Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

A Non Invasive Wearable Sensor for the Measurement of Brain Temperature

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Abstract— **As the thermoregulation centres are deep in the brain, the cerebral temperature is one of the most important markers of fever, circadian rythms physical and mental activities.**

However due to a lack of accessibility, the brain temperature is not easily measured.

The axillary, buccal, tympanic and rectal temperatures do not reflect exactly the cerebral temperature. Nevertheless the rectal temperature is used as probably the most reliable indicator of the core body temperature.

The brain temperature can be measured using NMR spectroscopy, microwave radiometry, near infrared spectroscopy, ultra-sound thermometry…

However none of those methods are amenable to long term ambulatory use outside of the laboratory or of the hospital during normal daily activities, sport, etc…

The brain core temperature "BCT" sensor, developed by the Biomedical Microsensors dpt of LPM at INSA-Lyon is a flexible active sensor using "Zero-heat-flow" principle.

The sensor has been used for experimental measurement: brain temperature during mental activity, and in hospital for the study of circadian rythms. The results are in agreement with the measurement by the rectal probe.

There are 2 versions of this sensor: a non ambulatory for the use in hospitals, and an ambulatory version using teletransmission. We are working for improving the autonomy of the ambulatory version up to several days.

This wearable biomedical sensor (WBS) can be used for circadian assessment for chronobiology studies and in medical therapies.

I. Introduction

THE brain temperature is one of the most important markers of fever, circadian rhythms, physical and mental activities.

The thermoregulation centres are deep in the brain and of the highest interest. But, because of a lack of accessibility the brain temperature is not easily measured [1].

Fig. 1: Brain Core Temperature sensor on the temple of a subject

II. Principle of Measurement

The brain temperature can be measured using NMR spectroscopy, microwave radiometry [2], near infrared spectroscopy, ultra-sound thermometry [3]…

However none of those methods are amenable to long term ambulatory use outside of the laboratory or of the hospital during normal daily activities, sport, etc…

The BCT sensor 4 x 9 cm is placed on temple and fixed with an elastic textile headband, fig. 1.

The principle of zero-head-flow is used for the measurement. This principle was mainly developed by Fox and coll. [4], [5] and used almost for the measurement of core temperature [6] – [11].

In the zero-head-flow method, an isothermal zone is induced under the sensor. So the deep temperature (>10 mm) is carried to the surface of the head, where it can be measured easily, fig. 2.

The sensor is built using flexible circuits and materials for a good adaptation to the shape of the head, a good thermal contact, and for the comfort of the subject.

Manuscript received April 21, 2006.

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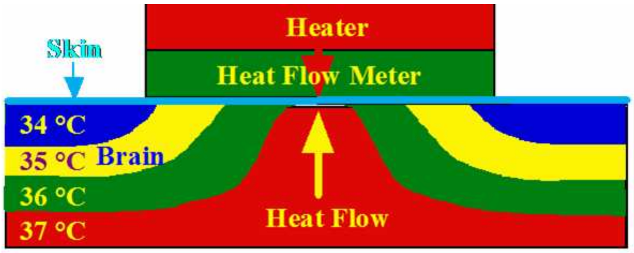

Fig. 2: Principle of the zero-head-flow method, deep temperature is bring at the surface skin

This sensor has 2 time constants:

-- Long time constant (>5 minutes) corresponding to the creation of the isothermal zone under the sensor (the "establishing time constant");

-- Short time constant ("functional time constant") corresponding to the small changes of the thermal field.

So when the thermal field is established, the sensor can record phenomenon which duration is about some seconds.

III. Calibration

The precision is about ±1/10°C, this sensor was calibrated and tested using several physical models and phantoms for the simulation of the thermal parameters of the layers under the sensor, skin, bone, brain …, fig. 3

The threshold of sensitivity is so small that 1/1000°C changes can be detected.

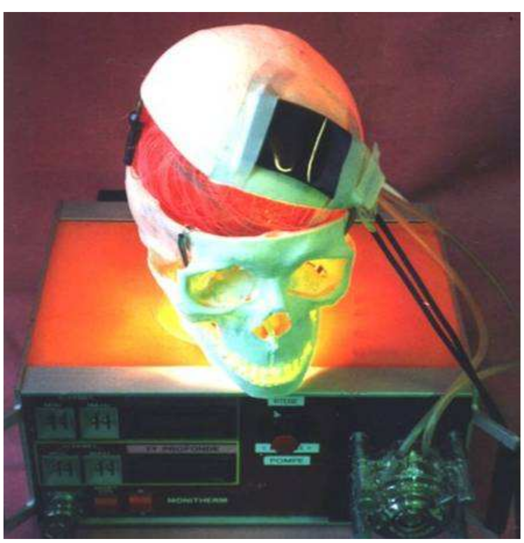

Fig. 3: Phantom of brain temperature with the simulation of perfusion used for the test of BCT sensor

IV. Measurement of Brain Temperature During Mental Calculation

The subject (volunteer male 50 years) is placed in a silent room at 22°c ambiant temperature.

