NOTE *Internal Medicine*

Influence of sickness condition on diurnal rhythms of heart rate and heart rate variability in cows

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ABSTRACT. Parameters of heart rate variability would explain changes in heart rate during the disease status in cows and to evaluate whether such changes might provide a more sensitive and quantitative indicator of these conditions than crude indices. For this purpose, we recorded electrocardiograms for 24 hr using a Holter-type electrocardiograph and applied power spectral analysis of heart rate variability in both five clinically healthy and four hospitalized cows. The significant findings of the current investigation were that the diurnal variations of autonomic nervous function are abolished in cows that are sick. This abnormal rhythm was induced by predominant parasympathetic inhibition in these cows. Therefore, the heart rate variability may be a useful indicator of sickness condition in cows.
KEY WORDS: autonomic nervous system, cattle, diurnal rhythms, heart rate

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There has been increasing interest in using a noninvasive index of autonomic nervous activity in the analysis of heart rate variability in animals. In our studies of autonomic nervous functions in many species, recordings of electrocardiograms (ECGs) via both a telemetry system and a Holter-type electrocardiograph have been obtained [1, 6, 8, 10, 11]. Usefulness of analysis of heart rate variability in cattle has also recommended in the literature [18]. However, only a small number of studies have been reported, with some using a heart rate monitor to investigate heart rate variability in cattle [5, 13]. Moreover, power spectral analysis of heart rate variability has not been performed to estimate the diurnal variation of the autonomic nervous activity in both healthy and sickness condition in cattle, although there are some studies in diseased cattle, such as evaluation of effects of bovine spongiform encephalopathy, using short term of ECGs [7, 17]. Therefore, we investigated the diurnal variation of heart rate variability in both clinically healthy and hospitalized cows with 24-hr ECGs. Our hypothesis was that a higher heart rate in hospitalized cows might be related to an altered sympathovagal balance.

Nine adult female Holstein cows, 5 clinically healthy (CH) and 4 hospitalized (HP) cows were studied. Information for these cows is summarized in Table 1. Moreover, no sign of cardiac disorder was observed in these cows. Although the CH and HP cows were kept in different places, both groups of cows were moved to almost the same environmental place to record ECGs, such as a sufficiently quiet place, that was large enough for them to move freely. Unfortunately, the lighting and room temperature in the places used for recording ECGs could not be controlled precisely, so the temperature in them was around 20°C. We defined the light phase was 07.00 to 19.00 and the dark phase as 19.00 to 07.00. Feeding (hay and grains), milking, cleaning and medical treatments were performed between 07.00 and 09.00 and between 16.00 and 18.00 in both places for recording ECGs. Only oral administration of a drag (Bovactin®) was used for treatment of the HP cows during the experiment to minimize additional stress due to handling. After acclimatization to the recording environment, ECGs were recorded with base-apex leads using a Holter-type electrocardiograph (SM-50; Fukuda Denshi Co., Ltd., Tokyo, Japan) once for each cow. In HP cows, ECGs were recorded after medical treatment and a few days before they were released from the hospital. A handmade jacket was used to hold the recorder during Holter recording. The recorded ECGs were analyzed with an ECG processor analyzing system (SRV-2W, Softron Co., Ltd., Tokyo, Japan) as described previously [8]. The program first detected R waves and calculated the R-R interval tachogram as the raw heart rate variability in sequence order. If there were artifacts in ECGs, these areas were omitted and excluded from the analysis. From this tachogram, data sets of 512 points were resampled at 200 msec. We applied each set of data to the Hamming window and a fast Fourier transform to obtain the power spectrum of the fluctuation. The low frequency (LF) power was set at 0.04–0.1, and the high frequency (HF) power was set at 0.1–1.0 Hz. We set a wider HF power range compared with an earlier study [18], because respiration rate may increase when cows are sick. Heart rate, the LF power, the HF power and the LF/HF ratio were obtained from each recording, and the values were used as indices of autonomic nervous function. Normalized units

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Table 1. Information for the cows used in this experiment

