MEASURING SKIN PERFUSION AFTER SUPERFICIAL HYPERTHERMIA USING IR-CAM TECHNOLOGY

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Introduction

Hyperthermia (HT) can be used in combination with radiotherapy (RT) to achieve an additional radio-sensitisation of tumours. In this study, we focus on in blood perfusion and subsequent re-oxygenation of the tumour. In a preliminary work, we modelled the impact of perfusion and oxygen-nation changes onto cell killing by ionising radiation [Scheidegger et al, 2014].

The model parameters have been estimated by using literature data. To validate these parameters, we measured the temperature decay after heating and estimated the perfusion-dependent contribution using a finite difference multilayer skin model.

Materials and Methods

For measurement of the skin surface temperature decay after a superficial HT treatment using a BSD 500 unit, an IR-camera system with a microbolometer array of 120×160 pixels (Optris PI160) has been used. A slab of a pig with skin and muscle tissue (non-perfused case) and volunteers have been measured.

The numerical multilayer skin model includes cutis (epidermis and dermis) sub-cutis and muscle, with tissue dependent densities, heat capacities and heat conductivities. For a laterally homogenous temperature distribution, the heat balance after switching off RF power leads to:

$$\frac{dT}{dt} = \kappa(z)\frac{\partial^2 T}{\partial z^2} - \frac{\Theta}{\rho_T(z)\cdot dV}\left[\frac{dm_b(z)}{dt}\right]_{T_b}\cdot\frac{c_b}{c_T(z)}\cdot(T-T_b) \tag{1}$$

with the heat capacity c_b and temperature T_b of the blood and a horizontal, vertically (z-) dependent reference blood flow dm_b/dt at T_b (set to 37°C). The density ρ_T and heat capacity c_T of the tissue are assumed to be constant within a layer (cutis, sub-cutis, muscle). The blood flow is governed by a perfusion control parameter Θ. This quantity is rising up by heating and decaying after heating:

$$\frac{d\Theta}{dt} = \vartheta_1\cdot(T-T_{ref}) - \vartheta_2\Theta \tag{2}$$

T_{ref} is set to 32°C and Θ is becoming 1 for baseline temperature (37°C). The parameter values have been estimated from literature data [Lokshina et al., 1985; Song, 1984]: $\vartheta_1 = 1.4\cdot10^{-2}\,\text{min}^{-1}\text{K}^{-1}$ and $\vartheta_2 = 7.0\cdot10^{-2}\ \text{min}^{-1}$.

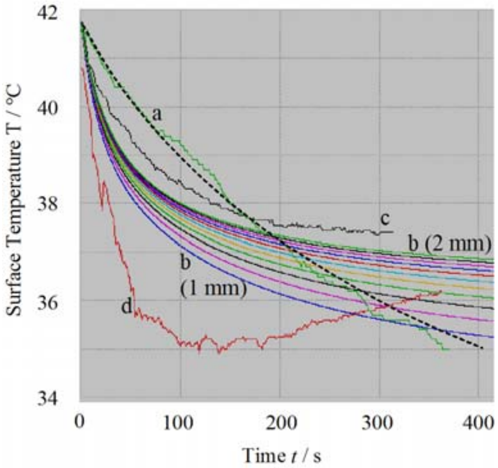

Figure 1: Measurements (a, d, c) and simulations of (a) non-perfused case and (b) perfused tissue with varying cutis-thickness (1-2 mm)

Results

The model is able to cover the non-perfused case and the perfused case as well. The curves (Fig.1,b) approach a steady state temperature of 34-36°C, which was measured at a room temperature of 20°C. The model is sensitive to the cutis-thickness. This is corresponding to the measurements.

Discussion and Conclusions

The parameter values found for ϑ_1 and ϑ_2 seem to be adequate. Some of the measurements (e.g. Fig.1,d) showed a reheating after a first temperature drop. A reason may be the recirculation of heated blood which is not considered in the model.

References

Lokshina et al, Int J Hyperthermia 1, 117-129, 1985
Scheidegger et al, Panminerva Medica 56, suppl. 1, (2), 24, 2014
Song, Cancer Res 44, 4721-4730, 1984