Preliminary Assessment of a Novel 14-Day Electrocardiographic Adhesive Patch Monitor in Dogs

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ABSTRACT

Cardiac arrhythmias often are transient and might not be detected using conventional electrocardiographic (ECG) techniques. The adhesive patch monitor (APM) is a single-lead, lightweight, up to 14-day continuous ambulatory ECG monitor. This study aimed to prospectively assess its usability in four boxer dogs considered either to be healthy or to have arrhythmogenic right ventricular cardiomyopathy. Optimal recording was obtained by placing the APM on the left side of the animal’s thorax, at the fifth intercostal space, slightly dorsal to the costochondral junction, and oriented either vertically or parallel to the long axis of the heart. In three dogs, the APM remained attached for 14 days. One dog removed the APM after 59 hr. Skin irritation was documented in all dogs and resolved spontaneously after removal of the APM. The analyzable time was >93% of the total wear time and recordings provided an unambiguous rhythm diagnosis at rest. Walking, running, or playing caused intermittent motion artifact that could impair ECG interpretation. APM results were comparable to those obtained with 24-hr Holter monitoring. Extended continuous ECG monitoring with the APM is feasible in boxer dogs and provides interpretable recordings. (J Am Anim Hosp Assoc 2018; 54:——–—. DOI 10.5326/JAAHA-MS-6626)

Introduction

The diagnosis of sporadically occurring cardiac arrhythmias in dogs is challenging and typically requires ambulatory electrocardiography.1 The use of various devices has been reported in veterinary patients, including the short-term (24- to 48-hr), continuous Holter monitor; the longer-term, intermittent event monitor (up to 14 days); and the implantable loop recorder (up to 3 yr).2–11 Each modality carries its own shortcomings. The Holter monitor is of limited utility when clinical signs occur infrequently (e.g., less than every 24-48 hr), and the multiple leads, as well as the bulky recorder, can be cumbersome for smaller patients. Event monitors and implantable loop recorders only allow intermittent data acquisition and need to be activated by the owners during a witnessed clinical event. Moreover, implantable loop recorders are placed in the subcutaneous tissues when the patient is under deep sedation or general anesthesia, and the rate of complications requiring removal of the device ranges from 4 to 8%.8–9

The adhesive patch monitor (APM)a is a single-lead, lightweight, up to 14-day continuous ambulatory electrocardiographic (ECG) monitor. This device, approved for human use by the FDA, does not have external leads or wires, is single-use, has a low-profile design, is water-resistant, and has a button that can be pressed to mark witnessed clinical events.

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APM (adhesive patch monitor); ECG (electrocardiogram/electrocardiography); PVC (premature ventricular complex)

Accepted for publication: October 8, 2016.
In the human adult population, the APM has detected a higher number of arrhythmias during the first 24 hr, as well as during the total wear time, when compared with the Holter monitor.12–15 In children, the diagnostic yield of the APM has been substantial, as 44% of first-detected arrhythmias and 50.4% of the first symptom-triggered arrhythmias occurred after the first 48 hr of cardiac monitoring.14

Given these findings in humans, the APM might provide information that could match or surpass the diagnostic yield of current techniques for assessing sporadically-occurring cardiac arrhythmias in dogs. The present study aimed to assess the feasibility of using the APM in four boxer dogs, a breed frequently affected by intermittent ventricular arrhythmias due to arrhythmogenic right ventricular cardiomyopathy (ARVC).

Materials and Methods

All procedures in this study were approved by the Institutional Animal Care and Use Committee. Written, informed consent authorizing participation of dogs in the study was obtained from all dog owners.

Animals

Four privately owned, adult (≥12 mo old) boxer dogs were prospectively recruited among patients or from staff of the Atlantic Veterinary College. To be enrolled, dogs had to be deemed healthy or to have ARVC (occult or overt, with no echocardiographic signs of cardiac remodeling) based on medical history, physical examination, a 1-min 6- or 10-lead ECGb (that showed normal sinus rhythm or its variants in normal dogs, and premature ventricular complexes [PVCs] of a morphology that suggested a right ventricular origin in dogs with ARVC) and a complete two-dimensional, M-mode, and Doppler echocardiogramc. Dogs were excluded if they (1) had an abnormal mean electrical axis (<+40° or >+100°) or ECG abnormalities other than PVCs; (2) had echocardiographic signs of myocardial dysfunction and/or dilation (including the following criteria: left ventricular fractional shortening <21%, left ventricular internal diameter in diastole >4.8 cm, and/or left ventricular internal diameter in systole >3.3 cm, according to previously published reference intervals in this breed); (3) had any systemic illness requiring ongoing medication (whereas monthly antiparasitic treatment was acceptable); (4) had a history, or visible signs, of dermatologic disorders; and (5) had an uncooperative temperament requiring sedation.15 Dogs receiving sotalol and omega-3 fatty acids as treatment for ARVC were accepted.

