Effects of a Canine Elizabethan Collar on Ambulatory Electrocardiogram Recorded by a Holter Recording System and Spontaneous Activities Measured Continuously by an Accelerometer in Beagle Dogs

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ABSTRACT. Ambulatory electrocardiogram (ECG) has been recorded in dogs wearing a jacket to protect a Holter recording system, but the jacket was often damaged by dogs. We compared ECG recorded by a Holter recording system and spontaneous activity measured by an accelerometer in Beagle dogs with or without an Elizabethan collar. There were few significant differences in mean values (per hr) of the heart rate and the amount of spontaneous activity between dogs with or without the Elizabethan collar. Mean values (per 23 hr) of them had no significant difference between them. We concluded that the Elizabethan collar did not have any effect on ambulatory ECG and canine movements and was effective to protect the recording apparatus.—KEY WORDS: Beagle, Elizabethan collar, Holter.

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Beagle dogs are commonly used as a nonrodent laboratory animal for drug-safety studies. During the course of these studies, it is very important to record electrocardiogram (ECG) under no anesthesia or restraint in order to assess the normal heart rate (HR) or the potential of test drugs to cause arrhythmia. For these purpose, some researchers have reported ambulatory ECG recorded by a Holter recording system recently [10–12]. These researchers used a canine jacket to protect electrodes and lead lines, and the Holter recording system was put into a pocket of the jacket. However, some dogs damaged the ECG recording components by biting them. A canine Elizabethan collar fixed around the neck has been often used clinically to protect the damaged part of the body or the operated part by surgery [3, 8, 14]. It will be reasonable to put on the canine Elizabethan collar around the neck to protect the Holter recording system if it does not have any effect on ambulatory ECG. There has been no report about the effect of the Elizabethan collar on ambulatory ECG. So the purpose of the experiment was to investigate the effect of the canine Elizabethan collar on ambulatory ECG recorded with the Holter recording system as well as on spontaneous activity recorded with an accelerometer.

Study subjects were 8 male purebred Beagle dogs (17-27 months old, 8.0–11.5 kg of weight) produced at a breeding company (Covance Research Products Inc., Michigan, U.S.A.). The animals were housed individually in a stainless steel cage. The cage size was 85 cm deep, 85 cm wide and 70 cm high. The experimental dogs, raised in and acclimated to the cage for more than 6 months, were used for recording ambulatory ECG and spontaneous activity. The room was maintained on the 13-hr light (8:00–21:00) and 11-hr dark (21:00–8:00). The dogs were given 300 g of commercial dry dog food each day. Water was provided *ad libitum* by a water-autosupply instrument. Laboratory personnel were not in the room during recording the ECG and spontaneous activity.

Ambulatory ECG was recorded by the Holter recording system (DMC-3253, Nihon Kohden Inc., Tokyo, Japan). Commercial ECG electrodes (Skinkact FS-50, Leonhard Lang, Austria) were placed to provide 3 bipolar leads: the positive electrode was placed at the processus xiphoideus of the sternum and the negative electrode at the manubrium sterni; the positive electrode was placed at the abdominal wall near the left groin and the negative electrode at the right axilla; the positive electrode was placed at the left costochondral articulation in the 5–6 intercostal space and the negative electrode at the manubrium sterni. The ground electrode was placed at the right thoracic wall. The electrodes and lead lines were fixed to the trunk by an elastic tape. A Holter ECG analyzing apparatus (DMC-4100, Nihon Kohden Inc., Tokyo, Japan) was used to identify the HR from the recorded tape. If necessary, the HR was measured manually.

The dogs put on a jacket (IAJ-03F, INA Research Inc., Japan) that covered the thorax and the canine Elizabethan collar (external diameter of 48 or 57 cm; Tsukawayoukou Inc., Tokyo, Japan) made of polypropene around the neck. The animals could move freely in the cage.

