A comparison between infrared tympanic thermometry, oral and axilla with rectal thermometry in neutropenic adults

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Abstract

Background: This study assessed the agreement between infrared tympanic membrane (TM), axillary, corrected axillary (–0.5 °C), oral, and corrected oral (+0.3 °C) to rectal thermometry as reference standard in neutropenic adults. The sensitivity and specificity of the mentioned thermometries in detecting rectal fever (≥38 °C) were also analysed.

Method: This is a comparative diagnostic test study. A total of 400 sets of blinded simultaneous temperature readings were measured from 21 haematology-in-patients with neutropenia following chemotherapy. Three-hundred sets were then randomly sampled. Agreements were analysed using random two-way intraclass correlation (ICC). Sensitivity and specificity were analysed using contingency 2 x 2 table.

Findings: Both right and left TM thermometry have good correlation with rectal thermometry: 0.810 (95% CI, 0.748–0.855) and 0.770 (95% CI, 0.713–0.815) respectively. Axilla thermometry has weak agreement (ICC 0.486 (95% CI, 0.118–0.689)) with rectal thermometry. The sensitivity (sn) and specificity (sp) in detecting rectal fever (≥38 °C) were: right TM (sn) 0.712 (95% CI, 0.586–0.814), (sp) 0.957 (95% CI, 0.920–0.978); oral (sn) 0.561 (95% CI, 0.433–0.681), (sp) 0.983 (95% CI, 0.954–0.995); and axilla (sn) 0.348 (95% CI, 0.238–0.477), (sp) 0.996 (95% CI, 0.973–0.999).

Interpretation: Single tympanic membrane thermometry is in good agreement with rectal thermometry. It is more sensitive than oral or axillary thermometry in detecting rectal fever.

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Introduction

Patients with haematological malignancies undergoing myelo-suppressive chemotherapy are expected to experience severe neutropenia. These patients are at risk of developing severe sepsis, which can turn fatal if not addressed quickly and appropriately. Among the earliest clinical signs of sepsis is the development of fever. Febrile neutropenia is defined as a single oral temperature of ≥38.3 °C (101 °F) or a temperature of ≥38.0 °C (100.4 °F) sustained for ≥1 h (Hughes et al., 2002). Hence close temperature monitoring has been a fundamental clinical practice for these patients.

Most hospitals including ours, still routinely use axillary mercury bulb thermometer for temperature reading. Accuracy in temperature measurement may not be so demanding in general medical patients but this is not true for neutropenic patients. A 0.5 °C difference in temperature reading may result in immediate commencement of aggressive febrile neutropenia protocols rather than watchful monitoring. It was shown that early initiation of goal-directed therapy in severe sepsis was associated with significantly lower mortality (Rivers et al., 2001). The majority of neutropenic sepsis qualifies as severe sepsis.

The use of tympanic membrane thermometry (TMT) has been widely studied. Studies concerning TMT accuracy in both paediatric and adult populations showed conflicting results. In the paediatric population, TMT demonstrated the smallest temperature deviation (0.03 ± 1.43 °F) from core body temperature represented by in situ bladder catheter thermometry compared to rectal, forehead and axilla. Axillary temperature measurement on the other hand showed the widest mean temperature difference from core body temperature, 1.25 ± 1.73 °F (Nimah et al., 2006) Among adults, Klein et al. (1993) showed that TMT has good correlation (r = 0.91) with pulmonary artery catheter thermometry (PACT) in intensive care patients. However agreement was not studied. Bock et al. (2005) studied adult patients undergoing cardiac surgery and found good agreement between TMT and PACT at +0.08 °C (95% CI –0.44 to +0.61 °C).

