Televet II
The Telemetric ECG and Holter System
How to take an ECG during Exercise ... and why bother?

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Introduction

Although cardiac disease is a rare primary cause of poor performance in the equine athlete, on the rare occasion that performance is affected by cardiac disease, dysrhythmia is the commonest underlying cause (5).

The technique of taking a resting electrocardiogram (ECG) using a base-apex lead configuration is now well established in equine practice (2); most equine practices being equipped with both the expertise and the technology to perform the task. Whilst the method can be valuable in confirming a diagnosis of sustained arrhythmias, like atrial fibrillation, or to diagnose the origin of premature beats, a resting ECG usually offers little to the client in establishing a prognosis for future use of their horse.

The limitations of a resting ECG arise largely because of the enormous cardiac reserve of the horse (7) which means that performance limiting cardiac disease, or abnormal rhythms during exercise, rarely manifest themselves at rest. This is compounded by the fact that alterations in resting cardiac rhythm are common in athletic horses because of normal high parasympathetic drive (3), yet some of these rhythms can also occur as a result of cardiac pathology. As a result, the effect of a resting arrhythmia on performance, or the effect of exercise on an arrhythmia, can only be established, if an ECG can be taken during strenuous exercise when sympathetic tone and myocardial oxygen demand are increased and parasympathetic influence is reduced.

In the past exercising ECG examination, though well described in the equine literature, was restricted to the specialist cardiologist, or the performance laboratory (1); largely due very high cost of radiotelemetric ECG equipment. However the newest technology, based on palm top and lap top computers, or specialised battery-operated devices, has become increasingly affordable for equine veterinarians in Europe. This equipment is rapidly becoming standard for equine practitioners in the United Kingdom and is now available in North America. As a result it is timely for this audience to review the methodology and application of the new generation of ECG devices capable of producing high quality exercising electrocardiographs in performance horses.

Materials and Methods

Horses

73 out of a total of 103 horses referred for cardiovascular examination from 22 equine and mixed practices in the United Kingdom between January 2006 and February 2007.

Methodology

The use of limb leads for recording ECG traces should be avoided in horses but this is especially the case for recordings during exercise. Wires and electrodes attached to the limbs are poorly tolerated, even at rest and the degree of movement artifact during exercise renders them entirely useless. Crocodile clips to make electrical contact with the skin must are also contraindicated for similar reasons. Limb leads, in any event, have no purpose in equids because the pattern of depolarization of the equine ventricle precludes using multiple vectors to assess cardiac size and mean electrical axis, so there is no point using anything other than a simple positive-negative lead system to record cardiac rhythm. As a result the base apex-lead in which single electrodes are placed above and below the heart is used for all equine EKG recordings as this lead system produces large complexes, which are easy to identify.
The conventional base apex lead placement in which the positive electrode is placed on the sternum and the negative electrode on the right jugular furrow is modified slightly to reduce movement artifact caused by neck flexion and extension during movement. The photograph shows placement of 4 silver/silver chloride adhesive electrodes suitable for recording an electrocardiogram during ridden exercise. High quality adhesive electrodes must always be used for recordings during exercise and spare electrodes can be applied before exercise commences, in case one gets dislodged during faster paces. For four lead systems based on the Einthoven limb leads, more familiar to small animal practice, the positive or left arm electrode (usually green) is positioned at the left cardiac apex, and the right arm, negative electrode (usually red) is placed on the left shoulder area. The third Einthoven lead, the left leg (usually yellow) is also placed caudal to the cardiac apex. This allows 2 identical tracings to be obtained from lead 1 and lead 2 in the Einthoven 3 lead system, allowing for a "spare", should one of the ventral leads be displaced. The trace in Lead 3 which is recorded between the left arm and left leg will be of no diagnostic value, due to the close apposition of these electrodes at the cardiac apex, but a rhythm trace only is required from a horse, so this is not a serious limitation. The fourth earth electrode, when present (usually black) is then attached on the shoulder close to the negative, right arm electrode. This vertical modification of the familiar base-apex lead system will still produce large "QRS" deflections, but the atrial deflection ('P' wave) will be slightly smaller in amplitude than that of a true base-apex configuration. Nevertheless the 'P' wave will still be clearly visible during exercise.

**Figure 1**
Configuration of electrodes to record an ECG during ridden exercise

Using the configuration of electrodes shown, the electrodes remain visible to the rider and/or the examiner. As a result, they can be reattached easily, should they become dislodged and are unlikely to be affected by the saddle or girth slipping backwards during exercise, or by the rider's hands or legs. The recording device can be attached to the metal "d" ring just below the pommel of most saddles. For harness racing, the electrodes must be similarly positioned away from any moving harness straps. The precise location of particularly the ventral electrodes or the device must often be varied slightly depending on the style of tack, or rider's leg position.

**ECG equipment**
Traditionally, radiotelemetric or digital Holter recording systems were used to obtain exercising traces. The former units use a local transmitter carried by the horse that continuously radio transmits the ECG signal to a local recorder. These units are expensive and also require that the recorder remain within at least 250m of the exercising horse. This can create practical problems for many equine athletes, unless the horse regularly exercises with a scurry or there is good vehicular access to the exercise grounds.

