11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

DETERMINING OF THE NEONATAL THERMAL MODEL PARAMETERS USING INVERSE THERMAL ANALYSIS

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Key words: *Compartment neonatal thermal model, Pennes bioheat equation, Blood perfusion, Inverse thermal analysis.*

The perinatal hypoxic-ischemic encephalopathy is a fairly frequent problem which the neonatologists have to cope with. Until recently there was not any method to remedy this disease. At present the therapeutic mild hypothermia of the infant's brain is more and more frequently used [3, 5]. Such hypothermal therapy generally stops apoptosis of neurons. However, to counteract the side effects of violent modifications of the temperature during the hypothermal therapy, the deep body temperature should be kept at the constant and secure level.

In order to perform the treatment in a proper way a distribution of the temperature inside the neonatal body (especially inside the brain) during the whole therapy has to be known. Since it was already proved [5] that temperature level of 34-34.5°C is secure during brain cooling, at the beginning of the therapy the deep body temperature is decreased to that level. In the case of neonate suffering from the hypoxia his temperature is usually decreasing spontaneously 0.5 K per hour, thus the deep body temperature at the certain moment is appropriate to start therapy. If not, his temperature has to be reduced utilising cooling helmet or other device. Next, during the therapy, the deep body temperature is maintained at the constant level. Since the most vulnerable organ is the brain, the temperature of the scalp is kept by cooling helmet at the lowered level equal to about 24°C. Simultaneously, in order to maintain the deep body temperature at the secure level, the skin of the rest of the neonatal body has to be heated by the radiant warmer. The therapy is carried out for 72 hours and then the deep body temperature is gradually increased to the normal level (about 37°C). It is very important to guarantee that temperature augments not faster than 0.5 K per hour, what entails many enormous difficulties.

In this work the attempt is made to develop a numerical thermal model within the neonatal body cable of controlling the brain cooling process. The main aim of the analysis was to find the proper parameters of the process. The simplified geometric model of newborn's body, consisting of the number of compartments [1, 3], was built using Design Modeler. As the shape of the head an ellipsoid was used. The forms of neck and trunk were simplified to elliptic cylinders. The limbs were modeled as cylinders. Inside the head the scalp, scull and brain were separated. The brain was surrounded by the brain cerebrospinal fluid. The remaining part of the head was modeled as a space occupied by the air. The neck consisted of the spine, muscle and skin. The spine was lengthened to the torso. Interior of the trunk was divided into lungs and viscera, which were surrounded by bone and skin. Limbs were split into three tissues: bone, muscle and skin. The neighbouring compartments exchange heat by conduction through tissues but also interact with each other through flowing blood. To simulate the natural heat transfer processes through the human tissues the Pennes bioheat equation [4] was implemented into Ansys Fluent [2], using UDF (User Defined Function) capability.

To retrieve the parameter values of the neonatal thermal model the inverse thermal analysis is carried out. The objective function Δ consists of the sum of squares of deviations between temperature $\boldsymbol{T}$ predicted by the mathematical model and temperature $\boldsymbol{T}^*$ measured at the selected places on the infant's skin and that :

$$\Delta = \left(\boldsymbol{T}^* - \boldsymbol{T}\right)^T \boldsymbol{\sigma}_T^{-2} \left(\boldsymbol{T}^* - \boldsymbol{T}\right) \tag{1}$$

where $\boldsymbol{\sigma}_T^2$ is the temperature measurements covariance matrix. Minimization of the objective function (1) is carried out making use the sensitivity coefficients determined numerically. The final values of parameters controlling the neonatal brain cooling process are extremely valuable from technical and scientific point of view.

ACKNOWLEDGEMENTS

This paper was elaborated within the frame of the grant No N519 657840 entitled The analysis of the brain cooling process supported by the National Centre for Research.

REFERENCES

[1] Fiala, D., *Dynamic Simulation of Human Heat Transfer and Thermal Comfort*, Institute of Energy and Sustainable Development, De Montfort Univerity Leicester (1998)

[2] *Ansys Fluent 12.1 in Workbench User's Guide*, ANSYS, Inc. (2009)

[3] Chenguang, D., Liang, Z., Huan, W., Cooling and rewarming for brain ischemia or injury: Theoretical analysis, *Annals of Biomedical Engineering*, **31** , 346-353 (2003)

[4] Pennes, H.H., Analysis of Tissue and Arterial Blood Temperatures in the Resting Human Forearm, *J Appl Physiol* 1:93-122 (1948)

[5] Walas,W., *Hypothermia of head - big chance for neonates with perinatal hypoxic-ischemic encephalopathy*, (in Polish), WCM.opole.pl, Vol. 23, 5-10 (2010)