A New Intravascular Loopless Monopole Antenna (ILMA) for MR Imaging

H. Yuan1, X. Lv1, R. Zhang1, X. Yang2, X. Wang1, X. Ma2, Z. Zhang1, J. Zhang1,2, and J. Fang1,3

1College of Engineering, Peking University, Beijing, China, People's Republic of; 2Dept. of Radiology, Peking University First Hospital, Beijing, China, People's Republic of; 3Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, China, People's Republic of

Introduction:
In recent years, intravascular MR coil, which utilizes a special coil placed neighboring to the target artery, has been proposed to improve the local signal-to-noise ratio (SNR) and spatial resolution of vessel wall images. Especially the intravascular coil has identified its advantage in detecting atherosclerotic plaques [1]. At present, there are two types of intravascular MRI receivers: loop coil and loopless antennae [2]. The intravascular MR detectors mentioned in previous reports are usually rigid and bulky, therefore are difficult to be inserted into small diseased vessels. Also the corresponding signal sensitivity of those small-loop coils falls off very rapidly. In this study, a novel long intravascular loopless monopole antenna (ILMA) design with a thin, non-shielded flexible guide-wire is presented. The guide-wire of ILMA, which was made of a flexible copper wire instead of conventional coaxial-cable, allowed a thinner volume to be applied into small vessels and enabled an enhanced longitudinal coverage. In vitro and in vivo test were carried out to assess the feasibility of the ILMA, including SNR, spatial resolution, and longitudinal coverage.

Materials and Methods:
Based on monopole antenna theory [3], the design of ILMA was shown in Fig. 1. The guide-wire, made of copper wire, was 23.11 inches long, 0.0118 inch in diameter, and was connected to a tuning/matching circuit for obtaining high gain of signals. In the tuning/matching circuit, represented in Fig.1, there are three adjustable capacitors, C1, C2, C3, respectively. C1 serves for the Q-factor adjustment after tuning the resonant peak at 127.72 MHz, C2 is used to tune the resonant frequency roughly close to the expected Larmor frequency, and C3 offers the fine-tuning near the Larmor frequency. To evaluate the sensing function of the proposed ILMA antenna, MR imaging was carried out by in vitro and in vivo experiments, via the tuning circuit to connect with a 3T whole-body MRI system (General Electric Medical System, Milwaukee, WI). A tube-flow phantom (3mm in inner diameter) was used to simulate the blood flow, and the average flow volume was set to 13.4 mL/min.

Results:
Scanning parameters were: sequence: GRE T2*, repetition time (TR) = 320.0 ms, echo-time (TE) = 11.0ms, Flip angle=15°, slice thickness = 5.0 mm, FOV=8×8cm, Matrix=320×256, Phase FOV=1.0 and NEX=2; A cucumber of regular shape was employed to test the spatial resolution and the longitudinal coverage capability of the proposed ILMA, and the corresponding scan parameters were: sequence: GRE T2*, repetition time (TR) = 200.0 ms, echo-time (TE) = 11.0ms, Flip angle=25°, slice thickness = 6.0 mm, FOV=8×8 cm, Matrix=320×256, Phase FOV=1.0 and NEX=4. Finally, a healthy New Zealand white rabbit, approximately 4 Kg in weight, was used to evaluate the abdominal artery wall, and the corresponding scan parameters were: sequence: Double IR FSE, repetition time (TR) = 800.0 ms, echo-time (TE) = 12.8ms, slice thickness = 2.0 mm, FOV=8×7cm, Matrix=256×224, and NEX=4. The SNR of MR images were estimated by: SNR = (S-N)/SD, where S is the signal amplitude of the region of interest (ROI) in the image, N represent noise and SD stands for the standard deviation of noise in the ROI.

Conclusion & Discussion:
As has been demonstrated, this study reports a new non-shielded MR imaging ILMA, which is different from the previous coaxial cable based catheter coil and loopless antennae [2]. The results suggest that the proposed ILMA can provide a larger longitudinal coverage for multi-slice vessel wall imaging with an acceptable SNR. It is worth mentioning that the flexible clinical-size guiding wire used in ILMA could be even thinner and thus easier to be manufactured, as it does not have any shielded wire at all. As a result, this type of antenna is convenient to be inserted into small vessels. In this study, since the guide-wire was touching the vessel wall (7 o' clock position), the signal of the vessel wall was overwhelmed locally, leading to a signal loss at partial artery wall. Although only the partial artery wall was observed in this study, it is believed that the loopless monopole based intravascular antenna can reveal more reliable diagnostic information on atherosclerosis in further study.

References: