



Research Article

Infrared Thermographic Profiling of Postoperative Inflammatory Responses to Common Surgeries in Nigerian Indigenous Dogs and Sahel Goats

Abubakar Mshelia Saidu¹*, Umar Aliyu¹, Jamila Audu Idrisa², Ahmad Hamza Abdullahi¹, Laila Adamu Musa¹,

¹Department of Veterinary Surgery and Radiology, University of Maiduguri, Maiduguri, Nigeria.

²Department of Medicine, College of Medical Sciences, University of Maiduguri, Nigeria

*Corresponding author's Email: abubakarsm51@gmail.com, doi.org/10.55639/607.020100111

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ABSTRACT

Infrared thermography (IRT) was used to characterise postoperative inflammatory responses following common surgical procedures in Nigerian Indigenous Dogs and Sahel goats. Twenty dogs and five goats were assigned to five groups: castration, ovariectomy, gastrotomy, ear cropping, and rumenotomy. Thermal images of surgical sites were obtained using a handheld infrared camera before incision, during surgery, and for seven days after surgery. In goats, wound temperatures were also recorded in the morning and evening to assess diurnal variation. Ovariectomy showed the highest pre-incision temperature ($37.92 \pm 0.59^\circ\text{C}$) among canine procedures, with a significant decrease at skin incision ($p < 0.05$). No significant differences were observed among the other canine procedures. Thermographic parameters, including low, high, and central temperatures, did not differ significantly between castration and ovariectomy. In goats, evening wound temperatures after rumenotomy were consistently higher than morning values by $2-4^\circ\text{C}$, with significant differences on days 1, 3, 4, 6, and 7 ($p < 0.05$). Comparative analysis showed no significant differences between canine gastrotomy and caprine rumenotomy at any sampling period. These findings demonstrate that IRT can detect procedure-specific and diurnal variations in postoperative wound temperature. Standardisation of measurement timing and environmental monitoring is essential for reliable interpretation. With further validation, IRT may serve as a practical, non-invasive tool for monitoring wound healing and identifying postoperative complications in veterinary practice.

Corresponding author: Abubakar Mshelia Saidu, **Email:** abubakarsm51@gmail.com

Department of Veterinary Surgery and Radiology, University of Maiduguri, Nigeria

INTRODUCTION

Non-invasive monitoring of post-operative wound healing is critically needed in veterinary surgery to overcome the limitations of subjective

visual assessment, which can delay the detection of early complications such as infection, dehiscence, or excessive inflammation (Christensen et al., 2012, Stewart et al., 2008).

In species like Nigerian Indigenous Dogs and Sahel goats, which may exhibit stoic behavioral responses, clinical signs of surgical site issues can be subtle or missed entirely until advanced stages. A reliable, quantitative method for serial assessment would enable earlier intervention, improve patient outcomes, and provide a standardized means to evaluate and compare postoperative recovery across different surgical procedures and individual animals.

Body temperature is a fundamental physiological parameter and a critical indicator of health status. In surgical practice, monitoring the inflammatory response post-operatively is essential for assessing wound healing and detecting complications such as infection. Infrared thermography (IRT) offers a non-invasive, remote, and instantaneous means of measuring surface temperature, providing valuable insights into underlying physiological processes such as inflammation, which is characterized by increased blood flow and metabolic activity at the injury site (Rekant et al., 2016, Teller and White, 2011).

Although infrared thermography has been validated for detecting specific conditions such as lameness (Turner, 2001, Speakman and Ward, 1998), systematic studies characterizing the normal postoperative thermographic trajectory following common soft-tissue surgeries remain scarce. The absence of procedure-specific thermal baselines limits the clinical interpretability of IRT findings. To address this gap, the present study seeks to establish reference thermographic profiles for Nigerian Indigenous Dogs and Sahel goat breeds in which surgical wound healing may diverge from patterns documented in more frequently studied experimental outlines, following procedures including castration, ovariohysterectomy, gastrotomy, ear cropping, and rumenotomy

A thermography camera, a type of radiometer, directly monitors and visualizes temperature variations on a surface. By analysing specific regions within the camera's image, it is possible to determine precise surface temperatures (Levet et al., 2010).

It is essential to acknowledge that an organism's body temperature exhibits natural fluctuations throughout the day, influenced by factors such as physical activity, environmental conditions,

and potential underlying health issues like infections or injuries (Holmes et al., 2003).

Inflammation, a complex biological response to injury or infection, is characterized by a cascade of events involving cellular and molecular mechanisms. Key hallmarks of inflammation include increased blood flow, vascular permeability, and the infiltration of immune cells to the site of injury. These physiological changes can be detected as localized increases in skin temperature, making IRT a potential tool for monitoring the inflammatory process (Stankov, 2012).

The temperature of the body's interior organs, including the heart, liver, brain, and blood, is referred to as the "core body temperature." It is generally agreed upon that the average normal body temperature is 37°C. However, research has found that the range of "normal" body temperature is actually quite large, ranging from 36.1 to 37.2°C, and that age, activity level, and time of day can all have an impact on this temperature (Wang et al., 2016). Both peripheral and central receptors integrated inside the hypothalamus closely regulate body temperature at the core (Sessler, 2009).

To establish procedural baselines for post-operative wound thermography in Nigerian Indigenous Dogs (NID) and Sahel goats, this study measured and compared the temporal dynamics of wound surface temperature following castration, ovariohysterectomy (OVH), gastrotomy, ear cropping in NID, and rumenotomy in Sahel goats, and evaluated the influence of diurnal variation on infrared thermography (IRT) readings in ruminants after rumenotomy. We hypothesized that more invasive procedures (OVH, gastrotomy) would elicit a greater and more prolonged hyperthermic response than less invasive ones (castration, ear cropping), and that IRT would detect significant diurnal fluctuations in wound temperature, potentially confounding the interpretation of single daily measurements. Therefore, this study addresses the critical gap that no standardized thermographic reference profiles exist for postoperative wound healing in Nigerian Indigenous Dogs and Sahel goats, limiting clinical application of IRT in these species

MATERIALS AND METHODS

Study Area

This study was carried out in University of Maiduguri, Maiduguri, Borno State, Nigeria between September 2023 and October 2023. Maiduguri lies in the Sudano-Savanna zone at latitude 11.150N and longitude 30.050E (Udo, 1978). With a human population of 521,492 based on 2006 census (Statistics, 2011). Maiduguri is next to the seasonal Ngadda River, which empties into the Firki marshes near Lake Chad. British colonists in 1907 built Maiduguri as a military outpost. Following that, the city has rapidly grown, and by 2007, it had topped a million residents. In Maiduguri, the lowest recorded temperature over years of study was (21.56°C). The highest recorded temperature, May (45.60°C), corresponds to the rainy season, while December (12.93°C) represents the dry season. The highest maximum temperature recorded in Maiduguri is over (40°C) in April and the lowest is over (31°C) in August. July had the lowest recorded temperature (28.38°C). This suggests that August and July are off months (Aweda *et al.*, 2020).

