

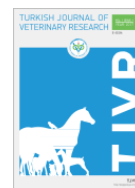


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Assessment of healing of wounds through thermography for cats after orchiectomy

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ABSTRACT

Objectives: The purpose of this study is to assess the variation of surface temperature in scrotal area in terms of days for cats after orchiectomy operation by using infrared thermography and to determine the effectiveness of this method for the follow up of its postoperative inflammatory response. Thermography is a method providing opportunity to follow up the surgical recovery process noninvasively and objectively, therefore its potential of use for small animals has been gradually increasing.

Materials and Methods: The study included eight healthy male cats presented to the clinic for elective orchiectomy. Starting from preoperative period, thermal imaging was made during seven postoperative days. Measuring was achieved by FLIR- trademark thermal camera by keeping emissivity value constant under the protection of standard filming and distance and angle. Room temperature (22.33±1.19°C) and animals' body temperatures (38.22±0.61°C) were kept under control, therefore the effect of the environmental variables was minimized. Surface temperatures of right and left scrotal regions were recorded separately and compared to preoperative values.

Results: No complications were observed at the incision site during the study period. The mean surface temperatures measured in the right and left scrotal regions were 29.01 ± 8.57 °C and 29.24 ± 8.65 °C, respectively and no statistically significant difference was found between the two sides. Moreover, no statistically significant difference was detected between the preoperative temperature and the temperatures measured on postoperative days 1–7 (p > 0.05). The thermal variation curve showed a slight decrease on postoperative day 1 and a gradual increase on postoperative days 4–7; however, all variations remained within physiological limits and were not statistically significant.

Conclusions: The findings indicate that orchiectomy induced only minimal inflammatory response in cats, and the recovery process was completed without any complication. The ability of thermography to reliably monitor temperature variations in the scrotal area suggests that this method may serve as a complementary diagnostic tool for assessing wound healing in small animal surgery.

Keywords: Cat, Orchiectomy, Thermography

INTRODUCTION

Thermography is a non-invasive imaging method enabling to measure the surface temperature through the perception of infrared radiation

emitted from tissues (Düzgün and Or, 2009). This technique provides important contribution to veterinary medicine for the early detection of pathophysiological processes which are accompanied by local blood flow, such as

inflammation and metabolic increase (Head and Dyson, 2001). In live tissues, increase of temperature is generally related with the increase of cellular metabolism and regional vascularization; for this reason, thermography is accepted as a reliable complementary method for the assessment of inflammatory reactions (Całkosiński et al., 2015).

In veterinary medicine, thermography was initially used for the early diagnosis of extremity diseases in large animals such as horses and cattle, and later it was also applied in small animal surgery (Düzgün, 2018). In clinical applications, thermography is used to assess inflammation in joints, tendons, muscles, and surgical wound areas, as well as to evaluate the healing process and objectively measure tissue perfusion (Koç, 2021). Early detection of inflammatory complications during the postoperative period is critically important for evaluating wound healing (Gumpert Herlofson, 2017).

Orchiectomy is a commonly performed surgical procedure in male cats. Following surgery, edema, hyperemia, and local inflammatory responses may develop at the surgical site. In this process, regional blood flow increases and surface temperature variations depending on this increase can be assessed objectively by thermography. Empirical surveys conducted so far reveal that; meaningful temperature increases were determined in early stages of inflammation and this increase reached maximum level within 48–72 hours (Całkosiński et al., 2015). For this reason, thermal imaging comes to forefront as a non-invasive, rapid and reliable procedure for tracing postoperative inflammation.

Studies conducted in small animal surgery through thermography revealed hopeful results for the determination of temperature changes occurred in inflammatory phase of wound healing. (Gumpert Herlofson, 2017). Besides, thermal cameras developing resolution and sensitivity levels provide opportunity for the more accurate measuring with minimal environmental effects (Düzgün and Or, 2009). Within this context, after orchiectomy operation, monitoring the surface temperature in scrotal area by thermography may enable the objective assessment of inflammatory activity during healing process.

