Diagnostic accuracy of three different methods of temperature measurement in acutely ill geriatric patients

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Abstract

Objective: we examined the diagnostic accuracy of different methods of body temperature measurement to diagnose infection in geriatric patients presenting to the emergency department (ED).

Methods: this observational study was done in consecutive patients ≥75 years old presenting to the ED. Body temperature was determined by tympanic thermometry, temporal artery thermometry and rectal temperature measurement. Adjudicated final diagnosis of infection was done by two experts including patient history, clinical and laboratory findings as well as radiographic studies.

Results: a total of 427 patients were included in the data analysis (age: 82.7 ± 5.1 years). Infection was present in 105 patients (24.6%). Respiratory rate, heart rate and body temperature were significantly higher in patients with infection, blood pressure was lower (P < 0.01). Body temperature measured by tympanic and temporal artery thermometry was correlated with rectal thermometry. Body temperature was significantly higher in patients with infection compared with those without infection independent of the method of body temperature measurement (P < 0.001). The diagnostic accuracy for infection quantified by the area under curve (AUC) was comparable among rectal [AUC: 0.72 (95% CI: 0.65–0.80)] and tympanic thermometry [AUC: 0.73 (95% CI: 0.66–0.81)], but significantly lower in temporal artery thermometry [AUC: 0.65 (95% CI: 0.57–0.73; P < 0.001)]. Compared with rectal measurement tympanic thermometry showed a higher bias than temporal artery thermometry (0.54 versus 0.03°C), while its limits of agreement were more narrow (−0.14 to 1.21°C versus −0.94–1.01°C).

Conclusion: diagnostic accuracy for the identification of infection was comparable among tympanic and rectal thermometry and lower for temporal artery thermometry. Different cut-off points should be used to identify infection using...
Introduction

The measurement of body temperature is used in ‘track and trigger systems’ to identify patients at increased risk for adverse outcome [1]. Increased body temperature is associated with infection in young patients, but can be absent or only slightly increased in up to 30% of old patients [2]. Of note, body temperature in old people is lower than in young people [3, 4]. Guidelines for the evaluation of fever and diagnosis of infection in older long-term care residents by the Infectious Disease Society of America (IDSA) define ‘fever’ as an increase of temperature by >2°F (>1.1°C) over the baseline or a single oral temperature >100°F (>37.8°C), repeated oral temperatures >99°F (>37.2°C) or rectal temperatures >99.5°F (>37.5°C) [5]. As far as to our knowledge, there are no guidelines or recommendations for the measurement or validated reference points for the body temperature of old patients presenting to the emergency department (ED).

Infections in old patients are associated with increased morbidity and mortality [6]. Early recognition of infections and immediate initiation of antibiotic therapy are crucial factors to reduce morbidity and mortality of affected patients. Thus, it is essential to choose the most accurate method of body temperature measurement for affected patients presenting to the ED. The primary goal of our study was to evaluate the diagnostic accuracy of body temperature measurement using different methods to diagnose infection in patients ≥75 years presenting to the ED. The secondary goal was to compare the reliability of tympanal and temporal artery thermometry with rectal temperature measurement.

Patients and methods

Study design

This is prospectively conducted quality measurement project which was retrospectively analysed to examine the quality of vital parameter measurement in consecutive patients ≥75 years old presenting to the ED. From August to November 2010, a study nurse performed the measurement of vital signs in consecutive old patients. Measurements were done on 1–3 days per week (8:00–15:00 h) [7]. The study was approved by the local Institutional Review Board and the ethical committee. We performed and reported the study according to the STARD criteria [8].

Setting and selection of participants

The study was conducted in the ED of a German urban university-affiliated hospital with 80,000 attendees per year. The proportion of patients ≥75 years presenting in the ED was 23.3% in 2010. All the patients presenting during the given time periods were screened for eligibility. Inclusion criteria were age ≥75 years and given informed consent. Patients were excluded from the study, if the patient did not speak German language, the patient’s cardiorespiratory status was unstable or the presence of contraindications to one of the temperature measurement methods.

