DEEP BODY TEMPERATURE DURING THE WARMING PHASE OF CARDIOPULMONARY BYPASS

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SUMMARY

We have compared deep body temperature (DBT) measured at the forehead with the core temperatures of the nasopharynx, oesophagus and rectum during the warming phase of cardiopulmonary bypass (CPB) (moderate hypothermia of 26.7-29.6 °C) in 12 patients. DBT was measured transeutaneously by an insulated thermistor probe that created an area of zero thermal flow between skin and subcutaneous tissue. The core temperatures measured at different sites lagged behind the increase in arterial blood temperature during warming. The trend was most marked with rectal temperature and least with oesophageal temperature. Among all measurements, the closest linear relationship was found between forehead DBT and nasopharyngeal core temperature (0.99 x nasopharyngeal temperature (°C) - 0.07; SEE = 0.53; r = 0.99; P < 0.0001). Forehead DBT measurement may be useful as a reliable non-invasive method of monitoring cerebral temperature during CPB. (Br. J. Anaesth. 1993; 71: 583-585)

KEY WORDS


Although tympanic membrane and nasopharyngeal temperatures are considered to reflect cerebral temperature, damage to the tympanic membrane [1] and nasal bleeding [2] may occur and there may be errors when placement of the probe is imprecise. Fox and colleagues proposed non-invasive deep body thermometry that measured deep body temperature (DBT) from the skin surface by creating an area under an insulated thermistor probe of zero thermal flow between skin and subcutaneous tissue [3]. This device was later improved by covering the probe with a heated aluminum frame that prevented radial heat loss in the tissue under the probe [4]. Recently, however, it was suggested that deep body thermometry may not reflect the rapid changes in body temperature that occur during cardiopulmonary bypass (CPB) [2].

We have evaluated a currently available non-invasive deep body thermometry system by measuring DBT at the forehead and comparing values with core temperatures obtained simultaneously in the nasopharynx, oesophagus and rectum during the warming phase of CPB in 12 patients.

METHODS AND RESULTS

We studied 12 ASA II and III patients (six male) undergoing elective cardiac surgery for valvar heart disease. Institutional approval was obtained, and informed consent from each patient. The mean age of the patients was 52 yr (range 39-66 yr), mean weight 54 kg (range 34-75 kg) and mean height 154 cm (range 140-169 cm). Eleven patients had valve replacement and one had open mitral commissurotomy.

Premedication consisted of diazepam 5-10 mg orally and hyoscine 0.3-0.5 s.c. Anaesthesia was induced and maintained with fentanyl 30-100 μg kg⁻¹ and midazolam 20-40 mg i.v. Tracheal intubation was facilitated by neuromuscular block with vecuronium. The lungs were ventilated mechanically using 100% oxygen. Volatile anaesthetics were not used. Moderate hypothermia (26.7-29.6 °C) was maintained during CPB with pump flow of 2.0-2.5 litre m⁻² min⁻¹. Warming was facilitated by active vasodilatation with prostaglandin E₁ 25-50 ng kg⁻¹ min⁻¹. The operating room temperature was maintained within the range 23.0-25.0 °C.

DBT was measured at the forehead with a 7-g, 2.5-cm diameter surface probe and a deep body thermometer (PD-31 and CORE TEMP model CTM-205, Terumo, Tokyo, Japan). The probe consisted of an insulated thermistor covered by a cast aluminum shell with a high thermal conductivity, in which an electrically controlled heater and a second thermistor were incorporated. The second thermistor measured the temperature of the aluminum frame. The two thermistors were connected by two bridges. Skin temperature and temperature difference signals were amplified; the latter controlled the electrical current to the heater so that the temperature of the frame equaled that of the skin under the probe.

After induction of anaesthesia, a DBT probe was secured to the midline of the forehead using double-faced adhesive tape, a nasopharyngeal probe was advanced a distance equal to that between the external meatus of the ear and the external naris, an oesophageal probe was placed at the location where

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the heart sounds were loudest and a rectal probe was advanced 10 cm. The nasopharyngeal, oesophageal and rectal probes were taped in position and were connected to a thermometer (TERUMOFINER, model CTM-303, Terumo, Tokyo, Japan). The temperatures were measured simultaneously eight or nine times for each patient during warming from 5 min before the arterial perfusate was warmed quickly to > 30 °C, until the discontinuation of CPB. The temperature of the oxygenated blood pumped into the aorta was considered to be the arterial blood temperature.

Values are expressed as mean (SD). The relationship between forehead DBT and other temperatures was assessed by correlation coefficient and linear regression analysis.

During the warming phase, arterial blood temperature increased from 27.9 (0.9) °C to 37.4 (0.4) °C. Pump flow increased from 2.1 (0.10) to 2.5 (0.03) litre m⁻² min⁻¹ and mean arterial pressure from 60 (13) to 65 (14) mm Hg.

