Established in 1871
Swiss Medical Weekly
Formerly: Schweizerische Medizinische Wochenschrift
The European Journal of Medical Sciences

Original article | Published 20 December 2010, doi:10.4414/smw.2010.13131
Cite this as: Swiss Med Wkly. 2010;140:w13131

Limitations of infrared ear temperature measurement in clinical practice

Raphael Twerenbold[a], Andreas Zehnder[b], Tobias Breidthardt[a], Tobias Reichlin[a], Miriam Reiter[a], Nora Schaub[a], Roland Bingisser[a], Gerd Laifer[c], Christian Mueller[a]

[a] Department of Internal Medicine and
[b] Department of Otorhinolaryngology, University Hospital Basel, Switzerland;
[c] Department of Internal Medicine, Stadtspital Triemli, Zurich, Switzerland

Correspondence:
Dr. med. Raphael Twerenbold
Department of Internal Medicine
University Hospital Basel
Petersgraben 4
CH-4031 Basel
Switzerland
rtwerenbold@uhbs.ch

Summary

PRINCIPLES: Detection of elevated body temperature is critical in the early diagnosis of sepsis. Due to its convenience, infrared ear temperature measurement (IETM) has become the standard of care. Unfortunately, the limitations of this method are largely unexplored.

OBJECTIVE: To evaluate potential limitations of IETM, including the presence of cerumen on otoscopy, depth of penetration, side of measurement, and the impact of acclimatisation to room temperature**.**

METHODS: In this prospective cohort study, 333 patients presenting to the medical emergency department underwent serial IETM before and after otoscopy and cleaning of the external auditory canal. The primary endpoint was defined as mean change in infrared ear temperature (IET) before and after removal of cerumen. We also tested for the effect of penetration depth, side of measurement and impact of acclimatisation.

RESULTS: Otoscopy revealed cerumen in 98 patients (29%). Cerumen had a weak but statistically significant impact on IETM. The removal of cerumen obturans resulted in a rise in IET of 0.20 °C (95% CI 0.10–0.28 °C, P = 0.03). The effects of penetration depth (P = 0.39), side of measurement (P = 0.78) and impact of acclimatisation (P = 0.82) were not significant.

CONCLUSIONS: Cerumen has a statistically significant, albeit not clinically meaningful, influence on IETM. Thus routine ear inspection prior to the use of IETM is not warranted. IETM provides highly reproducible assessments of IET irrespective of penetration depth, side of measurement and acclimatisation.

Abbreviations
ED = Emergency department
IET = Infrared ear temperature
IETM = Infrared ear temperature measurement

Key words: *fever; thermometry; limitations; cerumen; otoscopy*

Introduction

Since antiquity, temperature measurement has fascinated many scientists. The oldest known references to devices used to measure temperature date from the first or second century BC, when Philo of Byzantium and Hero of Alexandria are believed to have invented several such devices [1–3]. However, thermometry was not fully assimilated into medical practice until 1868, when Carl Reinhold August Wunderlich published a magnum opus and gave 37.0 °C its special meaning for normal body temperature [1]. He described diurnal variation of body temperature and, in the process, alerted clinicians to the fact that normal body temperature is actually a temperature range rather than a specific temperature [1–3].

The assessment of body temperature is important in clinical practice, since hyperthermia (fever) or hypothermia are warning signals for serious medical conditions, e.g. severe infections [2]. Among 1000 patients presenting with fever at the emergency department (ED), more than half were found to have a systemic infection [3].

During the last century various methods were used for the assessment of body temperature [4–6]. These included oral, axillary, rectal, pulmonary artery and urinary bladder measurements. Although useful in certain settings, all of these have significant limitations and disadvantages [4–6].

Infrared ear temperature measurement (IETM) detects infrared emissions from the tympanic membrane and was introduced into clinical care 20 years ago [6–8]. Theoretically, IETM has the potential to reflect the core temperature more appropriately, since the tympanic membrane is perfused by a tributary of the artery that supplies the body's thermoregulatory centre [9]. Due to its obvious advantages, such as speed, convenience, freedom from the need for direct contact with the mucous membrane and high acceptability to patients, IETM has become the standard of care in most hospitals in North America and Europe [4–8, 10].