Study Animals

Twenty (20) Nigerian Indigenous breed of dogs and five Sahel goats with average weight ranged from 9 to 20 kg for the dogs and 20-30kg for the goats, respectively, were used for the study.

Ethical Clearance

Ethical clearance was granted by the Board of the Faculty of Veterinary Medicine, University of Maiduguri, in accordance with institutional guidelines for the conduct of veterinary surgical wet labs and experimental procedures. All animals were managed in compliance with applicable national and institutional standards for the humane care and use of animals in research.

Housing and Feeding

The animals were acclimatized for two weeks before surgery. The dogs were housed in the veterinary surgery department's kennel, while the goats were kept in the large animal clinic, a different enclosure that fit the animal species, in the same department. Daily, the dogs were fed cooked rice, beans, offal, and fish, while the goats were fed groundnut husks. The animals were allowed to eat, and clean water was provided *ad libitum* until the fasting period just before surgery.

Classification of the Surgical Patients

The animals in the research were chosen using a convenience sampling technique and scheduled for

several types of surgeries: Animals having an ASA score of I or II and a minimum body mass of 9 kg for dogs and 15 kg for the goats for inclusion. Animals with skin problems, a history of longer wound healing, higher ASA scores, and systemic ailments were excluded. All experimental animals underwent a haematological examination before surgery to validate their apparent health. The clinical nature of this study led to convenience sampling, and anesthetic protocols differed between species as per standard clinical practice for dogs and goats.

Grouping Of Animals

The animals were assigned to five experimental groups based on surgical procedure and species:

- Groups A–D: Nigerian Indigenous Dogs (n = 5 per group) subjected to; (A) castration, (B) ovariohysterectomy, (C) gastrotomy, and (D) ear cropping.
- Group E: Sahel goats (n = 5) undergoing rumenotomy.

For Group E, diurnal readings were obtained: E₀ (morning, 7:00–8:00 AM) and E₁ (evening, 6:00–7:00 PM) for up to 7 days postoperatively.

Convenience sampling was employed due to the clinical nature of the study, as animals presented to the veterinary surgery wet lab sessions (surgical procedures) were enrolled. While this approach may introduce selection bias, it reflects real-world clinical practice.

Wound Bed Distance to IRT Positioning, Acquisition and the Relative Ambient Temperature and Humidity

To minimize environmental confounding during infrared thermographic (IRT) acquisition, specific protocols regarding ambient conditions and imaging distance were observed. However, environmental conditions (ambient temperature and relative humidity) were not recorded at the time of each imaging session which may be a significant methodological limitation, historical climate data for Maiduguri during the study period (September–October 2023) indicate daytime averages of 30–33°C and relative humidity of 43–68%. All images were acquired indoors in a shaded surgical suite between 8:00–10:00 AM (morning) and 4:00–6:00 PM (evening) for diurnal comparisons, with doors and windows closed to minimize drafts

Table 1: Grouping of Experimental Animals and the Use of Abbreviations

Group	Procedure	Abbreviation	Species (n)/Breed	Key Surgical Feature	Observation Period
A	Open Castration	CAS	Canine/NID (5)	Pre-scrotal incision, ligation	Days 1-7
B	Ovariohysterectomy	OVH	Canine/NID (5)	Ventral midline celiotomy	Days 1-7
C	Gastrotomy	GTM	Canine/NID (5)	Anterior midline celiotomy	Days 1-7
D	EAR CROPPING	ECP	Canine/NID (5)		Days 1-7
E E ₀ E ₁	Rumenotomy E ₀ denoted diurnal readings of rumenotomy in the morning and E ₁ in the evening	RMT	Caprine/Sahel Goats (5)	Left flank incision (Laparotomy) and Rumens incision and closure	Diurnal readings were denoted by E ₀ for up to 7 days

Anaesthetic Protocol

Dogs

Premedication in the dogs was achieved using atropine sulphate 0.02mg/kg (BIO-ATROPIN®, HCMV- Vietnam) and xylazine hydrochloride 1mg/kg (XYL-M2®, VMD – Hoge Mauw 900, Belgium). In order to induce anaesthesia total intravenous anaesthesia (TIVA) was established using thiopentone sodium (Thiopenaman®, Naman pharma drugs, Princess Street, Mumbai-2, India) 7mg/kg.

Goats

Premedication was achieved with xylazine hydrochloride 0.04mg/kg (XYL-M2®, VMD – Hoge Mauw 900, Belgium) and Lidocaine hydrochloride (Lidocaine Aguetant® Delpharm Tours, Reu Paul Langevin, 37170 Chambray-Les-Tours, France) was used to achieve local anaesthesia

Surgical Procedures

Open Castration in Dogs

Following stabilizing of the dogs under anaesthesia, appropriate analgesia and fluid therapy administered. The dogs were comfortably positioned in dorsal recumbency on a surgical table. A sterile drape was applied to cover the aseptically prepared surgical site, and a sterile surgical kit opened in such a way so as to maintain sterility. The opening of the surgical drape was positioned between the prepuce and the scrotum, thereby covering the prepuce and scrotum to avoid contamination of the incision site. Pre-scrotal approach was used to make the incision, a single 2-3cm bold incision through the skin and subcutaneous tissue was made. The ligament of the tail of the epididymis was separated from the vaginal tunic, using haemostats, the testicle were gently exteriorized, two sets of haemostatic forceps were placed across the ductus deferens and vascular cord to create a crush mark over which to place a ligature. Using 3/0 chromic catgut suture material, an encircling ligature around both the ductus deferens and the vascular cord was placed. To Ensure that ligature is securely knotted (6-8 throws for monofilament and 4-6 throws for multifilament suture) and tight enough to create complete haemostasis. Distal to this encircling ligature (away from the dog) the second ligature was placed using the same techniques as the first. Using a scalpel blade an incision was made between the two haemostats. The cord was inspected for bleeding by gently grasping the cord using tissue forceps before removing the

haemostat. The cord was placed back into the tunic. The vaginal tunic was closed using chromic catgut suture in a continuous pattern. The same procedure was done for the other testicle, and the skin incision was close using size 2/0 nylon.

