Original Research Article

Infrared thermography is applicable, ~~as a complementary test,~~ in differentiating the effectiveness of anti-inflammatory~~ies~~ drugs: A complementary test~~.~~

Comment [H1]: You may consider this title instead

Abstract

Purpose

Images obtained by infrared thermography (IT) have potential to become a useful and low-cost tool for a wide range of biological *in vivo* studies, including topical inflammation models. Local temperature is one of the cardinal signs of inflammation, although it is not commonly analyzed in experimental model of inflammation.In the present study IT was used to evaluate the variation in tissue temperature, as well as the temperature response to treatment with different anti-inflammatory drugs, in an experimental model of inflammation.

Methods

CFA-induced paw edema on rats were performed and discrepancies between animals treated or not with triamcinolone acetonide and diclofenac sodium were analyzed. Experimental times were: T0, before chemical induction of inflammatory process (control); and several times after induction: T1 (30 min); T2 (24 hours); T3 (48 hours); T4 (72 hours); T5 (96 hours); T6 (7 days); T7 (14 days); T8 (21 days); T9 (28 days). The measured parameters were temperature, paw volume, histological and leukometricanalysis.

Results

The profile of local temperature changes was similar to the volume and thickness of the paws, with an increase (peak) at 24 hours. From T7 onwards, the temperature values, as well as paw size returned to baseline values (T0).

Conclusions

The IT was effective in detecting the intensity of the tissue inflammation, as well as in differentiating the effectiveness of anti-inflammatory drugs with different mechanisms of action, in the animal model of inflammation induced by CFA.

Comment [H2]: To establish the fact, the study would require different approach.

Keywords: Thermography, Inflammatory response, Temperature, Disease, Animal model.

INTRODUCTION

Paw edema is a classical inflammation model [1]. In this model, a phloglogen agent is administered subcutaneously in the plantar region of rodent paws to generate an inflammatory response. Inducing agents such as carrageenan and Complete Freund's Adjuvant injection (CFA) are commonly used to trigger acute and chronic inflammatory response, respectively[2]which could be analyzed by radiographic features, histological analysis and presence of oedema.

The temperature of a surface can be obtained by thermographic profiles from images obtained by specialized radiation sensitive camera [3]. Therefore, it has potential to be a low-cost tool for a wider range of uses. For medical applicationsit is attractive by dispensinginvasive procedure traditionally used[4]. Infrared

thermography (IT) was used to measure temperature profiles offingers in order to detect inflammation in patients with rheumatoid arthritis and also to improve the diagnostic accuracy of the cold provocation test for such disease [5].This technology has been employed in animal studies[6, 7], like animal models of cancer being reported as a useful approach for the superficial vascularization [8]. Others animal applicationsmeasuredtemperatures different parts of animals, using ITand related it to feed efficiency, average daily gain and methane emission [9], evaluation of mastitis in cattle [10]and for fever investigation in pigs [11].

Therefore, considering that temperature is a classic marker of inflammation [12], the present study evaluated the effectiveness of the IT in analyzing the variation in tissue temperature related to the evolution of the inflammatory process, as well as the action of different anti-inflammatory drugs, in animal model. For this purpose, we tested the ITin CFA-induced paw edema on rats, and observed the discrepancies between animals treated or not with anti-inflammatory drugs.

Comment [H3]: The cause of edema and the effect of drug should be invariable with the IT to prove the effectiveness of the IT.

1. MATERIALS AND METHODS

Comment [H4]: The method to detect the effectiveness of an instrument was not portrayed in this study.

2.1 Animals

Comment [H5]: Maybe the study was aimed to find different objective, to evaluate the effective ness of IT would require different approach.

Fifteen male Holtzman rats from the UFVJM (Federal University of Jequitinhonha and Mucuri Valleys, Diamantina, MG/ Brazil) with 8 weeks old and average weight of 150-250 grams were used in this study. Experiments occurred during the light phase between 07:00 a.m. and 10:00 a.m. This study was previously approved by the Animal Ethics Committee of UFVJM regarding the Guiding Principles in the Care and Use of Animals, with protocol number of 050/2016.