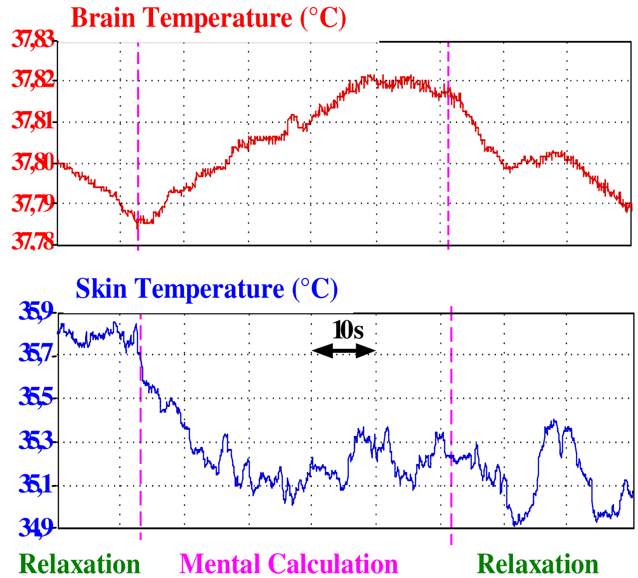

Fig. 4: Effect of Mental Calculation on Brain and Skin Temperatures, an increase of 0.03 °C is induced

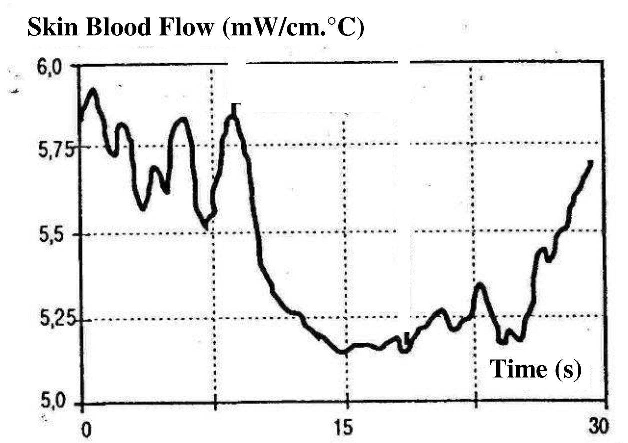

Fig. 5: Mental Calculation induces a vasoconstriction on the skin blood flow of the hand (Measurements with Hematron sensor [12])

Mental calculation: 3.141 x 7

Results are reported in figure 4:

-- The task induces an increase of the brain temperature: total increase 0.03°C, slope 3/100 °C/min.

-- At the end of the calculation the subject is informed that the result is correct then, the brain temperature decreases.

The skin temperature is measured on the opposite temple. During the increase of brain temperature the skin temperature decreases paradoxaly. In the same time the skin temperature of the distal territories decreases. Also the mental calculation induces a skin vasoconstriction generally, fig. 5.

Consequently the heat losses decreases, and the temperature of the afferent blood which perfuses the brain increases.

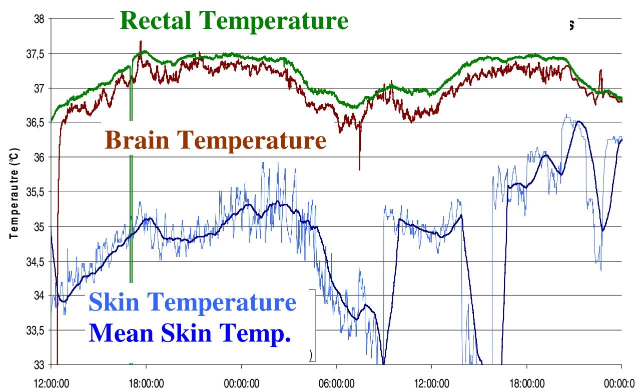

Fig. 6: Rectal, Brain and Skin temperatures during 48 hours

V. MEASUREMENT OF BRAIN TEMPERATURE DURING CIRCADIAN RHYTHMS

This measurement was performed at the center for study and treatment of circadian rhythms at the Douglas hospital in Montreal (Canada) [13]:

-- The subject is placed on a bed in a room in constant conditions. The results, using BCT sensors on 2 subjects show a very good agreement with the central temperature indicated by the rectal temperature, fig. 6.

-- It is obvious that the changes of the pattern and the mean levels of the skin temperature are different of those of the brain temperature showing that the active measurement of the sensors is not disturbed by the skin temperature.

-- The ambulatory version of BCT, the WBS (Wearable Biomedical Sensor) is designed with an "user friendly" strategy. Its shape and materials allow measurements without pain, and its size authorizes a discret use.

The electronics circuits, memories, informatics,

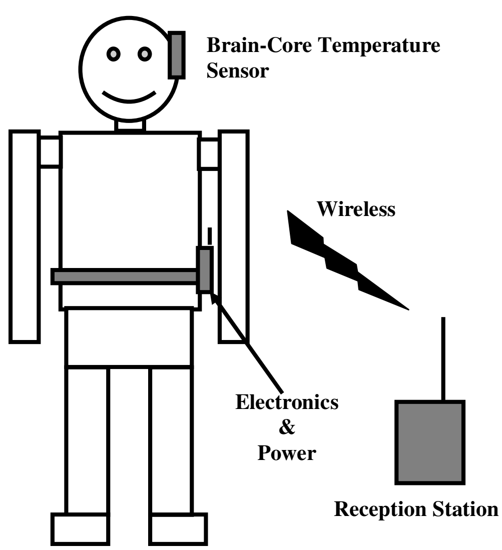

Fig. 7: Ambulatory measurement of brain temperature (version 2)

teletransmission and batteries are placed in a small ergonomic case fixed by a belt, fig. 7.

The autonomy and the distance of transmission depend on the size of batteries.

V. CONCLUSION

The first version of the BCT sensor for hospital shows the faisablility of the method and the second version is presently optimized for several medical purposes for:

- Chronotherapy: to deliver treatment at the right time, to maximize therapeutics effects, and to minimize toxics effects …
- Study of circadian rhythms for a continuous monitoring

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