the poison®

2026 | Vol. 3 | No. 1: 24-29

CASE SERIES

High-resolution infrared imaging for clinical monitoring of *Bothrops* spp. snakebite envenomations in Uruguay: A case series

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Submitted: 13/11/2025 - Accepted: 15/01/2026 - Published: 31/01/2026 - DOI: https://doi.org/10.62129/EXVU1128

ABSTRACT

Background. In Uruguay, approximately 50 *Bothrops* snakebite accidents are reported each year, most commonly involving *B. alternatus* and *B. pubescens*. Beyond systemic coagulopathy, *Bothrops* envenomation induces marked local inflammatory damage. Infrared (IR) thermography has emerged as a noninvasive technique that does not expose patients to ionizing radiation and is capable of detecting thermal changes associated with tissue inflammation.

Objective. Describe the characteristics and semiological utility of IR imaging compared with standard photographic documentation in the monitoring of local inflammatory processes following *Bothrops* snakebite envenomation.

Methods. Three clinical cases of *Bothrops* envenomation were evaluated using high-resolution IR thermography under controlled environmental conditions. Qualitative thermal images were acquired, and Regions of Interest (ROIs) were delineated to obtain quantitative temperature measurements. Thermal asymmetry was assessed by calculating ΔT values between affected and contralateral anatomical regions.

Results. All cases exhibited localized inflammatory findings—edema, erythema, and pain—without evidence of severe systemic involvement. IR thermography demonstrated thermal asymmetries consistent with active inflammation, with the average temperature difference (ΔTaverage) values >1 °C in all patients, in line with previously reported patterns in *Bothrops* envenomation.

Conclusions. IR thermography provided functional, quantitative assessment of local inflammation that was not attainable through conventional photography. The ability to measure thermal gradients supports its potential role as a semiological tool to monitor local phenomena and identify areas of higher infectious or inflammatory risk in *Bothrops* snakebite accidents.

Keywords: *Thermography; Bothrops; Snake bites; Envenomations; Diagnostic imaging.*

The Toxicological Information and Advice Center (CIAT) of Uruguay records approximately 100 snakebite accidents annually, of which about 50 are caused by two species of the genus *Bothrops*: *B. alternatus* ("Crucera") and *B. pubescens* ("Yara"). In addition to inducing fibrinogen-consumption coagulopathy—its main systemic effect—*Bothrops* venom produces marked local tissue alterations at the bite site, characterized by an inflammatory process that leads to localized edema and pain, often complicated by necrosis and secondary infections.[1-3]

Infrared (IR) imaging has potential as a semiological tool, as it is a bedside, noninvasive method that does not require sedation and does not expose the patient to ionizing radiation.[4] The technique relies on acquiring IR images capable of noninvasively quantifying skin-surface temperature by capturing the radiation normally emitted by the body and generating a high-resolution digital image (thermogram). Although relatively recent, it has become a common practice in several medical fields.[3-5] Analysis of IR images has enabled the study of diseases in which skin temperature reflects underlying tissue inflammation, as well as conditions associated with increased or decreased blood flow.[6-8] Recent studies have also highlighted its potential for assessing local changes observed in *Bothrops* envenomation.[5-9]

OBJECTIVE

Describe the characteristics of the IR image in comparison with the photographic image, assessing its semiological

utility for monitoring local inflammatory processes in *Bothrops* snakebite accidents.

METHODOLOGY

Three clinical cases of *Bothrops* snakebite accidents were analyzed using IR imaging. All images were obtained with informed consent, and the protocol was registered with the Ministry of Public Health. A high-resolution infrared sensor (UltraMax 307,200 pixels), model E75, was used, assuming a skin emissivity of 0.98. Measurements were performed in a controlled environment (23 ± 1°C), and patients were allowed to thermally equilibrate for 15 minutes. For image interpretation, the «rainbow» color scale was selected, in which warmer areas appear in white/red tones and cooler regions appear in blue/black tones. Images were processed using the Snake Fy Thermal software.

