A New Infrared Tympanic Thermometer in Surgery and Anesthesia

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We have evaluated a new infrared tympanic thermometer, IT-10, as an intraoperative temperature monitor in patients with or without open abdominal surgery. It determines temperature by measuring infrared radiation given off by a warm object. Temperatures measured with this device were closely correlated with those measured with rectal and bladder thermometries. We conclude that this new tympanic thermometer is safe, convenient, accurate, and easily usable in the clinical situation. (Key words: anesthesia, monitoring, temperature, thermometer, tympanic membrane)

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Continuous monitoring of body temperature during general anesthesia is a widely accepted clinical practice which includes a variety of techniques. The large temperature gradients between superficial and deep body tissues during general anesthesia[1] suggest that body temperature measurements are most reliable and useful when they reflect the temperature of the central core organs and tissues within the skull, chest, and abdomen[2].

Tympanic membrane probes accurately track rapid changes in blood temperature[3]. There are some studies of infrared thermometry which allows rapid and accurate measurement of tympanic membrane temperature[4,5].

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The present study was designed to compare a new infrared tympanic thermometer (IT-10) with other standard methods of temperature measurement during general anesthesia in patients with or without open abdominal surgery.

Patients and Methods

After obtaining approval from the institutional review boards and informed written consent from study participants, 30 patients [14 were with (Group 1) and 16 were without (Group 2) open abdominal surgery] were studied. Patients with a history of problems with the tympanic membrane or middle ear were excluded.

With preanesthetic medication (0.01 $mg{\cdot}kg^{-1}$ of atropine), anesthesia was induced with 5 $mg{\cdot}kg^{-1}$ of thiamylal and 0.1 $mg{\cdot}kg^{-1}$ of vecuronium. Anesthesia was maintained with isoflurane (0.5%–1.5% inspired concentration) in 66% nitrous oxide in oxygen.

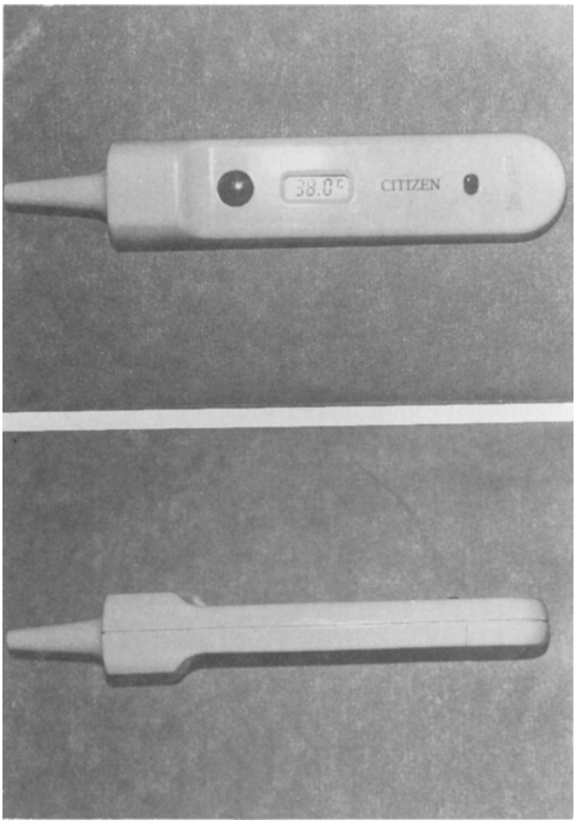

Fig. 1. A new infrared tympanic membrane thermometer. The instrument is 16 × 3 × 1.5 cm in large and 52 grams in weight.

Temperature was measured: 1) at the left or right tympanic membrane, 2) in the rectum (CTM-303, Terumo, Japan) and 3) in the bladder (Mon-a-therm Model 6500, Mallincrodt, U.S.A.). After induction of anesthesia, rectal probes were inserted to a depth of 10 cm and taped in place. A Foley catheter with an indwelling sensor was placed using sterile techniques.

Tympanic membrane temperatures were measured with a new noncontact infrared tympanic thermometer (IT-10, Citizen, Tokyo, Japan). The instrument is 16 × 3 × 1.5 cm in large and 52 grams in weight and consists of an otoscope-like probe tip covered by a disposable cellophane, an infrared sensing electronics, and a microprocessor circuit and calibration mechanisms. The recorded temperature is displayed on an integral liquid crystal display. The cellophane-covered probe tip is introduced into the outer third of the auditory canal as a conventional otoscope would be. When the scan button is depressed, the sensor gathers emitted infrared energy, mainly from the tympanic membrane. The output from the sensor is then fed through an analog to the digital converter, and then to a microprocessor. The instrument accumulates energy for approximately 1 sec and displays the resultant temperature on the liquid crystal display in Celsius degrees (fig. 1).

