

MR Endoscopy vs EUS: A Comparison

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Introduction Endoscopic ultrasound (EUS) is a well-established, safe modality for real-time imaging of the duodenum and nearby ductal systems^{1,2}. However, all echo-ranging imaging suffers from artifacts, the most significant being reverberation between impedance discontinuities. As a result, concentric artifacts dominate the near field even when a balloon is used. Acoustic shadowing is caused by strongly reflecting structures (voids such as lungs and bowel; bone and gallstones), while enhancement is caused by weakly attenuating fluid-filled structures (bladder and cysts). These artifacts cannot be suppressed without eliminating the fundamental contrast mechanism, unless a nonlinear contrast agent is used. As a result, EUS images are patient and operator dependent, and often hard to interpret. Although slower, internal MRI may therefore offer advantages, and suitable gastroscopes have already been developed³⁻⁵. The aim of this paper is to compare the performance of a new MR-imaging duodenoscope⁶ with EUS.

Methods A MR-imaging duodenoscope was developed for ¹H MRI at 1.5 T from an earlier non-magnetic instrument (13 mm OD) with a side-opening biopsy channel and a fibre-based optical system. The instrument was constructed from plastics, non-ferrous metals and glass, and the main modifications were at the PEEK tip. A saddle coil was provided for signal reception, with an opening to avoid interference with the biopsy channel and optics. The coil was constructed from copper-clad Kapton, as a thin-film resonator with integrated capacitors (Fig. 1a). Immersion imaging of test coils was carried out to determine the field of view (FOV) (Figs. 1b and 1c). The coil was encapsulated in a detachable sleeve (16 mm OD). For patient safety, the output was taken via an internal saddle coil located in a cavity at the tip and magnetically coupled to the external coil (Figs. 2a and 2b). A PIN diode was provided for active decoupling, and the RF cable was routed with the fibre bundle to the handle (Fig. 2c). Imaging of *ex vivo* porcine liver specimens with attached gall bladder, biliary ducts and duodenum was carried out to determine image quality, using a GE Signa Excite. Imaging was carried using a 3D GRE sequence with TE = 15 msec, TR = 33 msec and a flip angle of 10°. Axial images were obtained in slices with 1.2 mm thickness and separation, using 4 NEX. Results were compared with EUS images obtained from similar specimens using an Olympus GF-UM2000 EndoEcho Gastrovideoscope (12.7 mm OD) (Fig. 3a), a 360° mechanical radial ultrasonic videoscope with a wide-band composite piezo-electric transducer. Its scan frequencies are 5, 7.5, 12 and 20 MHz, the focal point is at 20 mm (C5, C7.5 and C12) or 23 mm (C20), and the FOV is 20 - 120 mm. A water-filled balloon was placed around the transducer (Fig. 3b) and liver specimens were imaged in a water bath (Fig. 3c).

Results Fig. 4a shows an axial immersion MR image across a test coil. The signal falls off approximately as 1/r. However, small artifacts can also be seen close to each of the coil conductors. Fig. 4b shows a 3D reconstruction obtained from a set of axial slices in a tip assembly, thresholded to a low signal level. This envelope simultaneously highlights the useful limit of detection and the formation of additional artifacts by the modest decoupling provided by the coupled-coil receiver used for intrinsic safety. Fig. 4c shows an axial image and Fig. 4d a 3D reconstruction of a duodenum (D), each of which shows high SNR. Despite the limited FOV, a useful image is obtained to r = 4 cm, and signal is clearly obtained from the tissue body. In contrast, Fig. 5a shows a water immersion EUS image obtained at 20 MHz that again highlights non-uniform reception. The signal falls off exponentially with r, and the range decreases at the high frequencies needed for high resolution. A reverberation artifact extending to several times the tip diameter may also be seen. Figs. 5b and 5c show axial EUS images of the gallbladder (GB) at 5 MHz and duodenum (D) at 20 MHz. The bile duct (BD) can be seen adjacent to the duodenum but required inflation with agar gel for visibility. In each case, the range of the artifact compared with the anatomical feature size is significant, the image is only bright at impedance steps, and the SNR and contrast are both only moderate.

Conclusions Internal MR imaging offer similar advantages to EUS, namely the increase in SNR provided by the close location of the transducer to the target tissue. In each case, appropriate transducers may be incorporated into endoscopic instruments, and the FOV is similar. However, the images are corrupted by short-range artifacts, which differ in origin and significance. For internal MRI, the static artifacts are short-range, and mainly derived from incomplete decoupling; however, further work is required to determine the effect of motion and rapid acquisition is essential. For EUS, the artifacts are longer-range, and caused by impedance mismatches intrinsic to the modality itself.



Fig.1: a) Thin film saddle coils, b) coil mounted for testing, c) immersion imaging.



Fig.2: a) Diagram of MR-imaging duodenoscope tip, b) tip, c) handle of MR-imaging duodenoscope



Fig.3: a) GF-UM2000 EUS gastrovideoscope and c) *ex-vivo* imaging.

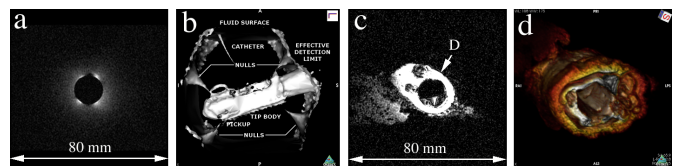


Fig.4: MR images: a) immersion, b) decoupling, c) and d) axial and 3D reconstructed images of porcine duodenum.



Fig.5: EUS images: a) immersion, b) gall bladder and c) duodenum.

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