


BRIEF RESEARCH REPORT

Infectious Disease

Comparing skin surface temperature to clinical documentation of skin warmth in emergency department patients diagnosed with cellulitis

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Abstract

Objective: To compare clinical documentation of skin warmth to patient report and quantitative skin surface temperatures of patients diagnosed with cellulitis in the emergency department (ED).

Methods: Adult patients (≥ 18 years) presenting to the ED with an acute complaint involving visible erythema of the lower extremity were prospectively enrolled. Those diagnosed with cellulitis were included in this analysis. Participant report of skin warmth was recorded and skin surface temperature values were obtained from the affected and corresponding unaffected area of skin using thermal cameras. Average temperature (T_{avg}) was extracted from each image and the difference in T_{avg} between the affected and unaffected limb was calculated ($T_{gradient}$). Clinical documentation of skin warmth was compared to patient report and measured skin warmth ($T_{gradient} > 0^\circ\text{C}$).

Results: Among 126 participants diagnosed with cellulitis, 110 (87%) exhibited objective warmth ($T_{gradient} > 0^\circ\text{C}$) and 58 (53%) of these cases had warmth documented in the physical examination. Of those with objective warmth, 86 (78%) self-reported warmth and 7 (6%) had warmth documented in their history of present illness (HPI) (difference = 72%, 95% confidence interval [CI]: 62%–82%; $P < 0.001$). A significant difference was observed for T_{avg} affected when warmth was documented (32.1°C)

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versus not documented (31.0°C) in the physical examination (difference = 1.1°C, 95% CI: 0.29–1.94; $P = 0.0083$). No association was found between Tgradient and patient-reported or HPI-documented warmth.

Conclusions: The majority of ED-diagnosed cellulitis exhibited objective warmth, yet significant discordance was observed between patient-reported, clinician-documented, and measured warmth. This raises concerns over inadequate documentation practices and/or the poor sensitivity of touch as a reliable means to assess skin surface temperature. Introduction of objective temperature measurement tools could reduce subjectivity in the assessment of warmth in patients with suspected cellulitis.

KEYWORDS

antibiotic stewardship, cellulitis, diagnostic errors, emergency department, pseudocellulitis, thermal imaging

1 | INTRODUCTION

1.1 | Background

Cellulitis, a common bacterial skin infection is overdiagnosed in up to 30% of cases because of the presence of mimicking, non-infectious pathologies termed pseudocellulitis.^{1,2} Associated diagnostic errors result in antibiotic overuse, which poses a threat to patient safety and public health.^{2,3} As cellulitis is primarily a clinical diagnosis, physicians must heavily rely on the reported history and subjective physical examination findings.⁴ One such finding is whether or not a patient exhibits excess skin surface warmth in the area of concern.

1.2 | Importance

Skin surface warmth is a commonly reported feature of cellulitis, resulting from the body's innate immune response after infection, often caused by *Streptococcus pyogenes* or *Staphylococcus aureus*.⁴ In response to bacterial invasion, cytokines and granulocytes are recruited, which triggers an epidermal response. Increased vascular permeability and blood flow within the skin combined with heightened metabolic activity raises the temperature of the affected skin and increases the rate at which thermal energy transfers to the surrounding air.⁵

With this in consideration, thermal imaging has been explored as a means to objectively characterize skin surface temperatures of patients presenting with potential cellulitis. Ko et al found that cellulitis and pseudocellulitis patients had average maximum affected skin temperatures of 34.1°C and 31.5°C ($P = 0.008$), respectively.⁶ They concluded that the observed temperature differences could improve differentiation of cellulitis and pseudocellulitis and reduce diagnostic errors.

