Termografia infravermelho da superfície abdominal ventral de coelhos (*oryctolagus cuniculus)* pré e pós-laparorrafia mediana com fios de quitosana ou poliglecaprone

Infrared thermography of ventral abdominal surface of rabbits (*oryctolagus cuniculus*) pre and post midline laparorrhaphy using chitosan or polyglecaprone yarns

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RESUMO

A termografia infravermelha foi utilizada para analisar inflamação, infecção ou trauma capaz de modificar o fluxo sanguíneo em uma região anatômica. Objetiva-se avaliar a temperatura superficial da parede abdominal ventral de coelhos (*Oryctolagus cuniculus*) pré e pós-laparorrafia com fios de quitosana, ou poliglecaprone, por termografia infravermelho. O experimento foi realizado em duas etapas. Na primeira etapa, foram utilizados sete coelhos machos e sete fêmeas. Neste período, as avaliações durante os períodos matutino e vespertino foram realizadas por dez dias consecutivos. Na segunda etapa, foram utilizados 42 coelhos, alocados em dois grupos com 21 animais cada. Um grupo foi submetido a laparorrafia mediana com sutura de quitosana e o outro com fio de Poliglecaprone 25. Nesta fase, as avaliações termográficas foram iniciadas no primeiro dia de pós-operatório e repetidas diariamente pela manhã. Na fase pré-operatória, as temperaturas da superfície abdominal variaram de 37,69 - 38,38. Em relação ao pós-operatório, notou-se diferença estatística para todas as comparações estudadas: P = 0,0035 entre a primeira e segunda etapas; P = 0,0003 entre os grupos Quitosana e Poliglecaprona. Em conclusão, a temperatura da superfície abdominal de coelhos, avaliada pelo método do infravermelho, varia entre os períodos do dia mesmo em ambiente controlado, e também diverge na reparação tecidual da laparorrafia com suturas de quitosana ou poliglecaprone.

Palavras-chave: biomaterial, cirurgia, laparotomia, linha alba, termograma, temperatura

ABSTRACT

Infrared thermography was used for analyze inflammation, infection or trauma that was capable to modified blood flow at an anatomical region. The objective of this study was to evaluate superficial temperature of ventral abdominal wall of rabbits (*Oryctolagus cuniculus*) pre and post-laparorrhaphy using chitosan, or poliglecaprone suture yarns, by infrared thermography. The experiment was conducted in two stages. In the first stage, seven male and seven female rabbits were used. During this period, evaluations during morning and afternoon periods were carried out for ten consecutive days. In the second stage, 42 rabbits were used, allocated to two groups with 21 animals each. One group underwent midline laparorrhaphy with Chitosan suture and another group was subjected to Polyglecaprone 25. At this stage, thermographic evaluations were initiated on the first postoperative day and repeated daily in the mornings. At the preoperative stage, abdominal surface temperatures ranged from 37.69-38.38. Regarding the postoperative period was noticed statistical difference to all comparisons studied: obtaining results = 0.0035 between the first and second stages; P = 0.0003 between the Chitosan and Polyglecaprone groups. In conclusion, temperature of abdominal surface of rabbits, evaluated by infrared method, varies between the periods of the day even in controlled environment, and also diverges in tissue repairing of laparorrhaphy with chitosan or polyglecaprone sutures.

Keywords: biomaterial, laparotomy, linea alba, surgery, temperature, thermogram

1 INTRODUCTION

Since Hippocrates, who historically detected cutaneous temperature difference in an individual using the hand dorsum and confirming thermal divergence by a mud drying method, body and cutaneous temperature have been used as a clinical sign and its fluctuations are related to a number of diseases[1]. Presently, with the introduction of infrared thermographic camera in clinical routine, the clinical sign of cutaneous temperature is no longer measured subjectively, but started to be evaluated quantitatively[2]. As technology evolved, the quality of images, sensitivity and capture speed of infrared thermography devices improved, increasing the use of this technique in multiple medical specialties[3].

Infrared thermography is a method employed to acquire and process thermal information without physical contact with the studied object[4]. The technique is based on a thermographic camera capture of infrared radiation emitted by a body that has a temperature higher than absolute zero (0 ° Kelvin)[5]. After capture, the infrared irradiation is transformed into electrical signals, which then are processed and converted to a visible image called thermogram[6].

The technique of evaluating temperature by infrared waves has been used in medical sciences due to its advantages of being a noninvasive, harmless, and painfulness technique with real-time processing. Under these conditions, it is possible to simultaneously compare different regions temperature, monitor a moving body temperature, and also minimize wound contamination risks and reduce stress interference and animal handling when measuring cutaneous temperature[7-9]. Therefore, it can be used in observations of local and systemic factors, including physiological hyperemia, inflammation, infection or trauma capable of altering blood flow in a specific anatomical region[10].

In veterinary medicine, infrared thermography has been used in several studies as an auxiliary diagnostic method for pregnancy and estrous period[11], viral[12], bacterial[13], and neoplastic[14] diseases, musculoskeletal injuries[15,16], and also in the study of thermoregulation[17,18] and in the follow-up of wound healing process[19-22]. These uses may enable early and less invasive diagnosis of certain diseases[23,24].

Notably, the thermographic camera proved to be versatile in inflammatory process evaluation during and after implant biomaterial cicatrization. It has been used in several anatomical regions and in different species presenting good correlation with the traditional histological evaluation method. In this scenario, infrared equipment has been

used in equines[19,20], dogs[25], rats[22,26], and rabbits[27] encompassing anatomical regions of knee joint[25], heel region[27], carpus[21], metacarpus[19,20], lower lip[22], and lateral thoracic wall[19,22]. However, most studies that evaluated inflammatory processes using infrared thermography technique did not observe a preoperative evaluation to standardize cutaneous temperature[20,27-30]. Moreover, in referred literature[11,12,19-27], there are no reports of evaluating ventral abdominal surface temperature, pre or post-implantation of biomaterials, furthermore, few studies used healthy animals in regulated environment with controlled temperature, luminosity, humidity, and air currents[31].

