

Thermographic Assessment of Lyme Borreliosis Without Erythema Migrans

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Background: In 11–18% of patients, infection with *Borrelia* is not accompanied by the characteristic skin lesion known as erythema migrans, complicating the timely diagnosis of Lyme borreliosis. To aid in identifying this atypical presentation, we assessed the tick bite site with thermographic imaging.

Aim: To determine the diagnostic value of infrared thermography in patients with Lyme borreliosis without erythema migrans.

Materials and Methods: We observed 16 patients with Lyme borreliosis without erythema migrans. The diagnosis was based on a history of tick bite and laboratory confirmation using two-tiered serological testing, performed 10–20 days after tick exposure. Thermographic imaging was performed with the device positioned 100–150 cm from the area of interest. Temperature differences (ΔT) were recorded.

Results and Discussion: Thermographic imaging revealed localized hyperthermia in all 16 patients at the site of tick attachment, presenting as annular thermal changes ($\Delta T = 0.6$ – 3.8 °C) that persisted for at least two weeks, even with ongoing antibacterial therapy. Nearly one-third of patients had ΔT in the range of 0.6 – 1.1 °C, half showed values of 1.2 – 1.6 °C, and in 18.7% of cases, ΔT exceeded 1.6 °C. These measurements were obtained and quantified using software-assisted analysis of the thermograms. Therefore, the absence of visible erythema migrans does not rule out localized inflammatory changes: centrifugal spread of *Borrelia* from the bite site can still induce subclinical cutaneous inflammation detectable with infrared thermography.

Conclusion: Infrared thermography of the tick bite site can reveal a “thermal erythema migrans” pattern, an annular zone of hyperthermia corresponding to the distribution of erythema migrans even when no rash is visible on clinical inspection. This early thermographic sign, detectable when a temperature exceeds 0.5 °C between the bite site and adjacent or symmetrical areas, may support timely initiation of etiotropic therapy to prevent long-term complications of Lyme disease.

Plain Language Summary: Lyme disease is usually diagnosed with the help of blood tests and a characteristic ring-shaped skin rash called erythema migrans. However, some people with Lyme disease do not develop this rash, and lab tests may take time to become positive after infection. In this study, we used a special imaging method called infrared thermography, which detects subtle changes in skin temperature, to examine the site of a tick bite in people who did not have a visible rash. In the cases studied, the thermal pattern revealed by this method resembled the typical ring-like shape of the Lyme disease rash, helping to uncover hidden inflammation. These findings suggest that infrared thermography may help identify Lyme disease earlier in patients without visible skin changes, supporting timely diagnosis and treatment.

Keywords: Lyme borreliosis, non-erythema migrans presentation, infrared thermography, tick bite, early detection

Introduction

Lyme disease (LD) is the most common vector-borne infection in the Northern Hemisphere, leading to substantial economic and medical burdens.¹ In the USA alone, insurance claims for clinician-diagnosed LD rose from approximately

329,000 in 2010 to 476,000 in 2018.^{2,3} If left untreated, LD can result in serious complications affecting the skin, joints, nervous system, and heart.^{4,5} Although most patients recover fully after antibiotic therapy, a subset experiences persistent symptoms lasting months or even years. This post-treatment manifestation, which remains poorly understood, is the focus of ongoing research due to its clinical and economic implications. Annual medical costs in the United States are estimated at \$712 million to \$1.3 billion.^{6–8}

Diagnosing LD can be challenging in the absence of erythema migrans, which is considered pathognomonic for the infection. While erythema migrans appears in the majority of cases, its absence has been reported in both US and European studies. In the United States, 13–18% of early LD cases lacked erythema migrans despite systemic symptoms or laboratory confirmation.^{9,10} Population-based data from Germany indicate that approximately 11% of cases lack classic erythema migrans.¹¹ In such cases, diagnosis relies on two-tiered serological testing, which detects specific antibodies to *Borrelia*. However, this approach has limitations: IgM appears in only 20–50% of acute cases and peaks 4–6 weeks after onset. Early testing may yield false negatives due to the serology window, immune suppression, or antigenic variability. False positives also occur in various infectious and autoimmune diseases.^{12,13}

