A Radiative Heater for Small Animal Coils to Prevent Hypothermia

M. Korn[1], R. Umathum[1], S. Müller[1], W. Semmler[1], and M. Bock[1]

[1]Medical Physics in Radiology, German Cancer Research Center (dkfz), Heidelberg, Germany

Introduction

Hypothermia due to anesthesia is a well known problem in MRI studies on rodents. Since some physiologic parameters are affected by body temperature, hypothermia can change the results of the measurement. Furthermore in cases, where the experiment is extraordinary long (>30 min) or the health status of the animal is compromised this hypothermia can be lethal. Therefore, a heater is integrated in most imaging devices. A heating device for use in an MR system must not distort the image, should be easy to handle and should not create artifacts [1].

Commercial MR imaging systems for small animals use either liquids or hot air for heating [2]. Liquid heating has several disadvantages: the device occupies space in the coil interior, the liquid itself can create an MR signal and it is complicated to avoid leakages. Hot air heating requires thermally well isolated tubes and the dry, warm air desiccates the respiratory tract of the animals so that a humidifier is needed. In this work we propose a radiative heating system with halogen light bulbs that are placed at a sufficiently large distance from the coil to prevent artifacts.

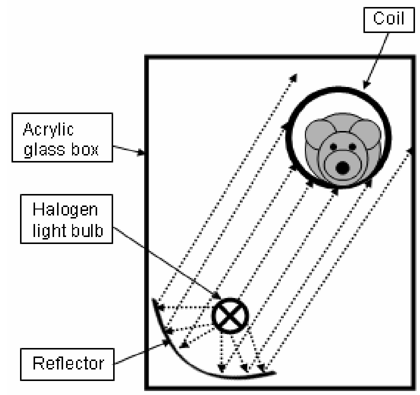

Fig. 1: Schematic of the heater in the coil setup.

Materials and Methods

An in-house designed, tunable solenoid Tx/Rx coil with an inner diameter of 26 mm and a length of 142 mm length was used for mouse imaging at a 1.5 T system (Magnetom Symphony, Siemens, Erlangen, Germany). The coil was wound on a substrate of acrylic glass, so that the radiation from the light bulbs could reach the mouse. The whole setup including coil and heater was in a box of acrylic glass, which captured the warm air and stored the heat of the light bulb.

For irradiation two 12V/10W halogen light bulbs were connected in series to two 12V lead-acid batteries (Panasonic LC-R127R2PG1, Matsushita Battery Industrial Co., Ltd, Japan). As transmission line a coaxial cable was used to reduce current-induced magnetic fields. To focus the light into the coil a parabolically shaped reflector was attached at the rear of the light bulbs which were positioned at a distance of approximately 10 cm from the coil center (Fig. 1).

To measure the heating efficiency an injection syringe filled with physiologic saline solution was placed in the coil. The syringe was heated to approx. 37°C and was covered with a moisturized tissue to emulate cooling due to sweating. The measurements were repeated with two syringes (10 ml and 20 ml) to simulate very small mice in the weight range of 16 g to 20 g, which are most susceptible to hypothermia. The measurements were performed with and without radiation heating with the coil at room temperature (18-21°C). After each measurement a sufficiently long time was waited for the coil to adopt room temperature.

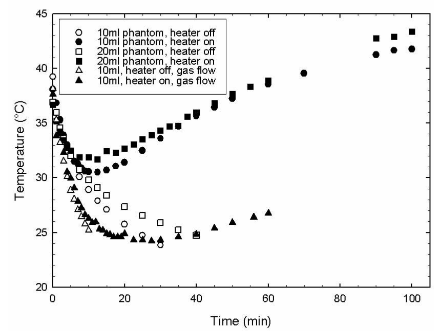

Fig. 2: Temperature curve of the filling of a 10ml and a 20ml syringe in an MRI coil with (filled symbols) and without (open symbols) heating with two halogen light bulbs.

Rodents are often anaesthetized with gases such as isoflurane where they are exposed to a gas flow of approx. 1 l/min. The gas is sometimes introduced from a colder room (e.g. at 16°C) leading to an additional temperature loss. This situation was simulated and the temperature of the phantom liquid was measured with a fiber-optic thermometer (3100 Fluoroptic Thermometer, Luxtron, Santa Clara (CA), USA) with the probes placed in the syringe.

To demonstrate the feasibility of the method the temperature was measured in two nude mice (weight: 30g) during MR imaging, in one case with and in the other case without heating. With heating the current was switched on for 10 min before introducing the mouse. Fiber-optic probes were placed below the abdomen of the mouse within the light cone.

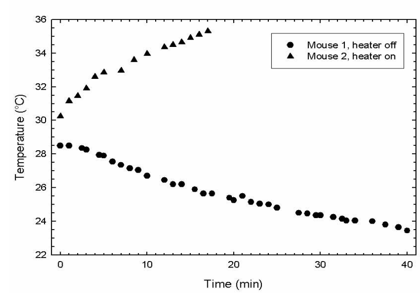

Fig. 3: Temperature measurement in two mice with (triangles) and without (circles) heating with halogen light bulbs.

Results and Discussion

The measured temperatures of the phantoms are shown in Fig. 2. Initially, in all cases a rapid temperature decrease is seen which stops 10 min (25 min with cooling gas flow) after heating and thereafter a temperature increase is notable. After 60 min the temperature amounted to 38.5°C/39°C (10 ml/ 20 ml syringe) in the phantoms without a cooling gas flow, whereas in gas-cooled phantoms only a temperature of 26.8°C could be achieved. The long times during which the temperature decreases can be explained by the heat capacity of the coil and the surrounding air which offer the possibility for pre-heating.

The efficiency of the halogen lamp heater was also tested during MR imaging of mice. The measured skin temperatures are shown in fig. 3. A temperature decrease of 2.9 K / 3.7 K was seen in the experiment without heating after 17 min / 40 min. After removing the mouse from the coil a sensible temperature could be felt. The temperature of the heated mouse increased significantly, and after 17 min the measurement was aborted at a temperature of 35.5 °C to avoid overheating of the animal.

Due to the positioning of the probes under the abdomen of the mouse, the measured temperatures provide only an indirect estimate of the core temperature. Since the metabolism of the mouse also creates heat, lower energies are required for mouse heating than in the phantom experiments. In future refinements of the heating system a regulator will be integrated which can be coupled with a temperature measurement. Halogen light bulb heating device is an effective measure to prevent anesthesia caused hypothermia in small animals during MR imaging.

Acknowledgements

This work was partly supported by a grant from the German Ministry of Research and Technology (BMBF) under grant number 13N8895 (EISENHERZ) and by SIEMENS Medical Solutions.

References

[1] Wiesmann F. et al., Magn Reson Med 50:69-74 (2003)
[2] http://www.i4sa.com/rodent_heater.shtml