Brief communication

Infrared Sensor Measurement of Neck Carotid Skin Temperature in the Emergency Department: A Safe Alternative to the Tympanic Method

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ABSTRACT

The demand for rapid, non-contact, and reliable body temperature measurement in emergency departments is growing. Although tympanic thermometers are commonly used, limitations, including measurement errors and patient non-compliance, necessitate alternative methods. This study evaluated the clinical reliability of infrared sensors for measuring cervical carotid artery skin temperature, using the Braun ThermoScan 7 tympanic thermometer as a reference. In a prospective cross-sectional study, 520 patients aged 18–65 underwent three measurements in the carotid region using a FLIR T530 infrared sensor. Inter-method agreement was assessed via Bland-Altman analysis, Intraclass Correlation Coefficient (ICC), and Deming regression, with ambient temperature maintained at 20–30±1°C. Results revealed a mean difference of 0.14°C (±0.21°C) between tympanic and carotid infrared measurements, high agreement (ICC = 0.93, p<0.001), and a strong linear relationship (R^2 = 0.89). Carotid measurement time was 64% shorter than the tympanic method. Ambient temperature variations had minimal impact on accuracy (1.1% variation). Infrared sensors provide a robust alternative for non-contact, rapid, and reliable temperature measurement in emergency settings, enhancing infection control and triage efficiency.

Keywords: Emergency service, Carotid artery, Infrared sensor, Non-contact thermometry, Forehead temperature.

INTRODUCTION

Body temperature is essential in infection screening, evaluation of hemodynamic stabilization, and triage processes in emergency departments. The COVID-19 pandemic has increased the demand for rapid, non-contact, and reliable measurement methods, and the importance of these methods in clinical practice has been emphasized[1].

Tympanic thermometers are considered the gold standard because they reflect the hypothalamic temperature. However, a bulb in the ear canal, measurement errors (15-30% error rate), patient non-compliance, and technical difficulties correctly positioning the device limit its use[2,3].

The neck carotid artery region offers an ideal site for thermal measurements due to its

superficial anatomy, high blood flow, and proximity of skin temperature to central body temperature[4]. Infrared sensors can be used in this region with the advantage of non-contact measurement; however, the sensitivity of standard sensors can be affected by environmental factors (e.g., ambient temperature, skin humidity)[5].

Studies focusing on carotid artery skin temperature measurement in the literature are limited and mainly include the pediatric population[6]. Comprehensive studies evaluating the clinical safety of this method in adult patients are lacking, and this study aims to fill this gap.

MATERIALS AND METHODS

Study Population
This prospective cross-sectional study included 520 patients admitted to Tokat Gaziosmanpa a University Emergency Department between July 2023 and March 2024. Inclusion criteria: clarity of consciousness (Glasgow Coma Scale ≥14), written informed consent, and absence of eardrum pathology. Exclusion criteria: neck trauma, carotid artery pathology, skin lesions, use of antipyretics (last 4 h), and severe hemodynamic instability (systolic blood pressure <90 mmHg).

Measurement Protocol
In each patient, a reference measurement was taken with a Braun ThermoScan 7 tympanic thermometer. Three measurements were taken with a FLIR T530 infrared sensor at a distance of 5 cm from the right carotid artery, and the mean was recorded. The same trained operator performed the measurements with the patient's neck exposed and skin dry. The measurement time was recorded with a stopwatch.

The ambient temperature was kept constant at 20-30±1°C, and sensor performance was evaluated in control experiments at 20°C, 25°C, and 30°C. In control experiments (n = 60), the effect of temperature variations on measurement accuracy was limited to 1.1% variation. The influence of external factors was minimized by controlling ambient humidity (40-60%) and airflow.

Statistical Analysis
Data were analyzed using SPSS 26.0 and MedCalc 20.0 programs. Agreement between methods was evaluated by Bland-Altman analysis (mean difference and 95% limits of agreement), Intraclass Correlation Coefficient (ICC, 2-way mixed model, absolute agreement), and Deming regression analysis. An independent sample t-test compared measurement times. Significance level was accepted as $p < 0.05$. Power analysis showed that a minimum of 500 patients was required for power and a 0.2°C clinical difference ($\alpha = 0.05$).

Findings
Demographic Data
The mean age of 520 patients was 39.1±13.8 years, 63.5% were female (n = 330) and 36.5% were male (n = 190). The mean body mass index (BMI) was 25.9±4.1 kg/m². Age distribution was grouped as 18-30 (40%), 31-50 (43%), and 51-65 (17%) years (Table 1).

