

## WATER BOLUS TEMPERATURE SELECTION IN SUPERFICIAL HYPERTHERMIA

**M.L. van der Gaag, M. de Bruijne, T. Samaras, J. van der Zee, G.C. van Rhoon**  
Erasmus MC-Daniel den Hoed Cancer Center, Rotterdam, The Netherlands  
(Email: g.c.vanrhoon@erasmusmc.nl)

### Introduction

In superficial hyperthermia, the two main parameters used for optimising the temperature distribution during clinical application are the electromagnetic power and the water bolus temperature. The dependence of the specific absorption rate (SAR) distribution on applicator type, water bolus shape and size and tissue configuration has been the subject of many experimental and theoretical studies. The exact thermal effect of the water bolus on the other hand is less clear and has not been explored extensively. To optimise the temperature distribution during hyperthermia treatments and to obtain a more uniform approach among hyperthermia clinicians, guidelines for water bolus temperatures are indicated.

### Objective

The goal of the research was to develop a guideline for the optimal water bolus temperature based on 3-D electromagnetic and thermal modelling.

### Material and Methods

A 3-D model was set up to simulate an abstraction of the treatment using our homebuilt LCA applicators and water boluses. The model was electromagnetically simulated using the finite difference time domain (FDTD) method and thermally using the Bio-Heat Transfer Equation (BHTE) by Pennes both part of the simulation package SEMCAD. In order to simulate the heat balance as realistically as possible, convection coefficients for the water bolus to skin surface were measured for each of the four available water boluses and ranged from 54 to 169 W/(m<sup>2</sup>K). The results of the model were evaluated through comparison of predicted temperature with those clinically measured for three patient treatments.

### Results

The heat sink terms and effective conductivities in the three test cases were set in a way that the mean error between the measured temperatures and the predicted temperatures was 0.0 °C. The model was found to predict the temperature distribution well on a global view, standard deviations between 0.7 °C and 1.5 °C were found for the three treatments. For some temperature probes a deviations of 1.5 – 2.0 °C between measured and predicted temperature were found. These large deviations can be explained by local variations of cooling by blood vessels, tissue inhomogeneity, a varying convection coefficient of the water bolus and of course the abstraction of the model.

### Conclusion

From the convection coefficient measurements performed in this research it can be concluded that it is absolutely necessary to measure the convection coefficients for each specific water bolus set-up. The convection coefficient depends on factors like the water bolus geometry, the capacity of the circulation pump and the use of a gauze. The model presented in this study gives a good prediction of the global temperature distributions achieved in tissue during superficial hyperthermia treatments. The relatively high standard deviations in the three cases are due to local temperature deviations, most likely caused by local cooling by blood vessels and inhomogeneity of the patient's tissue. Based on the model, a water bolus temperature gui-

deline for the LCA system was developed. The guideline specifies an optimal water bolus temperature for the four different set-ups and seven target depths as regular applied in the Rotterdam Erasmus MC.

**Acknowledgements**

Supported by the Dutch Cancer Society, grant DDHK 2001-2362.