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ORIGINAL RESEARCH

Comparing the Accuracy of Patient-Perceived Fever, Manual Fever Checking, and Non-Contact Frontal Infrared Thermometer; A Cross-sectional Study

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Abstract: **Introduction:** Non-contact frontal infrared thermometers (NCFITs) have gained popularity following the COVID-19 pandemic, but their accuracy remains debated. This study compared the accuracy of three index tests of patient-perceived fever (PPF), manual fever checking (MFC) by emergency nurses, and NCFIT against tympanic thermometer (TT). **Methods:** This single center, diagnostic accuracy study evaluated adult patients in the triage area of the emergency department (ED) between May and September 2023. Five emergency nurses (ENs) examined patients using convenience sampling with index tests, followed by TT measurement for fever detection as standard test (T≥38°C). The sensitivity, specificity, positive and negative likelihood ratios (PLR and NLR) and accuracy, of PPF, MFC, and NCFIT in detecting the fever were measured and reported with 95% confidence interval (CI). The inter-rater reliability of ENs for MFC among 10 patients (outside the study) was 100%. **Results:** We included 279 patients with the mean age of 52.2 ± 16.98 years (51.97% male). TT identified 147 as febrile and 132 as non-febrile. The most sensitive index test was MFC, achieving 100% (95%CI: 97.5–100.0) sensitivity, 0 NLR, and 8.25 (95%CI: 5.7–12.1) PLR, with moderate accuracy (93.9% (95%CI: 89.9–96.0)). NCFIT demonstrated the lowest sensitivity (85.71% (95%CI: 78.9–90.9)) but the highest specificity (98.48% (95%CI: 93.6–99.5)) and accuracy (97.5% (95%CI: 93.1-99.8)). When the fever threshold for NCFIT was lowered to 37.5°C, sensitivity increased to 99% (95%CI: 97.4-99.9), NLR decreased to 0.01 (95%CI: 0-0.6), and PLR rose to 49.5 (95%CI: 20.8-90.2), while specificity remained at 98% (95%CI: 94-99.6). **Conclusion:** MFC/PPF could rule out fever but required NCFIT/TT to rule it in. However, NCFIT achieved the highest NLR and PLR when its fever threshold was set at37.5°C.

Keywords: Fever; Touch; Skin temperature; Emergency nursing; Thermometers

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1. Introduction

The prevalence of fever symptom in the emergency department (ED) was about 15%, and a correlation with prognosis has been reported previously (1). Physicians assess the temperature as a vital sign both in and out of the ED, which influences the assessment of other vital signs (2), aids in differentiating diagnoses such as infections, toxidromes, environmental hyperthermia, and drug adverse effects, and assists in monitoring treatments; for example, determining whether to discontinue intravenous antibiotics or in neurocritical care (3, 4).

An accurate thermometer is defined as a device with a mean difference from the pulmonary artery temperature of ±0.3°C and a standard deviation ranging from 0.3°C to 0.5°C (5). However, this method and other central temperature measurements such as rectal, bladder, and esophageal thermometers are invasive and expensive, making them unsuitable for routine use. A 2015 systematic review demonstrated the inaccuracy of peripheral thermometers for measuring temperature in oral, axilla, ear, and various skin sites (more commonly frontal) in daily practice (6). In an era where precise tools are prioritized, the most common device for temperature assessment in the EDs is the non-contact infrared frontal thermometer (NCFIT), particularly after COVID-19