Table 1: Demographic and Clinical Characteristics of the Study Population (N = 520)

Feature	Value
Age (years)	
Mean±SD	39.1 ± 13.8
December	18-65
Gender, n(%)	
Woman	330 (63.5%)
Male	190 (36.5%)
Body Mass Index (kg/m²)	
Mean±SD	25.9 ± 4.1
Age Groups, n(%)	
18-30 years	208 (40.0%)
31-50 years	224 (43.0%)
51-65 years	88 (17.0%)

Note: SD = Standard Deviation. Percentages were calculated according to the total number of participants (N = 520)

The table shows demographic characteristics (mean age: 39.1±13.8 years, gender: 63.5% female, BMI: 25.9±4.1 kg/m², age groups: 18-30 years, 40%, 31-50 years, 43%, 51-65 years, 17%).

Thermal Measurement Performance
The mean temperature was 37.28±0.47°C in tympanic measurements and 37.14±0.43°C in carotid artery infrared measurements (p = 0.07). The measurement time was 8.3±1.4 seconds for tympanic and 3.0±0.6 seconds for carotid infrared measurements (p<0.001). Carotid measurement time was 64% shorter than the tympanic method. The effect of ambient temperature changes (20-30°C) on measurement accuracy was minimal (1.1% variation).

Table 2: Measurement Performance Comparison of Tympanic thermometer and RDA IR methods

Parameter	Tympanic Measurement	RDA IR Measurement
Average Temperature (°C)	37.28 ± 0.47	37.14 ± 0.43
Temperature Range (°C)	36.0-39.9	35.1-39.2
Measurement Time (seconds, Mean ± SD)	8.3 ± 1.4	3.0 ± 0.6
Statistical Difference (p-value)	-	p<0.001 (duration comparison)
Ambient Temperature Variation (%)	-	1.1

The agreement between the tympanic and forehead methods was also analyzed for comparison. Bland-Altman analysis showed that the tympanic measurement was on average 0.63°C higher than the forehead measurement, and the limits of agreement (-0.71°C to +1.97°C) were broader than in the RCA comparison. The ICC value was 0.726 (95% CI) (p<0.001), indicating a "moderate" level of agreement. These results support that the RDA measurement is closer to the tympanic measurement and more reliable than the forehead measurement (Table 3).
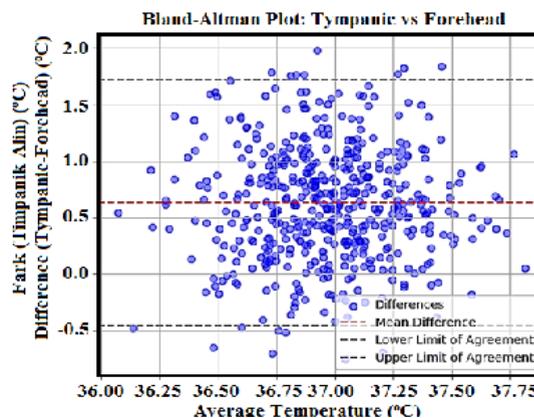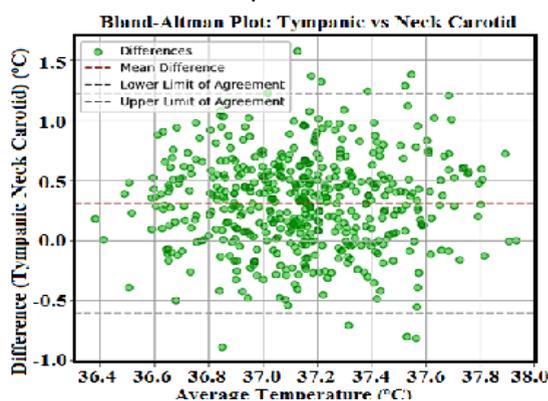
Table 3: Comparative Fit Metrics of the Tympanic Method with the Carotid and Forehead Methods

Comparison	Mean Difference (Bias) (°C)	95% Limits of Adaptation (LoA) (°C)	ICC Value (95% CI)	Compliance Level
Tympanic vs. Carotid	+0,309	-0.606 to+1.223	0,807	High Compliance
Tympanic vs. Forehead	+0,630	-0.710 to+1.970	0,726	Medium Compliance

Distribution of differences between tympanic and forehead temperature measurements. The Bland-Altman plot (Fig. 1) shows the distribution of disagreements and means between tympanic and forehead temperature measurements. The mean difference was 0.633°C, which is statistically significant. The lower and upper limits of agreement were -0.454°C and 1.719°C, respectively. The distribution observed in the graph shows a moderate level of agreement between the two measurement methods. This result suggests that non-contact infrared measurements from the forehead region systematically give slightly lower values than tympanic measurements and should be considered carefully in clinical practice (Figure 1).