Digital Holter monitors are also effective, but can be expensive unless they can also be used for other applications such as 24-hour ECG recordings in a small animal environment. These devices require specialised software for reading and interpretation of the stored ECG data, although data can be acquired for days at a time and is especially valuable for investigating horses with sporadic collapse. Commercial companies or individuals will read these recordings on a per case basis, reducing the practice's capital outlay, but such providers are generally more familiar with small animal traces.

The newest technology used to obtain these data is based on personal computers and a digital data logger. These units are the most widely applicable and affordable for equine practitioners in a field environment. Importantly, for general practitioners who might be unfamiliar with interpretation of ECG recordings during exercise, the digital format of the data allows them to be emailed easily specialists for review.

**Results**
Indications for exercising ECG examinations in equine practice based on United Kingdom experience

From the 103 cases referred for cardiovascular examination, 73 were deemed to require an exercising ECG examination. The type of exercise varied depending upon the function and fitness of the horse, but in general every attempt was made to replicate, or slightly exceed the intensity of the horse's normal activity. In this series, 52 horses were exercise under saddle and 21 worked on the lunge.

The horses not subjected to exercising ECG examination were those in which there were clear physical signs of cardiac failure at rest (tachycardia, tachypnoea, dependent oedema) (6 horses), horses with bacterial endocarditis (3 horses) horses with low-grade regurgitant murmurs or with functional murmurs, for whom procedure was not deemed necessary (15 horses), horses that were not used for ridden work (2 unbroken youngsters and 1 retired horse), and horses who were affected by concurrent lameness or other problems that precluded fast exercise (3 horses).

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1. Lifecard CF, Del Mar Reynolds Medical Inc 13 Irvine CA 92618 USA
2. Televet 100, Kruuse, Denmark

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In summary the distribution of cases and conditions in which the technique was used and its diagnostic yield were as follows:

- **12 Thoroughbred horses with disappointing training or race performance.** The procedure was performed to elucidate whether exercise-induced arrhythmias, such as paroxysmal atrial fibrillation, a condition with relatively high prevalence in racing Thoroughbreds was present (6). No case was positive for paroxysmal atrial fibrillation, nor were any atrial premature beats, potential triggers for the condition identified in this group of horses. However, 2 horses had multiple ventricular premature beats during exercise and recovery and 4 horses had 1 or more ventricular premature depolarization during recovery. The latter group was considered to be “normal” and they underwent further investigations of their upper airway function. The abnormalities in the former group were considered to be potentially significant and these horses underwent further cardiac investigations. An inappropriately high heart rate response to exercise occurred in 1 horse.

- **19 horses with diastolic murmurs of aortic valve regurgitation.** The procedure was performed alongside echocardiography to ensure that ventricular premature beats were not present and that the animals were not at an increased likelihood of sudden death (4). A normal ECG was obtained from 14/19 horses. Ventricular premature beats during appropriate ridden work were detected in 5 cases, all of whom were then immediately retired. Advanced aortic valve regurgitation results in left ventricular dilation and thence increases cardiac work and afterload, thus directly increasing myocardial oxygen demand. Simultaneously, diastolic aortic pressure progressively decreases as valve dysfunction progresses, reducing coronary perfusion and myocardial oxygen delivery. Myocardial oxygen demand is yet further increased during exercise and, in advanced cases of aortic valve regurgitation, ventricular ischemia can lead to ventricular ectopic activity and increase the risk of sudden death, or collapse during exercise. These changes are often present before the onset of clinical signs of heart failure and, as a result, regular exercising ECG is mandatory in this group of patients, if they continue to be ridden.

- **To assess the effect of exercise on an abnormal rhythm at rest to better determine the prognosis and the horse’s suitability for ridden work (2 horses).** One horse was affected by atrial tachycardia with 2nd degree AV block and another had multiple atrial premature beats at rest. Both were asymptomatic and in both cases cardiac rhythm normalized during exercise as their sinus node firing rate increased.

*Figure 3a*  
This resting ECG (25cm/min 10mm/mV) was obtained from a 13 year-old cob after an abnormal rhythm was noted during auscultation before his annual vaccination. The horse was otherwise asymptomatic. There are multiple atrial premature beats (arrowed) present at rest.

*Figure 3b*  
The second trace comes from the same horse during lungeing exercise (heart rate 169 beats per minute). The rhythm is now entirely regular as the sinus node rate has now overridden the ectopic focus. The ectopic beats only returned some 15 minutes after the horse returned to his stable and his rate fell to below 60 beats per minute. Exercising ECG in this case allowed a favourable prognosis to be given to the owner, as the rhythm did not deteriorate during exercise and the horse remained in work.

- **Assessment of horses with sustained atrial fibrillation (10 horses).** Conversion of atrial fibrillation to normal sinus rhythm is not always indicated in pleasure horses. However before making this decision it is important to ensure that their heart rate response is reasonable and that they do not suffer from uncontrolled supraventricular tachycardia (SVT) during exercise. This is crucial to ensure that any horse with AF is safe to continue in ridden work without treatment, or if treatment has failed. In this group only one horse failed to maintain acceptable heart rates during his usual levels of work.