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pandemic (7, 8). The reliability of NCFIT measurements ranges from ±0.3°C to ±2°C (9), contingent upon proper usage. The fever threshold for this device has been reported to range from 35.1°C to 38.5○C (9-12). According to a meta-analysis of 19 studies, its pooled sensitivity and specificity are 0.81 (95%CI: 0.66–0.90) and 0.92 (95%CI: 0.77–0.98), respectively (11). Notably, among peripheral digital thermometers, the tympanic thermometer (TT) demonstrated the closest correlation with central measurements and was used in temperature management of critically ill patients (1, 13). On the other hand, studies have examined non-technology-based methods for identifying the presence or absence of fever, particularly focusing on patient-perceived fever (PPF) and manual fever checking (MFC). In ED adult patients, PPF has shown a sensitivity and specificity of 83% (14), with a negative likelihood ratio (NLR) and positive likelihood ratio (PLR) of 0.7 and 4.2, respectively (1). MFC has been studied less frequently among nurses and clinicians and more commonly among parents (mostly mothers) in pediatric populations; one systematic review reported a sensitivity of 87.5% and specificity of 54.6%, with pooled PLR, NLR, and diagnostic odds ratio of 1.93, 0.23, and 8.46, respectively (15).

A common clinical scenario involves a discrepancy between PPF and MFC during history taking and physical examination, accompanied by a NCIFT reading of less than 38°C. Current literature does not allow definitive judgment regarding which measurement is accurate, with debates citing NCFIT's relatively low sensitivity (11), potential for measurement errors (9, 10), and uncertainty surrounding its fever threshold (12). A systematic review of NCFIT underscored the need for further investigation (7). Therefore, this study aimed to compare the diagnostic accuracy of PPF, MFC, and NCFIT with TT as the reference test.

2. Methods

2.1. Study design and setting

This cross-sectional diagnostic accuracy study was conducted at a Tehran University of Medical Science-affiliated hospital (Imam Khomeini Hospital Complex) between May and September 2023. Convenience sampling was performed in the ED triage room, with no additional follow-up after data collection. The diagnostic accuracy of PPF, MFC, and NCFIT in detecting the fever were compared considering TT as the reference standard test.

We obtained written informed consent from both patients and nurses, and confidentiality was maintained throughout the study. The research ethics committee approved the study (IR.TUMS.IKHC.REC.1402.243). Researchers adhered to the principles of Helsinki declaration and confidentiality of patients' information.

2.2. Participants

All patients aged >18 years who presented to the triage room were eligible. We excluded patients with emergency severity index level one, those with ear complaints, and any patient whose temperature was revealed to the examiners.

2.3. Data gathering

Baseline demographic and clinical characteristics were collected by an emergency medicine resident (EMR; M.S) by enquiring documents or, if unavailable, by direct questioning, and recorded in a researcher developed checklist. Past medical and medication histories with potential effects on body temperature were obtained in detail. Hypo- or hyperthyroidism (16) was considered present if the patient was receiving relevant medication or had abnormal laboratory values per American Thyroid Association guidelines (17, 18). Diabetes mellitus (DM) (19) was defined by abnormal blood glucose per American Diabetes Association criteria (20) or use of oral hypoglycemic agents or insulin. Chronic kidney disease (21) was considered significant if estimated glomerular filtration rate was <60ml/min or the patient was receiving peritoneal or hemodialysis. Cirrhosis was diagnosed based on prior medical records or ultrasonographic findings. Human immunodeficiency virus was defined as a confirmed positive third or fourth generation ELISA antibody test. We referred to previous documents for evaluating cancer and transplant status. Other diseases (22, 23) were recorded based on patient history. We also documented current drug use with possible temperature effects.

Antipyretics (acetaminophen and NSAIDs (non-steroidal anti-inflammatory drugs)) were recorded if they were used during the last 6 hours. Chemotherapy was considered active if administered within the preceding month (24). We assumed corticosteroid usage significant for both chronic and acute use, given their potential to suppress the hypothalamic–pituitary axis and alter arachidonic acid metabolism (acute use<24h or chronic use>20mg/day prednisolone equivalent for>5days) (25, 26). Other drugs were recorded if used routinely, based on patient history.

