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Research article

The appropriate technique for blood pressure measurement in healthy geriatric cats using an automatic oscillometric device

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Abstract

Currently, the popularity of owning cats is increasing, together with improvements in diet, management, and veterinary specialism. The population of older cats has accordingly increased markedly. There are several health problems that accompany aging, such as degenerative diseases and cardiopulmonary disorders. Hypertension is the most common clinical sign that has been found in aging cats. Therefore, early screening for hypertension is necessary to prevent disease progression. However, cats are sensitive and are likely to develop mental stress during the measurement procedure, so an appropriate technique is required. The experiment was performed in 60 healthy elderly cats, whereby each cat was randomly assigned to one of the two trial groups. There were two groups in the experiment: 1) the cuff was placed on the forelimb at all times and the blood pressure was measured at 0, 5, 15, 30, and 60 minutes, and 2) the cuff was placed after waiting to rest at 30 and 60 minutes, followed by blood pressure measurement using the automatic oscillometric device. The results showed that blood pressure measurement at 15 minutes while placing the forelimb cuff at all times provided appropriate clinical reliability. Thus, this procedure could be used for hypertension screening in geriatric cats.

Keywords: Automatic oscillometric device, Blood pressure measurement, Geriatric cat

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INTRODUCTION

Cats are solitary and elusive animals whose characteristics make them popular pets among some people. There was evidence for the domestication of cats starting in Egypt approximately 5,000 years ago (Bradshaw, 2018). At present, more than 600 million cats live with humans worldwide, mainly distributed in the United States, China, Russia, Brazil, France, Italy, the United Kingdom, Germany, Ukraine, and Japan (Driscoll et al., 2009; O'Neill et al., 2019). In Japan, the number of cats with owners is expected to surpass the number of dogs owned in the country (Mitsui et al., 2020). The main factors leading to these countries having a large number of cats are the size of the country and the cultural and religious feelings towards cats (Torrey, 2022).

Recently, owned cats living in a house have been reported to have a longer lifespan. The factors promoting longevity are good nutrition, meticulous parenting, and good veterinary services (Sordo et al., 2020). However, aging in cats is a risk factor that contributes to the spontaneous degeneration of organs in various body systems (Zadik-Weiss et al., 2020; Yu et al., 2022), especially due to the chronic non-communicable diseases that are caused by environmental exposure, chemicals in housing, air pollution, and particulate matter (Natterson-Horowitz et al., 2022). Therefore, routine physical and vital signs examinations are necessary to analyze and assess the risks in the future of both internal medicine and surgery, particularly when considering individual reference ranges (Chester and Rudolph, 2011). Additionally, for those who have cats at home, this monitoring becomes even more useful (Niranen et al., 2012). However, it was found that taking animals to the hospital for physical examination results in their health deteriorating (Sykes and Weese, 2014). In geriatric cats, a vital sign that should be given special consideration is blood pressure, due to clinical signs sometimes not being noticeable in the early stages of disease progression (Jepson, 2011). In addition, no relationship has been established between gender, breed, or body weight and blood pressure in cats (Hori et al., 2019). Blood pressure disorders are often associated with various diseases (Thompson, 2004; García San José et al., 2020) due to the complexity of cause-and-effect relationships (Lawson and Jepson, 2021). It is recommended to measure animals' blood pressure using the doppler ultrasound method, but the clinical practice in cats is limited. Noise generated by the equipment, the measurement method, or the timing of the measurement may result in insufficient data for analysis (Uematsu et al., 2023). Therefore, establishing convenient and reliable guidelines for measuring blood pressure in cats could greatly assist veterinarians and pet owners in maintaining good care standards and evaluating health plans.

The objective of this study was to determine the appropriate practice in blood pressure measurement for obtaining blood pressure values in cats that closely resemble clinically valid values by using an automatic oscillometric device.

MATERIALS AND METHODS

Ethics statements

This study was approved by the Institutional Animal Care and Use Committee of Rajamangala University of Technology Tawan-Ok. Approval certificate number RMUTTO-ACUC-2-2022-0024.

