



NOTE

Internal Medicine

# Epidemiological study of indirect blood pressure measured using oscillometry in clinically healthy cats at initial evaluation

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**ABSTRACT.** We investigated the clinical characteristics of healthy cats in accordance with the target organ damage (TOD) risk category, on the basis of systolic blood pressure (SBP). This prospective multi-center study included 137 healthy cats. Indirect blood pressure was measured using an oscillometric technique. The median SBP in all cats was 147 mmHg (interquartile range: 134–158). On the basis of the TOD risk category, 57.7, 19.7, 21.9, and 0.7% of the cats were classified into categories I–IV, respectively. Age, sex, and body weight did not affect the SBP. This study provides basic information on the distribution of TOD risk categories in clinically healthy cats.

**KEY WORDS:** blood pressure, feline, oscillometry, systemic hypertension

Systemic hypertension is defined as a persistent increase in systemic arterial pressure, and the recognition of this disorder in cats has increased in recent times. Systemic hypertension often induces clinical complications, including ocular injury, encephalopathy, renal abnormalities, and cardiovascular abnormalities; these are referred to as target organ damage (TOD) [10, 13]. In 2007, the American College of Veterinary Internal Medicine (ACVIM) consensus panel published guidelines for the definition, diagnosis, and management of systemic hypertension. The guidelines proposed four classifications, i.e., TOD risk categories, on the basis of the risk of developing TOD using systolic blood pressure (SBP): TOD is more likely to occur at SBP  $\geq$ 160 mmHg (category III), while SBP  $\geq$ 180 mmHg (category IV) is thought to confer a very severe risk of TOD [4, 16].

Three methods of indirect blood pressure measurement are commonly used in clinical practice: Doppler, oscillometry, and photoplethysmography techniques. The distribution of indirect blood pressure in healthy cats has been reported to be between 121 and 162 mmHg [2, 3, 14, 16, 17]. Although some studies have shown that indirect blood pressure measurements using oscillometry provide diagnostic information related to systemic hypertension in cats [3, 6, 16], the diagnostic criteria for systemic hypertension have varied across these studies. Furthermore, no basic information is available on the relationship between clinical features and

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**Table 1.** Comparison of blood pressure measurements between devices

	BP100D	petMAP
Systolic blood pressure	90.6 ± 11.8	94.9 ± 13.2
Mean blood pressure	65.3 ± 13.2	63.3 ± 12.6
Diastolic blood pressure	50.6 ± 13.9	46.3 ± 13.3

Data are described as the mean ± standard deviation. No significant difference in blood pressures is observed between devices.

**Table 2.** Breed distribution

	Number
Domestic short hair	102
Scottish fold	9
American short hair	7
Abyssinian	3
Russian blue	3
Chinchilla persian	2
Maine coon	2
Munchkin	2
Singapura	2
Other breeds	5

the TOD risk category measured by oscillometry. Therefore, the objectives of the present study were to investigate the clinical features of healthy cats based on TOD risk categories, and to describe the relationship between SBP and age, sex, and body weight.

This prospective multi-center study included cats examined between July 2014 and March 2017. The 140 cats were recruited from veterinary students and clients of the referral clinics at animal hospitals. Client-owned cats were presented at each center for routine health checks. The owners provided informed consent before their cats participated in the study. All cats underwent a physical examination, indirect blood pressure measurement, echocardiography, and blood sampling at the time of initial examination, which were performed without sedation in a quiet examination room. Cats ≥6 months old were included in this study if they appeared normal on clinical examination, provided that the owner did not report any clinical symptoms [15]. After data collection, the cats were classified into four groups on the basis of the TOD risk categories in the ACVIM guidelines: category I (SBP <150 mmHg), category II (150–159 mmHg), category III (160–179 mmHg), and category IV (≥180 mmHg) [4]. Cats with heart disease, chronic kidney disease (plasma creatinine concentration >1.6 mg/dl) [9], diabetes mellitus (plasma glucose concentration ≥280 mg/dl), hyperthyroidism (serum thyroxine concentration ≥4.2 µg/dl) [18], or other systemic diseases were excluded.