To enhance diagnostic accuracy in patients without erythema migrans, we supplemented serological testing with thermography – a non-invasive technique that records infrared radiation from the body. Thermography detects pathological changes through alterations in thermal distribution, primarily reflecting vascular responses.¹⁴ This method has been explored in diverse medical fields, including oncology, surgery, neurology, rheumatology, dermatology, and infectious diseases.^{15–17} A recently published study¹⁸ demonstrated the use of infrared thermography to visualize erythema migrans in patients with early Lyme borreliosis, showing localized hyperthermia and distinct thermal patterns in visible lesions. While that work confirmed the feasibility of thermography in clinically apparent erythema migrans, it did not address cases without visible skin changes.

The aim of the present study is to explore whether this infrared thermography can also detect subclinical cutaneous inflammation at the site of a tick bite in patients lacking erythema migrans.

Patients and Methods

We observed 16 patients with Lyme disease without erythema migrans who received outpatient or inpatient care at the Infectious Disease Department of the Ternopil City Communal Hospital of Emergency Medicine. The diagnosis was based on clinical history (notably, tick bites confirmed by visits to the hospital's trauma center for tick removal) and laboratory findings (positive two-tiered Lyme disease serologic testing results)¹⁹ in serum samples taken 10–20 days after the bite. At the time of sampling, hyperemia at the site of the bite was typically resolved, and no visible erythema migrans was present. Antibodies to *B. burgdorferi* sensu lato (s.l.) complex antigens in the blood serum of patients were detected using enzyme-linked immunosorbent assay (ELISA) with test systems from Euroimmun AG (Germany): IgM antibodies were determined using the Anti-Borrelia burgdorferi ELISA (IgM) test, and IgG antibodies using the Anti-Borrelia plus VIsE ELISA (IgG) test.

A control group consisted of 22 individuals who had experienced a tick bite but tested seronegative for *Borrelia burgdorferi* (serum IgM and/or IgG antibodies negative on samples taken 10–20 days after the bite). These controls were representative of the patient group in terms of age and sex distribution.

All subjects completed a questionnaire that included personal information, as well as history details about the time, place, and circumstances of the tick bite, along with any prior treatment. Participation in the study was based on voluntary consent.

Thermographic Assessment

It was hypothesized that *Borrelia*, after penetrating the skin during a tick bite, causes minimal local inflammation. Even in the absence of visible hyperemia, this inflammation may still be associated with a localized increase in body temperature, or “warming”, which can be detected by infrared thermography. Initial thermography was performed at the same visit when the first serology sample was taken (10–20 days after the bite), before results were available, to assess its potential as an *early* detection method.

Preparation for thermography and the examination itself followed the guidelines provided by the manufacturer, ULIRvision (China).²⁰ Patients refrained from physiotherapy, massage, vasoactive drugs, and topical preparations for at least 24 hours, and from smoking or eating for 40–60 minutes before the examination. The room temperature was

maintained at 18–22 °C, with a 10–15 minute acclimatization period. The camera was positioned 100–150 cm from the site of interest. The focus was on the site of tick attachment and surrounding tissues. For paired areas (eg, limbs or lateral sides of the torso), the symmetrical part of the body was also examined.

Thermal images were initially analyzed visually by comparing color patterns to those of surrounding areas. In cases where thermal asymmetry was observed, the thermograms were described using the following criteria: presence of asymmetry, localization of areas with increased or decreased infrared radiation intensity, absolute temperature values, and differences relative to the symmetrical area. Subsequently, the images were processed using IRSee software, which automatically recorded temperature values at all points within the image. For greater precision, thermographs and histograms were used to present temperature distributions in the region of interest, as well as in specific points. When analyzing the area of interest, the shape (focal or diffuse), uniformity (homogeneous or heterogeneous), and contour clarity (clear or fuzzy) of the thermally active region were considered. The system can simultaneously process up to 20 point objects, 10 lines, 20 fields, and 10 polygonal or elliptical shapes. To compare symmetrical areas or the thermographically detected warm focus with surrounding tissues, points, horizontal lines, and oval fields were primarily used. The temperature at marked points was recorded, enabling the calculation of the temperature difference (ΔT) along the line of interest. A temperature difference (ΔT) of more than 0.5 °C between symmetrical areas is considered indicative of localized inflammatory activity, as described in previous studies.^{15,21,22} Extreme values (maximum and minimum temperatures) were automatically indicated, and an oval field enabled the construction of a histogram that visually represented the temperature distribution from minimum to maximum. Processed thermograms were stored in an electronic archive for future comparison during patient follow-up. All study subjects, both patients and controls, underwent repeat examination 3–4 months after the initial visit.