The objective of this study was to evaluate superficial temperature of ventral abdominal wall of New Zealand White rabbits (*Oryctolagus cuniculus*), in pre and post-midline laparorrhaphy moments, with chitosan, or poliglecaprone suture yarns, by infrared thermography method. Thus, it intended to suggest a reference temperature interval of ventral abdominal surface of healthy rabbits, as well as to identify possible thermal variations occurring considering morning or afternoon periods and different sexes in the preoperation, besides evaluating the influence of chitosan and polyglecaprone yarns in wound repair after laparorrhaphy.

2 MATERIALS AND METHODS

This study was carried out, after project approval by Ethics Committee on Animal Use (CEUA). In the study, we used 49 New Zealand Albino rabbits (*Oryctolagus cuniculus*), weighing 3.0 kg on average, being 42 males and seven females. During the experiment, animals were individually housed on a room in steel cages, measuring 50 cm X 60 cm, with free access to water and food based on pelleted feed and alfalfa hay, suitable for the species. This place was also used to perform thermographic evaluations, as it is climate controlled, with an average temperature of 22°C, guaranteed by air conditioning and illuminated with artificial light, during 12 hours throughout the day. Healthy state of animals was confirmed by serial clinical examinations carried out during an adaptation period of 15 days.

Infrared thermographic evaluation of rabbits' abdominal surface was carried out in two stages. During evaluation, we used thermal imaging camera FLIR® T440 (Flir® Systems, Inc. Wilsonville-Oregon-USA). The equipment has a spatial resolution of 320X240 pixels, sensitivity for detecting thermal differences of 0.04°C, with real-time screen reporting of temperature, wave spectrum between 7.5 and 13μm, with 60Hz, touch screen, four-times zoom and with automatic and manual focus adjustment. In the first

stage, evaluations took place before midline laparorrhaphy was performed and, in the second stage, temperature was measured after surgical procedure. On the first evaluation, a total of 14 rabbits, 7 males and 7 females were used. Temperature measurements were performed for ten consecutive days. One evaluation was performed in the morning, between hours eight and nine, and another assessment in the afternoon period, between 16 and 17 hours. Thus, we constructed four subgroups, named male morning, male afternoon, female morning and female afternoon (MM, MA, FM, FA).

At the second stage of the experiment, 42 rabbits with same racial characteristics and body weight were used, but all were male. Animals were allocated to two groups containing 21 animals each. One was submitted to midline laparorrhaphy with chitosan yarn (group C) and other to polyglecaprone 25 (group P) after laparotomy. According to the time elapsed between surgery and euthanasia, each major group was subdivided into three subgroups (5 days, 15 days and 25 days), totaling six possible treatments denominated C-5, C-15, C-25, P-5, P-15, P-25. In this stage, thermographic evaluations began on the first postoperative day and were repeated daily in the pre-established morning period, using the following methodology: in C-5 and P-5 subgroups, evaluations finished on the 5th day; In C-15 and P-15 subgroups, measurements were completed on the 15th postoperative day and in C-25 and P-25 subgroups, temperature measurements occurred daily up to the 15th day, with one additional evaluation on the 25th postoperative day.

Temperature variations of lagomorphs' ventral abdominal surface were quantitatively assessed in a similar manner in stages corresponding to pre and postoperative periods of the experiment. During these moments, we scanned abdominal temperature, from xiphoid process to pubis, targeting the peri-umbilical or cicatricial region, which presented higher temperature. For the thermographic evaluation, rabbits had the fur on target region shaved with trichotomy machine coupled with blade number 50, at least 24 hours before measurements and were held in dorsal decubitus on a wooden table. Camera was always positioned 30 cm away, producing a 90° angle between the machine and abdominal surface of experimental model.

The device was configured to rainbow color standard, distance of one meter (minimum setting) between camera and subject, temperature reflected 26ºC (according to foil test), emissivity set at 0.98 and thermal color range between 30 and 40°C. In addition, the infrared device was programmed according to humidity and ambient temperature data obtained by the thermohygrometer located in the examination room. The environment

was covered, sheltered from sun's rays and air currents, and had an ambient temperature of 22ºC maintained by air-conditioning.

For surgical procedures, chitosan yarn was obtained from Medovent Gmbh Implants That Care located in Mainz, Germany. Production related to lot number F16-1010/01, with 45 cm length and thicknesses 0 and 4.0 in the USP standard. Subsequently, threads were attached to semicircular traumatic needles sterilized on ethylene oxide action at FBMFARMA pharmaceutical industry (Anápolis – GO – Brazil). Polyglecaprone 25 was purchased from Shalon (Goiânia – Goiás – Brazil), which comes sterilized and with threaded needle.

For surgical interventions, at the preoperative time animals were submitted to a wide trichotomy of abdominal region, from the xiphoid process to retropubic region, including the medial aspect of thighs. Preoperative fasting was not performed. Anesthetic management consisted of pre-anesthetic medication, venous access, induction and maintenance. Rabbits received pre-anesthetic medications, ketamine 10.0 mg/kg, midazolam 0.2 mg/kg and xylazine 1.0 mg/kg all in the same syringe and administered intramuscularly (IM). Next, the saphenous or marginal auricular vein was accessed for infusion of drug and Ringer's lactate solution during surgical act. Following, induction was performed with propofol IV, with dose-effect application, requiring in the majority of the animals, a 2.0 mg/kg dose. In addition, orotracheal intubation was performed with a cuffed D 3.5 mm tracheostomy tube for airway protection, oxygenation and anesthesia maintenance. This maintenance was made with isoflurane (1-3%) diluted in oxygen using HB inhalation anesthesia machine, non-rebreathing (open) circuit and manual ventilation, if necessary, with a 500 mL bag. For intraoperative pain control, fentanyl was applied at a 5.0 μg/kg dose. In addition, immediately after induction, antibiotic therapy was started with 10 mg/kg intravenous (IV) enrofloxacin.