2.4. Procedure

2.4.1 Index tests

Five emergency nurses (ENs), each with >5years of experience (three were male, all with >20years of total experience), performed MFC during clinical shifts in the triage room. Before assessments, examiners remained in the room until their body temperature equilibrated with the environment. The EMR measured room temperature and humidity and obtained each EN's temperature using a TT immediately before MFC. ENs touched patients without restrictions on contact site or method and reported MFC results (positive/negative) to the EMR.

Inter-rater reliability (IRR) was assessed for four ENs on 10 patients (five febrile, five afebrile) outside the study population, with 100% agreement observed.

PPF was evaluated by directly asking patients, "Do you feel feverish?". A "yes" response was considered positive; all other responses were negative. NCFIT measurements were

obtained using a Beurer Medical FT90 held at a 90° angle, 1cm from the glabella, per manufacturer guidelines (9). Temperatures≥38°C were classified as fever (1).

2.4.2 Gold standard

The final step in patient evaluation was TT measurement, which served as the gold standard, and classified febrile patients as those with a temperature≥38°C (1, 27). Although none of non-invasive thermometers perfectly matches central temperature (6), TT has been widely adopted as a reference standard in previous studies (1, 13). TT measurements were taken using a Beurer Medical FT70 by an EMR trained in the technique, pulling the ear helix upward and backward before measurement.

2.5. Statistical analysis

Baseline characteristics were summarized descriptively. Differences in MFC room temperature, humidity, and EN body temperature were examined using independent t tests, with statistical significance set at P<0.05. Diagnostic accuracy indices (sensitivity, specificity, positive likelihood ratio (PLR), negative likelihood ratio (NLR)) were computed in Microsoft Excel, while accuracy was assessed via area under the receiver operating characteristic (ROC) curve analysis in SPSS (Statistical Package for the Social Sciences) version26. We calculated sample size as 280 (140 with and 140 without fever), assuming an index test sensitivity of 90% and 95% confidence interval (CI) (Supplementary file 1). CI for all diagnostic accuracy indices were calculated using the Clopper–Pearson exact binomial method. If any of the temperature related variables, whether demographic or measurement, were missing, all data for that patient was excluded from the analysis.

3. Results

3.1. Baseline characteristics of participants

This study ultimately included 279 patients with the mean age of 52.21 ± 16.98 (range:18.-89) years (51.97% male). 43 (15%) presented during the night shift. Approximately half of patients (50.2%) had no previous medical history; among those with a history, diabetes mellitus (DM) (54 patients) and cancer (24 patients) were the most prevalent conditions with possible influence on body temperature. In addition, most patients (60.9%) were not taking medications known to affect body temperature (Table 1).

Nurses examined patients in the mean room temperature and humidity of 24.8°C (±1.1) and 20.6% (±4.7), respectively. The mean body temperature of patients using the NCFIT and TT was 37.5°C (±1.7) and 35.9°C (±0.7), respectively. TT identified 147 febrile and 132 non-febrile patients.

3.2. Diagnostic accuracy of studied methods

As shown in Table-2, the most sensitive index test was MFC (100% (97.5–100.0)), with the lowest NLR (0), but moderate accuracy (93.90 (95%CI: 89.9–96.0)) and PLR (8.25 (95%CI: 5.7–12.1)). The MFC results did not differ significantly across measurements taken at varying room temperatures (p=0.059), humidity levels (p=0.10), or based on nurses' body temperatures (p=0.45). Similar to MFC, PPF was highly sensitive (99.31% (95%CI: 93.1–99.3)) with a near zero NLR but had the lowest specificity (80.30% (95%CI: 74.3–87.9)) and accuracy (89.80 (95%CI: 84.5–92.9)). In contrast, NCFIT exhibited the lowest sensitivity (85.71% (95%CI: 78.9–90.9)) but the highest specificity (98.48% (95%CI: 93.6–99.5)) and accuracy (97.50% (95%CI: 93.1-99.8)).

According to ROC curve analysis, the sensitivity, NLR, and PLR improved to 99% (95%CI: 97.4-99.9), 0.01 (95%CI: 0-0.6), and 49.5 (95%CI: 20.8-90.2), respectively, when the fever threshold for NCFIT was set at 37.5°C, while specificity remained at about 98% (95%CI: 94-99.6) (Figure 1).