The purpose of this study is to monitor surface temperature variations in scrotal area after orchiectomy operation in cats by using thermography and to assess the trend of inflammatory response developing in

postoperative period which depends on the time. Accordingly, thermography's usability shall be revealed for monitoring wound healing and for determining probable complications in early stages within the scope of small animal surgery.

MATERIALS and METHODS

Animals

This survey consisted of 8 male crossbreed healthy cats which were brought to Siirt University Animal Health Application and Research Center in various times for orchiectomy purpose. In clinical routine examinations no pathological finding was found. Before the procedure, animals were individually housed for one day. Orchiectomy was performed on the following day. Food and water were given as ad libitum and water and food restriction was applied 8 hours before the surgery. The surgical site was shaved on the day of admission, and the patient was subsequently hospitalized. The room temperature in the hospitalization area was maintained at approximately 22°C using air conditioning. Room temperature was continuously monitored using a digital room thermometer to ensure environmental stability. However, temperature values were recorded only at the time of each thermographic imaging session.

Surgical procedure

Patients were taken into general anesthesia before the operation. For sedation, xylazine hydrochloride (2 mg/kg intramuscular [IM] Xylazinbio, Bioveta, Ankara, Türkiye) were given whereas ketamine hydrochloride (10 mg/kg intramuscular [IM] İnterhas, Ankara, Türkiye) was applied for the induction of anesthesia. The patient was intubated, and anesthesia was maintained with 3% sevoflurane (Sevoflurane, Aesica Queenborough Ltd., England). Hair removal was performed by shaving as part of routine preoperative preparation. Although exact dimensions were not measured, the dehaired area corresponded to the standard surgical field required for feline orchiectomy and was applied consistently in all animals. The surgical area was cleaned with antiseptic solution. It was limited by sterile covers. Feline orchiectomy was performed using the open surgical technique described by Fossum, 2007. After exteriorization of the testicle, the parietal vaginal tunic was incised, and the testis was exposed. The spermatic cord components, including the ductus deferens and spermatic vessels, were individually ligated using absorbable suture material and transected distal to

the ligatures. The same procedure was repeated for the contralateral testis. After the operation, patients wearing Elizabeth collars were allowed to recover from anesthesia. After surgery, a 10% povidone-iodine solution was applied to the incision site twice daily until discharge.

For antibiotic therapy, sefaleksin 20 mg/kg, BID, PO (Maksipor 250mg/5ml, Actavis, Kırklareli, Türkiye) was used. In pre-surgery or post-surgery period no non-steroid anti-inflammatory medicine was used. NSAIDs were not administered because of their potential pharmacological effects on the inflammatory response and thermographic surface temperature measurements, which constituted the primary outcome measures of the study.

Infrared thermography imaging

IRT images, FLIR E50 thermal camera (FLIR Systems Inc., Wilsonville, Or, USA) with $<0.05^{\circ}\text{C}$ thermal sensitivity was used. The emissivity setting of the thermal camera was kept at the manufacturer's default value throughout all measurements. All the imaging was performed when the animals were hospitalized. Thermographic images of the incision line in the right and left scrotal areas were obtained from a distance of 30 cm at a right angle, and all results were recorded. Afterwards, room temperature and animals' body temperature were measured and recorded. Initial imaging was performed six hours after the animals were admitted to the clinic and hospitalized (Figure 1). Second imaging was accomplished after 6 hours than the hospitalization of the animal following the animal's awakening period just after the operation in following days, thermographic imaging was repeated once daily at the same time for six consecutive days. Thus, a total of eight measurements (one preoperative and seven postoperative) were obtained for each animal.

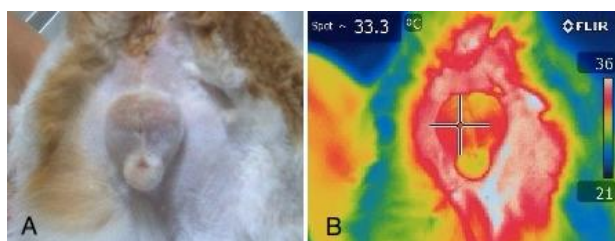


Figure 1. A: The image of the preoperative normal. B: Thermographic measuring of case 5.