In order to perform surgical procedures, rabbits were placed in dorsal decubitus on a flat stainless steel table. Antisepsis was performed in two stages, the former with chlorhexidine 2% with surfactant and alcohol and the later, definitive, with 0.5% alcoholic chlorhexidine. Initiating the surgical act itself, an incision of five centimeters was made with a number 20 scalpel blade, pre-retro umbilical in all planes of linea alba, through skin, subcutaneous tissue, and muscle fascia of rectus abdominis muscles. Laparorrhaphy was performed with Sultan (X) suture with chitosan yarn (group C) or polyglecaprone (group P), both size 0.0 in the U.S.P. standard. Subcutaneous tissue was reconstituted with simple continuous suture using polyglecaprone 4.0 or chitosan 4.0

yarn, according to the group the animals belonged to. Finally, skin was closed with the same pattern in the two groups, applying single stitches with nylon 3.0 yarn, which were removed after 12 days.

In postoperative period, animals were monitored in daily clinical evaluations and medicated with tramadol 3.0 mg/kg SC/BID and meloxicam 0.6 mg/kg /SC/SID during days and enrofloxacin 7.0 mg/kg SC/SID for seven days. During follow-up, rabbits were also submitted to quantitative thermographic evaluation, corresponding to second evaluation stage. After completing thermographic evaluations of each group (postoperative days 5, 15, 25), animals were submitted to euthanasia, in accordance with norms presented in the annex to Normative Resolution No. 13, dated 09.20.2013, with overdoses of propofol followed by administration of 5.0ml 10% potassium chloride, both intravenously.

Data obtained by thermographic evaluations were analyzed by the average temperature values of each treatment. Then, temperature difference between treatments was evaluated by analysis of Latin square design, with comparison means by Tukey test. For standardization of abdominal infrared temperature, mean $\pm$ two standard deviations were used. Furthermore, the normality of the data was tested by Shapiro-Wilk test. For all statistical tests, a significance level of 5% was adopted and the R software Core Development Core Team was used.

3 RESULTS

Figure 1 (A, C) shows thermograms of rabbits' (*Oryctolagus cuniculus*) ventral abdominal surface, in pre and postoperative stages. Figure 1 (B) shows the final appearance of midline laparorrhaphy with chitosan surgical yarn.

FIGURE 1 - Thermograms and photograph of rabbits' (*Oryctolagus cuniculus*) ventral abdominal surface lustrating the pre, intra and postoperative stages. Thermogram targeted on umbilical scar obtained before surgical procedure, in the first stage (A). Midline laparorrhaphy with chitosan yarn (B). Thermogram obtained in the second stage, at midline laparotomy 10th postoperative day targeted at the cicatricial region (C).
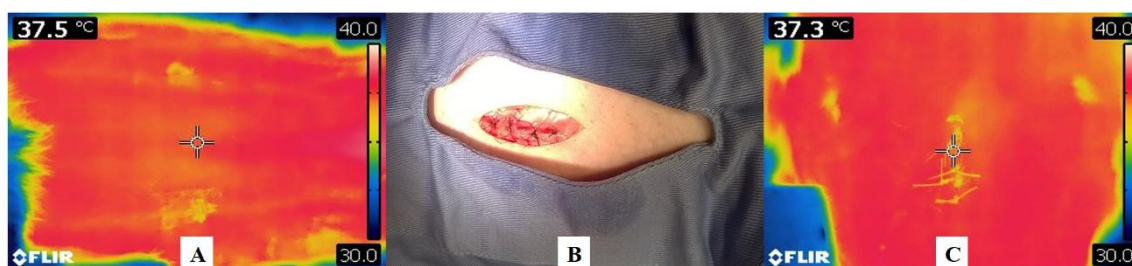
A total 700 thermograms were obtained during infrared thermographic evaluations of rabbits' abdominal surface. From this amount, the averages, maximum and minimum values, standard deviation, coefficient of variation and normality test were obtained for each treatment (Table 1).

TABLE 1 - Minimum values, maximum, standard deviation (Ds), means, coefficient of variation (CV) and normality test of the temperatures measured at pre-stage (first stage) and postoperative (second stage) times in rabbits (*Oryctolagus cuniculus*) submitted to laparorrhaphy with chitosan and polyglecaprone yarns

Group	Mean	Minimum	Maximum	S.D.	Mean ± 2S.D.	C.V (%)	Shapiro-Wilk
Morning (M)	37.59	37.28	37.96	0.18	37.23 – 37.95	0.48	0.96
Afternoon (A)	37.82	37.41	38.15	0.22	37.37 – 38.26	0.58	0.84
Female (F)	37.78	37.65	37.92	0.11	37.55 – 38.00	0.30	0.17
Male (M)	37.63	37.36	37.84	0.19	37.26 – 38.00	0.50	0.47
Female Morning (FM)	37.63	37.41	37.78	0.13	37.38 – 37.89	0.34	0.68
Female Afternoon (FA)	37.95	37.67	38.10	0.17	37.60 – 38.30	0.45	0.19
Male Morning (MM)	37.58	37.28	37.96	0.24	37.10 – 38.10	0.64	0.77
Male Afternoon (MA)	37.68	37.41	37.98	0.18	37.31 – 38.04	0.48	0.98
First stage	37.70	37.69	38.38	0.27	37.17 – 38.24	0.71	0.50
Chitosan (C)	37.40	35.00	38.80	0.55	36.30 – 38.50	1.47	-
Polyglecaprone (P)	36.99	34.20	38.50	0.76	35.50 – 38.50	2.06	-
Second stage	36.98	34.20	38.80	0.69	35.60 – 38.36	1.86	-

In the first stage of evaluation, all data presented normality and values of abdominal wall temperature oscillated between different animals, or even in consecutive measurements of the same animal, resulting in a ± 0,27ºC standard deviation. Using the global mean ± two standard deviations, a range of 37.2-38.2, representing 95.45% of the measurements was created. This value was used as reference interval of abdominal temperature in healthy rabbits to compare with values obtained in the second evaluation stage.