After capturing the qualitative thermal images, Regions of Interest (ROIs) were delineated based on anatomical reference points using the camera software's polygon-drawing tool. This allowed comparison of quantitative data from affected areas with corresponding normal or contralateral regions. Thermal magnitudes in the ROIs (quadrilaterals, circles) of the affected limb were compared with their counterparts in the contralateral limb by calculating the temperature differences (ΔT) between the arithmetic means of all pixel temperatures within each ROI. These data enabled a quantitative assessment of temperature asymmetries between venom-affected areas and surrounding tissues of the affected limb or their contralateral equivalents. The average temperature difference (ΔTaverage) across the ROIs was calculated. For this case series, the procedures followed the recommendations of the American Academy of Thermology Point-of-Care Protocol and the Glamorgan Protocol.

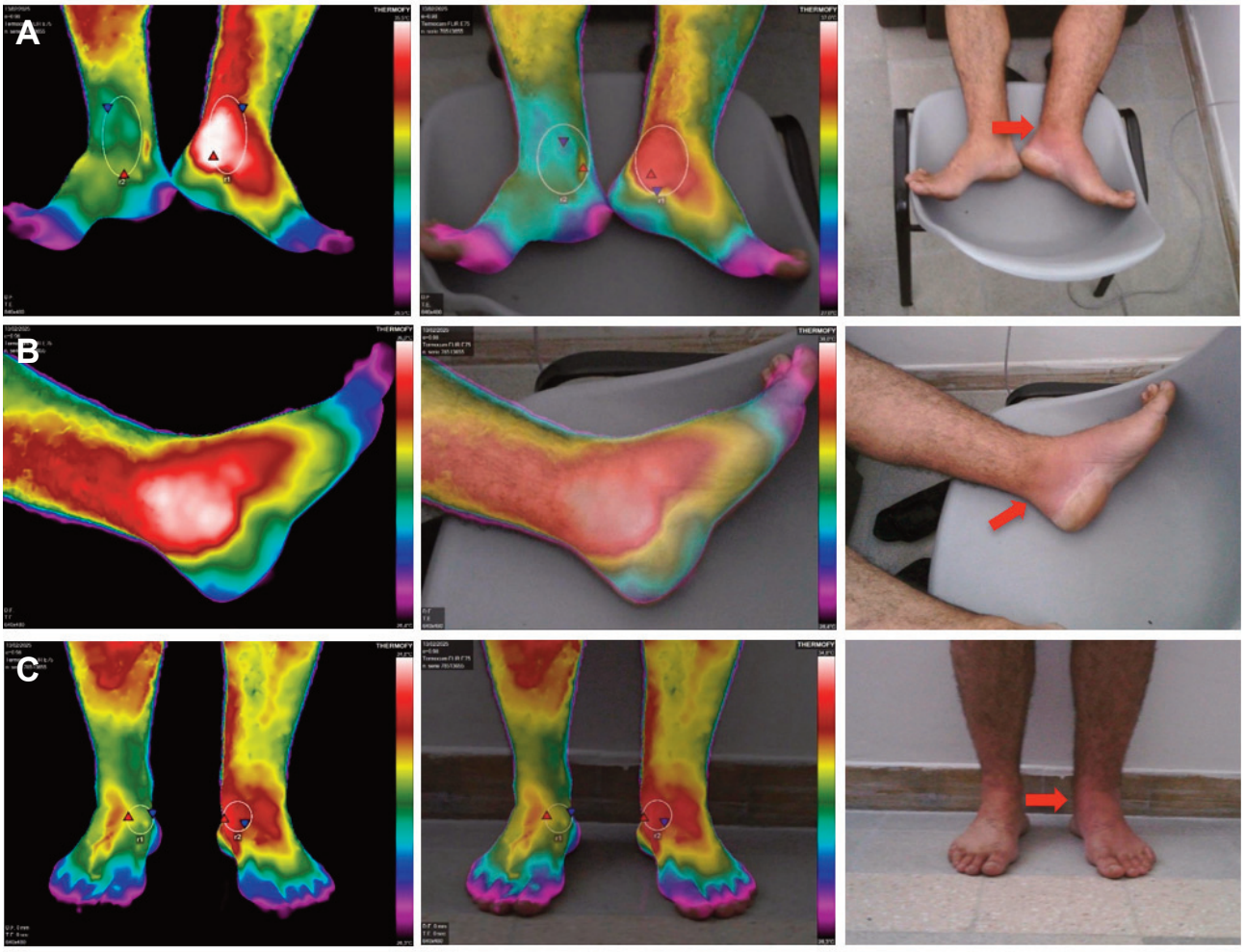

Figure 1 (A, B and C). Thermal images obtained on day 18 from three different approaches, demonstrating a ΔTaverage of 4.02°C in ROI 1 (small red arrow A). The corresponding photographic images show the puncture site (large red arrows) with visible edema and erythema (Credits: courtesy of the authors).

CLINICAL CASES

Clinical case 1

A 36-year-old male patient with no significant past medical history presented with a *B. pubescens* bite on the medial aspect of the left foot. He exhibited no systemic manifestations and received 8 vials of BIOL antivenom (produced by Instituto Biológico Argentino S.A.I.C.) 3 hours after the accident. After 72 hours, he was discharged without systemic abnormalities, although loco-regional edema persisted.

At the 18-day follow-up, the patient reported moderate pain, increased edema, erythema, and local warmth, without fever. Laboratory tests showed leukocytosis (15.8 × 10^3/L) and elevated C-reactive protein (CRP, 43 mg/L). Physical examination revealed edema extending to the mid-leg, two puncture marks without blistering, and localized erythema. Fig. 1 shows clinical photographs of the lesion alongside the corresponding thermographic image, which demonstrated qualitative asymmetry due to the extent of inflammatory changes in ROI 1 (Fig. 1A), with a ΔTaverage value of 4.02°C compared with the contralateral area.

Clinical case 2

A 46-year-old male patient with a history of achondroplasia presented with a *B. alternatus* bite on the medial aspect of the right thigh. He developed incoagulability and received 16 vials of BIOL antivenom 2 hours after the accident.