APM Use

The APM was placed on the left side of the dog’s thorax, at the fifth intercostal space, slightly dorsal to the costochondral junction, and oriented either vertically (perpendicular to the spine) in two dogs or diagonally with a 45° angle from the vertical position, parallel to the long axis of the heart in the other two dogs (Figure 1). These positions were chosen to meet the following requirements: (1) minimal discomfort for the dog; (2) easy access for the owner (to press the event button if necessary); and (3) visible QRS complexes as investigated prior to placement of the APM, using a standard event monitord equipped with two electrodes placed with approximately the same interelectrode distance (8 cm) as the APM. The two electrodes of the event monitor were placed in four different orientations, with 45° between each orientation (dorsoventral; craniocaudal; cranioventral to dorsocaudal; and craniodorsal to caudoventral). The orientation associated with the highest QRS complex amplitude was chosen to place the APM. The concave edge of the APM was always directed caudally. Each APM was attached to the skin according to the manufacturer’s recommendations for humans. The skin was clipped and cleaned with a 70% isopropyl alcohol solution. The skin was then allowed to dry, before being gently abraded using the pads included in the APM package. The two electrodes of the APM were wet using the provided saline pads, while keeping the backings that protected the adhesive part. The backings were then pulled off and the APM was applied to the skin of the thorax with continuous pressure applied for 2 min. Before applying the APM, a few (4–6) very small drops of tissue adhesivee were added to its edges, to improve adhesion of the APM to the skin (not a manufacturer recommendation). The APM was activated by pressing the button for a few seconds until the green light flashed 3 times. Finally, the APM was protected from scratching using a child-size T-shirt in two dogs or a vest made from bandage material in the other two dogs.

At the time of APM placement, a standard Holter monitorf also was placed before sending the dog home. The Holter monitor was removed 24 hr later and the APM was left in place for 13 additional days, before being removed either in-hospital (preferred; n = 3) or at home by the owner (n = 1). At home, during the 14-day monitoring period, each dog was allowed to have an almost normal lifestyle. However, bathing or excessive playing with other dogs had to be avoided. Each owner was instructed to press the event button in case any of the following clinical signs occurred: syncope, ataxia or other evidence of dizziness, abnormal behavior, or seizure. Owners also were asked to press the event button 8 times during each week, consisting of 2 times for each of the following 4 situations: playing/running, walking, sleeping, and eating (total of 16 activations per dog). The time interval between two similar situations had to be at least 2 days. The owners were instructed to keep a diary and to record the date, time, and dog’s activity for each of these activations. Total wear time and possible

Figure 1

1. APM placement upon the front of the dog’s chest. B. APM placement upon the dog’s thorax, at the fifth intercostal space, slightly dorsal to the costochondral junction, and oriented either vertically (perpendicular to the spine) in two dogs or diagonally with a 45° angle from the vertical position, parallel to the long axis of the heart in the other two dogs.

References


complications associated with the use of the APM were recorded by the investigators.

Analysis of Recordings and Comparison with Holter Monitoring

After removal, all four APMs were returned to the manufacturer to extract the data for analysis (Figure 2). A full disclosure report was provided for each dog, as well as a summary including 90-s strips for each event button activation (encompassing 45 s before and 45 s after button activation). The recording quality was assessed using the percentage analyzable time over the total wear time, as well as visual inspection of the 90-s strips obtained during each situation (playing/running, walking, sleeping, and eating). A score of 0–4 was attributed to each 90-s strip by the same observer (J.L.) as follows: 0 if non-interpretable or no identifiable cardiac activity; 1 if marked artifact (>70% of the tracing) preventing accurate interpretation; 2 if moderate artifact but still interpretable, 3 if mild artifact (<30% of the tracing) and easy interpretation; and 4 if no artifact (pristine recording).

For each dog, the full-disclosure reports obtained from Holter monitoring and the APM during the first 24 hr were manually evaluated and ventricular ectopic beats (including single PVCs, doublets, triplets, and runs of ventricular tachycardia were counted by the same observer (J.L.).

Statistical Analysis

Statistical analysis was performed using a commercial software package. Data were expressed as median and range (minimum–maximum). Considering the small sample size, counts of ventricular ectopic beats were compared using a Wilcoxon matched-pairs signed rank test, as well as personal judgment. Tests were two-sided, and the level of significance was set at $P < .05$.