Also on preoperative period, no significant changes in ventral abdominal surface temperature were identified between male and female sexes (p = 0.1). However, a significant difference between measured temperatures in Morning and Afternoon

periods (p = 0.0061) was identified, with a thermal increase in the afternoon period. Furthermore, there is an interaction of temperature (p = 0.0269) between gender and period of studied region. Therefore, a statistical difference was observed with a temperature increase in Female Afternoon treatment compared to other interactions (Figure 2, Table 2).

FIGURE 2- Boxed graph showing the mean temperature variations of ventral abdominal surface of rabbits (*Oryctolagus cuniculus*) in relation to treatments. Legend: ♀ female; ♂ male; Blue asterisk - mean temperature of each animal / period; Red diamond - period mean temperature; Brackets delimit the data dispersion within each treatment; Box height delimits values found in mean interval ± 1 S.D.; Red dashed line - marks first stage mean temperature ± two standard deviations. Statistically we have a comparison between sexes represented by capital letters and between periods represented by lowercase letters, so that different capital letters or lowercase letters mean a significant statistical difference using p = 5%.
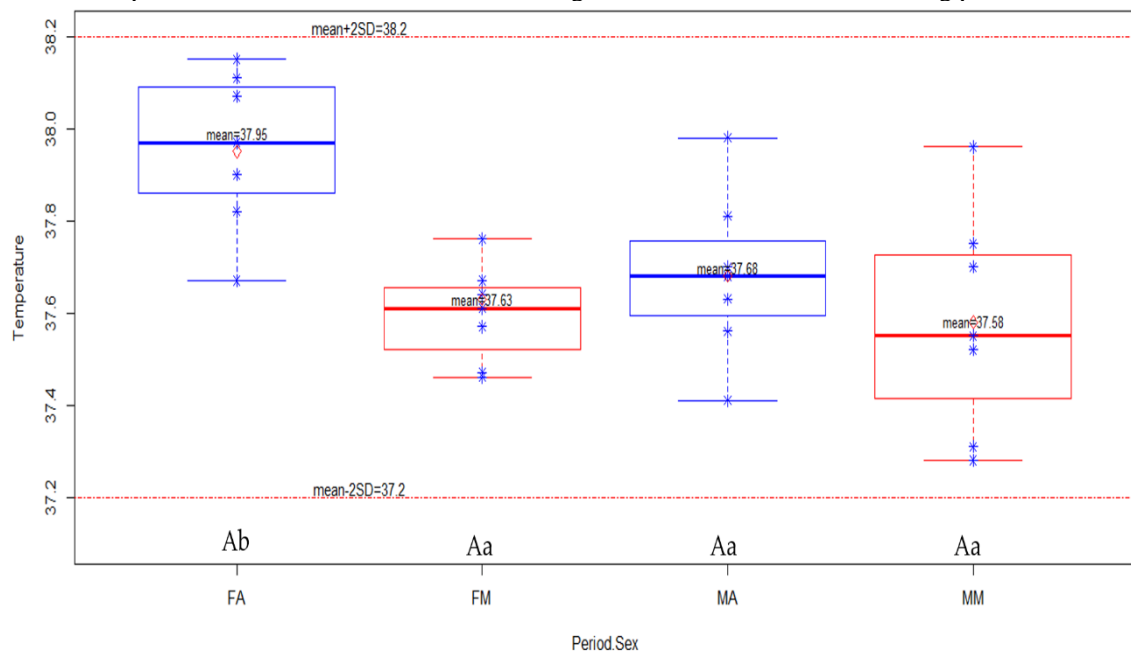
During second stage evaluation, two animals (4.7%) damaged the surgical wound and were withdrawn from the experiment due to possible interference of evaluated temperature. A statistical difference was observed when comparing to first and second stage data, obtaining p = 0.0035. It was also observed a difference, p = 0.0003, between Chitosan (C) and Polyglecaprone (P) groups; P = 0.0001 between Polyglecaprone group and the first stage and p = 0.049 between the Chitosan group and the first stage (Table2).

TABLE 2 – P values after variance analysis (ANOVA) and its following statistic conclusion adopting p = 5% for treatments compared in first and second stages on rabbits (*Oryctolagus cuniculus*) submitted to laparorrhaphy with chitosan and polyglecaprone yarns

Compared treatments	P value	Conclusion (p=0,05)
Morning X Afternoon	0.0061	≠
Male X Female	0.10	=
Female Morning X Female Afternoon	0.0032	≠
Female Morning X Male Afternoon	0.31	=
Female Morning X Male Morning	0.87	=
Female Afternoon X Male Afternoon	0.016	≠
Female Afternoon X Male Morning	0.0061	≠
Male Morning X Male Afternoon	0.32	=
First X Second stage	0.0035	≠
First stage X Polyglecaprone (P)	0.0001	≠
First stage X Chitosan (C)	0.0499	≠
Polyglecaprone (P) X Chitosan (C)	0.0003	≠

Additionally, in second stage, which sought to refer suture yarn influence on inflammatory response during healing process, temperature difference between treatments Chitosan (C) and Polyglecaprone (P) was compared over postoperative days with the reference range obtained in first stage. Thus, it was possible to observe a clear reduction in abdominal surface temperature on the first postoperative day, with a subsequent gradual increase until the reference temperature of healthy rabbit's abdominal surface temperature was reached.

