# Diurnal Variations of Blood Pressure in Dogs

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ABSTRACT. Using the telemetry system, we measured the blood pressure (BP) invasively in seven adult mongrels while unanesthetized and unbound. Post-operative BP after implanting the telemetry BP transmitter showed temporarily high values due to the invasive nature of the surgery. It was, however, observed that BP gradually decreased thereafter, and showed settled trends from the eighth day post-operatively. When we took the average of the systolic, mean and diastolic BP at hourly intervals for each of the dogs once their BP had settled, a twin peak diurnal variation (at 8:00 and 19:00) was observed. Moreover, significantly high values ($p<0.05$) were identified in active state compared with when sleeping or at rest. The 24 hr BP measured by the telemetry system in seven normal dogs resulted in the following values: systolic 123.4 ± 7.9 mmHg, mean 91.1 ± 5.6 mmHg, and diastolic 74.5 ± 4.9 mmHg.—KEY WORDS: blood pressure, canine, diurnal variation.

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For measuring blood pressure (BP) in awake dogs, there are either invasive method by arterial puncture or non-invasive methods such as the oscillometry, stethoscopy and the ultrasonic Doppler method, etc [3, 10, 11, 19, 22, 25]. However, invasive methods are not suited to repeated measurements due to the invasive nature to the body. Further, with non-invasive methods there are the effects of stress due to attaching the equipment, retaining body and so forth, thereby limiting the accuracy of BP measurement. In order to solve these problems, it is necessary to measure the BP under awake, unbound and no stress conditions. The stress is usually caused by drugs used at the time of measurement, artificial and environmental factors, and the BP measurement per se.

Although it is already known that there exists a circadian BP variation in both rats and humans [1, 7, 12, 15–17], no detailed reports regarding dogs have been published. For this reason, we examined these diurnal variations by measuring the BP across a long period of time in normal awake dogs who were unbound, using the telemetry system which makes 24 hr continual observation possible without stress.

## MATERIALS AND METHODS

*Animals*: In this experiment, we used seven mongrel dogs (three male, four female) weighing 7.0 to 13.0 kg each, in whom no abnormalities could be identified by general clinical examination, blood and serology tests, or urine examination. The dogs were raised and acclimatized in a cage for several months in advance and were fed twice a day, between 8:00 to 9:00 and 19:00 to 20:00, in addition to drinking water *ad libitum*.

*BP measurement method*: Dogs were prepared for telemetric monitoring of blood pressure (Data Science Co., Ltd., Minnesota, U.S.A.). The femoral arteries of the dogs were exposed under anesthesia, and BP measuring transmitter (model TL10M2-D70) catheter was indwelled. The transmitter body was implanted into a subcutaneous pocket that had created first. After examining the BP by use of transmitter, the digital signal was received by a receiver (RLA2000), and was sent in turn to a consolidation matrix (BCM-100), and a universal adapter (UA10). Finally, the digital signal was converted to an analogue signal by the universal adapter, and output to an analytical computer system (Softron ECG Processor SBP4.8:Softron Co., Tokyo, Japan) (Fig. 1). Further, the systolic, mean and diastolic BP were calculated from the continuous BP readings input for approximately 10 sec at a time at 5 min intervals, and the average were taken to be the systolic, mean and diastolic values for each hour. These measurements were taken continuously for 24 hr, and the following examinations were conducted.

*Examination of the BP changes after implanting transmitter*: We examined the effect of the invasive surgery on BP after the transmitter had been implanted for 14 days post-operatively. For the BP examination, we used the total and average values (24 hr BP) taken every 24 hr using the systolic, mean and diastolic pressure measured at 5 min intervals.

*Examination into the diurnal BP variations*: We examined the diurnal BP variations in normal dogs for a period of seven days after at least one month had passed since the transmitter were implanted. First of all, the systolic, mean and diastolic BP were measured at 5 min intervals and totaled in hourly blocks and examined using their average values. In order to observe the relationship between BP and activity, a comparison was made among the sleeping period (1:00–6:00), the resting period (12:00–17:00), awaking but comparatively settled period, and the periods of intense activity (7:00–9:00 and 18:00–20:00). In addition, comparisons were also made with both the 24 hr BP and each of the time blocks cited above.

For the statistics, the Kruskal-Wallis test was used following analysis of variance (ANOVA) using Bartlett's method. The Scheffe method was used if a significant difference was identified. The significance level was set at 5% or less and the BP values were all expressed as the mean ± SD.