1.3 | Goals of this Investigation

Although the assessment of skin surface warmth is considered a key component of the clinical evaluation for potential cases of cellulitis, the extent to which warmth is currently reported by patients and documented by emergency department (ED) clinicians is unknown. Therefore, the objective of this study was to compare clinically documented (history of present illness [HPI] and physical exam) and patient-reported skin warmth to quantitative skin surface temperatures obtained with surface thermal imaging in patients diagnosed with cellulitis in the ED. We hypothesized that the frequency of skin temperature clinical documentation would increase as measured skin surface temperatures increased because of increased detection.

2 | METHODS

2.1 | Patient selection

This study was reviewed and approved by the local institutional review board and was part of a larger validation study that aimed to compare skin surface temperatures of cellulitis and pseudocellulitis patients. Patients 18 years and older presenting to the ED with a chief complaint related to a visibly erythematous lower extremity were prospectively enrolled upon written consent from October 2018 to March 2020 at a quaternary care center in the Midwest. Of these patients, only those who had a final diagnostic impression of cellulitis or assigned *International Classification of Diseases* code for cellulitis plus received antibiotic therapy for cellulitis, as indicated on the order, were included in this analysis. Patients were excluded if their chief complaint resulted from acute traumatic injury within the past 5 days, if the skin changes were present on both legs (bilateral) or exclusive to the toes, if the affected area included a confirmed fracture or an implant/hardware, they applied ice or heat within the past hour, or if the area included a recent surgical site (past 4 weeks). Additionally, patients were excluded if

The Bottom Line

Objective warmth is a key clinical finding that can discriminate infectious cellulitis from pseudocellulitis. In this study of 126 participants with cellulitis, the majority of diagnosed cellulitis patients exhibited objective warmth, yet significant discordance was observed between patient-reported, clinician-documented, and measured warmth. This study highlights the need for more reliable means to assess skin surface temperature.

they were non-English speaking, pregnant, a prisoner, or had impaired decision-making.

2.2 | Baseline data collection

During the ED encounter, trained research coordinators collected baseline patient demographics such as age, race, biological sex, and ethnicity. Additionally, patients were asked detailed symptom inventories, including if they had been experiencing excess warmth in their affected area of skin related to their acute complaint. All these questions were asked before obtaining the thermal images.

2.3 | Thermal imaging data collection

Surface temperature images were taken of the patient's affected area of skin and the exact corresponding area on the contralateral extremity (unaffected control limb) with a FLIR One thermal camera (Generation One, FLIR Systems) attached to an iPad from a distance of ~30 cm. This camera measures surface temperatures ranging from -20°C to 120°C without direct contact and detects temperature differences as small as 0.1°C .⁶

All thermal images were stored on a secure computer and FLIR Tools (Tools+ 5.13) was used to manually select areas of interest within the thermal images to derive the average temperature (T_{avg}) of each patient's affected and corresponding unaffected area of skin. The temperature difference between these two areas (T_{avg} affected [$^{\circ}\text{C}$] – T_{avg} unaffected [$^{\circ}\text{C}$]) was defined as the patient's temperature gradient (T_{gradient}). Patients with a $T_{\text{gradient}} > 0^{\circ}\text{C}$ were considered to have objective warmth in their affected area. All data were collected and stored in REDCap.

2.4 | Data extraction from electronic health record

Structured chart review was done to manually abstract the documentation of skin temperature in the HPI and physical exam. Before

beginning chart review, all abstracted variables were clearly defined and their definitions were documented in a study codebook. Data abstraction forms were setup using REDCap software, and research coordinators, who were blinded to the study's hypothesis, were trained on the first 20 charts to ensure consistent data abstraction. Abstraction performance was monitored by double-abstracting 15% of charts (randomly selected) and checking for consistency in responses. Routine check-in meetings and frequent email communication were used to clarify questions about specific patients.

For abstracting clinically documented warmth, keywords or phrases suggestive of increased warmth (eg, "warmth noted," "right leg warmer than left," "warm to the touch," and "hot") were considered documentation of an elevated skin surface temperature. The skin exam macro templates used by the group, "warm and dry" and "warm and well perfused," were not considered specific documentation of an elevated skin surface temperature.