Results

The patients ranged in age from 20 to 62 years, with an average age of 36.8 ± 3.4 years. Among the participants, 7 (43.8%) were men and 9 (56.2%) were women. Thermography of the affected areas in all 16 patients with the non-erythematous form of LB revealed hyperthermia (local inflammation of the skin) around the tick bite site in the form of a ring-shaped zone of higher temperature ($\Delta T = 0.6$ – 3.8°C) resembling erythema migrans. This annular thermal pattern persisted for at least two weeks, even after antibacterial therapy. In approximately one-third of the patients, ΔT ranged from 0.6 to 1.1°C ; in half, it ranged from 1.2 to 1.6°C ; and in 18.7% of cases, ΔT exceeded 1.6°C (Table 1).

In 17 of the 22 seronegative controls, a primary hyperemia at the site of tick attachment was observed but resolved spontaneously or after desensitizing therapy within 3–7 days. The remaining five controls did not develop hyperemia at the bite site. Thermographic examination performed 10–20 days after the bite revealed no abnormal localized warming in any control subject. A follow-up thermographic assessment conducted 3–4 months after the initial visit likewise revealed no local hyperthermia or pathological thermal asymmetry in either the patient or control groups. The transient hyperemia observed in 17 control individuals is consistent with a typical short-lived allergic reaction to the bite rather than infection-related inflammation.

Table 1 Results of Thermal Imaging Examination of Tick Bite Sites in Patients with Non-Erythematous Form of LB (n=16)

Presence of Hyperthermia (ΔT °C)	Patients with Local “Warming” of the Skin in the Area of a Tick Bite	
	Absolute Number	%
0–0.5 (normal)	0	0.0
0.6–1.1	5	31.3
1.2–1.6	8	50.0
>1.6	3	18.7

Illustrative Case Study

A 36-year-old male, presented with a history of a tick bite, which had been successfully removed at the trauma center of the Ternopil City Municipal Emergency Hospital. The tick measured over 6 mm, indicating a prolonged attachment (more than 3 days). At the site of the bite (Figure 1A), a hyperemic spot approximately 5 mm in size was observed, which appeared to be an allergic reaction to the tick bite. No erythema migrans was noted.

Thermography during this period revealed significant hyperthermia ($\Delta T = 1.1^{\circ}\text{C}$) at the site of the bite, coinciding with the hyperemic spot's outline (Figures 1B and 2). No antibiotics were administered at this stage, and serological tests (ELISA) did not initially confirm the presence of specific antibodies to *Borrelia burgdorferi* s.l. However, a follow-up serological examination after 30 days, using both ELISA and immunoblot, showed seroconversion of IgM and IgG antibodies against *B. burgdorferi* s.l. This, combined with the unaltered appearance of the skin on the lower leg (Figure 3A), led to a diagnosis of the cutaneous, non-erythematous form of Lyme borreliosis.

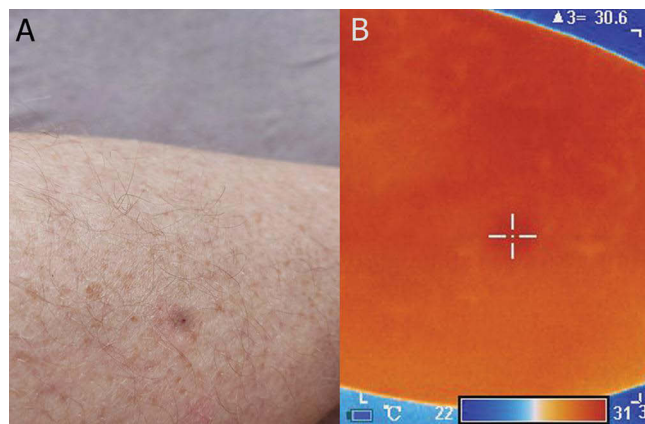


Figure 1 Primary lesion at the site of a tick bite (A) and the corresponding hot spot (automatically marked with a cross) on the thermogram of the affected leg (B) of the patient with Lyme borreliosis, where erythema migrans is absent, but localized inflammation is detected through thermography (suberythematous form).