*Figure 2*  
The example shown here was taken from a 16 year-old Thoroughbred during fast work on an all-weather gallop (10mm/mV, 25 cm/min). There had been no change in the clinical characteristics of his grade 4/6 diastolic murmur over 3 years. His resting heart rate was 32 beats per minute with regular 2nd degree atrioventricular block. The trace shows a triplet of ventricular ectopic beats. This triplet occurred at a heart rate of 168 beats per minute during hack canter. Multiple episodes ventricular and junctional ectopic beats occurred during this exercise session, although the horse appeared clinically normal and had no history of poor performance. As this rhythm is a trigger for ventricular fibrillation, the horse was immediately retired from ridden work.
This trace was taken from a 6 year old Warmblood gelding used for dressage. An irregularly irregular rhythm was diagnosed when the horse was presented for a pre-purchase examination. There was no history of performance problems since the gelding had been imported from Holland a year previously. Resting heart rate was 38 beats per minute and resting ECG confirmed that the irregularly irregular rhythm was due to atrial fibrillation.

The trace, taken during sustained canter, shows that the gelding develops a rapid supraventricular rhythm with a rate of almost 400 beats per minute that is sustained for 1.4 seconds. The complexes are wide and bizarre, but this is probably caused by aberrant conduction of the rapid supraventricular rhythm, rather than being of ventricular origin. Regardless of the rhythm diagnosis, ventricular filling and myocardial oxygenation would be severely compromised, if this rhythm and rate were sustained for any length of time and the horse is not therefore safe for his rider, unless his rhythm can be treated, despite the fact that the abnormal rhythm was not adversely affecting his performance. In this case, conversion to normal sinus rhythm was achieved with quinidine sulphate per os and a repeat ECG taken during similar strenuous exercise 18 weeks later was entirely normal.

- Assessment of horses affected by murmurs of mitral and tricuspid valve regurgitation (32 horses). To ensure that these horses’ heart rate response to exercise was normal and that no abnormal rhythms developed during exercise. Twenty-two of these horses were examined after their murmur was detected at a pre-purchase or insurance examination. No significant ECG abnormalities were detected in this group of animals in this series.

Conclusions

Given that the horse is endowed with a large cardiac reserve, evaluation of the equine cardiovascular system and electrocardiography (ECG) at rest only provides limited information, an EKG during exercise is an integral tool in the clinical evaluation of horses presented for episodes of exercise associated collapse, decreased exercise tolerance, poor athletic performance or cardiac murmurs. Recent technological advances now allow this technique to be easily performed in equine practice and the new devices are ideally suited to performing resting ECG and longer term monitoring. Additionally digital storage of the acquired ECG data, allows the traces to be easily transferred to a specialist cardiologist for interpretation, if required.

Reference List


In-Practice use of exercise ECG

New technology has made it possible to carry out simple and easy ECG recordings when exercising horses.

Rikke Buhl, DVM, Ph.D.
Department of Large Animal Sciences, Royal Veterinary and Agricultural University, Copenhagen, Denmark.

Cardiac arrhythmias are common occurrences in horses. Most arrhythmias are second degree atrioventricular block in which pulse rates fail to appear at regular intervals due to the high parasympathetic tone via the Vagus nerve, whereby impulse propagation from the atria to the ventricles is blocked and the pulse beat does not occur. When the horse is exercised or stressed, the sympathetic tone will increase and the pulse irregularities disappear.

Pathological illnesses in the myocardium or Vagus nerve can also cause AV blocks, which will not disappear during exercise, resulting in fatigue and decreased performance. Other relatively frequently occurring arrhythmias are supraventricular ectopic beats where the atria will release an extra heartbeat which occurs too early compared to the normal pulse rate. These arrhythmias can be seen in horses suffering from valvular insufficiency and they may be a precursor to developing atrial fibrillation which also occurs in horses.

Generally, the clinical relevance of arrhythmias is less important if they disappear during exercise. However, in some cases, less important arrhythmias can evolve into severe arrhythmias if the horse is put under an intensive exercise. In other cases the arrhythmias will disappear during exercise, only to reoccur following the exercise when the pulse rate drops. Consequently, it can be difficult to evaluate the influence of exercise on the arrhythmias without access to in-practice exercise ECG monitoring.

An electrocardiogram (ECG) is ideal for diagnosing cardiac arrhythmias. Traditionally, an ECG reading will be taken from a resting horse. However, it would often be more relevant to evaluate the rhythm during exercise, where the heart’s conduction system is put under strain. A resting ECG is less relevant to the clinician in comparison to an ECG taken during exercise.

Until now it has not been possible for equine practitioners to get an exercise ECG, as this kind of examination previously was based on tests done on treadmills. However, new technology (KRUTECH Televet 100, KRUUSE, Denmark) has made it possible to carry out simple and easy ECG recordings when exercising horses (Fig. 1), whether on the dressage, jumping or race track.

This article describes two examples of in-practice use of exercise ECG readings of horses.