Evaluating treatments separately, it was observed that animals submitted to laparorrhaphy with polyglecaprone yarn had greater reduction, followed by a more expressive temperature elevation in the first five days, with continuously high temperatures until normalization, on the 13th post-surgery day. Animals submitted to laparorrhaphy with chitosan yarn had lower temperature reduction after surgical procedure, with subsequent shorter period elevation, stabilizing on the fifth postoperative day (Figure 3).

FIGURE 3 - Graph showing the evolution rabbit (*Oryctolagus cuniculus*) temperature in Chitosan and Polyglecaprone treatments during postoperative days or second evaluation stage. The comparison between Chitosan and Polyglecaprone treatments is represented by capital letters and within the treatment represented by lowercase letters. Different capital letters, or lowercase letters, represent a significant statistical difference adopting p = 5%.
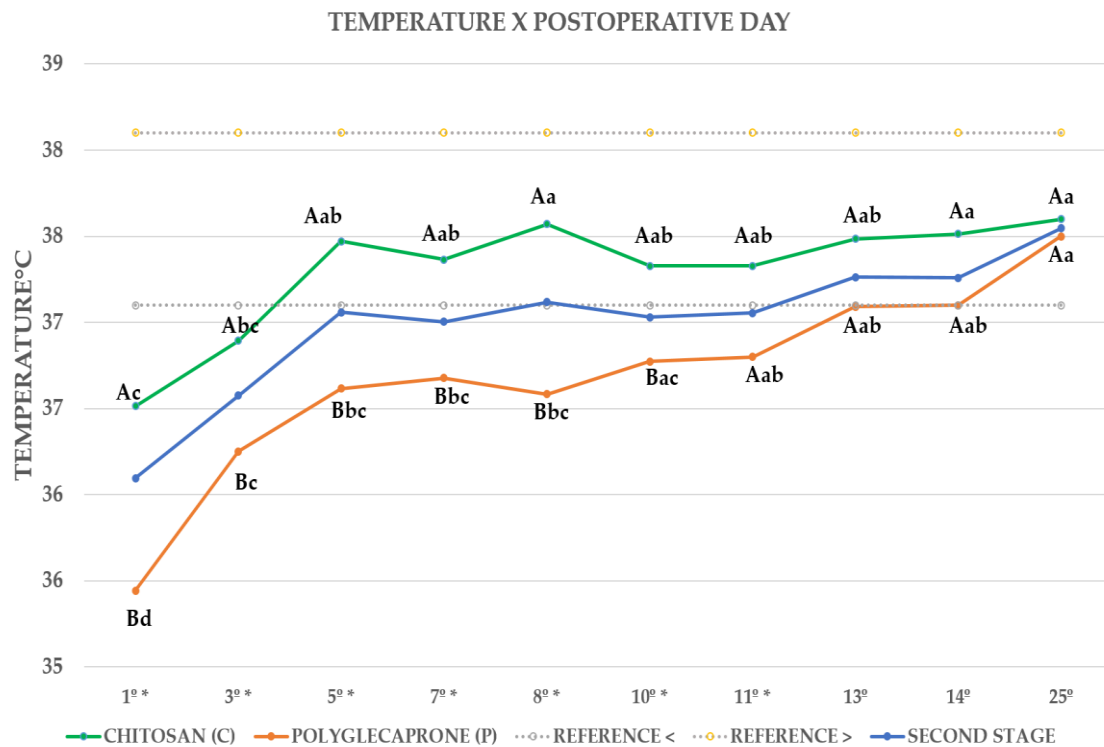
Evaluating data in Figure 3, from second stage 13th day, there was a trend, in both groups, of temperature accommodation within the interval established in first stage.

4 DISCUSSION

Thermograms performance in the same established conditions, in both experimental stages, indicates these measures were adopted with the purpose of reducing interferences of external temperature, wind, luminosity and animal handling on measured temperatures. The assessment of temperature values obtained by a thermographic camera is not solely based on radiation emitted by the body. It also depends on other factors such as: the object, emissivity, surface, presence of fur; environmental and surrounding factors, such as atmospheric and reflected temperature, humidity and wind flow; operational factors, such as camera angulation and distance to object; and also camera internal calibrations, such as thermal scale and color spectrum[32,33].

Infrared thermography devices capture electromagnetic energy of a body, which is produced by atoms vibrations around a point of equilibrium and converts it into a temperature measure. Thus, the higher the temperature of the object, the greater atomic

vibration and energy radiated by the body, consequently the higher infrared electromagnetic energy captured by the thermographic camera, indicating a higher surface temperature of the studied body[34].

Also, analyzing the importance of maintaining rabbits in an environment with controlled temperature, humidity, luminosity and absence of wind flow, in addition that measurements carried out by the same operator, was probably a correct behavior, considering that variations in skin temperature, particularly in the first stage, were not of great consequence. Similar conducts were also recommended by other authors[31,32,33].

Additionally, trichotomy performed on the previous day of evaluations was advantageous, for it minimized influence applied by friction between skin, blade and fur covering on abdominal skin temperature. Other authors did not have the same concern, proceeding with chemical depilation with cream and waiting only two hours before starting evaluations[22]. For some authors, the absence of fur increases the uptake of radiation emitted by skin, which is more vascularized and has more pronounced metabolic activity than fur[32,35]. Regarding the recommended minimum time of 30 minutes for acclimatization of animals[37], in the present study it was not taken into account, since animals were evaluated in the same environment they were accommodated.

Contemplating abdominal temperature oscillations identified in the first stage of this study between consecutive measurements of the same animal and between distinct animals, it can be deduced that there are individual factors that contributed to these variations. Although no reference values for rabbit abdominal cutaneous temperature were found, other investigators subjected horses to a temperature-controlled environment and after serial evaluations suggested standardization of dorsal temperature at 29.8 ± 0.2 ° C for the lumbar region, 28.2 ± 0.2 ° C for the pelvic region and 29.5 ± 0.2 ° C for the thoracic region[36].