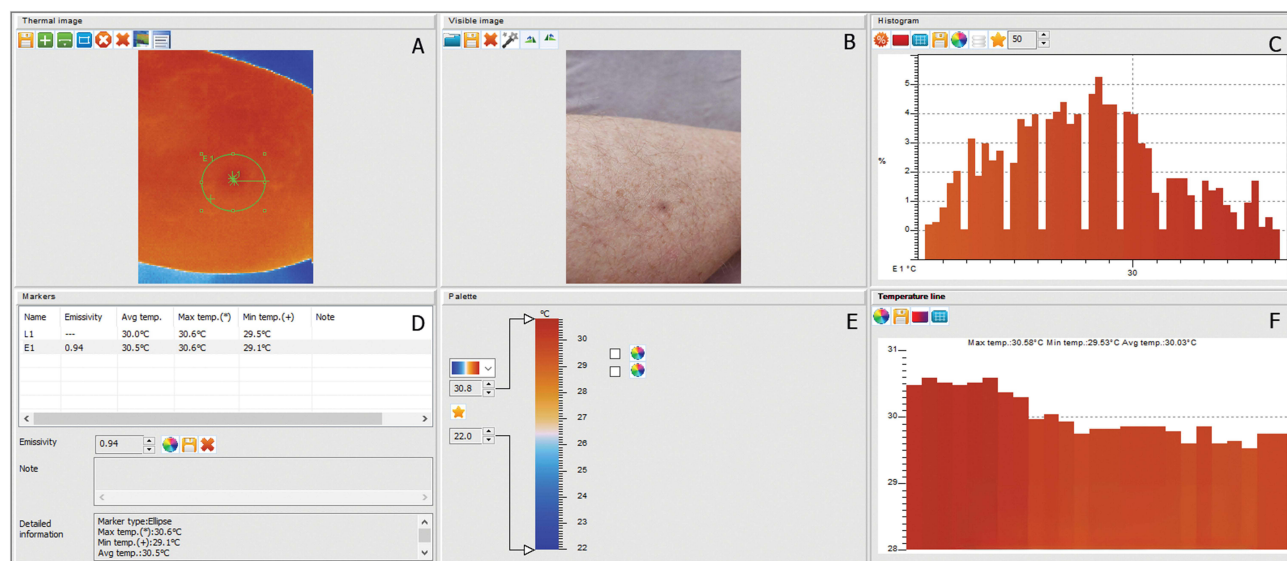


Figure 2 Analysis of the thermogram of the patient using IRSee Software. Upper left corner (A) Infrared image with line L1 (indicating the warming epicenter) and the zone of interest E1 (surrounding area) encircled by an ellipse; markings L1 and E1 represent measurement points as displayed in the software during analysis. Center upper section (B) Tick bite site on the left shin showing a primary lesion without erythema migrans. Upper right corner (C) Histogram of temperatures within zone E1 (surrounding tissue near the bite site), ranging from 29.1 to 30.6°C, shown as relative frequency (%). Lower left corner (D) Display of the obtained indicators. Center lower section (E) Temperature palette corresponding to the different temperature values. Lower right corner (F) Temperature plot along line L1, showing temperatures from 29.5 to 30.6°C.

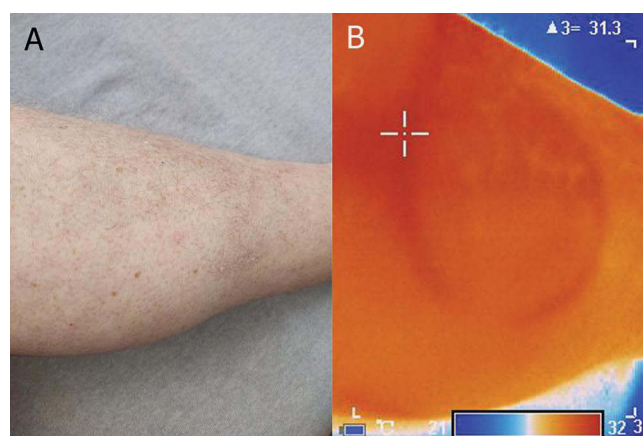


Figure 3 (A) Absence of any visible changes in the skin of the left shin of the patient 30 days after the tick bite; (B) infrared thermogram of the patient: despite the absence of visible erythema migrans, the annular hyperthermia is visible, corresponding to the pathognomonic erythema migrans rash, not detectable to the unaided eye.

