Thermoelectric Brain Cooler Helmet

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Abstract—Hypothermia is known to provide protective effect on brain following a trauma. A helmet with flexible thermoelectric modules inside was designed recently to generate hypothermia for brain. In this study, cooling performance and temperature control performance of this helmet were assessed and compared with traditional methods. Temperature measurements were taken in an experimental set-up under loaded and unloaded conditions. The same type of flexible thermoelectric modules was used for temperature measurement. The results showed that the helmet had important advantages over the traditional methods. The cooling performance of the helmet could be controlled. Cooling performance as good as 10°C/minute could be obtained. The temperature was lowered to the required level within five minutes after starting of the temperature control, the highly critical duration for saving the brain. The temperature can be kept under control and can also be raised when necessary.

Keywords—Hypothermia, Brain Cooling, Thermoelectric, Thermoelectric Cooling.

I. INTRODUCTION

Death and disability caused by traffic accidents is a major problem all over the world. To protect brain during a stroke or a life saving procedure like one after a traffic accident is critical. It is also important to protect the brain during open heart surgery as the brain is very likely to have the ischemic damage. When the heart beat stops, the blood cannot circulate in the body and oxygen cannot be supplied to tissues and organs. Functioning of some organs like the kidneys are not easily affected by cessation of oxygen supply but the brain is extremely sensitive to oxygen deprivation. Some brain cells start to die only five minutes after oxygen supply is cut. If not fixed on time, this may end up with complete dying of brain or serious brain damage. Even if the heart re-starts to function, the cells may continue to die. This may happen as the blood that starts to reflow suddenly are charged with inflammatory cells that are generated during lack of oxygen supply. Every centigrade degree under the normal body temperature reduces the metabolism by 5-7 %. Hypothermia also avoids starting of some biochemical reactions. Therefore, stopping of death of the cells by cooling the head as soon as possible is a must.

Cranial-Cerebral Hypothermia is commonly used for protection and the therapy of the brain. This is done traditionally by placing ice on the head or inserting the head inside cold water. Hypothermia reduces oxygen consumption of tissues and hence protects organism and especially the brain against deathly effect of hypoxin. When temperature in the brain is reduced to 30-32 °C, the brain can survive without blood, oxygen, and glucose. The brain can survive for 45-60 minutes even when the heart stops. 30-32 °C is 5-7 °C less than the body temperature. When the brain is kept at this temperature, the brain can be kept in a better condition even when the heart stops. The purpose here is to limit neurologic problems during trauma or stroke. Otherwise, the person may be exposed to numerous neurologic damages such as memory, speech, and motion problems. Because of these facts, hypothermia has been started to be used for treatment of brain injury [1-4].

Reducing body and brain temperature in case of stroke is not a new treatment method. Protective effect of cooling on brain has been known since 1950’s. However, the method could not be used because of problems with the cooling methods and insufficiency in cell research. It was not possible to control temperature graph. Temperature change could cause some risks to the person’s organs. The developments in electronics and cell science made usage of the method possible again.

The traditional methods to generate hypothermia by cooling the head externally such as placing the head inside cold water, or placing ice on head are quite primitive, unpractical and inefficient. These days brain hypothermia is realized by placing the whole body inside cold water. It is not possible to reduce brain temperature to desired level because this requires to keep the body inside cold water for a long time. This causes extra loading to the heart and may cause complications. Clearly, it is much more preferable to cool only the brain by cerebral hypothermia method. Placing an ice on the brain does not provide the desired cooling speed and level. Research to develop local cerebral hypothermia techniques are being done these days as this technique is very practical and expected to cause no complications [6-10].

Recent research in this field is focused on developing new hypothermia techniques and clinical studies. In this study, performance of a recently designed thermoelectric helmet was studied. The flexible thermoelectric modules were placed inside the helmet to generate hypothermia. A precise measurement system was designed, set up and used to get the measurements. A head can be cooled to lower the temperature to the desired level by energizing the flexible thermoelectric modules. When needed, the helmet is used in heating mode by changing direction of the current to warm up the head. [6-10]

The recent publications on therapy with this method are
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mostly focused on general hypothermia. It has also been stated that this method can be risky and dangerous. It has been accepted that local cerebral hypothermia is a safer technique. The general hypothermia cannot cool the brain to the desired level and the process is uncontrollable.

Thermoelectric cooling is capable of reducing the temperature to a very low level quickly, keeping the temperature at that level, and re-warming the brain when needed. These advantages make this new technique a suitable candidate for local cerebral hypothermia. The helmet in this study was built using 96 thermoelectric micromodules. These modules were connected in series electrically and in parallel thermally [11-13].

