Reference values of Holter electrocardiography in normal horses

Zoltan Bakos* and Louise Lohne1
School of Veterinary Medicine, Faculty of Medical Sciences, The University of the West Indies, St. Augustine, Trinidad and Tobago.
1Manor Veterinary Clinic, 20 Manor Road North, Hinchley Wood, Esher, KT10 0SH, UK

*Corresponding author: Tel.: +1868-333-0844; Fax: +1868-645-7428; Email: zoltan.c.bakos@gmail.com

Abstract
The aim of the study was to obtain a set of relevant measurements from healthy, resting horses that can be used as reference values for Holter electrocardiography. Twenty healthy horses (eight mares, two geldings and ten stallions) were selected randomly. The animals varied in age from three to nine years. Electrocardiography was performed at rest in the stable without the presence of the examiner causing additional stress. Each horse was monitored for one hour. P-wave duration, P-wave peak interval, P-R segment, P-R interval, QRS interval, S-T segment, Q-T interval and S-T interval were determined. Median values of the above-mentioned parameters in milliseconds were as follows: 110, 65, 153, 273, 131, 218, 557 and 426, respectively. These values differ significantly from previously published results based on standard electrocardiography.

Key words: Holter, electrocardiography, ECG, horse, reference values

Introduction
One of the principal problems of examination with standard electrocardiography (ECG) is that the cardiac rhythm is only recorded over a short period of time. Consequently a significant arrhythmia may not be detected during the examination, particularly if the arrhythmia is intermittent. In addition, the animal is not truly at rest because of the presence of the clinician, which may cause a different heart rate and rhythm to be observed. Examining the heart rate and the cardiac rhythm of a horse by cardiac auscultation or by standard ECG usually causes some sympathetic stimulation, which may influence the cardiac function and confound the determination of the ‘normal’ resting sinus rate. Holter ECG monitoring allows clinicians to examine the electrocardiogram of a horse over a longer period of time, usually up to twenty-four hours. This method also allows horses to be monitored during strenuous exercise, either on a treadmill or on the racetrack, and may be an invaluable tool in diagnosing diseases that affect performance.

Although several studies have been published on the application of Holter ECG in the horse, there are no previously published data concerning the duration of the different waves, segments and intervals of the electrocardiogram while using the Holter method. The aim of this study was to obtain a set of relevant measurements from healthy, resting horses that can be used as reference values.

Materials and Methods
Twenty healthy Warmblood horses (eight mares, two geldings and ten stallions), used for pleasure riding, were selected randomly. The animals varied in age from three to nine years. The average weight of the horses was 495 kg (from 400 to 550 kg). Prior to the monitoring, all horses were checked for their health status through detailed physical examination with particular attention paid to the cardiovascular and respiratory system.

Electrocardiography was performed at rest in the stable without the presence of an examiner causing extra stress. It was important to collect data from horses stabled in an environment as close to normal conditions as possible. A blanket surcingle was fitted tightly around the thorax, and the Holter device (Argusys FD Holter ECG, Innomed Medical Inc., Budapest, Hungary) was securely fitted on the left side of the horse, at the level of the flank. The positive electrode was passed across to the right side over the withers of the horse and fixed at the seventh intercostal space in the ventral region of the thorax. The negative electrode was fixed in the ventral region of the thorax, at the fifth intercostal space on the
left side. The basal electrode was fixed on the left side at the withers.

Each horse was monitored for one hour. The results of the examinations were then transferred to a computer, using Argusys 2.50 (Innomed Medical Inc., Budapest, Hungary) software. The programme allowed an individual file to be made for each horse. Once the ECG measurements for one full hour were downloaded to the computer, certain segments and intervals of the ECG curves were measured. These points were as follows: P-wave duration, P-wave peak interval, P-R segment, P-R interval, QRS interval, S-T segment, Q-T interval and S-T interval (Figure 1). The recorded heart rate was also calculated manually by using the speed of recording and the square millimetre background of the software. Thirty measurements were recorded per hour of ECG monitoring, the equivalent of one measurement every second minute. The time intervals were measured in milliseconds by using a function of the computer programme that allowed the distance between two points of the ECG curve to be measured. Also, twenty measurements per hour were made of the height and depth (amplitudes in mV) of the P-, QRS- and T-waves using the square millimetre background. Special attention was directed to detecting whether there was a single or double P-wave, and a single or a biphasic T-wave in the individual horses.

Exploratory data analysis was performed using the univariate procedure of SAS\textsuperscript{13}. Centrality of the distribution in the present study was represented by the median and was compared to average figures in published data using the binomial test for the median\textsuperscript{13}.

**Results**

All ECG curves were analysed individually. Ninety-five per cent confidence intervals, mean values and standard deviations of the measured parameters were calculated and are represented in Table 1.

The amplitude of the different components of the curves was also measured, but during this process some problems were encountered. It turned out that there was a substantial deviation in the height and form of the curves from horse to horse. Five horses had bifid P-waves, while the other fifteen horses had simple positive P-waves. Fourteen horses had negative T-wave deflexions, only one horse had positive T-waves, and the remaining five horses had biphasic T-waves. QRS-complex morphology also showed marked differences. These results made it impossible to analyse the data fully.