Results

Animals

The study population consisted of three spayed female (4, 5, and 9 yr old; 28, 27, and 30 kg, respectively) and one neutered male (7 yr old and 34 kg) boxer dogs. Hereinafter, these four dogs will be referred to as F1, F2, F3, and M1, respectively. Two dogs, F2 and F3, were previously diagnosed with ARVC causing syncopal episodes and were both medically managed with sotalol (F2: 3 mg/kg per os q 12 hr; F3: 1.3 mg/kg per os q 12 hr) and, for one of them, omega-3 fatty acid supplementation. The two other dogs (F1 and M1) showed no overt

FIGURE 1  Placement of the adhesive patch monitor on a boxer dog’s chest, vertically (A) or diagonally (B).

FIGURE 2  Sample electrocardiographic strip obtained with the adhesive patch monitor in a boxer dog, showing sinus arrhythmia and ventricular ectopic beats. bpm, beats per minute; Pt, patient’s owner; VT, ventricular tachycardia.
clinical signs, but their 1-min ECG revealed occasional PVCs of left bundle branch block morphology (F1 and M1) and periods of ventricular trigeminy (F1).

**APM Use**

In three dogs (F2, F3, and M1), the APM remained attached for the entire study period (14 days). One dog (F1) removed the APM after 59 hr and developed signs of stress colitis. This dog was wearing a tight T-shirt to protect the APM. No other complications were seen by the owners of the four dogs, except mild-to-moderate superficial skin irritation (redness with no discharge or odor) in all dogs at the time of removal, which resolved spontaneously within a few days. No dogs had clinical events during the study period. For two dogs, the owners activated the event button in all four situations (11 and 10 activations for dogs F2 and M1, respectively).

**Analysis of Recordings and Comparison with Holter Monitoring**

In all dogs, the analyzable time was >93% of the total wear time. Quality scores are presented in Table 1. Recordings provided an unambiguous rhythm diagnosis at rest (sleeping or eating). Walking or playing/running caused intermittent moderate-to-marked motion artifact that sometimes impaired ECG interpretation.

During the first 24 hr, counts of ventricular ectopic beats (PVCs, couplets, triplets, and runs of ventricular tachycardia) were comparable between both monitoring modalities (Table 2).

**Discussion**

This preliminary study describes the use of a novel, noninvasive ambulatory ECG monitoring modality in boxer dogs. The APM allowed 14-day continuous ECG recording in three of four dogs with minimal and tolerable side-effects.

Although the diagnostic yield of this APM still has to be evaluated in larger groups of dogs, several studies have demonstrated the benefits of using long-term monitoring compared with conventional ECG and 24- to 48-hr Holter monitoring for the diagnosis of sporadically occurring arrhythmias, both in human and canine populations.5,8–14,16 In a study of 50 dogs with syncope, the diagnostic yield of Holter monitoring was 42%, and a correlation between syncope and a recorded cardiac rhythm was possible in only 24% of the dogs.2 In comparison, another study reported a diagnostic yield of 85% using a cardiac event monitor for a maximal duration of 2 wk.5 However, event monitors need to be activated by the owners during a witnessed clinical event, unless automatic activation/trigger for cardiac pauses, tachyarrhythmias, and bradyarrhythmias are built into the monitor.6-7

The APM offers the advantage of continuous recording, ideal for the detection of unwitnessed clinical events or clinically silent arrhythmic episodes. It also maintains the “event function” thanks to the event button that can easily be pressed by the owner during a clinical event, which helps the clinician correlate an event and the cardiac rhythm at that time. In humans, the time that elapses before the first clinically relevant arrhythmia is recorded averages 5.8 ± 6.1 days (Shinbane JS. Wearable wireless arrhythmia detection patches: diagnostic arrhythmia yield, time to first arrhythmia, and patient compliance. Proceed 34th Heart Rhythm Society Annual Scientific Sessions, Denver, 2013). Thus, the APM has a high likelihood of providing a diagnosis where Holter or event monitors fall short.

In the diagnosis of ARVC in boxer dogs, echocardiography is of limited use because myocardial function typically is preserved, and the disease usually is diagnosed using 24-hr Holter monitoring. It was previously demonstrated that spontaneous variability accounted for as much as 80% of the change in frequency of PVCs in dogs with frequent arrhythmias between 2 consecutive days.4 Long-term recording using the APM may provide a more accurate assessment of the extent of the disease in individual boxer dogs that could alter therapeutic or breeding decisions.