Temperatures from all sites were recorded 30-min intervals throughout anesthesia. Correlation coefficient (r), regression analysis, and bias (the mean difference between two methods), were used to statistically compare the agreement of rectal (Tr) and bladder (Tb) temperature with tympanic mem-

Table 1. Patient Demography

	Group 1 (n=14)	Group 2 (n=16)	
Age	53.8 ± 20.9	39.7 ± 24.5	N.S.
Sex (Male/Female)	6/8	9/7	N.S.
Height (cm)	156.6 ± 5.6	145.1 ± 31.4	N.S.
Weight (kg)	56.9 ± 9.3	50.4 ± 20.3	N.S.
Operation time	222.9 ± 95.6	137.7 ± 65.1	$P < 0.01$

N.S.: no significant difference

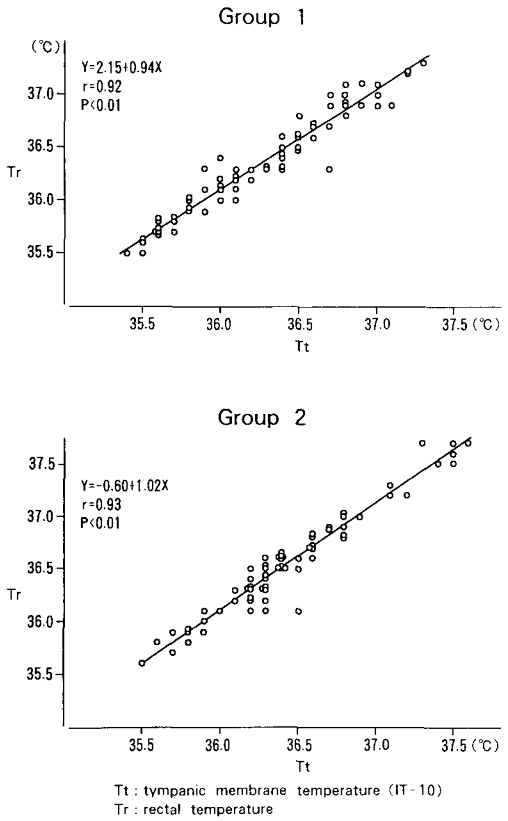

Fig. 2. Linear regression analysis of rectal temperature (Tr) against tympanic membrane temperature (Tt) in both group 1 for 66 paired points and group 2 for 65 paired points.

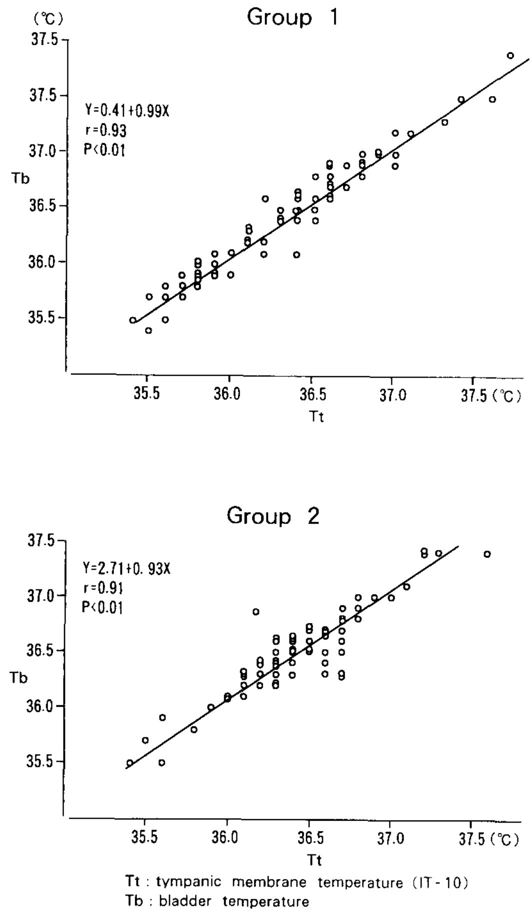

Fig. 3. Linear regression analysis of urinary bladder temperature (Tb) against tympanic membrane temperature (Tt) in both group 1 for 65 paired points and group 2 for 63 paired points.

brane temperature (Tt). Differences were considered statistically significant when $P < 0.05$.