Keywords:
- Temperature
- Tympanic membrane thermometer
- Neutropenia
- Febrile
- Sensitivity
- Specificity

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On the other hand, a systematic review comparing TM to rectal thermometry in children showed a pooled sensitivity to detect rectal fever (38 °C and above) of only 63.7%. (Dodd et al., 2006) In other words, one-third of the time TMT may fail to detect fever. Similarly another study involving ambulatory adult but non-neutropenic patients in a general medical ward showed sensitivity and specificity of single TMT measurement to detect rectal fever (≥38 °C) of only 58 and 94% respectively (Stavem et al., 1997). Farnell et al., 2005 compared agreement between TMT and PACT versus axillary temperature and PACT in a population of patients in ICU. In this study TM temperature has an inferior limit of agreement (−1.2 to +1.2 °C) compared to axillary temperature (−0.5 to +0.9 °C). Also, more events (21.1%) of TM readings resulted in patients receiving delayed intervention compared to axillary temperature readings (15.3%). Hence, they concluded that axillary thermometry was more accurate and reliable than TMT. Thus an important clinical question especially in the setting of neutropenia needs to be answered before TM thermometry can be safely used; which is the best non-invasive temperature measuring tool?

Comparative studies on thermometry have so far excluded patients with neutropenia based on the concern of inducing procedural related bacteremia. Hence there are no direct data to address the above issue in this subset of patients. Stavem et al. (1997) demonstrated that rectal thermometry has agreement to PACT (−0.16 ± 0.5 °C) comparable to oesophageal temperature measurements (−0.11 ± 0.26 °C) and better than TMT (0.45 ± 0.38 °C) in adult patients in intensive care settings. Thus we selected rectal temperature as the most suitable reference standard representing core body temperature for this study.

This study was designed to assess the agreement between infrared tympanic membrane, axillary and oral thermometry to rectal temperature as a reference standard in febrile and non-febrile neutropenic adult cancer patients. We were also interested in evaluating the sensitivity, specificity, and positive and negative predictive value of the above modalities to detect rectal fever (≥38 °C).

Materials and methods

Subjects

We conducted this study at Hospital Universiti Sains Malaysia, Kubang Kerian, Kelantan between January and May 2007. All inpatients above 12 years old with haematological malignancies undergoing chemotherapy and having neutropenia during this period were evaluated for inclusion in the study. Neutropenia was defined as neutrophil count of <500 cells/mm³, or <1000 cells/mm³ with a predicted decrease to <500 cells/mm³8 (Hughes et al., 2002). Patients who were suffering from diarrhoea, other anal disorders such as perianal infection or fistula, ear infection, severe mucositis or mouth ulcers were excluded. The Human Research Ethics Committee of Universiti Sains Malaysia approved the study. Each patient or his guardian if below 18 years old provided informed consent. Patients were recruited by convenience sampling until a total of 400 sets of simultaneous oral, axilla, TM and rectal temperature measurement were reached.

Instruments

We used Braun Thermoscan (IRT 4020. Braun GmbH, Kronberg, Germany) for the infrared detection of TM temperature. The device has been validated in a previous publication (Chamberlain et al., 1995). Non-self-adjusted mercury bulb thermometer was used to measure both oral and axilla temperature. Temperature measured via indwelling pulmonary artery catheters is considered the gold standard representing core body temperature (Nierman, 1991). However, this method is invasive and unsuitable for our cohort of patients. Among non-invasive methods, rectal thermometry was found to correlate the best with pulmonary artery thermometry (Schmitz et al., 1995). Hence we used rectal thermometry as the standard reference. Rectal temperature was measured using standard non-self-adjusted mercury bulb rectal thermometers. We calibrated all mercury bulb thermometers in a single water bath set at 38 °C. Only those thermometers that deviated less than 0.1 °C were used for the study.

Each patient underwent otoscopic examination to exclude ear infection. Occluding caerumens were cleared. During TM temperature measurement the ear was tugged and the probe placed snugly into the external auditory canal.