2.2 Inflammation induction

The inflammation was induced by injecting 200 µL of CFA (lyophilized Mycobacterium powder, Santa Cruz Biotechnology, Inc., Dallas, Texas, USA) into the right hind paw at the plantar region of each animal at a concentration of 5% (mv-1). In the left paw of the animals 200 µL of saline solution was injected. The animals were divided in 3 groups: Control (n=5) - animals that received CFA injection and no treatment; Triamcinolone (n=5) - animals that received CFA and treated with 0,3 g the topic anti-inflammatory drug, triamcinolone acetonide (1mgg-1; daily application for 1 minute), and Diclofenac (n=5) -animals that received CFA and treated with topic anti-inflammatory drug diclofenac sodium (10mgg-1; daily application for 1 minute). Experimental times were: T0, before chemical induction of inflammatory process (used as a control time for comparison); and times after injection, T1 (30 minutes); T2 (24 hours); T3 (48 hours); T4 (72 hours); T5 (96 hours); T6 (7 days); T7 (14 days); T8 (21 days); T9 (28 days). The measured parameters were temperature, oedema of animal's paw, histological and leukometryanalysis.

2.3 Euthanasia

At the end of the experiment, all the animals were anesthetized with ketamine (60 mgkg-1) and xylazine (8 mgkg-1) intraperitoneally and the animals were euthanized by the exsanguination process [13].

2.4 Volume and thickness of paws (Oedema)

The thickness (in mm) of the hind paws was obtained by means of a digital caliper (0,01mm/0.005" resolution, 500 series, Mitutoyo, São Paulo, Brazil) positioned in the middle region of the plantar surface. The volume (mL) of the paws was obtained with a plethysmometer (SLFC 008, ScienLabor, RibeirãoPreto, Brazil), using standarized anatomical reference regions (tibio-tarsal articulation). Measurements were performedin triplicate, bytrained researchers. Mean values were used to calculate the difference (Δ) between values for thickness or volume of the right paw (RP) and the left paw (LP) as follow: $\Delta = RP - LP$.

2.5 Histological analysis

After euthanasia, tissue fragment from the CFA injection site, of each animal, were surgically removed and immersed in (10% vv-1) buffered formalin solution for 72 hours, washed with saline transferred to cassettes and stored in (10% v v-1) formaldehyde buffer solution. Sections (3-4 µm) were obtained using a microtome (HM 430, Thermo Scientific™ Massachusetts, EUA) and then stained with hematoxylin and eosin

(HE). Histological analysis was performed with light microscopy (Opton®, Guiyang, China), for a qualitative description.

2.6 Total and differential blood cells counting

A blood volume of 4 mL (milliliters) was collected from the animals by cardiac puncture andstored in heparinized tubes. The profile of the different leukocyte populations (differential leukogram) was performed by blood smear analysis. Leukocytes were counted on a Neubauer chamber, after blood dilution on Turk's erythrocytes lysis solution [14].

2.7 Thermography analysis

A thermographic camera (FLIR i7®, Flir Systems, Portland, United States) was used for recording images at different experimental times of the right and left hind paws of all animals. The camera was positioned perpendicularly at a distance of 0.6 meters from the plantar surface of the hind paws and the images were obtained in triplicate by a trained researcher, prior to the administration of CFA (T0) and then at the other experimental times (T1 to T9).Thermographics profiles were analyzed using FLIR® Tools software (FLIR® Systems, Portland, OR, United States) where the experimental parameters and emissivity $\varepsilon = 0.95$ were assumed. After processing, maximum, minimum and average temperature values of the plantar region of each ofthe animal'shind paws were obtained.

2.8 Statistical analysis

Data was analyzed using Minitab and GraphPad Statistical Software, version 3.0 (GraphPad, La Jolla, CA, USA). Results were expressed as mean and standard error of the mean (SEM) from triplicates to the independent experiments, with a significance level of 95% ($P < 0.05$). One-way ANOVA, with Tukey post-hoc were used for multiple comparisons.

2. RESULTS

3.1 Temperature profiles

The figure 1 exemplifies 3 images taken at each timefor each animal and group. There was a maintenance of low values with standard deviations (SD) that ranged from 0.00 to 0.54 ° C, thus demonstrating the good repeatability of the method.