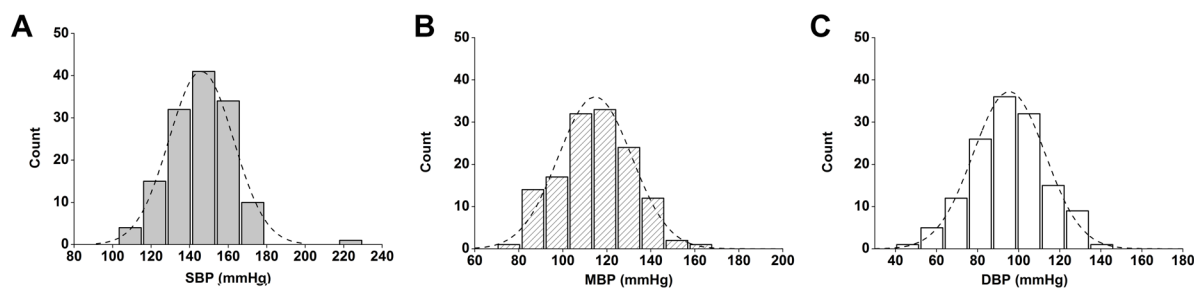
Indirect blood pressure was measured using a noninvasive oscillometric monitor (BP100D, FUKUDA ME, Tokyo, Japan; petMAP, Ramsey Medical, Inc., Tampa, FL, U.S.A.). Measurements were recorded at the initial examination. All cats were allowed a minimum 5-min acclimation period before the blood pressure measurements. An appropriately sized cuff (inflatable bladder width approximately 0.3–0.4 times the circumference of the measurement site) was applied. The cats were restrained minimally and positioned in sternal recumbency. The cuff was placed directly around the forelimb, minimizing the vertical distance between the cuff site and the heart, eliminating the need for reading correction to account for such a difference. A minimum of five readings were obtained from each cat at each measurement occasion and the mean of the series, calculated. If a high SBP is recorded during the first measurement, repetition of the SBP measurement after an acclimatization period has been reported to be better at differentiating normal from abnormal SBP [17]. In this study, if the SBP exceeded 160 mmHg, a second set of measurements was conducted after a 30–60 min acclimatization period, and the mean of the second measurements was used. To evaluate the variations in blood pressure values between devices, blood pressures in four healthy cats under anesthesia were compared. The blood pressures between devices were comparable (Table 1).

The blood samples were collected from the cephalic vein in heparinized and plain tubes and then centrifuged at 3,000 rpm for 10 min at 4°C. Plasma biochemistry and serum thyroxine concentrations were measured at a commercial laboratory (FUJIFILM Monolith, Co., Ltd., Tokyo, Japan).

Transthoracic echocardiography was performed using an ultrasonographic unit with a 7.5–12 MHz probe by experienced echocardiographers. The left atrium to aorta (LA/Ao) ratio was determined and B-mode or M-mode echocardiography was performed from the right parasternal short-axis view. Then, the intraventricular septum (IVSd), left ventricular internal (LVIDd), and left ventricular posterior wall (LVPWd) dimensions at end-diastole were calculated.

All data were described as median (interquartile range). The normality of data was assessed with the Kolmogorov-Smirnov test. The Kruskal-Wallis test was used to compare data from three groups or more. *A post hoc* analysis was performed using the Dunn test. Univariate regression analysis was used to evaluate the correlations between SBP and other variables. A value of  $P < 0.05$  was considered statistically significant.

Clinically healthy cats aged 0.7–16.6 years and weighing between 2.0–10.1 kg were enrolled. Among the cats in TOD risk category IV, three were ≤3.0 years old and were excluded from the analysis because of excitement during the blood pressure measurements. Thus, the study population consisted of 137 cats. Overall, the breed most commonly represented was the domestic short hair ( $n=102$ ). Other breeds are listed in Table 2. The blood pressures of 108 cats were measured by BP100 D while pet MAP was used for 29 cats. The median SBP, mean blood pressure (MBP), and diastolic blood pressure (DBP) were 147 mmHg (134–158), 117 mmHg (105–127), and 98 mmHg (82–108), respectively. Distributions of blood pressure are shown in Fig. 1. The kurtoses of SBP, MBP, and DBP were 4.92, 2.57, and 2.60, respectively. On the basis of TOD risk categories, 79 (57.7%), 27 (19.7%), 30 (21.9%), and 1 (0.7%) cats were classified into categories I to IV, respectively. Table 3 summarizes the results of the physical examination, biochemistry, and echocardiography based on TOD risk categories. No significant differences were found



**Fig. 1.** Distribution of oscillometric blood pressures in the 137 cats (A to C). SBP, systolic blood pressure; MBP, mean blood pressure; DBP, diastolic blood pressure.

