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A comparative study on the accuracy of noninvasive thermometers

Background

This study assessed the concordance of the temperatures of the digital, liquid crystal forehead and digital infrared tympanic thermometers with the mercury in glass thermometer.

Methods

Temperatures in degrees celsius were taken simultaneously using the four thermometers in 207 patients at the casualty department of a Malaysian hospital. The Bland Altman statistical test was used to assess the concordance by the 95% limits of agreement between the three newer thermometers and the mercury in glass thermometer.

Results

The digital thermometer gave the best concordance (limits of agreement 0.48–0.59°C). The liquid crystal forehead thermometer gave the least concordance (limits of agreement -1.14–0.98°C). The digital infrared tympanic was in between (limits of agreement -0.88–0.85°C).

Discussion

The digital thermometer provides the best agreement with the mercury in glass thermometer. The infrared tympanic thermometer may be a preferable option for the uncooperative patient. The liquid crystal forehead thermometer is best used at home.

Keywords: temperature; thermometers; reproducibility of results; fever; sensitivity and specificity

Temperature is one of the most common and important clinical signs. The 'gold standard' for ambulatory patient temperature recording has been the mercury in glass thermometers (generally used orally or rarely, under the armpit or rectally) but these pose some problems. Patient cooperation is important when using the mercury in glass thermometers and their use may not be suitable for the comatose or uncooperative patient as a stabilisation time of 3 minutes is needed. In addition, breakages are a constant problem and there are concerns about the environmental hazards of mercury. Newer methods have evolved with the hope of replacing these thermometers.

Digital thermometers, liquid crystal forehead thermometers and digital infrared tympanic thermometers are newer substitutes. Each has its advantages and disadvantages, especially for patients in the general practice setting because of patients' varied ages and levels of cooperation. However, the reliability and accuracy of these newer thermometers have not been studied extensively.

The purpose of our study was to evaluate the concordance in temperature between the three newer methods of taking a patient's temperature and the mercury in glass oral thermometers.

Methods

Two hundred and seven patients were randomly selected among the nonacute willing and able patients (triage category 3 and 4) who presented to the emergency department (ED) of the University Malaya Medical Centre between March and June 2008. Patients were selected on the days when the nurses on duty were trained in using the various thermometers and in giving proper instructions to the patients. The temperatures were taken during the secondary triaging in the consultation room. The average time lapse from first walking into reception to having the temperature taken was around 10 minutes.

There were five paediatric patients, the youngest was 6 years of age. There were 19 patients aged older than 60 years, the oldest was aged 88 years. Verbal informed consent was obtained from the subjects, or from their parents if they were younger than 12 years of age. No data is available on those not included (those who were not approached or who declined to consent). No patient had any food or drink from the time they arrived at the ED to the time their temperatures were taken.

Temperature measurements were taken simultaneously using the four different types of thermometers:

- mercury in glass thermometer (DMcare Clinical Thermometer)
- digital thermometer (DT-01[A])
- liquid crystal forehead thermometer (Liquid Crystal Fever Temp Ultra®, DigiTemp), and
- digital infrared tympanic thermometer (Microlife IR 1DB1, Microlife).

All measurements were taken following the manufacturer's recommendations.

Both the mercury in glass and digital thermometers were used to measure oral temperatures. They were put under the tongue of the subjects (posterior sublingual pocket) with the lips sealed for 3 minutes before readings were taken. The digital thermometer was left under the tongue until the device beeped. The nondisposable liquid crystal forehead thermometers were put on the centre of subject's forehead until the colour stopped changing, a green colour appearance indicated the correct temperature reading – this usually took about 15 seconds.

Measurements were taken using the digital infrared tympanic thermometer by pulling the pinna upwards and backwards and inserting the probe into the external auditory canal. The probe was held in position until the device beeped, this usually took a few seconds. For each measurement, a new probe cover was attached. All temperatures were measured in degrees celsius (°C). If there were any doubts about the temperatures taken, the nurses had the discretion to repeat the process.

Ethical approval for the study was obtained from the Medical Ethics Committee, University Malaya Medical Centre.

Statistical analysis

To assess the concordance between the mercury in glass thermometer readings and the new methods, the Bland Altman[1] test was used. This is an exploratory diagnostic test between the difference of the two temperature readings of each patient plotted on the Y axis against the means of the two temperatures plotted on the X axis. There are two parameters of interest. The first is the overall mean differences for the paired readings of each patient. A value of zero implies perfect concordance. The second and more important parameter is the 95% limits of agreement between the two paired readings across the range of temperatures seen – the tighter the limits of agreement, the better the concordance. It is a range within which we would expect 95% of the differences to lie – the wider the range the less the concordance in the two readings.

