Influence of Thermistor Probe Depth from the Anterior Nares on Measurement of Nasopharyngeal Temperature

Hiroaki Sato¹, Michiaki Yamakage², Katsumi Okuyama¹, Yusuke Imai¹, Hiromobu Iwashita¹, Taishi Masamune¹, Tadahiko Ishimaya¹ and Takashi Matsukawa¹

¹Department of Anesthesiology, University of Yamanashi, Faculty of Medicine, Chuo, Yamanashi, Japan. ²Department of Anesthesiology, Sapporo Medical University School of Medicine, Sapporo, Hokkaido, Japan.

Summary: Nasopharyngeal temperature is allegedly accurate and is generally used during cardiopulmonary bypass for open-heart surgery. However, adequate depth from the anterior nares to measure nasopharyngeal temperature has not been evaluated. To test whether nasopharyngeal temperature is sufficiently accurate and precise for clinical use and to clarify the suitable depth of insertion, we compared nasopharyngeal temperature measurements to simultaneous tympanic temperature measurements during open-heart surgery with cardiopulmonary bypass. Subjects comprised 4 women and 6 men undergoing cardiac surgery with a target core temperature of 32 °C. Nasopharyngeal temperature was measured at 4 sites by placing thermocouples in the nasal cavity in 1-cm increments starting at 2 cm from the anterior nares. The reference temperature (tympanic temperature) was measured at the right tympanic membrane using a thermocouple. Both temperatures were measured every 5 min and compared using correlation coefficients of linear regression ($r^2$) and bias (mean difference between the two methods). Compared to tympanic temperature, nasopharyngeal temperature showed regression slopes of 0.91–1.03 and correlation coefficients of 0.55–0.65 at all 4 depths. Accuracy (offset or bias) was 0.9–2.1 °C compared to tympanic temperature. Precision (standard deviation) of measurements was 0.8–1.2 °C. Nasopharyngeal temperature collected at 2 cm varied the most from tympanic temperature. In conclusion, the reliability of $T_{\text{naso}}$ is low for monitoring core body temperature during open-heart surgery with CPB, particularly if the probe is placed at a shallow depth from the anterior nares. Nasopharyngeal temperature obtained closest to the anterior nares (2 cm) were the least accurate.

Keywords: core temperature, nasopharyngeal temperature, tympanic temperature, cardiopulmonary bypass

Introduction

Core temperature perturbations are common in the perioperative period. Continuous core temperature monitoring is therefore standard practice during general anaesthesia, and anaesthesiologists need to maintain temperature in a normal range. Various sites are available to measure core temperature, including the rectum, bladder, oesophagus, tympanic membrane and nasopharynx. Temperature at the nasopharynx ($T_{\text{naso}}$) is allegedly accurate and is generally used during cardiopulmonary bypass (CPB) for open-heart surgery. However, adequate depth from the anterior nares to measure $T_{\text{naso}}$ has not been evaluated. Accordingly, to test whether $T_{\text{naso}}$ is sufficiently accurate and precise for clinical use and to clarify the appropriate depth of measurement, we compared $T_{\text{naso}}$ during CPB for open-heart surgery to simultaneous measurement of temperature at the tympanic membrane ($T_{\text{tym}}$), which is known as a reliable measure of core temperature even during CPB.

Materials and Methods

With the approval of the Ethics Committee on Human Research of the Faculty of Medicine at the University of Yamanashi, and after obtaining informed consent from prospective patients, a total of 10 patients (4 women, 6 men) with ASA physical status II or III who were to undergo cardiac surgery were enrolled in this study. All subjects were scheduled for induced hypothermia in CPB with a target core temperature of 32 °C. Patients with a history of nasopharyngeal disease (e.g. sinusitis), carotid arterial disease (e.g. internal carotid artery stenosis) and/or external auditory canal disease (e.g. otitis externa) were excluded from the study. No premedication was administered. General anaesthesia was...
induced by intravenous injection of midazolam (8–12 μg/kg) and fentanyl (6–10 μg/kg), and muscle relaxation was facilitated with vecuronium (0.15 mg/kg). After tracheal intubation, anaesthesia was maintained using sevoflurane (1.0%–2.0%) in 50% oxygen with intermittent administration of fentanyl (50–100–200 μg) as an adjuvant analgesic. After induction of general anaesthesia, thermistor probes were inserted into the right and lower nasal cavity and right ear canal for measurements of T Naso and T Tym, respectively. T Naso was measured at 4 sites simultaneously by placing thermocouples (Mon-a-Therm®; Tyco-Mallinckrodt Anesthesiology Products, St. Louis, MO, U.S.A.) in the right nasal cavity in 1-cm increments starting at 2 cm from the anterior nares. The reference temperature (T Tym) as a core temperature during CPB was measured at the right tympanic membrane using a Mon-a-Therm® thermocouple.9,10 These measured temperatures were monitored and recorded automatically to a personal laptop computer at 5-min intervals. Temperature in the operating room was kept at 19–21 °C, and a conductive warming/cooling system (Medi-therm III®; Gaymar Industries, Orchard Park, NY, U.S.A.) was used to control the body temperature. Neither head nor neck part of the subjects was covered.

T Naso was evaluated in comparison with T Tym as core body temperature9,10 only during cooling and rewarming phases. Correlation coefficients of linear regression (r2) and Bland-Altman plots were used to evaluate correlations and limits of agreement between these temperatures, respectively. An r2 value >0.60 was considered clinically useful. Mean difference (i.e. bias) >0.5 °C and 2 standard deviations (SDs) (i.e. repeatability or precision) >± 1.0 °C were considered clinically significant11. Correlation coefficients among the groups were also compared with the Fisher’s Z-transformation, and p < 0.05 was considered significant.

