The Use of MR Thermometry in Legal Medicine: A Feasibility Study utilizing Rat Rectal Temperature.

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INTRODUCTION

Rectal temperature measurements are an important legal medicine tool used in criminal investigations. To estimate the time of death, the rectal temperature of a cooling dead body is recorded over intervals of hours and is fitted to a rectal temperature-time curve based on thermodynamics. The curve has been discussed using different models. The heat transmission model, using an infinite cylinder, is considered to be reliable because the environmental temperature and the size of the deceased are factors in the model (1). In this model the heat transfer equation was solved using the simple geometric model and a single tissue compartment. However a human body contains multiple compartments with different thermal tissue properties and unique shapes. Another more complex model, which uses different tissue compartments, has been simulated and has been used to validate an empirical model (2-3). In this study, we introduce proton resonance frequency shift-based MR temperature imaging (MR thermometry) as a method to collect data for validation of heat transmission models. Because MR thermometry is applicable to any water-rich tissue, cooling rates not only in the rectal wall but also in almost all tissues (except fat and bone) in dead bodies could be observed experimentally.

METHODS

MR images were acquired using a 7 T horizontal MRI system (UNITYINOVA, Varian) with a 6-cm quadrature birdcage coil (Varian). Male SD rats (~250 g, n = 8) were scanned under halothane and a gas mixture of NO_2 and O_2 (70:30) anesthesia. The rats were positioned prone (n = 3) or supine (n = 5) with a thermocouple inserted into the rectum. No heating was applied. A single axial slice was positioned 2 cm superior to the anal verge. After recording the in-vivo rectal temperature, the thermocouple was withdrawn in preparation for MR scans. Spoiled gradient-recalled echo (SPGR) T_2*-weighted images were acquired sequentially. Parameters for the SPGR image were: TR = 200 ms, TE = 7 ms, flip angle of the excitation pulse = 20^o, slice thickness = 2 mm, field-of-view = 60 × 60 (mm)^2, matrix = 128 × 128, 8 averages. Scan time per image was 4.5 minutes. After obtaining 5 images, the rats (still in the MR scanner) were euthanized by halothane overdose (5%). Body motion from respiration was carefully inspected visually through the magnet bore to determine the cessation of breathing. The scans were continued until 2.5 hours after the halothane overdose. Temperature difference maps were constructed from each SPGR phase image using MATLAB (MathWorks).

RESULTS

Temperature difference images were successfully obtained by choosing the last image in a series of post-mortem scans as a temperature reference, instead of images when the rats were alive. Fig. 1 shows MR temperature difference maps in a supine rat pelvis acquired 0.5, and 1.5 hours after the halothane overdose. The fall of temperature in tissues surrounding the rectal cavity could be monitored. Distribution of the temperature difference in the imaging plane was observed too. The results show that the rate of temperature decrease in the tissues located near the body core was slower than that in tissues close to the body surface, i.e. muscles of hip and hindlimb, and testicles. Fig. 2 shows the results in a rat positioned decubitus. The results show that the falling temperature in the tissues adjacent to the animal bed was slower than that in the hindlimb muscle and in testicles which were exposed to the air. Another supine rat with similar body position to the rat in Fig. 2 showed similar cooling evidence. In the prone rats, on the other hand, the falling temperature in hip muscles surrounding the spine was slower than that in the other tissues, even though the hips were exposed to the air.

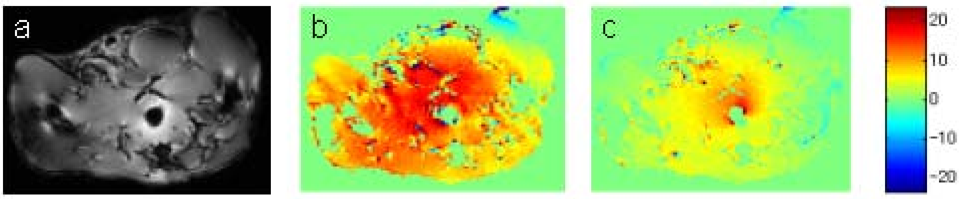

Fig. 1 SPGR image (a) and MR temperature (^{o}C) difference maps in a supine rat pelvis obtained at 0.5 (b) and 1.5 (c) hours after halothane overdoes. The reference of the temperature difference was an image obtained at 2.5 hours after halothane overdose.

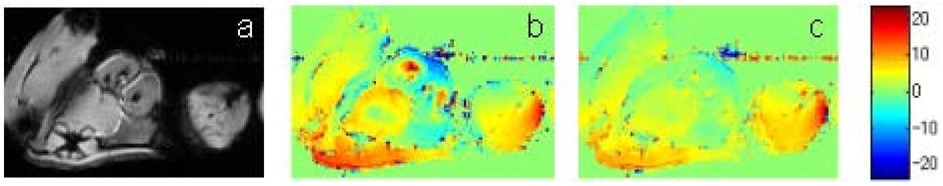

Fig. 2 Additional result showing an additional supine rat pelvis.

DISCUSSION

We successfully demonstrated temperature measurement in the pelvic region of cooling dead rats using proton resonance frequency shift-based MR temperature imaging for legal medicine. Moreover this study showed us that the distribution of cooling rates among tissues varies with respect to the body position. The imaging approach using laboratory animals can give experimental evidence of cooling dead bodies with many different environmental conditions including non-standard cooling situations. Mapping cooling rates in dead bodies may provide accurate and efficient methodologies for estimation of time since death for use in criminal investigation.

REFERENCES

1. Hiraiwa K et al. *Med Sci Law* 1980;20:115-125. 2. Mall G et al. *Legal Med* 2005;7:1-14. 3. Mall G et al. *Legal Med* 2005;7:69-80.