Spontaneous activities were recorded by an accelerometer (Activtracer®AC-200, GMC Inc., Tokyo, Japan) that contained the central processing unit and memory. The accelerometer, 100 g of weight and 57 x 85 x 18 mm in size, could measure a range of 0.01–4 G. It had a piezoelectric transducer that could measure three dimensional accelerations (X, Y and Z axes) and produce

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the composite acceleration $(X^2 + Y^2 + Z^2)^{1/2}$. The composite accelerations were averaged every 0.1 sec. When the averaged value of the composite acceleration during 0.1 sec passed over the threshold, the count 1 was given to the memory of the accelerometer. The accumulated numbers for 60 sec (maximum 600 = 1 × 600) were recorded as the number of acceleration on a recorder in a time-series. We set the threshold of the accelerometer at 0.02 G and 0.1 G, because all movements of the parts of the body were recorded at the threshold of 0.02 G and only the movements of the whole body such as locomotion or shaking at the threshold of 0.1 G [15]. The PC-9801NA (NEC, Tokyo, Japan) was used for setting of measuring conditions in the accelerometer, and for taking out the data from the accelerometer to make a secondary processing of the data. The accelerometer was fixed to the withers with an elastic band surrounding the thorax. The accelerometer fixed to the withers remained at the same position through the experiment in all investigated dogs.

Using the Holter recording system and accelerometer, ambulatory ECG and spontaneous activity were measured in all dogs from 10:00 o'clock to 9:00 next morning for consecutive 23 hr. On the first day dogs put on the canine Elizabethan collar and jacket. On the second day ambulatory ECG and spontaneous activity were recorded in dogs wearing the canine Elizabethan collar and Jacket. On the third day the Elizabethan collar was removed after finishing the recordings, but the dogs continued to put on the jacket. On the fourth day the ECG and the number of acceleration were recorded from the dogs wearing the jacket without the Elizabethan collar. On the fourth day a dog bit the jacket and damaged the electrodes. So the ECG and the number of acceleration in the dog without the collar was recorded after the jacket was devised not to be damaged by putting a cover in front of the jacket. Another dog damaged the jacket immediately after removing the collar. So these recordings in the dog without the collar was performed with the jacket having the cover.

Mean HR and mean spontaneous activity of each hour and of 23 hr were calculated from those of a minute and an hour, respectively. Paired t test was used to determine significant differences in mean values of the HR and the number of acceleration between the dogs with or without the canine Elizabethan collar, where $P<0.05$ was considered significant. Linear regression analysis was done to the HR and the number of acceleration.

There was no significant difference in averages (per 23 hr) of the HR calculated from the Holter recording system and the spontaneous activity measured from the number of acceleration between the dogs with or without the canine Elizabethan collar (Table 1). The mean HR (85–120 beat per min, bpm) was similar or rather lower to those already reported [2, 7, 9, 10]. Spontaneous activity of dogs increased with human contact [5, 6, 15], which increased the HR [12, 13, 15]. In our experiment there was no personnel in the room during recording the ECG and spontaneous activity, which might cause the rather lower mean HR. The mean amount of movements of spontaneous activity was depicted as the response number during a minute. Spontaneous activity during 23 hr was recorded in 14–16% of the total hours at the threshold of 0.02 G and in 4% at the threshold of 0.1 G.

Table 1. Mean values (per 23 hr) and standard deviation of the heart rate recorded by a Holter recording system and the spontaneous activity measured by an accelerometer. Bpm is short for beat per minute. Above 0.02 G and above 0.1 G indicate that the threshold of an accelerometer was set at 0.02 G and 0.1 G, respectively. No statistical significance was observed between the values recorded in dogs with or without a canine Elizabethan collar

	With collar	Without collar
Heart rate (bpm)	84 ± 11	83 ± 12
Spontaneous activity		
above 0.02 G	95 ± 24	85 ± 22
above 0.1 G	26 ± 10	25 ± 12

The HR had a circadian rhythm: the HR increased under lighting condition and decreased under dark condition (Fig. 1). As already reported [1, 4, 12], the lowest value of the HR was recorded before awaking in the morning (5:00–6:00) and the HR rapidly increased immediately before lighting of the room (7:00–8:00). The dogs with the Elizabethan collar had significantly lower HR only around 7:00 o'clock than those without the collar, although the amount of the movements at this time did not change between the dogs with or without the collar (Fig. 1). Although the dogs with the collar increased significantly spontaneous activity during 2 hr after beginning of the recording and decreased significantly it about 2 hr before turning on the light, there was no significant difference in the mean spontaneous activity per 23 hr between the dog with or without the collar (Table 1).

Spontaneous activity recorded by the accelerometer at the threshold of 0.1 G had similar circadian changes observed in the HR (Fig. 1). There was no significant difference in the mean values (per hr) of the number of acceleration recorded at the threshold of 0.1 G between the dogs with or without the collar. The movements recorded at this threshold indicated the movements of the whole body such as locomotion or shaking [15]. So the canine Elizabethan collar did not have effect on the movements of the whole body.