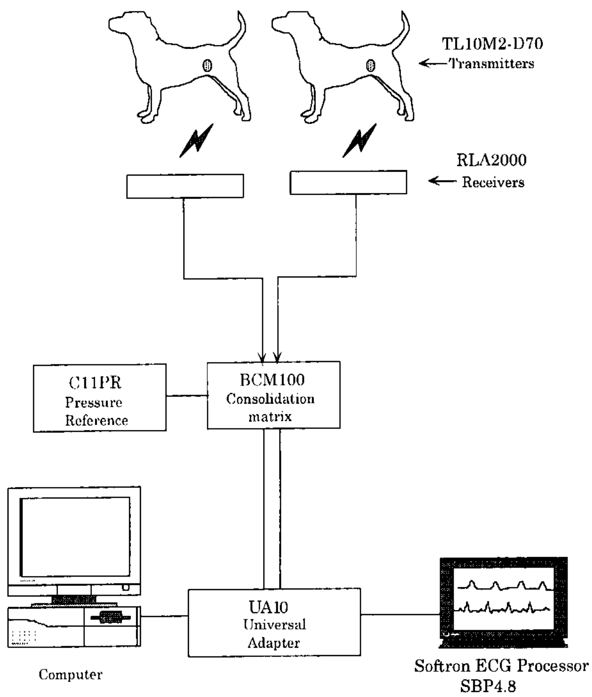


Fig. 1. The diagrams of blood pressure measurement using radiotelemetry system

RESULTS

*Examination for BP changes following the subcutaneous insertion of transmitter*: When the post-operative effects were examined using the 24 hr BP, systolic, mean and diastolic BP all showed high values both on the day on which the transmitter was implanted and one day post-operatively. However, BP decreased by seven days post-operatively and thereafter BP levels proved stable (Fig. 2).

*Examination into diurnal BP variations*: When the systolic, mean and diastolic BP measured at 5 min intervals were plotted on a graph, the BP fluctuates normally (Fig. 3). Moreover, when each average values of the systolic, mean and diastolic BP were calculated per hour, all BP showed twin peaks at 8:00 and 19:00. With regard to the diurnal BP variation, whereas BP increased sharply at the time of the 8:00 peak, a mild increase was identified during the 19:00 peak. Further, BP tended to be stable after dropping rapidly within 1 hr following both the 8:00 and 19:00 peaks. From night until daybreak (21:00 to 6:00), BP values were comparatively stable (Fig. 4).

Moreover, considering BP associated with activity, the all three types of BP values proved to be significantly high ($p<0.05$) during periods of activity compared with when asleep or at rest. In addition, although a significant difference ($p<0.05$) was identified for both during activity and during sleep when BP was compared with both the 24 hr BP and each time block BP, no significant difference could be identified during periods of rest (Table 1).

DISCUSSION

In small animal practice, no scientific evaluation system relating to hypertension has yet been established. One major

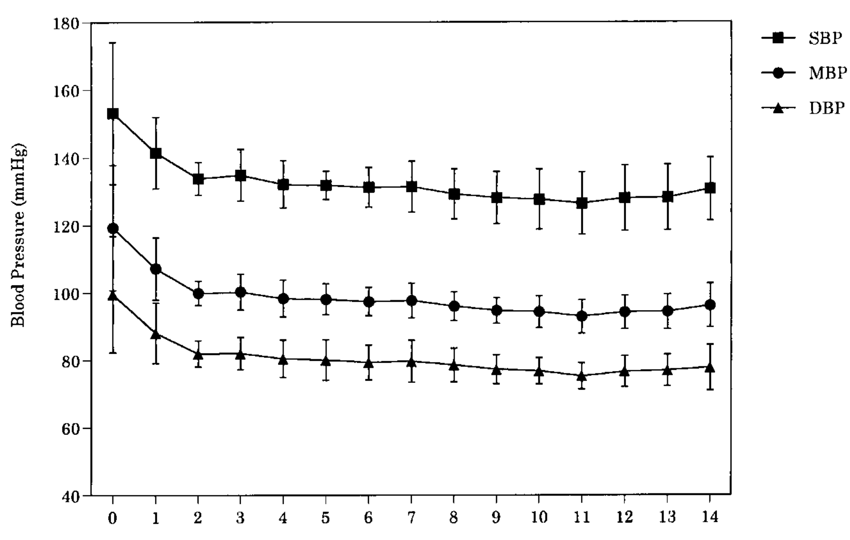


Fig. 2. Line graphs show systolic blood pressure (SBP), mean blood pressure (MBP) and diastolic blood pressure (DBP) measured with radiotelemetry. (Surgery was conducted at time zero in dogs)