Procedure

The authors and six clinical nurses received training on the proper use of all temperature measuring devices. Their visual acuity in both eyes were tested 6/6. Patients had their blood count measured daily as per routine care following chemotherapy. Patients who fulfilled the criteria for neutropenia had their oral, axilla, rectal and TM temperatures simultaneously measured twice a day around 0800 and 1600 h. The oral and rectal thermometers were randomly selected from their respective pools and reused for the same patient. A single operator would place the thermometers at all sites at the same time. The tip of the rectal thermometer, sheeted with disposable plastic sheets and lubricated with KY gel was placed 4 cm beyond the anal ring for 4 min. The tympanic membrane thermometer was placed until it beeped whereas the mercury bulb thermometers were placed for a minimum of 4 min. The same operator would read and document the digital reading from the tympanic membrane thermometer. He would then pass each of the mercury thermometers to other members of the team to read and document, blinded from each other. The temperature readings were repeated at the scheduled time until the patients' neutrophil counts had recovered.

Analysis

This is a prospective diagnostic accuracy study. A total of 400 sets of oral, axilla, TM and rectal temperature readings were measured. MacCowiak has suggested adjustment of (+0.5 °C) to axilla and (+0.3 °C) to oral temperature measurements. These corrections are to compensate for the influence of environmental cooling on core body temperature (MacCowiak, 1997). Analysis was carried out for both the unadjusted and adjusted oral and axillary temperature.

Temperature measurement agreements between sites (tympanic membrane, oral, axilla) were analysed using intraclass correlation coefficient (ICC) using SPSS 12.0.1 statistical software. We chose a two-way random effect ANOVA model with absolute agreement for analysis. We estimated the expected correlation as 0.40, width at 0.2, power at 0.8 and at 95% confidence interval the calculated sample size was 272 sets (Bonett, 2002).

Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and the corresponding 95% confidence interval for right, left and mean TM, adjusted and unadjusted oral and axilla temperature in detecting rectal fever (≥38 °C) were measured using an online standard contingency 2 × 2 table software (Lowry, 2001). With a reported sensitivity of 0.58 (Stavem et al., 1997), specificity of 0.85, expected prevalence of febrile neutropenia at 35%, desired precision of 0.1, and at 95% confidence interval, the calculated sample size using an online statistical software was 269 (Naing, 2004).
Hence, we randomly selected 300 temperature sets from the studied dataset using SPSS 12.0.1 software for analysis.

Results

In order to reach the intended 400 sets of temperature measurement, we enrolled 21 patients who made a total of 29 series of temperature sets. There were 11 (52.4%) women and 10 (47.6%) men. The age distribution ranged from 15 to 63 years old. There were nine non-Hodgkin lymphoma, seven acute myeloid, and five acute lymphoblastic leukaemia patients. Eighteen (62%) series of temperature sets documented fever in at least one reading based on rectal temperature of 38 °C and above. Among these series with febrile neutropenia, 10 (55.5%), seven (38.9%), and two (11.1%) had pyrexia of unknown origin, microbiologically and clinically documented fever respectively. The microbiology profile is shown in Table 1. Two patients died during this study. Their deaths were not attributed to the study procedures, as they were already septic prior to inclusion. The rest of the febrile patients recovered from their febrile neutropenia. The ambient air-conditioned room temperature during this study ranged between 23 and 26 °C.

From the 300 randomly selected datasets, rectal temperature ranged from 35.0 to 41.1 °C. There were 66 (22%) sets with rectal fever (≥38 °C). Table 2 shows the intraclass correlation coefficient (ICC) for right, left and mean tympanic membrane, adjusted and unadjusted oral and axilla compared to rectal temperature. The right tympanic membrane showed the highest agreement with rectal temperature (ICC = 0.810, 95% CI 0.748–0.855). The right tympanic membrane has better agreement than the left. Oral and axillary thermometry both have weaker agreement than TMT. However only the difference in agreement for axillary thermometry was statistically significant (ICC = 0.486, 95% CI 0.118–0.689) compared to TMT. This remains so despite temperature adjustment. The confidence interval for oral and TM thermometry overlapped.

