Permanent Non-invasive Device Safety Monitoring for Clinical MRI

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Objective: Devices carrying electric leads or other conductive material e.g. for mechanical stabilization, imply an inherent safety risk for the patient and the physician during an MR measurement. This safety risk arises from the coupling of the RF transmit coil with an electrical conductor. The permanent presence of a device inside a patient (e.g. pacemaker or deep brain stimulator) or the necessity to use other devices for diagnosis and treatment (e.g. catheters or guidewires), therefore, usually represents a contraindication for an MR examination.

This work relates to the non-invasive detection of RF coupling to conductive parts of a device during an MR measurement. Unsafe events related to this RF coupling and resulting energy absorption into such a device can be detected immediately. For interventional applications, the MR measurement parameters can then be changed to ensure safety, or the transmission of RF power can be prohibited, until the RF-coupling to the device is resolved. The proposed technique is evaluated in phantom and volunteer studies.

Material and Methods: A 3T MR system (Philips Achieva, Philips Medical Systems, Best, The Netherlands) equipped with an 8-channel real-time RF transmission monitoring system [1,2] is used to monitor RF-coupling into intra-corporal devices during regular MR imaging experiments. The system is capable of measuring the signals during transmission via 8 independent pick-up coils (PUCs). Amplitude and phase of all applied RF pulses can thus be monitored in real-time.

A safe catheter [3] and an unsafe catheter are used to demonstrate the system's capability to automatically detect dangerous RF coupling to these devices during imaging experiments.

In a first phantom experiment, the catheters are advanced into a tubular vessel phantom during real-time imaging (Cartesian SSFP, TR = 9ms, TE = 3.5ms, α=65°, matrix 172x172, whole body SAR < 0.9W/kg.). The PUC signals and simultaneous fiber-optic temperature measurements (LumaSense Technologies, Santa Clara, CA, USA) are recorded at 22 different positions.

In a second experiment, a volunteer was placed inside the scanner, and the vessel phantom was placed along the arms and on top of his breast. Safe and unsafe catheters were advanced during imaging of the volunteer. The volunteer was requested to perform normal respiration and minor movements to imitate a normal compliance level. The feasibility to detect unsafe events under regular patient imaging conditions was thus assessed.

Results and Discussion: In Fig.1a.), a high degree of correlation is visible between temperature measurements and PUC signals at the selected catheter positions. It should be noted, that power reflections due to detuning of the RF transmit coil were not considered for this measurement. The PUC signal variation results from both, power dissipation in a device, and power reflections, and therefore, is a conservative measure for potential RF coupling. Fig.1b.) indicates that the incorporation of a typical power reflection behaviour (maximum and minimum reflection if catheter inside and outside bore, respectively) may further increase the observed correlation.

The measurements performed with the volunteer loading the body coil, demonstrate the feasibility of this approach, since the unsafe situation was still accurately detected. The variation of the PUC signals due to respiration was 3.6% (not shown) compared to up to 95% in case of an RF coupling event. Fig. 2 shows amplitude curves of the received RF signal during transmission. A significant signal alteration can be observed with the unsafe catheter. In contrast, the signal change is not present for a safe catheter [3]. Fig.2b.) shows the tuning effect by repeatedly touching the hand-piece of a device resolved via the PUC signal.

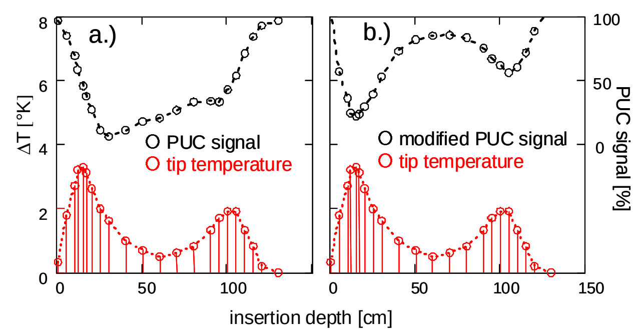

Fig. 1: Phantom study: a.) Strong correlation of temperature measurements at the device tip with PUC monitoring signal. b.) After correction for typical power reflection due to detuning of the RF transmit coil.

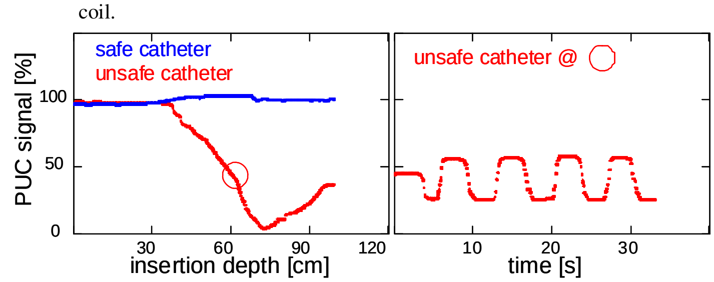

Fig. 2: Volunteer study: a.) The PUC signal visualizes the RF coupling of RF with a safe (blue) and an unsafe catheter (red) during their advancement. b.) Impact on the PUC signal for tuning and detuning of a device by touching the hand-piece.

Conclusion and Outlook: The proposed system and approach allowed the detection of unsafe events related to conductive components of a device in a phantom and a volunteer setup. It was shown exemplarily by comparative temperature measurements, that the signal received by the internal pick-up coils during RF transmission had a good correlation with the measured RF heating of MR-unsafe active catheters. Consideration of power reflection due to detuning of the RF transmit coil as a consequence of RF coupling will be subject to further investigation to increase the specificity to detect unsafe events. The system allows the detection of RF-coupling to MR-related equipment and may be useful as a general failsafe technique.

References:

[1] Graesslin, I. et al., ISMRM 2007, p1086 [2] Graesslin, I. et al., ISMRM 2007, p867 [3] Weiss, S. et al MRM 2005;54:182–189.