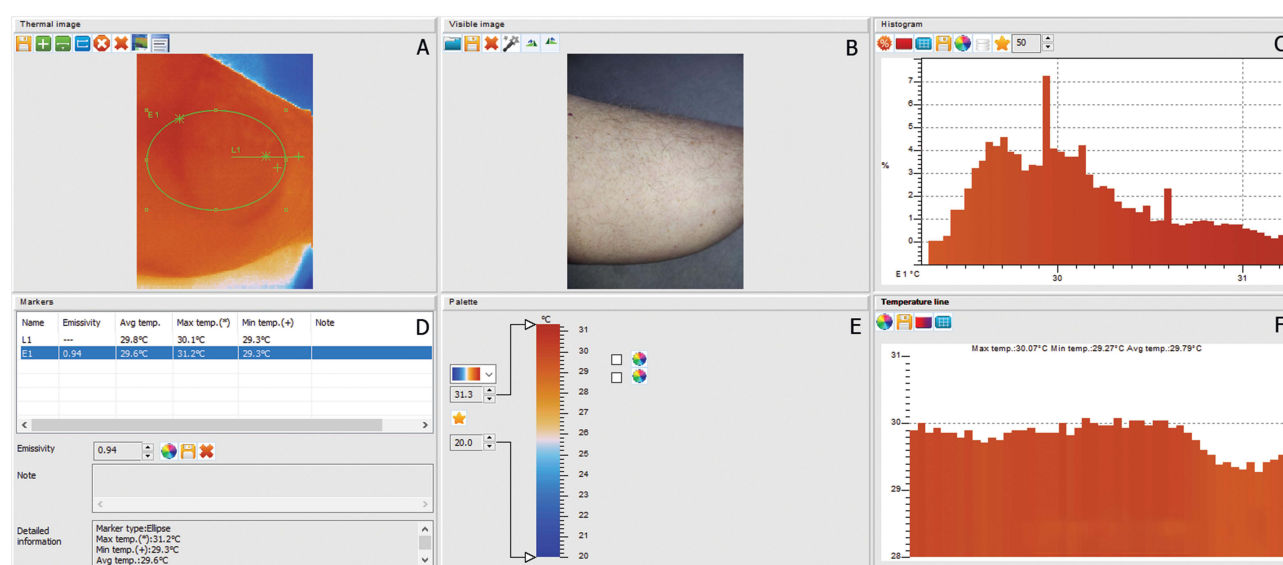


Figure 4 Thermogram of the left shin of the patient depicting the ring-shaped infrared glow, a thermographic pattern in which a distinct ring of increased temperature surrounds the area of inflammation, with a moderate temperature difference ($\Delta T = 0.8^{\circ}\text{C}$), despite the absence of visible erythema. Upper left corner (A) Infrared image of the same area as in Figure 2A (line L1 and the zone of interest E1 within the ellipse) 30 days after the bite. Center upper section (B) Tick bite site on the left shin with no visible changes 30 days after the bite. Upper right corner (C) Temperature distribution in zone E1 (surrounding tissue near the bite site), ranging from 29.3 to 31.2 °C, shown as relative frequency (%). Lower left corner (D) Display of the obtained indicators. Center lower section (E) Temperature palette corresponding to the different temperature values. Lower right corner (F) Temperature plot along line L1, ranging from 29.3 to 30.1 °C.