2.5 | Data analysis

McNemar's test was used to compare patient report with clinical documentation (HPI and physical exam) for patients with objective skin surface warmth. Chi-square was used to compare patient report and clinical documentation of warmth across increasing T_{gradient} by sorting cases as follows: >0 to 1°C , >1 to 2°C , >2 to 3°C , >3 to 4°C , >4 to 5°C , and $>5^{\circ}\text{C}$. Two-sided t tests were used to compare differences in average affected T_{avg} and T_{gradient} when warmth was both present and absent in the patient report, HPI, and physical exam. All data were analyzed in STATA (Stata/SE 16.1).

3 | RESULTS

From October 2018 to March 2020, 126 patients diagnosed with lower extremity cellulitis met inclusion criteria. This final cohort was 37% female, 87% White, had an average age of 55.4 years, and 56% were discharged from the ED (Table 1). A total of 110 (87%) cases exhibited objective skin surface warmth ($T_{\text{gradient}} > 0^{\circ}\text{C}$). In cases where objective skin warmth was present median T_{gradient} was 2.6°C and the interquartile range was 1.6°C to 4.5°C . Of these cases, 58 (53%) had warmth documented in their physical examination. Additionally, 86 (78%) of patients reported warmth when asked by the study team whereas only 7 (6%) had warmth documented in their HPI (difference 72%, 95% confidence interval [CI]: 62% to 82%; $P < 0.001$). A total of 16 (13%) of cases had no objective skin warmth. In these cases, median T_{gradient} was -1.0°C and the interquartile range was -1.6°C to 0.65°C . Of these cases, 7 (44%) had warmth documented in the physical examination, 12 (75%) reported warmth to the study team, and 0 (0%) had warmth documented in their HPI.

No association was found between increasing T_{gradient} and patient report ($P = 0.893$) or clinical documentation ($P = 0.483$) (Figure 1). No significant differences were found between average T_{gradient} when

TABLE 1 Demographics of participants, n (%)

	Overall n = 126	Objective warmth n = 110	No objective warmth n = 16
Mean age (SD) (years)	55.44 (15.75)	56.15 (16.00)	50.53 (13.29)
Race n (%)			
American Indian or Alaska Native	2 (1.59)	2 (1.82)	0 (0.00)
Black or African American	6 (4.76)	5 (4.55)	1 (6.25)
White	109 (86.51)	97 (88.18)	12 (75.00)
Multiple races	5 (3.97)	3 (2.73)	2 (12.50)
Declined to answer	4 (3.17)	3 (2.73)	1 (6.25)
Ethnicity			
Hispanic, Latino, or Spanish origin	5 (3.97)	4 (3.64)	1 (6.25)
Gender			
Female	46 (36.51)	37 (33.64)	9 (56.25)
Male	80 (63.49)	73 (66.36)	7 (43.75)
Disposition			
Discharge	71 (56.35)	61 (55.45)	10 (62.50)
Admit	55 (43.65)	49 (44.55)	6 (37.50)
Patient-reported warmth			
Warmth documented in history of present illness	7 (5.56)	7 (6.36)	0 (0.00)
Warmth documented in physical exam	65 (51.59)	58 (52.73)	7 (43.75)