Patient 1
Danish Warmblood, 9 year old dressage horse. During the past few months getting increasingly tired and difficult for the rider to motivate. e clinical evaluation of the horse did not show any abnormalities, but auscultation of the heart revealed regularly irregular pulse, where pulse beat was absent every 2nd to 4th heart beat. As the arrhythmia did not disappear subsequent to exercise, the horse was referred for further cardiologic testing. Auscultation of the horse after trotting revealed that the arrhythmia persisted. Cardiac scanning and ECG of the horse at rest showed no abnormalities apart from a 2º AV block (Fig. 2). e haematological values were normal. A subsequent 30-minute longeging (trot and gallop) of the horse with the ECG electrodes placed was carried out. e horse completed the exercise test successfully. However, a slight bilateral lameness of the forelimbs was noticeable. e heart rhythm during the exercise test was characterised by persistence of the 2º AV block when the pulse was lower than 100 beats/minute, but disappeared when the pulse increased above this level (Fig. 3). e maximum pulse during the 30-minute exercise test was 170 beats/minute. Pulse irregularities failed to appear immediately after cessation of the exercise test, when the pulse started to drop.

Discussion and conclusion
As mentioned, 2º AV block occurs frequently in resting horses due to a very high parasympathetic tone via the Vagus nerve, but it disappears during exercise. Pulse irregularities in this horse were highly predominant, and this being the case at a relatively high pulse, made it impossible, even with auscultation immediately following exercise, to hear a normal, high pulse without irregularities. Combined with increased fatigue during exercise, the obvious assumption would be that this was a classic case of a pathological 2º AV block, which persisted during exercise.

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Exercising with the ECG electrodes placed, showed that the heart rhythm was normal during trot and gallop which means that the cardiac arrhythmias could not be the cause of the poor performance. The horse went through an orthopaedic examination and was subsequently diagnosed with ringbone in both forelimbs, which would account for the decreased performance.

**Patient 2**
Danish Warmblood, 8-year-old mare. Has recently shown signs of exercise fatigue. Healthy with normal pulse, respiration and temperature. During auscultation of the lungs, pronounced vesicular respiration was heard, but the horse was not coughing. Ventral oedemas could not be palpated, but venous pulse was identified in approximately half of the venous jugular as well as intermittent venostasis. During cardiac auscultation, arrhythmias were identified: beats in cascades followed by pauses at varying lengths. Over the tricuspid valve, a short systolic murmur (grade I/VI) could be heard.

Ultrasound examination of the heart showed no pathological abnormalities. Resting ECG showed atrial fibrillation (Fig. 4). During light longeing at a trot, atrial fibrillation persisted and ventricular fibrillation developed periodically (Fig. 5) which caused fatigue and slight weakness of the hindlimbs. During the exercise test the horse suffered from severe fatigue, heavy breathing and perspiration. The pulse rate was constant at 200 beats/minute, which is too high for a standard trotting workout.

**Discussion and conclusion**
Atrial fibrillation is the most common pathological arrhythmia in horses. For horses which are expected to function during hard, physically demanding working conditions, this type of arrhythmia will cause decreased performance, whereas dressage horses often will function satisfactorily despite this problem.

The ventricular fibrillation, which developed during exercise of this particular horse is an arrhythmia that can cause a collapse, and after a short time, death of the horse. Even though the ventricular arrhythmia only was identified periodically during exercise, the owner was advised not to ride the horse, as there was a risk of the horse collapsing. Consequently this horse should not be used for riding.

These two examples involved horses where the ECG recording during exercise was crucial in terms of diagnosis and advice. For patient number 1, the ECG reading during exercise showed that the heart was working normally and that the heart was not the cause of decreased performance. In contrast, patient number 2 developed severe arrhythmia during exercise, which could lead to its death, so this horse should be retired immediately.

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Cardiac arrhythmias in the horse: the role of new ambulatory ECG technology
Dr Eduard Jose-Cunilleras DVM PhD Dip ACVIM(LA) MRCVS

Cardiac arrhythmias are not uncommon in horses. At rest, athletic horses often have 2nd degree atrioventricular block and sinus arrest, which are abolished at exercise. Given that the horse is endowed with a large cardiac reserve, evaluation of the equine cardiovascular system and electrocardiography (ECG) at rest only provides limited information. Exercise ECG is an integral tool in the clinical evaluation of horses presented for episodes of exercise associated collapse, decreased exercise tolerance or poor athletic performance. However, until recently assessment of exercise ECG and 24h holter ECG was restricted by the need to use equipment for human applications. The recent development of Televet 100, a light weight battery powered ECG digital recorder with telemetric on-line monitoring, easily allows assessment of cardiac arrhythmias at rest, during and after exercise in ambulatory equine practice.

The applications of ambulatory ECG recorders in equine practice beyond that of standard mains powered human and veterinary ECG systems may include:

1. Exercise ECG
   a. Paroxysmal atrial fibrillation (AF)
   b. Supraventricular premature depolarisations (SPDs) and ventricular premature depolarisations (VPDs) during and after exercise
   c. Level of fitness and heart rate response to exercise
   d. In the context of assessment of heart murmurs (mitral regurgitation and aortic insufficiency) and likelihood of exercise-induced arrhythmias secondary to left atrial or left ventricular dilation

2. 24 h Holter monitor
   a. AF conversion during quinidine therapy: ventricular and supraventricular rhythms and tachycardia
   b. Atrial premature depolarisations as triggers of AF
   c. Arrhythmias as a cause for collapse: ventricular tachycardia, persistent 2nd degree AV block during exercise, 3rd degree AV block