Subsequent thermographic analysis of the left lower leg revealed local rounded hyperthermia in the form of a concentric circle with a diameter of up to 7 cm ($\Delta T = 0.8^{\circ}\text{C}$, Figures 3B and 4). Fourteen days after the completion of doxycycline hydrochloride therapy (200 mg per day, divided into two 100 mg doses for 2 weeks), the local hyperthermia at the tick bite site resolved, as confirmed by a follow-up thermogram (Figure 5). Repeat thermographic assessment performed 34 days later (64 days after the tick bite) showed a normal thermal distribution without any signs of abnormal thermal asymmetry.

Discussion

To our knowledge, this is the first study to investigate the diagnostic utility of infrared thermography in patients with Lyme borreliosis (LB) who do not exhibit the pathognomonic sign of erythema migrans, building on our prior preliminary report²² that proposed this method for forms of the disease lacking visible erythema. In such cases, the

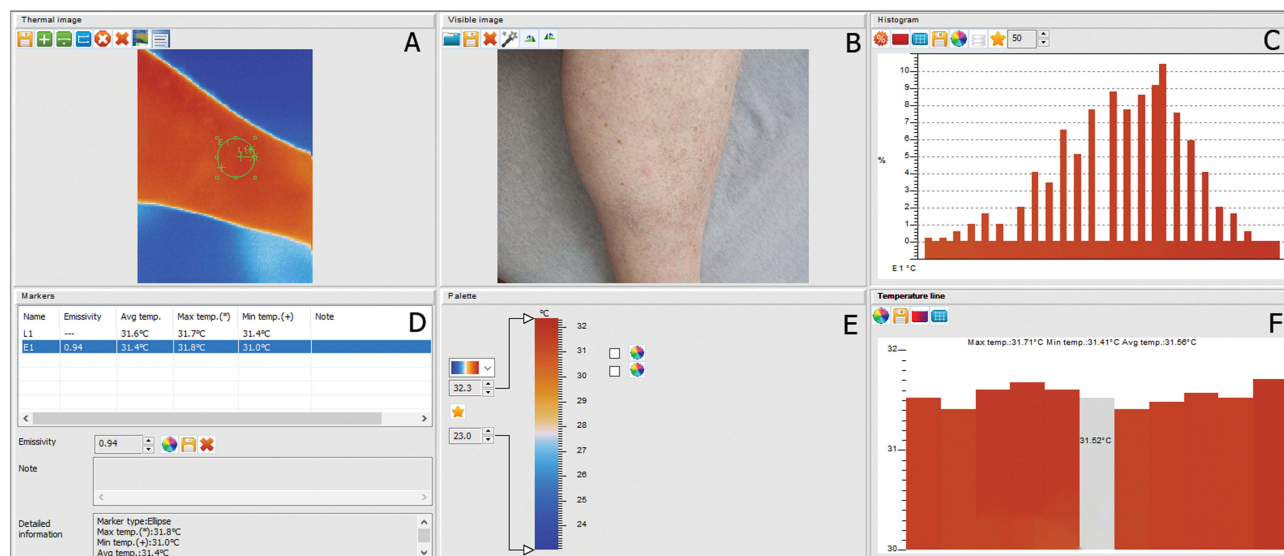


Figure 5 Analysis of the thermogram of the left shin of the same patient, 2 weeks after the completion of antibiotic therapy. Upper left corner (A) Infrared image of the same zone as in Figure 2A after completion of therapy. Center upper section (B) Tick bite site on the left shin with unchanged appearance after therapy. Upper right corner (C) Temperature distribution in zone E1 (surrounding tissue near the bite site), ranging from 31.0 to 31.8 °C, shown as relative frequency (%). Lower left corner (D) Display of the obtained indicators. Center lower section (E) Temperature palette corresponding to the different temperature values. Lower right corner (F) Temperature plot along line L1, ranging from 31.4 to 31.7 °C.

absence of cutaneous manifestations significantly complicates timely diagnosis, particularly during the early phase of infection, when serological tests may still yield negative results. In this study, we employed thermography as a non-invasive, radiation-free technique for detecting localized increases in skin temperature suggestive of inflammation. From a practical standpoint, the method is simple, requiring only brief patient acclimatization, basic environmental control, and standard camera positioning. These steps are easily reproducible and demand minimal additional resources. The procedure can be carried out in standard outpatient settings without the need for specialized infrastructure beyond the imaging device itself. In addition to the aforementioned advantages, this method, unlike serological testing, does not depend on the development of a detectable antibody response, making it potentially useful in the very early stages of infection. Our findings suggest that infrared thermography can serve as a practical, noninvasive adjunct to serological testing in suspected Lyme borreliosis, particularly in cases without visible erythema migrans. In addition to the patient cohort, we also evaluated a control group of seronegative individuals with documented tick bites; none demonstrated abnormal localized warming on thermography at either 10–20 days or 3–4 months post-bite, which is consistent with the absence of infection-related inflammation in this group.