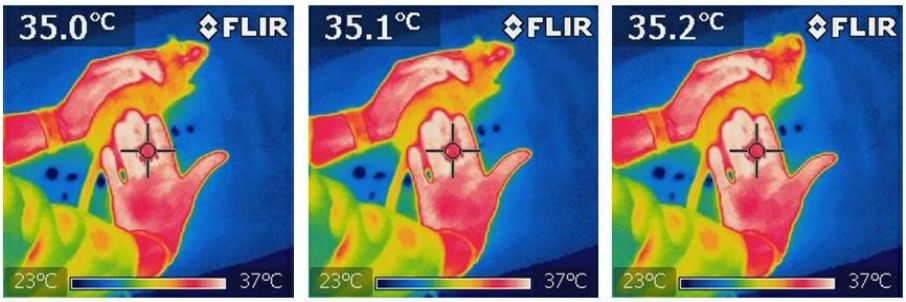

Fig.1 Data on repeatability of the evaluated method. In A, B and C are represented three thermographic records at different times of the same hind paw (within the black circle) of the same animal.SD values of 0.00 to 0.54 ° C

The values of temperature for the left paw (injected with 200 µL of saline solution) are presented in Fig.2 and showed no difference between groups for all evaluated times.

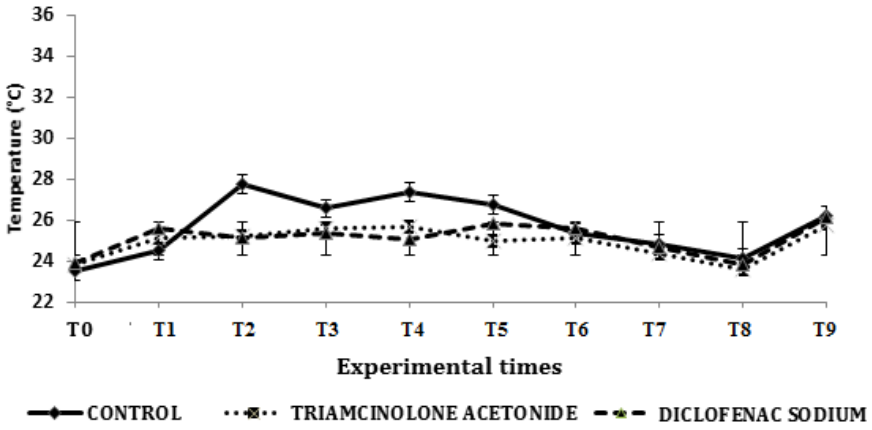

Fig.2 Variation in rat paws temperature, after saline injection. Values represented as mean ± standard error of the mean at different experimental times.

The mean temperature values for the right hind paws are presented in Fig. 3. It is possible to notice that, after the induction, temperatures increased for all groups and at 24 hours presented the maximum values. In general, after 24 hours temperatures tended to decrease towards to the values of the baseline (T0), 21 days after CFA injection. The results for ANOVA were also observed, comparing the initial time (T0) with other experimental times. There was difference between temperature means for the time before induction (T0) compared to times of 24h (T2), 48h (T3), 72h (T4) and 96h (T5). The other experimental times did not present

difference for the means when compared with baseline. There were differences in temperature at T2 for all groups. AtT3, there were differences for groups control and diclofenac. At T4, there weredifferences for groups control and triamcinolone and in T5 the difference was achieved only for group control.

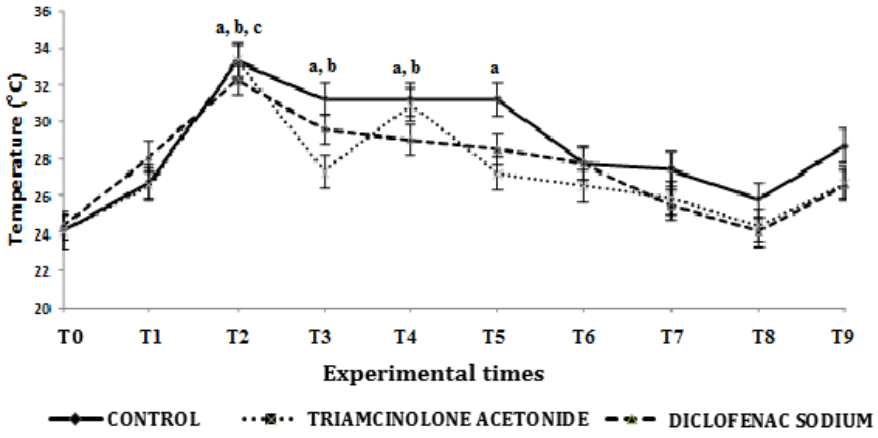

Fig. 3 Variation in rat paws temperature, after CFA injection. Values represented as mean ± standard error of the mean at different experimental times. [a]statistical differencewhen compared to: T0 for control group; [b] T0 for the group treated with triamcinolone and[c] T0 for the group treated with diclofenac.

