

Intraoperative MR Image Guided Endoscopic Surgery on a Closed Bore MR Scanner

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Introduction

Open MR systems have enabled minimally invasive surgical procedures for thermoablation of liver tumors with rigid and straight puncture needles and electrodes. Continuously-acquired near real-time MR images were used to guide the needle to the target location. With this system, rigid endoscope could also be combined to assist image navigation as thoracoscope or laparoscope [1]. It is difficult to perform the same procedure on conventional closed MR scanners because of its poor patient access. Surgeon needs to have longer arm and shorter legs to puncture the ablation needle to the target lesion from the outside of the magnet bore. In addition, rigid endoscopy cannot be used in such systems. Introduction of a flexible endoscope helps to deliver the surgical tools to the targets from the outside of the bore. Endoscopy suffers narrow field of view and inability to see the target beneath the surface. Therefore, we propose an integrated environment where surgery can be performed with an MR-compatible flexible endoscope in a standard diagnostic closed bore MR scanner. We have developed a visualization system to navigate the endoscope for image-guided surgical procedures of thermal ablation. In this system, endoscope camera images and near real-time MR images controlled by the endoscope tip (ET) help to guide the endoscope to the target position at the magnet center from the outside of the bore. In this paper, preliminary results of animal experiment will be presented.

Methods

Microwave in vivo thermal ablation of medium size pig liver was conducted on a closed bore 1.5T Signa Excite system (GEHC, Milwaukee, WI). Surgeons stand on one side of the bore (Fig. 1a) and controlled a fibroscope inserted into the abdominal cavity through a port at the umbilicus. The MR-compatible flexible endoscope ($\phi 11\text{mm/L } 1025\text{mm}$ with 3 working channels) (Fig. 1b) transferred optical information at the tip. A 1.4 mm in diameter and 11 mm in length electromagnetic tracking sensor (Fig. 1c) *Endoscout* (Robin Medical, Baltimore, MD)[2] was placed at the distal end of the endoscope through one of the channels to track the ET. The other two channels was be used to carry MR-compatible microwave surgical instruments for ablation. Our navigation application was built with the capabilities to control MR scanner and to visualize the near real-time MR images. MR images were continuously acquired in the alternate two perpendicular planes controlled by the ET at every second as it advances to the target. Superimposition of the MR images and navigational information on the endoscope camera image was used to guide the endoscope, which was called *Endo-Director*. Reformatted images in the corresponding planes from preoperative 3D data were also used to improve image guidance.

Results and Discussion

We demonstrated a possibility of minimally invasive image-guided surgery using endoscope and continuously acquired MR images with a closed-bore MR scanner. This integrated system allows more accurate localization for the endoscopic surgical procedures. Comprehension of the full extent of the disease with definition of correct tumor margins and anatomic landmarks may improve surgical efficiency and diminish the invasiveness. Superimposed *Endo-Director* on the endoscope camera image provides the heading direction of ET as pan, tilt and roll (Fig. 2). Relative direction and distance to targets beneath the visual surface from the ET was also visualized in patient coordinate space. In addition, temperature changes of the target were also visualized on two orthogonal planes by proton resonance frequency method during the ablation. This integrated navigation system will provide a novel minimally invasive surgical procedure using conventional MR scanner.

References

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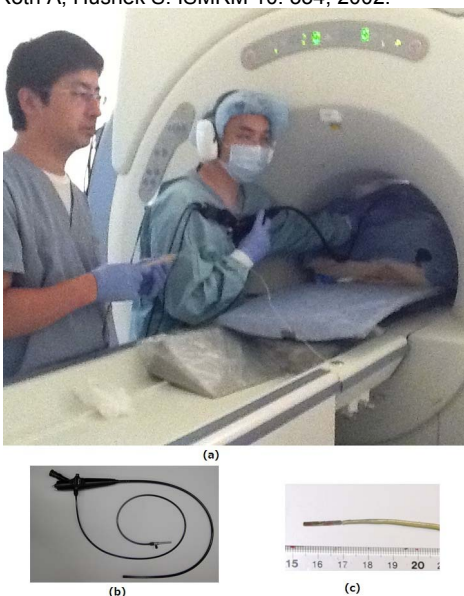


Fig.1 (a) Surgeon and assistance surgeon manipulate the endoscope from outside of the MR magnet bore during procedure. (b) MR compatible flexible endoscope/fiberscope equipped with (c) *Endoscout* a MR gradient sensing 6 coil electromagnetic catheter sensor placed through one of the active channel in the endoscope

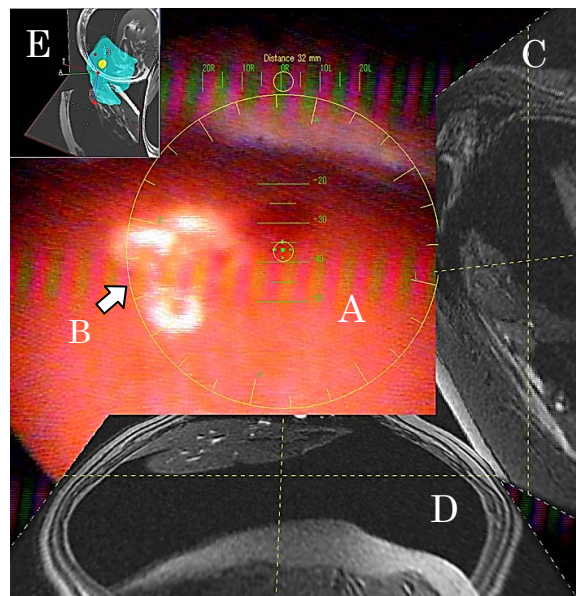


Fig. 2 (A) Endoscope camera image, (B) superimposed with *Endo-Director* shows the augmented target beneath the visible surface, (C)(D) are two orthogonal T1W near real-time image planes correspond to the ET updated in every second and (E) 3D display of liver boundary, target volume, ET and three orthogonal reformatted image planes from preoperative images