The physiological basis for thermographic findings lies in the vascular and metabolic changes associated with inflammation. Skin temperature reflects the underlying dynamics of blood flow, tissue metabolism, and immune activity, with vascular factors being the primary determinant of thermal asymmetry.^{15–18}

Our findings align with the known pathophysiology of LB. In typical cases, the hematogenous or lymphogenous dissemination of *Borrelia* from the site of inoculation leads to the development of erythema migrans, mediated by inflammatory cytokines such as TNF- α , IL-1, and IL-6.^{20,22} However, the absence of visible erythema in some patients may reflect either a lower inoculum of spirochetes, individual variability in immune response, or its poor visibility on darker skin tones. Nonetheless, the local tissue still mounts a subclinical inflammatory reaction – one that includes warmth (*calor*) as a cardinal sign of inflammation.^{21–24} Thermography appears to capture this subvisible inflammatory process with high sensitivity, as evidenced by the concentric hyperthermic zones we observed around the tick bite sites, even in the absence of clinically evident erythema.

In this context, we propose the descriptive term “suberythematous form” for cases without visible erythema migrans but with thermographically detected annular hyperthermia. While not a formally recognized subtype, this presentation may benefit from early detection via infrared thermography, which could serve as a valuable adjunct to serological testing. The infrared thermography technique is already well-established in other fields eg, oncology, neurology, angiology, and dermatology,

among others and its application to infectious diseases has been developed by several groups.^{15–18} Our results complement recent works applying infrared thermography to visible erythema migrans lesions, including both single and disseminated forms.^{18,25} In contrast, the present study demonstrates that infrared thermography can also reveal localized hyperthermia in the absence of visible erythema, which we define as the suberythematous form of LB. This finding supports emerging evidence that infrared thermography can detect inflammatory changes associated with *Borrelia burgdorferi* infection even when erythema migrans is not clinically apparent. Importantly, such imaging may be valuable not only when the rash is absent, but also when it is subtle, difficult to discern in visible light, or less apparent in patients with darker skin pigmentation.¹⁸ Given its non-invasiveness, lack of contraindications, and ability to detect otherwise occult inflammation, infrared thermography has potential as a complementary diagnostic tool alongside serology and clinical evaluation in suspected Lyme borreliosis. We did not perform tick testing because the presence of *Borrelia burgdorferi* in a tick does not guarantee transmission, which typically requires ≥ 36 –48 hours of attachment,²⁶ and negative results cannot reliably exclude infection, as cases of LD have been documented after bites from PCR-negative ticks.²⁷ Future studies with larger cohorts and standardized thermographic criteria are needed to refine diagnostic utility of infrared thermography and define its role within clinical guidelines.

Conclusions

1. Infrared thermography of the tick bite site can visualize the pathognomonic sign of Lyme borreliosis, the annular erythema migrans rash, even when it is not detectable on visual inspection.
2. In patients with Lyme borreliosis who lack visible erythema migrans, thermographic imaging enables the detection of a temperature difference greater than 0.5 °C between the site of the tick bite and adjacent or symmetrical areas of the body.
3. Early thermographic identification of the suberythematous cutaneous form of Lyme borreliosis supports the initiation of etiotropic therapy to prevent the development of long-term complications.

Data Sharing Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

This study was approved by the Institutional Bioethics Committee of Ivan Horbachevsky Ternopil National Medical University (protocol №. 81 dated April 3, 2025). All patients gave informed consent for participation in the study. Informed consent for publication of the case details and accompanying images was obtained from the patient described in the illustrative case study. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki and its subsequent amendments.

Author Contributions

All authors made a significant contribution to the work reported, including conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the manuscript; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests in this work.

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