Visualization of porcine gastric ulcer in vivo using intracavitary RF probe and its navigation system

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Purpose:
An endoscope provides information about the surface of tissue, but it does not provide cross-sectional information, such as the depth of tumor invasion. Visualization underneath the tissue surface is needed to improve the accuracy and safety of endoscopy and endoscopic surgeries. The high contrast of soft tissue, the lack of ionizing radiation exposure, and imaging with arbitrary slice orientation are advantages of using MRI instead of ultrasound and x-ray CT, although the imaging speed of MRI is a disadvantage. Therefore, we suggest an integrated MR-endoscope system that provides high-quality MR images with an endoscopic view and information of the scope position with orientation inside the body. The key components of this system, which are an RF coil[1] that is placed inside the gastrointestinal (GI) tract and navigation software[2] to show the scope location and orientation inside the body and MR images with a scope view, have already been developed. In this study, the MR imaging of a gastric ulcer model in animal experiments was conducted *in vivo* using this system, and the quality of these images was assessed.

Methods:
The gastric ulcer models in pigs (n = 2, weight: 32.8 and 34 kg) were formed by removing the mucosal and submucosal layers using an endoscopic surgery technique. We used a 1.5T MR scanner (Signa EXCITE TwinSpeed ver. 11, GE Healthcare), an MR-compatible endoscope (XGIF-MR30C, Olympus), and a tracking system (EndoScout, Robin Medical, Inc.) to detect both locations of the RF coil and the scope tip. In addition, a receive-only intracavitary RF coil (2-turn flexible surface structure with 40 × 50 mm^2)[1] and the navigation software we had previously developed were also used. The tuning and matching of the RF coil were roughly adjusted by considering shifts that could happen when the coil was placed inside the body. Tracking devices were attached to the RF coil and the scope tip. At first, the multi-slice MR images covering the stomach were obtained using the body coil by T2FSE (TR, 3000 ms; TE, 95.9 to 101.9 ms; ET, 10 to 20; RBW, 15.63 kHz; slice thickness, 3 to 5 mm; slice gap, 0 mm; FOV, 30 × 30 cm; acquisition matrix, 256 × 128; signal acquisition, 1 to 2; number of slices, 30 to 44). A 3D image based on these images was created using a multiplanar reconstruction (MPR) in the navigation software.[2] Next, the MR-compatible endoscope with the tracking device was inserted into the stomach to observe the ulcers and to measure their ulcer coordinates, which were then used to determine the imaging volume. The scope was removed from the stomach, and the intracavitary RF coil with the tracking device was inserted into the stomach and placed near the ulcer region. The navigation detected the location of the RF coil. The T1- and T2-weighted images by the RF coil were obtained using FSE (TR, 500 ms; TE, 21.4 to 27 ms; ET, 8 to 12; RBW, 10 to 15.63 kHz; FOV, 8 × 8 cm; slice thickness, 3 mm; acquisition matrix, 256 × 256; signal acquisition, 2 to 6 for T1WI; and TR, 3000 ms; TE, 110.1 to 119.3 ms; ET, 28 to 32; RBW, 10.42 kHz; FOV, 8 × 8 cm; slice thickness, 3 mm; acquisition matrix, 256 × 160 to 256; signal acquisition, 1 to 4 for T2WI). The digestive peristalsis was not suppressed, however the gastric cavity was inflated by CO2 gas to hold the cavity shape. The animals underwent general anesthesia during the experiment. In addition, their breathing was stopped by a ventilator during the MR scan.

Results:
The navigation successfully determined the imaging volume based on the ulcers' coordinates and indicated the location of the RF coil on the 3D image of the stomach. In two experiments, the averages of the resonant frequency and impedance of the RF coil placed inside stomach were 64.638 MHz and 40.2 ohm, respectively. The Q factor, which was measured for only one experiment, was 23.7. The resonance characteristic of the RF coil was not completely optimized. Nevertheless, the T1- and T2-weighted images showed the ulcer region (Figure 1); in particular, the defect of the mucosa and a part of the submucosa in the gastric wall were more clearly depicted in the T2-weighted image than in the T1-weighted image. This region in the T2-weighted image could correspond to a histological specimen (Figure 2). The SNRs of the mucosa, submucosa, and muscularis indicated in Figure 1 were 27.8 ± 2.5, 17.1 ± 1.7, and 11.1 ± 2.6, respectively, in the T1-weighted image and 29.2 ± 1.5, 53.5 ± 10.2, and 16.3 ± 2.2, respectively in the T2-weighted image. In addition, the CNRs of the mucosa versus the submucosa and the submucosa versus the muscularis were 10.7 ± 1.7 and 6 ± 2.3, respectively, in the T1-weighted image and 24.3 ± 9.9 and 37.2 ± 8, respectively, in the T2-weighted image.

Conclusion:
In these experiments, we demonstrated the ability to depict a gastric lesion with high spatial resolution MR imaging using the integrated MR-endoscope system. This can be useful for safer and more precise endoscopy and endoscopic surgeries. To improve SNR, the resonant characteristic of the RF coil placed inside body should be adjusted precisely and quickly using the remote tuning and matching technique. This would help shorten the total scanning time and provide a more accurate diagnosis. In addition, the control mechanism of the RF coil's posture inside the stomach should be established and the suppression of digestive peristalsis should be applied.

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References:
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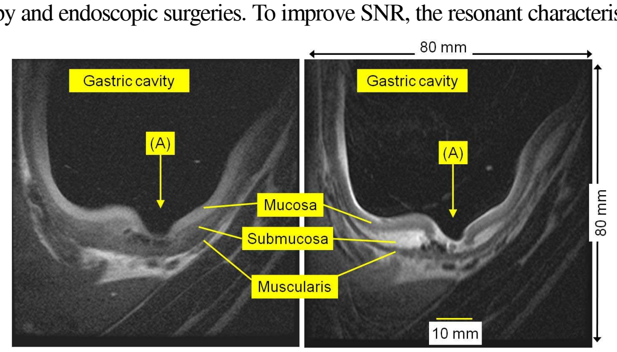

Figure 1: MR images of the gastric wall by the intracavitary RF coil; (left) T1-weighted image and (right) T2-weighted images. (A) indicates the defect of the mucosa and a part of the submucosa.

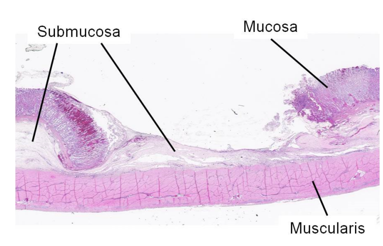

Figure 2: Histological specimen of the gastric ulcer region in Figure 1.