Experimental animals

A total of 60 cats aged between 10-14 years old and of weight between 1.5-7 kg were selected. All cats were healthy without any reported serious diseases such as cardiovascular, kidney, joint, and endocrine problems. The cats' owners gave their consent to participate in this experiment. All cats in the experiment received two types of testing: 1) cuffed at all times, and 2) cuffed before measuring.

The experiments were separated by 1 day. The selection of the experimental design for each cat, before and after, was done randomly, so each experimental design had 60 cats. All cats were examined to obtain the physical data including body temperature, heart rate, respiratory rate, mucous membranes, and hydration status. The experiment was divided into 2 groups: 1) the forelimb cuff was attached upon arrival at the animal hospital and the blood pressure measured at 0, 5, 15, 30, and 60 minutes without removing the forelimb cuff throughout the trial, and the animal was kept in the quiet room while waiting for measurement at each interval, and 2) when the cats arrived at the animal hospital, they waited for 30 and 60 minutes, and then the forelimb cuff was attached and the measurements taken. While waiting for measurement at each interval, the animal was kept in the quiet room. The average value of each parameter was obtained from only 3 measurement times to reduce the stress and excitement that would be caused by more frequent measurement.

Therefore, the owners had to take the animal to the animal hospital twice to complete both experiments.

Cuff selection and blood pressure measurement

An automatic oscillometric device (BP-AccuGard), various sizes of cuffs, and measurement tape were used in this experiment. A flexible metric ruler was used to measure the forelimb circumference and a cuff was selected according to the American College of Veterinary Internal Medicine (ACVIM) (Acierno et al., 2018). The width of the cuff should be 30-40% of the circumference of the extremity at the site of cuff placement. Once the appropriate cuff size had been selected, the cuff was placed mid-radius on the forelimb. The cats were placed in right lateral recumbency with cuffs and limbs positioned at heart level. Then the blood pressures of the cats were measured 3 times with an interval of 1 minute. The averaged systolic and diastolic blood pressure, mean arterial blood pressure, and heart rate were recorded.

Statistical analysis

The R program version 4.3.1 was used to analyze the descriptive statistics of the experimental cats and compare the blood pressure values of each cat at each time for each method using the repeated-measures ANOVA blocked by cats. The Bonferroni method was used to compare the blood pressure values of cats at different time points in both groups using the *P-value* of <0.05. Comparison between the 2 groups at 30 minutes and 60 minutes used the method of paired t-test.

RESULTS

Characteristic and physical examination data of the experimental cats

A total of 60 healthy cats with an average age of 10.91 ± 1.84 years were studied. Of these cats, 95% were mixed breed while 5% were pure breed. There were 3 types of gender and sexuality including castrated male (40%), spayed female (55%), and intact 5%. The cats were raised indoors (23.33%), or both indoors and outdoors (76.67%). There were various living patterns; i.e., 3.33% had only 1 cat in the house, while 96.67% of cats were raised with other cats, and all cats lived with only cats and not with other pets. The experimental cats were fed with commercial dry food (36.67%) or with the combination of commercial dry food and home cooked food (63.37%). The summation of these data can be seen in Table 1.

The body condition scores of the experimental cats were 3.78 ± 0.42 out of 5 with the weight about 4.08 ± 0.96 kg. Respiratory rate was recorded at 63.65 ± 0.45 breaths per minute. The average body temperature was 101.47 ± 0.61 °F as shown in Table 2.

Table 1 Characteristics of 60 cats

Characteristics.	Percentage
Breed	
Mixed	95%
Purebred	5%
Gender	
Castrated male	40%
Sprayed female	55%
Intact	5%
Livelihood	
Indoor only	23.33%
Indoor and outdoor	76.67%
Outdoor only	0
Pattern of living	
Raised only 1 cat	3.33%
Raised more than 1 cat	96.67%
Raise cat only	100%
Raised with other animals	0
Type of food	
Commercial dry food	36.67%
Home cooked	0%
Commercial dry food and home cooked	63.33%