Table 3 shows the sensitivity and specificity for right, left and mean tympanic membrane, adjusted and unadjusted oral and axilla thermometry to detect rectal fever (≥38 °C). The left TM and axillary thermometry were the most (71.2% 95% CI 58.6–81.4) and least (34.8% 95% CI 23.8–47.7) sensitive respectively in detecting rectal fever. The difference in sensitivity between axillary thermometry and either left or right TM thermometry was statistically significant. This difference in sensitivity was no longer statistically significant when 0.5 °C was added to the measured axillary temperature. Oral thermometry was also less sensitive than TMT but it was not statistically significant.

The positive and negative predictive values for the above thermometry are shown in Table 4. Left TM thermometry has the highest NPV (0.922 95% CI 0.879–0.951). Axillary thermometry has the lowest NPV (0.844 95% CI 0.795–0.884) and it was statistically significant to either left or right TM thermometry. Oral thermometry has lower NPV than TM thermometry but it was not statistically significant.

Table 1

<table>
<thead>
<tr>
<th>Organism cultured</th>
<th>Clinical sepsis</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escherichia coli</td>
<td>Septicaemia</td>
<td>2</td>
</tr>
<tr>
<td>Candida tropicalis + Bacillus sp.</td>
<td>Disseminated fungal infection</td>
<td>1</td>
</tr>
<tr>
<td>Candida sp.</td>
<td>Septicaemia</td>
<td>1</td>
</tr>
<tr>
<td>Methicillin resistant Staphylococcus aureus (MRSA)</td>
<td>Catheter related blood stream infection</td>
<td>1</td>
</tr>
<tr>
<td>Methicillin sensitive coagulase negative Staphylococcus (MSCoNs)</td>
<td>Catheter related blood</td>
<td>1</td>
</tr>
</tbody>
</table>

Discussion

This is the first study evaluating tympanic membrane thermometry specifically addressing adult neutropenic patients. Both the right and left TM temperatures have good correlation with rectal temperature with ICC about 0.8. The right tympanic membrane thermometry has the best agreement. This is also reflected in another study in an intensive care setting where the right TM temperature \((r = 0.78)\) correlated more strongly with standard pulmonary artery blood temperature than with the left TM \((r = 0.63)\) (Fulbrook, 1997). Lateral flexion of the head in the upright position, rotation of the head to the side while in supine position and lateral recumbent position leads to TM temperature asymmetry. The dependant TM has a higher recorded temperature (Ogawa et al., 1993). Unlike patients in intensive care, our patients were independent and ambulating and the temperatures were recorded during an active part of the day. Some patients may have been asleep in the recumbent posture during the evening measurement but no attempt was made to correct this confounding factor. This decision was made to simulate daily routine. Although the left tympanic membrane thermometry was more sensitive in detecting rectal fever, this was offset by a weaker PPV compared to the right TM thermometry. These findings suggest that either a single right or left tympanic membrane thermometry would be acceptable with a slight advantage for the right.

Rectal thermometry is not suitable for routine clinical practice especially in neutropenic patients. There is a theoretical concern of bacteremia attributed to the procedure. Our study was not designed to answer this question but in general we did not see an increase above baseline in the rate of gram-negative bacteremia during the study period. A few female patients decided to drop out after a couple of temperature readings because of repeated rectal thermometer probe insertion, demonstrating its unpopularity.

The unadjusted axillary thermometry in our study has low agreement to rectal thermometry \((r = 0.48)\). This difference in agreement was statistically significant when compared to TM thermometry. Its agreement improved slightly to 0.6 following temperature adjustment, but it was still inferior to TM thermometry. Fulbrook (1997) showed TM temperature correlates better with pulmonary artery (PA) blood temperature \((r = 0.63)\) as the reference temperature compared to between axillary and PA temperature \((r = 0.48)\). Correlation does not necessarily mean that the two methods agree over the measured values. On the other hand, a subsequent study showed that axillary thermometry agreed with PA more than TMT (Farrell et al., 2005). We noted that there are major methodological differences between these studies and ours. The reference tool in both the above studies was PA temperature, which differs from ours, which was rectal temperature. Those studies also used disposable chemical thermometers instead of mercury thermometers to measure axillary temperature.