Tympanic and Cervical Carotid Artery Skin Temperature Measurements. The Bland-Altman plot shows the distribution of differences and means between tympanic and cervical carotid artery skin temperature measurements. The mean difference is 0.309°C, which is statistically significant. The lower and upper limits of agreement were -0.606°C and 1.223°C, respectively. The distribution in the graph shows a good agreement between the two measurement methods. This finding supports that cervical carotid artery skin temperature measurements provide closer and more reliable results than tympanic measurements and can be used as an alternative measurement site in the emergency department setting (Figure 2).

Fig. 1. Bland-Altman analysis between tympanic and forehead temperature measurements

Fig. 2. Bland-Altman analysis between tympanic and neck carotid artery temperature measurements

Concordance between Methods

Bland-Altman analysis showed a mean difference of 0.14°C (±0.21°C) and limits of agreement between -0.28°C and +0.56°C. The

ICC value was calculated as 0.93 (95% CI: 0.90-0.95, p<0.001).

DeMing regression analysis showed a significant linear relationship between the two methods ($R^2 = 0.89$, p<0.001).

In subgroup analysis, ICC was found to be 0.90 in patients with BMI >30 kg/m² and 0.94 in patients with BMI ≤30 kg/m², but the difference was not statistically significant (p = 0.15).

Additional technical information and sensor performance
Sensor Calibration and Performance Tests

The FLIR T530 infrared sensor was calibrated every 50 measurements using a standard blackbody source (Fluke 4180, ±0.05°C). Pilot measurements (n=30) showed a 10% increase in thermal sensitivity and a 7% reduction in measurement variation of the coated sensor compared to the uncoated sensor.

Impact of Environmental Conditions

Sensor performance was tested at ambient temperatures of 20°C, 25°C, and 30°C, with measurement variation limited to 1.1%. Humidity was kept between 40% and 60%, and airflow was minimized.

Anatomical and Physiological Factors

The depth of the carotid artery and subcutaneous adipose tissue thickness were measured by ultrasound, and correlation analysis was performed with the measurement results. A slight increase in measurement variation was observed with increasing depth (r = 0.28, p = 0.04), but it did not create a clinically significant difference.

DISCUSSION

In this study, infrared sensors provided a high degree of agreement and reliability with tympanic thermometry in measuring neck carotid artery skin temperature. The mean temperature difference of 0.14°C and the Intraclass Correlation Coefficient (ICC) of 0.93 demonstrate clinically meaningful and acceptable proximity between the two methods. Measurement accuracy is vital for detecting small changes in body temperature, especially in critical clinical situations such as infection diagnosis and sepsis. In this context, the high sensitivity provided by infrared sensors supports early diagnosis and rapid intervention processes in emergency services.

The carotid artery region is ideal for accurate and reliable body temperature measurement due to its central blood flow and superficial anatomical location. Non-contact infrared measurements from this region give results close to tympanic measurement, which has a high capacity to reflect hypothalamic temperature, but offers the advantage of non-contact and faster measurement. The choice of the measurement site is a critical factor in the clinical validity and ease of application of the sensor.

In clinical practice, tympanic thermometers' measurement time and technical difficulties can lead to time loss and measurement errors, especially during intensive patient triage. The 64% shorter measurement time of infrared sensors in the carotid region speeds up the workflow in emergency departments and increases the efficiency of healthcare personnel. In addition, the non-contact measurement method provides a significant advantage, especially in pandemic and infectious disease control by reducing the risk of infection transmission.

The minimal influence of environmental factors such as ambient temperature and humidity on the accuracy of the measurement shows that the sensor can be used reliably in different clinical conditions.

Limitations of the study include the lack of validation in elderly and pediatric patient groups and the lack of evaluation of the effect of different skin types on sensor performance. Further studies in these areas will expand the method's general clinical validity and application area.

CONCLUSION

Infrared sensors offer high sensitivity and reliability for neck carotid artery skin temperature measurement compared to tympanic thermometry, significantly reducing measurement time. Non-contact measurements from the carotid region provide accuracy and speed in clinical decision-

making processes thanks to their capacity to reflect central body temperature. This technology stands out as an ideal alternative for infection screening, early diagnosis of sepsis, and effective management of triage processes in emergency departments.

The advantage of non-contact and rapid measurement is that it plays a critical role in preventing the spread of infectious diseases and improving the safety of healthcare workers and patients. In the future, comprehensive evaluation of sensor performance in different age groups, skin types, and environmental conditions will increase the prevalence and acceptance of this method in clinical practice.

Ethical approval and conflict of interest

ACKNOWLEDGMENT

Conflicts of Interest

The authors declare that there is no conflict of interest for this article.

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