Intravascular MRI-receiver coils in combination with traps: Reducing troubling thermal effects.

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Introduction
For the evaluation of the vessel wall respectively the histological constitution of atherosclerotic plaque magnetic resonance imaging is becoming more and more interesting. Additionally, an application of an intravascular coil can improve the signal-to-noise ratio and thus, the spatial resolution, because of the proximity to the vessel wall. Hazardous thermal effects may arise due to the neighbouring position of the coil to the vessel wall. Wildermuth et al. report on relative temperature increases up to 20°C at 1.5 Tesla [2]. These effects are primarily caused by so called sheath waves. This expression means electromagnetic waves, which are diffusing over the sheath of the coaxial cable, which connect the detection coil with the MR-scanner. These waves come into existence, because the coaxial cable of the special coils lies parallel to the very high electric field of the bodyresonator in case of transmission. Therefore, they cross the equipotential lines of the electric field. The result is an accordingly high radio-frequency current, which diffuses over the outer conductor of the coaxial cable. As a consequence the cable itself irradiates (troubling) electro-magnetic fields again. They can produce, not only field distortions, but heatings or burnings in the investigated region of the body. For suppressing these effects so called sheath wave traps [3] in combination with intravascular receiver coils were evaluated.

Methods
The applied intravascular imaging catheter bases on the single-loop design monted onto a commercial PTA-ballon catheter [1] (diameter of copper wire of the single-loop: 0.1 mm; ballon-catheter: 5 French, balloon segment: diameter 8 mm, length 40 mm). The adjusted electronic (tuning, matching, decoupling, trap) was specially developed for this invasive application and is located outside the body in a RF shielded box. The trap consists of a coaxial cable, that is wounded on a teflon body like an inductance. The sheath is bridged at the beginning and the end with a fixed capacity and a tuneable capacity. The result is a parallel resonant circuit, that is attuned to the measurement frequency. This parallel resonant circuit represents a high impedance for the outer sheath, whereas the wave propagation inside the cable is undisturbed. Thereby, the formation of currents on the outer sheath of the coaxial cable can be prevented.

For testing the effectivity of traps in combination with intravascular receiver coils the imaging catheter was orientated along the z-direction of the scanner. A 0.1 ml reservoir of water was placed on the tip of the coil to be coupled thermally with the sensor of the resistance thermometer (using thermal conductivity of the water). The resistance thermometer was run externally. We paid attention, that the necessary lead in wire went out of the scanner in z-direction. So, direct heating of the thermometer is prevented by irradiated radio frequency power. Without intravascular receiver coil no measurable relative temperature changes were observed. The relative temperature changes were determined from the difference of the temperature direct after the sequence and the temperature at the beginning of each measurement. The measuredness amounts about 0.1°C. We investigated the relative temperature depending on the height from the connector in the patient table to the actual catheter position. Thus, an indirect dependence to the equipotential lines of the electric field can be observed.

All measurements were performed on a 1.0 Tesla clinical scanner (Magetom Expert, Siemens, Erlangen, Germany) with commercially available gradients capable of 1200 μsec rise time and 20 mT/m maximum gradient strength. According to Wildermuth et al. the heating was directly proportional to the RF power of the transmitter. So, it can be assumed that the heating is reduced by the factor (1.5/1.0)² at 1.0 Tesla in comparison to a 1.5 Tesla scanner [2]. For a better clarification of this sheath wave effect a very power intensive sequence (3D gradient-echo-sequence: TR = 5.4 ms, TE = 2.2 ms, FA = 25°, TA = 2.28, bandwidth = 390 Hz/pixel) was applied.

Results
Up to a height of 12 cm over the patient table without trap and 18 cm with trap there are not any measurable temperature changes with a measuredness of 0.1°C. From this level on the temperature development seems to rise exponential. However, the temperature increase is obviously attenuated by the use of traps. At the maximal applied height the heating can be reduced from 3.9°C to 1.4°C. This corresponds to an attenuation of relative temperature changes of approximately 65%.

Discussion
The combination of intravascular MRI-receiver coils and sheath wave traps allows a reduction of the relative temperature increase up to 65% in our experiment. Thus, this combination can be an efficient protection for patients, who are investigated with intravascular receiver coils.

References