It is possible to notice (table 1) that at T2 (24 hours) the mean values for paw temperature were different for groups G2 (triamcinolone). At T3 (48 hours), the means for all groups were different. From T4 (72 hours) to T7 (14 days) there were no differences. Nevertheless, for T8 (21 days)the means for all groups were again different and at T9 (28 days) there wasdifference only for group G3 (diclofenac).

Table. 1 Variation in rat paws temperature, after CFA injection. Values represented as mean ± standard deviation, *(p<0,05).

Groups	**Mean temperature (°C)**									
	T0	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**
Control	23,6 (±0,21)	26,8 (±0,89)	33,24 (±2,94)	31,26 (±2,86)	31,22 (±3,79)	31,24 (±3,8)	27,78 (±1,88)	27,48 (±3,21)	26,86 (±0,86)	28,7 (±2,80)
Triamcinolone	24,04 (±0,36)	26,62 (±1,26)	33,32* (±0,92)	27,32* (±2,05)	30,92 (±3,53)	27,22 (±1,41)	26,54 (±1,45)	25,90 (±2,22)	24,38* (±1,05)	26,68 (±2,49)
Diclofenac	24,38 (±0,98)	28,10 (±1,21)	32,24 (±2,44)	29,58* (±3,45)	29,00 (±2,31)	28,59 (±3,58)	27,74 (±3,14)	25,50 (±2,51)	24,02* (±1,05)	26,60* (±2,86)

The room temperature during the experiment did not change significantly, presenting a mean value of 19.12 °C (± 1.05°C).

3.2 Volume and thickness of paws (Oedema)

Comment [H6]: Was this study aimed to differentiate the effect of drugs?

The paws volume and thickness values are presented in Fig. 4 and 5, respectively. There was an increase of the parameter's values, with maximum values at 24 hours followed by a decrease, in both Graphs.

The values of the paws volume were different compared to values at baseline (T0) for groups control and triamcinolone for all times. In group diclofenac, this difference was achieved for times from T2 (24 hours) to T7 (14 days). The paws thickness measured presented difference for all times and groups when compared to T0.

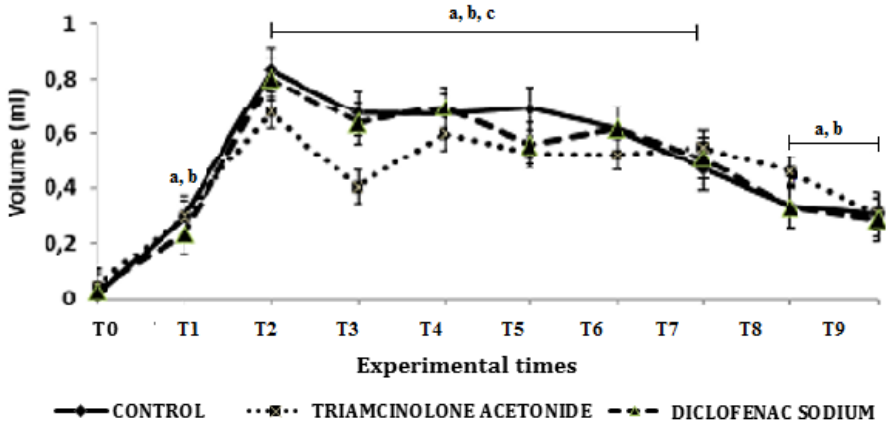

Fig. 4 Variation in the volume of the paw of rats, after injection of CFA. Value in Δ (Δ = RP - LP) represented as mean ± standard error of the mean, in different experimental times.[a,b,c](P <0.05)statistical difference between T0 and the time evaluated on the (x) axis for the groups: control, treated with triamcinolone and treated with diclofenac respectively. CFA (Complete Freund Adjuvant). RP and LP (Right and Left paw respectively).