Results
The patients’ height [median (range)] was 162 (154–174) cm, total body weight (TBW) 59 (48–81) kg, and age 58 (35–72) yr. Duration of surgery was 321 min (245–434 min). Measured ambient temperature ranged from 18.2 °C to 22.1 °C in this study. After deletion of obvious artifacts caused by high-frequency coagulation, we obtained 179 measurements with each of the two devices. Temperatures measured during cooling and rewarming phases of CPB ranged from 31.5 °C to 38.0 °C. No complications related to the site of probe insertion were encountered for either the ear canal or nasal cavity.

Correlations between T Tym and T Naso measured at the 4 depths of the nasopharyngeal airway in this study are shown in Figure 1. Although significant relationships were apparent between these temperatures (p < 0.001) and slopes between temperatures were very high (0.90–0.97), correlation coefficients of linear regression (r2) were rather low (0.49–0.65) in all situations. The value (r2) at the shortest depth (2 cm) was significantly lower than those at the depths of 4 cm and 5 cm. Bland-Altman plots of temperature measurements during cooling and rewarming phases with CPB are shown in Figure 2. The accuracy of T Naso (offset or bias) was 0.93–2.12 °C compared to T Tym. The precision (SD) of measurements was 0.83–1.22 °C. T Naso collected at the shortest depth, 2 cm, varied the most from T Tym. Accuracies and precisions of T Naso at various depths investigated in this study are summarized in Table 1.

There were not any specific complications regarding to this study (e.g. perforation of tympanic membrane or epistaxis).

Discussion
The present study investigated the reliability of T Naso, which is believed to offer a reliable marker for body core temperature in clinical settings.3–5 Furthermore, as no previous studies have described the appropriate depth of temperature probe insertion, the present study also evaluated this point. In general, body temperature does not change extremely in general anaesthesia without CPB. As a result, we considered that the reliability of T Naso as a marker for body core temperature could be more accurately than that assessed in cardiac surgery with CPB, during which body temperature changes rapidly. T Tym is used as a reliable marker for body core temperature,7,8 and thus was also measured for comparison. While a contact-type temperature probe was used in the present study, non-contact-type infrared tympanic and intraaurnal probes can also reportedly monitor rapid changes in body temperature.7,8 The internal carotid artery supplies blood to the tympanic membrane and the tympanic membrane side of the external auditory canal, and thus the arterial blood temperature of
the CPB circuit in open-heart surgery directly affects tympanic membrane temperature. According to a recent survey conducted in Europe, nasopharyngeal temperature is most frequently used in general anaesthesia to monitor core temperature, further supporting the relevance of this study.

The present investigation focused on the cooling and rewarming phases of open-heart surgery. The results showed a correlation between $T_{\text{Naso}}$ and $T_{\text{Tym}}$ (Fig. 1), but this correlation was not strong. In addition, Bland-Altman analysis to assess accuracy and precision showed a large bias, and $T_{\text{Naso}}$ was lower by about 1°C than $T_{\text{Tym}}$ (Fig. 2).

The reliability of $T_{\text{Naso}}$ in representing body core temperature is thus not particularly high and is inferior to $T_{\text{Tym}}$. Akata et al. conducted a similar study and reported that $T_{\text{Naso}}$ most closely reflected pulmonary arterial temperature as well as forehead deep-tissue temperature during stabilized profound hypothermia. They placed a probe about 5 cm from the anterior nares and plugged the anterior nares with cotton gauze. That study did not measure oesophageal temperature or $T_{\text{Tym}}$, which are markedly affected by blood flow, and concluded that $T_{\text{Naso}}$ was superior to other methods including urinary bladder temperature. Johnson et al.
placed a probe 10 cm from the anterior nares and reported a large difference from arterial blood temperature of the CPB circuit in open-heart surgery. Based on the results, they recommended that strict criteria should be implemented for the management of temperature during CPB, in conjunction with more emphasis on monitoring arterial blood temperature as a marker of potential cerebral hyperthermia. We should not, therefore, rely on TNaso alone during CPB. TNaso is not an appropriate marker for body core temperature during CPB, which is accompanied by rapid temperature changes. In other words, TNaso is unsuitable for monitoring real-time brain temperature in open-heart surgery, as have been reported previously.4,13–15

The present study also investigated suitable depths of insertion from the anterior nares. The probe was placed at different depths without plugging the anterior nares. The results showed that reliability was higher when the probe was placed deep. Thus, when body core temperature must be monitored using TNaso, more accurate measurements may be obtained by placing a probe deep. While the results cannot be compared simply, Johnson et al.12 placed the probe 10 cm from the anterior nares and obtained comparable results to the present study, where the probe was placed 5 cm from the anterior nares. Placing a probe too deeply into the nasal cavity is thus unnecessary.4 As CPB requires heparinization, excessively deep
probe placement should be avoided, to prevent inadvertent bleeding.

In conclusion, the reliability of TNaso is low for monitoring core body temperature during open-heart surgery with CPB, particularly if the probe is placed at a shallow depth from the anterior nares. However, since the present study examined body temperature monitoring with rapid temperature changes, the usefulness of TNaso in conventional general anaesthesia has not been ruled out.

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Disclosure
The authors report no conflicts of interest.

References