Unfortunately, only partial attention has been focused on the potential limitations of IETM. Of greatest importance is preliminary evidence suggesting that the presence of cerumen may significantly affect IETM and result in lower recordings [11–14]. This would be of major clinical importance since cerumen could, by its effect on IETM, obscure the presence of fever and thereby limit the identification of patients at risk for severe infections. This feature may be particularly deleterious in the frail elderly, in whom thermoregulation may be impaired and more than 30% of whom have impacted cerumen [15, 16]. By delaying the recognition of severe infections and the initiation of appropriate treatment, cerumen-induced false low IETM may significantly increase morbidity and mortality, especially in emergency care [17–19].

To address these concerns we performed a large prospective cohort study assessing potential limitations of IETM in the ED.

Methods

Study design and patients

The FEver DEtection Routinely needs EaR inspection (FEDERER) study was a prospective, single-centre cohort study performed at the Emergency Department of Basel University Hospital. Patients presenting at the medical emergency department were randomly selected irrespective of their main symptoms and body temperature, in order to represent the full range of IETM, and asked to participate in the study. Each patient was requested to give written informed consent before measurements were taken. The study was conducted in accordance with the ethical principles stated in the most recent version of the Helsinki Declaration.

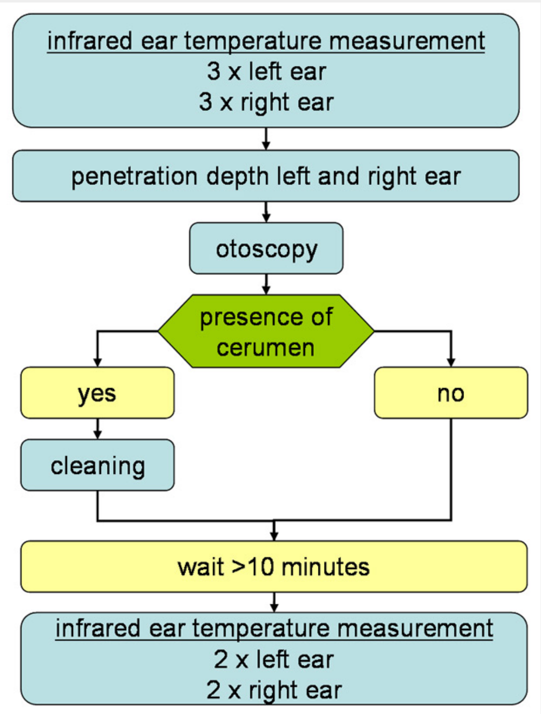

Figure 1

Flow chart of the standard procedure.

To minimise the effect of interindividual variations, only one experienced investigator performed the measurements throughout the study. Exclusion criteria were age under 18, acute life-threatening conditions including circulatory shock and respiratory failure, acute head trauma, previous ear surgery [13, 20, 21] and acute ear disease [6, 13, 22, 23].

Procedure

Initially, baseline characteristics, vital signs, and any use of antipyretic drugs such as acetylsalicylic acid >500 mg or paracetamol were recorded.

Temperature was measured three times in the left ear and then three times in the right ear using a First Temp Genius® infrared thermometer (Sherwood Davis & Geck, Gosport, UK) (fig. 1). The infrared detector senses electromagnetic radiation emissions from tissue within view of the probe. A microprocessor calculates the temperature value of the observed structures. Measurements on the left side were taken with the device held in the left hand, measurements on the right side with the device held in the right hand, as recommended by the manufacturer and clinical experts [12]. We pulled the ear superiorly and posteriorly while aiming the infrared sensor at the midpoint between the opposite ear and the eyebrow [11, 12, 24]. All measurements were taken with the same thermometer throughout the study, with the device set for core mode displaying one decimal. Disposable probe covers were changed for each measurement. The depth of penetration into the external auditory canal was marked with a pen on the single-use probe covers on each side and measured in millimetres after removal of the probe.