	Cows	Age (years old)	Lactation or pregnancy	Diagnosis
CH (n=5)	1	5	Non-lactating and nonpregnant	—
	2	12	Non-lactating and nonpregnant	—
	3	9	Non-lactating and nonpregnant	—
	4	6	Non-lactating and nonpregnant	—
	5	6	Non-lactating and nonpregnant	—
HP (n=4)	6	8	8 months pregnant	Right abomasal displacement
	7	5	Lactating	Hepatic dysfunction
	8	3	Lactating	Chronic mastitis
	9	6	Non-lactating and nonpregnant	Chronic pyogenic mastitis

(nu) of the LF and the HF power were also obtained to minimize the effect of the changes in total power on the values of LF and HF components [12]. Statistical comparisons were made using the Student's *t* test and Mann-Whitney's U test ($P<0.05$).

Representative ECGs in both CH and HP cows in the dark phase are shown in Fig. 1A and 1B, respectively. Arrhythmias were not observed in the ECGs of any of the cows. The averaged heart rate throughout the day in the HP cows (93.0 ± 5.5 bpm) was significantly higher than that in the CH cows (71.4 ± 8.5 bpm). Diurnal patterns, in which the values for the heart rate during the light phase were higher than those during the dark phase, were observed in the CH cows (Fig. 2). The changes in 24-hr plots of parameters of heart rate variability also showed diurnal patterns in the CH cows. However, these tendencies disappeared in the HP cows. Figure 3 shows the light- and dark-phase heart rate and parameters of heart rate variability. The LF and HF powers in the CH cows were higher than those in the HP cows during both the light and dark phases. The LF/HF ratio also showed a diurnal pattern. Furthermore, the LF (nu) and HF (nu) values in the CH cows showed diurnal variations, because there were significant differences between the light and dark phases in these parameters. However, these tendencies were not observed in the HP cows.

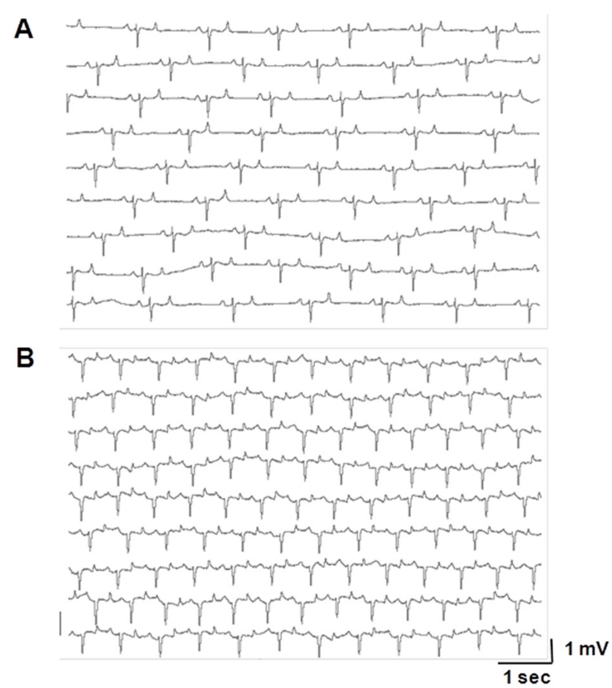

Fig. 1. Representative ECGs in both healthy and hospitalized cows. ECGs recorded for about 1 min during the same period in the dark phase for healthy (A) and (B) hospitalized cows.

Regarding the power spectrum of heart rate variability in the HF power is generally thought to reflect primarily parasympathetic nervous function. Both the sympathetic and parasympathetic nervous systems have been shown to contribute to the LF power. Thus, the LF/HF ratio is considered to be an index of the sympathovagal balance. The LF (nu) and the HF (nu) power emphasize the controlled and balanced behavior of the two branches of the autonomic nervous system [16]. Furthermore, it has been shown that these parameters exhibited diurnal rhythms in normal horses and miniature pigs [9, 10]. The results obtained in the CH cows confirm that the parameters of heart rate variability have diurnal variations. Therefore, these results suggest that autonomic nervous functions also have a diurnal rhythm and that parasympathetic nervous activity may be predominant during the dark phase in the CH cows.