Regarding the thermal variations obtained in consecutive evaluations in the same animal, it was considered that these modifications occur, unlike body temperature, because skin temperature is very dynamic. It is possible that this statement elucidates, in part, inter and intra individual variations observed at the study first stage. Skin contributes intensely to thermal homeostasis, thanks to its ability of perceiving changes between body and external environment temperatures. For some authors, according to a zone of body thermoneutrality, skin temperature fluctuates broadly, always reflecting changes in vasomotor tone and, consequently, blood flow. At vasoconstriction, skin temperature

approaches the environment temperature, in contrast, in moments of vasodilation skin temperature approaches that of the body[37].

As for oscillations of skin temperature in different animals, they probably resulted due to factors related to the animals themselves. Other researches suggested those differences could be explained as a consequence of tissue thickness inequality and composition, metabolic activity, cell multiplication and due to the amount of gases, oxygen, carbon dioxide, water and hemoglobin present in superficial tissues. Moreover, one cannot ignore the disparity of movement and muscular contraction, or even due to ambient temperature variations[38,39]. However, in this experiment, all measurements were taken in the same environment, with the same ambient temperature, thus excluding differences credited to ambient temperature variations.

In this experiment, it was also observed that the cutaneous temperature did not differ between sex, but between the evaluated periods, evidencing an 0.23°C increase in mean abdominal surface temperature during the afternoon period. The same temperature elevation effect was also observed in other studies in humans, in which face[40] and of thoracic surface temperatures were measured[41]. The authors concluded that, just like body temperature, cutaneous temperature follows circadian patterns, influenced by hormonal action and catecholamines throughout the amplitude of the day[41]. In these circumstances, vasomotor tonus disparity occurs between periods, and in the afternoon period vasodilatation and consequent greater peripheral blood flow were observed[42]. Temperatures were milder in the morning, with peaks between 00-04 hours and with acrophase phase between 16-20 hours on the afternoon period[41].

Furthermore, over the afternoon period, in the present study, females presented higher temperature increase, allowing observation of 0.32ºC average increase in relation to the morning period and 0.27ºC in relation to males in the same period. Concerning temperature elevation in females, it is known that body temperature in healthy animals of this genus can also be elevated depending on the estrous cycle stage[43]. In order to contribute to the affirmation that there is a hormonal influence on the skin temperature, in another study, the surface temperature of the perineal region in cows increased during estrus[11]. Therefore, although body temperature was not evaluated, much less the serum hormonal assessment of gonadotrophic hormones, the possible presence of rabbits in different estrous period stages may have contributed to body, and consequently, cutaneous temperature increase in Female Afternoon group of this current study.

Analyzing results obtained in the second stage of the experiment, it was established that the thermographic camera used was efficient to detect temperature variations on ventral abdominal surface of rabbits (*Oryctolagus cuniculus*). Variations were detected when first second stage results were compared and throughout the tissue healing period. It is emphasized that inflammatory process resulting from surgical intervention produces and radiates heat, thanks to physical and biochemical phenomena that occur during cicatrization, such as vasodilation and increased blood flow, followed by increased proliferation and cellular activity, as well as by catabolic reactions to destroy microorganisms and cellular debris present in the wounds, as described by other authors[22,27,36,44]. The same method was used in other studies in which wounds tissue reparation after surgical procedures was evaluated[19,27-29,44].

The sharp reduction followed by gradual increase in temperature until reaching reference value obtained in the first stage should be highlighted in the present study. Reduction may be justified in part by tissue trauma, vascular rupture, or peripheral vasoconstriction induced by increased sympathetic tone, conditions that impair blood flow by altering perfusion and oxygen supply. These arguments were also pointed out by other researchers[45]. Other aspects such as presence of edema, scar and thermogram interpretation technique may also interfere with measured temperature. On these factors, it was observed that edema causes greater emitted radiation absorption and in turn the scar increases radiation refraction, together reducing capture of radiation emitted by the object and consequently the studied region surface temperature[39]. This possibility must be considered as the technique of interpretation of the thermogram used only one point of maximum temperature on the wound[38]. The suture line influence, could be summarized by interpreting the thermogram with a region of interest (ROI) demarcating technique, as performed and proposed in other works[27,36]. However, evaluated area increase would result in measuring temperature of possibly different regions between the animals, since it is a technique that depends on the operator, and also evaluating healthy regions peripheral to tissue trauma.

As for temperature increase observed during second stage, it behaved similar to other studies, which also showed a more intense thermal elevation in the first five days after surgical intervention. Some authors credit the findings to inflammatory phase evolution of the cicatricial process[19,20,22]. Studies using inflammatory markers such as C-reactive protein and thermography to evaluate post-surgical inflammatory processes observed a high correlation between the findings[29]. Although several studies have

observed the same initial behavior, it is clear that depending on tissue reaction induced by the implant used, the temperature rise can last for different intervals. For example, in human hip and knee prosthesis implants, temperatures remained higher than the basal value up to 90 postoperative days[29].

As animals were medicated, with nonsteroidal anti-inflammatory in the second stage, during postoperative care implementation, it is probable that the medicine could have interfered by decreasing local temperature. Another study observed that patients pre-medicated with diclofenac sodium had lower lateral surface temperature after tooth extraction compared to patients without medication[28]. Thus, it is believed that meloxicam administration may have also modulated inflammatory process in order to reduce the magnitude and/or duration of temperature elevation in postoperative period.

Finally, these results indicate that chitosan yarn provided an earlier and more intense tissue reaction, but less durable after implantation in midline laparorrhaphy in rabbits when compared to polyglecaprone thread. Confirming this assumption, a study that histopathologically evaluated after seven days a surgical subcutaneous implantation of a collagen matrix with chitosan in rats revealed an intense inflammatory cells migration, which stimulated increase of fibroblasts expression and proliferation and deposition of collagen, guaranteeing a faster healing process[46]. However, to confirm this assumption in this research, other studies with histopathological analysis using chitosan as a suture yarn should be performed.