The number of acceleration (per hr) at the threshold of 0.02 G or 0.1 G had a positive correlation to the mean HR (per hr): $r^2=0.5886$, $P<0.05$ at the threshold of 0.02 G; $r^2=0.6288$, $P<0.05$ at the threshold of 0.1 G. This positive correlation coincided with the report in which the amount of canine movement had a positive correlation to the HR [4, 15].

One day might be enough for the canine acclimatization to the Elizabethan collar, because although some dogs were going to take off it immediately after the Elizabethan collar was put on, on the second day there was no dog to perform

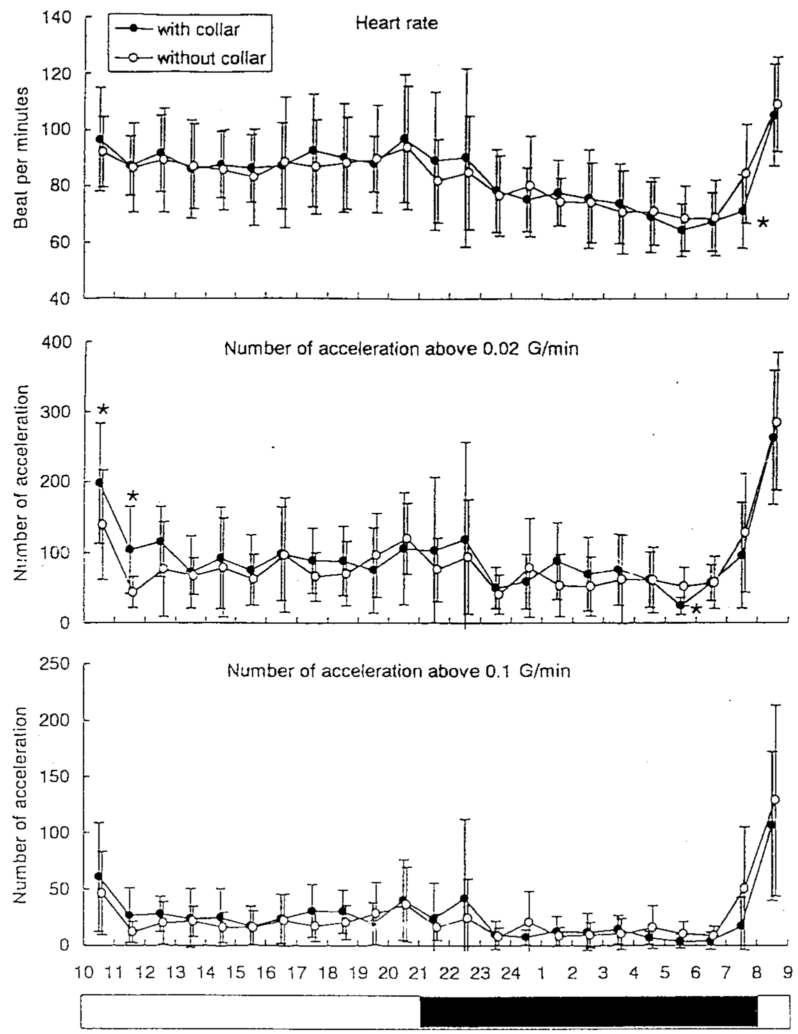

Fig. 1. Mean values (per hr) and standard deviations of the heart rate recorded by a Holter recording system and the spontaneous activity measured by an accelerometer at the threshold of 0.02 G and 0.1 G. Closed circles indicate mean values in 8 dogs with the canine Elizabethan collar and open circles those without the collar. The column at the bottom means the lighting condition (open column) and the dark condition (solid column). The asterisks indicate statistically significant ($P<0.05$).

such a behavior, and there were few significant differences in ambulatory ECG and spontaneous activity in dogs with or without the collar on the second day. However, it remains to be investigated whether the Elizabethan collar put on for about 2 days or more might give some stress to the dogs or not.

These results indicated that putting on the canine Elizabethan collar in dogs might not have effect on ambulatory ECG and spontaneous activity. As 2 dogs in 8 dogs damaged the jacket in our experiment, we concluded that it might be effective to put on the canine Elizabethan collar in the dog for recording ambulatory ECG and acceleration of their movements.

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