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EVALUATION OF LAPAROTOMY SURGERY WOUND HEALING IN DOGS USING THERMOGRAPHIC ANALYSIS

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ABSTRACT

This study aimed to develop the use of thermographic analysis to evaluate wound healing for laparotomy surgery in animals. The experiment used nine adult dogs 5 males and 4 females, bodyweight 5-10 kg) that had undergone the same general anesthesia and laparotomy procedures. Evaluation of wound healing was performed at 24, 48, and 72 hours after surgery and 7 days after operations using a digital thermal camera. During each thermographic evaluation period, blood samples were taken for analysis of total leukocytes and leukocyte differential. The results of thermal imaging were compared with the values of inflammatory cells and the clinical condition of wound healing. Comparison of thermographic analysis with inflammatory status was evaluated using the regression equation and showed a strong correlation coefficient (Y= -0.4847 + 40.14, R^2= 0.867), that is, the higher the temperature, the lower the inflammation. The conclusion of study is that thermographic analysis can be used to evaluate wound healing of laparotomy surgery in dogs.

Key words: dog, laparotomy, thermal camera, thermography, wound healing

ABSTRAK

Penelitian bertujuan mengembangkan penggunaan analisis termografi untuk mengevaluasi kesembuhan luka operasi laparatomi pada hewan. Penelitian menggunakan sembilan ekor anjing dewasa (5 ekor jantan dan 4 ekor betina, berat badan 5-10 kg) yang telah menjalani prosedur anestesi umum dan operasi laparatomi yang sama. Evaluasi kesembuhan luka dilakukan pada jam ke-24, 48, 72 jam setelah operasi dan padahari ke-7 setelah operasi menggunakan kamera termal digital. Pada setiap periode evaluasi termografi, darah diambil untuk analisis leukosit total dan diferensial leukosit. Hasil pencitraan termal dibandingkan dengan nilai sel-sel radang dan kondisi klinis kesembuhan luka. Perbandingan analisis termografi dengan status keradangan dievaluasi menggunakan persamaan regresi. Hasil menunjukkan koefisien korelasi yang kuat (Y= -0,4847+ 40,14, R^2= 0,867), yaitu semakin tinggi suhu, semakin turun keradangan. Kesimpulan penelitian adalah analisis termografi dapat dimanfaatkan untuk evaluasi kesembuhan luka operasi laparatomi pada anjing.

Kata kunci: anjing, laparatomi, kamera thermal, termografi, kesembuhan luka

INTRODUCTION

Infrared Thermography (IRT) is a new diagnostic technology that has not been widely used in the veterinary field. This technique has received great attention in medicine and industry as a non-invasive method that does not use radiation (Rocha and Póvoas 2017). Thermography is used to diagnose several disorders of the body, including vascular, neurological, orthopedic, and neoplastic diseases, or other conditions that involve changes in body surface temperature. An increase in body temperature is associated with an increase in local circulation and metabolism, which can be clinically correlated with inflammation; whereas a decrease in body temperature is clinically associated with decreased tissue perfusion due to infarction or changes in the autonomic nervous system (Grossbard *et al.* 2014).

The IRT technique detects the radiation spectrum of an object using a camera that produces a thermal image which is visualized and interpreted using special software. Infrared thermography makes it possible to visualize temperature changes on the surface of the skin which can be correlated with the organs of the body being evaluated, for example, in cases of osteoarthritis, spinal cord injury, conducting evaluations, infectious diseases, and malignant neoplasia. In contrast to existing clinical methodologies, IRT has the advantage of being non-invasive for assessing the thermal state of animals without the need for physical examination or chemical restraint. This technology is considered a non-contact attachment technique that does not require attaching a device to the animal's body and may be a useful method for avoiding hyperthermia induced by the stress of handling. Hildebrandt *et al*. (2010) observed that several types of local tissue lesions are associated with variations in blood flow that affect surface temperature, such as inflammation leading to hyperthermia. The distribution of heat in the thermography method indicates the dynamics of inflammation in the tissue, and can be evaluated continuously during the healing process. This technique is without contact, non-invasive and fast (Ireneusz *et al*. 2015). The use of effective and non-invasive IRT technology is also in line with animal welfare which emphasizes the rights of animals not to be hurt and their freedom disturbed. This study aims to utilize IRT with a digital thermal camera to evaluate wound healing during laparotomy surgery in dogs. As a comparison, clinical observation of the wound and blood sampling will be carried out to evaluate inflammatory cells together with the thermographic evaluation.