Results

There were no significant differences between the two groups in age, sex, height, and weight. However, operation time of Group 1 was significantly longer than that of Group 2 ($P < 0.01$)

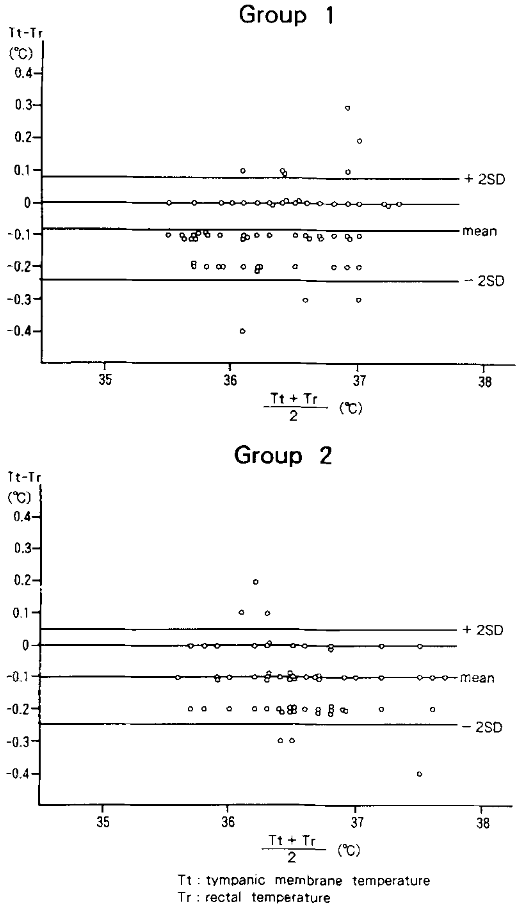

Fig. 4. The difference between tympanic membrane temperature (Tt) and rectal temperature (Tr) against the average temperature in both group 1 and group 2.

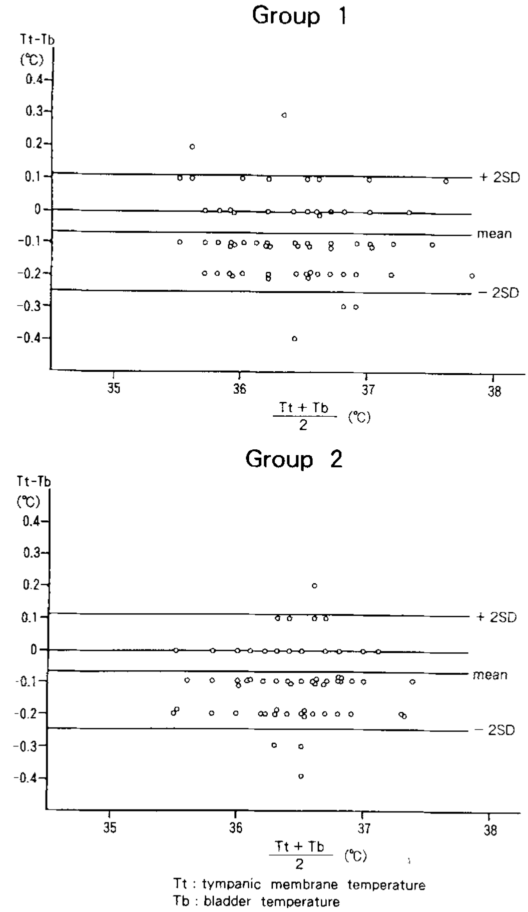

Fig. 5. The difference between tympanic membrane temperature (Tt) and bladder temperature (Tb) against the average temperature in both group 1 and group 2.

(table 1).

Correlation of Tr and Tb with Tt by regression analysis revealed that temperatures at all sites were almost identical over a broad range of recordings, though there were no significant differences in any temperature measurements between the two groups. Tr and Tb had correlation coefficients greater than 0.90 with Tt in both groups (fig. 2, 3).

Figure 4 and 5 are plots of the difference between Tt and Tr, Tt and Tb in both groups. The statistical results for Tt and Tr, Tt and Tb agreement for all patients were summarized in table 2. Differences between Tt and Tr, Tt and Tb are from −0.2 to 0.1°C.