**TABLE 1**

<table>
<thead>
<tr>
<th>Situation</th>
<th>Median</th>
<th>Range (Minimum–Maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Playing/running</td>
<td>2</td>
<td>1–3</td>
</tr>
<tr>
<td>Walking</td>
<td>1</td>
<td>1–3</td>
</tr>
<tr>
<td>Sleeping</td>
<td>3</td>
<td>3–4</td>
</tr>
<tr>
<td>Eating</td>
<td>3</td>
<td>3–4</td>
</tr>
</tbody>
</table>

0, noninterpretable; 1, marked artifact; 2, moderate artifact; 3, mild artifact; 4, pristine.

**TABLE 2**

<table>
<thead>
<tr>
<th>Arrhythmia</th>
<th>Adhesive Patch Monitor</th>
<th>Holter</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVCs</td>
<td>216 (26–391)</td>
<td>223 (22–364)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Couplets</td>
<td>1 (0–4)</td>
<td>1 (0–6)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Triplets</td>
<td>0 (0–1)</td>
<td>0 (0–2)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>VT</td>
<td>0 (0–1)</td>
<td>0 (0–1)</td>
<td>No difference</td>
</tr>
</tbody>
</table>

Data are expressed as median (minimum–maximum). PVCs, premature ventricular contractions; VT, ventricular tachycardia.
Other main advantages of the APM are that it is easy to use, leadless, water-resistant, small in size (123 × 53 × 10.7 mm), and lightweight (34 g). In comparison, Holter or event monitors typically weigh more than 100 g, which can be cumbersome in smaller patients. The single-use nature of the APM eliminates any upfront cost (monitor unit, analyzer) for the initial investment as compared with the wearable, reusable devices. Finally, the cost of wearing an APM is also substantially less than the cost of wearing a Holter monitor for a comparable period (approximately $600 USD; i.e., $43/24 hr for the APM versus $250 for a 24-hr Holter) and no damage deposit by the owner is needed.

Disadvantages of the APM include dependence on the device manufacturer for raw data retrieval, the manufacturer technician’s accurate collection and reporting of raw data, and generation of a summary report. However, high-resolution ECG samples of all arrhythmic events detected are provided in the report and can be verified by the prescribing clinician (Figure 2). We also obtained full disclosures upon request, allowing manual evaluation of the recordings. The APM requires that the owner or the prescribing clinician return the device in a postage-paid envelope to the manufacturer. The turnaround time from device submission to availability of a summary report takes up to 4 days, which can be problematic in some unstable patients requiring rapid therapeutic intervention. This typical timeframe may be modified in case of emergency by contacting the manufacturer.

Once detached from the skin, the APM also loses its adhesive strength, preventing optimal contact of the electrodes with the skin in case a dog removes the APM prematurely. In this study, one dog removed the APM after only 59 hr of recording. Based on this experience, protection of the APM by a vest made of bandage material could be considered, to reduce the risk of this complication.

Finally, only single-lead recordings can be obtained with the APM, as opposed to three-lead recordings with a Holter monitor. Multi-lead recordings are less vulnerable to motion artifact and may allow for improved detection of abnormal P waves and QRS complexes. However, in the present study, similar counts of PVCs were obtained after manual evaluation of the full disclosures during the first 24 hr. This suggests that the APM may be at least as effective as the three-lead Holter monitor in detecting PVCs in boxer dogs. A patient’s physical activity during the recording may create motion artifact, which can complicate interpretation of the tracing. Although we avoided placing the APM directly in the axilla region to prevent excessive motion induced by the forelimbs, this type of artifact may be impossible to eliminate if muscular activity (e.g., tremor) is a feature of a clinical event. Interestingly, slightly more artifact was seen when dogs were walking compared with when dogs were playing or running. However, this small difference may not be relevant because each dog owner’s interpretation of his/her dog’s gait was subjective and unverified.

The study reported here was a preliminary assessment and results should be interpreted with caution. Only a small number of boxer dogs were included, and all were affected with—or predisposed to—the same cardiovascular disease (ARVC). Therefore, the results of this study await validation in larger numbers of dogs of various breeds.

Conclusion
Extended noninvasive continuous ECG monitoring (up to 14 days) using the APM is feasible in boxer dogs. The APM provides interpretable recordings similar to those obtained with Holter monitoring during the first 24 hr.

The authors thank Mr. Alexandre Bodet for assisting in the preparation of the figures. This study was supported by a grant in kind (donation of monitors) from iRhythm Technologies, San Francisco, California, and material support from the Atlantic Veterinary College, UPEI, Charlottetown, Prince Edward Island, Canada, and the NC State College of Veterinary Medicine, NCSU, Raleigh, North Carolina.

FOOTNOTES

REFERENCES


