

## EQUINE INFLAMMATORY PROCESS EVALUATION USING QUANTITATIVE THERMOGRAFIC METHODOLOGY

### AVALIAÇÃO DE PROCESSOS INFLAMATÓRIOS DE EQUINOS UTILIZANDO A METODOLOGIA DE TERMOGRAFIA QUANTITATIVA

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#### SUMMARY

Thermography has been used as an important diagnostic tool in order to evaluate muscle and skeletal affections in equine sports medicine. However, many evaluation procedures are restricted to qualitative analysis of the images, becoming strongly dependent of the clinician expertise. Moreover, thermal cameras measures superficial skin temperatures, becoming susceptible to influences of environmental temperature variations. The quantitative thermography is a method presented to rationalize the infrared data evaluations, allowing the temperature follow on along time and correcting the effects of atmosphere conditions on the lesion temperature. The objective of this study is to evaluate an induced inflammatory process using a deterministic method for temperature data evaluation. An inflammation severity scale was established correlating clinical signs and local temperature variations to readily grade the inflammatory process. Three sound horses were submitted to an induced inflammation of the third proximal left metacarpus by circulatory restriction of the area. The exposure time for the procedure was 6 hours for two animals, and 3 hours for the other one. Afterwards, the evolution of the inflammatory process was monitored through 8 assessments along 150 hours. The quantitative thermography method allowed visualizing the individual temperature behavior throughout the time, hence the dynamic evolution of the inflammatory state. The maximum level of inflammation for each animal was reached at 25, 28 and 32 hours after finished the induction and the inflammatory process has shown tendency to resolution from 59, 142 and 64 hours, respectively. The 6 hours induction time animals have presented severe inflammation grade while the 3 hours induction time animal reached only moderated inflammation. The presented method has shown an analytical capability to evidence individual thermal responses along the time due to induced inflammatory process.

**KEY-WORDS:** Thermography, diagnosis, prognosis, inflammation, equine.

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## RESUMO

Termografia tem sido usada como uma importante ferramenta de diagnóstico, de forma a avaliar as afecções musculares e esqueléticas em medicina esportiva equina. Porém, muitos procedimentos de avaliação estão restritos à análise qualitativa das imagens, se tornando fortemente dependente da perícia do clínico. Além disso, câmeras térmicas medem a temperatura superficial da pele, se tornando susceptíveis a variações da temperatura ambiente. A termografia quantitativa é um método apresentado para racionalizar as avaliações dos dados de infravermelho, permitindo o acompanhamento da temperatura ao longo do tempo e corrigindo os efeitos das condições atmosféricas sobre a temperatura da lesão. O objetivo deste estudo é avaliar um processo inflamatório induzido utilizando a análise dos dados pelo método da termografia quantitativa. Uma escala de severidade de inflamação foi estabelecida correlacionando sinais clínicos e variações de temperatura local de forma a graduar os processos inflamatórios. De forma a validar este método, três equinos saudáveis foram submetidos à indução da inflamação da região do terço proximal do terceiro osso metacarpiano por restrição circulatória. O tempo de exposição ao procedimento foi de 6 horas para 3 animais e 3 horas para 1 animal. Em seguida, o processo inflamatório foi avaliado em 8 seções durante 150 horas. A aplicação do método permitiu visualizar o comportamento individual de temperatura ao longo do tempo, assim como a evolução dinâmica do estado inflamatório. O nível máximo de inflamação foi obtido para cada animal 25, 28 e 32 horas após finalizado o tempo de indução e o processo inflamatório demonstrou tendência à resolução a partir de 59, 142 e 64 horas, respectivamente. Os animais de 6 horas de indução apresentaram grau severo de inflamação, enquanto que o animal de 3 horas de indução apresentou somente inflamação moderada. O método apresentado demonstrou capacidade analítica para evidenciar as respostas térmicas ao longo do tempo devido ao processo de inflamação induzida.

**PALAVRAS-CHAVE:** Termografia, diagnóstico, prognóstico, inflamação, equino.

## INTRODUCTION

The infrared cameras have been applied in veterinary medicine as a diagnostic tool of locomotor system injuries for sport horses. However, the clinicians only use the images provided by those devices, resulting in a strictly qualitative evaluation, with low diagnosis repeatability and highly dependent on individual experience for proper interpretation.