Discussion

Findings of the present study confirmed the evidence that this new infrared tympanic thermometer is a useful method of measuring the body temperature of a patient during general anesthesia.

Thermoregulation consists of two kinds of temperature: central, which reflects the temperature of the body core, and peripheral, which reflects

Table 2. Tt agreement with Tr and Tb

	Group 1				Group 2			
	Tt v.s. Tr		Tt v.s. Tb		Tt v.s. Tr		Tt v.s. Tb	
No	r	(Tt-Tr) ± 2SD	r	(Tt-Tb) ± 2SD	r	(Tt-Tr) ± 2SD	r	(Tt-Tb) ± 2SD
1	0.86	0.09 ± 0.16	0.69	0.15 ± 0.20	0.91	−0.13 ± 0.10	0.88	−0.16 ± 0.19
2	0.80	−0.16 ± 0.20	0.71	−0.17 ± 0.22	0.96	−0.02 ± 0.28	0.94	−0.08 ± 0.18
3	0.96	−0.07 ± 0.16	0.91	0.02 ± 0.18	0.76	−0.28 ± 0.16	0.79	−0.13 ± 0.26
4	0.68	0.00 ± 0.32	0.84	−0.04 ± 0.28	0.67	−0.17 ± 0.28	0.56	−0.24 ± 0.16
5	0.78	−0.13 ± 0.12	0.75	0.00 ± 0.22	0.99	−0.01 ± 0.12	0.79	−0.17 ± 0.22
6	0.97	0.08 ± 0.24	0.97	−0.01 ± 0.10	0.78	−0.14 ± 0.22	0.80	0.22 ± 0.36
7	0.99	−0.15 ± 0.12	0.99	−0.20 ± 0.16	0.63	−0.08 ± 0.13	0.62	−0.08 ± 0.20
8	0.94	−0.10 ± 0.10	0.86	−0.01 ± 0.24	0.73	0.06 ± 0.20	0.77	0.09 ± 0.21
9	0.95	−0.26 ± 0.26	0.87	−0.13 ± 0.08	0.76	−0.02 ± 0.12	0.88	−0.08 ± 0.29
10	0.76	0.06 ± 0.20	0.70	0.03 ± 0.20	0.54	0.18 ± 0.22	0.66	0.17 ± 0.18
11	0.77	−0.14 ± 0.38	0.82	−0.16 ± 0.12	0.94	−0.11 ± 0.12	0.94	−0.15 ± 0.20
12	0.91	−0.08 ± 0.20	0.88	−0.09 ± 0.12	0.92	−0.14 ± 0.20	0.95	−0.20 ± 0.11
13	0.95	0.26 ± 0.20	0.92	0.04 ± 0.14	0.76	−0.15 ± 0.24	0.80	−0.17 ± 0.12
14	0.94	−0.23 ± 0.10	0.80	−0.10 ± 0.18	0.91	−0.10 ± 0.20	0.96	−0.14 ± 0.14
15	–	–	–	–	0.79	−0.18 ± 0.28	0.82	−0.04 ± 0.16
16	–	–	–	–	0.97	−0.17 ± 0.10	0.70	−0.12 ± 0.26
All	0.92	−0.08 ± 0.16	0.93	−0.07 ± 0.18	0.93	−0.10 ± 0.15	0.91	−0.06 ± 0.17

Tt: tympanic membrane temperature (IT−10), Tr: rectal temperature
Tb: bladder temperature, No: number of patient

the temperature of the body shell and environment[6]. Physiological thermoregulation is a complex core and shell interaction that attempts to balance body heat gain against loss. In an unanesthetized human, core temperature is maintained within 0.4°C of normal. However, in an anesthetized patient, anesthesia and surgery alter the body's balance[7,8].

Intraoperative hypothermia is difficult to avoid because: 1) cold exposure increases environmental heat loss; 2) general anesthesia decreases metabolic heat production; and 3) anesthetic drugs inhibit thermoregulatory responses[9,10]. Therefore, body temperature measurement, especially core temperature, provides important information during anesthesia[11].

There are various measurements of core temperature such as rectal, bladder, esophageal, and tympanic membrane[12]. The true core temperature should be regarded as that of the hypothalamus, because the hypothalamus is the control center for temperature regulation[13,14]. The tympanic membrane shares the same vascular supply that perfuses the hypothalamus and is an excellent, readily accessible site for core temperature measurement[15]. Therefore, it is recommended that tympanic membrane temperature is the most reliable core temperature in clinical practice[16]. However, patient discomfort and complications such as perforation have restricted the use of indwelling contact type tympanic membrane temperature probes[4,17].