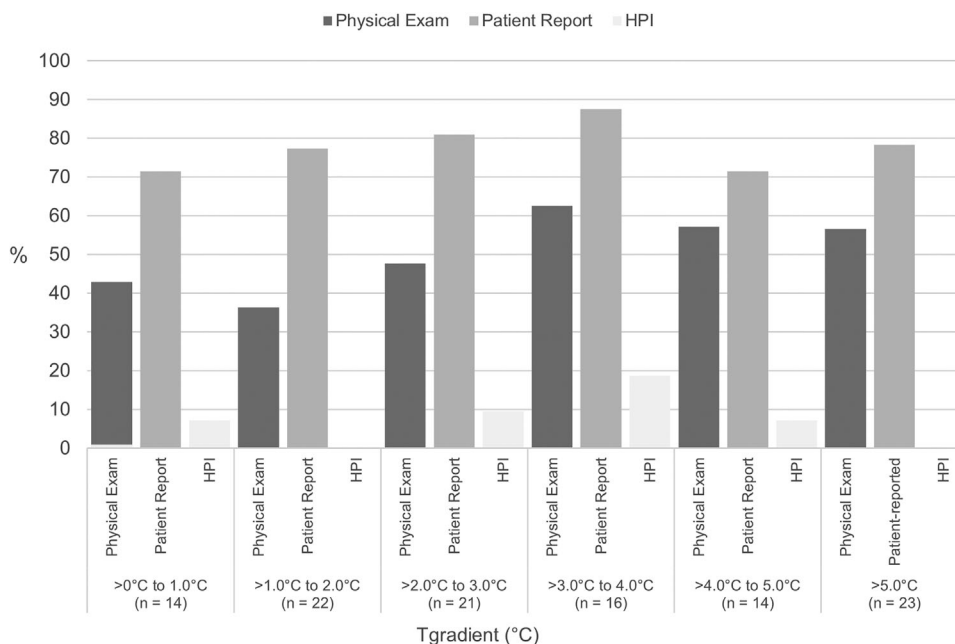
**FIGURE 1** Percentage of cellulitis cases with objective warmth that were also documented/reported as warm in the physical exam, patient report, and history of present illness (HPI) with respect to the temperature difference between participants' affected and unaffected skin (Tgradient)

TABLE 2 Comparing the average affected skin temperature (Tavg affected) of cellulitis cases when warmth was mentioned and not mentioned in the patient report, history of present illness (HPI), and physical exam

Source	Tavg affected (°C) when warmth was mentioned (95% confidence interval) [n]	Tavg affected (°C) when warmth was not mentioned (95% confidence interval) [n]	Difference (95% confidence interval) (P value)
Patient-reported	31.70 (31.22–32.19) [98]	31.03 (30.14–31.91) [28]	0.67 (–0.34 to 1.68) (P = 0.19)
HPI	32.16 (30.89–33.42) [7]	31.52 (31.07–31.99) [119]	0.64 (–1.20 to 2.49) (P = 0.49)
Physical exam	32.10 (31.63–32.56) [65]	30.98 (30.27–31.68) [61]	1.11 (0.29 to 1.94) (P = 0.0083)

warmth was documented versus not documented in the patient report, physical examination, or HPI. Additionally, no significant differences were found between Tavg when warmth was documented versus not documented by patient report or in the HPI. However, a significant difference was found between Tavg affected when warmth was documented (32.1°C) versus not documented (31.0°C) in the physical examination (difference = 1.1°C, 95% CI: 0.29 to 1.94; P = 0.0083) (Table 2)

3.1 | Limitations

This was a single-center study and documentation practices for cellulitis may vary significantly based on local practice patterns. As the clinicians were not asked if they assessed for or perceived skin surface temperature elevation, we can only comment on what was documented and not what actually may have occurred during the encounter. In light of the aforementioned limitation, we are unable to exactly determine the factor(s) driving the observed discrepancies. Finally, as ED overdiagnosis of cellulitis is reported in the literature, it is possible that some cases in the analysis would not be deemed cellulitis upon secondary review.

4 | DISCUSSION

Elevated skin temperature is considered a key feature of cellulitis diagnosis, yet the extent to which this is captured as part of the HPI, detected on physical examination, and documented by clinicians in the ED is unknown. To our knowledge, this is the first study to examine skin temperature documentation practices in the ED and compare them to both patient-reported warmth and quantitative skin surface temperatures measured by surface thermal imaging.

