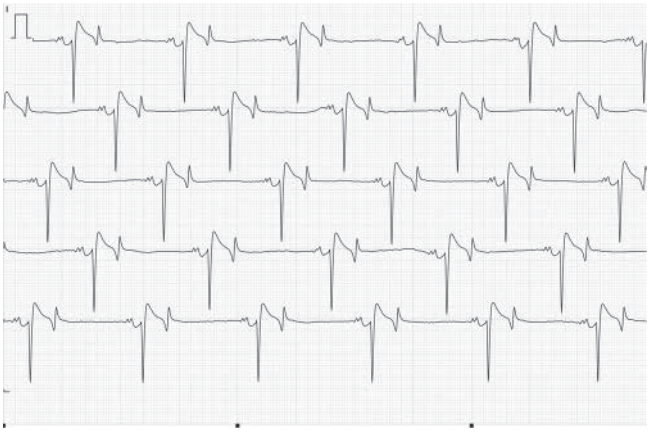

Fig. 2 ECG tracing obtained with Ekuore device and archived as PDF file. The page shows 1-min ECG recording from a horse included in the study. Paper speed 25 mm/sec; amplitude 10 mm = 1 mV. *EKG-Aufzeichnung mit Ekuore-Gerät erstellt und als PDF-Datei archiviert. Die Seite zeigt eine 1-minütige EKG-Aufzeichnung eines in die Studie einbezogenen Pferdes. Papiergeschwindigkeit 25 mm/Sek, Amplitude 10 mm = 1 mV.*

Cardiac arrhythmias were considered physiological in 21 horses and pathological in 13 horses (Figure 3a-g).

The percentage of agreement in the classification of the cardiac rhythm between the two observers was 100%.

Discussion

Our case study demonstrates the utility of the single-lead Ekuore device for recording heart rhythm in horses referred for a cardiovascular examination. The ECG tracings recorded by the Ekuore device were obtained in all horses and judged interpretable in 100% of cases. Using traditional base-apex configuration with the Ekuore device allowed one to obtain a standard ECG waves/complexes aspect (no precordial leads, compared with previous smartphone devices) and a stabler recording because the operator did not need to maintain the device in place; moreover, the operator could be in a safer position.

The single-lead Ekuore device has been compared previously with a reference ECG system in healthy horses and showed an excellent agreement.[11] Similar to this previous study,[11] the morphology of the sinus P-QRS-T complexes recorded with the Ekuore device in our study agrees with that recorded by a standard electrocardiograph using base-apex configuration.[1] Concerning the non-sinus P-QRS-T complexes, the Ekuore device facilitated, following the criteria reported previously,[12,13] the easy diagnosis of cardiac arrhythmias in all horses. Most of the horses with arrhythmias showed physiological heart rhythm disturbances: this is not surprising because healthy horses commonly have a high vagal tone, which can block sinus node or delay (or even block) AV nodal conduction.[1,13] Atrial fibrillation represented the most frequent heart rhythm disturbance (7/13 horses) among the pathological arrythmias. This agrees with previous studies in which atrial fibrillation was reported as common arrhythmias in horses.[12,13]

We obtained ECG tracings in stables for 10 horses. This shows that the Ekuore device can be a practical tool for the assessment of cardiac rhythm in the field. A resting ECG examination is frequently less available in the field and ECG telemetry/holter systems cannot be economical for many equine practitioners. The Ekuore device is a readily available, portable and economical diagnostic tool, capable of connecting to a smartphone or similar device. Moreover, the fast sharing of ECG tracings as PDF files by email or apps allows a consultation to be easily requested. As reported in the American Veterinary Medical Association guidelines for the use of telehealth in veterinary practice (https://www.avma.org/resources-tools/animal-health-and-welfare/telehealth-telemedicine-veterinary-practice), the term "telemedicine" involves the use of a tool to exchange information about a patient's clinical health status electronically from one site to another, and the term "teleconsulting" refers to a primary care veterinarian using telehealth tools to communicate with a veterinary specialist or other qualified expert to gain insights and advice on the care of a patient. Thus, the easy sharing of ECG tracings, as available for the Ekuore device and other smartphone devices, can provide clinicians with the access to specialists who can help in the assessment and care of cardiac arrhythmias in the field.

