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Temperature gradients in domestic cats over seven-years-old: descriptive analysis[1]

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ABSTRACT.- Rabelo R.C., Pereira Neto G.B.., Carvalho V.J. & Carvalho G.J. 2020. **Temperature gradients in domestic cats over seven-years-old: descriptive analysis**. *Pesquisa Veterinária Brasileira 40(3):-*. Faculdade de Agronomia e Medicina Veterinária, Universidade de Brasília, Av. L4 Norte, Setor de Clubes Norte, Campus Universitário Darcy Ribeiro, Brasília, DF 70910-900, Brazil. E-mail: intensivet@gmail.com

The temperature gradients are dynamic and noninvasive monitoring techniques that provide information on peripheral blood flow and have been related to the prognosis of patients with circulatory shock. This study evaluated 47 elderly domestic cats' temperature gradients, and we measured central (rectal) and peripheral (palmar, plantar and medial region of the radio) temperatures. Values found in this study are compatible with studies in young felines and differ from dogs and humans. The mean gradients found were 7.5°C for the central-peripheral; 5.6°C for the peripheral-environmental; 2.7°C for the skin-diff; and 0°C for the member-diff and the variables age and gender do not seem to influence these measurements. To the authors' knowledge, there is no description of temperature gradients in elderly domestic cats, so this study pretends to clarify the vasoconstriction response in this group of animals.

INDEX TERMS: Temperature gradients, domestic cats, peripheral perfusion, vasoconstriction.

RESUMO.- [**Avaliação descritiva dos gradientes de temperatura em felinos domésticos com mais de sete anos.**] Os gradientes de temperatura são técnicas de monitoração dinâmicas e não-invasivas que fornecem informações sobre o fluxo sanguíneo periférico, e têm sido relacionados ao prognóstico de paciente com choque circulatório. O presente estudo avaliou os gradientes de temperatura em 47 felinos domésticos idosos aferindo as temperaturas central (retal) e periférica (palmar, plantar e região medial do rádio). Os gradientes encontrados foram 7,5°C para o centro-periférico; 5,6°C para o periférico-ambiental; 2,7°C para o *skin-diff*; e 0°C para o *member-diff*. As variáveis idade e sexo não pareceram influenciar as mensurações. Não há, em conhecimento dos autores, descrição prévia dos gradientes de temperatura em felinos domésticos idosos, e por isso esse estudo pretende contribuir com o entendimento sobre a capacidade de resposta de vasoconstrição nesse grupo de animais.

TERMOS DE INDEXAÇÃO: Gradientes de temperatura, felinos domésticos, gatos, deltas de temperatura, perfusão periférica, vasoconstrição.

INTRODUCTION

Proper perfusion and oxygen delivery to cells and tissues are the main functions of the cardiovascular system. When this does not occur, there is the onset ofshock syndrome. This syndrome is defined by a severe hemodynamic and metabolic imbalance caused by low tissue perfusion and consequent imbalance between oxygen supply (DO_2) and oxygen uptake (VO_2) (Le Dran 1743, Weil & Shubin 1971).

Hemodynamic monitoring aims at the early detection of perfusion and oxygenation failures, which allows rapid intervention to prevent organ dysfunction. Critically ill patients are highly predisposed to tissue hypoperfusion and multiple organ dysfunctions. When the goal is to anticipate microcirculatory decompensation, an evaluation through macro-hemodynamic parameters, such as blood pressure and central venous pressure is considered ineffective. According

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to Réa-Neto et al. (2006), about 30% of the circulating volume may be lost before there is central repercussion in humans, that is, blood pressure and central venous pressure may be supported by the sympathetic compensatory response. In this case, the patient will have a hemodynamic state called occult shock, initially represented by hyperlactatemia in a stable macrocirculatory environment (Réa-Neto et al. 2006, Rabelo & Ribeiro 2012, Cecconi et al. 2014).

During this shock, the blood is diverted to the vital organs through sympathetic activity and by reducing efferent vagal activity, which results in peripheral vasoconstriction. Given that peripheral perfusion is the first compensatory response line to change, it is important to note that after hemodynamic resuscitation, the critically ill patient completes his recovery with perfusion normalization (Genderen et al. 2012, Vincent et al. 2012, Morais 2016).