Table 2 Physical examination of 60 experimental cats

Parameter	Mean ± S.D.
Age (year)	10.91 ± 1.84
BCS out of 5	3.78 ± 0.42
BW (Kg)	4.08 ± 0.96
RR (bpm)	63.65 ± 0.45
Temperature (0F)	101.47 ± 0.61

BCS: Body Condition Score; BW: Body Weight; RR: Respiratory Rate

Measurement results of blood pressure and heart rate

The heart rates of the cats were measured and reported as shown in Figure 1. There was no significant difference in heart rates at all time points of each trial (P-value >0.05) in both groups of the experiment. Systolic, diastolic, and mean arterial blood pressure were measured using an automatic oscillometric device. The results are shown in Figures 2-4 respectively. Both systolic and diastolic blood pressure were significantly different between each group with P-value <0.01. In addition, mean arterial blood pressure showed significant differences between groups with P-value <0.01.

Heart rate and blood pressure measurements were performed using an automatic oscillometric device (Table 3). The heart rate value was not significantly different at any time point in the “cuff at all times group”. In addition, the systolic blood pressure of the “cuff at all times group” at time 0 was significantly different compared with the times of 5, 15, 30, and 60 minutes. Interestingly, there was no significant difference in systolic blood pressure values obtained from times 5, 15,

30, and 60 minutes. The results of the diastolic blood pressure measurement in the "cuff at all times group" showed that time 0 and time 5 minutes were significantly different compared with times 15, 30, and 60 minutes. Moreover, mean arterial blood pressure of the "cuff at all times group" was examined and it was reported that time 15 minutes was significantly different compared with other time points.

Meanwhile, all parameters were investigated in the "rested group" and it was found that there was no significant difference in heart rate and systolic blood pressure values between time 30 and time 60 minutes. Notably, the diastolic and mean arterial blood pressure values were significantly different between time 30 and time 60 minutes.

To validate the appropriate time to perform blood pressure measurement, the data between the "cuff at all times group" and the "rested group" were used. The results indicated the differentiation of blood pressure values at both 30 and 60 minutes between both groups, whereas cuffing and measuring at 15 minutes showed no significant difference in diastolic and mean arterial blood pressure values. Therefore, cuff at all times and measuring blood pressure at 15 minutes was considered the proper way to perform the measurement in clinical practice.

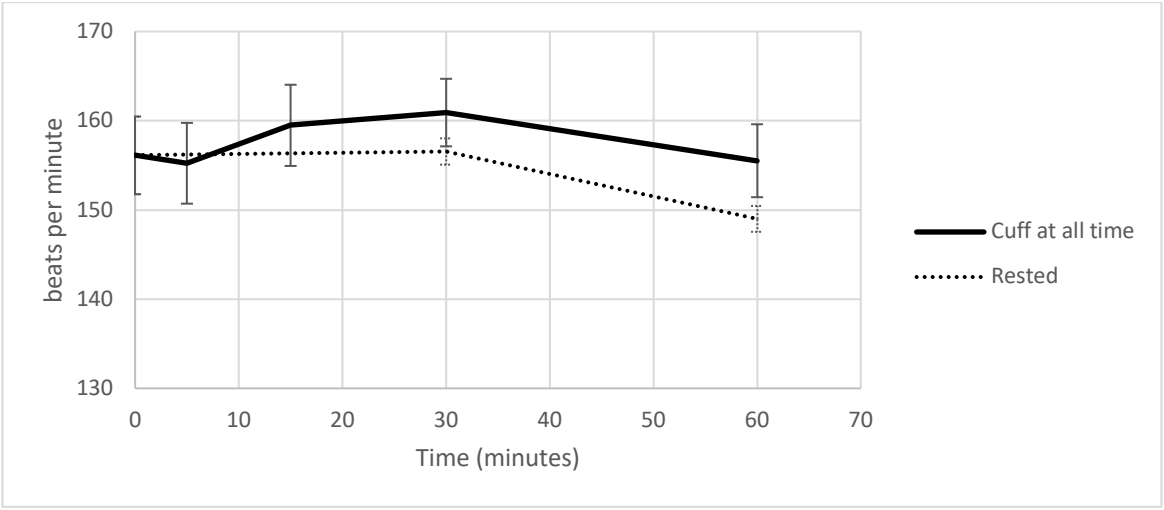

Figure 1 Graph showed heart rate (HR) values with error bars representing standard errors obtained from measurements at all times in cats that were cuffed throughout and rested periods of 30 and 60 minutes (*P-value* = 0.5822 for the group with cuff at all time and *P-value* = 0.1343 for the rested group).