Interventions

All measurements were carried out during the first hour of patients’ presentation to the ED. Body temperature was measured by a single trained study nurse using tympanal thermometry, temporal artery thermometry and rectal temperature measurement. Other vital signs (heart rate, blood pressure, respiratory rate) were measured by the triage nurse and all results were made available to the staff in order to avoid diagnostic or therapeutic delay.

Demographic data, mode of admission, chief complaints, comorbidities, transfer to an intensive medical care unit and length of stay as well as missing vital parameters were obtained by reviewing all medical records available. Patients with missing parameters for body temperature were excluded from the data evaluation. Data verification was conducted for all data collected from medical records by two independent persons of the research team.

Adjudicated final diagnosis

To determine the final diagnosis for each patient, two experienced physicians independently reviewed all available medical records of the index hospital stay, including clinical history, findings on physical examination, results of laboratory tests (including blood count, C-reactive protein, pro-calcitonin values and microbiological testing) and radiographic studies. Infection was diagnosed, if there were laboratory signs and clinical signs in reference to the related IDSA clinical practice guideline [5].

Instruments and methods

Measurements of body temperature were carried out by the use of following methods:

- Tympanal temperature was measured by the use of infrared ear thermometry (Braun Thermoscan® ear thermometer, Kaz Europe SA, Lausanne, Switzerland). For quality reasons, measurement was performed in both ears and the mean temperature was used for further analysis. Hearing aids were removed 15 min before the measurement. To straighten the acoustic meatus, the concha was retracted
Temporal artery thermometry (Exergen TemporalScanner™ Model TAT-5000, Exergen Corporation, Watertown, MA, USA), which uses infrared technology, was done using recommended methods: probe was only taken on exposed site. Probe was put flush on the forehead and slowly slid midpoint across forehead to the hairline, afterwards the probe was lifted from the forehead and touched on the neck behind the ear lobe.

Rectal temperature was measured using a IVAC® TEMP PLUS II® Model 2080 Thermometer (IVAC®, San Diego, CA, USA). Depth of insertion of the probe was 5–8 cm into the rectum [9].

All data were recorded in degrees Celsius. Instruments were assessed for accuracy and reliability according to the legal regulations of the hospital.

Outcomes and data analysis

Primary endpoint was the diagnostic accuracy of rectal, tympanic and temporal artery thermometry to diagnose infection in old patients presenting to the ED. In a secondary analysis, agreement of tympanic and temporal artery thermometry and rectal body temperature measurement was evaluated. Continuous variables are presented as means (±SD) or medians [inter-quartile range (IQR)]. Categorical variables (gender, diagnosis of infection) are presented as numbers and percentages. Comparison of temperatures obtained at different sites or in different subgroups of patients were performed using Student’s paired t-test or the Mann–Whitney U test for independent variables. For categorical data, the Pearson Chi-square test was used. Agreement between measurement methods was assessed [10]. Receiver operating characteristic (ROC) curves were constructed to assess the sensitivity and specificity for the different methods of temperature measurement obtained at presentation. The comparison of areas under the ROC curves (AUC) was performed as recommended by DeLong et al. [11]. Proportions are described with 95% confidence intervals (CI). All hypothesis testing was two-tailed, and P-values <0.05 were considered statistically significant. Data were analysed using SPSS version 16.0 for Windows, Munich, Germany.

Results

Characteristics of study subjects

In 2010, 77,783 patients, 18,081 of them ≥75 years old, presented to the ED in 2010. During the study period, 877 patients ≥75 years presented to the ED; 458 patients that presented during the above-mentioned time periods when the study nurse was present, were invited to participate in the quality measurement project. Owing to missing consent to measure the rectal temperature 427 patients were finally enrolled.

Demographic characteristics of patients are displayed in Table 1. The mean age of the cohort was 82.7 ± 5.1 years, 159 (37.2%) were male; 165 patients (38.6%) were admitted to the ED by the emergency medical service and 236 patients by their family physician (55.3%). Infection was present in 105 patients (24.6%); 17 were urinary tract infections (16.2%), 8 soft tissue infections (7.6%), 47 pulmonary infections (44.8%), 17 GI infections (16.2%) and 16 other infections (15.2%). Twenty-four (5.6%) of the patients had to be treated in an intensive care unit and 25 (5.6%) of the patients died during hospitalisation. The median length of stay in the hospital was 7 days (IQR: 9). Patients with infections suffered more often from chronic renal disease, dementia and heart failure. At presentation, respiratory rate, heart rate and body temperature were significantly higher in patients with infection, whereas blood pressure was lower (Table 1).