MATERIALS AND METHODS

The research was conducted at the Prof Soeparwi Animal Hospital, Karangmalang, Yogyakarta, from September to November 2022. This research has received ethical approval from the Ethics Commission

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of the Faculty of Veterinary Medicine, Universitas Gadjah Mada (number: 072/EC-FKH/Int./2022).

Determination of Experimental Animals

The animals used in the study were nine adult male and female mixed-breed dogs, with a body weight range of 5-10 kg. All animals underwent standard laparotomy using ketamine-xylazine anesthetic. The surgical diagnosis in dogs was for cystitis, ovariohysterectomy, and gastrotomy. Postoperative care was carried out by administering povidone iodine antiseptic and enrofloxacin antibiotics. Operation recovery control is carried out every day.

Thermography Procedure

Thermography was taken using a digital thermal camera model RQ-AAA, with general specifications 320-240 thermal censor, 32° field of view, accuracy 5° C or 5% (at 25° C), 15 to 550 cm distance, works day and night. Images were taken perpendicularly at 50–60 cm with a focus on wound healing, namely around the umbilical scar at the midline. Thermography collection was carried out in five periods, namely pre-surgery, 24 hours, 48 hours, and 72 hours after surgery, and 7 days after surgery for all sampled dogs, in a room with a temperature of 25° C and humidity of 50-56%.

Blood sampling was carried out in each period of taking thermography through the saphenous vein as much as 3 mL. Blood was collected in a tube containing ethylene Diamine Tetra Acetic Acid (EDTA) to be sent to the laboratory for leukocyte analysis and differential counting. Wound healing was observed every day, especially in the midline area of the postoperative wound.

Data Analysis

The data obtained are total leukocyte and neutrophil values which will be compared with the results of thermographic imaging in the form of temperature values in the former surgery area. The relationship between inflammation and the temperature of the postoperative area will be analyzed using a linear regression equation to obtain a correlation coefficient.

RESULTS AND DISCUSSION

The results of the thermographic image in Figure 1 (left) show the temperature value in the dog's abdominal area before the laparotomy. Figure 1 (right) shows the position of the dog and the operator when taking thermography using a digital thermal camera. Interpretation of the thermal imaging and clinical observations at 24, 48, 72 hours, and 7 days after surgery are shown in Figures 2a-2d. The abdominal area and surgical wound on thermography show temperature images that form various patterns of green, yellow, indigo, red, and bright white. Low to high temperatures are shown through color lines ranging from blue, light blue, green, yellow, indigo, red, and bright white. Color and temperature interpretation follow the standards of thermal camera products as presented in Figure 3.

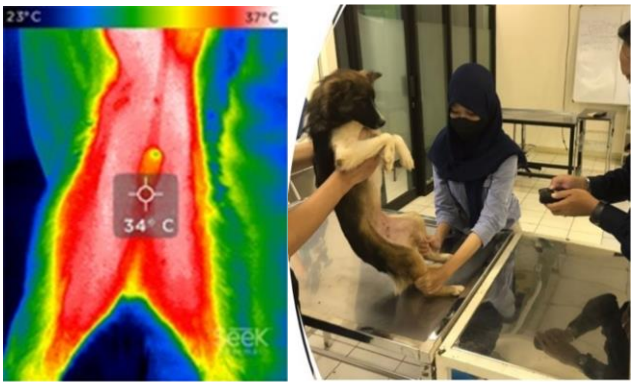

Figure 1. The thermography imaging before laparotomy (left) and thermography simple procedure with the digital thermal camera (right)