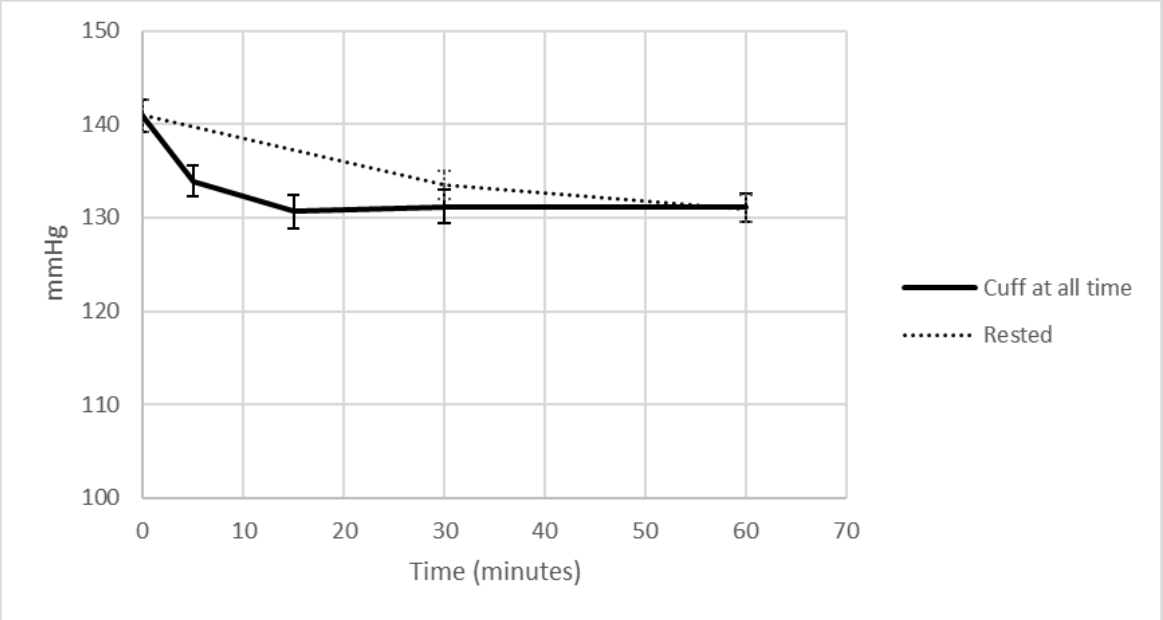

Figure 2 Graph showed systolic blood pressure (SBP) values with error bars representing standard errors obtained from measurements at all times in cats that were cuffed throughout and rested periods of 30 and 60 minutes (P-value <0.01 in both groups).