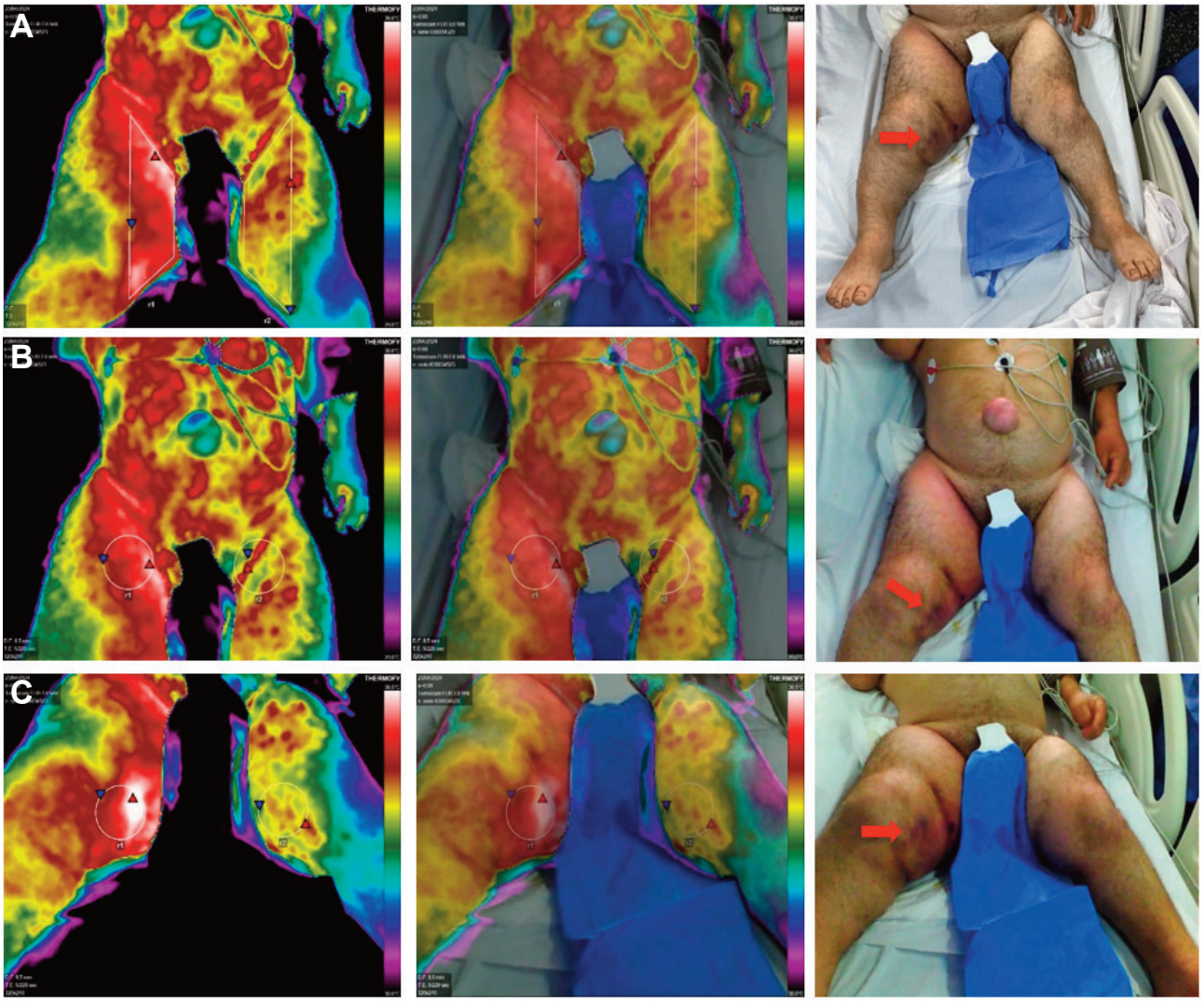

Figure 2 (A, B and C). Thermal images obtained on day 4 showing a ΔTaverage of 1.42°C in ROI 1 (small red arrow C) and extension of the inflammatory process. The corresponding photographic images show the bite site (large red arrows) with visible edema and erythema (Credits: courtesy of the authors).

At the day-4 follow-up, the patient reported pain. Physical examination revealed edema involving the entire right lower limb, with limited mobility, and a large hematoma at the bite site. Laboratory tests showed a leukocyte count of 10.8 × 10^3/L and a CRP level of 10 mg/L. Fig. 2 shows an IR image demonstrating qualitative asymmetry with extension of inflammatory changes toward the right iliac fossa. In ROI 1 (Fig. 2C), a ΔTaverage value of 1.42°C was recorded compared with the contralateral side.

Clinical case 3

An 11-year-old previously healthy male patient sustained a bite from *B. alternatus* on the anterior–inferior third of the left leg. A tourniquet had been applied for 20 minutes prior to arrival at a primary-care facility. He presented without systemic manifestations and received 8 vials of BIOL antivenom 2 hours after the incident. Clinically, he exhibited pain, two puncture marks, ecchymosis around the bite site, and localized edema. The patient was referred to a tertiary-care center, where thermal imaging was performed on day 2 after the bite (Fig. 3). Laboratory evaluation showed leukocytosis (14.5 × 10^3/μL) and a CRP level of 12 mg/L. Arterial and venous Doppler ultrasonography revealed no abnormalities. A ΔTaverage of 1.36°C was recorded in ROI 1 (Fig. 3A) compared with the contralateral limb.