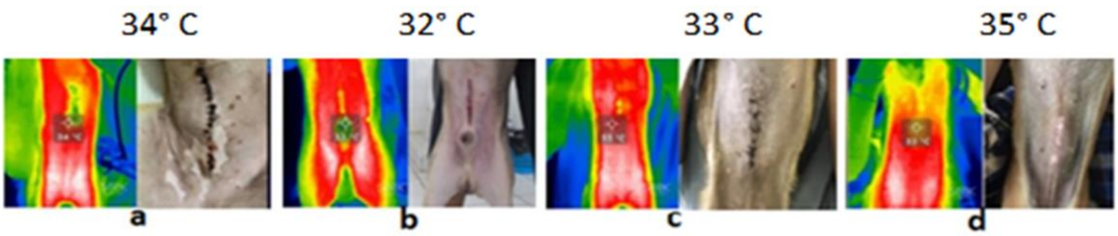

Figure 2. The pairs of thermography (left) and clinical imaging (right) of 24 hours (a), 48 hours (b), and 78 hours (c) post-operation, and 7 days post-operation (d)

Figure 3. Standard thermographic imaging color degradation from thermal cameras

The shooting distance is carried out at 40-50 cm perpendicular to the surgical wound, which shows the best focus for taking objects. The thermographic results are images of color variations according to temperature values, and in this study the results ranged from 30-38° C with the lowest average in the 24-hour postoperative period and the highest preoperative (32.60±2.31 and 36.20±2.22° C, respectively). A comparison of the results of the hematological test (using the total leukocyte and neutrophil values, as an indication of the predominant inflammatory cells in acute inflammation) with the interpretation of the temperature of the thermographic results is shown in Table 1. Clinically, all dogs experienced wound healing on the 7^{th}-10^{th} day after surgery, the wound closed well and there was no indication of infection.

Interpretation Table 2 shows the clinical assessment of the results of thermography on wound healing. Based on the results of the correlation between temperature and neutrophils or leukocytes, which shows that the higher the temperature, the lower the neutrophil or leukocyte value, the increase in temperature can be explained because of improved vascularity in the surgical wound area. The results of thermography 24 hours postoperatively showed a significant decrease in temperature accompanied by an appropriate staining image (yellow and green colors were seen in the wound area). In the observation of 48 operating posts, swelling was seen with a predominance of yellow in the wound area and loss of green color, indicating an increase in temperature. Observations at 72 operating posts and 7 days of operating posts are increasing, and the scars from surgery have started to fade and disappear. On the 7^{th} postoperative day, the wound had physically closed and healed, and on the thermographic appearance it showed a bright white image dominating the abdominal area, like the preoperative period.

Neutrophils are the most numerous inflammatory cells, play a role on the front line in responding to injuries and infections, and are cells that will trigger a series of pro and anti-inflammatory mechanisms (Heuer *et al.* 2021). Wang (2018) also said that neutrophils have an important role in triggering the inflammatory process by releasing toxic effectors to accelerate the process of tissue repair due to injury. Based on the results of the analysis of inflammatory cells, the neutrophil value seems to have the most influence on each stage of the observation of the wound period and has a correlation with the results of the interpretation of thermographic temperature (Table 1). These results agree with Casas-Alvaro *et al.* (2020) reported that IRT evaluates surface microcirculation based on variations in tissue temperature associated with changes in the autonomic nervous system from inflammation, infection, neoplastic, and stress-induced pain. The correlation between decrease in total leukocyte and absolute neutrophil values with increasing thermographic imaging temperature showed a correlation coefficient R^2= 0.8569 and 0.8676, respectively. This value shows good linearity with a value of Y= -0.5091x+43.495 and Y= -0.4847 + 40.14 (Figure 4).