Data analysis and statistics

Data were analyzed using Repeated Measures Analysis of Covariance (RM-ANCOVA) to examine the changes in scrotal surface temperature over time (8 measurements: preoperative and postoperative

days 1–7). To ensure a precise assessment of the surgical inflammatory response, room temperature (RT) and animals' body temperatures (BT) were included in the model as continuous covariates. This approach allowed for the statistical adjustment of scrotal measurements against fluctuations in ambient and systemic heat, providing Adjusted Means (Estimated Marginal Means - EMMs) for the final comparison. The assumption of normality was assessed using the Shapiro-Wilk test. The homogeneity of regression slopes was verified by ensuring no significant interaction existed between the covariates (RT and BT) and the time factor ($p > 0.05$). Sphericity was assessed using Mauchly's test. Since the assumption of sphericity was violated ($p < 0.05$), the Greenhouse-Geisser correction was applied to adjust the degrees of freedom and ensure the validity of the F-statistics. Post-hoc comparisons with Bonferroni adjustment were utilized to identify specific differences between time points. The results were expressed as Adjusted Mean $\pm$ Standard Error (SE) along with their 95% Confidence Intervals (CI). Statistical significance was set at $p < 0.05$. All analyses were conducted using SPSS 14.01.

Ethical approval

This study was approved by Siirt University Animal Experiments Local Ethical Commission (HAYDER)'s decision no. 2019/04-01 and conducted in Siirt University Animal Health Application and Research Center (HAYMER).

RESULTS

In the animals which comprises the study material, the healing was provided as requested in wound line during postoperative period without any complication. The room temperature which was measured during the study was determined; $22.33 \pm 1.19^{\circ}\text{C}$. During the study period, animals' body temperature was measured; $38.22 \pm 0.61^{\circ}\text{C}$. The mean thermographic surface temperatures of the right and left scrotal regions were $29.01 \pm 8.57^{\circ}\text{C}$ and $29.24 \pm 8.65^{\circ}\text{C}$, respectively. No statistically significant difference was detected between the thermographic surface temperatures of the right and left testes ($p > 0.05$). Similarly, no statistically significant difference was found between the preoperative temperature and the temperatures measured on postoperative days 1–7 ($p > 0.05$).

This finding indicated that postoperative inflammatory changes were not sufficient to

produce a distinct increase in surface temperature, and healing occurred within physiological limits.

Although a thermal variation trend was observed (a slight decrease on postoperative day 1 and an increase on postoperative days 4–7), these changes were not statistically significant (Table 1).

Table 1. Time-dependent changes in adjusted scrotal surface temperature (°C) (n=8).

Time	Adjusted* Scrotal Surface Temperature (EMM ± SE)	95% Confidence Interval (LB - UB)	P (Time)
Preoperative	31.9 ± 0.65	30.63 - 33.17	0.173
Day1	29.8 ± 0.76	28.31 - 31.29	
Day2	31.8 ± 0.68	30.47 - 33.13	
Day3	31.9 ± 0.71	30.51 - 33.29	
Day4	32.3 ± 0.66	31.01 - 33.59	
Day5	32 ± 0.67	30.69 - 33.31	
Day6	32.3 ± 0.65	31.03 - 33.57	
Day7	32.8 ± 0.65	31.53 - 34.07	

*Adjusted for room (RT) and body temperature (BT). Covariates in the model were evaluated at the following values: RT=22.1°C, BT=38.3°C. P values of the covariates in the model: RT=0.133, BT=0.955; EMM: Estimated Marginal means, SE: Standard error, LB: Lower bound, UB: Upper Bound, RT: Room temperature, BT: Body temperature

DISCUSSION

In this study, the variation of the surface temperature, in terms of time, in scrotal area after orchiectomy operation in cats was assessed by thermography method. No complication developed in postoperative period and the normal healing was observed in the wound line, and this supports that the thermographic data obtained were all measures under physiological conditions.