4. Discussion

MFC and PPF were highly sensitive, while the most specific test was NCFIT. In other words, fever could be ruled out using MFC or PPF, but ruling it in required NCFIT or TT. However, when the fever threshold for NCFIT was set at approximately 37.5°C, its sensitivity, NLR, and PLR improved to 99%, 0.01, and 49.5, respectively, while specificity remained around 98%. In this scenario, NCFIT could effectively rule fever both in and out simultaneously.

The hypothalamic region in the brain maintains central temperature around a set point by regulating the autonomic nervous system. Both the set point itself and the thermoregulatory process can be influenced by numerous factors including circadian rhythm, age, cytokines, brain injury, medications, and chronic medical illnesses such as cirrhosis (28, 29). Additional complexity arises when considering the relationship between central and peripheral temperature, given the differing accuracies of various devices at different body sites (3, 6, 30-32). The literature contains multiple cut off points or ranges for defining normal and elevated temperature across devices and measurement sites (33), and debates over defining normal, elevated, and decreased temperatures have persisted more than for other vital signs (3, 31, 34). To date, no study has evaluated patients with identical demographics, comorbidities, and medication use, at the same time of day, using a gold standard central thermometer to assess the accuracy of peripheral thermometers, nor compared these findings with both clinical and paraclinical diagnoses in the ED or other settings. Such a study would likely be neither feasible nor cost-effective, making it unlikely to provide a definitive definition of fever or precise accuracy indices for various temperature assessment tools.

Our study showed that the specificity and the accuracy increased progressively as temperature assessment became more objective and instrument based, from PPF (80.30% and 89.80) to MFC (87.88% and 93.90) and NCFIT (98.48% and 97.50). Consequently, it is not unexpected for a patient to report feeling feverish and/or ENs to perceive fever on examination, while the NCIFT reading is below 38°C. In such

cases, using TT or another confirmatory method may be beneficial. Conversely, if the patient does not report fever and it is not detected on examination, but NCFIT shows >38°C, the patient should be considered febrile. A previous study suggested using a 35.1°C cut-off for fever screening (9), which appears unacceptably low (12). A systematic review (11) found no significant difference in the sensitivity or specificity of NCIFT at thresholds above or below 38°C. However, such results are clinically meaningless, as interpretation of temperature requires a defined cut-off, and statistically, the specificity of a 34°C threshold will certainly be lower than that of 38°C. In the present study, ROC curve analysis identified a 37.5°C cut-off for NCIFT, providing sensitivity and specificity of 99% and 98%, respectively, which appears sufficient for ruling in or ruling out fever.

5. Limitations

Our study focused on elevated body temperature; however, a decrease below 36°C is also clinically important, occurring in conditions such as intoxication, environmental exposure, or serious infectious diseases.

The optimal gold standard for temperature assessment is a central thermometer, such as a photoacoustic (PA) thermometer. However, because our research question concerned the comparative accuracy of peripheral thermometers, we selected the TT as the most accurate, available, and feasible option. Since this device is itself susceptible to measurement error, EMR was trained to minimize systematic error. Nonetheless, potential errors related to cerumen impaction or fluid accumulation in front of or behind the tympanic membrane were not assessed—consistent with routine clinical practice, where such assessments are typically not performed prior to TT use.

MFC as a physical examination can be influenced by many factors, including age, sex, experience, and information bias. In our study, accuracy was recorded exclusively for ENs, which may differ in other professional groups, such as emergency physicians (EPs), warranting further investigation in diverse clinical settings. We recruited five ENs with varying demographic characteristics to improve validity; however, conducting examinations during nurses' clinical shifts could have exposed them to patients' complaints, such as fever or infectious symptoms, potentially biasing their differentiation between febrile and afebrile conditions. The inter-rater reliability (IRR) assessment was performed after completion of data collection, during which one of the ENs was unavailable. Consequently, the exact IRR among all examiners remains unknown. However, IRR among the remaining four ENs was 100%, allowing us to reasonably assume that the worst case scenario for the fifth nurse would still be acceptable. Intra rater reliability was not assessed due to feasibility constraints and the potential for changes in patient temperature over time.

