

## THEORETICAL COMPARISON OF INTRALUMINAL HEATING TECHNIQUES

H.P. Kok, P.M.A. van Haaren, J.B. van de Kamer, J. Crezee

Dept. Radiation Oncology, Academic Medical Center, University of Amsterdam,  
The Netherlands

### Introduction

Hyperthermia has been proven to be a strong chemo and radiosensitiser. The oesophageal lumen is easy accessible and therefore intraluminal devices seem a natural choice for hyperthermia treatment of oesophageal tumours. A disadvantage of intraluminal heating devices is their mediocre (thermal) penetration depth, while for oesophageal tumours external heating alone is suboptimal in achieved tumour temperatures and in power steering capabilities. To improve hyperthermia treatment of patients with oesophageal cancer, we are developing intraluminal heating devices to be combined with the 70 MHz AMC-4 waveguide system.

### Purpose

This study compares simulated temperature distributions of a balloon filled with hot water, a 434 MHz coaxial monopole, a 915 MHz dipole antenna and a 27 MHz current source applicator. Thermal penetration and axial homogeneity were studied.

### Methods

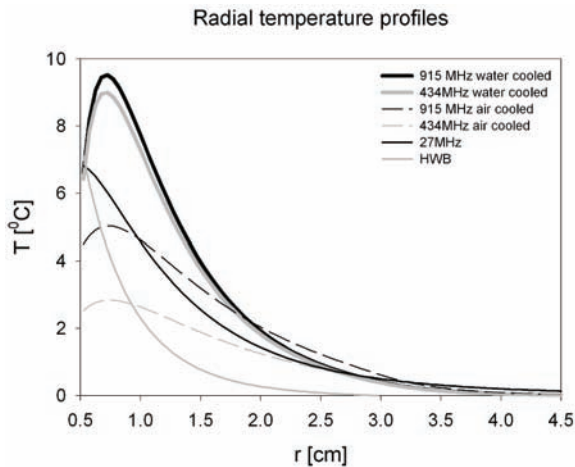
Simulations were performed at a resolution of  $0.5 \times 0.5 \times 1.0 \text{ mm}^3$ . A block of homogeneous muscle tissue was modelled, containing a cylinder ( $\varnothing 1 \text{ cm}$ ), which represents the oesophagus. All modelled applicators had a length of 8 cm and a diameter of 1 cm. Active water or air cooling was modelled to improve the thermal penetration depth of the 434 and 915 MHz applicators, of which the metal core had a diameter of 5 mm.

Power distributions of the 434 and 915 MHz applicators were calculated using the finite difference time domain (FDTD) method. The power density distribution of a 27 MHz current source applicator consisting of a single electrode segment was calculated using a quasi-static approximation of Maxwell's equations. All power density distributions were scaled to a total power of 10 W in tissue.

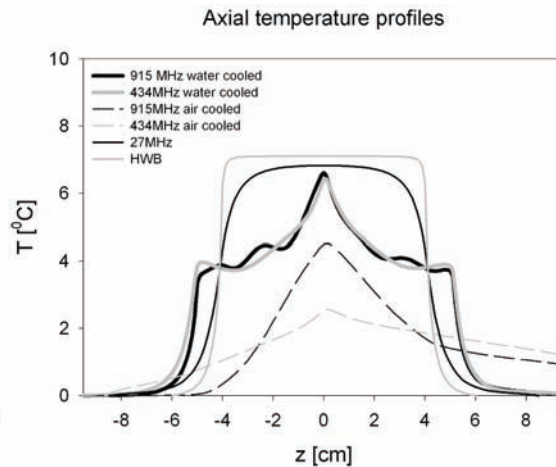
For temperature calculations the Pennes Bio Heat Transfer Equation was solved, assuming a perfusion of  $5 \text{ kg m}^{-3} \text{ s}^{-1}$  and thermal conductivity values under normal conditions. The hot water balloon was kept at a constant temperature of 45 °C. Water cooling at 41 °C was applied for 434 and 915 MHz over a length of 10 cm, symmetric in relation to the aperture. For air cooling the complete length of the modelled oesophagus was kept at 37 °C.

### Results

Radial temperature profiles at the aperture ( $z=0 \text{ cm}$ ) and axial profiles next to the applicator ( $r=0.5 \text{ cm}$ ) are shown in Figures 1 and 2. The hot water balloon showed the smallest penetration depth ( $\sim 4 \text{ mm}$ ). The penetration depth of 434 and 915 MHz was approximately equal, since the antenna radius is the limiting factor. Water and air cooling resulted in a penetration depth of  $\sim 1.3$  and  $\sim 1.7 \text{ cm}$ , respectively. The 27 MHz applicator had a thermal penetration depth of  $\sim 1 \text{ cm}$ .



**Figure 1**



**Figure 2**

Water cooling yielded a higher temperature at the oesophageal surface than air cooling, partly due to better coupling of E-Fields to tissue. Despite this better coupling air cooling provided a larger penetration depth, because air cooling resulted in a line source-like behaviour of the applicator.

The hot water balloon and the 27 MHz applicator provided the most homogeneous temperature distribution in axial direction. A benefit of 27 MHz electrodes is that multiple segments can be applied to compensate for inhomogeneities in tissue properties and/or perfusion.

**Conclusion**

Intraluminal hyperthermia may be useful for heating oesophageal tumours in conjunction with external hyperthermia devices. Air cooling yields a higher thermal penetration depth than water cooling. A hot water balloon is useful for superficial heating, while a 27 MHz electrode device consisting of multiple segments can be applied when axial steering is important.

*Supported by Dutch Cancer Society grant 2002-2622.*