5 CONCLUSION

Rabbits' (*Oryctolagus cuniculus*) abdominal surface temperature evaluated by infrared thermography technique, even in controlled environment, varies between animals and period of the day, being higher in afternoon period.

Infrared thermography used to assess rabbits' ventral abdominal surface temperature, before and after laparorrhaphy with chitosan or polyglecaprone yarn, suggests an earlier and more intense tissue reaction, but less durable when using chitosan yarn.

Infrared thermography method allows identification and follow-up of the transient inflammatory response due to laparotomy trauma, followed by laparorrhaphy with chitosan or polyglecaprone yarns, and when in absence of a control group, it is recommended to use male rabbits and adopt a 37.2-38.2°C range of reference.

REFERENCES

1. Adams, F. The genuine Works of Hippocrates. Baltimore: *Williams&Wilkins*, **1939**.

2. Lawson, R.N. Implications of surface temperatures in the diagnosis of breast câncer. *Can Med Assoc*. **1956,** *75, 4,* 309-11.

3. Usamentiaga, R.; Venegas P.; Guerediaga J.; Vega L.; Molleda J.; Bulnes F.G. Infrared thermography for temperature measurement and non-destructive testing. *Sensors*. **2014,** *14*, 123305-48.

4. Maldague, X. Theory and Practice of Infrared Technology for Nondestructive Testing. New York: *Wiley*, **2001**.

5. Modest, M.F. Radiative Heat Transfer. Massachusetts: *Waltham Academic Press,* **2013**.

6. Gaussorgues G. Infrared Thermography. Berlin: *Springer*, **1994**.

7. Gade, R.; Moeslund, T.B. Thermal cameras and applications: a survey. *Mach Vision Appl*. **2014,** *25,* 245–62.

8. Stewart, M.; Webster, J.; Schaefer, A.; Cook, N.; Scott, S. Infrared thermography as a non-invasive tool to study animal welfare. *Anim Wel*. **2005,** *14,* 319–25.

9. Redaelli, V.; Ludwig, N.; Costa, L.N.; Costa, L.; Riva, J.; Luzi, F. Potential application of thermography (IRT) in animal production and for animal welfare: a case report of working dogs. *Ann Ist Super Sanitá*. **2014,** *50, 2,* 147-52.

10. Ng, Y.E.K. A review of thermography as promising non-invasive detection modality for breast tumor. *Int J Therm Sci*. **2009,** *48,* 849-59.

11. Hurnik, J.F.; De Boer, S.; Webster, A.B. Detection of health disorders in dairy cattle utilizing a thermal infrared scanning technique. *Can J Anim Sci*. **1984,** *64*, 1071-3. DOI: 10.4141/cjas84-124.

12. Rainwater-Lovett, K.; Pacheco, J.M.; Packer, C.; Rodriguez, L.L. Detection of foot-and-mouth diseases virus infected cattle using infrared thermography. *Vet J*. **2009,** *180*, 317-24.

13. Nikkhah, A.; Plaizier, J.C.; Einarson, M.S.; Berry, R.J.; Scott, S.L.; Kennedy, A.D. Infrared thermography and visual examination of hooves of dairy cows in two stages of lactation. *J Dairy Sci*. **2005,** *88,* 2749-53.

14. Pavelski, M.; Silva, D.M.; Leite, N.C.; Junior, D.A.; de Sousa, R.S.; Guerios, S.D.; Dornbusch, P.T. Infrared thermography in dogs with mammary tumors and healthy dogs. *J Vet Intern Med*. **2015,** *29*, 1578-83.

15. Fonseca, B.P.A.; Alves, A.L.G.; Nicoletti, J.L.M.; Hussni, C.A.; Thomassian, A.; Mikail, S. Thermography and ultrasonography in back pain diagnosis of equine athletes. *J Equine Vet Sci*. **2006,** *26, 11*, 507-16.

16. Steiss, J.E. Muscle disorders and rehabilitation in canine athletes. *V Clin N Am*. **2002,** *32*, 267–85.

17. Van Hoogmoed, L.M.; Snyder, J.R. Use of infrared thermography to detect injections and palmar digital neurectomy in horses. *Vet J*. **2002,** *164*, 129-41.

18. Vainionpää, M.; Tienhaara, E.P.; Raekallio, M.; Junnila, J.; Snellman, M.; Vainio, O. Thermographic imaging of the superficial temperature in Racing grayhounds before and after the race. *Sci World J*. **2012**, 1-6.

19. Celeste, C.; Deschesne, K.; Riley, C.B.; Theoret, C. Skin temperature during cutaneous wound healing in an equine model of cutaneous fibroprolifetative disorder: kinetics and anatomic-site differences. *Vet Surg*. **2013,** *42*, 147-53.

20. Nóbrega, F.S.; Ferreira, M.P.; Facó, L.L.; Selim, M.B.; Zoppa, A.L.V. Uso da termografia para avaliação da resposta tecidual após implante de polímero a base de poliuretana de Mamona em osso III metacarpal de equinos. *Acta Sci Vet*. **2014,** *42*, 1-5.

21. Machado, L.F.S.; Dittrich, R.L.; Pavelski, M.; Afonso, A.M.C.; Deconto, I.; Dornbusch, P.T. Padronização do exame termográfico nas articulações do carpo e matacarpofalangeanas de cavalos em treinamento. *Arch Vet Sci*. **2013,** *18, 4,* 40-5.

22. Calkosinski, I.; Dobrzynski, M.; Rosinczuk, J.; Dedek, K.; Chrószcz, A.; Fita, K.; Dymarek, R. The use of infrared thermography as a rapid, quantitative, and noninvasive method for evaluation of inflammation response in difference anatomical regions of rats. *Biomed Res Int*. **2015,** 1-9.