Case studies

Case 1.
19 year old Thoroughbred gelding in light training, grade 3/6 aortic insufficiency murmur detected during recent mild colic episode, owner concerned about apparent excessive tiredness after exercise. Cardiac auscultation: 36 beats per minute, no arrhythmias detected, grade 3/6 diastolic murmur with point of maximal intensity over aortic valve. Echocardiography: moderate aortic insufficiency on colour flow Doppler, mild left ventricular enlargement and normal myocardial contractility. ECG at rest: no abnormalities (normal sinus rhythm with occasional 2nd degree AV block). Exercise ECG during cantering exercise undertaken to rule out exercise-induced cardiac arrhythmias: short run of ventricular premature depolarisations (red arrows) during fast exercise (Fig. 1) resulting in peak heart rate of 200 beats per minute.

![Fig. 1: 2mV/divider and 400msec/divider](image)

It was judged this horse was unsafe to ride and should be retired given the aortic insufficiency with mild left ventricular enlargement and accompanying ventricular arrhythmia. These arrhythmias detected at exercise could lead to collapse or sudden death due to persistent ventricular tachycardia or ventricular fibrillation.
Case 2.
15 year old Thoroughbred and Irish Sport Horse cross mare with irregularly irregular heart rhythm for several days. Trainer first noticed the mare could not keep up with the rest when cantering uphill. Cardiac auscultation: irregularly irregular rhythm with heart sounds of varying intensity and grade 2/6 systolic murmur characteristic of mitral regurgitation. Resting ECG: confirmed atrial fibrillation. Echocardiography: moderate mitral regurgitation on colour flow Doppler, normal left atrial dimensions and cardiac contractility. Battery powered ambulatory ECG digital recorder was used to detect cardiac arrhythmias and excessive tachycardia due to oral quinidine sulphate treatment. ECG tracing was assessed in real-time on a computer screen and recorded for later review. Atrial fibrillation is observed prior to quinidine treatment (Fig 2A), supraventricular tachycardia (HR 190 bpm) is detected after the third dose of oral quinidine (Fig 2B) and normal sinus rhythm with reduced P-R interval is seen 3 h after the last oral quinidine dose (Fig 2C). A 24 h ECG recording was performed on this mare 1 month after treatment and no atrial premature depolarisations were detected.

Fig. 2. 1mV/divider and 400msec/divider

These two clinical cases serve to illustrate the versatility, ease of use and the increased ability to prognosticate when using the modern ambulatory ECG recorders specifically designed to suit the needs of ambulatory and referral equine clinicians.
Atrial Fibrillation in a Horse

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A 5 year old, racing Standardbred Gelding, presented to the Purdue University Large Animal Veterinary Teaching Hospital for poor performance. The gelding was reported to have raced 3 days earlier. During the race, the horse suddenly slowed down and stopped. Cardiac arrhythmia was suspected at the track. The horse was referred for further evaluation. The horse had a decrease in performance over the past 3 months. No other abnormalities were noted in his history. The horse was fed free choice grass hay and was up to date on all vaccinations.

Presenting Physical Examination

Body Condition: 5.0/9.0
Temperament: bright, alert and responsive
Temperature: 98.9 degrees F
Pulse: 44 bpm, good pulse quality
Respiration: 12 rpm
General Appearance: Normal
Integumentary: Normal
Musculo-Skeletal: Normal
Cardiovascular: Abnormal - irregularly irregular heart rhythm on auscultation
Respiratory: Eupneic; lung sounds clear
Digestive: Normal - adequate intestinal sounds on auscultation
Genito-Urinary: Normal
Nervous System: Normal
Ears: Normal
Eyes: Normal
Lymph Nodes: Normal
Mucous Membranes: MM pink and moist, CRT < 2 sec.

Upon presentation, the only abnormality on physical examination was an irregularly irregular heart rhythm, which was most suggestive of atrial fibrillation. An electrocardiogram was performed (Televet® 100), confirming the presumptive diagnosis of atrial fibrillation (Fig. 1).

Figure 1: ECG Atrial Fibrillation

Then, the patient was fitted with a Holter monitor (Televet® 100; Fig. 2), allowing continuous electrocardiogram monitoring of the ECG in preparation for treatment. Treatment was initiated with a half dose of quinidine sulfate (5g; 10 mg/kg) administered via nasogastric intubation to ensure that no adverse reaction would occur. No reactions were detected in the following 2 hours therefore, the first full dose of quinidine sulfate was administered via nasogastric intubation (10g; 20 mg/kg). Two hours later, conversion had not occurred.
A second equivalent dose of quinidine sulfate (10 g) was administered via the same route. Following the second dose, the patient began to exhibit supraventricular tachycardia. Tachycardia was recorded as high as 200 bpm, though consistently remained between 80 and 150 bpm (Fig. 3). Vasovagal response via ocular pressure was able to reduce the tachycardia. During the vasovagal treatment, episodes of atrial flutter and secondary atrio-ventricular block were noted. Rapid supraventricular tachycardia is a common occurrence in horses treated with quinidine as a result of removal of vagal tone on the AV node. Therefore, quinidine administration was discontinued and the horse was treated with digoxin (15 mcg/kg; PO). The atrial fibrillation had still not converted but heart rate slowed down.