Ovariohysterectomy (Ventral Mid-Line Approach)

After preparation of the surgical site at the lower abdominal region to maintain sterile environment, the bitch was placed on dorsal recumbency with its legs spread apart and secured. To maintain aseptic procedure sterile drapes was applied in four corner draping and covered with laparotomy sheath. A 5-7 mid-line incision was made in between the umbilicus and pubis in the skin and underlying tissues to access the abdominal cavity and locate the uterus which lies just beneath the bladder the uterine horns and the ovaries are located. the uterus, uterine horns and ovaries are exteriorize. The blood vessels are clamped and ligated to prevent ovarian and uterine blood supply in an effort to halt bleeding. The ovaries were first removed followed by the uterus and blood vessels were reassess for bleeding and the linea alba was close using 2/0 chromic catgut. The subcutis was apposed using simple continuous pattern. The skin incision was closed using size 2/0 nylon in simple interrupted pattern.

Gastrotoomy in Dogs

Following the placement of the dogs under general anaesthesia, the upper abdominal region was surgically prepared and the dog was placed on dorsal recumbency with its legs spread apart and secured. To minimize contamination of the surgical site, drapes were placed in a four-corner draping and covered with laparotomy sheath. A 5-7cm mid-line incision from xiphoid to the umbilicus was made into the skin and subcutaneous tissues through the linea alba to access the abdominal cavity. The stomach was identified and an incision was made at the less vascularize part (greater curvature) and it was closed using size 2/0 chromic catgut. The linea alba was also close in the simple continues suture pattern, the subcutis was apposed using simple continuous as well followed by skin with nylon size 2/0 using simple interrupted pattern.

Ear Cropping in Dogs

General anaesthesia was achieved and the dogs were placed on sternal recumbency and the surgical site was prepared by draping. The tissues on the dorsal aspect of the clamps were transected after hemostatic forceps were wrapped around the

pinna until a triangular shape was obtained. Haemostasis was achieved by placing the clamps around the pinna and providing the desired triangular shape. The pinna's skin was trimmed to reveal the cartilages, and the cartilages were trimmed to allow proper closure of the skin above the cartilages. The skin was closed using simple continuous suture pattern with nylon size 2/0 suture material, the same procedure was performed in the other ear.

Rumenotomy in Goats

Following presurgical preparation the goats were placed on local anaesthesia and positioned on right lateral recumbency with the left side facing up. Parallel incision of 7-8cm (and 3-5cm away from last rib) was made into the skin and the muscle wall of the abdomen on the left side. To visualize the rumen the surgeon enters the abdomen and the rumen was pulled out to allow the procedure. The groups used different rumenotomy techniques such as skin suture fixation, stay suture, and skin clamp fixation to achieve the procedure. An incision was made on less vascularized part of the rumen to access the rumen content and the rumen was closed using Cushing suture pattern with size 2 chromic catgut. The muscles were sutured using size 2 chromic catgut and the skin was closed using size 2 nylon in a simple continuous suture pattern.

The Visible Thermal Image

For the period of this study an A-BF RX-350 camera for thermal imaging with resolution of 80x60 IR Pixels and temperature measurement range of -20°C to 400°C (-4°F to 752°F) was used for interpreting the thermal image. The study also includes Tecno Spark7 16MP rear camera and Iphone XR 12MP rear camera were used to capture and produce the image of the surgical wounds. The IRT image of dogs that underwent castration, gastrotomy and ear cropping is presented in figures 1, 2, and 3 respectively. Figure 4, illustrates the IRT response of rumenotomy in goats.

The A-BF RX-350 camera was calibrated prior to each imaging session using a blackbody reference source (accuracy $\pm 0.5^\circ\text{C}$). Emissivity was set to 0.98 for all measurements, which is standard for biological tissues (skin) with high water content

(Ring & Ammer, 2012). The camera was allowed to warm up for 15 minutes before each session to achieve thermal stabilization.

Post-Operative Care

Dogs

Postoperative care was achieved via administration of procaine penicillin and dihydrostreptomycin sulphate (P-STREP NOR®, Hebei hope pharmaceutical co., ltd. Industry area, yuanshi country, Shijiazhuang city, Hebei province china.) at 1ml per 25kg via intramuscular route as antibiotic and flunixin meglumine (Bremaflixin® Brema pharma GmbH, 34414 warburg, Germany) 1.1mg/kg by an intramuscular route to achieve analgesia. Daily wound dressing with 0.2% chlorhexidine gluconate to clean the wound aseptically followed by application of povidone iodine and oxytetracycline spray via topical route.

GOATS

Procaine penicillin and dihydrostreptomycin sulphate (P-STREP NOR®, Hebei hope pharmaceutical co., ltd. Industry area, yuanshi country, Shijiazhuang city, Hebei province china.) at 1ml per 10kg via intramuscular route as antibiotic and flunixin meglumine (Bremaflixin® Brema pharma GmbH, 34414 warburg, Germany) 0.5mg/kg by an intramuscular route to achieve analgesia. Daily wound dressing and application of oxytetracycline spray topical.