According to Turner (1998), the thermography has been used as a detection tool of inflammation process, since it is capable to reflect more deep changes in the tissues circulatory pattern, evidenced by the increase of temperature (hot spot). Due to the fact of being a non-invasive device, it becomes ideal for equine muscle and skeleton lesions evaluations.

Eddy et al. (2001) pointed out that thermography has been proved very useful in the diagnosis, prognosis and damage evaluations or alterations in the soft tissues and superficial orthopedic lesions, in which the bones are minimally covered by soft tissue. Besides, they affirm that thermography reveals capsulitis and synovitis associated inflammations, subclinical miositis and neck-spine related diseases. Since the alteration in the skin temperature corresponds to the changes in the sympathetic autonomic nervous system, the thermography is useful to identify the vasomotor tone disorders, which is often associated with chronic pain and shows up, thermographically, as a region of decreased temperature (cold spot).

Moreover, the thermography may reveal changes in the temperature normal pattern up to two weeks before the first clinical signs. Head and Dyson (2001) add that infrared images might be easily used to portray inflammation graphically, monitor its progression and resolution and detect early recurrence.

Digital data provided by the thermograph and the image portraits, altogether, may be suitably used to evaluate deterministically the evolution of the lesion and the efficiency of the therapeutic application. Nevertheless, using data without proper calibration and correction may become unfruitful since the external conditions might introduce artifacts.

## MATERIALS AND METHODS

### *Quantitative thermography evaluation*

A procedure based on induced inflammation of the third proximal left metacarpus through circulatory restriction in this region was developed as depicted below.

### **I. Horses**

In this study, three sound horses, two males (M1 and M2) and one female (F1), weighing  $423 \pm 35$  kg and approximately 3 years old were used. During the test period, the horses were maintained in the field and supplied with concentrate and hay.

## II. Protocol for induced inflammation

The protocol consisted on circulatory restriction of the third proximal left metacarpus region in the three horses by an elastic band. M1 was submitted to the protocol through 3 hours while M2 and F1 were equally applied to 6 hours. It was provided a systemic analgesic procedure using tramadol (2.1 mg/kg) and xylazine (0.5 mg/kg). The methodology was approved by the Institutional Animal Welfare Committee protocol 022528/09.

## III. Thermographic evaluations

For the thermal evaluations, a basal evaluation (initial condition) was performed before the inflammation induction and 8 assessments were performed after induction, named as sampling time 6h, 12h, 18h, 30h, 54h, 78h, 102h and 150h so as to close monitor the inflammatory process and its dynamic behavior throughout the time. The proper choice of sampling time defines the data quality and may affect the clinician decisions during the evaluation period.

## IV. Thermography snapshot procedures

A Flir™<sup>1</sup> model i50 infrared camera was used during all trials and the value of 0.15°C measurement uncertainty was calculated taking in account the device precision, snapshot distance and ambient temperature measurement uncertainty. For obtaining good and reliable temperature data from the subject, a minimum set of procedures shall be properly followed by the clinician. An indoor place should be chosen to perform the thermograph snapshots, free of airflow and direct sunlight exposure. The ambient temperature should be within 20 to 30°C range, in order to not significantly interfere in the tissue temperature pattern. The equipment emissivity should be set in 0.98, typically adequate to animal tissues. The region of measurement must be clean and dry, and the data acquisition should be conducted after around 20 minutes for local temperature stabilization. The device distance between the equipment and the subject must be held constant throughout the evaluations and in this experiment was used 0.90 m. A surface region, representative of the overall environment temperature, must be portrayed and recorded for supplying the method with the average ambient temperature for further lesion snapshots calibration.

## V. Statistical analysis

As far the experiment was conducted with just two animals at same induction time (6h), it was not performed any statistical analysis of the data. The experiment aids to demonstrate the individual thermal behavior of the animals along the time.