In assessing the concordance of two readings the standard statistical methods generally used have either been the correlation coefficient (r) regression techniques or simply pared (t) tests. These tests were not appropriate for a number of reasons, one of which is that an outlier can significantly affect the analysis.[1] Bland and Altman[1] used an alternative approach for assessing agreement between two methods of clinical measurements and this has now been accepted as an appropriate method.[2] However, the acceptable limits of agreement must be based on clinical and not statistical grounds. The Stata Statistical Package Version 9 (Timberlake) was used for the analysis.

Results

A summary of the temperatures taken by the various instruments is shown in *Table 1*. With the exception of the differences in the minimum and maximum measurements, there seems to be a close concordance between the four methods. The mean temperatures average around 36.8°C.

Table 2 summarises the results of the Bland Altman plots between the various methods and the mercury in glass thermometers. Overall, the digital thermometer gave the best concordance, having the smallest limits of agreement across the range of temperatures. The infrared tympanic thermometer was the next best with a narrower mean difference than the digital thermometer but unacceptable limits of agreement. The liquid crystal forehead thermometer gave the least concordance.

Table 1. Summary measurements of temperatures

Thermometer	Observations	Mean °C	Standard deviation	Min °C	Max °C
Mercury in glass	207	36.795	0.695	35.0	41.0
Digital	207	36.845	0.632	34.9	39.6
Liquid crystal forehead	207	36.718	0.723	35.0	39.5
Digital infrared tympanic	207	36.780	0.717	34.4	39.6

Table 2. Summary of the results of the Bland Altman plot

Comparison	Mean difference	Limits of agreement
Digital versus mercury in glass	0.049°C	0.48–0.59°C (0.11°C)
Liquid crystal forehead versus mercury in glass	–0.077°C	–1.14–0.98°C (2.12°C)
Digital infrared tympanic versus mercury in glass	–0.015°C	–0.88–0.85°C (1.73°C)

Discussion

The results of the study show that the oral digital thermometer agreed best with the mercury in glass thermometer. This thermometer is easy to use, takes less time to use than the mercury in glass and liquid crystal forehead thermometers, has a beeper indicating the optimal time of use and is environmentally friendly. But like the mercury in glass thermometers it cannot be used reliably in an uncooperative or comatose patient.

The accuracy of the infrared tympanic thermometer was a close second. Although initially produced for home use, it is now being used more frequently in hospitals and general practice clinics. It is easy and quick to use and can be used with an uncooperative or comatose patient. Care must be taken however, to have an adequate seal in assessing the infrared emission for the tympanic membrane.

In our study, temperature readings from only one ear were taken as it was more convenient and in line with common clinical practice to do so. Some studies of the infrared tympanic thermometer have shown no difference between temperatures measured in the contralateral ears,[3] others have shown differences.[4] It has been shown that the amount of cerumen (wax) did not affect readings.[3] Other studies have shown that the infrared tympanic thermometer tended to underestimate the temperatures measured when compared to the mercury in glass thermometers.[5]

Although easy to use, the liquid crystal forehead thermometer showed the least concordance. Though not seen here, others have reported that it tends to overestimate temperatures.[6] It is therefore preferable for use in the home rather than in a clinical setting. On the other hand, Mauta et al[7] used a newer generation of these liquid crystal thermometers in Papua New Guinea and showed acceptable concordance in its readings when compared to the mercury in glass thermometers.

In our study we used the mercury in glass thermometers as the standard as it was most practical to do so. However, results could be influenced by the fact that the mercury in glass

thermometer can be affected by the temperature of fluids for up to 30 minutes after ingestion,[8] and the average time between arrival in the ED and temperature taking was 10 minutes. However, the more invasive methods of temperature measurement, such as rectal, oesophageal and temporal arterial, though very accurate, pose not only practical but ethical problems,[9,10] so the oral reading was used.

Limitations of this study

There are limitations to the results of our study. First, the study is Malaysian and the febrile illnesses seen may be different to those in western countries. Second, the results are applicable to patients from an ED, and patients seen in general practice may differ (eg. in Australian general practice 11.4% of patients are aged 0–14 years and 29.5% are aged over 65 years).[11] Finally, the results are applicable only to the range of temperatures encountered, they may have been different for more extreme temperatures on either side.

Conclusion

Based on a sample of our population of cooperatives, predominantly adult patients from a Malaysian ED, the digital thermometer appears to be the best alternative to the traditional and time tested mercury in glass thermometers. It is reliable, safe, easy to use and cost effective. The infrared tympanic thermometers, though quick and easy to use, should preferably be used for children and the uncooperative patient. The liquid crystal forehead thermometer is best used at home and even so, readings must be interpreted with caution.

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