There are several studies of an infrared tympanic thermometer and it is reported that the instrument of noncontact type accurately measures core temperature and it is of much clinical use[4,5,18]. In this study, Tt and Tr, Tt and Tb were highly correlated.

Bland-Altman analysis[19,20] reveals a slight error in Tt. Methods comparison studies, such as the present study, involve between-technique variability. The between-technique variability of two different measurement methods of measuring the same variable can be evaluated by correlation, regression, and bias. The bias represents the systematic error between two measurement techniques[21]. In this study, the slight bias error in Tt might be due to technical error, such as not introducing a probe tip of IT-10 correctly toward the tympanic membrane because of misalignment of the probe in the ear canal[18]. More careful observation in introducing the probe tip into the auditory canal should be required to gain correct core temperatures.

Comparing our new infrared tympanic thermometer with already used one, our thermometer is also non-contact type and safe, and able to reliably reproduce standard methods of clinical temperature measurement. Furthermore, our instrument is more convenient, light-weighed, easier of use, and will be cheaper than one already marketed. When these advantages are considered, the new infrared tympanic thermometer becomes an acceptable option for temperature measurement during general anesthesia with or without open abdominal surgery.

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References

1. Smith NT: Subcutaneous, muscle, and body temperatures in anesthetized man. J Appl Physiol 17:306–310, 1962
2. Holdcroft A: Body temperature controll in anesthesia, surgery, intensive care. London, Bailliere Tindall, 1988, pp. 4–40
3. Dickey WT, Ahlgren EW, Stephan CR: Body temperature monitoring via the tympanic membrane. Surgery 67:981–984, 1970
4. Shinozaki T, Deane R, Perkins FM: Infrared tympanic thermometer: Evaluation of a new clinical thermometer. Crit Care Med 16:148–150, 1988
5. Johnson KJ, Bhatia RNP, Bell EF: Infrared thermometry of newborn infants. Pediatrics 87:34–38, 1991
6. Imrie MM, Hall GM: Body temperature and anaesthesia. Br J Anaesth 64:346–354, 1990
7. Vaughan MS: Shivering in the recovery room. Curr Rev R R Nurse 6:2–7, 1984
8. Sessler DI: Temperature regulation and anesthesia. ASA Annual Refresher Course Lectures 1991, 243
9. Sessler DI, Olofsson CI, Rubinstein EH, et al: The thermoregulatory threshold in humans during halothane anesthesia. Anesthesiology 68:836–842, 1988
10. Sessler DI, Moayeri A: Skin-surface warming: heat flux and central temperature. Anesthesiology 73:218–224, 1990
11. Hall GM: Body temperature and anaesthesia. Br J Anaesth 50:39–44, 1978
12. Cork RC, Vaughan RW, Humphrey LS: Precision and accuracy of intraoperative temperature monitoring. Anesth Analg 62:211–214, 1983
13. Benzinger TH, Tayler GW: Cranial measurements of internal temperature in man. Temperature: its measurement and control in science and industry. New York, Reinhold, 1963, pp. 111–120
14. Hensel H: Neural processes in thermoregulation. Physiol Rev 53:948–1017, 1973
15. Benzinger TH: Clinical temperature: new physiological basis. JAMA 209:1200–1206, 1969
16. Benzinger M: Tympanic thermometry in surgery and anesthesia. JAMA 209:1207–1211, 1969
17. Wallace CT, Marks WE, Adkins WY, et al: Perforation of the tympanic membrane, a complication of tympanic thermometry during anesthesia. Anesthesiology 41:290–291, 1974

18. Kenney RD, Fortenberry JD, Surratt SS, et al: Evaluation of an infrared tympanic membrane thermometer in pediatric patients. Pediatrics 85:854–858, 1990
19. Bland JM, Altman DG: Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1:307–310, 1986
20. LaMantia KP, O'Connor T, Barash PG: Comparing methods of measurement: An alternative approach. Anesthesiology 72:781–783, 1990
21. Wong DH, Tremper KK, Stemmer EA, et al: Noninvasive cardiac output: Simultaneous comparison of two different methods with thermodilution. Anesthesiology 72:784–792, 1990