A resistive heating system for homeothermic maintenance in small animals.

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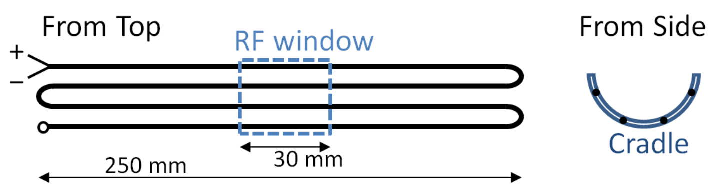
Target audience: Users and developers of preclinical MRI systems.

Purpose: Optimised physiological maintenance of the anaesthetised animal requires a heat input to the animal. High sensitivity imaging requires the high filling factor achieved when using small RF coils that are proximal to the tissue of interest. We have developed a resistive heating system using a narrow diameter twisted pair resistor wire, built into the animal loading cradle, that presents no detectable image artefacts, and which is suitable for use within a small volume coil at high magnetic field where the effective use of circulating warm fluids, the standard method of temperature maintenance in preclinical MRI, is not possible.

Methods: A commercially available homeothermic temperature maintenance control unit (Harvard Apparatus) was used. The standard heater pad was replaced with a 2 Ω resistor made from 150 µm diameter copper wire that was formed into a tightly wound (12 turns/cm) twisted pair, and embedded into the fibre glass animal loading cradle in a 4 legged arrangement, schematically shown in Fig 1. This was repeated with a single strand wire. A 10 Ω power resistor is placed in series to limit the current delivered from the standard voltage-regulated commercial unit.

Fig. 1. Schematic of the heater wire and cradle apparatus.



The legs of the resistor pass coaxially through the RF coil and B_0, and SNR is unaffected. The twisted pair was designed to avoid any B_0 field distortions that would arise from passing current through a single strand wire, and the power resistor ensures the current passing through the loop is limited to a maximum of ca. 1 A, sufficient to warm an animal to target temperatures that can be set in the range 34-38 °C. As the animal approaches the target temperature the current delivered through the resistor is reduced to avoid any overheating.

To demonstrate performance of the heater system, an anesthetised mouse (60 g) was placed into the cradle, positioned within a 40 mm i.d. birdcage RF coil, and the whole assembly was placed in a 4.7 T magnet. PRESS spectroscopy and fat-suppressed gradient echo imaging (TE=2.5 ms) were performed with the heater turned off, and turned on for both a single strand wire and for the twisted pair.

Results and Discussion: For the single strand wire PRESS spectroscopy showed position-dependent lineshape distortions and frequency shifts of up to 200 Hz. These defects lead to incomplete fat suppression and image distortion proximal to the single strand wire (Fig 2C, 2E). No measureable spectroscopy or image defects were seen for the twisted pair (Image 2B, 2D).

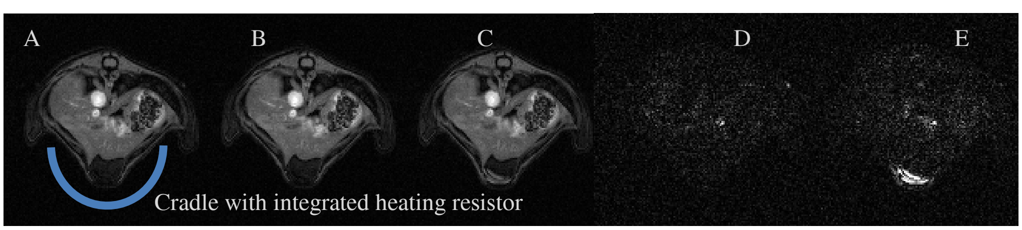


Fig 2. Fat-suppressed images of mouse abdomen: A) without current. B) with current in the twisted pair. C) with current in the single strand wire. D) difference image of |A-B| indicating absence of artefact for the twisted pair. E) difference image of |A-C| indicating magnetic field distortions arising from use of the single strand wire as heater. The shape of the distortion indicated both a B_0 shift and field gradients.

This system is very simple to implement, requiring no specialist electronics knowledge, is sufficient to recover any temperature that is lost during induction of anaesthesia, and to maintain the animal's temperature indefinitely and has been used successfully in hundreds of consecutive scans. Similar results are obtained at 9.4 T.

Conclusion: The tightly wound twisted pair resistor requires no additional space, and provides adequate heating capacity without causing any observable distortion of the magnetic field or the images, and can be implemented very easily.