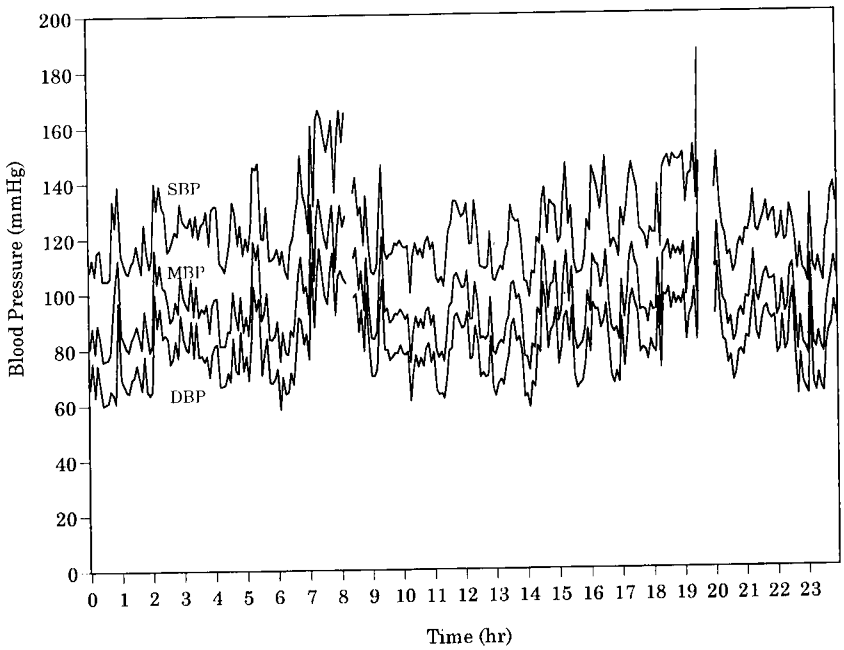


Fig. 3. Tracings show systolic blood pressure (SBP), mean blood pressure (MBP) and diastolic blood pressure (DBP) measured with radiotelemetry in a dog.

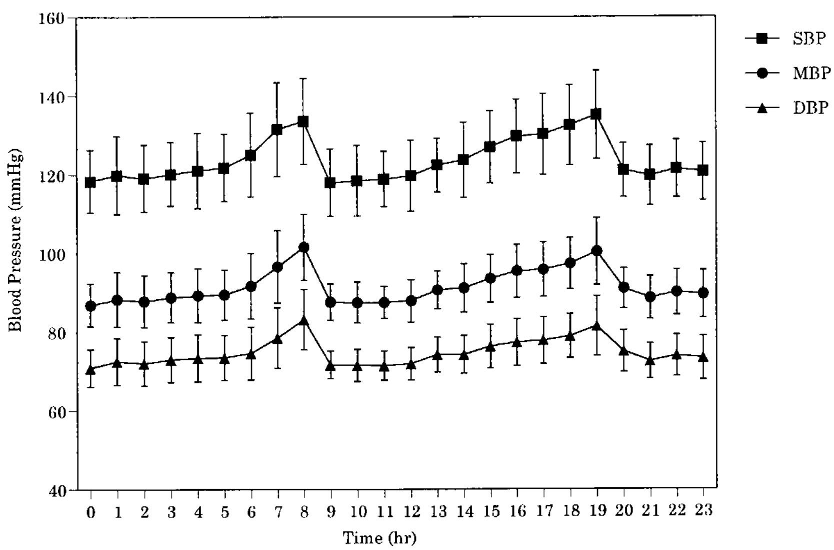


Fig. 4. Line graphs show circadian profiles plotted by 1 hr intervals of systolic blood pressure (SBP), mean blood pressure (MBP) and diastolic blood pressure (DBP) measured with radiotelemetry in dogs.

reason for this is that hypertension itself progresses with no specific symptoms. Moreover, BP measuring in the awake patient, which forms the most basic procedure in the diagnosis of hypertension, has yet been fully established in the field of veterinary medicine. These issues have also been factors preventing hypertension research.

It is theoretically feasible to measure BP in the dogs in the same way as for humans. However, regarding BP values in the dogs normal BP and hypertension, standard value of BP for the dogs are generally set higher than for humans [3, 4, 10, 11, 22, 25]. Our previous work demonstrated the reason for this that stress is a factor influencing the BP measurement in dogs [19].

Similarly, this phenomenon can also be seen in the field of human medicine. It is well known that the BP of the patient may rise only when in a hospital environment, which

Table 1. The 24 hr monitoring of the telemetry blood pressure in four different periods in dogs

| | SBP | MBP | DBP | |
|---|---|---|---|---|
| Sleep | 121.1 ± 8.3 | 88.4 ± 6.1 | 72.4 ± 5.3 | |
| Relax | 123.6 ± 8.9 | 91.0 ± 6.0 | 74.2 ± 5.0 | * * |
| Active | 131.3 ± 10.7 | 97.2 ± 8.2 | 79.1 ± 7.0 | * |
| 24-Hour | 125.0 ± 10.4 | 92.2 ± 7.7 | 75.3 ± 6.4 | |

Values are means ± SD.
SBP=systolic blood pressure; MBP=mean blood pressure; DBP=diastolic blood pressure; HR=heart rate. *: $p<0.05$.

is known as "white coat hypertension" [20, 21], while BP may be normal while at home. For this reason, ambulatory blood pressure monitoring (ABPM) is recently being investigated clinically [1, 9, 14–17, 21, 23].

Considering the above points, we used the telemetry system on dogs and invasively measured their BP under unanesthetized and unbound conditions. The telemetry system has been developed as a new BP measurement method in animal experiments, and makes possible accurate BP measurements in an unanesthetized and unbound setting [2, 5–8, 12, 13, 24].

BP in normal dogs after surgically implanting the transmitter resulted in high values for BP one day post-operatively. It is thereafter observed that BP decreased gradually, and became stable from five days post-operatively. This indicates that surgical invasion influences BP for one week post-operatively. Considering the above, individual difference, familiarization with the environment etc., it is necessary to examine BP measured by telemetry system at least two weeks post-operatively.

When the dog's BP is measured continuously for 24 hr at 5 min intervals, BP fluctuated normally over the 24 hr period, and that the breadth of fluctuation during a single day is confirmed to be extremely large. Nevertheless, when the average BP values per hour is calculated for all of the systolic, mean and diastolic pressures for each dog, which was measured at 5 min intervals, a twin peak diurnal variation was observed. Broten *et al.* [6] reported that low mean BP was obtained throughout the night to early morning using the telemetry system, and high BP from early morning and throughout the day in dogs. This circadian variation clearly differs from our observations using our telemetry system.

Reports into circadian BP fluctuations in humans have demonstrated a trend whereby BP rises during the day and falls at night. However, in rats, a trend has been identified in which BP rises during periods of darkness and falls during periods of exposure to light. This is thought to be due to the nature that humans are diurnal, sleeping during the night and active throughout the day, whereas rats are nocturnal, active during periods of darkness and sleeping during periods of exposure to light [1, 7, 9, 12, 15–17]. It has been recognized in humans that shift-workers who work at night show the high BP values at night [1, 23]. This indicates that they are influenced not only by the circadian rhythm, but also by the body's activities due to the external environment. It is therefore suggested that BP fluctuations may depend mainly on sleeping, waking, and activities.

In our study, we attempted to relate BP to activities in dogs, indicating that the BP exhibited the highest values during periods of activity, and the lowest values during periods of sleep. The discrepancy between our results and Broten's reports [6] may be due to the environment in which the animal was raised. The diurnal BP variation obtained in this experiment is thought to be due to the body's rhythm acquired by learned and external factors such as the number of feeding times per day and the environment in which the animals were raised, etc., in addition to the essential endogenous circadian rhythm per se.

In this study, it was demonstrated that a diurnal rhythm with large fluctuations exists in the BP of dogs. Due to large BP fluctuations, it is possible that an error is generated in evaluating the BP measured at a single point in the course of one day's fluctuations. Moreover, 24 hr BP at rest is considered as the absolute BP of the individual animals.

In addition, the 24 hr BP in the seven normal dogs using the telemetry system showed almost identical values compared with the reported 24 hr BP values in humans [1, 17, 23]. It is, therefore, concluded that BP in dogs can be considered to be no higher than that of humans.

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