Thermography is considered a reliable, rapid, and non-invasive method for assessing inflammatory responses (Head and Dyson, 2001; Christensen et al., 2012). In our study, surface temperature in the scrotal area during the post-orchiectomy period did not show a statistically significant variation compared with preoperative values, indicating that the postoperative inflammatory response remained limited. These findings suggest that thermography is capable of detecting even minimal fluctuations in surface temperature during uncomplicated healing periods (Całkosiński et al., 2015; Gumpert Herlofson, 2017).

In the studies conducted on wound healing physiology in literature, it has been reported that in

the primary phase of the inflammation an apparent increase was determined in the surface temperature, thereafter the temperature reaches a plateau in proliferative phase or decreased slightly (Robson, 2001; Eming et al., 2007; Düzgün and Or, 2009). In our study, the slight decrease in temperature observed on postoperative day 1 likely reflects the early vasoconstrictive phase following surgical trauma, whereas the gradual increase observed on postoperative days 4–7 may correspond to the transition to the proliferative phase of wound healing. However, these changes were not statistically significant, suggesting that the inflammatory response at the surgical site remained limited.

Christensen et al. (2012) reported that the thermographically measured surface temperature increased significantly during the inflammatory period following dental surgery, and that this increase decreased after anti-inflammatory treatment. Similarly, Ventä et al. (2001) reported that anti-inflammatory treatment reduced the surface temperature values. In the present study, although no anti-inflammatory treatment was administered, no statistically significant increase in surface temperature was detected, suggesting that orchiectomy induces relatively minor surgical trauma and that the associated inflammatory response remains mild and localized.

In veterinary literature (Head and Dyson, 2001; Levet et al., 2009) and dog models (Gumpert Herlofson, 2017), in postoperative assessments made by thermography, it is shown that; inflammatory response reached its peak within the first 48–72 hours and displayed a decreasing trend thereafter. Compared to these data, the lower amplitude shown by temperature variations measured in cats can be explained by scrotum's rich vascular structure and thermoregulation capacity. Pampiniform plexus and surface venous mesh limits the reflection of hyperemia, which develops after surgery, to the surface temperature and protects the thermal balance (Vianna and Carrive, 2005).

In our study, no statistically significant difference was found between the temperatures of the right and left testes. And this result is coherent with the literature which set forth that thermal symmetry is an expected property in healthy animals (Yanmaz et al., 2007; Całkosiński et al., 2015). Bilateral thermal parallelism after the operation reveals that the inflammatory load of the surgical area has

distributed symmetrically, and the local response has not created symmetric effects.

In case of making an assessment methodologically, keeping room temperature ($22.33 \pm 1.19^\circ\text{C}$) and animals' body temperature ($38.22 \pm 0.61^\circ\text{C}$) constant meets the necessities of IACT (Amalu, 2015) standards. This increased the repeatability of the measuring and minimized environmental factors' effect on thermal data. Düzgün and Or. 2009, similarly, emphasized that; as regards the wound healing, the standardization of environmental conditions is critical for the reliability of thermographic assessments. However, considering the limited number of samples and considering that the measuring only depends on surface temperatures; this situation limits the quantitative assessment of inflammatory variations at microvascular level. In future studies, using thermography along with doppler ultrasonography and tissue biomarkers shall provide opportunity to the versatile characterization of the inflammatory response (Wicke et al., 2000; Robson, 2001).

CONCLUSION

Results obtained in this study showed that no statistically significant differences in scrotal surface temperature were detected following orchiectomy in cats.

Thermography, as a non-invasive and repeatable method that does not induce additional stress, has the potential to monitor postoperative wound healing dynamics. The findings suggest that this method may be clinically useful, particularly for establishing physiological reference values in uncomplicated surgical cases and for the early detection of abnormal inflammatory responses. Advanced studies with larger samples, in different types and supported by multi-mode imaging techniques, shall reveal the diagnostic value of the thermography more apparent in veterinary surgery.

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