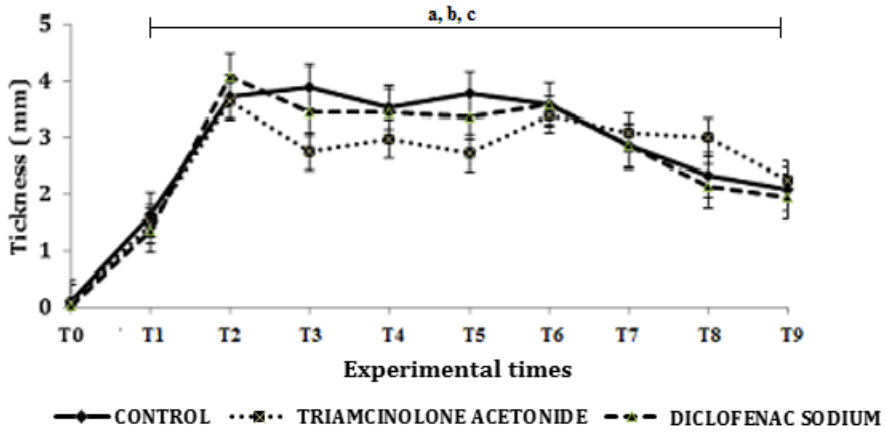

Fig. 5 Variation in the thickness of the paw of rats after injection of CFA. Value in Δ (Δ = RP - LP) represented as mean (± standard error of mean), in different experimental times.[a,b,c](P <0.05)statistical difference between T0 and the time evaluated on the (x) axis for the groups: control, treated with triamcinolone and treated with diclofenac respectively. CFA (Complete Freund Adjuvant). RP and LP (Right and Left paw respectively).

3.3 Histological analyses

Figure 6 shows the histological sections obtained for all experimental groups at the end of the experiment (T9). The three histological sections showed areas of inflammatory cell infiltration in all groups. A granuloma formation was revealedin groups control e triamcinolone.

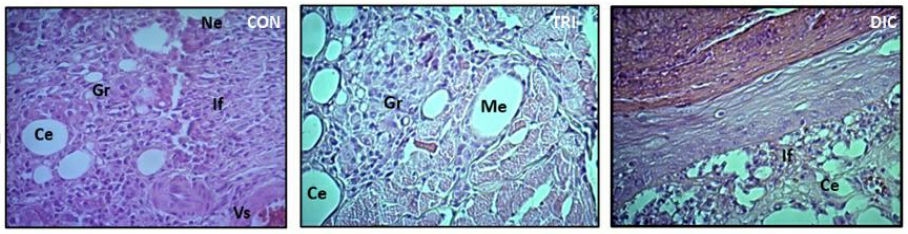

Fig. 6 Histological aspects of rat paws after CFA injection. Presence of inflammatory cell infiltration in the hind right paws, after 28 days of CFA injection. HE staining and 400 magnitude.CON: Histological aspect of rat paw of the control group (no treatment) - Sites with intense inflammatory cell infiltration (If) with lymphocytes, foreign body oily substance (Ce), necrosis area (Ne), granuloma (Gr) and part of a blood vessel site with red blood cells inside (Vs). TRI: Histological aspect of rat paw treated with triamcinolone - Sites with the presence

of foamy macrophages (Me), granuloma (Gr) and foreign body oily substance (Ce) were observed. DIC: Histological aspects of the rat paw treated with diclofenac potassium. It was observed sites with intense inflammatory cell infiltration (If) and foreign body oily substance (Ce).

3.4 Total and differential blood cells counting

The table 2 presents the results for total and differential blood cells counting for all the groups. There was no difference between the groups.

Table. 2 Total and differential blood cells counting for all groups. Values represented as mean ± standard error of mean, (p<0,05).

Groups	Total Leucocytes (%)	Neutrophils (%)	Monocytes (%)	Lymphocytes (%)	Eosinophils (%)	Basophils (%)
Control	5880 (100)	3132 (53,3)	791 (13,4)	1936 (33)	7 (0,1)	14 (0,2)
Triamcinolone	5180 (100)	3227(62,3)	528 (10,2)	1376 (26,6)	33(0,6)	16 (0,3)
Diclofenac	7510 (100)	4713(62,8)	1177 (15,7)	1588 (21,1)	14 (0,2)	18 (0,2)

3. DISCUSSION

Thermography is a method of imaging using an infrared radiation detection sensor to measure radiation emitted from a surface. After acquisition, such images are organized as a distribution diagram with temperature information [15] so it is a non-invasive method. High sensitivity [8; 16;17]is reported for such method and it allows the registration of the trophic conditions of the tissues, in areas with increased tissue metabolism or with an inflammatory response [18; 19]. By this method, temperature is represented graphically (thermogram), with different colors for each temperature interval [7]. Each pixel in the thermogram represents a measured temperature of the surface of an object. Variations in the color pattern indicate thermal differences due to changes of surface temperature, which can be quantified by heat transfer principles[20; 21].