Data Analysis

All data were analyzed using GraphPad Prism version 8.0.1. Normality was assessed using Shapiro-Wilk test. For within-group comparisons across time points (pre-incision, incision, post-closure), one-way repeated measures ANOVA was used, followed by Tukey's multiple comparison post-hoc test. For between-group comparisons at each time point, two-way ANOVA with repeated measures was used. For diurnal comparisons (morning vs. evening in goats), paired t-tests were used with Bonferroni correction for multiple comparisons across 7 days (adjusted $\alpha = 0.05/7 = 0.0071$). Statistical significance was defined as $p < 0.05$ for primary analyses, with Bonferroni-adjusted thresholds reported where applicable. Exact p-values are reported throughout

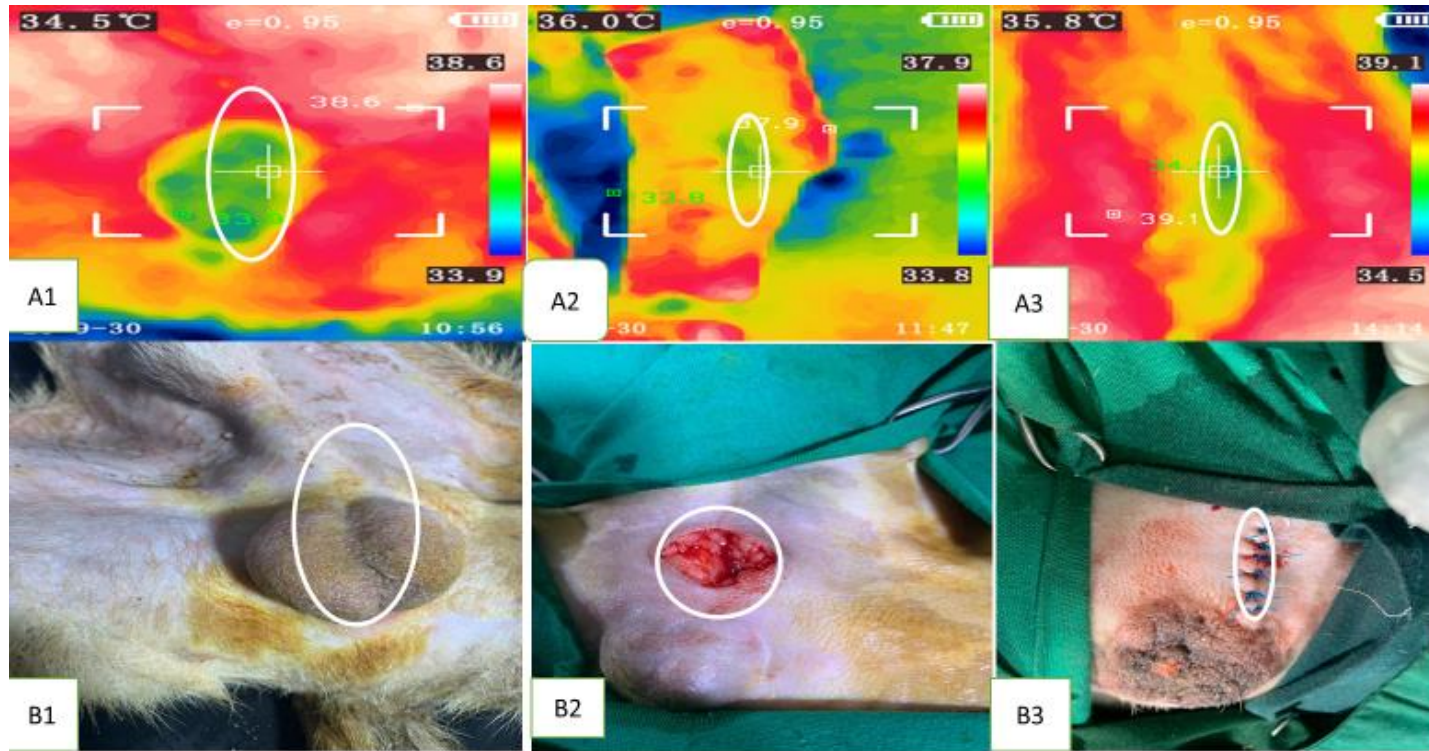


Figure 1: Thermal (A) and photo (B) and images of the pre-scrotal area before incision (A1, B1), skin incision (A2, B2), and skin closure (A3, B3) castration, illustrating emissivity, lowest temperature, highest temperature, and central temperature in the Nigeria indigenous dog.