23. Fikackova, H.; Ekberg, E. Can infrared thermography be a diagnostic tool for arthralgia of the temporomandibular joint? *Oral Surg Oral Med Oral Pathol Oral Radiol Endodontology*. **2004,** *98*, 643–50.

24. Se-Wook, U.M.; Min-Su K.I.M.; Ji-Hey, L.I.M.; Sun-Young, K.I.M.; Kang-Moon, S.E.O.; Tchi-Chou, N.A.M. Thermographic Evaluation for the Efficacy of Acupuncture on Induced Chronic Arthritis in the dog. *J Vet Med Sci*. **2005,** *67, 12*, 1283-4.

25. Infernuso, T.; Loughin, C.A.; Marino, D.J.; Umbaugh, S.E.; Solt, P.S. Thermal imaging of normal and cranial cruciate ligament-deficient stifles in dogs. *Vet Surg*. **2010,** *39*, 410-7.

26. Malafaia, O.; Brioschi, M.L.; Aoki, S.M.S.; Dias, F.G.; Gugelmin, B.S.; Aoki, M.S.; Aoki, Y.S. Infrared imaging contribution for intestinal ischemia detection in wound healing. *Acta Cir Bras*. **2008,** *23*, 511-19.

27. Arenhart, R.; Severo, A.L.; Maia, P.E.C.; Silveira, D.A.; Lopez, R.R.; Bocaccio, D. Thermographic and histological analysis of rabbit different tenorrhaphies techniques (4 and 6 strands) after early active mobilization. *Fisioter Mov*. **2014,** *27, 4,* 611-19.

28. Venta, I.; Hyrkas, T.; Paakkari, I.; Ylipaavalniemi, P. Thermographic imaging of postoperative inflammation modified by anti-inflammatory pretreatment. *J Oral Maxillofac Surg*. **2001,** *59*, 145-50.

29. Romano, C.L.; Romano, D.; Dell'Oro, F.; Logoluso, N.; Drago, L. Healing of surgical site after total hip and knee replacements show similar telethermograph patterns. *J Orthoped Traumatol*. **2011,** *12*, 81-6.

30. Bharara, M.; Schoess, J.; Nouvong, A.; Armstrong, D.G. Wound inflammatory index: a "proof of concept" Study to assess wound healing trajectory. *J Diabetes Sci Technol*. **2010,** *4, 4*, 773-9.

31. Ring, E.F.J.; Ammer, K. Infrared thermal imaging in medicine. *Physiol. Meas*. **2012,** *33*, 33–46.

32. Okada, K.; Takemura, K.; Sato, S. Investigation of various essential factors for optimum infrared thermography. J Vet Med Sci. 2013, 75, 10, 1349-53.

33. Zaproudina, N.; Varmavuo, V.; Airaksinen, O.; Närhi, N. Reproducibility of infrared thermography measurements in healthy individuals. Physiol Meas. 2008, 29, 515-24.

34. Barreiros, A.L.B.S.; David, J.M. Estresse oxidativo: relação entre geração de espécies reativas e defesa do organismo. Rev Quim Nova. 2006, 29, 113-23.

35. McCafferty, D.J. Applications of thermal imaging in avian science. Ibis. 2013, 155, 4-15.

36. Pavelski, M.; Basten, M.S.; Busato, E.; Dornbusch, P.T. Infrared thermography evaluation from the back region of healthy horses in controlled temperature room. Cienc Rural. 2015(a), 45, 7, 1274-9.

37. Romanovsky, A.A.; Ivanov, A.I.; Shimansky, Y.P. Selected contribution: ambient temperature for experiments in rats: a new method for determining the zone of termal neutrality. J Appl Physiol. 2002, 92, 2667–79.

38. Merla, A.; Mattei, P.A.; Di Donato, L.; Romani, G.L.; Thermal imaging of cutaneous temperature modifications in runners during graded exercise. Ann Biomed Eng. 2010, 38, 158–63.

39. Thatcher, J.E.; Squiers, J.J.; Kanick, S.C.; King, D.R.; Lu Y.; Wang, Y.; Mohan, R.; Sellke, E.W.; DiMaio, J.M. Imaging techniques for clinical burn assessment with a focus on multispectral imaging. Adv Wound Care. 2016, 5, 8, 360-378.

40. Rustemeyer, J.; Radtke, J.; Bremerich. Thermography and thermoregulation of the face. Head Face Med. 2007, 3, 1-8.

41. Reily, T.; Brooks, G.A. Exercise and the circadian variation in body temperature measures. Int J Sports Med. 1986, 7, 358-362.

42. Stephenson, L.A.; Wenger, C.B.; O'Donovan, B.H.; Nadel, E.R. Circadian rhythm in sweating and cutaneous blood flow. Am J Physiol. 1984, 246, 321-4.

43. Redaelli, V.; Tanzi, B.; Luzi, F.; Stefanello, D.; Proverbio, D.; Crosta, L.; Di Giancamillo, M. Use of thermographic imaging in clinical diagnosis of small animal: preliminary notes. Ann Ist Super Sanita. 2014, 50, 2, 140-146.

44. Christensen, J.; Matzen, L.H.; Vaeth, M.; Schou, S.; Wenzel, A. Thermography as a quantitative imaging method for assessing postoperative inflammation. Dentomaxillofac Radiol. 2012, 41, 494-9.

45. Hopf, H.W.; Rollins, M.S. Wounds: an overview of the role of oxygen. Atioxid Redox Signal. 2007, 9, 1183-92.

46. De Brito, M.K.M.; Schellini, S.A.; Padovani, C.R.; Pellizzon, C.H.; Netto, C.G.T. Inclusão de quitosana no subcutâneo de rato: avaliação clínica, histológica e morfométrica. An Bras Dermatol. 2009, 84, 35-40.