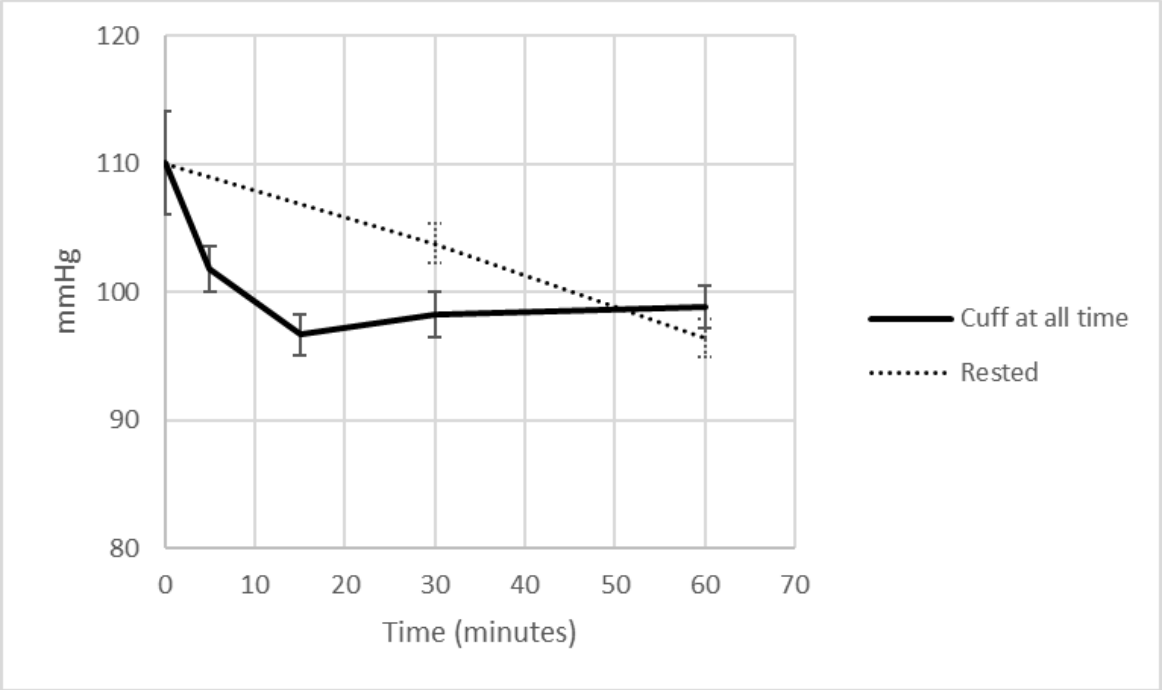

Figure 3 Graph showed diastolic blood pressure (DBP) values with error bars representing standard errors obtained from measurements at all times in cats that were cuffed throughout and rested periods of 30 and 60 minutes (P-value <0.01 in both groups).

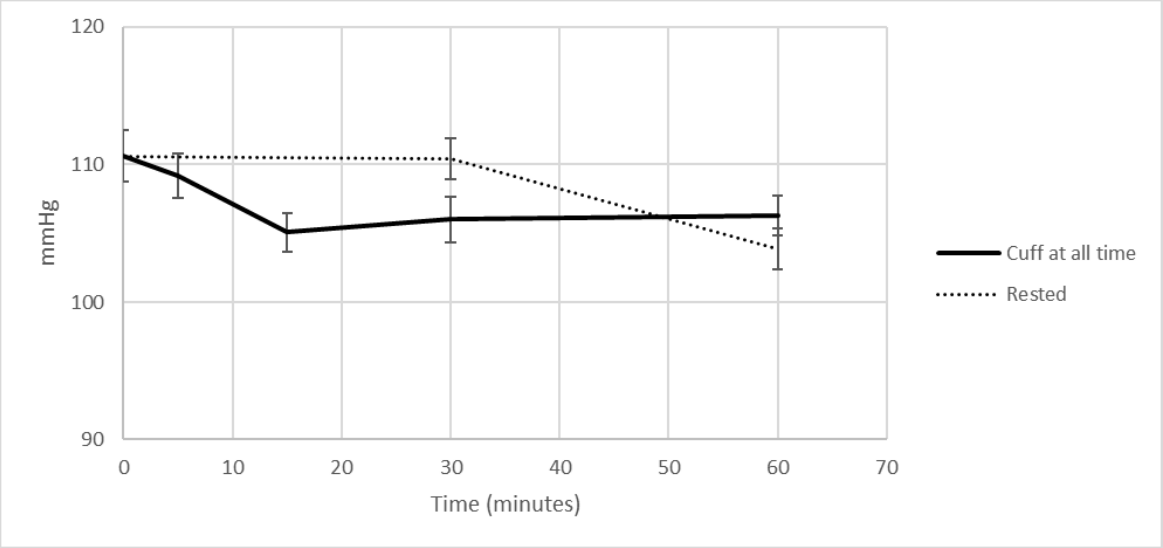

Figure 4 Graph showed mean arterial blood pressure (MAP) values with error bars representing standard errors obtained from measurements at all times in cats that were cuffed throughout and rested periods of 30 and 60 minutes (P-value <0.01 in both groups).