6. Conclusions

MFC and PPF were highly sensitive for ruling out fever, while NCFIT was the most specific method. At a 37.5°C threshold, NCFIT demonstrated both high sensitivity and specificity, making it effective for simultaneously ruling in and ruling out fever.

7. Declarations

7.1. Acknowledgments

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7.2. Authors' contributions

Moojan Shabani: Investigation; Mohammad Jalili: Supervision; Ali Pasha Meysamie: Software, Validation; Atoosa Akhgar: Data curation; Hamideh Akbari: Data curation; Mahdi Zangi: Writing-Reviewing and Editing; Mehrnoosh Zahrai: Writing-Original draft preparation; Saeed Aghavil-Jahromi: Visualization; Mohammad Eftekhari: Conceptualization, Methodology, Writing-Reviewing, and Editing. All authors read and approved the final version.

7.3. Conflict of interest

None.

7.4. Funding

None.

7.5. Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request and subject to approval by the journal editors.

7.6. Using artificial intelligence chatbots

The authors declare that artificial intelligence (AI) tools were used only for linguistic revision of the manuscript. No AI tools were used in the conception, analysis, interpretation of data, or in drawing scientific conclusions.

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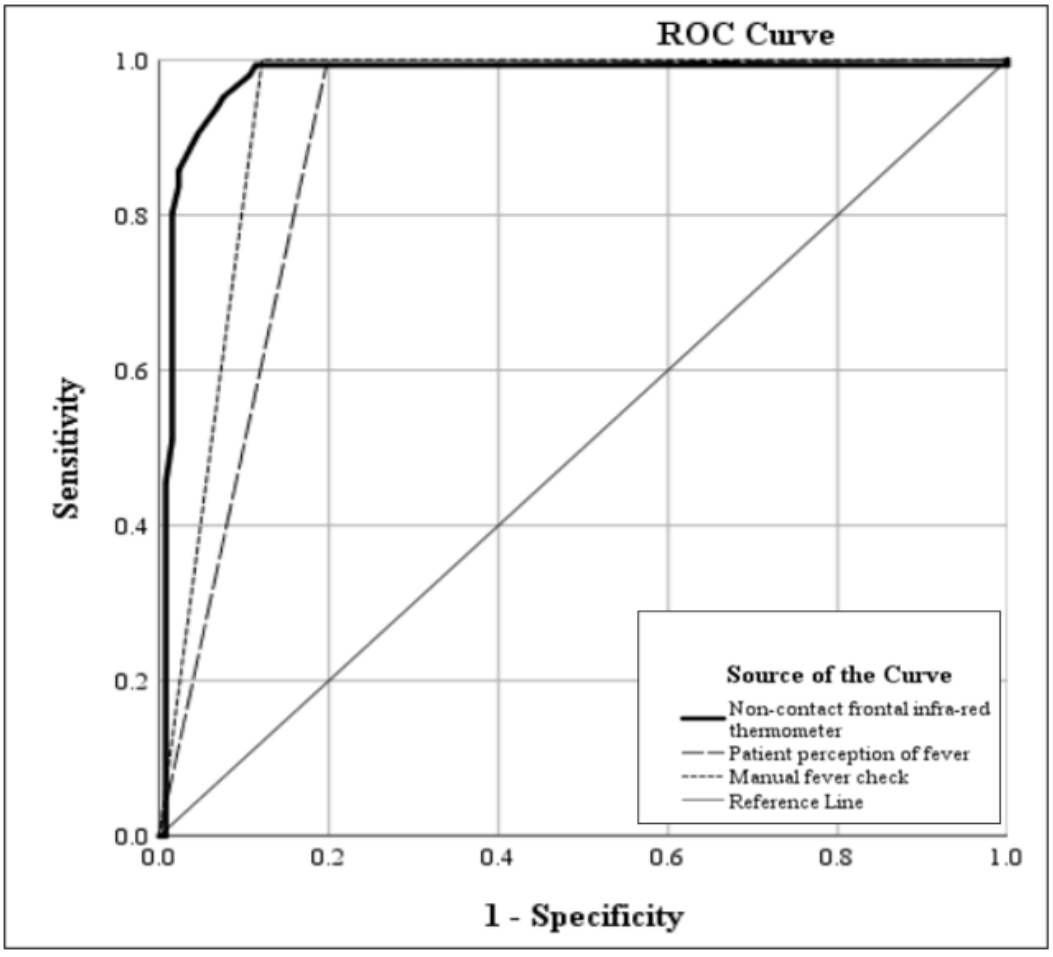