After the initial measurements the ear was inspected by standard otoscope to estimate the extent of cerumen. A semi-quantitative scale (0%, 25%, 50%, 75%, 100%) was prospectively defined and used to quantify obliteration of the external ear canal by cerumen. If cerumen was detected it was removed mechanically using surgical instruments such as hooks and small vacuum pumps. If necessary, cerumen was softened by applying some drops of a 3% solution of hydroxyperoxide for 10 minutes. It was then mechanically removed as described above. To avoid a cooling effect the solution was warmed to 37 °C in an infusion-box.

To minimise the potential effect of reactive hyperaemia we waited for at least 10 minutes after the final instrumentation of the external auditory canal before taking the last two measurements in each ear.

Main outcome measures

We examined the mean change in infrared ear temperature (IET) accompanied by removal of cerumen. The effects of penetration depth, side of measurement and time since presentation were also analysed.

It was our hypothesis that five variables might influence the change in IET: removal of cerumen, instrumentation in the external auditory canal, acclimatisation to the room temperature in the emergency department, antipyretic medication, and a potential learning effect for directing the probe after otoscopy to the tympanic membrane.

To adjust for these confounders, the difference between change in patients with cerumen obturans and change in patients with 25% cerumen was defined as the primary endpoint (Δ100% – Δ25%). In patients with 25% cerumen we hypothesised that the small extent of cerumen should only marginally impact on the IETM, whereas all other confounders including instrumentation should equally apply to patients with 25% and 100% cerumen.

Additional analyses were performed to examine the association between depth of penetration and IETM. It was our hypothesis that in patients with only shallow penetration into the external auditory canal the variation between consecutive measurements would be greater.

Data collection and statistical analysis

Baseline characteristics, vital signs, cause of presentation, use of fever-reducing drugs, all IETMs, depth of penetration and extent of cerumen were anonymously documented on a standardised datasheet using Excel (Microsoft, USA).

All statistical analyses were performed using an SPSS software package (PC version 15.0, SPSS Inc., Chicago, IL). A statistical significance level of 0.05 and two-tailed tests were chosen. Comparisons were made using the t-test, paired t-test, Mann-Whitney-U test, Wilcoxon signed-rank test and Jonkheere-Terpstra test, correlations using Pearson's correlation index or Spearman's rank correlation coefficient, as appropriate.

Results

A total of 333 patients were included in this trial (table 1). The unselected study cohort represented 18% (333 of 1814) of all patients presenting at the medical emergency department within the study period of five weeks. The most frequent reasons for presentation were unspecific pain (n = 61, 18%), cerebral or neurological problems (n = 54, 16%) and abdominal discomfort (n = 54, 16%).

Otoscopy revealed cerumen in 98 patients (29%). The prevalence of cerumen was comparable in men and women. No correlation was found between the extent of cerumen and sex (P = 0.92). The incidence of cerumen was similar in the left (n = 63) and the right ear (n = 82) (P = 0.08). Overall, bilateral cerumen was found in 47 patients (14%).

Among 145 ears presenting with cerumen, 33 (23%) showed obliteration of 25%, 20 (14%) obliteration of 50%, 19 (13%) obliteration of 75%, and cerumen obturans was found in 73 ears (50%) Increasing age was associated with a greater extent of cerumen (r = 0.24, P <0.001).

IETM during the first three measurements was comparable in patients with different extent of cerumen (P = 0.40) (fig. 2). The mean range of three consecutive measurements in the same ear was 0.2 °C.

The primary endpoint, quantifying the impact of cerumen on IETM, represented a median rise of 0.20 °C (95% CI 0.10–0.28 °C, P = 0.03) after removal of cerumen obturans compared to the change of temperature after cerumen removal in patients with a 25% stenosis of the external auditory canal (fig. 3).

Depth of penetration was not correlated with level of measured temperature (r = –0.03, P = 0.39), but a very weak but statistically significant correlation with the range of the first three measurements was found (r = 0.11, P = 0.007) (fig. 4).

Mean temperature (37.3 °C in both ears; P = 0.78 for comparison) and range of temperature (left ear, 0.25 °C; right ear, 0.24 °C; P = 0.46) were comparable in the left and the right ears and reproducible irrespective of side of measurement (fig. 5). Between the first three and the last two measurements a median time of 26 minutes elapsed (IQR 16–36 minutes). No correlation was found between time since admission to the ED and IET (r = 0.07, P = 0.79).

