An integrated MR-endoscope for diagnosis of luminal organ

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Introduction

The magnetic resonance imaging (MRI) is much useful for the anatomical investigation such as excellent tissue contrast, absence of ionizing radiation, intra-operative imaging. However, as far as the noninvasive imaging technique of luminal region is concerned, it might be too difficult to visualize the anatomical structure and to diagnose the lesion precisely. Therefore, the diagnosis of the tumor infiltration in the luminal organ could not be facile. To overcome this limitation, a few MR-endoscope systems have been proposed [1]-[3]. In this study, we have proposed a dedicated MR-endoscope system that could provide the high quality image focused on the target area and has the feasibility for the both applications of the endoscopy and the MRI simultaneously. The proposed system is comprised of the navigation based on MR volume data obtained before the endoscopy, the motion compensation technique, the real time MR image processing, and the display of pre- and intra-operative images with the optical image via the endoscope.

Methods and Materials

The quality of MR image depends on the RF coil and its placement to the target region. When the RF coil is closed to the target, not only the resolution but signal to noise ratio (SNR) could be significantly increased. The 2-turn saddle type with copper wire in diameter of 0.2mm RF coil integrated on the endoscope tip was developed and mounted on the silicone tube in diameter of 12mm as the model of MR-compatible endoscope (XGIF-MR30C, Olympus Corporation, Tokyo, Japan). To track the endoscope tip position inside the body, the multi-element loop coil was made of the copper wire with the diameter of 0.1mm and built on the same silicone tube. These coils were tuned to the resonant frequency in 0.5T Open MRI (Signa SP/i, GEMS, Milwaukee, USA) and matched to 50 ohm (Figure 1). The navigation system consisted of AR (Augmented Reality) and VR (Volume rendering) was also developed. AR system has visualization capability of the live optical image via the endoscope, multi-plane MR images such as axial, sagittal, and coronal obtained before the operation and the MR image by the endoscope coil. VR system can control the MR volume data, which could be rotated by the endoscope tip location. Before the operation, the volume rendering process should be done with the obtained MR volume data. In this system, the motion compensation was also applied by using the synchronization of the respiratory phase, which was detected by an optical displacement detection system (AZ-733, Anzai Medical Co., Tokyo, Japan). With this method, the MR images displayed in AR and VR system were modified to the image correspondents with the respiration. The calculation process for this system is as follows; first, the volume data of the patient body, especially around the abdomen, should be obtained before the endoscopy, and needed to be processed for the 3D volume rendering. Second, the location of the endoscope in the patient body must be detected by the use of the MR scan with the tracking coil, and hence the accurate coordinate of the endoscope coil is calculated with this data. Third, the MR image of the target region should be acquired by using the endoscope coil closed to the surface of the interested tissue. Finally, these images and the information of endoscope position are indicated on the display of the AR and VR system. The scan with the tracking coil and the endoscope coil should be operated in such a way that the coil is selected automatically for the next data acquisition. In this stage, the ability of the endoscope coil was examined with the bucca of the volunteer, and the location of the endoscope was investigated in the water bath with the tracking coil. To simulate the navigation system, MR images for AR and VR system were collected and processed with the head image of a volunteer. Then, the optical image was taken in the mouth of same volunteer using the MR-compatible endoscope in imitation of the endoscopy in the MR room. The off-line process was done to superimpose these images.

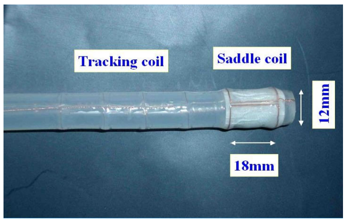

Fig.1: Endoscope coil and tracking coil

Results

Fig.2 shows the MR image by the endoscope coil placed inside the volunteer mouth acquired with SPGR, FA=10degree, TR=100ms, TE=8ms, RBW=7.81kHz, matrix=256×128, FOV=6×6cm, slice thickness=5mm, 2NEX. In this figure, the region near the coil was expressed well and the structure like the layer could be observed. The SNR in the bucca region was about 10. The image from the tracking coil shown in Fig.3 was obtained with SPGR, FA=10degree, TR=100ms, TE=15ms, RBW=6.94kHz, matrix=256×128, FOV=24×24cm, slice thickness=10mm, 1NEX. The signal around the loop coil was extracted clearly to detect the endoscope position accurately. Figs. 4 and 5 show the simulated display of the navigation system. Fig.4 was illustrated as AR system with 5 images; *A* was optical image of the endoscope, *B*, *C*, and *D* were the MR image of axial, sagittal, and coronal, and *E* was the MR image by the endoscope coil. Fig.5 was exhibited as VR system with 3 images; *F*, *G*, and *H* were perpendicular, in plane0, and in plane90 to the endoscope tip respectively.

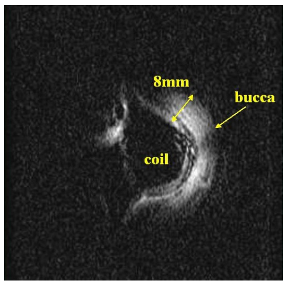

Fig.2: Oblique image of the endoscope coil

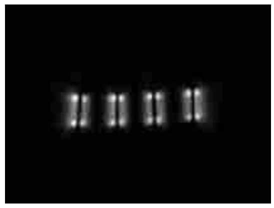

Fig.3: MR image of tracking coil

Conclusion

The image by the endoscope coil might have higher resolution than that by ultrasound endoscope system, and could facilitate the precise diagnosis of the luminal lesion as tumor invasion. The navigation system could have the useful information as the 3D volume image, the structure image of the tissue by MRI and the optical image by the endoscope lens. The proposed system should be worked out countermeasures to reduce the affect from the motion of the organ and the blood flow, but this problem could be settled. In conclusion, the newly developed MR-endoscope system could make the diagnosis of the endoscopy more accurate.

Acknowledgements

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References

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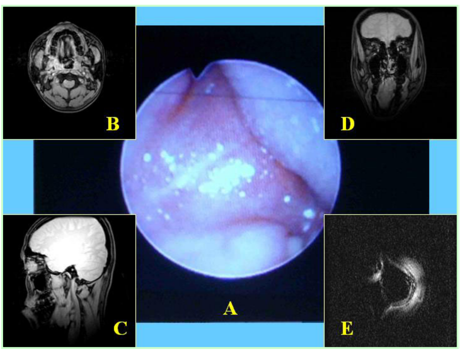

Fig.4: Simulated display for AR system

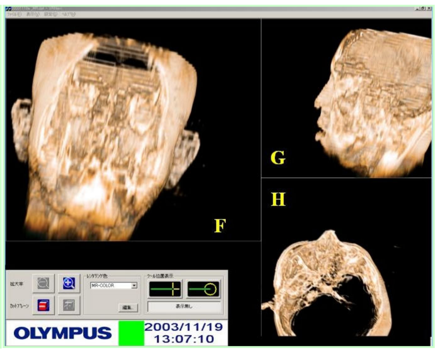

Fig.5: Simulated display for VR system