Results indicate the vast majority (87%) of ED-diagnosed cellulitis cases exhibit objective warmth (Tgradient > 0°C). Based on the previously established ED cellulitis misdiagnosis rate of 30%, the percentage of true cellulitis cases that exhibit objective warmth is likely higher. This notion is supported by the findings of Ko et al. that objective warmth was present in 96.6% of dermatology-diagnosed cellulitis.⁶ This reaffirms the traditional clinical teaching that increased skin warmth is a reliable diagnostic feature of cellulitis.

Although surface thermal imaging demonstrated objectively elevated skin temperature in the majority of cases, clinical documentation was inconsistent. Most notable was that although 78% of patients with

measured skin warmth reported experiencing warmth in the affected area of skin, only 6% had this documented in their HPI. As the clinical history is a key component of the diagnostic process, this finding may partially explain the reported diagnostic errors rates for cellulitis.^{1,2,4,7} This finding reflects observations by Caterino et al. that ED patient self-reported infection-related symptoms are often missing from the clinical documentation.^{8,9} Although we recommend improved questioning through direct inquiry and documentation of patient-reported skin warmth in all cases of suspected cellulitis, it is interesting that patient report was not associated with objective temperature measures.

Regarding the physical examination, a significant difference was found in the Tavg of affected skin when warmth was documented. This finding suggests that when ED clinicians detect and document warmth, patients' affected skin surface temperature is higher on average. Unsurprisingly, the physical examination appears to be a more reliable means of assessing skin warmth than patient report. However, only 53% of patients with objectively measured increased skin temperature had warmth documented in their physical examination. Although this number is better than patient-reported warmth or documentation of warmth in the HPI, it still raises concern over either inconsistent assessment, inability to detect warmth, or inadequate physical exam documentation of skin temperature in cases of suspected lower extremity cellulitis. A study by Tse et al found that physicians detected a >3.0°C difference in extremities only 75% of the time.¹⁰ This failure to detect a significant number of cases despite a high temperature gradient raises concerns about the reliability of warmth detection during the physical examination, particularly when lower temperature gradients are involved. Our findings suggest that this is not solely a detection issue because clinical documentation did not increase as skin surface temperature gradients increased. One would assume the ability to sense elevated skin temperature by touch would increase along with the actual temperature; however, this was not our observation. Further study of temperature detection limits by touch are needed to clarify the optimal clinical scenario for use of objective skin surface temperature measurement.

In conclusion, the observed inconsistencies between patient report, clinician documentation, and objective skin surface temperature measurements indicate the need for improved documentation and tools to objectively quantify skin warmth in patients with potential cellulitis. Cellulitis is commonly misdiagnosed in the ED, which leads to unnecessary use of antibiotics.^{1,2} Increased tissue warmth is a classic feature of cellulitis that can be used to differentiate it from mimics. However, our results suggest there are significant challenges to the assessment

of warmth in this population. Although available data suggest objective temperature data obtained from surface thermal imaging cameras can differentiate cellulitis from pseudocellulitis, there needs to be further validation of this technology and evaluation of its impact on diagnostic accuracy.^{10,11} Developing interventions that can reduce diagnostic error in the evaluation of cellulitis is an important patient safety and public health objective.³

CONFLICTS OF INTEREST

None.

AUTHOR CONTRIBUTIONS

Edward Harwick and Michael S Pulia conceived the study. Michael S Pulia designed the trial and obtained research funding. Michael S Pulia and Rebecca J Schwei supervised the conduct of the trial and data collection. Rebecca J Schwei undertook recruitment of participating patients and managed the data, including quality control. Rebecca J Schwei, Edward Harwick, and Michael S Pulia provided statistical advice on study design and analyzed the data. Edward Harwick, Michael S Pulia, and Rebecca J Schwei drafted the manuscript, and all authors contributed substantially to its revision. Michael S Pulia takes responsibility of the paper as a whole.

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