In the present study, using the thermographic camera, it was possible to observe an increase in tissue temperature in 24 hours and a further slow decrease until 21 days. From T7 onwards, the temperature values, in all groups, returned to baseline values (T0). To verify if detected modifications in temperature occurred simultaneously with other inflammatory signals, the paws thickness and volume were also evaluated. A similar increase at 24 hours observed in the temperature trough the thermography method, also were noticed in the thickness and volume paws. Such finding is stimulating since, for this specific type of inflammation model, this

Comment [H7]: Differential blood cannot prove the study objectives

Comment [H8]: Please include the findings in the result sections for discussion.

biological behavior is expected (the 24 hours peak).The ITwas also effective in differentiating the effectiveness of anti-inflammatory drugs with different mechanisms of action.

Considering the animal's paw thickness, differences were demonstrated between the initial time and all subsequent experimental times, in all groups. Considering data from the paw volume analysis for animals treated with topic diclofenac there was no difference at 30 minutes or 21 and 28 days, which demonstrated that in this group and times volume changes reached values similar to the baseline. This result could suggest that, for this group, the diclofenac topic treatment was more effective in volume change than to thickness.The formation of granuloma, as observed in the present study, could explain why the volume of the animals' paws did not return to the initial values with exception of the animals treated with topic diclofenac.

The graphics curves demonstrated that temperature behavior followed oedema (thickness and volume) behavior with an increase at 24 hours followed by a decrease reaching values similar to those of the baseline in a shorter experimental time, compared to volume and thickness parameters. A hypothesis considered for these outcomes is that temperature decrease could be solved faster in the inflammatory response than oedema, however other studies must be performed with different animal models of inflammation.

The induction of chronic inflammation in rodents was achieved with injection of suspension of inactive strains of *Mycobacterium tuberculosis* in Freund's adjuvant and it is expected a larger sensibilization period by the presence of non-metabolizable oils, such as paraffin that promotes the continuous release of antigens. With this, a chronic inflammation is trigged inducing a strong and persistent inflammatory response that could achieve 35 days of duration [1; 22-24]. Some of musculoskeletal disorders, related to chronic inflammation lack in objective diagnostic and gold standards, then it is a challenge to effectively validate the present technique.

In histological sectionsit was possible to qualitatively determine the presence of cellular infiltrate, consistent with a chronic inflammation. Leukocyte differential counting informed the relative amount of different leukocyte types in blood cells (neutrophils, lymphocytes, basophils, eosinophils and monocytes) according to their morphological characteristics. There is no reduction in the percentage of lymphocytes in the blood of groups that received the CFA injection and were treated with triamcinolone (26,6%) and diclofenac (21,1%) when compared to animals in the control group (33%), could be related to the anti-inflammatory effect of the drugs used.

Inflammation is the process of recruitment of leukocytes and plasma proteins from the blood, their accumulation in tissues and their activation to destroy the microorganisms. Many of these reactions involve cytokines, which are produced by dendritic cells, macrophages and other types of cells during innate immune reactions. The major leukocytes that are recruited in inflammation are phagocytes neutrophils (which have short life span in tissues) and monocytes (which develop into tissue macrophages) [12]. Therefore, a possible cause for reduction in the percentage of lymphocytes in the blood cell counting could be due to their accumulation in tissues. In the present study, we also noticed a reduction, although not significant, of blood neutrophils in the control group (without treatment). However, we cannot say that these neutrophils would be more concentrated in the inflamed tissue, since the characterization of the tissue cells was not carried out.

Comment [H9]: Discussion could not be correlated with the study result and analysis

Drugs used were selected since topical treatments for inflammation disorders are frequently well-tolerated and preferred by many patients [25]. For these reasons a topical corticosteroid was used. Another anti-inflammatory drug was used due to the current evidence that indicates that topical non-steroidal anti-inflammatory drugsmay be effective for pain relief in osteoarthritis [26]. Diclofenac sodium is a potent inhibitor of cyclooxygenase-2 with analgesic and anti-inflammatory properties; however, it has little antipyretic action. It is recommended for the treatment of chronic inflammatory conditions such as rheumatoid arthritis and osteoarthritis [27]. Triamcinolone acetonide is a synthetic corticosteroid that has anti-inflammatory, antipruritic and antiallergic action [27]. Components of the formula act as an adhesive vehicle to the active medication [28].