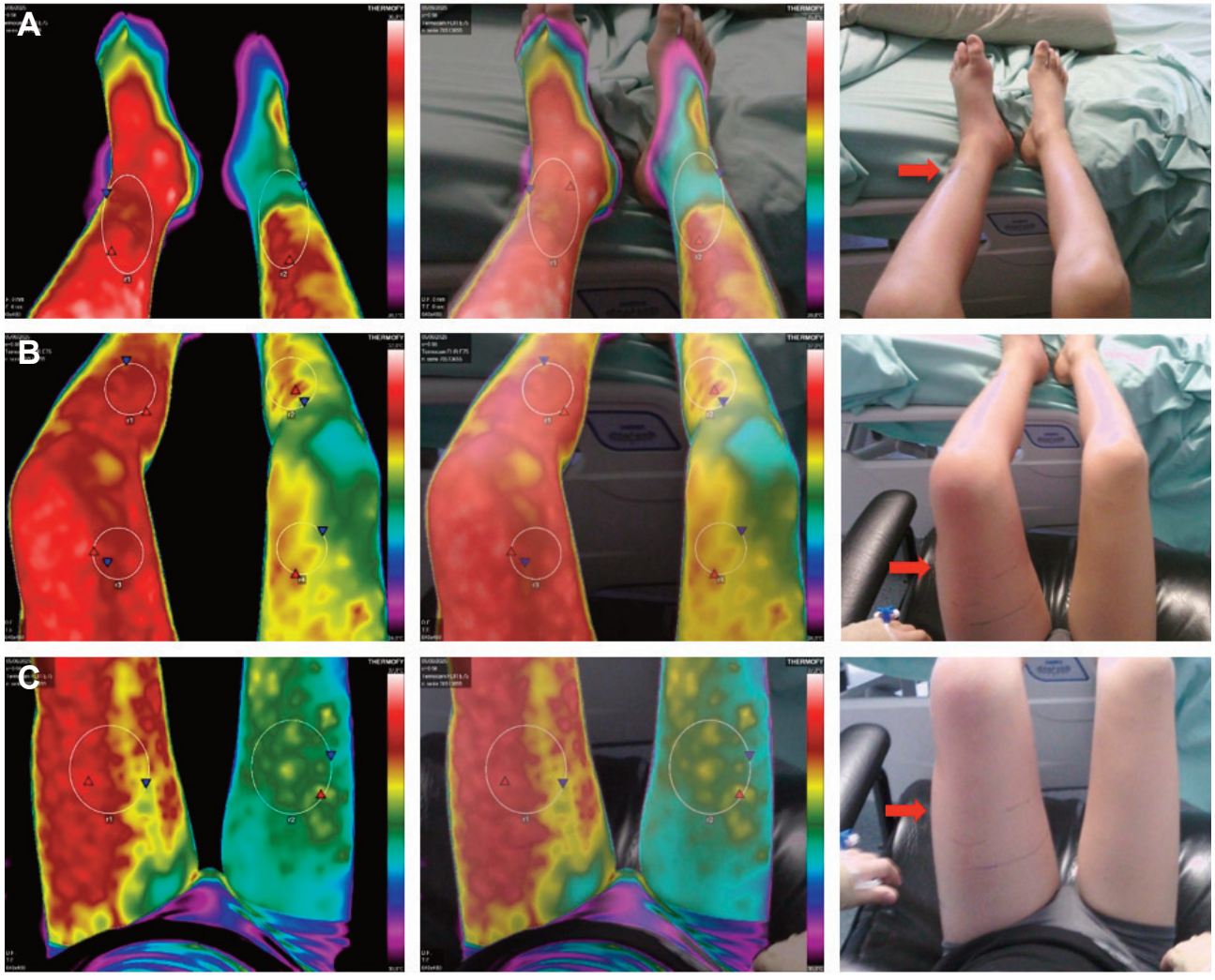

Figure 3 (A, B and C). Thermal images obtained on the second day show an average ΔT of 1.36°C in ROI 1 (small red arrow A) and the extent of the inflammatory process along the left lower extremity, with associated edema and pain. The corresponding photographic images show the bite site (large red arrow A) with edema extending beyond the puncture site (large red arrows B and C) (Credits: courtesy of the authors).