Twelve hours later, the horse had converted to a normal sinus rhythm with a heart rate of 40 bpm (Fig. 4). The patient was kept overnight to ensure that the tachycardia and atrial fibrillation did not recur. Twenty four hours later the atrial fibrillation had remained resolved. The patient was discharged with the recommendation of being turned out to pasture for 6 months and digoxin per os twice daily at 0.008 mg/kg was prescribed to aid in maintenance of normal sinus rhythm.

The horse resumed training 6 months later and was able to race successfully initially but then raced poorly again. Persistent atrial fibrillation was noted but the owner declined echocardiography to rule out potential underlying cardiac disease. The horse was again treated with quinidine following the same protocol as above. Heart rate converted to normal sinus rhythm after the 4th dose of quinidine without development of supraventricular tachycardia as observed before. The horse was rested for 2 weeks and then resumed training but was subsequently retired from racing.
Dear M. H. Pedersen, Kruuse

We are happy to inform you about our experience with the Televet 100 use in horses in our department of Large Animal Internal Medicine, Ghent University, Belgium.

Monitoring heart rate and rhythm represents an important tool in the daily examination of horses with poor performance or cardiac related disease. The Televet 100 system is used at our department for both diagnosis and research purposes.

**Approach:**
The Televet 100 transmitter is attached to a girth. Self-adhesive electrodes or a girth with build-in electrodes are used. Once the electrodes are attached one can choose to (1) display and/or record the ECG on a laptop via Bluetooth connection, (2) record the ECG to the memory card of the transmitter or (3) record/display the ECG on both devices. After recording, the ECG data are analysed with the laptop or stand-alone computer. Automatic R wave detection allows heart rate calculation throughout the recording. Arrhythmias are detected on manual analysis of the ECG trace. During manual analysis, ECG amplitude and speed can be adapted and one can swap between single channel or multi channel (Eindhoven or Goldberger) recordings. An artefact filter and 50/60 Hz filter can be activated to improve signal quality. For each patient the software allows data management of ECG recordings, patient details, diagnosis,...

**Clinical patients**
- First the ECG at rest is taken. The ECG trace is immediately displayed and recorded on a laptop via Bluetooth connection. For an exercise stress test the quality of the ECG recording is first verified via Bluetooth on the laptop. Afterwards, the stress test is performed while the ECG is recorded on the memory card of the Televet 100 transmitter. In case the stress test is performed on a treadmill, the ECG is simultaneously visible on the laptop via the Bluetooth connection. When the stress test is performed on a racetrack, the ECG is only recorded on the memory card. After completion of the stress test the recorded ECG data are transferred to a stand-alone computer and manually analysed for the presence of dysrhythmias.
- In patients with a history of (pre)syncope, a 24 hour ECG recording is made and manually analysed in a similar way.
- In horses with atrial fibrillation the Televet 100 is used to:
  1. monitor horses during and after pharmacological treatment of atrial fibrillation. Continuous ECG monitoring during the treatment is mandatory to adjust treatment regime. The wireless transmission of the ECG to the laptop facilitates continuous monitoring these patients with minimal distress.
2. monitor horses after successful transvenous electrical cardioversion of atrial fibrillation. The monitoring of successfully cardioverted horses allows diagnosing atrial or ventricular arrhythmias, which is important for prognosis.

**Research**

The Televet 100 is used for:
- diagnosis of exercise-related arrhythmias
- ECG monitoring during and after pacemaker implantation in horses
- ECG monitoring in a horse model of pacing-induced atrial fibrillation
- transvenous electrical cardioversion in horses

**Our conclusion**

The Televet 100 is an easy to use portable system to obtain good quality, short-term or long-term ECG monitoring and recording in horses, both for diagnostic and investigational purposes.

Yours Sincerely,

Prof. Dr. G. van Loon, DVM, PhD, Dipl ECEIM
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**Televet testimonial**

“The Televet wireless ECG system is a rarity in biomedical instrumentation: A device that works exactly as promised out of the box the very first time. It is without question the best ECG system I have ever used, in the field or in the lab. The Televet wireless ECG system has become a basic, mandatory piece of equipment for all of our exercise studies because it is simple and reliable, and collects valuable data in a variety of conditions ranging from controlled laboratory treadmill exercises on horses to sled dog training runs across miles of tundra at subzero temperatures.”

Michael S. Davis, DVM PhD Dipl ACVIM
Director, Comparative Exercise Physiology Laboratory
College of Veterinary Medicine, Oklahoma State University
Atrial fibrillation is the commonest pathological cardiac dysrhythmia in the horse and frequently presents with acute onset of poor performance. The treatment of choice for this condition remains quinidine sulfate, administered by nasogastric tube. With careful case selection this offers a prognosis for successful conversion of approximately 80%. Therefore animals with recent onset atrial fibrillation (less than 3 months duration) without a cardiac murmur of mitral or tricuspid regurgitation are usually good candidates for treatment. However, quinidine is not without complications, and these can be cardiac or extra-cardiac and in some cases can result in sudden death.