<table>
<thead>
<tr>
<th>Thermometry</th>
<th>Intraclass correlation coefficient</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right tympanic membrane</td>
<td>0.810</td>
<td>0.748–0.855</td>
</tr>
<tr>
<td>Left tympanic membrane</td>
<td>0.770</td>
<td>0.713–0.815</td>
</tr>
<tr>
<td>Mean tympanic membrane</td>
<td>0.806</td>
<td>0.749–0.849</td>
</tr>
<tr>
<td>Oral</td>
<td>0.629</td>
<td>0.367–0.768</td>
</tr>
<tr>
<td>Axilla (≥0.3 °C)</td>
<td>0.486</td>
<td>0.118–0.689</td>
</tr>
<tr>
<td>Axilla (≥0.5 °C)</td>
<td>0.700</td>
<td>0.637–0.753</td>
</tr>
</tbody>
</table>

* Single measure ICC carried out with SPSS 12.0.1.
showed unadjusted oral thermometry detected less rectal fever (Hooker and Houston, 1996). On the contrary, our study to detect fever compared to oral thermometry (Erickson and Yount, 1991; Khorshid et al., 2005). Having considered these differences, the ICC value for both TM and axillary temperatures in our study was more consistent with Fulbrook's conclusion than Farnell's.

The sensitivity of axillary thermometry to detect rectal fever was only 34.8%. It also has statistically significant lower NPV compared to TMT. Its sensitivity improved to 65.2% following temperature adjustment and was comparable to that of TMT. However in the process its PPV deteriorated from 0.96 to 0.77.

Temperature reading is affected by the duration of thermometer placement at the axilla. In one study, maximum temperature reading was reached after 3 min in only 9% of the test subjects, in 25% after 6 min, and in 66% after 9 min (Greyling et al., 2000). We chose 4 min placement as this has been the routine day-to-day practice in our hospital. This decision may have partially contributed to lower axillary temperature measurement in our study. Outside the research setting, it is not practical to expect routine temperature measurement to go up to 10 min each reading.

This study demonstrates that in neutropenic patients it is unwise to continue measuring core body temperature using axillary mercury thermometer even with temperature adjustments. Whether this conclusion can be extended to other methods of axillary thermometry such as single use chemical thermometer is debatable. Khorshid et al. (2005) showed that body temperature readings measured by axillary disposable thermometer was lower than mercury thermometer readings by 0.53 °C. The mercury thermometer readings were also lower than TMT readings by 0.12 °C (Khorshid et al., 2005).

Previous studies in adults showed TMT to have lower sensitivity to detect fever compared to oral thermometry (Erickson and Yount, 1991; Hooker and Houston, 1996). On the contrary, our study showed unadjusted oral thermometry detected less rectal fever than TMT. Besides it has weaker intraclass correlation with rectal thermometry than with either ear TMT. These differences were however not statistically significant. We would like to point out that both the above studies were carried out with electronic thermometers whereas our study used mercury bulb thermometers.

Temperature adjustment as suggested by MacCowiak is not a standard clinical practice. Nevertheless we applied this adjustment and studied the outcome. Adjusted oral thermometry has sensitivity and PPV to detect rectal fever similar to right TM thermometry. Its negative predictive value was only marginally inferior to right TM thermometry. In other word adding 3 °C to oral temperature reading improves its accuracy and sensitivity to detect fever comparable to that of TM thermometry. We still have to be concerned that some patients developed severe mucositis following chemotherapy rendering oral temperature measurement unsuitable.

The sensitivity and specificity of either right or left TM thermometry in detecting rectal fever in our study (rounded to approximately 70 and 95% respectively) were comparable to figures obtained through a systemic review of similar studies conducted on children. The pooled estimates of sensitivity and specificity for random effects models were 63.7 and 95.2% respectively. (Dodd et al., 2006) We agree with the author's conclusion that TM thermometry sensitivity in detecting fever is unacceptably low for clinical practice in critical situations but our study showed that TM thermometry is apparently still the best available tool to detect rectal fever compared to other non-invasive methods.