Our purpose in conducting this study was to test the hypothesis that the parameters of heart rate variability would explain changes in heart rate during ill health in cows and to evaluate whether such changes might provide a more sensitive and perhaps quantitative indicator of these conditions than crude indices (e.g., heart rate alone or plasma cortisol concentrations). The significant findings of the current investigation were that the diurnal variations in autonomic nervous function were abolished during ill health in the cows (in agreement with our hypothesis). This abnormal diurnal rhythm was induced by autonomic control shifted towards an increase in sympathetic modulation and a decrease in parasympathetic modulation in these cows, as the LF/HF ratio in the HP cows was higher than that in the CH cows. These results are coincident with the data obtained from during transportation stress in Thoroughbred horses [15].

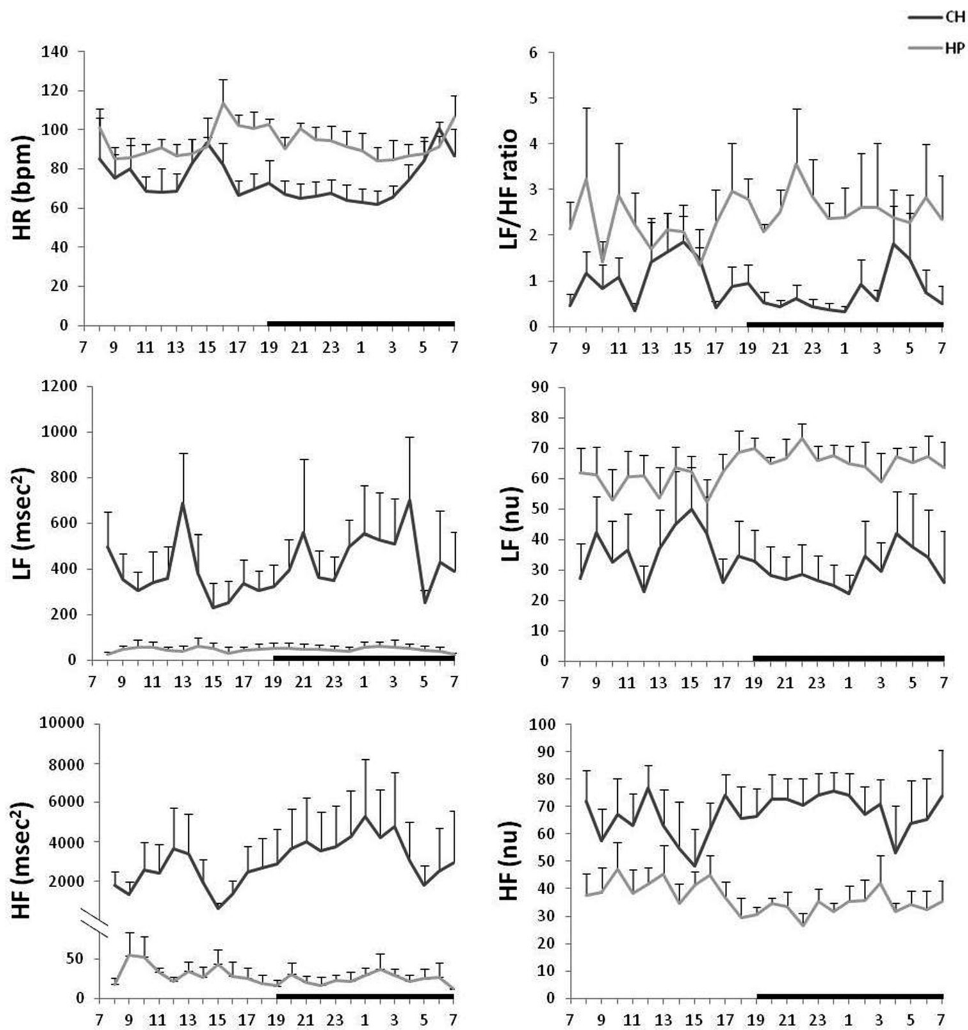

Fig. 2. Changes in 24-hr plots of heart rate and heart rate variability indices. CH=clinically Healthy group (n=5), HP=hospitalized group (n=4) HR=heart rate, HF=high frequency power, LF=low frequency power, LF/HF=LF-to-HF ratio. The values are expressed as the mean ± SD.