Figure 1: Receiver operating characteristic (ROC) curve of non-contact infrared frontal thermometer (NCIFT), manual fever check (MFC), and patient perception of fever (PPF) considering the tympanic temperature as the gold standard.

Table 1: Baseline characteristics of studied patients

Variables	Values	Variables	Values
Sex		Age (year)	
Female	134 (48)	Mean ± SD	52.2 ± 16.98
Male	145 (52)	Drug history	
Past medical history		Antipyretics2	13 (4.7)
Hypothyroidism	8 (2.9)	Aspirin	14 (5.1)
Hyperthyroidism	1 (0.4)	levothyroxine	8 (2.9)
Diabetes mellitus	54(19.3)	Methimazole	1 (0.4)
Chronic kidney disease	3 (1.1)	Corticosteroid3	2 (0.8)
Cirrhosis	7 (2.6)	Active chemotherapy4	8 (2.9)
HIV	1 (0.4)	Immuno-modulator/suppressant5	2 (0.8)
Solid or hematologic cancer	24 (8.7)	Others	82 (29.4)
Organ transplant	3 (1.1)		
Others1	70 (25.1)		

Data are presented as mean ± standard deviation (SD) or number (%). HIV: Human immunodeficiency virus;
1. Hypertension, dyslipidemia, cardiac disorder/surgery, and neurologic disorder/surgery.
2: Acetaminophen and non-steroidal anti-inflammatory drugs.
3: Chronic or acute uses.
4: Chemotherapy was considered active if last dose was taken during the previous month.
5: Methotrexate and Omalizumab.

Table 2: Diagnostic accuracy indices of non-contact infrared frontal thermometer (NCIFT), manual fever check (MFC), and patient perception of fever (PPF) considering the tympanic temperature as the gold standard

Indices	NCIFT	MFC	PPF
True positive	126	147	143
True negative	129	116	108
False positive	3	16	24
False negative	21	0	4
Sensitivity	85.71 (78.9–90.9)	100 (97.5–100.0)	99.31 (93.1–99.3)
Specificity	97.72 (93.6–99.5)	87.88 (81.1–92.9)	80.30 (74.3–87.9)
NLR	0.15 (0.10–0.22)	0.00 (0.00-0.00)	0.03 (0.01–0.09)
PLR	37.7 (12.2–116.2)	8.25 (5.7–12.1)	5.35 (3.7–7.8)
PPV	97.7 (93.4–99.5)	90.2 (84.6–94.2)	85.6 (79.3–90.5)
NPV	86.0 (79.2–91.1)	100.0 (96.9–100.0)	96.4 (91.1–99.0)
Accuracy	97.50 (93.1-99.8)	93.90 (89.9–96.0)	89.80 (84.5–92.9)

Data are presented with 95% confidence intervals. NLR: Negative likelihood ratio; PLR: Positive likelihood ratio; PPV: positive predictive value; NPV: negative predictive value.