

Clinical Article



# Temperature Difference between Brain and Axilla according to Body Temperature in the Patient with Brain Injury

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Conflict of Interest

The authors have no financial conflicts of interest.

## ABSTRACT

**Objective:** Commonly, brain temperature is estimated from measurements of body temperature. However, temperature difference between brain and body is still controversy. The objective of this study is to know temperature gradient between the brain and axilla according to body temperature in the patient with brain injury.

**Methods:** A total of 135 patients who had undergone cranial operation and had the thermal diffusion flow meter (TDF) insert were included in this analysis. The brain and axilla temperatures were measured simultaneously every 2 hours with TDF (2 kinds of devices: SABER 2000 and Hemedex) and a mercury thermometer. Saved data were divided into 3 groups according to axillary temperature. Three groups are hypothermia group (less than 36.4°C), normothermia group (between 36.5°C and 37.5°C), and hyperthermia group (more than 37.6°C).

**Results:** The temperature difference between brain temperature and axillary temperature was 0.93±0.50°C in all data pairs, whereas it was 1.28±0.56°C in hypothermia, 0.87±0.43°C in normothermia, and 0.71±0.41°C in hyperthermia. The temperature difference was statistically significant between the hypothermia and normothermia groups ( $p=0.000$ ), but not between the normothermia and hyperthermia group ( $p=0.201$ ).

**Conclusion:** This study show that brain temperature is significantly higher than the axillary temperature and hypothermia therapy is associated with large brain-axilla temperature gradients. If you do not have a special brain temperature measuring device, the results of this study will help predict brain temperature by measuring axillary temperature.

**Keywords:** Brain; Axilla; Temperature; Brain injury

## INTRODUCTION

The control of brain temperature was regarded as a cornerstone therapy for brain injury. Once the brain is injured, brain temperature is generally regarded to rise above body temperature.<sup>22)</sup> In cases of brain injury, the brain is extremely sensitive and vulnerable to small variations in temperature.<sup>24)</sup> Fever is considered a secondary injury to the brain in neurosurgical patients with severe traumatic brain injury, subarachnoid hemorrhage, or

stroke.<sup>3,8,12)</sup> Elevated body temperature was independently associated with a longer intensive care unit (ICU) and hospital length of stay, higher mortality rate and worse outcome.<sup>7)</sup> Current opinion seems to prefer to treatment of pyrexia in patients with brain injury.

To regulation of brain temperature, assessment of body temperature is important for making decisions about nursing care, medical diagnosis, treatment, and the need for laboratory tests.<sup>6,9,11,30-32,36)</sup> For optimal use of thermoregulation as a therapeutic tool for neurosurgical patients, target brain temperature should be measures directly with specifically designed devices or by means of some other reliable site temperature that indirectly reflects the brain temperature.<sup>2,6,15)</sup> Brain temperature is usually considered a central temperature, and in the absence of intracranial pathology, it can be estimated by measuring tympanic or esophageal temperatures.<sup>24)</sup> However, in cases of severe cerebral injury, the estimates yielded by such measurements may be inaccurate.<sup>22,27)</sup>

There are several studies of the temperature difference between the brain and other body temperatures. However, the magnitude of temperature differences between brain and body remains unclear after brain injury.

The aim of this study is to determine whether the difference axilla temperature and brain temperature in patient with brain injury actually exists and to evaluate axilla temperature monitoring helps predict brain temperature.

## MATERIALS AND METHODS

The data accumulation and analysis were approved by our Institutional Review Board (PC17RES10027). All patients or their representatives provided informed written consent for surgical management. This study is a retrospective observatory data analysis.

In this study, we measured the brain temperature with a thermal diffusion flow meter (TDF) and measured the axillary temperature with a standard mercury thermometer simultaneously every two hours after a brain operation.<sup>4,21,25,29,36,39)</sup> We tried to assess the temperature difference in terms of the axillary temperature. Body temperature was divided three groups, according to the axillary temperature: hypothermia group (less than 36.4°C), normothermia group (between 36.5°C and 37.5°C), and hyperthermia group (more than 37.6°C). We analyzed the temperature difference according to the axillary temperature.

### Patients

Between May 1997 and January 2009, 135 patients who had undergone craniotomy with various neurosurgical diseases were enrolled in this analysis. There were 57 males and 78 females, with a mean age of 46.4±15.8 years (range: 6–66 years). According to the regional cortical blood flow meter, SABER 2000 (SABER 2000; Flowtronics, Phoenix, AZ, USA) used in 52 cases and Hemedex (Bowman perfusion monitor; Hemedex, Waltham, MA, USA) in 83 cases ; 33 patients were given mild to moderate hypothermia by using the cold-water blanket (Mdi-therm II, Gaymar Ind., NY, USA).