Our results suggest that thermography may also be useful to differentiate the anti-inflammatory efficacy of different drugs. When compared to the diclofenac sodium animalgroup (96 hours), the animals treated with triamcinolone acetonide returned faster (48 hours) to the initial temperature values.Thepharmacology of triamcinolone as corticosteroid drug could explain anti-inflammatory effects and also its vehicle, since adhesive vehicles could improve drug substantively by prolonging the supply of drug in the site as result of the ability to adhere to the substrate and persist at effective drug concentration [29].

The right paws temperatures (injected with saline solution) were not different, as expected,since they are regions that did not receive pro-inflammatory stimulation.

Temperature of the extremities and skin depends on the blood flow dynamics and temperature. Additionally, individual variations at different times of the day can occur [19]. For this reason, all images were recorded at the same time, early in the morning in a controlled environment to prevent such aspects.

The temperature patterns can be associated to healthy or pathological situations [30]. Thermography does not provide specific details of a disease however it may be useful in defining the area affected by inflammation,assist progression of the lesion as well as the effectiveness of different types of treatments.

4. CONCLUSIONS

Comment [H10]: From this study cannot conclude anything.

The infrared thermography technique was effective in detecting the intensity of the tissue inflammatory process, as well as in differentiating the effectiveness of anti-inflammatory drugs with different mechanisms of action, in an animal model of inflammation induced by CFA.

Statements &Declarations

Ethics approval

This study was previously approved by the Animal Ethics Committee of Federal University of Jequitinhonha and Mucury Valleys (UFVJM) regarding the Guiding Principles in the Care and Use of Animals, with approved protocol number of 050/2016.

Consent to participate

No applicable

Consent to publish

No applicable

5. REFERENCES

1. Webb DR. (2014) Animal models of human disease: Inflammation.*Biochemical Pharmacology*. 87: 121-130.
2. Parvathy SS and Masocha W. (2013) Gait analysis of c57bl/6 mice with complete Freund's adjuvant-induced arthritis using the catwalk system. *BMC Musculoskelet Disord*.14:14.
3. Santana MA, Silva Pereira JM, Silva FL, Lima NM, Sousa FN, Arruda GMS, Fernandes de Lima, RC, Silva WWA, Santos WP (2018). Breast cancer diagnosis based on mammary thermography and extreme learning machines. *Res. Biomed. Eng.* 34:45-53.
4. Long B, April MD, Summers S, Koyfman A. (2017). Whole body CT versus selective radiological imaging strategy in trauma: an evidence-based clinical review, *The American Journal of Emergency Medicine*. 35 1356-1362.

5. Pauk, J, Ihnatouski M. & Wasilewska A. (2019) Detection of inflammation from finger temperature profile in rheumatoid arthritis. *Med BiolEngComput* 57, 2629–2639

6. Snekhalatha U, M. Anburajan T, Teena B, Venkatraman M, Menaka and B. Raj. (2012) Thermal image analysis and segmentation of hand in evaluation of rheumatoid arthritis. *International Conference on Computer Communication and Informatics*, Coimbatore, pp. 1-6.

7. Całkosiński I, Dobrzyński M, Rosińczuk J, Dudek K, Chrószcz A, Fita, K, Dymarek R (2015). The Use of Infrared Thermography as a Rapid, Quantitative, and Noninvasive Method for Evaluation of Inflammation Response in Different Anatomical Regions of Rats. *BioMed Research International*, 2015;9 p. http://dx.doi.org/10.1155/2015/972535.

8. Diakides N and Bronzino J.(2008). Medical Infrared Imaging, *CRC Press*, Boca Raton, Fla, USA, 448p.

9. McManus C, Tanure CB, Peripolli V, Seixas L , Fischer V, Alexandre M. Gabbi, Silvio R.O. Menegassi, Marcelo T. Stumpf, Giovani J. Kolling, Eduardo Dias, João Batista G. Costa. (2016). Infrared thermography in animal production: An overview, *Computers and Electronics in Agriculture*. 123, 10-16.

10. Colak A, Polat B, Okumus Z, Kaya M, Yanmaz LE, Hayirli A (2008). Short communication: Early detection of mastitis using infrared thermography in dairy cows. *J. Dairy Sci* 91: 4244-4248.