The use of antipyretic drugs such as acetylsalicylic acid >500 mg or paracetamol did not significantly lower IETM between the first three and the last two measurement within the study period (P = 0.13).

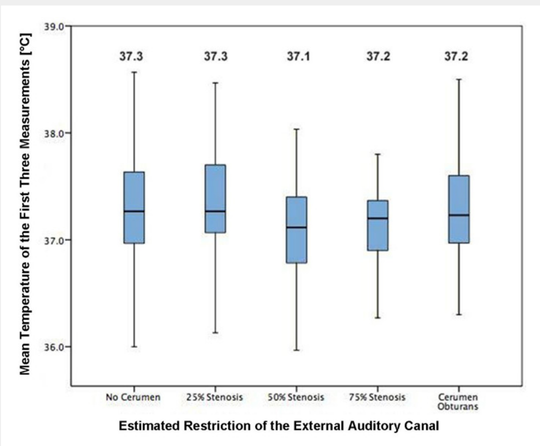

Figure 2

Infrared ear temperature measurements according to extent of cerumen.
Box contains 50% of the median values, Whiskers define 95% CI.

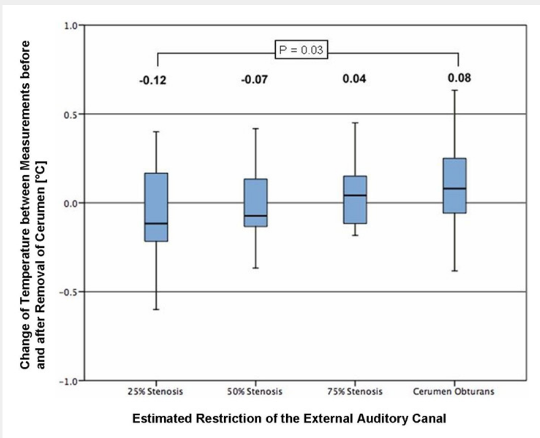

Figure 3

Effect of cerumen removal on mean temperature.
Box contains 50% of the median values, Whiskers define 95% CI.

Discussion

This large prospective cohort study was performed to evaluate potential limitations of IETM. We report four major findings: first, cerumen was present in 29% of patients presenting at the ED. This finding is in complete agreement with earlier reports and suggests that the incidence of cerumen obturans has not changed significantly in recent decades [15, 16] Although cerumen obturans significantly reduced IETM, the difference induced was small (–.20 °C) and in general not clinically meaningful. Hence, in contrast to earlier recommendations, routine ear inspection prior to the use of IETM is not warranted [12]. Second, neither the mean temperature nor the range of measurements was influenced to a clinically meaningful extent by the depth of penetration of the IETM probe in the external auditory canal. This observation negates our hypothesis that IETM may be associated with high range in patients with shallow penetration of the probe, assuming a less good angulation of the sensor to the tympanic membrane as compared to deep penetration [11]. Overall, IETM proved highly reproducible irrespective of penetration depth. Third, IETM provided comparable results in the left and right ears. This observation is of major importance, since earlier smaller-scale studies reported conflicting data and provoked con-

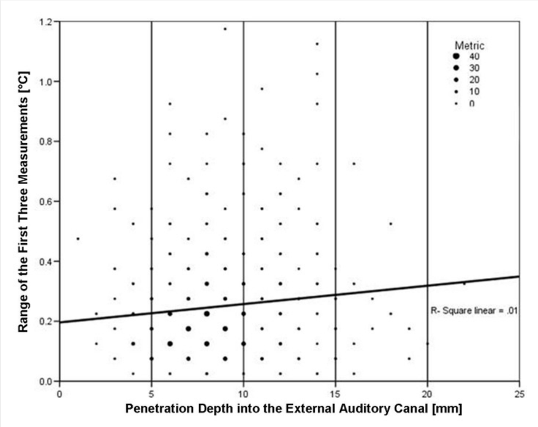

Figure 4

Correlation between penetration depth and range of infrared ear temperature measurement.
Size of the dots represents number of measurements.