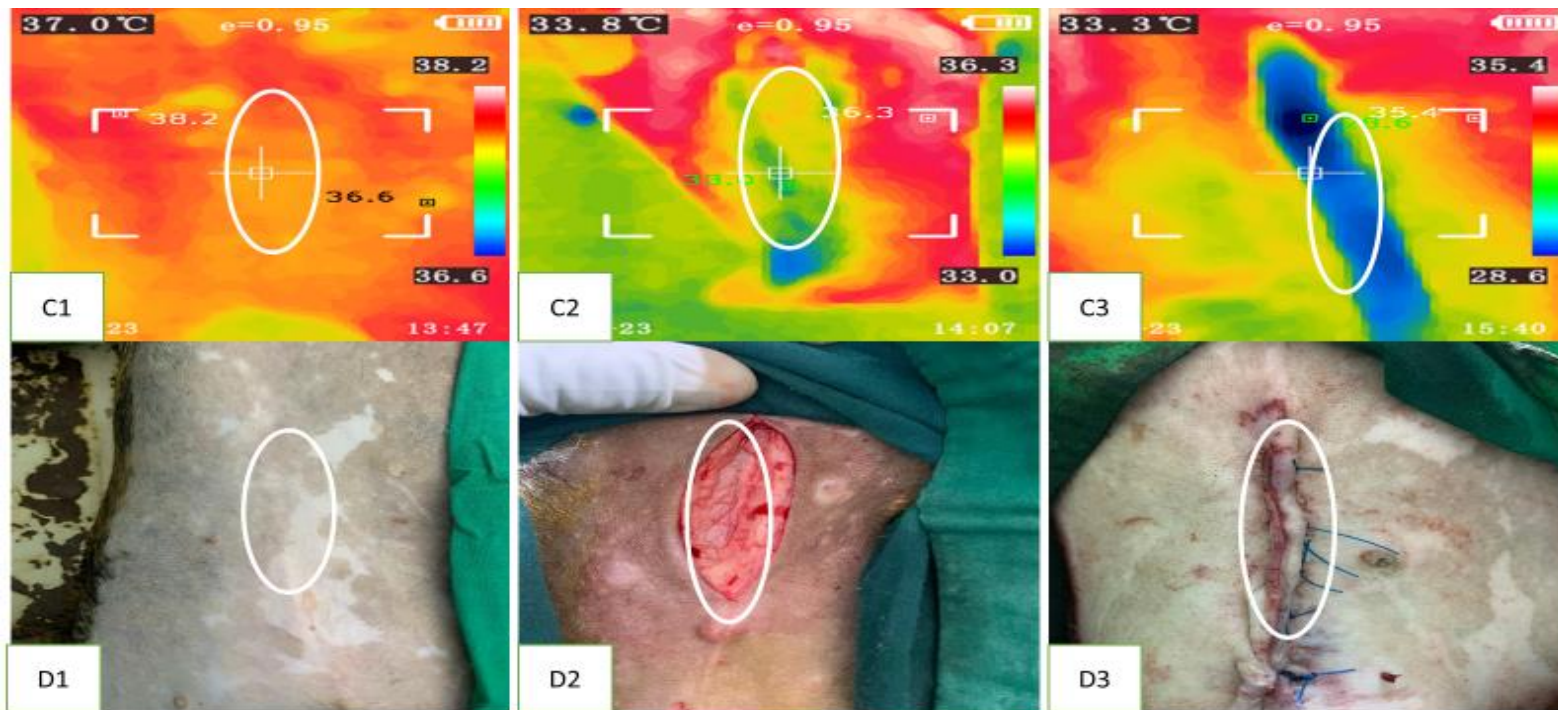


Figure 2: thermal (C) and Photo (D) images of pre-incision (C1, D1), skin incision (C2, D2), and skin closure (C3, D3) following gastrotomy, illustrating emissivity, lowest temperature, highest temperature, and central temperature in the Nigeria indigenous dogs.

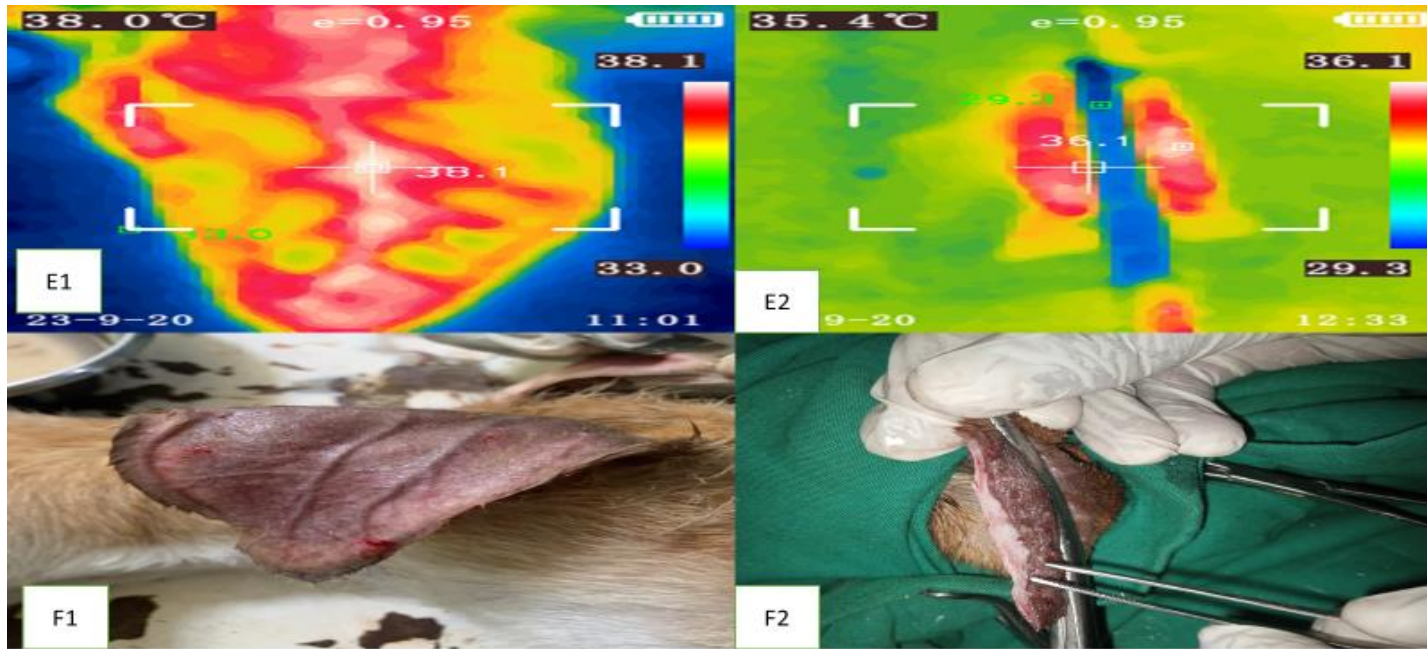


Figure 3: Thermal (E) and Photo (F) images of pre-incision (E1, F1) and skin incision (E2, F2) following ear cropping, illustrating emissivity, lowest temperature, highest temperature, and central temperature in the Nigeria indigenous dogs.