**Discussion**

The measurements of waves, segments and intervals were relatively easy to obtain with the same level of precision in all horses. Since there are no previously published data concerning the duration of the different parts of the ECG curve while using the Holter method, the results were compared to values obtained by using the standard ECG method (Table 2). A problem was encountered with this comparison in that the other authors did not all measure the same parameters. Also, the number of horses measured in those studies is not known. There were significant differences (p < 0.0001) between the median values for P-wave duration, P-wave peak interval, P-R interval, QRS-interval, Q-T interval and S-T interval, and the average values in the published data for these variables.

The magnitude of P-R and Q-T intervals is rate dependent and decreases as rate increases\textsuperscript{14}. On the basis of this statement and the notion that heart rate is probably lower during ECG recording using the Holter method, it is difficult to explain the lower P-R interval value in the present study relative to those from published data. A possible explanation could be that the number of horses examined in the present study was too small. However, some differences in the values obtained are to be expected since the standard ECG and the Holter ECG are two different methods. A mean value of 0.33 seconds for the P-R interval has however, been reported in an earlier study\textsuperscript{15}, and this value is consistent with the result obtained in the present study. This kind of disparity was not present in the data for the Q-T interval.

Comparing the mean value of the S-T interval to the data published earlier\textsuperscript{12}, the difference is remarkable (0.424 second and <0.06 second, respectively, Table 2). The authors of this study are of the opinion that those results cannot be accurate. There are two pieces of evidence that point to this conclusion. Firstly, the QRS-complex duration is always shorter than the S-T interval in healthy horses. This value is less than 0.17 seconds in the cited reference, so the S-T interval cannot be < 0.06 seconds\textsuperscript{12}. Secondly, the S-T interval can be calculated as the difference between the Q-T interval and QRS-complex duration. Doing this with the combined data in Table 2 gives a result of 0.43-0.46 seconds, which is consistent with the mean value (0.424 seconds) shown in the present study.

The present work provides useful reference values in the field of equine Holter electrocardiography. The study could serve as a basis for future examinations. It would
be desirable to work with a bigger group of subjects, and to compare different lead systems over time periods exceeding one hour. There are also very few studies examining the reference values of Holter ECG during standardised exercise tests. Therefore, future studies could investigate the relationships between heart rate and ECG measurements while controlling for the possible effects of training level and breed.

Conclusion

With larger and more representative samples, reference intervals may be compiled based on the mean plus or minus two standard deviations (for normally distributed data) or on the interval between the 2.5th and 97.5th percentiles (for skewed distributions), as is currently done in other disciplines16. An objective of future studies that builds on the present findings could be the development of software that automatically analyses the results of Holter measurements in the equine patient.

References

Reference values of Holter electrocardiography in horses

Table 1. Ninety-five per cent confidence intervals for the median, mean and median values, standard deviations and interquartile ranges of Holter electrocardiographic measurements obtained from normal resting horses.

<table>
<thead>
<tr>
<th></th>
<th>P-wave duration</th>
<th>P-wave peak interval</th>
<th>P-R segment</th>
<th>P-R interval</th>
<th>QRS interval</th>
<th>S-T segment</th>
<th>Q-T interval</th>
<th>S-T interval</th>
<th>Heart beats/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% CI</td>
<td>109-120</td>
<td>65-71</td>
<td>153-164</td>
<td>262-273</td>
<td>120-131</td>
<td>218-218</td>
<td>546-557</td>
<td>415-426</td>
<td>36-38</td>
</tr>
<tr>
<td>Mean</td>
<td>118</td>
<td>67</td>
<td>160</td>
<td>279</td>
<td>132</td>
<td>221</td>
<td>558</td>
<td>424</td>
<td>38</td>
</tr>
<tr>
<td>Median</td>
<td>110</td>
<td>65</td>
<td>153</td>
<td>273</td>
<td>131</td>
<td>218</td>
<td>557</td>
<td>426</td>
<td>36</td>
</tr>
<tr>
<td>SD</td>
<td>44</td>
<td>12</td>
<td>47</td>
<td>61</td>
<td>40</td>
<td>41</td>
<td>67</td>
<td>53</td>
<td>7</td>
</tr>
<tr>
<td>IQR</td>
<td>56</td>
<td>18</td>
<td>65</td>
<td>88</td>
<td>44</td>
<td>44</td>
<td>80</td>
<td>66</td>
<td>6</td>
</tr>
</tbody>
</table>

All values are given in milliseconds, except heart rate (beats per minute).
CI: confidence interval; SD: standard deviation; IQR: interquartile range

Table 2. Average values of electrocardiographic measurements from published data and median values from the present study.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P-wave duration</td>
<td>&lt; 0.17</td>
<td>≤ 0.16</td>
<td>0.110</td>
</tr>
<tr>
<td>P-wave peak interval</td>
<td>&lt; 0.08</td>
<td></td>
<td>0.065</td>
</tr>
<tr>
<td>P-R interval</td>
<td>&lt; 0.44</td>
<td>≤ 0.5</td>
<td>0.273</td>
</tr>
<tr>
<td>QRS-complex duration</td>
<td>&lt; 0.17</td>
<td>≤ 0.14</td>
<td>0.131</td>
</tr>
<tr>
<td>Q-T interval</td>
<td></td>
<td>≤ 0.6</td>
<td>0.557</td>
</tr>
<tr>
<td>S-T interval</td>
<td>&lt; 0.06</td>
<td></td>
<td>0.426</td>
</tr>
</tbody>
</table>

All values are given in seconds.
Reference values of Holter electrocardiography in horses

Figure 1. Determination of electrocardiographic waves, segments and intervals for measurements.