In the present case series, the Ekuore device allowed the diagnosis of physiological and pathological arrhythmias in all horses included. However, few horses with supraventricular or ventricular arrhythmias were present in our study. We take into account that a 2 min ECG recording could be too short and limit the arrhythmias recorded. This limits the validation of the ability of the smartphone-based ECG device to differentiate ventricular from supraventricular premature complexes. Moreover, no atrial tachycardias were recorded in this case study. Multiple simultaneous ECG leads could be useful for complex arrhythmia diagnosis allowing the inspection of electrical depolarisation patterns in several planes: this can help clinicians to differentiate various types of supraventricular tachycardias or supraventricular from ventricular beats. The present study assessed the clinical utility of a new smartphone-based ECG device for heart rhythm analysis in horses at rest. However, cardiac arrhythmias can frequently occur during exercise and exercising ECG recordings are needed. Finally, we have not compared the ECG tracing obtained from the Ekuore device with a standard electrocardiograph. However, the aim of our study was not to compare the device with a conventional electrocardiogram but to evaluate the use of the new device in clinical practice. Moreover, it should be underlined that this comparison could be unnecessary because

Fig. 3 Representative ECG tracings from a horse in (a) sinus rhythm, (b) second-degree atrioventricular blocks, (c) sinus tachycardia, (d) atrial fibrillation, (e) atrial premature complex, (f) second-degree atrioventricular block with 3 consecutively blocked P waves, (g) atrial fibrillation with ventricular premature complexes. All tracings were obtained with Ekuore device. Paper speed 25 mm/sec in all ECG tracing; amplitude 10 mm = 1 mV in a, b, d and f; amplitude 5 mm = 1 mV in c, e and g. | Repräsentative EKG-Aufzeichnungen einzelner Patienten der Studie mit (a) Sinusrhythmus, (b) atrioventrikulärem Block zweiten Grades, (c) Sinustachykardie, (d) Vorhofflimmern, (e) atrialem vorzeitigen Komplex, (f) atrioventrikulärem Block zweiten Grades mit 3 aufeinanderfolgenden blockierte P-Wellen, (g) Vorhofflimmern mit ventrikulären Extrasystolenkomplexen. Alle Aufzeichnungen wurden mit dem Ekuore-Gerät erstellt. Papiergeschwindigkeit 25 mm/Sek für alle EKG-Aufzeichnungen; Amplitude 10 mm = 1 mV in a, b, d und f; Amplitude 5 mm = 1 mV in c, e und g.

the Ekuore device allows one to obtain a standard electrocardiogram using traditional base-apex configuration and an excellent agreement was found previously with conventional ECG exams in healthy horses.

In conclusion, we provide a first report of the use of the single-lead, bipolar Ekuore device in clinical practice to evaluate heart rhythm in horses. The new smartphone-based, single-lead ECG device can be more easily available in the field and help veterinarians to evaluate cardiac arrhythmias in both the hospital and the field. Moreover, the Ekuore device allows the easy sharing of ECG tracings, and this can open up new perspectives for equine telemedicine.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

Ethical animal research

No ethical approval was obtained because all data were collected as part of routine clinical practices. Client consent for the acquisition of ECG exams was obtained for all animals in the study.

Source of funding

No source of funding was required for this study.

Authorship

All authors have contributed to the study design, study execution, data analysis and interpretation and manuscript preparation and have reviewed and approved the final version.

Acknowledgments

Authors thank Michela Bassi and Luca Poggesi (Quet) for their technical support.

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