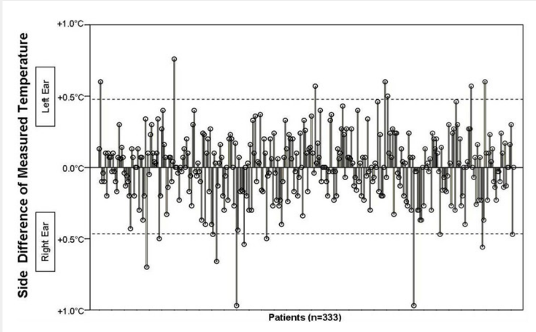

Figure 5

Effect of side of measurement on infrared Ear temperature measurement.
Bland-and-Altman plot for comparison of right and left ear measurements. Dotted lines represent the upper and lower limit of the 95% confidence interval of the mean difference.

Table 1: Basic characteristics and infrared ear temperature measurements of all 333 patients.

Characteristics	
Sex Females – n (%) Males – n (%)	160 (48) 173 (52)
Age – yr [a]	64 [46–77]
Height – cm [b]	169 ± 9
Weight – kg [b]	72 ± 15
Heart rate- bpm [b]	82 ± 19
Systolic blood pressure – mm Hg [a]	132 [120–150]
Diastolic blood pressure – mm Hg [a]	83 [74–91]
Penetration depth left ear – mm [a]	8 [6–10]
Penetration depth right ear – mm [a]	9 [7–10]
Temperature measurements	
Left ear – °C	
1st temperature [a]	37.3 [37.3–37.7]
2nd temperature [a]	37.3 [37.0–37.6]
3rd temperature [a]	37.2 [36.9–37.6]
4th temperature [a]	37.3 [37.0–37.6]
5th temperature [a]	37.3 [37.0–37.6]
Range of first three measurements [a]	0.2 [0.1–0.3]
Range of all five measurements [a]	0.3 [0.2–.05]
Right ear – °C	
1st temperature [a]	37.3 [37.0–37.7]
2nd temperature [a]	37.3 [36.9–37.6]
3rd temperature [a]	37.2 [36.9–37.6]
4th temperature [a]	37.3 [37.0–37.7]
5th temperature [a]	37.3 [36.9–37.6]
Range of first three measurements [a]	0.2 [0.1–0.3]
Range of all five measurements [a]	.03 [0.2–0.5]

[a] Medians [25th-75th percentile]. [b] Means ± SD.

siderable uncertainty [25–28]. The results of this large contemporary study strongly suggest that the selection of the ear does not matter in clinical practice. In consequence, there is no particular need to use the same ear for repetitive measurements. Fourth, IETM does not change significantly within a period of 30 minutes in the ED, as long as there are no manipulations to the external auditory canal.

Our findings extend and corroborate previous studies on the use of IETM. The effect of cerumen in lowering IETM may be related to several factors [11]. First, the ear canal has a temperature gradient, warmest at the tympanic membrane and coolest at the outer entrance of the external auditory canal [29, 30]. Cerumen is a poor heat conductor and its presence blocks the thermometer's view into the warmer inner portion of canal. Second, the deep cavity shape of the external auditory canal causes it to act much like a "blackbody", a perfect structure that is an ideal absorber and emitter of radiant energy in the far- infrared range. Large amounts of cerumen may cause a departure from the cavity shape and thus fewer emissions. Third, soiling of thermometer's probe window by cerumen may interfere with IETM.

Preliminary evidence suggested that the presence of cerumen may significantly affect IETM and result in lower recordings [11–14]. However, these pilot studies were small and had several methodological limitations. Doezema and colleagues placed paraffin-coated plugs in one randomly chosen ear in 43 volunteers, and after 20 minutes of equilibration IETM was performed in each ear. The mean temperature of the occluded ear was 0.30°C lower than that of the opposite ear canal [11–14]. Hasel and colleagues performed IETM in 14 elderly nursing home residents before and 3 to 4 days after irrigation to clear cerumen from the occluded ear [11–14]. They found a mean rise of 0.13 °C, which is similar to our finding (a median rise of 0.20 °C).

