# Modelling of scalp cooling to prevent hair loss due to chemotherapy

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**Introduction** Hair loss is a common and distressing side effect of chemotherapy treatment against cancer. Cooling the scalp during treatment may be used to prevent hair loss. Supposedly a decrease in temperature leads to: reduced skin blood flow, decreasing drug delivery; and slower reaction rates, reducing both drug uptake and hair follicle damage. However, the biological and physiological principles of scalp cooling are hardly understood. To help improve scalp cooling efficacy, a numerical model is being developed.

**Physiological Model** The physiological model of scalp cooling describes heat transfer and blood flow in the head due to cooling with a dedicated scalp-cooling cap. The model uses the Pennes' Bioheat equation to describe heat transfer in the tissue including the effect of blood flow.

$$\rho c \frac{\partial T}{\partial t} = \nabla k \cdot \nabla T + \rho_{\mathrm{bl}} c_{\mathrm{bl}} w_{\mathrm{bl}} \left(T_A - T\right) + q_m$$

where $\rho, c, k$ are respectively the density, specific heat and thermal conductivity, $w_{\mathrm{bl}}$ is the volumetric perfusion, $T_A$ the temperature of the arterial blood supply, and $q_m$ is the metabolic heat production. Temperature dependent properties in this equation are the perfusion, and the volumetric heat production. These are both thought to behave according to the so-called $Q_{10}$-effect: $\varphi \equiv \frac{w_{\mathrm{bl}}}{w_{\mathrm{bl},0}} = \chi^{(T-T_0)/10}$, with $\chi$ between 2 and 3. Laser Doppler perfusion experiments are being performed to define a more precise relationship between temperature and perfusion for the cooled scalp. In the numerical model, the head is approximated by a sphere, containing different tissue layers, each with their own distinctive physical properties. With the model, scalp cooling procedures can be simulated. Different simulations show that skin temperature at the site of the hair follicle drops to about 20ºC. A decrease in skin blood flow has little effect on local skin temperature. The model shows that perfusion drops down to 20-40% of the normal value with realistic values for $\chi$ to calculate skin blood flow.

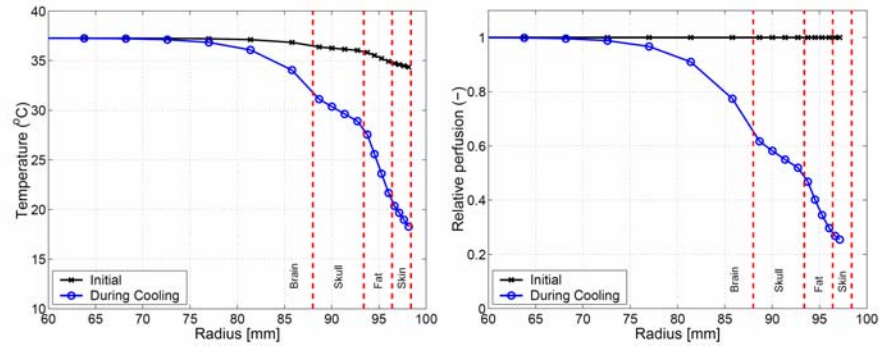


*Figure 1: Calculations showing the temperature and the relative perfusion in the head before and during cooling with a cooling cap.*

**Pharmacological Model.** A Physiologically Based Pharmacokinetic model is used to describe Doxorubicin (DOX) pharmacology in the body. The body is divided into compartments that represent individual organs. Transport, clearance and metabolism of DOX between and in these compartments are described using mass balances. With the complete model, simulations are performed with and without cooling. In these simulations, DOX concentration in the scalp skin compartment is less than half the concentration when cooling is applied compared to no cooling.

**Conclusion** Coupled physiological and pharmacological models predict the accumulation of cytostatics in the tissue. Dedicated experiments are being performed to refine the relations. Future experiments must elucidate the relation between concentration, temperature and hair loss.