Color images from thermography results for each observation period show the development of temperature dynamics which corresponds to a decrease in neutrophil values and developments refer to preoperative images. Bright and white color indicates a temperature exceeding 37° C, where circulation and vascularization return to normal along with tissue repair. Anatomy-centered IRT can be used as a thermal window to determine changes in peripheral blood flow that reflect autonomic nerve activity. The term thermal window refers to the area with peripheral blood vessels where changes in temperature can be detected (Kwon and Brundage 2019). When the sympathetic elements of the autonomic nervous system are stimulated, an initial vasoconstrictive response is generated due to the neurosecretion of adrenaline and noradrenaline, causing changes in peripheral temperature. These findings demonstrate the usefulness of IRT for the early detection of inflammatory conditions (Travain *et al*. 2015). Temperature from thermographic imaging cannot match the dog's normal body temperature (38-39° C) or actual body temperature, because of their different functions. Body temperature measurements are still carried out with a body thermometer.

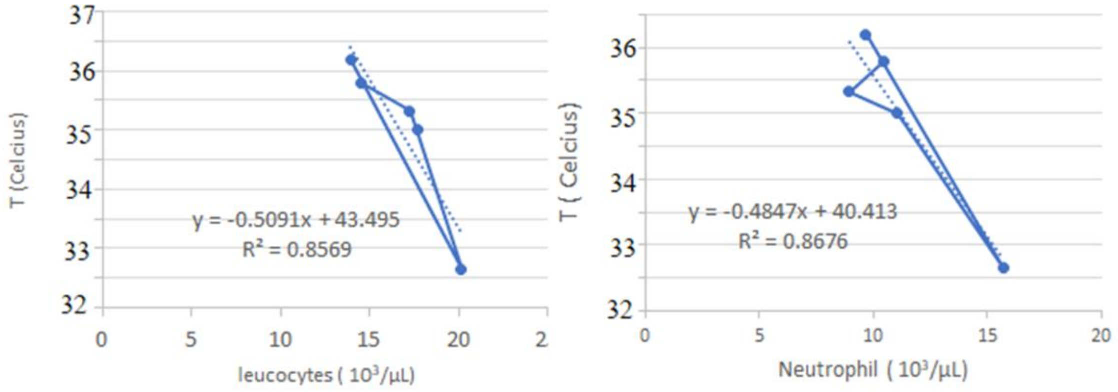

Figure 4. The regression analysis of thermography results of leucocytes and neutrophil

Table 1. Correlation of total leukocyte and neutrophil values (relative and absolute) by temperature of thermographic interpretation.

Leucocytes		Pre operation	24 hours	48 hours	72 hours	7 days
Total (10^3/µL)		13.94±4.05	20.12±8.64	17.65±6.42	17.23±6.52	14.50±1.30
Neutrophile	Relative (%)	69.15±7.83	77.16±5.35	61.19±16.67	54.50±17.62	72.28±0.10
	Absolute (10^3/µL)	9.66±2.99	15.71±7.09	11.06±6.06	8.95±3.68	10.48±0.20
Thermography	T (° C)	36.20±2.22	32.66±2.31	35.00±1.15	35.33±1.86	35.80±0.78

Table 2. Imaging description of thermography results in the healing period of surgical wounds

Period	Temperature average (° C)	Description
Pre-operation	36.20±2.22	Normal temperature (>37° C) is evenly distributed on the abdomen with a bright white color, the lineal alba and peripheral ares have lower temperatures
24 hours post-operation	32.60±2.31	The temperature is lower than normal, the temperature of the surgical scar and its surroundings is lower, it is clear that the dominance of green-yellow in the area of the surgical wound
48 hours post-operation	35.10±1.15	The temperature rises in the posterior abdominal area, the surgical wound is detected with a lower temperature
72 hours post-operation	35.22±1.86	The temperature increases more evenly in the midline area, the surgical wound shows a lower temperature
7 days post-operation	35.80±0.78	The temperature is near normal in the operating area and abdomen, shown by the predominant white and bright color

CONCLUSION

Based on thermographic data analysis and inflammatory cells and clinical interpretation of postoperative wounds, it can be concluded that thermographic interpretation with a digital thermal camera can be used as an evaluation of surgical wound healing. There is a strong correlation between temperature based on thermographic images and neutrophil and leukocyte values, that is, the higher the temperature, the lower the inflammation in the surgical wound.

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