Diagnostic accuracy of body temperature measurement

The mean temperature in enrolled patients measured by the study nurse was 36.9 ± 0.7 (tympanic), 37.4 ± 0.6 (temporal artery) and 37.4 ± 0.7 (rectal). The mean difference between the left and right ear was 0.07 ± 0.29°C. Tympanal temperature was also measured by the triage nurse. The mean difference between the measurement of the triage nurse and the study nurse was 0.11 ± 0.48°C. Body temperature as measured by rectal thermometry was significantly higher in patients with compared with those without infection [median: 37.7°C (IQR: 1.1) versus 37.3°C (IQR: 0.6); P < 0.001]. The same holds true for tympanal thermometry [37.3°C (IQR: 0.9) versus 36.8°C (IQR: 0.6); P < 0.001] and temporal artery thermometry [37.6°C (IQR 1.2) versus 37.3°C (IQR: 0.6); P < 0.001]; 25 (5.8%), 62 (14.5%) and 67 (15.7%) of 427 patients had a temperature >38°C using tympanic, temporal artery or rectal thermometry (P < 0.001). In patients with an adjudicated final diagnosis of infection, 22.8, 35.5 and 43.8% of patients had a temperature >38.0°C using tympanic, temporal artery and rectal thermometry. Rectal temperature >38.0°C was present in 6 (35%) urinary tract infections, 18 (38%) pulmonary infections, 4 (50%) soft tissue infections, 6 (35%) infections of the gastrointestinal tract and 11 (68%) infections due to other reasons. Rectal temperature >38.0°C in 21 (6.5%) patients without infection was present due to underlying malignant disease, cerebral insult or fever of unknown origin.

The diagnostic accuracy for infection as quantified by the AUC was comparable between rectal thermometry [AUC: 0.72 (95% CI: 0.65–0.80)] and tympanic temperature measurement [AUC: 0.75 (95% CI: 0.66–0.81)]. However, the AUC of temporal artery thermometry was significantly lower compared with tympanic or rectal thermometry [AUC: 0.65 (95% CI: 0.57–0.73); P < 0.001; Figure 1]. Optimum cut-off levels are different for rectal, tympanic and temporal artery thermometry (37.8, 37.3 and 37.9°C). Decision statistics for different cut-off levels are shown in Table 2 using cut-off levels suggested in the literature (37.2, 37.5 and 38.2°C [2]). The analyses show that decision statistics strongly depend on the method of thermometry used and different cut-off
levels have to be used for different temperature measuring methods: a much lower cut-off level for tympanal thermometry has to be used than for rectal thermometry. Data analysis for temporal artery thermometry shows lower diagnostic accuracy than tympanal or rectal thermometry.

**Methods of body temperature measurement**

For the tympanal thermometry, nearly all the measurements were lower compared with rectal thermometry yielded in an average bias of 0.54°C (Figure 2A). When temporal artery thermometry and rectal temperature were matched there was only a bias of 0.03°C and a more symmetrically distribution of the measurements around the line of equality (Figure 2B). But tympanal thermometry showed a tighter 95% limits of agreement than temporal artery thermometry (−0.14°C to 1.21°C versus −0.94°C to 1.01°C). The total difference range for tympanal and rectal thermometry was −0.7 to 1.7°C, and −3.9 to 1.8 for temporal artery thermometry.

