Intracoronary 3.0T MRI: An ex vivo feasibility study in swine hearts

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PURPOSE: MRI is becoming a useful imaging tool for the diagnosis and treatment atherosclerotic coronary arteries. To date, there are no reports on intracoronary MRI using a clinical 3.0T MRI scanner, which requires the placement of a small sized (usually 0.014-inch in diameter) endovascular MR coil into the coronary arteries. In this study, we attempted to confirm, ex vivo, the possibility of generating intracoronary 3.0T MRI via establishment of an imaging system with combining use of a 0.014-inch endovascular MR antenna and two surface coils**.**

METHODS: We first designed and built a combo imaging system, which consisted of a custom-made 0.014-inch Nitinol MR loopless antenna and two custom-made 3.5-inch surface coils (Fig. 1). The loopless antenna and the two coils were adapted, via a custom-designed multi-channel preamp box, to a clinical 3.0T Philips MR System (Achieva, Philips Medical Systems, Best, The Netherlands), with the channel 3 connected to the loopless antenna and channels 1 and 2 connected to the two surface coils. When operated at receive-only mode, the loopless antenna could generate high signal-to-noise (SNR) imaging with low tissue penetration due to its small diameter, while the two surface coils could create good tissue penetration but no high SNR quality. Thus, the combining use of the endovascular MR loopless antenna with the two surface coils should compensate each other.

To confirm its functionality, we tested and then optimized the Q factor of the combo imaging system by turning it using a network analyzer (Agilent Technologies, Santa Clara, CA). Once we achieved the best Q factor, we then validated the feasibility of using the combo imaging system for ex vivo coronary 3.0T MRI. The entire hearts of four healthy pigs were harvested, and then positioned into a plastic box that was filled with 0.9% physiological sodium solution. The two surface coils were placed anteriorly and posteriorly around the heart, and the 0.014-inch Nitinol MR loopless antenna was positioned into the left anterior descending (LAD) coronary artery via the aortic sinus. Subsequently, we achieved a series of ex vivo coronary MRI by (i) using the loopless antenna only; (ii) using the two surface coils only; and (iii) simultaneously operating the antenna and the two coils. For each of the LAD MRI, we used a turbo spin echo (TSE) sequence for (i) T2-weighted images (T2WI) with TR=4000ms, TE=60ms, and TSE factor=6; and (ii) and T1-weighted images(T1WI) with TR=550ms, TE=12ms, and TSE factor=3. Other MRI parameters were the same between T2WI and T1WI, including FOV=60mm×60mm, slice thickness=1mm, slice gap=1mm, matrix=120×114, and NSA=4.

RESULTS: The antenna and the two coils of the combo imaging system could work separately or together. When they worked together, the Q factor of the loopless antenna should not be turned too high for avoiding non-homogeneity of imaging, while the Q factor of surface coils could be tuned as high as possible for generating the highest SNR. Of the ex vivo experiment, the combo imaging system with the optimized Q factors generated excellent imaging quality with a high SNR of the coronary arterial wall and enough penetration of the entire heart (Fig. 2).

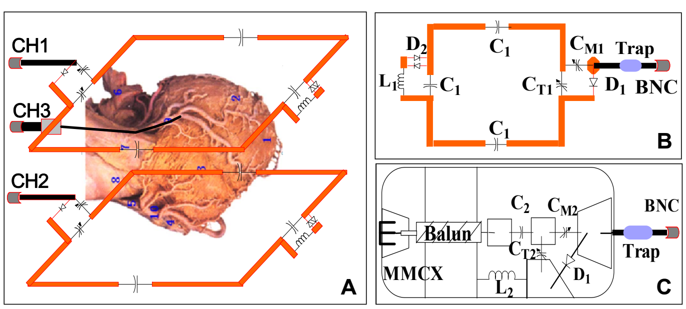

Fig. 1. Schematic diagram of the combo imaging system. (A) Channel (CH) 1 and CH2 are used to connect the two surface coils to the 3T MRI system for background imaging of the heart, while CH3 connected to the 0.014-inch MR loopless antenna for intracoronary 3.0T MR imaging. (B) The circuitry diagram of the surface coil. C_{T1} and C_{M1} are capacitors for coil tuning and matching to 50ohm at 127.72MHz; D_1 is pin diode for active protection; D_2 is an anti parallel diode for passive protection. (C) The circuitry diagram of the tuning box for the 0.014'' intracoronary MR loopless antenna. Balun and trap are added to enhance the electrical isolation and reduce the system interference.

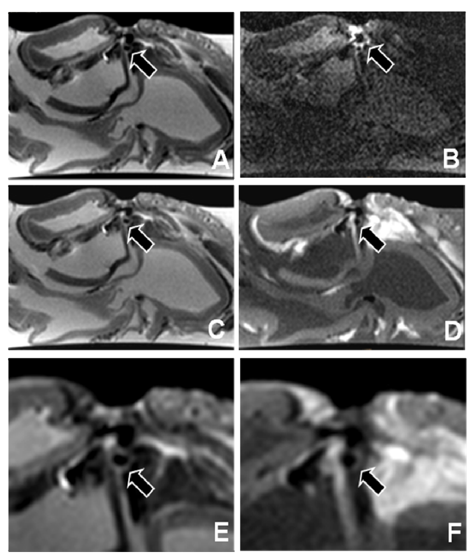

Fig. 2. A series of ex vivo 3.0T MRI of a pig coronary artery (arrows). (A) T2WI using two surface coils with the S_{11} parameter turned -35dB. (B) T2WI using the intracoronary-placed 0.014'' loopless antenna with the S_{11} parameter tuned -25dB. (C&D) T2WI (C) and T1WI (D) by combining use of the two surface coils and the loopless antenna, which offers simultaneous visualization of both the coronary artery wall and the heart background. (E&F) Magnified views of the coronary arteries from images C and D,

Conclusions: This study demonstrates the first attempt on the development of intracoronary 3.0T MRI technology. The combo imaging system with simultaneous use of the 0.014-inch Nitinol loopless antenna and two surface coils can function together in a clinical 3.0T MR scanner. These results have established the groundwork towards the next step –– in vivo intracoronary 3.0T MRI for high resolution imaging of coronary artery walls/plaques, and, ultimately, intracoronary interventions under 3.0T MRI guidance.

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