It is generally thought that changes in autonomic nervous response during transportation might be associated with stress and immune suppression in horses. Studies of heart rate variability during various forms of stress in other species have reported reductions in the heart rate variability indices whether triggered by panic anxiety [20], sepsis [4], endotoxemia [3], chronic hepatitis [2] or respiratory disease [19]. Therefore, the heart rate variability may be a useful indicator of sickness condition in cows.

We used only non-lactating and nonpregnant cows as healthy controls. Moreover, all the HP cows, except one cow, were in lactating or pregnant in this study. Therefore, we cannot deny that lactation or pregnancy could have affected heart rate variability in these cows rather than sickness. Although the significance of lactation on heart rate variability was the only parameter observed in non-linear analysis in cows [14], further studies will be necessary using healthy lactating or pregnant cows to clarify this issue. Moreover, it should be determined if other factors in healthy and unhealthy animals might be modifying the relationship between the heart rate variability indices and heart rate.

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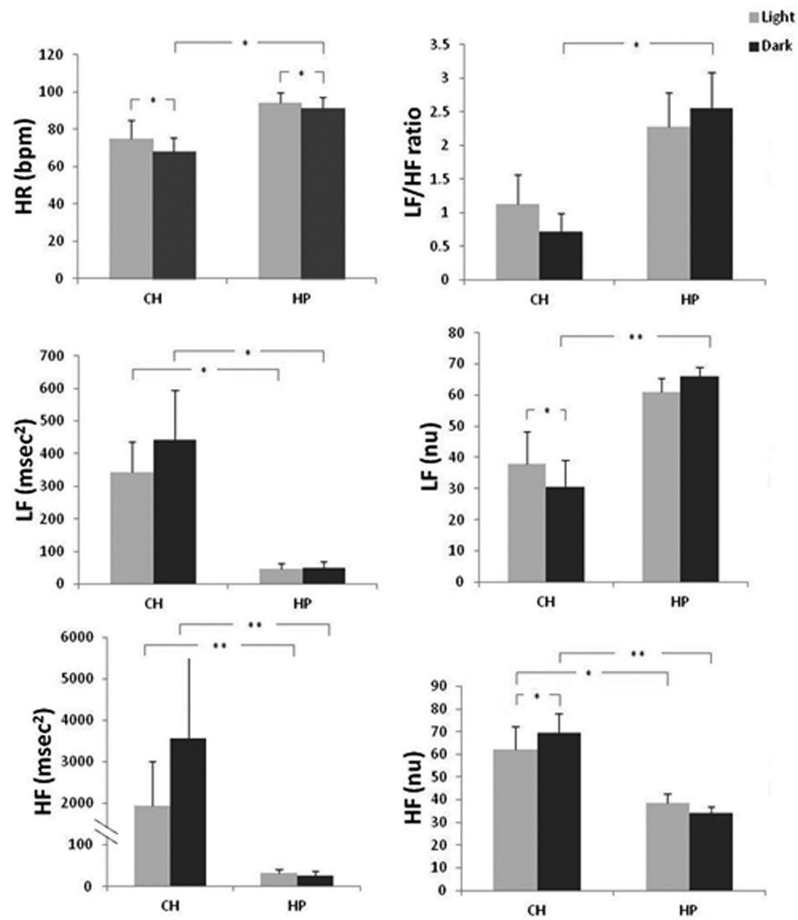

Fig. 3. Light- and dark-phase heart rate variability. Twelve hourly values for each cow in each period were taken and averaged to get the average per cow and then are summarized for each group to get the mean ± SD for each of the periods. See Fig. 2 for key. *P<0.05, **P<0.01.

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