Craniotomy or craniectomy because of a ruptured subarachnoid hemorrhage (SAH) caused by an intracerebral aneurysm was 23 cases, intracerebral hemorrhage (ICH) was 15 cases, major infarction (MI) was 26 cases, and traumatic brain injury (TBI) was 71 cases (**TABLE 1**).

**TABLE 1.** Demography of 135 patients

Patients	Total (n=135)	Aneurysm (n=23)	ICH (n=15)	MI (n=26)	TBI (n=71)
Age (years)	46.4±15.8	54.1±8.6	55.8±9.2	62.4±3.0	36.0±13.7
Male	57 (42.8)	4 (17.4)	6 (40.0)	3 (11.5)	44 (62.0)
iGCS	8.1±3.6	6.9±2.5	6.8±4.0	7.6±3.3	9.0±3.8
eGCS	9.3±4.1	8.0±3.2	7.4±4.6	8.0±4.1	10.5±3.9
Dead	20 (14.8)	3 (13.0)	6 (40.0)	5 (19.2)	6 (8.5)
Mean axillary temperature (°C)	36.8±1.05	37.0±0.97	36.0±1.51	36.3±1.40	37.1±0.58
Mean brain temperature (°C)	37.7±0.83	38.0±0.75	37.1±1.10	37.2±1.07	37.9±0.49
Temperature, difference (°C)	0.89±0.33	0.99±0.36	1.05±0.41	0.92±0.37	0.81±0.25

Data are presented as the mean±standard deviation or number (%).

eGCS: end Glasgow Coma Scale, ICH: intracerebral hemorrhage, iGCS: initial Glasgow Coma Scale, MI: major infarction, TBI: traumatic brain injury, Temp.: temperature.

### Cerebral blood flow monitoring devices

The implanted thermal diffusion flowmeter sensor, the SABER 2000 (SABER 2000; Flowtornics, Phoenix, AZ, USA),<sup>4,34)</sup> was used to measure the brain cortex surface temperature in 52 cases, between 1997 and 2002. The Bowman perfusion monitor (Hemedex, Waltham, MA, USA),<sup>21,29)</sup> was used to measure the brain cortex temperature at about 1–2 cm below the surface in 83 cases, between 2003 and 2009. Both devices were designed to check cerebral blood flow (CBF) by monitoring the thermal diffusion. This monitoring system provides CBF calculations by employing a thermal-diffusion methodology, where CBF is expressed in mL/100 g/min.

The SABER2000 sensor is a thin, 3-mm leaf that looks like the kind of subdural strip electrode used for epilepsy monitoring. The sensor is placed on the cortex either through a burr hole or at the time of craniotomy. Two gold disks rest on the cortex. One is heated and the other is neutral. The heated disk is designed to stop heating if the temperature exceeds 44°C so as not to overheat the small area of cortex. The temperature difference between the heated disk and the neutral disk is carefully monitored, and it is converted to CBF mL/100 g/min by the monitor.<sup>4)</sup>

The Hemedex (Bowman perfusion monitor) catheter is flexible, biocompatible, and radio-opaque, of about 1-mm (3 French/19 gauge) diameter, which is inserted into the brain parenchyma for measuring regional cerebral blood flow. The data obtained are displayed on a bedside monitoring device on a real-time basis.<sup>25)</sup>

### Operative procedures

The operation was performed after endotracheal induction of anesthesia in the patient. The patient was placed supine, and the ventricular puncture was done at Kocher's point on the side opposite the lesion. The EVD tube (EVD catheter; Yushin Medical, Seoul, Korea) was connected to the continuous cerebral perfusion pressure (CPP) monitor (Spiegelberg, Hamburg, Germany) via a transducer (Druckmesset; Smiths Industries, Kirchseeon, Germany). Sometimes the EVD catheter is connected to a Philips patient-monitoring system, which can measure the mean ventricular pressure continuously, with proven accuracy. And in some patient who did not need EVD catheter insertion, which thus could not be used to monitor the ventricular intracranial pressure (ICP), an epidural-type air-pouch ICP monitoring sensor (Spiegelberg, Hamburg, Germany) at the temporal side bone edge was used to measure the epidural ICP.<sup>40)</sup>

### Data collection

Temperatures (cerebral cortex and axilla), ICP (ventricular or epidural), mean blood pressure, and neurological status (Glasgow Coma Scale; GCS) were measured simultaneously every 2 hours for several (1–7) days after the operation.