While the commonest form of complication of quinidine treatment are gastrointestinal (colitis and colic), further cardiac dysrhythmias may also be induced. These include both supraventricular and ventricular tachycardia and can be rapidly fatal. Therefore continuous ambulatory monitoring is useful for rapid diagnosis and intervention. The Televet ambulatory ECG system is a cost effective ambulatory telemetric ECG system designed for veterinary use. The system utilises Bluetooth technology to transmit a signal up to 100m to a Windows based computer. The system is easy to use, and can record a 6 lead ECG both on to a SD memory card within the unit (acting as a traditional Holter monitor) or transmitted to PC where the trace can be recorded for an unlimited time. Unlike traditional long term ECG solutions there is no paper output (unless printed) so there is no need to store paper traces, and no chance of the trace quality deteriorating as thermal paper does not produce a long lasting solution. A patient database means that the ECG recording can be stored and reviewed at any time.

The ECG software has been well designed and as the trace above shows, is free from artefact. The designers have included artefact and AC filters, electronic callipers to measure complexes, and both acoustic alarms and an acoustic heart beat. Therefore the Televet ECG system can replace both a paper trace ECG, a Holter monitor, a telemetric ECG and an anaesthetic / intensive care monitor all for the price of a single monitoring device.

New therapeutic options are being investigated for the treatment of atrial fibrillation, these include amiodarone, diltiazem and flecainide, although at this time, there is no evidence to recommend these as a first line treatment instead of quinidine. However intracardiac electrical cardioversion offers a novel treatment option for horses with atrial fibrillation of over 3 months duration where the prognosis for successful pharmacological cardioversion with quinidine is poor and the frequency of complications is higher.

Mark Bowen BVetMed PhD CertVA CertEM(IntMed) MRCVS
Associate Professor in Veterinary Internal Medicine
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11/16/2006
Dear Henrick,

We have used the Televet 100 radiotelemetry ECG unit on our equine athletes to evaluate poor performance at our equine performance center at Cornell University Hospital for Animals. We have been very pleased with the quality of the recordings, both during lunging and on high speed treadmill examinations. Attached is an ECG from a young racehorse during treadmill evaluation at high speed. His heart rate at the time was near 200 bpm. Using the software allows us to spread out the waveforms to allow for improved visualization of morphology and timing.

Sincerely,
Marc Kraus, DVM, Dipl. ACVIM (Cardiology)
Sophy A. Jesty, DVM, Dipl. ACVIM (Large Animal Internal Medicine)
Use of a new telemonitor for ECG in horses
Claire Scicluna, DVM, Clinique vétérinaire équine Du Plessis, 60300 Chamant, France

The last 15 years are without contest a new area regarding the evolution of equine veterinary medicine and surgery. Anesthesia, critical care and sports medicine are some of the specialties that can benefit a lot from new technologies as monitoring is becoming more efficient, reliable, smaller and easy to use everywhere in any condition.

Heart rate monitoring and ECG analysis can now be achieved in several practical field conditions with very small and wireless monitors like the Televet 100®.

The hand-size machine fits in a small box that can be attached to the horse easily (on a girth or a saddle if training or taped on the neck). The four sticky electrodes are positioned according to the rules of ECG practice without clipping and can resist to movements of a training horse and the large sweating induced by strenuous exercise.

In the telemetric mode, the bluetooth system of the monitor allows to send data in real time directly on to a notebook or computer within almost 500m around from the transmitter. All ECG derivations (DI, DII, DIII, avL, avR, avF) can be seen "live" from the horse on the lab top screen.

If the distance is too important to allow a good bluetooth transmission, a memory card (SD-card) placed into the box can be switched on to record data for 30-hours long. After recording, all data can be easily transferred to the computer by plugging in the card directly in it: this is the holter mode. Telemetric and holter modes can be used in parallel: ECG is then always recorded.

The software provided with the monitor allows a large screen to show the 6 leads curves and to examine them simultaneously. Good filters can be switched on to delete nearly all artifacts, even at high-speed trot or gallop. All segment measurements needed to analyze the ECG can be done easily and can be compared automatically by the computer. The software is then also an help to the diagnosis if necessary. All data can be stored in a special file for each horse on the computer, which can facilitate comparisons of further exams or allows later printing or mailing when needed.

Even if the first equine clinical application of this ambulatory system is heart monitoring of the horse during exercise, it can be useful in anesthesia or intensive care cases. Special event during those periods can be closely recorded and then examined in real time or later analyzed.

Moreover, for such situations, the software upgrade allows now to check 4 equipped patients at the same time and on the same screen. Considering all the circumstances in which it can be useful, this wireless ECG Televet 100® is an ideal tool to be used for exercise heart function analysis, as well as for anesthesia and critical care patients monitoring either in field conditions, an equine hospital or why not by distance on internet…