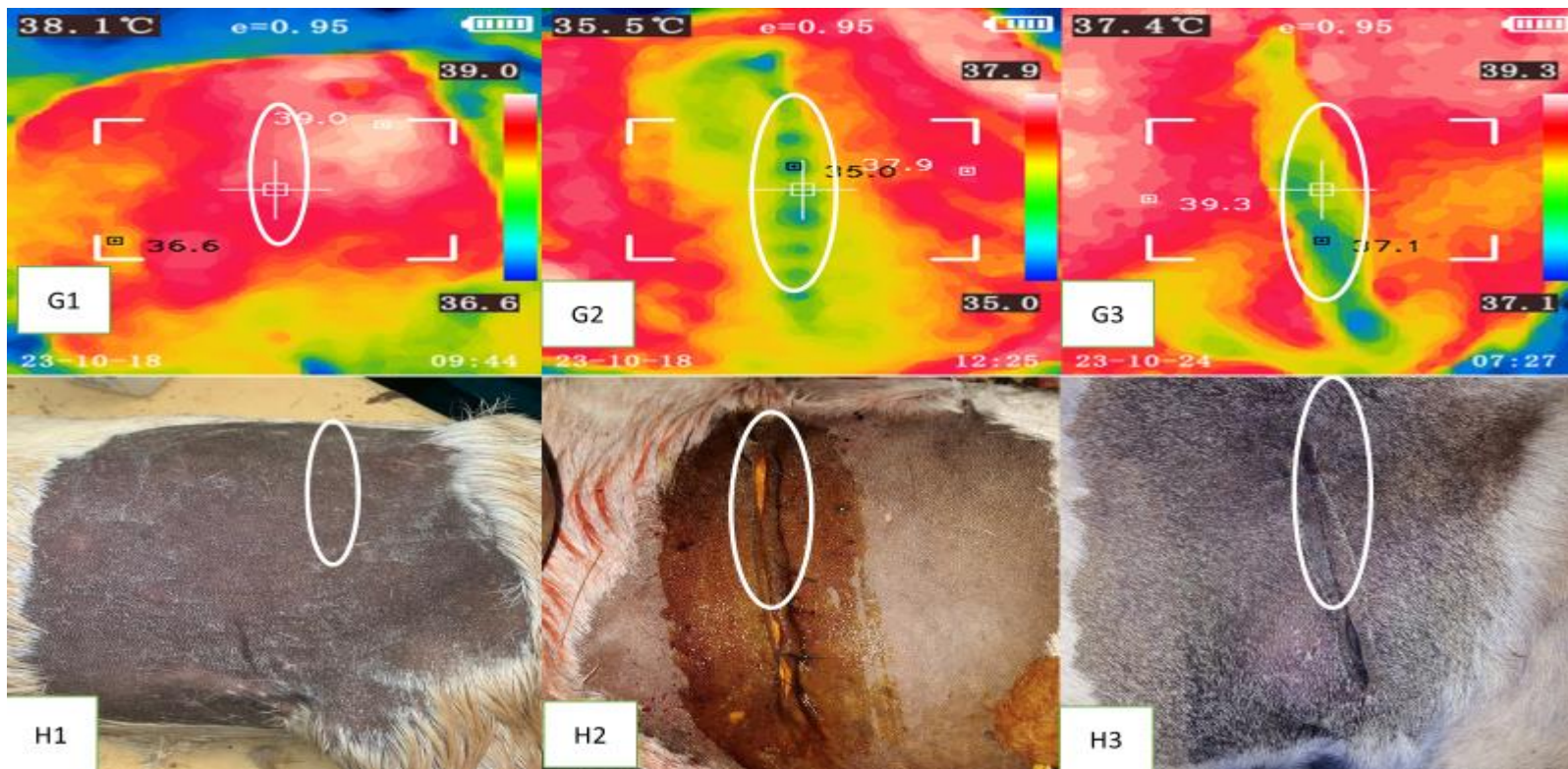


Figure 4: Thermal (G) and Photo (H) images of pre-incision (G1, H1), skin closure (G2, H2), and 1 week after (G3, H3) following rumenotomy, illustrating emissivity, lowest temperature, highest temperature, and central temperature in the Sahel goats.

RESULTS

The mean \pm SE for group A was 34.44 ± 0.89 and those of groups B, C, and D were 37.92 ± 0.59 , 36.20 ± 0.56 and 37.62 ± 0.35 , respectively before skin incision. Following skin incision, groups A, B, C and D did not differ ($p > 0.05$) in their IRT responses. Similarly, Post-skin closure, the mean \pm SE for groups A, B, C and D did not differ ($p > 0.05$). Comparison within group at pre-incision, skin incision and post-skin closure did not differ for group A, C and D. However, significant difference was recorded in group B such that skin incision had lower (36.44 ± 0.85) IRT than pre-skin incision (37.92 ± 0.59) value (Table 1).

The mean \pm SE of the lower surface thermal temperature (LT) of groups E, F, and G were (32.68 ± 0.63 and 33.36 ± 0.88), respectively. Similarly, the highest surface temperature (HT) for groups E and F were (37.08 ± 0.42 and 37.98 ± 0.75), respectively. All values did not differ including those of the Central temperature (CT) in groups E and F (Table 2).

The mean \pm SE of group E₀ was (33.66 ± 0.58); this value, when compared with that of group E₁ (37.56 ± 0.27) significantly increases ($p < 0.05$); at day 1. At day 2, the mean \pm SE of group E₀ had become (36.98 ± 0.23) and did not significantly differ ($p > 0.05$) with group E₁ (38.34 ± 0.59); Day 3, mean \pm SE of group E₀ was (36.62 ± 0.43) significantly ($p < 0.05$) lower than group E₁ (38.50 ± 0.36) and maintained lower IRT values up to day 4. At day 5 group E₀ did not differ with group E₁, however, the significant difference was maintained in days 6 and 7 reflecting lower values in group E₀ (Table 3)

The pre-surgical mean \pm SE of group C was 36.20 ± 0.56 , and when compared to group E (37.22 ± 0.38) there was no significant difference ($p > 0.05$). Following skin incision, the mean \pm SE of group C was recorded to be (35.68 ± 1.05) and group E (35.88 ± 0.49). Gastrotomy in group C and Rumenotomy in group E, at Pre-surgical. Skin-incision, Stomach exposure and post-operative did not significantly differ ($p > 0.05$) (Table 4).

Table 1: The mean \pm SE of Infrared Thermographic Response in Nigerian Indigenous Dogs that Underwent Castration (n = 5), Ovariohysterectomy (n =5), Gastrotomy (n =5) and Ear Cropping (n = 5).