Body temperature was divided into three groups, according to the axillary temperature: hypothermia group (less than 36.4°C), normothermia group (between 36.5°C and 37.5°C), and hyperthermia group (more than 37.6°C).

### Statistical analysis

All data are presented as the mean±standard deviation. We did the statistical analysis using SPSS 12.0v. (Statistical Package for Social Sciences; IBM, Chicago, IL, USA). Data were extracted to modified Excel files, and then were transferred to SPSS for further processing. We used a paired t-test to compare brain and axillary temperatures, and a Student's t-test for comparisons between groups. Statistical significance was set at  $p=0.05$ .

## RESULTS

### Temperature differences between neurosurgical disease

Comparing the factors according to the etiologic diseases, initial GCS was better in the TBI group than in the aneurysm group (TBI,  $9.0\pm 3.8$  vs. aneurysm,  $6.9\pm 2.5$ ;  $p=0.001$ ). But initial GCS and neurological outcomes between other groups were not statistically significant (TABLE 1).

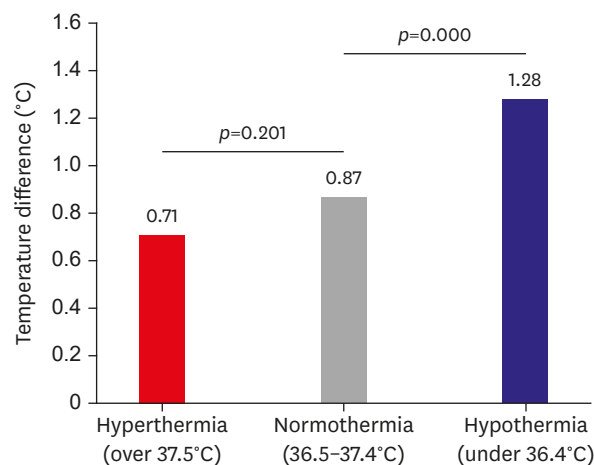
Brain temperature and axillary temperature in the aneurysm group were higher than in other groups ( $p=0.05$ ), and in the TBI group both temperatures were lower than in the aneurysm group but higher than in the other ICH and MI groups ( $p=0.05$ ). In the ICH and MI groups, the brain temperature and axillary temperature were statistically not different ( $p>0.05$ ).

### Temperature difference between the brain cortex and axilla

Among the 4,125 paired data from 135 patients, the axillary temperature was  $36.9\pm 1.1^\circ\text{C}$ , the brain temperature was  $37.8\pm 0.96^\circ\text{C}$ , and the temperature difference between brain and axilla was  $0.93\pm 0.5^\circ\text{C}$  ( $p=0.000$ ). In the hypothermia group, the axillary temperature was  $35.3\pm 0.96^\circ\text{C}$ , the brain temperature was  $36.5\pm 0.91^\circ\text{C}$ , and the temperature difference between brain and axilla was  $1.28\pm 0.56^\circ\text{C}$  ( $p=0.000$ ). In the normothermia group, the axillary temperature was  $37.0\pm 0.31^\circ\text{C}$ , the brain temperature was  $37.9\pm 0.49^\circ\text{C}$ , and the temperature difference between brain and axilla was  $0.87\pm 0.43^\circ\text{C}$  ( $p=0.000$ ). In the hyperthermia group, the axillary temperature was  $38.0\pm 0.47^\circ\text{C}$ , the brain temperature was  $38.7\pm 0.59^\circ\text{C}$ , and the temperature difference between the brain and axilla was  $0.71\pm 0.41^\circ\text{C}$  ( $p=0.000$ ). The amount of temperature difference in the hyperthermia, normothermia, and hypothermia conditions was statistically significant.

### Amount of temperature difference between groups

The temperature difference between the groups was statistically significant between the hypothermia and normothermia groups (unpaired t-test,  $p=0.000$ ). But it was statistically non-significant between the normothermia and hyperthermia groups (unpaired t-test,  $p=0.201$ ) (FIGURE 1).



**FIGURE 1.** Temperature difference according to the axillary temperature. And statistical significance of amount of temperature difference in hyperthermia, normothermia and hypothermia condition.

### Correlations between temperatures and other factors

Increased axillary temperature decreased the amount of temperature difference ( $p=0.000$ ). The brain temperature decreased the ICP decreased (epidural ICP,  $p=0.006$ ; ventricular ICP,  $p=0.06$ ). Mean blood pressure was not correlated with CBF values ( $p=0.26$ ).