### Quantitative thermography modeling

#### I. Ambient temperature standardization

The temperature data obtained in the monitoring conditions,  $T_{amb_i}$ , must be calibrated as a function of ambient temperature in the initial condition,  $T_{amb_0}$ , so as to eliminate the environmental interferences and to standardize the information, Basile *et al.* (2010), according to ICAO International Standard Atmosphere ISA:

$$\theta_i = \frac{T_{amb_i}}{T_{amb_0}} \quad (1)$$

where,

$T_{amb_i}$  - Ambient temperature in the posterior instants, in Kelvin,

$T_{amb_0}$  - Ambient temperature in the initial evaluation, in Kelvin.

#### II. Lesion local temperature standardization

The lesion local temperature,  $T_{lesion_i}$ , must be corrected by the factor  $\theta_i$  in order to eliminate the changes in environmental temperature, following (2):

$$T_{lesion_i\_corr} = \frac{T_{lesion_i}}{\theta_i} \quad (2)$$

where,

$T_{lesion_i}$  - Lesion temperature at the interest instant, in Kelvin,

$T_{lesion_i\_corr}$  - Corrected lesion temperature at the interest instant, in Kelvin.

#### III. Lesion local temperature variation

The adequate way to evaluate the temperature changes along the time is to express the data in terms of variation of temperature,  $\Delta T_{lesion}$ , related to the initial condition, summarized by (3):

$$\Delta T_{lesion} = T_{lesion_i\_corr} - T_{lesion_0} \quad (3)$$

where,

$\Delta T_{lesion}$  - Temperature variation in the local of the lesion, in Celsius degrees,

$T_{lesion_0}$  - Local lesion temperature at the initial evaluation, in Celsius degrees.

#### IV. Inflammation severity classification

The evaluation of temperature variation  $\Delta T_{lesion}$  allows classifying the lesion in different levels of inflammation as described in Table 1.

**Table 1** – Inflammatory levels according to local variation of temperature.

Temperature Variation $\Delta T_{lesion}$ [ $^{\circ}\text{C}$ ]	Inflammatory process classification
below $-0.5^{\circ}\text{C}$	Compensatory reduction of temperature. Increased risk of ischemia.
between $-0.5^{\circ}\text{C}$ and $0.5^{\circ}\text{C}$	Healthy
between $0.5^{\circ}\text{C}$ and $1.5^{\circ}\text{C}$	Mild Inflammation
between $1.5^{\circ}\text{C}$ and $2.5^{\circ}\text{C}$	Moderate Inflammation
above $2.5^{\circ}\text{C}$	Severe Inflammation

#### RESULTS AND DISCUSSION

After completing the induction time, the clinical signs in the region submitted to the induced inflammation were being promptly detected. However, by just looking to the edema in each animal, it would not be possible to distinguish who was in more critical condition.

Table 2 shows raw temperature data as collected ( $T_{lesion_0}$ ), the environmental ( $T_{amb_0}$ ) and correction (q) parameters used to correct the temperature, as per quantitative thermography modeling section previously presented, and the maximum temperatures variation ( $\Delta T_{lesion}$ ) for each evaluation session, which shows that the maximum temperature level was reached 30 hours after removing the inflammation inductor agent.

F1 presented  $3.01 \pm 0.15^{\circ}\text{C}$  maximum local temperature variation correlating to severe inflammation level as per Table 1, while M2 reached  $2.61 \pm 0.15^{\circ}\text{C}$  (severe inflammation) and M1 showed  $1.92 \pm 0.15^{\circ}\text{C}$  (mild inflammation). The lower value at 30 hours observed in M1 is consistent with the 3 hours induction time in this animal when compared to the 6 hours applied to the two others.

