Brief communication - Cardiac general

Accuracy of core temperature measurement in deep hypothermic circulatory arrest*  

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Received 16 April 2008; received in revised form 19 June 2008; accepted 19 June 2008

Abstract

Deep hypothermia is an effective technique for neuroprotection in cardiac surgery. However, standard body temperature measurement may deviate from actual brain temperature. Therefore, we simultaneously measured brain and core temperatures during neurosurgical interventions in hypothermic circulatory arrest to determine its accuracy. Between 1994 and May 2007, 26 patients (12 female, mean age 46 ± 14 years), with complex intracranial aneurysms, underwent resection or clipping applying closed chest cardiopulmonary bypass and hypothermic circulatory arrest via inguinal cannulation. During surgery, temperature probes were positioned in the brain, tympanum, bladder, rectum and pulmonary artery. Mean cardiopulmonary bypass time was 147 ± 39 min, mean circulatory arrest time was 28 ± 8 min. Brain temperatures were best reflected by bladder and tympanum probes (Pearson’s correlation coefficients: bladder = −0.83; tympanum = −0.80; pulmonary artery = 0.63; rectum = 0.37; P < 0.05). Mean deviations from brain temperature were +0.2 ± 2.7°C at the tympanum, −0.8 ± 2.6°C in the bladder, −0.7 ± 2.6°C in the pulmonary artery and −1.8 ± 4.4°C in the rectum. In conclusion, temperature monitoring in the bladder and tympanum reliably reflects brain temperature. Temperature measurements in the pulmonary artery and rectum are less optimal.  

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Keywords: Circulatory arrest; Temperature monitoring; Hypothermia; Cardiopulmonary bypass; Cerebral aneurysm

1. Introduction

Preservation of unimpaired neurological function is one of the crucial issues in cardiac surgery. The installation of systemic hypothermia remains the mainstay of neuroprotection [1]. To estimate actual brain temperature, clinicians and cardiac surgeons rely on body temperatures taken from bladder, rectum, esophageal and tympanum probes. However, body temperatures may substantially deviate from true intracranial temperature [2, 3].  

Complex intracranial aneurysms, that would otherwise be considered inoperable by standard therapies, are resected in hypothermic circulatory arrest [4, 5]. These operative procedures provided us the opportunity to evaluate the relationships between intracranial and extracranial temperatures during closed chest hypothermic circulatory arrest.

2. Methods

2.1. Patients

From March 1994 to June 2007, 26 patients (n = 14 male, n = 12 female) were operated on for cerebral aneurysms under utilization of closed chest cardiopulmonary bypass and deep hypothermic circulatory arrest in our institution. All patients suffered from complex intracranial giant aneurysms. The Glasgow Outcome Scale (GOS) is a score ranging from 1 (= death) to 5 (= good recovery), which is normally used to assess the neurological outcome after severe brain damage. Preoperative GOS score was 4 ± 1. Pertinent patient data are shown in Table 1. Patients with aortic valve incompetence were not eligible for this neurological approach.

2.2. Monitoring and temperature measurement

Hemodynamic monitoring included a radial artery cannula and a pace port Swan Ganz catheter (Standard Thermodilution Swan Ganz Catheter, Edwards Lifesiences, USA). Thermocouples were positioned in the ear canal near the tympanum (Mon-a-therm™ Tympanic; Malickrodt Inc., USA). Bladder temperature was monitored with a Foley catheter with an integrated temperature sensor (Curity™, Degania; Israel). Rectal temperature was measured continuously with a thermocouple probe (Mallickrodt Medical, USA). Tympanum, bladder and rectal probes were connected to Mallickrodt Model 6510 electronic thermometers. These thermometers require no user calibration and have accuracy close to 0.1°C when used with Mon-a-therm disposable thermocouples (industrial information). Visual inspection with an otoscope confirmed that the ear canal...
was free of debris in each patient. The aural canal was occluded with cotton, the probe securely taped in place, and a gauze bandage positioned over the external ear. Ambient temperature was maintained at 20–22 °C during surgery.

2.3. Operative procedure and perfusion technique

The aneurysm was exposed as far as safely possible by the neurosurgeon and a needle probe was inserted for direct measurement of brain temperature (Mon-a-therm Myocardial 18 mm×0.71 mm, Mallinkrodt Medical, USA). After surgical exposure of the femoral vessels the cannulae were inserted (21 or 23 Fr, Medtronic Biomedicus, Eden Prairie, MN). To optimize blood rheology we accomplished a dilution up to a hemoglobin value of 5 g/dl. Maximal cooling was performed with high pump flows until a brain temperature of 21 °C was reached. Then CPB was stopped and the venous blood actively or passively drained by pressure controlled vacuum assisted drainage into the venous reservoir.

3. Results

3.1. Extracorporeal circulation

Extracorporeal circulation time was 147±39 min and mean duration of cardiac arrest was 28±8 min. In the majority of patients multiple intermittent circulatory arrests (4±2) at intervals of 1–20 min were applied. All patients except two regained spontaneous sinus rhythm during reperfusion. The latter had to be defibrillated externally. An average of 2.0±1 U of packed red blood cells was transfused during surgery or in the early postoperative course.

3.2. Temperature measurements

At the start of circulatory arrest mean brain temperature was 21.3±1.4 °C, whereas the mean tympanum temperature was slightly higher at 21.7±1.6 °C. Pearson’s correlation analysis of all measured temperatures obtained during surgery, from all different localizations, demonstrated a high correlation of actual brain temperature with measured tympanum temperature \( r = 0.80 \) and an even higher correlation with the bladder temperature \( r = 0.83 \). Rectal as well as blood temperatures taken in the pulmonary artery by the Swan Ganz catheter were not as exact as tympanum and bladder temperatures (rectum: \( r = 0.37 \); pulmonary artery \( r = 0.63 \)). All correlation coefficients reached statistical significance \( P < 0.05 \).

The maximal difference between brain temperature and all other reading points was ±0.2±2.7 °C at the tympanum, \(-0.8±2.6 °C\) in the bladder, \(-0.7±2.6 °C\) in the pulmonary artery, and \(-1.8±4.4 °C\) in the rectum, on average.

4. Discussion

The emphasis of our study was the investigation of accuracy of body temperature measurements to estimate brain temperature. Statistical analysis found the highest and strongest relationship between bladder and brain temperature. The explanation of this high correlation could be the proximity of the bladder to the inguinal introduced cannulae. The validity of bladder temperatures for estimation of core temperatures has been demonstrated before [6]. On the other side, the rectal temperature deviated up to 11 °C from the actual brain temperature. The rectum is provided with good isolation; therefore, recordings lag behind core temperature, and thus also brain temperature. Rectal readings may also be influenced by the presence of impacted stool [7]. Probably because of all these reasons...
we calculated the weakest correlation between rectally measured temperature and brain temperature.

Tympanum temperature represented brain temperature as reliable as bladder temperatures. This is not surprising, since the tympanum is located close to the brain in the cranium. The thermal link is hypothesized to be due to convection of heat from warm venous outflow from the brain passing close to the tympanic cavity reaching the jugular bulb [8].

The pulmonary artery blood is a result of convective mixing from all over the body [9]. Despite the fact that the temperature in the pulmonary artery is considered the gold standard, we noticed only a weak correlation with the actual brain temperature during cooling and rewarming.

In conclusion, our results recommend multiple temperature probes in different locations during cardiac surgery and circulatory arrest to assess a homogenous cooling and rewarming of patients. The bladder temperature and the tympanum temperature are most suitable to guide circulatory arrest in deep hypothermia as they reflect brain temperature reliably.

References