Table 3 Comparison of heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial blood pressure (MAP) at different time points in cats with cuff at all times and in cats with periods of 30 and 60 minutes rested

		With cuff at all times		With periods of 30 and 60 minutes rested	
Variables	Time (minutes)	Mean	SD	Mean	SD
HR	0	156.1	33.7	156.1	33.7
	5	155.2	35.1		
	15	159.5	35.3		
	30	160.9	29.3	156.6	28.7
	60	155.5	31.7	149.0	27.6
SBP	0	141.0[a]	13.3	141.0[a]	13.3
	5	133.9[b]	13.2		
	15	130.7[b]	13.7		
	30	131.2[b]	14.2	133.5[b]	11.9
	60	131.1[b]	11.6	131.0[b]	10.9
DBP	0	110.1[a]	30.9	110.1a	30.9
	5	101.8[ab]	13.4		
	15	96.7[b]	12.0		
	30	98.3[b]	13.6	103.8[a#]	11.7
	60	98.9[b]	12.7	96.4[b]	11.4
MAP	0	110.6[a]	14.7	110.6[a]	14.7
	5	109.2[ab]	12.6		
	15	105.1[bc]	10.8		
	30	106.0[ab]	12.6	110.4[a#]	11.4
	60	106.3[ab]	11.0	103.9[b]	11.2

[a, b, c] Different letters indicated statistically significant difference (P-value <0.05) by column (among HR, SBP, DBP, and MAP at different time points) with Bonferroni method
[#] Indicated statistically significant difference (P-value <0.05) by row (between with cuff at all times and with periods of 30- and 60-minutes rested group at that time point) with paired t-test method

DISCUSSION

The blood pressure measurements in elderly healthy cats at various time points using an automatic oscillometric device in 2 different groups of the experiment, i.e., cuff at all times, and rested group, indicated significant differences in systolic, diastolic, and mean arterial blood pressure between groups with P-value <0.05. Remarkably, cuff at all times with 15 minutes of waiting provided appropriate blood pressure values according to the ACVIM consensus statement (Acierno et al., 2018). Therefore, cuff at all times with 15 minutes of waiting is suggested for use in clinical practice.

Taking blood pressure measurements in cats is difficult because cats are sensitive animals and have a variety of emotions and behaviours. An appropriate approach for blood pressure measurements is essential to ensure data accuracy and reliability, and to cause less stress, which has a positive impact on the basic clinical record and next visit. In this study, we performed blood pressure measurement using an automatic oscillometric device while the cats were placed in right lateral recumbency, and the cuff was applied on the left leg which was aligned at the same level as the heart position.

There were several factors contributing to feline blood pressure variation including the cardiovascular system, nervous system, endocrine systems, and kidneys (Hanås, 2021). Moreover, other factors such as excitement, stress, and anxiety due to the clinical environment, known as the “white coat effect”, could also have an impact upon the blood pressure measurement (Belew et al., 1999). Notably, the magnitude of systolic blood pressure is dependent upon the device and measurement procedure (Belew et al., 1999). In addition, negative behaviour of animals while visiting veterinarians leads to stress and changes in vital signs (Beyer et al., 2023).

The blood pressure data might be doubted during uncontrollable circumstances. Therefore, it is recommended to take steps to obtain the most accurate values. For the most accurate readings, cats should be measured at home to minimize the white coat effect that is commonly seen in animal hospitals (Sastravaha et al., 2020; Koo and Carr, 2022). However, conducting the blood pressure measurement in the home environment is challenging due to multiple factors such as lacking veterinary staff, veterinary specialists, and expensive instruments. Therefore, it is still necessary to bring the cat to the animal hospital for blood pressure measurement. When cats have to be brought to the animal hospital, it is suggested that the animal should be relieved of stress or should be accustomed and adjusted to the animal hospital. To achieve this, it is recommended to wait for 5-60 minutes to allow the cats to relax and relieve stress (Sparkes, 1999; Payne et al., 2017; Taylor et al., 2017). However, the experiment revealed that even when measuring blood pressure after resting, the cats’ heart rates remain unchanged due to the measurement technique.