**Discussion**

Body temperature belongs to the classic vital signs for the risk stratification of patients presenting to the ED and is used at triage for risk assessment [1,12]. To our knowledge no data exist about the diagnostic accuracy of different methods of body temperature measurement among geriatric patients.
Table 2. Decision statistics of temperature measurement in elderly patients in the emergency department for identification of infection

<table>
<thead>
<tr>
<th>Optimum cut-off</th>
<th>Tympanal thermometry</th>
<th>Rectal thermometry</th>
<th>Temporal artery thermometry</th>
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<tbody>
<tr>
<td>Sensitivity</td>
<td>0.46</td>
<td>0.44</td>
<td>0.38</td>
</tr>
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<td>Specificity</td>
<td>0.91</td>
<td>0.93</td>
<td>0.91</td>
</tr>
<tr>
<td>PPV</td>
<td>0.62</td>
<td>0.69</td>
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<tr>
<td>NPV</td>
<td>0.83</td>
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</tr>
<tr>
<td>LR+</td>
<td>5.00</td>
<td>6.61</td>
<td>4.42</td>
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<tr>
<td>LR−</td>
<td>0.59</td>
<td>0.60</td>
<td>0.68</td>
</tr>
<tr>
<td>Cut-off 37.2°C</td>
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<td>37.2°C</td>
<td>37.2°C</td>
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<tr>
<td>Sensitivity</td>
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</tr>
<tr>
<td>Specificity</td>
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<td>0.47</td>
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<tr>
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<td>0.81</td>
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<tr>
<td>LR+</td>
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<td>1.46</td>
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<tr>
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<tr>
<td>Sensitivity</td>
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<td>0.60</td>
<td>0.50</td>
</tr>
<tr>
<td>Specificity</td>
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<tr>
<td>PPV</td>
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<tr>
<td>NPV</td>
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<tr>
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<td>8.38</td>
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<td>1.73</td>
</tr>
<tr>
<td>LR−</td>
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<td>0.70</td>
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<tr>
<td>Sensitivity</td>
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<tr>
<td>NPV</td>
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<td>0.80</td>
</tr>
<tr>
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</tr>
<tr>
<td>LR−</td>
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</table>

Statistical analysis is presented for optimum temperature cut-offs of tympanal (calculated cut-off 37.3°C), rectal (calculated cut-off 37.9°C) and temporal artery thermometry (calculated cut-off: 37.8°C). Optimum temperature cut-offs were calculated from ROC curve analysis. In addition, decision statistics are given for suggested cut-offs for the elderly (37.2, 37.5°C) and for 38.2°C (2). The prevalence of infection in the study population was 24.9%.

patients presenting to the ED. We analysed the diagnostic accuracy of tympanal, rectal and temporal artery thermometry in unselected, old patients presenting to the ED. The main results are the following: (i) the diagnostic accuracy of tympanal and rectal thermometry in ED patients ≥75 years to identify the presence of infection is comparable (AUC: 0.72 and 0.73), while it is lower for temporal artery thermometry (AUC: 0.65). (ii) Different cutpoints indicating increased body temperature in patients with infections have to be defined for different methods of temperature measurement. (iii) Temperature measurement is an insensitive method to identify old patients with infection, and large variabilities of measured values exist. Temperature measured below the cut-off level does not rule out infection. (iv) There is a significant linear association of temperature measurement using tympanal or temporal artery thermometry with rectal temperature measurement. The difference between tympanal and rectal thermometry was less variable than the difference between temporal artery and rectal thermometry.

Accurate measurement of body temperature is essential, especially in geriatric patients in whom infection is a common reason for presentation [13] and associated with an increased morbidity and mortality [6]. Although rectal measurement of body temperature is considered as one of the most accurate methods to detect fever [14], it is often difficult to use in old patients in daily practice due to immobility or deterioration. Rotello et al. [15] reported that tympanal measurement of body temperature provided closer estimate of body core temperature measured by pulmonary catheter than rectal measurement. The results of our study support the use of non-invasive measurement of body temperature (tympanal and transtemporal) in geriatric patients in the ED. As the difference between tympanal and rectal thermometry was less variable than the difference between temporal artery and rectal thermometry and the diagnostic accuracy of tympanal thermometry showed to be significantly better to detect infections, tympanal measurement should be the preferred method for detection of infection in old patients in the ED. Application of the correct technique and high quality of instruments are essential [9, 16, 17].