Forehead DBT, nasopharyngeal temperature, oesophageal temperature and the rectal temperature increased at a slower rate than the arterial blood temperature (Ta) during warming. This trend was most marked with rectal temperature (0.49 x Ta (°C)+13.62; r = 0.67; see = 1.94; P < 0.0001) and least with oesophageal temperature (0.99 x Ta (°C)−0.78; r = 0.92; see = 1.48; P < 0.0001). The patterns of deviation from Ta of forehead DBT and nasopharyngeal temperature were similar (DBT, 0.87 x Ta (°C)+2.38; r = 0.84; see = 1.99; P < 0.0001 (fig. 1); nasopharyngeal temperature, 0.88 x Ta (°C)+2.13; r = 0.86; see = 1.87; P < 0.0001). In one patient, temperature was measured during hyperthermia when cold cardioplegia solution was used. Oesophageal temperature registered 4 °C less than that of arterial blood. The temperature measured at other sites did not reflect the event.

Of the measurements made, the closest to linear relationship was found between forehead DBT and nasopharyngeal temperature (0.99 x nasopharyngeal temperature (°C)−0.07; r = 0.99; see = 0.53; P < 0.0001 (fig. 1)). The relationship of DBT to oesophageal and rectal temperatures was 0.89 x oesophageal temperature (°C)+2.67; r = 0.93; see = 1.40; P < 0.0001 and 1.22 x rectal temperature (°C)−4.91; r = 0.86; see = 1.86; P < 0.0001.

COMMENT

In this study, core temperature measured at different sites lagged behind the increase in arterial blood temperature during the warming period of CPB. Rectal temperature was slowest in reflecting arterial blood temperature changes, responses of nasopharyngeal temperature and forehead DBT were intermediate in speed and oesophageal temperature lagged least behind changes in arterial blood temperature. Of all the measurements of core temperature, the closest and directly linear relationship was found between forehead DBT and nasopharyngeal temperature.

Core temperature is considered to be the temperature of the central core of the body, within which temperature fluctuates minimally. The core is covered by the skin and subcutaneous tissues, through which temperature gradients exist. Core temperature is maintained nearly constant by active thermoregulation in the peripheral tissues against cold and warm environments. Although core temperatures measured at different sites are similar in
unanaesthetized subjects or anaesthetized subjects in a steady state, surface temperature measured on the forehead is approximately 2 °C less than the core temperature and varies widely because of thermoregulation [5].

The DBT device, as described by Muravchick, exteriorizes core temperature [2]. The current device reduces radial thermal flow markedly in the tissues under the probe by heating the aluminium frame that covers an insulated thermistor to the same temperature as the thermistor and the reduction in the radial heat flow allows the region of zero thermal flow under the probe to enlarge [4]. Clinical trials have shown that the agreement between DBT and core temperature measured by conventional methods was good and that DBT tends to be 0.05–0.2 °C less than the core temperature measured by other methods [3, 4]. When an initial temperature equilibrium was attained between the insulated thermistor and deep tissues, DBT responded rapidly and followed the changes in core temperature closely when an endogenous pyrogen was injected i.v. [3]. DBT measured over the biceps also closely mirrored the rapid increase in muscle temperature measured by an i.m. thermocouple during isometric exercise [4]. The transcutaneous DBT measurement, thus, was thought to be a satisfactory continuous monitor of core temperature [4].

A large difference between forehead DBT and nasopharyngeal temperature has been reported during the rapid cooling and warming phases of CPB [2]. The DBT lagged behind nasopharyngeal temperature during cooling, but the difference was not predictable during warming: DBT lagged behind in some subjects, but increased ahead of nasopharyngeal temperature in others. In contrast, forehead DBT closely followed nasopharyngeal temperature in our study. The cause for this difference in the findings is not clear. During rapid changes in body temperature, regional temperature gradients may develop in core organs, depending on the differences in size, thermal conductivity and heat capacity of and arterial blood flow to the organs. As uniform changes in temperature of tissues depend on an even distribution of temperature in the tissues, the regional gradients may cause temperature discrepancies in different tissues measured. However, the non-systematic differences demonstrated appear to suggest that the difference between Muravchick's findings and ours may have been a result of mechanical rather than physiological causes. In our study, the probe was smaller and weighed less, and a headstrap was not used to secure the probe on the forehead. Excessive pressure may interfere with circulation to the tissue under the probe when perfusion pressure is reduced. Uneven pressure exerted on the frame of the probe may change the distribution of arterial blood flow under the probe, which may have accounted for a greater temperature under the probe.

The mechanism for the identical responses found in this study of forehead DBT and nasopharyngeal temperature during the warming phase of CPB may have been the similarity in the pattern of arterial blood supply to and the proximity of the measurement sites. The forehead area and the posterior and lateral walls of the nasopharynx receive a rich supply of arterial blood from the external carotid artery. The forehead also receives an arterial supply from the internal carotid artery through the supraorbital arteries. As reported previously [2, 6], the oesophageal temperature in this study tended to reflect the temperature of mediastinal structures during warming, and the rectal temperature showed a marked delay in changes in arterial blood temperature, presumably secondary to a relatively smaller arterial blood flow and possibly to the conduction of heat from a large amount of tissues surrounding the rectum. Prostaglandin E1 used during the warming phase may also have helped to equalize the temperature in the nasopharynx and the forehead by active vasodilatation. DBT measurement is a non-invasive procedure. The response of the probe was rapid and the forehead DBT closely followed the changes in nasopharyngeal temperature during rapid warming; thus DBT measurement may be a reliable, non-invasive method of monitoring cerebral temperature during CPB.

**REFERENCES**