Since depth of penetration is not correlated with mean temperature or range of measurements, there is no need to maximise the insertion depth of the probe into the external auditory canal as long as the probe is continuously pointed in the estimated direction of the tympanic membrane.

We showed that time elapsed since admission to the ED, a correlate to any kind of potential acclimatisation, has no influence on measured body temperature. This finding has its special relevance in busy EDs where it is not always possible to take the IET within the first minutes after presentation.

Various studies have compared IETM with other clinically available methods for the assessment of body temperature [4, 6, 10, 31, 32]. Unfortunately, as none of the alternative methods can be considered an accepted "gold standard", these comparisons are difficult to interpret. For example, finding a difference between the temperature measured at the rectum and in the ear may simply reflect that body temperature differs from site to site. It is noteworthy that these differences between sites may also vary during the course of illness, due to a lag in temperature change at the rectum [31, 33]. We therefore decided to refrain from comparing IETM with other methods, and concentrated exclusively on potential limitations of the IETM. A systematic review showed that the mean differences between rectal and IETM – at least in children – were small [6].

Potential limitations of the current study merit consideration. First, since we recruited consecutive patients rather than healthy volunteers, we cannot comment on what may be the best cut-off value to define fever. Based on oral temperature measurements from 148 healthy individuals [34], Mackowiak et al. defined 37.2 °C in the morning and 37.7 °C in the afternoon as the upper limit of the normal temperature range. Second, our study was performed in the setting of a medical emergency department, where the fast and reliable assessment of body temperature in a wide range of patients is of major clinical importance. The findings from our study may not be extendable to IETM in rare and extreme situations such as avalanche victims or near drowning. Third, having the IETM performed by only one investigator following a standardised technique in our study, IETM might not be performed as reproducibly in clinical practice.

In conclusion, our findings confirm that IETM is a useful and reliable tool for the assessment of body temperature in clinical practice. None of the tested potential limitations, including the effect of cerumen obturans, impacts on IETM in a clinically meaningful way. Therefore, routine ear inspection prior to the use of IETM does not seem warranted.

References

1 Wunderlich CRA. Das Verhalten der Eigenwärme in Krankheiten. Leipzig, Germany: Otto Wigard, 1868.

2 Mackowiak PA. Concepts of fever. Arch Intern Med. 1998;158(17):1870–81.

3 Mackowiak PA, Worden G. Carl Reinhold August Wunderlich and the evolution of clinical thermometry. Clin Infect Dis. 1994;18(3):458–67.

4 Castle SC, Toledo SD, Daskal SL, Norman DC. The equivalency of infrared tympanic membrane thermometry with standard thermometry in nursing home residents. [erratum appears in J Am Geriatr Soc. 1993;41(7):781–2]. J Am Geriatrics Soc. 1992;40(12):1212–6.

5 Joly LM, Giraudeau B, Monchi M, Oswald AM. La mesure de la température corporelle par thermometre tympanique infrarouge est-elle reproductible? Annales Francaises d'Anesthésie et de Réanimation 2001;20(10):833–7.

6 Craig JV, Lancaster GA, Taylor S, Williamson PR, Smyth RL. Infrared ear thermometry compared with rectal thermometry in children: a systematic review. Lancet. 2002;360(9333):603–9.

7 Benzinger M. Tympanic thermometry in surgery and anesthesia. JAMA. 1969;209(8):1207–11.

8 Benzinger TH. Clinical temperature. New physiological basis. JAMA. 1969;209(8):1200–6.

9 Klein DG, Mitchell C, Petrinec A, Monroe MK, Oblak M, Ross B, et al. A comparison of pulmonary artery, rectal, and tympanic membrane temperature measurement in the ICU. Heart Lung. 1993;22(5):435–41.

10 Farnell S, Maxwell L, Tan S, Rhodes A, Philips B. Temperature measurement: comparison of non-invasive methods used in adult critical care. J Clin Nurs. 2005;14(5):632–9.

11 Hasel KL, Erickson RS. Effect of cerumen on infrared ear temperature measurement. J Gerontol Nurs. 1995;21(12):6–14.

12 Doezema D, Lunt M, Tandberg D. Cerumen occlusion lowers infrared tympanic membrane temperature measurement. Acad Emerg Med. 1995;2(1):17–9.