II. EXPERIMENTAL WORK

In this study, Ahiska’s method was used to take temperature measurements to assess the performance of the helmet. The method was developed by a study of some experimental data. The method is based on measuring thermally generated electromotive force (emf) on the flexible thermoelectric modules [14-18]. A special measurement set, composed of 4 modules, was developed as shown in Fig. 1. These modules were the same type of modules used in helmet development. The modules were connected in series electrically, and in parallel thermally. Cold sides of the modules were placed face to face. A heating unit was placed between them to load the helmet. Electrically non-conducting sheets were placed between the cold side of the modules and the heaters to provide electrical insulation. Thin copper sheets were used to distribute the temperature uniformly. CIE 307 model digital thermometer with double thermocouple was used to measure the temperatures on both cold and hot surfaces. The electric current fed to the thermoelectric modules was measured with a Fluke 380 digital multimeter. Another 380 multimeter was used to measure the voltage on thermoelectric modules and the generated emf. The modules were fed by a 0-50 A DC power supply. The heater was fed by a 0 – 50 volt variable voltage source. The heating side of the modules was cooled by water flowing through series parallel connected thin pipes. The water entered the upper pipes in parallel and leaves the lower pipes in parallel. To study the dynamic characteristics of the modules, they were run first in unloaded condition and then in loaded condition by turning on the heater. Experimental system is shown in Fig. 2.

Variable Transformer 1: This transformer was used to adjust electric current to thermoelectric modules. As the modules draw a high current, a clamp ammeter was used to measure the current. The voltage was measured with a voltmeter.

Variable Transformer 2: Variable transformer -2 provides power for heating, which is needed to study the system under loaded condition. The total resistance was measured with an ohmmeter as 163 ohms. The heating load was determined according to this value. An ampermeter and voltmeter were added to the circuit to make the measurements.

![Fig. 1. Cross section of the Module a) Structure of a single cell b) Experimental set up composed of four cells 1) P and N type of semiconductors 2- Cold surfaces of the modules, which were made up by copper sheets, 3 - hot surfaces of modules, which made up by copper pipes, 4 – Copper wires for voltage inputs, 5- Aluminum sheet over which the heating wire was wounded. 6 – Outputs of the heater used to obtain heat load, 7-Thin copper sheet which distributes heat uniformly, Tc and TH K type thermocouples used to measure cold and hot surface temperatures, A and Ampermeter and voltmeter](image)

Thermometer: Temperature of the cold surface was measured with a CIE 307 digital thermometer and K type thermocouple. A multi-pole switch was used to measure temperature at different cold surfaces.

DC Power Supply. The modules were fed by a 0 – 50 A power source. A variable transformer was used to adjust the input voltage and current.

Taking the Measurements: The measurements were taken at certain temperatures under loaded and unloaded conditions. Temperature of the water circulation was set to 15 °C, 25 °C, 35 °C, and measurements were taken with at all these settings. When the water temperature was increased to each of these values, water circulation was started by a pump and the temperature at the hot side was fixed. As TH was fixed, only Tc1 and Tc2 temperatures were measured. These measurements were made with a single thermometer and multi pole switch. The measurements were made at each temperature level with 10, 20, 30 and 40 Amperes adjusted by the variable source. The cold surface temperatures were measured and recorded every 5 minutes. The system was de-energized and the thermal emf induced at the terminals of modules was
measured. The ambient temperature was also measured with an external thermometer. The measurements were taken until the cold surface temperature started to remain constant.

After the temperature was fixed, the heater was turned on and hence the heat load was applied to the system. The measurements were taken until the temperature started to remain fixed. The heat load was increased gradually; the temperatures and thermal emf were measured. The loading continued until the thermal emf became zero. These measurements were done at all temperatures and at these current values.

III. RESULTS AND CONCLUSIONS

The measurement results obtained are sketched as graphs and plotted in Figures 3 - 5. The graphs show clearly that the thermoelectric modules have very high cooling capacity in the first 5 minutes. The ambient temperature is an important parameter that affects cooling performance of the modules. For 10 A current, the cooling rate in the first 5 minutes was calculated as 4.34 °C/minute at 15 °C, 3.46 °C/minute at 25 °C, 2.08 °C/minute at 35 °C. Increasing the current through the modules improved the cooling rate, which rose up to 10.74 °C/minute for 40 A. current. Measurements made on flexible thermoelectric modules by this experiment showed that the cooling performance is much better than the traditional methods. It is possible to reach the cooling rate of 10 °C/minute. For the loaded case, cooling rate depends on the heat load but is still better than those obtained with traditional methods.

As it was stated earlier, the first 5-minute duration is critical for protection of the brain. Temperature of the brain should be brought to the desired level in a very short time, and kept at that level with a control technique. This study showed this can be achieved with the usage of thermoelectric modules. The cooling rate can be adjusted. The modules can operate at both cooling mode and heating mode. Therefore, the system can be used for heating too when needed. Thus, it is possible to keep the brain temperature at an optimal value or under control with the usage of the cooling and heating capabilities of the modules. This is not possible with the traditional hypothermia methods.

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