**Table 3.** Comparison of variables in cats among the groups

	TOD risk			
	Category I	Category II	Category III	Category IV
Male/Female	50/29	14/13	11/19	1
Age (Y)	5.2 (2.5–8.9)	8.0 (4.2–11.5)	6.4 (3.0–11.3)	11.8
Body weight (kg)	4.2 (3.6–5.0)	4.2 (3.3–5.3)	4.1 (3.5–4.6)	3.5
Heart rate (bpm)	180 (150–196)	180 (165–202)	194 (178–207)	210
Echocardiography				
IVSd (mm)	4.2 (3.7–5.0)	4.4 (3.5–5.0)	4.3 (4.1–5.1)	5.0
LVIDd (mm)	14.2 (13.0–16.0)	14.6 (13.5–16.5)	15.5 (12.3–16.7)	13.0
LVPWd (mm)	4.8 (3.9–5.3)	5.0 (4.1–5.5)	4.7 (3.8–5.4)	5.0
LA/Ao ratio	1.36 (1.22–1.49)	1.32 (1.19–1.54)	1.36 (1.21–1.49)	1.44
Biochemistry				
Total protein (g/dl)	7.3 (6.9–7.8)	7.3 (7.0–8.0)	7.4 (7.1–8.2)	6.4
Albumin (g/dl)	3.1 (2.8–3.3)	3.0 (2.9–3.2)	3.1 (2.9–3.3)	2.4
Glucose (mg/dl)	114 (98–139)	118 (105–153)	110 (94–133)	130
Urea nitrogen (mg/dl)	25 (21–29)	24 (20–27)	24 (21–29)	22
Creatinine (mg/dl)	1.3 (1.1–1.5)	1.2 (1.0–1.4)	1.3 (1.0–1.5)	1.6
Sodium ( $\mu$ Eq/l)	154 (152–156)	155 (153–156)	155 (153–158)	149
Potassium ( $\mu$ Eq/l)	4.0 (3.6–4.2)	3.9 (3.5–4.0)	4.1 (3.7–4.3)	3.5
Chloride ( $\mu$ Eq/l)	119 (116–122)	120 (116–122)	118 (115–123)	107
Thyroxine ( $\mu$ g/dl)	2.0 (1.7–2.5)	1.9 (1.5–2.3)	2.1 (1.7–2.5)	0.9

Data are described as the median (interquartile range). IVSd, end-diastolic intraventricular septum; LVIDd, end-diastolic left ventricular internal dimensions; LVPWd, end-diastolic left ventricular posterior wall; LA/Ao ratio, the ratio of the left atrium to the aorta.

among the categories for each parameter. The SBP showed no correlation with age, sex, or body weight.

Previous studies have reported indirect SBP levels measured by oscillometric techniques in healthy cats in the range 115–146 mmHg [3, 6, 14, 16]. However, the populations of cats in these reports were relatively small ( $n=37$  to 104), and some cats were classified as normal on the basis of only clinical symptoms, so cats with underlying diseases may potentially have been enrolled in these studies. One study of 104 healthy cats reported a median SBP, measured using oscillometry, of 139.4 mmHg (standard deviation; 26.9), which included 32 cats with suspected hypertensive retinopathy [3]. Our study, comprising a larger population that consisted only of healthy cats, found a median SBP of 147 (interquartile range: 134–158) mmHg. Furthermore, this is the first study to show the distribution of TOD risk categories in healthy cats: 57.7, 19.7, 21.9, and 0.7% of the cats were classified into categories I–IV, respectively. Our results provide basic information regarding oscillometric blood pressure measurements in healthy cats.

In the present study, age, sex, and body weight did not affect the SBP in healthy cats. Previous studies have reported that SBP increases with age in cats [3, 14, 16]; however conflicting findings have also been reported [12, 17], and our study did not show any relationship between age and blood pressure. This discrepancy may reflect differences in study populations; further some studies did not assess underlying disease, such as renal function and cardiomyopathy, in all cats [3, 14, 16]. However, a recent longitudinal study demonstrated that SBP increases slightly with age (0.4 mmHg/100 days) in healthy cats [2], hence routine blood pressure measurements are necessary for older cats.

A diagnosis of idiopathic hypertension is established when there is a sustained increase in blood pressure with no identifiable underlying cause. Idiopathic hypertension has been reported in 13–55% of cats with systemic hypertension [8, 11, 13]. This large

range in prevalence may reflect differences in the study populations. For example, in a study of cats with hypertensive retinopathy, no clearly identifiable cause was detected in 55.1% of the cats [13]. Among our healthy cats, four cats were in TOD risk category IV, and one of these was suspected of having idiopathic hypertension. Idiopathic hypertension accounts for 95% of all cases of hypertension in humans [5], while its prevalence may be markedly lower in clinically healthy cats. Since the prevalence of idiopathic hypertension in cats remains unclear, additional studies are needed.

This study had several limitations. First, the ACVIM statement recommends that to diagnose systemic hypertension the blood pressure of cats with TOD should be re-evaluated within 1–2 weeks [4]. Although 61 cats were classified as TOD risk category  $\geq$ II in our study, it was difficult to re-evaluate SBP, so we cannot exclude white-coat hypertension [1]. Second, SBP in anesthetized cats has been reported to be significantly higher when measured using oscillometry than when measured using the Doppler technique [7]; therefore, the use of a different method, *i.e.*, the Doppler technique, may affect the results of blood pressure measurements.

This study measured indirect blood pressure in cats using an oscillometric technique. This is the first study to determine the distribution of TOD risk categories in healthy cats. The median SBP in cats was 147 mmHg (interquartile range: 134–158), and 0.7% were classified as TOD risk category IV. These results provide basic information on the distribution of TOD risk categories in healthy cats.

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