## DISCUSSION

The therapeutic effect of hypothermia is thought to result from the reduction in cerebral metabolic requirement, leading to both favorable oxygen/metabolic delivery-demand ratios and a reduction of cerebral blood volume, resulting in decreased ICP.<sup>1,9,19,26</sup> In various animal models, researchers have shown that mild hypothermia is protective during and immediately after an ischemic insult, whereas severe hyperthermia (42–43°C) causes brain-tissue damages.<sup>6,13,15,23,28</sup> But in randomized controlled human trials, results are variable and limited for complex reasons. Therefore, the application of therapeutic hypothermia outside of strictly supervised clinical trials has to be considered absolutely carefully.<sup>6,9,10,25,26</sup> Even, so the current weight of opinion for brain injured patients is that a rise in body temperature (and by assumption, a rise in neuronal temperature) is damaging and should be treated.<sup>17</sup> There is evidence that fever (i.e., body core temperature >38.3°C) is associated with increased mortality and morbidity (i.e., long-term outcome, Glasgow Outcome Scale and modified Rankin Scale, hospital and Intensive-care unit length of stay) in patients with acute severe neuronal injury.<sup>6,10,11,23,28</sup>

Methods of decreasing body temperature include cooling by conduction, by using a water blanket, cooled intravenous fluids, cooling ambient temperature, and the use of ice packs. More recently, a forced-air cooling device has been introduced into clinical practice.<sup>35</sup> Cooling by convection has been proven effective in decreasing central nervous system and core temperature within the range of cerebral protection in animals and humans without impairing tissue oxygen delivery.<sup>35</sup> Most cooling devices are equipped to automatically adjust the body temperature.

A well-designed clinical trial shows that short-term hypothermia, 33°C for 48–72 hours, does not appear to increase the risk for coagulopathy and infections, although hypothermic

patients have exhibited significant increments in inflammatory markers, such as C-reactive protein and white blood-cell counts after rewarming.<sup>9,20,26,38)</sup> But prolonged hypothermia also carries risks of extracranial complication, such as infection, coagulopathy, or arrhythmia, between patients who were treated with hypothermia and those treated with normothermia.<sup>11,38)</sup> Therefore, in an intensive-care unit, to accomplish successful targeted temperature therapy, continuous recording of body temperature is absolutely pivotal in all patients with acute severe neurological disease, and a fever should be regarded as an independent predictor of morbidity and mortality.<sup>6,9,10)</sup> However, the correlation between body temperature and brain temperature is not clear, and it is not always possible to measure brain temperature directly. The search for a surrogate non-invasive body site, which best reflects brain temperature remains of interest to clinicians.

Assessment of body temperature is important for decisions about nursing care, medical diagnosis, treatment, and the need for laboratory tests.<sup>6,9,11,30,32)</sup> In clinical practice, rectal, oral, axillary, forehead, and ear measurements are used to measure body temperature. Each site of body-temperature measurement has pros and cons, just like other physical measuring factors.<sup>2,11,13,16,23,30-33,35,36)</sup>

The rectal temperature is higher than at other sites because of the low blood flow and high isolation of the area, giving a low heat loss, located far from the central nervous system as well as from the pulmonary artery. So, it significantly lags behind changes at other core sites, especially during rapid temperature changes, such as warming and cooling during surgery, exercise, and fever. Rectal temperature measurement is unhygienic and can pose a risk of injury to the intestinal mucosa, especially in infants.<sup>6,16,30-33,36)</sup>

Tympanic membrane temperature, 1.5 cm away from the tympanic membrane, is close to brain tissue, but the reading can depend on the heat from both the tympanic membrane and the ear canal size. In brain-operation patients, it is difficult to place the probe correctly through the acoustic canal.<sup>30-33,35,36)</sup>

At the axillary site, accuracy is affected by ambient temperature, local blood flow, underarm sweat or closure of the axillary cavity, and duration of the reading. There is a temperature difference of 1.4°C between the right and left axilla, a large difference in repeated measurements, but it is familiar to most nursing-staff members and is convenient for repeat checking and hygiene.<sup>30-33,35,36)</sup>