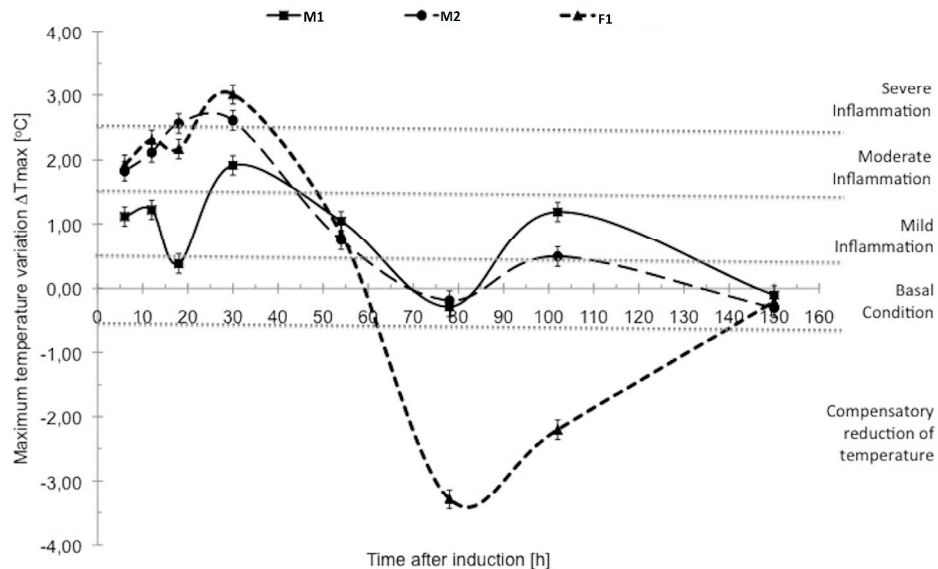
**Table 2** – Maximum temperatures variation of the third proximal left metacarpus region submitted to induced inflammation.

		Initial Condition	6 h	12 h	18 h	30 h	54 h	78 h	102 h	150 h
Raw data $T_{lesion}$ [ $^{\circ}\text{C}$ ]	F1	31.7	33.0	34.0	34.1	34.9	32.5	28.4	29.6	31.6
	M1	32.0	32.0	33.0	32.6	34.1	33.0	31.7	33.3	32.0
	M2	31.9	33.0	34.0	34.7	34.0	32.6	31.7	32.5	31.7
Correction Parameters	$T_{amb}$ [ $^{\circ}\text{C}$ ]	20.7	17.0	22.3	22.7	22.3	20.3	20.6	21.7	21.7
	$\theta$ [adm]	1.0000	0.9874	1.0054	1.0068	1.0054	0.9986	0.9997	1.0034	1.0034
Corrected $T_{lesion_i}/\theta_i$ [ $^{\circ}\text{C}$ ]	F1	31.7	33.6	34.0	33.9	34.7	32.5	28.4	29.5	31.5
	M1	32.0	33.1	33.2	32.4	33.9	33.0	31.7	33.2	31.9
	M2	31.9	33.7	34.0	34.5	34.5	32.6	31.7	32.4	31.6
$\Delta T_{lesion}$ [ $^{\circ}\text{C}$ ]	F1	N/A	1.92	2.31	2.17	3.01	0.84	-3.29	-2.20	-0.21
	M1	N/A	1.12	1.22	0.38	1.92	1.04	-0.29	1.19	-0.11
	M2	N/A	1.82	2.11	2.57	2.61	0.74	-0.19	0.49	-0.31

The sixth evaluation at 78 hours showed an expressive reduction in the F1 limb temperature towards a possible ischemic process. Analyzing Figure 1, which clarifies the dynamic, oscillatory and damped temperature behavior along the time, it was possible to assess that the assessments after 102 hours has showed a tendency to resolve the inflammatory process without any intervention.

Nevertheless, if the ischemic process would have confirmed, i.e., no return tendency towards the

initial condition, would have been possible a clinical intervention to revert the process. The choice of the evaluation sampling time is a key point to allow taking proper and timely clinical decisions. For the inflammatory processes follow up it is recommended 3 to 4 assessments in the first 24 hours and one daily-based evaluation afterwards till the affection resolution.



**Figure 1** – Temperature dynamic behavior of the third proximal left metacarpus region after inflammation induction (measurement uncertainty = ± 0.15).

## CONCLUSIONS

The application of the quantitative thermography allows screening the animals in accordance with its lesion criticality. Moreover, the proposed methodology offers quantitative parameters about the inflammatory processes along the time, making available for the clinician means to perform a more precise diagnosis and a deterministic prognosis.

## MANUFACTURER ADDRESS

<sup>1</sup> FLIR Systems, USA, Boston, MA, Phone: 1-800-GO-INFRA (464-6372) [www.flir.com](http://www.flir.com).

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