11. Soerensen DD, Pedersen LJ. (2015) Infrared skin temperature measurements for monitoring health in pigs: a review. *Acta Vet Scand*. 57(1):5.

12. Abbas AK, Lichtman AHH, Pillai S. *Cellular and Molecular Immunology*. 7th ed. 2011 Elsevier Saunders, Philadelphia, USA. 560 p.

13. Wixson SK, Smiler KL. Anesthesia and Analgesia in Rodents. (1997) In: *Anesthesia and Analgesia in Laboratory Animals*. Kohn DF, Wixson SK, White WJ, Benson GJ. Academic Press, p165-203.

14. Queiroz-Junior CM, Pacheco CM, Fonseca AH, Klein A, Caliari MV, de Francischi JN. (2009) Myeloperoxidase content is a marker of systemic inflammation in a chronic condition: the example given by the periodontal disease in rats. *Mediators Inflamm*. 2009:760837.

15. Hamaguchi S (2014). The instrument for thermography. *Masui*. 63:728-36.

16. Merla A and Romani GL. (2006). Functional infrared imaging in medicine: a quantitative diagnostic approach, in Proceedings of the *28th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. 224–227.

17. Soroko M, Dudek K, Howell K, Jodkowska E, Henklewski R. (2014). Thermographic evaluation of racehorse performance. *Journal of Equine Veterinary Science.* 34:1076–1083.

18. Jiang LJ, Ng EYK, Yeo ACB, Wu S, Pan F, Yau WY, Chen JH, Yang Y (2005). A perspective on medical infrared imaging. *Journal of Medical Engineering and Technology*. 29: 257–267.

19. Heimann K, Jergus K, Abbas AK, Heussen N, Leonhardt S, Orlikowsky T. (2013). Infrared thermography for detailed registration of thermoregulation in premature infants. *Journal of Perinatal Medicine*. 41: 613–620.

20. Eddy AL, Van Hoogmoed LM, Snyder JR (2001). The role of thermography in the management of equine lameness. *Vet. J.;*162: 172–181.

21. Costa RMG, Silva AM, Rocha AF, Oliveira PA, Gabriel J, Abrantes AM, Botelho MF (2017). Thermography in Animal Models of Cancer: A Tool for Studying Oncobiology in Laboratory Animals. In: *Innovative Research in Thermal Imaging for Biology and Medicine*. Editors: Vardasca, R and Mendes JG. IGI-Global p 237-263.

22. Freund J and McDermott K (1942). Sensitization to Horse Serum by Means of Adjuvants. *Proc. Soc. Exp. Biol. Med.*49: 548-553.

23. Freund J (1956a). The mode of action of immunologic adjuvants. *Adv.Tuberc. Res.* 7: 130–148.

24. Freund J (1956b). The mode of action of immunologic adjuvants. *BiblTuberc.* 10:130-148.

25. Zengdong M and Rongzhong H. (2018) Topical Treatment of Degenerative Knee Osteoarthritis, The *American Journal of the Medical Sciences.* 355: 6-12, ISSN 0002-9629, https://doi.org/10.1016/j.amjms.2017.06.006.

26. Persson MSM, Stocks J, Walsh DA, Doherty M, Zhang M. (2018) The relative efficacy of topical non-steroidal anti-inflammatory drugs and capsaicin in osteoarthritis: a network meta-analysis of

randomised controlled trials. *Osteoarthritis and Cartilage* 26: 1575-1582. https://doi.org/10.1016/j.joca.2018.08.008.

27. Katzung B , Masters S , Trevor A (2014). *Basic and Clinical Pharmacology* 13 ED. McGraw-Hill Medical Publishing, United States of America.1216p.

28. ANVISA, Bulárioeletrônico, 2013. Available at *http://www.anvisa.gov.br/datavisa/fila_bula/index.asp.* consulted in January 10th, 2019.

29. Quintas V, Prada-López I, Donos N, Suárez-Quintanilla N, Tomás I. (2015) In situ neutralization of the antibacterial effect of 0.2% Chlorhexidine on salivary microbiota: Quantification of substantivity, *Archives of Oral Biology*. 60: 1109-1116.

30. Berry RJ, Kennedy AD, Scott SL, Kyle BL, Schaefer AL (2003). Daily variation in the udder surface temperature of dairy cows measured by infrared thermography: Potential for mastitis detection. *Can. J. Anim. Sci* 83: 687–693.