Different optimum cut-off values for different methods of thermometry have been found for rectal, tympanal and temporal artery thermometry (37.8, 37.3 and 37.9°C). This is in accordance to a previous study conducted with a small group of patients in an acute geriatric and intensive care setting. Fever in the study was defined by a rectal temperature of ≥37.6°C or a tympanal temperature ≥37.2°C [18]. Our results corroborate and extend those findings: cut-off levels for tympanal thermometry have to be substantially lower than cut-off levels for rectal thermometry. This is of clinical importance as inappropriate use of cut-off levels will alter the sensitivity for the detection of infection possibly delaying correct diagnosis and initiation of treatment [19, 20].

Of note, body temperature below the cutpoint does not rule out infection in old patients. Severe infections in old patients such as endocarditis [21, 22], pneumonia [23] or sepsis [24] go along with normal body temperature in 20–30% of the cases [2]. Average difference in baseline temperature of healthy adults ≥65 years during the day is 0.4°C, Further differences depend on gender, site of measurement, ambient temperature, time of day an season and other variables [25] explaining the variability among the three methods used in our study.

In the ED, basal temperature of the patients is frequently unknown and treatment decisions have to be made using a single temperature measurement. This is in contrast to the possibility of repeated measurements as recommended for long-term care facilities [5]. A delay in the onset of fever as reported by McAlpine of >12 h in 12% of the old patients [26] also aggravates the identification of patients with infections. Comorbidities and the use of different medications such as acetaminophen or novaminsulfone for pain control also contribute to the absence of fever or lower the increase of body temperature during infection. Therefore, the diagnosis of infection of old patients in the ED should not rely on the measurement of body temperature as a single
component, but also take into account other parameters such as delirium, acute decline in the functional status of the patient, reduced food intake, falls or new onset of incontinence [27].

Some limitations of this study merit consideration: (i) diagnosis of infection was done using a retrospective analysis of patient files during hospitalisation, which may bias the adjudicated final diagnosis. In addition, clinical diagnosis of infection is challenging in older patients. We are strongly convinced of the validity of this data analysis, because the diagnosis of infection was made by two experienced physicians considering related ‘IDSA Clinical practice guideline’ and all available medical records of the index hospital stay [5]. (ii) Body temperature was measured during the first hour after presentation. Although the presence of fever may have been missed by a single measurement of body temperature, this is common practice in a busy ED and supports the clinical relevance of our data. (iii) Prior medication was not assessed in the study, so medication could have affected body temperature prior to coming to the ED. In the ED temperature measurement took place before any medication was given to the patient. (iv) Tympanal thermometry may be hampered by earwax [16]. However, diagnostic accuracy of tympanal thermometry was comparable with diagnostic accuracy of rectal temperature measurement suggesting that removal of earwax may not be necessary if measurements were performed in both ears. (v) Sample size calculation was not prospectively performed and results of the study may be subject to coincidence. However, compared with previous studies the sample size is large and the coherence of study results suggesting that presented data are meaningful.

In summary, diagnostic accuracy for the identification of infection in patients ≥75 years in the ED is comparable among tympanal and rectal thermometry, whereas diagnostic accuracy for temporal artery thermometry is significantly lower. It is essential to define different cut-off points for the different methods of temperature measurement used as inadequate cut-off level might lead to a delay in diagnosis and initiation of treatment [28]. For daily practice, it has to be considered that temperature measurement is an insensitive method to identify geriatric patients with infection and further findings such as patient’s history, clinical findings, laboratory values and microbiological findings have to be taken into account.

Figure 2. Scatter and Bland–Altman plots of temperature measurement using rectal, tympanal and temporal artery thermometry. (A) Body temperature measured by tympanal thermometry was significantly associated with temperature measured by rectal temperature measurement (left). The average bias determined by the plot is 0.54°C. The difference range is −0.7 to 1.7°C. (B) Body temperature measured by temporal artery thermometry was significantly associated with temperature measured by rectal measurement (left). The average bias determined by the plot is 0.03°C. The difference range is −3.9 to 1.8°C (right).
Key points

- Accuracy of temperature measurement.
- Acutely ill geriatric patients.
- Definition of different cut-off points.

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Conflicts of interest

None declared.

References


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