There are no 100% sensitive or specific methods for hemodynamic monitoring, so any clinical or laboratory evaluation that is related to the clinical context should be used. (Réa-Neto et al. 2006, Morais 2016).

Due to the self-regulation of vital central organs (heart, lung, and brain), the blood flow is diverted from less vital peripheral tissues (skin, intestines, and kidneys) by increasing resistance in the peripheral vascular bed. Due to the reduced blood flow, there will be a reduction in perfusion with a consequent decrease in skin temperature. Peripheral cells intensify anaerobic pathways; consequently, there is an increase in lactate production as a substrate of the alternative pathway (Rabelo & Ribeiro 2012, Morais 2016, Lima & Bakker 2005).

Less vital tissues may be early markers of changes in blood flow. Obtaining the temperature gradients, capillary refill time, mucosal staining, urinary output, and intestinal borborygmi usually occur through simple and non-invasive methods, allowing a quick and widespread use. Vincent et al. (2012) make an analogy of peripheral markers as "windows" through which we can see a "fire" (Lima & Bakker 2005, Vincent et al. 2012).

Since the 1960s, the skin temperature measurement has been suggested as a noninvasive method for blood flow monitoring. The prognostic value of the measurements was further described by Joly & Weil (1969), who reported the correlation between first toe temperature, cardiac output, and survival in humans. A physical examination that includes skin temperature should be the first step for the perfusional assessment of critically ill patients. Cold extremities, when associated with increased lactate, assist in identifying hypoperfusion (Joly & Weil 1969, Vincent et al. 1988, Kaplan et al. 2001, Lima & Bakker 2005).

Temperature gradients can be obtained by the difference between two body temperature measurements at different points: center-peripheral ($DeltaT_{CP}$), peripheral-environmental ($DeltaT_{PE}$) and the forearm to the tip of the first digit of the left pelvic limb ($DeltaT_{skin-diff}$) (Joly & Weil 1969, Réa-Neto et al. 2006, Genderen et al. 2012, Rabelo & Ribeiro 2012, Morais 2016).

The center-peripheral temperature gradient ($DeltaT_{CP}$) reported in humans between 3°C and 7°C should be less than 6.5°C in dogs and below 8°C in cats. Higher values indicate that the patient maintains a central (rectal) temperature through the vasoconstriction peripheral (Genderen et al. 2012, Beccon 2013, Morais 2016, Rabelo 2018).

In 2012, Vinkers et al. (2012) demonstrated the effect of stress on the peripheral temperature in humans as an important factor in reducing digit temperature. Morais (2016) observed such an effect on felines and justified the higher stress potential as a cause for the higher center-peripheral gradients in the species (Vinkers et al. 2012, Morais 2016).

Delta T_{PA} is the difference between the patient's ambient and the peripheral temperatures. Usually, these values should not be below 4°C-6°C when the animal is kept in thermoneutral temperatures (24°C), i.e., that do not influence the vasoconstriction of the skin. There is a reduction in survival rate when temperatures are kept below these values for more than 12 hours in the hospital setting. Morais (2016) and Rabelo (2018) describe a temperature of 7°C in cats up to seven years old and 7.43°C in dogs.

The Skin-Diff temperature gradient seems to be adequate in environments with extreme thermal variations and physiologically should be close to 0°C. In anesthetized patients with severe vasoconstriction, values were close to 4°C. In cats under seven years old, Morais (2016) reported temperatures around 2.6°C, and in dogs, the values were close to 1.3°C (Lima & Bakker 2005, Rabelo & Ferrari 2010, Morais 2016, Rabelo 2018).

Delta member-diff is the difference between the temperatures of the palmar and plantar regions of the homolateral limbs. The literature describes values close to 0°, but this parameter may be altered in cases of occlusive diseases, considering that the affected limb will have a drastic reduction in blood flow (Genderen et al. 2012, Morais 2016).