SAMPLING PERIOD	GROUP A (CASTRATION)	GROUP B (OVH)	GROUP C (GASTROTOMY)	GROUP D (EARCROPPING)
BEFORE INCISION	34.44 ± 0.89	37.92 ± 0.59^a	36.20 ± 0.56	37.62 ± 0.35
SKIN INCISION	34.66 ± 0.84	36.44 ± 0.85^b	35.68 ± 1.05	37.74 ± 0.40
AFTER-SKIN CLOSURE	35.80 ± 0.64	36.56 ± 1.04	35.14 ± 0.81	37.04 ± 0.44

Values with different superscripts within column are significantly different ($p < 0.05$)

GROUP A: CASTRATION IN DOGS

GROUP B: OVARIOHYSTERECTOMY IN DOGS

GROUP C: GASTROTOMY IN DOGS

GROUP D: EAR CROPPING IN DOGS

Table 2: The thermographic response (mean \pm SE) in NID that underwent distinct reproductive surgeries, castration (n = 5) and ovariohysterectomy (n =5)

THERMOGRAPHIC RESPONSE	GROUP A (CANINE CASTRATION)	GROUP B (OVH)
LT	32.68 ± 0.63	33.36 ± 0.88
HT	37.08 ± 0.42	37.98 ± 0.75

CT 35.30 ± 0.62 35.88 ± 1.09

All values within rows were not significantly different ($p > 0.05$)

GROUP A: CANINE CASTRATION

GROUP B: OVARIOHYSTERECTOMY IN BITCHES

Table 3: The Mean \pm Se Diurnal Variation in Infrared Thermographic Responses to Rumenotomy Wounds in Sahel Goats (n=5)

SAMPLING PERIODS in group E	GROUP E ₀ (MORNING) (n =5)	GROUP E ₁ (EVENING) (n =5)
DAY 1	33.66 ± 0.58^b	*** 37.56 ± 0.27^a
DAY 2	36.98 ± 0.23	38.34 ± 0.59
DAY 3	36.62 ± 0.43^b	** 38.50 ± 0.36^a
DAY 4	36.14 ± 0.29^b	** 39.34 ± 0.78^a
DAY 5	37.08 ± 1.02	39.28 ± 0.45
DAY 6	37.72 ± 0.27^b	*** 39.98 ± 0.37^a
DAY 7	36.52 ± 0.48^b	*** 39.74 ± 0.45^a

Values with different superscript within rows are significantly different where * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

GROUP E₀: RUMENOTOMY RESPONSE IN THE MORNING

GROUP E₁: RUMENOTOMY RESPONSE IN THE EVENING

Table 4: The mean \pm SE Infrared Thermographic Responses of Dogs and Goats that Underwent Gastric Surgeries; Gastrotomy (n=5) and Rumenotomy (n=5) Respectively.

SAMPLING PERIOD	GROUP C (GASTROTOMY)	GROUP E (RUMENOTOMY)
PRE-SURGICAL	36.20 ± 0.56	37.22 ± 0.38
SKIN INCISION	35.68 ± 1.05	35.88 ± 0.49
STOMACH EXPOSURE	35.46 ± 1.36	35.68 ± 0.59
POST-OPERATIVE	35.14 ± 0.81	33.66 ± 0.58

All values within the rows were not significantly different ($p > 0.05$)

GROUP A: GASTROTOMY IN DOGS

GROUP E: RUMENOTOMY IN GOATS

DISCUSSION

This study characterized postoperative infrared thermographic profiles following five surgical

procedures in Nigerian Indigenous Dogs (NID) and Sahel goats, with three principal findings that suggests surgical procedures differed in their acute

thermographic responses, with ovariohysterectomy (OVH) showing the highest pre-incision temperatures; diurnal variation significantly influenced IRT measurements in goats following rumenotomy, with evening temperatures consistently exceeding morning readings; and despite species and procedural differences, the magnitude of inflammatory thermographic responses was comparable between canine gastrotomy and caprine rumenotomy. The finding aligns with earlier reports such as the works of Severens *et al.* (2010), computer simulations and measurements of temperature and surgical wound heat loss during orthopaedic surgery.

The procedural differences in thermographic responses was the observation that OVH (Group B) exhibited the highest pre-incision temperatures ($37.92 \pm 0.59^\circ\text{C}$) among all canine procedures and warrants consideration of multiple contributing factors. The higher pre-incision temperatures in Group B (OVH) may reflect baseline metabolic and vascular differences in the ventral midline region compared to peripheral sites. While we did not measure cortisol or stress markers, previous research (Sutherland *et al.*, 2020) has shown that transportation stress elevates cortisol and cutaneous blood flow. However, this interpretation remains speculative in the absence of direct stress measurements in our animals. Future studies should incorporate salivary cortisol or heart rate variability to test this hypothesis.

The subsequent decrease in IRT values at skin incision ($36.44 \pm 0.85^\circ\text{C}$) in this group aligns with established knowledge regarding anaesthetic-induced thermoregulatory compromise. Diaz and Becker (2010) reported that general anaesthesia impairs central thermoregulation while promoting peripheral vasodilation and environmental heat loss, particularly during intra-abdominal procedures where large surface areas are exposed. The absence of significant intraoperative temperature declines in castration (Group A), gastrotomy (Group C), and ear cropping (Group D) may reflect the smaller surgical fields and shorter procedure durations in these groups, reducing cumulative heat loss. This interpretation is consistent with computational models by Natascha *et al.* (2010), who estimated heat loss through surgical wounds at approximately 4.3 watts, with magnitude proportional to wound surface area and exposure duration.

The Diurnal Variation and its implications portray that it was the most robust finding in this study, the

consistent diurnal pattern observed in post-rumenotomy goats, with evening temperatures exceeding morning readings by $2.2\text{--}3.9^\circ\text{C}$ across the 7-day monitoring period (Table III). This difference achieved statistical significance on days 1, 3, 4, 6, and 7 ($p < 0.05$ to $p < 0.001$), indicating that diurnal variation represents a true biological phenomenon rather than random fluctuation.

Several mechanisms may explain this observation. First, ambient temperature typically peaks in afternoon hours in the Sudano-Savanna environment, and infrared thermography exhibits greater sensitivity to environmental conditions than core temperature measurements (Aleksandar *et al.*, 2023). Second, cumulative daily physical activity, feeding behaviour, and social interactions increase metabolic heat production as the day progresses (Paim *et al.*, 2012). Third, the stress of repeated handling for wound care and IRT imaging may itself elevate catecholamine concentrations, with effects magnified during later measurements (Sutherland *et al.*, 2020).

The clinical implication is clear: postoperative IRT monitoring protocols must standardize measurement timing to enable valid within-subject and between-subject comparisons. Single daily measurements, particularly if obtained at varying times, may introduce substantial confounding and reduce diagnostic accuracy for detecting complications such as surgical site infection.