13 Garcia Callejo FJ, Platero Zamarreno A, Sebastian Gil E, Marco Sanz M, Alpera Lacruz RJ, Martinez Beneyto MP. Otologic determining factors on infra-red tympanic thermometry in children. Acta Otorrinolaringol Esp. 2004;55(3):107–13.

14 Holtmann S. Ear thermometry from the otologic viewpoint. Laryngorhinootologie. 1999;78(1):9–11.

15 Mahoney DF. One simple solution to hearing impairment. Geriatric Nursing. 1987;8(5):242–5.

16 Lewis-Cullinan C, Janken JK. Effect of cerumen removal on the hearing ability of geriatric patients. J Adv Nurs. 1990;15(5):594–600.

17 Norman DC. Fever in the elderly. Clin Infect Dis. 2000;31(1):148–51.

18 Brody GM. Hyperthermia and hypothermia in the elderly. Clin Geriatric Med. 1994;10(1):213–29.

19 Yoshikawa TT. Perspective: aging and infectious diseases: past, present, and future. J Infect Dis. 1997;176(4):1053–7.

20 Pandey A, Ingrams DR, Jones M, Raman R, Marks ND. Reliability of a tympanic thermometer in measuring temperatures in children after minor ear surgery. J Laryngol Otol. 2006;120(5):375–7.

21 Schmal F, Loh-van den Brink M, Stoll W. Effect of the status after ear surgery and ear pathology on the results of infrared tympanic thermometry. Eur Arch Otorhinolaryngol. 2006;263(2):105–10.

22 Terndrup TE, Wong A. Influence of otitis media on the correlation between rectal and auditory canal temperatures. Am J Dis Children. 1991;145(1):75–8.

23 Kelly B, Alexander D. Effect of otitis media on infrared tympanic thermometry. Clin Pediatr. (Phila) 1991;30(4 Suppl):46–8; discussion 49.

24 Terndrup TE. An appraisal of temperature assessment by infrared emission detection tympanic thermometry.[see comment]. Ann Emerg Med. 1992;21(12):1483–92.

25 Heusch AI, McCarthy PW. The patient: a novel source of error in clinical temperature measurement using infrared aural thermometry. J Altern Complement Med. 2005;11(3):473–6.

26 Talo H, Macknin ML, Medendorp SV. Tympanic membrane temperatures compared to rectal and oral temperatures. Clin Pediatr. (Phila) 1991;30(4 Suppl):30–3; discussion 34–5.

27 Shenep JL, Adair JR, Hughes WT, Roberson PK, Flynn PM, Brodkey TO, et al. Infrared, thermistor, and glass-mercury thermometry for measurement of body temperature in children with cancer. Clin Pediatr. (Phila) 1991;30(4 Suppl):36–41; discussion 49.

28 Childs C, Harrison R, Hodkinson C. Tympanic membrane temperature as a measure of core temperature. Arch Dis Child. 1999;80(3):262–6.

29 Cooper KE, Cranston WI, Snell ES. Temperature in the External Auditory Meatus as an Index of Central Temperature Changes. J Appl Physiol. 1964;19:1032–5.

30 Greenleaf JE, Castle BL. External auditory canal temperature as an estimate of core temperature. J Appl Physiol. 1972;32(2):194–8.

31 Robinson JL, Seal RF, Spady DW, Joffres MR. Comparison of esophageal, rectal, axillary, bladder, tympanic, and pulmonary artery temperatures in children. J Pediatr. 1998;133(4):553–6.

32 Hooker EA, Houston H. Screening for fever in an adult emergency department: oral vs tympanic thermometry. South Med J. 1996;89(2):230–4.

33 Wilson RD, Knapp C, Traber DL, Priano LL. Tympanic thermography: a clinical and research evaluation of a new technic. South Med J. 1971;64(12):1452–5.

34 Mackowiak PA, Wasserman SS, Levine MM. A critical appraisal of 98.6 degrees F, the upper limit of the normal body temperature, and other legacies of Carl Reinhold August Wunderlich.[see comment]. JAMA. 1992;268(12):1578–80.