When taking blood pressure measurements in cats, it is important to consider their uncertain behaviour that might cause problems such as aggression, stress, and anxiety (Yamada et al., 2020). Generally, dogs are calm and exhibit stable behaviour which makes them easy to approach and handle for blood pressure measurement. On the other hand, cats’ behaviour varies from breed to breed and these varieties could be passed on to the next generation making the cats difficult to approach, and posing challenges in managing a stress-reducing environment during blood pressure measurement (Salonen et al., 2019).

Psychological stress can alter the blood pressure (Quimby et al., 2011). There have been several efforts made to identify stress-reduction strategies for cats such as using automatic devices and aroma. It was found that cats have an olfactory system which is linked to the part of the brain that contributes to the stress response. In addition, the odours of animal hospitals containing the smell of dogs,

detergent solutions, disinfectants, and alcohol, induce stress in cats by creating an unpredictable physical and social environment (Zhang et al., 2022). Therefore, odour management should be carried out to help reduce stress. A good restraint strategy significantly reduces stress and offers benefits in terms of safety for veterinary staff and the welfare of the animal (Herron and Shreyer, 2014). Veterinarians have tried to use aroma, cannabis, and lavender to adjust the cats' behaviour and relieve stress. However, the response to aromatic substances is individually different in both the duration and behaviour, and the effects of the substance gradually decrease due to habituation (Ellis and Wells, 2010). Hence, the efficiency of using aroma to prevent stress in cats is open to inconsistency and becomes less effective with repetitive use.

Currently, domestic cats receive good care resulting in longer lifespans and a higher chance of obesity (Wall et al., 2019). Geriatric cats may encounter health problems such as diabetes mellitus, hyperthyroidism, kidney disease, liver disease, heart disease, cognitive dysfunction syndrome, neoplasia, osteoarthritis, and hypertension (Knies et al., 2023). Most of these health problems display obvious clinical signs which are easily noticed by the owner, and will be followed by an early veterinary visit and proper treatment (Ray et al., 2021). On the other hand, hypertension is a challenging issue since it does not show obvious clinical abnormalities (Prost, 2023). Pet owners are unable to detect the problems from the beginning. Remarkably, the cases with extremely high blood pressure can cause damage to the target organs (TOD) such as retinal detachment, proteinuria, heart failure, and renal failure (Acierno et al., 2018). Hypertension in elderly cats is often associated with chronic renal failure and hyperthyroidism (Conroy et al., 2018). Thus, feline practitioners' guidance states that hypertension assessment is an important component of counselling for cats at ages above 10 years old (Caney et al., 2023).

Blood pressure disorders in geriatric cats have an impact on their survival duration and quality of life. Both hypertension and hypotension can develop in cats. Hypotension can be caused by severe blood loss, trauma, shock, dehydration, heart diseases, infection, and the side effects of some drugs (Kobluk and Pypendop, 2022). Notably, hypotension rarely occurs compared with hypertension. Hypertension is commonly found in aging cats (Taylor, 2017). However, the primary cause remains unclear. Hypertension is a secondary occurrence stemming from multiple underlying conditions including abnormal renal function, hyperthyroidism, diabetes mellitus, pheochromocytoma, and central nervous system diseases.

Continuous blood pressure measurement upon each visit is beneficial for veterinarians to evaluate a cat's health. By using the database of obtained results to assess the risk or relationship with the factors to which the cat is exposed at various times, such as diet, medication, and surgical history, it will be possible to better understand the impact of those factors on blood pressure disorders. Blood pressure measurement can be divided into two types, which are the invasive and non-invasive methods. The invasive method is the most accurate protocol used as the gold standard (Cooper and Cooper, 2012; Skelding and Valverde, 2020a). However, the invasive method is not generally performed in clinical practice due to the difficulty of invasiveness for animals, the expensive equipment, and several potential complications from the procedure. Therefore, non-invasive methods similar to human examination including oscillometric devices, doppler devices, and auscultatory techniques are preferred (Skelding and Valverde, 2020b). Even so, the auscultatory technique is not accurate when performed in pets (Harvey et al., 1983).