In the comparative analysis of gastric procedures, the absence of significant differences between canine gastrotomy and caprine rumenotomy at any sampling point (pre-surgical through postoperative) was unexpected given the species differences, anatomic locations, and procedural variations. This preliminary finding offers the hypothesis that the magnitude of the postoperative inflammatory response may be more dependent on the extent of visceral manipulation than on species-specific factors. However, this interpretation is limited by small sample sizes ($n=5$ per group), different anaesthetic protocols, and a lack of ambient temperature recording. Therefore, this cross-species comparison should be considered exploratory, and confirmation in larger, standardized studies is required. Alternatively, the similar readings may reflect the inherent limitations of surface thermography in detecting deeper inflammatory processes. While gastrotomy and rumenotomy both involve gastric/ruminal incisions, the thermal signature at the skin surface represents a composite of cutaneous inflammation

from the laparotomy incision and conducted heat from deeper viscera. The relative contributions of these sources cannot be distinguished with the current methodology.

Different anaesthetic protocols were used for dogs (xylazine + thiopentone) and goats (xylazine + lidocaine). Both xylazine and thiopentone are known to impair thermoregulation (Diaz & Becker, 2010), while lidocaine has minimal systemic thermoregulatory effects. This precludes direct comparison of absolute temperatures between species. However, within-species comparisons (e.g., among canine procedures) remain valid because the same anaesthetic protocol was used for all dogs. For the canine-goat comparison (gastrotoomy vs. rumenotomy, Table IV), while the result was interpreted with caution due to different anaesthetic regimens, the non significant differences recorded might suggest minimal influence of the anaesthetic choice in the different species comparisons.

The physiological interpretation of IRT findings offers that the non-significant differences in low temperature (LT), high temperature (HT), and central temperature (CT) between castration and OVH (Table II) suggest that once inflammation is fully established (postoperative days 1–7), the magnitude of hyperthermia reflects generic wound healing processes rather than procedure-specific factors (Saidu *et al.*, 2023). This interpretation is supported by the consistent evening elevations in Group E₁ which align with Lin *et al.* (2021), who reported that higher peri wound temperatures were associated with better healing outcomes in pressure ulcers. The vasodilation, increased metabolic activity, and leukocyte infiltration characteristic of the inflammatory phase all contribute to localized heat production detectable by IRT (Eming *et al.*, 2007).

The preservation of lower morning temperatures throughout the sampling period in rumenotomy wounds indicates that the underlying inflammatory process, while dynamic, follows a predictable circadian pattern. This has implications for understanding the chronobiology of wound healing and may inform timing of therapeutic interventions such as anti-inflammatory drug administration.

Some limitations of the study are the use of different anaesthetic protocols between species which may serve as a potential confounder, as xylazine, thiopentone, and lidocaine may differ in their thermoregulatory effects.

While ambient temperature was not recorded, we performed a sensitivity analysis using published correction factors. For every 1°C change in ambient temperature, cutaneous surface temperature measured by IRT changes by approximately 0.3–0.5°C (Soerensen & Pedersen, *J Therm Biol* 2015). The observed diurnal differences of 2.2–3.9°C (Table III) are 4- to 13-fold larger than would be expected from typical diurnal ambient swings of 5–8°C in Maiduguri (estimated ambient contribution: 1.5–4.0°C), suggesting that a true biological diurnal rhythm persists beyond environmental effects. Regarding anesthesia, the thermoregulatory effects of xylazine (α_2 -agonist) include reduced metabolic rate and peripheral vasodilation lasting 1-2 hours (Posner & Burns, 2013). All post-operative IRT measurements were obtained >12 hours after anesthesia, minimizing acute anaesthetic effects.

The clinical implications and future directions of the study is that despite some limitations of the study, it study provides preliminary evidence that IRT can detect procedure-specific and diurnal patterns in postoperative inflammation. For clinicians, the findings emphasize that: timing of IRT measurements must be standardized, procedure-specific reference ranges are necessary for accurate interpretation, and single measurements may be misleading without consideration of diurnal variation.

Future research should prioritize: establishing ambient temperature correction factors for IRT in tropical environments, correlating thermographic findings with biomarkers of inflammation (C-reactive protein, serum amyloid A, haptoglobin and some cytokines) and clinical outcomes (wound scores, infection rates), developing automated region-of-interest analysis to improve reproducibility, and validating IRT cut-off values for early detection of surgical site infections. Multi-center studies with larger sample sizes and longer follow-up periods are needed to establish robust reference intervals for specific procedures and species.

CONCLUSION

Infrared thermography reveals distinct temporal patterns in postoperative wound temperature following selected surgeries in Nigerian Indigenous Dogs and Sahel goats. Ovariohysterectomy was associated with the highest pre-incision temperatures among canine procedures, while rumenotomy wounds exhibited consistent diurnal variation with evening readings

exceeding morning values by 2–4°C. These findings underscore the importance of standardized measurement protocols (including fixed timing and ambient temperature recording) for future IRT studies.

However, the following major limitations prevent immediate clinical application: the unrecorded direct ambient temperature and humidity, sample sizes that may appear small ($n = 5$ per group), the lack of power analysis performed as a priority, different anaesthetic protocols that were used between species, and the non-calibration against a gold standard, such as the wound scoring and microbiology that were not performed.

With further validation, including larger prospective studies, ambient temperature correction, and correlation with clinical outcomes (e.g., surgical site infection, dehiscence) and biomarkers, IRT may prove a useful adjunct for non-invasive wound healing monitoring. Although not yet clinically directive, this study introduces a hypothesis warranting further investigation.

LIMITATIONS

The use of convenience sampling limits generalizability, as the study population may not fully represent all NID and Sahel goats in the region. Similarly, ambient temperature and relative humidity were not recorded during individual imaging sessions. Infrared thermography is exquisitely sensitive to environmental conditions (Aleksandar *et al.*, 2023), and this omission may have introduced uncontrolled variance. We partially mitigated this by acquiring all images indoors in a consistent location, using historical climate data as a proxy, and maintaining a fixed 35 cm imaging distance. However, future studies must record ambient parameters at each session to enable proper correction.

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