Finally, studies showed that a detailed physical examination assists in identifying changes in peripheral perfusion parameters that faithfully reflect the imminent risk of acute circulatory failure. Soares et al. (2018) demonstrated that patients with chronic stage C mitral valve disease had increased lactate values even if stable macro-hemodynamically, but with normalized temperature gradients, while animals in stage B2 had altered center-peripheral deltas. The two possible explanations for reducing the ability to perform peripheral vasoconstriction were the age of these animals or the use of the pimobendan vasodilator drug. Feger & Braune (2005) corroborated these data by reporting that the advancing age directly influences sympathetic responsiveness in humans, with a reduction in the physiological temperature gradient in elderly patients (Feger & Braune 2005, Lima et al. 2009, Soares et al. 2018).

So far, there has been no description of the normality of temperature gradients in domestic cats older than seven years old, so this study intends to collaborate with understanding the vasoconstriction response in this group of animals.

MATERIALS AND METHODS

Forty-seven male and female cats of different breeds, aged over seven years old, from the routine care of the "Serviço de Clínica de Felinos" of the "Hospital Veterinário" of "Universidade de Brasília" (UnB) were evaluated. Initially, we performed screening covering physical examination (heart rate - HR, respiratory rate - RR, mucosal membrane staining - mm, capillary refill time - CRT, lymph nodes, abdominal palpation, and cardiopulmonary auscultation). Cats with skin lesions that could interfere with the measurement of peripheral temperature were not part of the experiment. Sequentially, after acclimatization of the animals at room temperature for 15 minutes, all were gently placed in sternal decubitus and the following temperatures were recorded:

a) Environmental through the infrared thermometer with two laser tips (ST-700), the emissivity of 0.95 in °C, using the average between 4 points on the walls.

b) Peripheral of the left thoracic limb in two distinct points: palmar cushion and proximal radial region of the radius, always keeping the hairs apart; and peripheral pelvic limb in the plantar cushion through infrared thermometer (ST-700, Incotherm®), the emissivity of 0.98 in °C (Villaseñor-Mora et al. 2009). The distance from the thermometer to the measurement point was approximately 13 centimeters and the laser was left in contact with the skin for 10 seconds to perform each measurement. The cushions were chosen for the study because they are a glabrous distal region and easily accessible.

c) Central (rectal) in °C using a nine-second digital thermometer (Geratherm® Rapid).

The measured temperatures were the basis of the calculations of the following gradients, expressed in °C:

i. Center-peripheral temperature gradient ($DeltaT_{CP}$): the difference between the central (rectal) temperature and the left thoracic limb cushion temperature ($DeltaT_{CP1}$) and the difference between the central (rectal) temperature and the left pelvic cushion temperature ($DeltaT_{CP2}$);

ii. Same-limb temperature gradient ($DeltaT_{skin-diff}$ or $DeltaT_{SD}$): the temperature difference between the proximal region of the radius in the forearm of the left thoracic limb and the cushion;

iii. Temperature gradient between different limbs ($DeltaT_{member-diff}$ or $DeltaT_{MD}$): based on the temperature difference between the left thoracic limb cushion and the left pelvic limb cushion;

iv. Peripheral-environmental temperature gradient ($DeltaT_{PE}$): the difference between ambient and left thoracic cushion temperature ($DeltaT_{PE1}$); and environmental and left pelvic limb cushion ($DeltaT_{PE2}$) temperatures.

RESULTS

We performed descriptive analysis on 47 cats aged seven years old and over, of which 26 were female and 21 were male (Table 1).

Data normality was tested using graphical analysis, Shapiro-Wilk, Kolmogorov-Smirnov, and Anderson-Darling as a statistical basis. *P*-values were above 0.05 (95%) for all variables, ensuring normal distribution (Miot 2017).

The averages of each variable reported by Morais (2016) and Rabelo (2018) were the base for the hypothesis testing to conclude some statistical differences when evaluating felines over seven years old. There was a statistical difference for the $DeltaT_{skin-diff}$ variable and the $DeltaT_{PE1}$ and $DeltaT_{PE2}$ (Table 2).

We grouped the cats into males and females to study the effect of sex, and there was no statistically significant difference between the groups (Table 3).

The cats were allocated into three groups to study the effect of age. The first group was composed of animals aged 7 to 10 years old considered adults, the second group was composed of animals aged 11 to 14 years old called elderly and the third group was formed by geriatric animals older than 15 years old, according to Hoyumpa Vogt et al. (2010). There was no statistically significant difference (Table 4-6).