With proper staff training, TM thermometry is a simple, quick and accurate method of temperature monitoring, which is crucial in the neutropenic setting. We conclude that a single tympanic membrane temperature measurement of either right or left ear is

<table>
<thead>
<tr>
<th>Thermometry</th>
<th>Rectal fever (≥38 °C)</th>
<th>Sensitivity</th>
<th>95% CI</th>
<th>Specificity</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td></td>
<td>Lower bound</td>
<td>Upper bound</td>
</tr>
<tr>
<td>Left tympanic membrane temperature (≥38 °C)</td>
<td>Yes</td>
<td>47</td>
<td>10</td>
<td>0.712</td>
<td>0.586</td>
</tr>
<tr>
<td>Right tympanic membrane temperature (≥38 °C)</td>
<td>No</td>
<td>19</td>
<td>224</td>
<td>0.682</td>
<td>0.554</td>
</tr>
<tr>
<td>Mean tympanic membrane temperature (≥38 °C)</td>
<td>Yes</td>
<td>42</td>
<td>6</td>
<td>0.636</td>
<td>0.508</td>
</tr>
<tr>
<td>Oral temperature (≥38 °C)</td>
<td>No</td>
<td>24</td>
<td>228</td>
<td>0.561</td>
<td>0.433</td>
</tr>
<tr>
<td>Oral temperature (≥38 °C)</td>
<td>No</td>
<td>29</td>
<td>230</td>
<td>0.554</td>
<td>0.433</td>
</tr>
<tr>
<td>Axilla temperature (≥38 °C)</td>
<td>Yes</td>
<td>45</td>
<td>7</td>
<td>0.682</td>
<td>0.554</td>
</tr>
<tr>
<td>Axilla temperature (≥38 °C)</td>
<td>No</td>
<td>21</td>
<td>227</td>
<td>0.348</td>
<td>0.238</td>
</tr>
</tbody>
</table>

Table 3
Sensitivity and specificity for right, left and mean tympanic membrane, oral and axilla thermometry to detect rectal fever (≥38 °C).

<table>
<thead>
<tr>
<th>Thermometry</th>
<th>PPV</th>
<th>95% CI</th>
<th>NPV</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower bound</td>
<td>Upper bound</td>
<td>Lower bound</td>
<td>Upper bound</td>
</tr>
<tr>
<td>Left tympanic membrane temperature (≥38 °C)</td>
<td>0.825</td>
<td>0.696</td>
<td>0.908</td>
<td>0.922</td>
</tr>
<tr>
<td>Right tympanic membrane temperature (≥38 °C)</td>
<td>0.900</td>
<td>0.774</td>
<td>0.963</td>
<td>0.916</td>
</tr>
<tr>
<td>Mean tympanic membrane temperature (≥38 °C)</td>
<td>0.875</td>
<td>0.741</td>
<td>0.948</td>
<td>0.905</td>
</tr>
<tr>
<td>Oral temperature (≥38 °C)</td>
<td>0.902</td>
<td>0.759</td>
<td>0.968</td>
<td>0.888</td>
</tr>
<tr>
<td>Oral temperature (≥0.3 °C) (≥38 °C)</td>
<td>0.865</td>
<td>0.736</td>
<td>0.940</td>
<td>0.915</td>
</tr>
<tr>
<td>Axilla temperature (≥38 °C)</td>
<td>0.958</td>
<td>0.769</td>
<td>0.988</td>
<td>0.888</td>
</tr>
</tbody>
</table>

Table 4
PPV and NPV for right, left and mean tympanic membrane, oral and axilla thermometry in detecting rectal fever (≥38 °C).

PM, positive predictive value; NPV, negative predictive value.
an optimal temperature measuring tool in adult neutropenic patients following chemotherapy. In the absence of contraindication, a corrected oral temperature (∆+0.3 °C) measurement is a reasonable alternative.

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Conflict of interest statement

There was no conflict of interest.

References


