# In vivo heating measurements near pacemaker leads during MRI

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**Introduction:**

The presence of a cardiac pacemaker is usually regarded as a contraindication for MRI due to safety reasons[1]. Heating effects at the lead tip is one of the potential risks. However, only in-vitro data on heating effects are available so far[2]. The aim of this study was to measure heating effects at the tip of a pacing lead in an animal model during standard heart MRI scans at 1.5T. For this purpose, a pacing lead with an additional thermocouple as temperature sensor was developed and evaluated. Heat-induced tissue damage and changes of pacing performance have been evaluated.

**Methods:**

Pacemaker systems with three active fixation leads were implanted in six 70kg pigs. All leads were equipped with a T-type thermocouple as temperature sensor. The thermocouples were connected over shielded wires with a high precision voltmeter (NI 4350 PCMCIA card). The accuracy of the thermocouple and its influence on the heating was investigated in-vitro with a fiber-optic sensor. To have a stable lead-tissue interface, four weeks have been waited after implantation of the leads until performing the MRI measurements. The pigs were placed in supine position with the heart at the isocenter of the scanner. TSE scans with a SAR-value of 3.8W/kg were performed. The influence of position on heating was evaluated in an additional animal (used to setup the study) by moving it stepwise 40cm out of the scanner. Pacing parameters like capture threshold and pacing impedance were measured after implantation, pre, during, and after MRI and two weeks after MRI. Troponin-levels, known as good indicator for myocardial cell death, were measured from blood samples taken before and 8h after MRI. The animals were sacrificed two weeks after MRI and gross morphological and pathological examinations and histology of the regions around the lead tips were performed.

**Results:**

The in-vitro validation of the thermocouple showed a good agreement with the fiber-optic sensor. The thermocouple leads showed no additional heating, compared with an identical lead with removed thermocouple. Significant heating effects could be seen in all animals and at all pacing positions. The temperature increased rapidly and reached a stable value in less than 15sec. The overall scan times and temperature changes at the lead tip are shown in table 1. The significant changes ($p<0.05$ pre MRI → post MRI and $p<0.001$ pre MRI → 2 weeks after MRI) of the pacing impedance are shown in table 2. Minor increases in stimulation thresholds were seen. However, the stimulation threshold changes did not prevent further pacing of the heart. All troponin tests were negative, indicating that no major heart tissue damage occurred. Pathology showed no clear evidence of heat-induced damage.

| | pre MRI | post MRI | 2 weeks after MRI |
|---|---|---|---|
| Right atrial lead | 492±57 Ω | 516±29 Ω (+5.5%±6.2%) | 575±86Ω (+16.8%±9%) |
| Right ventricular lead | 567±93 Ω | 629±86 Ω (+11.5%±6.8%) | 601±58 Ω (+7.5%±14.5%) |
| Right ventricular lead (Outflow track) | 525±27 Ω | 560±23 Ω (+6.9%±5.9%) | 595±43 Ω (+13.6%±9.4%) |

*Table 2*: Pacing impedance changes

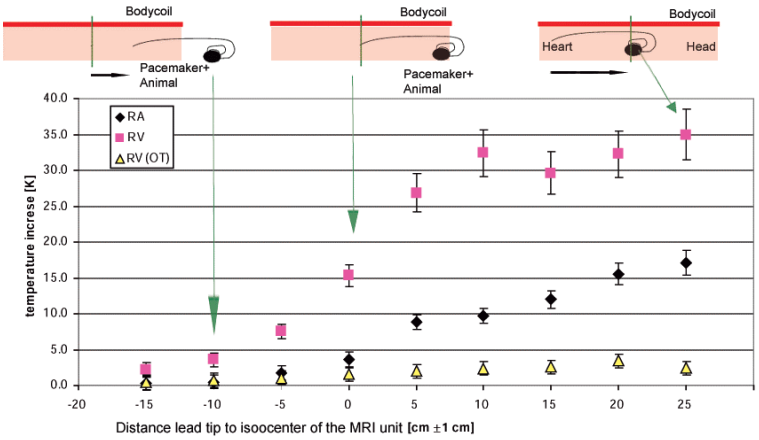


*Figure 1:* By moving the animal out of the scanner, it could be seen that, as soon as part of the pacemaker lead was outside the body coil of the scanner, the temperature increase was reduced.

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| Animal | Total scan time [min] | Atrium $\Delta T_{avg}$[°C] | Ventricle $\Delta T_{avg}$[°C] | Ventricle (Out-flow track) $\Delta T_{avg}$[°C] |
|---|---|---|---|---|
| 1 | 30 | - | - | - |
| 2 | 41 | - | 5.7 | 5.4 |
| 3 | 41 | 15.7 | 11.1 | 12.2 |
| 4 | 37 | 5.7 | 9.3 | 9.7 |
| 5 | 40 | 9.1 | 7.5 | 9.0 |
| 6 | 42 | 3.7 | 3.9 | 11.4 |

*Table 1*: Total scan time and average temperature increase. Only parts of the temperature measurements are available for the first two animals due to broken thermocouples.

Cell damage induced by the implantation could not be distinguished from potential cell damage induced by heating 2 weeks after MRI. No strong relation between measured temperatures and heat-induced inflammation could be found. Shifting the pacemaker more or less into the MRI unit showed highest temperature increases in case the whole lead and pacemaker was inside the body coil.(figure 1).

**Discussion:**

MRI at 1.5T produces a temperature increase of more than 15°C at lead tips. It is known from simulation, that the heating drops fast with increasing distance from the lead tip[3]. The temperature increase in the tissue circumventing the 2-3mm thick scar tissue at the tip may therefore be reduced by more than a factor of two. Changes in the essential pacing parameters like capture threshold due to MRI were demonstrated. The location of implanted pacing leads and the position of the animal within the MRI-scanner result in marked differences in heating, which is in good agreement with in vitro evaluations[4]. Despite the aim of introducing maximum heating effects, no specific heating related pathological changes were seen. Limitations: The pigs have been placed in the center of the magnet in right-left direction. Higher heating could have occurred if the animal was placed differently. Furthermore, only a limited number of lead positions have been evaluated. Potential risk of tissue damage cannot be totally excluded. Reduction of the SAR-value by changing the MRI parameters and limiting MR measurements to lower extremities and head are likely to reduce the risk of heat-induced tissue damage.

**References:** [1]Duru, F., et. al. EHJ, **22**, 113-124, 2001, [2]Sommer, T. et al., Radiology, **215**: 869- 879, 2000, [3]Luechinger, R., et al., in Proceedings ISMRM 2001 Glasgow, [4]Luechinger, R., et al., in Proceedings ESMRMB 2000 Paris.