Table 1. Descriptive analysis of the obtained variables

Variable	Mean	Standard deviation	Minimum	Maximum	N	Median
Age	12.06	3.26	7	18	47	11
$DeltaT_{CP1}$	7.58	2.22	3.7	11.9	47	7.6
$DeltaT_{CP2}$	7.59	2.36	2.4	13.1	47	7.5
$DeltaT_{SD}$	2.74	2.11	-2.7	6.5	47	3.3
$DeltaT_{MD}$	0.01	1.67	-5.4	4.6	47	0.1
$DeltaT_{PA1}$	5.66	2.16	-0.5	9.1	47	6.1
$DeltaT_{PA2}$	5.65	2.02	0	9.9	47	5.8

N = Sample size.

Table 2. Comparison between values of this sample with Morais (2016) and Rabelo (2018)

Variable	Sample		Population	*P*-value
	Mean	S	Mean	
$DeltaT_{CP1}$	7.58	2.22	8⁺	0.201
$DeltaT_{CP2}$	7.59	2.36	8⁺	0.24
$Delta_{SD}$	2.74	2.11	0*	0.001
$DeltaT_{MD}$	0.01	1.67	0*	0.967
$DeltaT_{PA1}$	5.66	2.16	7⁺	0.001
$DeltaT_{PA2}$	5.65	2.02	7⁺	0.001

S = Standard deviation; *P*-value determined with T-test for a sample; *values reported by Rabelo (2018), ⁺ values reported by Morais (2016).

Table 3. Study of the sex effect on the studied variables

Variable	Sex				*P*-value
	Male		Female		
	Mean	S	Mean	S	
$DeltaT_{CP1}$	8.09	2.3	6.94	1.97	0.71
$DeltaT_{CP2}$	8.11	2.32	6.93	2.29	0.088
$Delta_{SD}$	3.06	1.94	2.32	2.28	0.244
$DeltaT_{MD}$	0.01	1.8	-0.001	1.52	0.982
$DeltaT_{PA1}$	5.19	2.29	6.23	1.88	0.094
$DeltaT_{PA2}$	5.17	2.03	6.24	1.87	0.067
FC	188.38	39.54	191.91	36.19	0.751

S = Standard deviation; *P*-value determined with T-test for two samples.

Table 4. Study of the age effect on the studied variables (adults x elderly)

Variable	Age				*P*-value
	Adults		Elderly		
	Mean	S	Mean	S	
$DeltaT_{CP1}$	7.75	1.92	7.46	1.92	0.659
$DeltaT_{CP2}$	7.26	2.44	7.87	2.09	0.797
$Delta_{SD}$	2.13	2.17	3.12	1.97	0.167
$DeltaT_{MD}$	-0.48	1.82	0.4	1.35	0.11
$DeltaT_{PA1}$	5.89	2.15	5.41	2.06	0.673
$DeltaT_{PA2}$	6.38	1.71	5	1.86	0.03
FC	187.19	47.39	192.1	30.54	0.714

S = Standard deviation; *P*-value determined with T-test for two samples.

Table 5. Study of the age effect on the studied variables (adults x geriatricians)

Variable	Age				*P*-value
	Adults		Geriatricians		
	Mean	S	Mean	S	
$DeltaT_{CP1}$	7.75	1.92	7.53	2.83	0.808
$DeltaT_{CP2}$	7.26	2.44	7.56	2.47	0.751
$Delta_{SD}$	2.13	2.17	2.92	1.96	0.992
$DeltaT_{MD}$	-0.48	1.82	0.03	1.65	0.452
$DeltaT_{PA1}$	5.89	2.15	5.74	2.19	0.858
$DeltaT_{PA2}$	6.38	1.71	5.7	2.19	0.364
FC	187.19	47.39	191.63	34.56	0.786

S = Standard deviation; *P*-value determined with T-test for two samples.