The doppler device is recommended to measure the systolic blood pressure of pets in clinical practice. These devices work by applying ultrasound to measure the pulse and to detect arterial blood flow. However, there are some problems concurrent with the measurement guidelines that differ from performance in dogs. The cats are restrained by a capable practitioner and further shaved to apply conductive gel over the skin. In addition, noise generated by the measurement

induces the cat's resistance and stress, which can further interrupt the data accuracy, particularly for the diastolic blood pressure. Therefore, an alternative technique that overcomes the limitations due to feline stress in noisy situations is required.

Use of an oscillometric device based on the principle of automatic cuff devices that detect the pulse vibration when the cuff compresses and releases is an alternative choice. The device with its vibration sensor calculates various blood pressure values as well as the heart rate. Compared to doppler, both devices provide accurate data of systolic arterial blood pressure (Petric et al., 2010). However, the accuracy of diastolic blood pressure values obtained from an oscillometric device was higher than when using the doppler device. In addition, using oscillometric measurements at the coccygeal artery position is shown to be more reliable compared to doppler devices (Haberman et al., 2006). Notably, oscillometric devices are suitable for cats due to causing less excitement and stress during handling in the measurement procedure. Accordingly, an oscillometric device is the appropriate choice for blood pressure screening and health assessment. Importantly, the device must be calibrated at least every six months to ensure the accuracy of the blood pressure value. The measurement should be documented, including the person who performed the assessment, the cuff size used, the animal's position, the obtained data, and the reasons for eliminating any outliers.

According to the guidelines of blood pressure measurement, the suggested time for resting which allows the cats to relax and decrease mental stress is in a wide range (Van Vertloo et al., 2021). There was no evidence to support the idea that increases in waiting duration could facilitate greater stress relief in cats while being in the animal hospital. Hence, the optimum time that is necessary for cats to relieve stress is required. There have been multiple studies performed to evaluate feline mental condition concurrent with duration of stay in the animal hospital. However, longer stays in the animal hospital induce higher rates of complicating infections such as hospital-acquired infections, accidental infections, and respiratory infections during outbreaks of pandemic disease (Monegro et al., 2023). If there is an appropriate stress measurement model, owners will continually bring their cats to the animal hospital for the service. This can be helpful in assessing and planning the cats' health, especially for geriatric cats. In addition, veterinarians should advise the owner to observe any physical and behavioural changes that might be associated with chronic diseases (Dowgray et al., 2022).

CONCLUSIONS

This study suggests that an automatic oscillometer with cuff at all times is suitable for blood pressure measurement in geriatric cats. The appropriate procedure starts with cuffing at the beginning of the service and waiting for 15 minutes before measuring the blood pressure to obtain a reliable value. Feline blood pressure measured by an automatic oscillometric device (BP AccuGard) will be further calculated from mean ± 1.96 S.D., and a recommended 158 mmHg as the cutoff value for systemic hypertension in geriatric cats.

In addition, good odour management and a proper, less invasive, restraint technique are needed to prevent psychological stress in cats. There are several advantages of using the oscillometric device, including less equipment usage, shortened service time, convenience for measuring blood pressure under a clear procedure pattern, reduced stress in cats, and addressing the owner's concerns about restraint and measurement. Minimizing stress is important, due to stressed cats being more susceptible to infection when in the hospital. A clear and simple form of blood pressure measurement encourages the use of a database to evaluate

and monitor disease progression. It will be useful to notice abnormalities earlier, aligning with the saying, “prevention is better than cure”.

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AUTHOR CONTRIBUTIONS

Collected samples: AC, KC
Collected and categorized data: AC, KC, CL
Conceived and designed analysis: AC, CL
Analyzed the data: AC, CL
Artwork and table designed: AC, CL
Wrote the manuscript: AC, CL

CONFLICT OF INTEREST

All authors declare no conflict of interest.

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