Several different brain-body temperature measurement comparisons were reported. In an early paper that measured ventricular temperature with a type T thermocouple (copper/constantan), the brain temperature was usually greater than the bladder and rectal temperatures.<sup>6,14)</sup> The average difference between brain and bladder temperature ranged from 0.32°C to 1.9°C, and brain and rectal temperature difference ranged from 0.1°C to 2.0°C. They reported that the differences (brain and bladder, brain and rectum) were greater at temperatures outside of the normothermic temperature range (under 36°C and over 38°C).<sup>1,6,13)</sup> Childs and colleagues compared the difference between brain temperature with rectal temperature in 19 patients.<sup>5)</sup> They report a mean difference of -0.04°C between the two sites. There was no evidence of a systematic difference between brain and rectal temperature. By contrast, Rumana and colleagues,<sup>28)</sup> measuring temperature at the same sites, report a temperature mean difference (brain parenchyma-rectum) of 1.1°C. This showed that mean brain temperature was more than 1°C higher than mean rectal temperature. Tokutomi and

colleagues<sup>37)</sup> studied 31 patients who were cooled to 33°C then slowly re-warmed after 48 to 72 hours of hypothermia. The reported a mean difference of 0.3°C between brain and jugular vein temperature. Kirk and colleagues<sup>18)</sup> compared brain parenchyma temperature and tympanic membrane temperature in 20 patients with severe traumatic brain injury. A mean difference 0.9°C was reported between the 2 measurement sites. On most reports concerned about body temperatures, the brain is 'hotter' than the rest of the body.<sup>6,13,28)</sup> The polarity and magnitude of temperature difference between brain and other body temperatures, however, remains unclear after severe TBI.<sup>20)</sup>

Most of the studies have compared the core body temperature (e.g. rectum, esophagus, jugular vein, tympanic membrane) for a surrogate measurement of brain temperature. Few studies compare peripheral temperature to brain temperature.

In our study, axillary temperature was not a core temperature, but rather a kind of peripheral temperature. However, in most clinical situation axillary temperature is the most adopted body-temperature measuring method, easy to repeat and familiar to most medical personals, does not need a specific device, and does not cause infections. So, we regarded axillary as a standard measured body temperature and tried to find temperature difference between the brain temperature and axillary temperature. We analyzed the data on grades, defined normothermia (axillary temperature 36.5–37.4°C), hyperthermia (axillary temperature over 37.5°C) and hypothermia (axillary temperature under 36.4°C) according to the axillary temperature and examined whether it was possible to predict the change in the patient's brain temperature by simply measuring the axillary temperature, which is easy to measure without invasive measurement.

Among the 4,125 paired data from 135 patients, the axillary temperature was 36.9±1.1°C, the brain temperature was 37.8±0.96°C, and the temperature difference between brain and axilla was 0.93±0.5°C ( $p=0.000$ ). This result was similar to the previous study, which measured core body temperature and compared with brain temperature. The temperature difference between the groups was statistically significant between the hypothermia and normothermia groups (unpaired *t*-test,  $p=0.000$ ). But it was statistically non-significant between the normothermia and hyperthermia groups. This result showed that hypothermia condition (axillary temperature under 36.4°C) is associated with large brain-axilla temperature gradients. It is thought that the significant temperature difference between the groups (hypothermia vs normothermia) was caused by the induced hypothermia condition, not the natural hypothermia condition. Since, measuring axillary temperature is affected by the ambient temperature and the temperature of the atmosphere, induced hypothermia using the cold-water blanket is likely to lower axillary temperature than the core body temperature.

In patients with subarachnoid hemorrhage and traumatic brain injury, brain temperature and axillary temperature were significantly higher than those of cerebral infarction and cerebral hemorrhage patients, but the cause is unclear. In our opinion, this reason is that craniectomy is high rate in cerebral infarction and intracerebral hemorrhage patients than in subarachnoid hemorrhage and traumatic brain injury patients. In the case of craniectomy, heat loss in the brain is well and the brain temperature drops easily. In this study, no comparison was made between craniectomy and craniotomy, but we think it will be helpful to understand the mechanism of brain temperature regulation if we study the changes in brain temperature following craniectomy and craniotomy in the future.

In addition, this study showed statistically significant decrease in intracranial pressure as the axillary temperature decreased. This is in line with studies showing that high body temperatures have a poor prognosis.

The results of recent systematic review show that core body temperature (measured at various sites of the body) is not a reliable proxy for brain temperature in patients with severe Traumatic brain injury.<sup>6)</sup> Direct brain measurement is still the best way to monitor brain temperature in brain injury patients. Unfortunately, not all institutes can prepare a direct brain-temperature monitoring device and the accuracy of such devices can be troublesome.<sup>4,25)</sup> Measuring the axillary body temperature is the most non-invasive primary method. Knowing the relationship between axillary temperature and brain temperature will be of great help in treating patients with brain injury.

## CONCLUSION

Our results demonstrate that the temperature difference between brain and axilla was  $0.93 \pm 0.5^\circ\text{C}$  ( $p=0.000$ ). The temperature difference between the brain and axilla was increased in hypothermia more than in the normal temperature condition.

The correlation between brain temperature and axillary temperature shown in this study will help manage brain temperature in patient without available core-temperature monitoring devices.

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