DISCUSSION

The three cases presented correspond to snakebite envenomations caused by species of the *Bothrops* genus, which are responsible for the majority of envenomations in Uruguay. All patients exhibited local inflammatory manifestations such as edema, erythema, and pain, without severe systemic complications. IR thermography enabled non-invasive visualization of thermal changes associated with the local inflammatory response, as demonstrated in the consulted literature.[4-12] The images showed thermal asymmetries and dysfunction, with ΔTaverage values greater than 1°C, consistent with previously reported findings in *Bothrops* bites by Medeiros et al.[5] Across all cases, a local effect of the venom was evident, independent of systemic neutralization. Areas of decreased temperature—potentially associated with local ischemic activity—were observed, along with proximal and distal inflammatory changes characterized by thermal signatures described by Medeiros et al.[5] and Machado et al.[8]

In *Case 1*, the ΔTaverage of 4.02°C reflected persistent active inflammation 18 days after the bite, correlating with the clinical findings of edema and erythema, as well as elevated inflammatory markers, similar to reports from various authors.[4,5,13] This suggests that thermography may detect residual inflammatory activity even in late stages of clinical evolution, similar to reports by Medeiros et al.[5] and Machado et al.[6,8-10] where ΔTaverage values greater than 2.2°C were associated with humoral markers of infection. In *Case 2*, the ΔTaverage of 1.42°C corresponded to an extensive inflammatory process with a significant hematoma. Similar inflammatory patterns with ΔTaverage values below 1.5 °C have been reported by Medeiros et al.,[5] Sabitha et al.,[12] and Machado et al.[8-10] In *Case 3,* the ΔTaverage of 1.36°C was associated with areas of lower temperature around the puncture sites, suggesting local enzymatic activity, along with an inflammatory response extending to the proximal thigh, a behaviour that has been reported by several authors.[5,9,12,13] Thermography revealed localized thermal abnormalities compatible with acute inflammation but without significant vascular compromise, which was corroborated by a normal Doppler ultrasound, as reported in several international studies.[5,10,14,15]

In Uruguay, the CIAT is the first national toxicology reference center to complement clinical semiology with high-resolution IR imaging for monitoring snakebites caused by *Bothrops* species.[5,6,8] Compared to standard clinical photography, which does not provide quantitative information on inflammatory activity, IR imaging offers a functional assessment of tissues, allowing for the identification of the extent of inflammatory phenomena and the objective quantification of temperature differences through ΔT measurements.[6,8,12,14,15] Therefore, this non-invasive tool can significantly contribute to clinical practice by obtaining objective and quantitative data in emergency departments and intensive care units.[8-10] Its usefulness extends internationally to the monitoring and prognosis of possible local complications—for example, in the early assessment of local tissue damage and the risk of infection—as well as to clinical follow-up.[6,8,12,14] Based on these promising preliminary results, a prospective study is underway to validate and further analyze these thermal findings using a rigorous statistical approach.

CONCLUSIONS

High-resolution IR thermography represents a valuable complement to the assessment of *Bothrops* envenomation, as it provides objective, non-invasive quantification of local inflammatory activity without exposing the patient to ionizing radiation, using temperature delta values at the bedside. It can help in understanding changes in local phenomena that are independent of antivenom neutralization. These findings underscore its potential as a complementary tool, alongside traditional photography, for understanding the metabolic, vascular, and inflammatory phenomena in snakebite envenomation, which are invisible to the naked eye, and justify further investigation through prospective studies.

Conflicts of interest

The authors declare no conflicts of interest.

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