First step towards the new equine telemedicine of the future!
The new Televet II replaces the Televet 100 which so far has set a "Gold Standard" for veterinary ECG. Before Televet 100 the veterinary surgeon was limited to a resting ECG using a traditional ECG system. Now with the development of Televet the veterinary surgeon is able to monitor the animal during its normal daily activities. This allows to diagnose cardiac rhythm abnormalities which may only occur during exercise or at rest. The Televet provides a telemetric two channel (3 / 6 vector) ECG system. It has been especially developed to be used for small and large animals. The Televet allows convenient ECG recordings at rest as well as during exercise with an excellent quality even during strenuous exercise. In telemetric mode the Televet transmits data in real-time. The ECG is displayed on a laptop or PC and it is stored on the hard disk. In addition Android or iOS phones and tablets can be used remote control the Televet II device or to display and record an ECG in real-time. In Holter mode, data is stored on a standard micro SD-Card or micro SDHC card which is plugged into the ECG device for up to 3 days. A telemetric connection to host PC or laptop is not required during recording. Telemetric mode and Holter mode can be used in parallel, this ensures that an ECG is always recorded. The system includes software which enables ECG recordings to be reviewed at any time, printed or emailed for a second opinion. Televet II now supports the Televet Cloud Service for simple data exchange between mobile devices and desktop computers.

System requirements for Televet Complete software on Windows
• Windows 7, 8 or 10
• PC or laptop with min.1,5 GHz clock frequency
• Minimum 2 GB RAM

System requirements for Televet Complete software on Mac/Apple
• MacOS 10.1 or newer

System requirements for Televet Light on Android
• Android Version 4.2 or newer
• Android Phone or Tablet

System requirements for Televet Light on Apple iOS device
Look into "App Store" to find a list of devices compatible with the Televet light app. Also see http://www.televet.de/iPadCompatibility for Televet II compatible devices

Televet II Complete software includes:
• Holter recording on micro SD and micro SDHC cards
• License Key for Holter Analysis for small animal and Equine Feto-Maternal ECG/HR recording

Televet II Basic includes:
• Televet Light software which can display and record ECG, but does not includes the analysing software

Three years of Televet Cloud Service included for both Televet II and Televet II Basic.
Technical Data

- Channels: Two; for simultaneous recording of Einthoven I, II, III and Goldberger aVR, aVL, aVF
- Range: 100m clear range with external Bluetooth adapter
- Batteries: 2 Mignon Alkaline (Type AA)
- ECG devices per PC: Up to 4
- PC Sampling rate: 500 Hz
- Frequency Range: 0.05 Hz – 125 Hz

Features

- Wireless telemetric transmission of ECG to PC or laptop, smartphone or tablet
- Two physical channel ECG for small and large animal
- Holter ECG (>3 days) on standard micro SD/SDHC-Card
- Clear range of about 100 m (Bluetooth Class 1) with external Bluetooth in PC
- Very small:
  - Size: 113 x 71 x 20 mm (4.44 x 2.79 x 0.78 inch)
  - Weight: 129 g incl. batteries

Televet II includes:
Transmitter, Bluetooth Class 1 receiver, Micro SDHC-Card, Televet Complete software, Televet Light software, protection bag and carrying case.
Cat. No 291308

Televet II Basic includes:
Transmitter, Bluetooth Class 1 receiver, Televet Light software, protection bag and carrying case.
Cat. No 291309

*Patient cables and KRUUSE ECG Electrodes are not included, and need to be ordered separately.*

Cat. No 291311 Televet II patient cable, Equine

Cat. No 291312 Televet II patient cable, Small Animal
Cat. No 291310 KRUUSE ECG Electrodes 40/pk

These Ag/AgCl electrodes are free of latex and with Aqua-Wet gel for fast pick-up of the ECG signal. The electrodes have great adhesive effect which often makes it possible to apply the electrodes without any removal of haircoat.

Televet Bluetooth Hub

The Televet Bluetooth Hub is ideal solution in an ICU settings. Televet Bluetooth Hub feeds the ECG signal into the clinic’s internal network.

- Real-time conversion of ECG real-time stream from Bluetooth to the clinic’s internal network
- Support for up to four Televet II devices in parallel
- Automatic reconnect to Bluetooth for ECG stream in case the patient was out of reach
- Monitoring of up to 4 patients at a time per Monitoring Station
- No need for Bluetooth Support at the Monitoring Station
- Multiple Monitoring Stations supported on a single Bluetooth Hub

Streaming of the ECG data via the Bluetooth Hub is not limited to the clinic’s internal network only. By additional use of the Televet Gateway (see Televet Mobile Option) the streams are accessible any time from any location, even at night from the veterinarian’s home.

Cat. No 291304 Televet Bluetooth Hub

Mobile Gateway Kit

By employing a smartphone to connect the Televet II to the mobile phone infrastructure (GPRS, EDGE, 3G or others), the real time and heart rate data is supplemented by data from the Global Positioning System (GPS). As a result ECG and Heartrate can be monitored together with speed, altitude, tracking information etc.

- With the Televet Mobile Option a smartphone connects to the Televet II and transmits the ECG data from anywhere
- Available on any mobile network
- Used for Exercise Physiology Applications
- Rider can monitor heart rate and speed on a mobile phone
- Veterinarians can monitor ECG, heart rate, speed and position on a laptop
- ECG may also be displayed on mobile phones or tablets for initial check of trace quality

The Televet Gateway Option provides mobility for you and your patient. It consists of:

- Televet Light software
- Access to the Televet Cloud Service for three years

The mobile phone hardware is not part of “Televet Gateway Option”

Cat. No 291305 Mobile gateway kit

For more information visit www.televet.de