Table 6. Study of the age effect on the studied variables (elderly x geriatricians)

Variable	Age				*P*-value
	Elderly		Geriatricians		
	Mean	S	Mean	S	
$DeltaT_{CP1}$	7.46	1.92	7.53	2.83	0.935
$DeltaT_{CP2}$	7.87	2.09	7.56	2.47	0.711
$Delta_{SD}$	3.12	1.97	2.92	1.96	0.785
$DeltaT_{MD}$	0.4	1.35	0.03	1.65	0.5
$DeltaT_{PA1}$	5.41	2.06	5.74	2.19	0.675
$DeltaT_{PA2}$	5	1.86	5.7	2.19	0.348
FC	192.1	30.54	191.63	34.56	0.969

S = Standard deviation; *P*-value determined with T-test for two samples.

DISCUSSION

In this study with domestic cats over seven years old, the gradients $DeltaT_{CP1}$ and $DeltaT_{CP2}$ were 7.58°C and 7.59°C respectively. Currently, according to Rabelo & Ribeiro (2012), for dogs, values above 6°C are considered a warning sign, and values above 10°C are harmful and correlated with higher mortality. In another study, with healthy and young cats, it was demonstrated that these animals would have $DeltaT_{CP}$ alarm values close to 8°C (Rabelo & Ribeiro 2012, Morais 2016).

The results in this study differ from the expected since, with advancing age, there would be a reduction in sympathetic response and, thus, a reduction in gradients (Feger & Braune 2005).

Given that this sample is non-probabilistic for convenience, it is possible that the cats that were used, even if stable, were already showing some degree of vasoconstriction, keeping the value close to the reference of young animals. We suggest further studies only with elderly and healthy animals. Still, using the 8°C value for patient assessment is efficient and reduces the possibility of false negatives.

Regarding the temperature gradient from the forearm to digit tip or $DeltaT_{SD}$, the present study found an average value of 2.74°C. Human studies have reported $DeltaT_{SD}$ values close to 0°C when there is no vasoconstriction, and 4°C during severe vasoconstriction. For dogs, the expected value is 1.3°C and in young cats, a study found values of 2.6°C. The effect of stress on skin temperature may be the explanatory factor for the slightly higher results found in cats (Rabelo & Ribeiro 2012, Vinkers et al. 2012, Morais 2016).

$DeltaT_{member-diff}$ is the difference between the temperatures of the first digit of the left thoracic limb relative to that of the first digit of the left pelvic limb. The value found in this study was 0.01°C, with no statistical and biological difference with the literature reference. This parameter may be altered in cases of occlusive diseases, given that the affected limb will have a drastic reduction in blood flow (Genderen et al. 2012, Morais 2016).

The values for $DeltaT_{PE1}$ and $DeltaT_{PE2}$ were 5.66°C and 5.65°C and were statistically different from the 7°C value found by Morais (2016). Given that the patients were kept in a thermoneutral environment, these results may be the result of peripheral vasoconstriction related to the hemodynamic unhealthiness of the sampled patients (Morais 2016).

The sex effect study did not generate a statistical difference between the groups. However, males presented $DeltaT_{CP1}$ and $DeltaT_{CP2}$ at 8.09°C and 8.11°C, and for females, $DeltaT_{CP1}$ and $DeltaT_{CP2}$ were 6.94°C and 6.93°C respectively. Although in the absence of statistical significance, there is biological importance in the difference of 1°C, and further studies are needed to evaluate if females are more predisposed to stress vasoconstriction.

To study the effect of age, we divided the sample into three groups, according to Hoyumpa Vogt et al. (2010), that is adults (7 to 10 years), elderly (11 to 14 years), and geriatricians (>15 years). There was no statistical difference between the groups. Still, within this sample, we expected to find lower values in the older group (Hoyumpa Vogt et al. 2010).

CONCLUSIONS

The center-peripheral, skin-diff and member-diff temperature gradients in elderly domestic cats do not appear to differ from values found in young cats, at least in this non-probabilistic convenience sample.

Statistically, sex does not appear to affect temperature deltas; however, a 1°C difference was reported between males and females concerning the center-peripheral gradient.

The present study was unable to determine statistical differences for gradients in older animals compared to young animals. However, it reinforces the importance of the reference values already reported, which probably have good specificity.

Conflict of interest statement.- The authors have no competing interests.

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