Clinical Use of Robot Assistance in MR Image-Guided Microwave Thermocoagulation Therapy of Liver Tumors

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INTRODUCTION

For the image guidance of minimally-invasive thermoablation of liver tumors, ultrasonography has been mainly used, but it is not easy to treat tumors in the deep part or critical part close to the lung or colon using it. For the treatment of such tumors, navigation with real-time MR images is useful[1)]. Endoscopic assistance and navigation software have been also combined with MR image guidance[2)]. In this procedure, the choice of the optimal puncture route is an important and time-consuming process. To assist this process in MR image-guided microwave thermocoagulation therapy of liver tumors, we have developed a motorized robot with a virtual remote-center-of-motion control. The applicability of the robot for the clinical use was confirmed to start clinical study.

MATERIALS AND METHODS

An open configuration MR scanner, 0.5 T GE SIGNA SP/i, was used. The robot consists of a passive end effecter with 2-degree-of-freedom rotation and active 3-degree-of-freedom XYZ-base stages with 3 ultrasonic motors, which automatically chased the preset target point with a virtual RCM control. A hand piece of an optical tracking system was also fixed to the end effecter and controlled the image plane for real-time MR images. A mechanical fuse was prepared on the robot arm for the safety of patients. When the force to the robot arm exceeds the threshold level, the joint is released and the arm goes up. A ratchet mechanism easily keeps the arm at the lifted position and returns it to the original position. An electrical shut-down switch was also prepared for an additional safety mechanism. The clinical use of this robot for microwave ablation of liver tumors was approved by the Ethics Committee of Shiga University of Medical Science.

RESULTS AND DISCUSSION

The virtual RCM control worked properly in the strong magnetic field. The root mean square errors of the needle tip position by robot control compared to the information by the optical tracking system were 1.69 mm with a 5 cm needle and 1.64 mm with a 15 cm needle. By shielding the cables of the ultrasonic motors, the noise in MR images were negligible even during the robot arm was moving. The mechanical fuse could sufficiently guarantee the patient safety. Actually, the authors were the first volunteers. When the robot arm intentionally pressed a volunteer, the mechanical fuse spontaneously snapped without causing actual pain. At the lifted position, the robot arm can not touch the volunteer physically. After the confirmation of the safety issue, we have commenced the clinical use of this robot. The end effecter including the robot arm was sterilized. All the preparation process including the assembling of the robot, docking to the magnet and automatic calibration to the magnet coordinates could be completed within 10 minutes. The first case was 64 years old female with a metastatic liver tumor from colon cancer. The surgeon easily targeted the tumor with robot assistance (Fig. 1). In this case, 4 sessions of microwave ablation were performed at different locations. Our navigation software clearly showed the tumor volume, treated and untreated areas (Fig. 2). We could set the next target point in this software and directly instruct this point to the robot. The robot immediately led the surgeon to this point and the procedure completed accurately and quickly. Other cases of liver tumors are subsequently scheduled for this procedure. At present, however, there is a limitation of the applicable locations of tumors, because both the visibility of the optical tracking system and the moving range of the robot arm need to be satisfied. Endoscopic assistance is not available in combination with this robot, because of the limited space in the magnet. Further improvements of the robot mechanism to increase the applicability are now in progress. The advantage of the robot will need to be certified with clinical data.

REFERENCES

1. Morikawa S, Inubushi T, Kurumi Y, et al. J Magn Reson Imaging 16: 576-583, 2002.
2. Morikawa S, Inubushi T, Kurumi Y, et al. Acad Radiol 10:180-188, 2003.

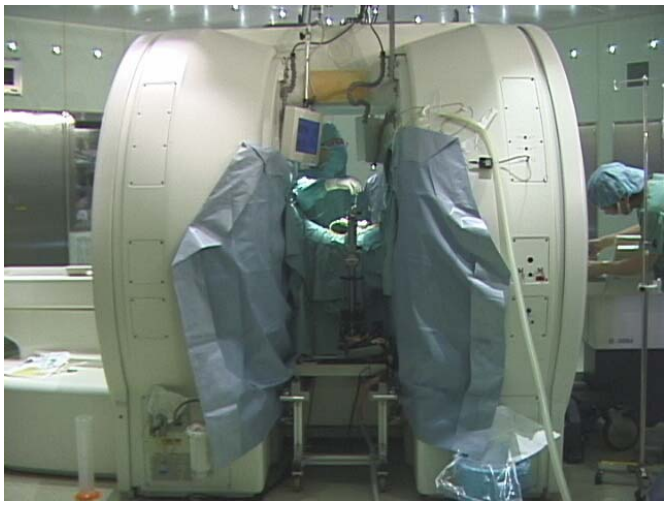

Fig. 1 A clinical case of microwave thermocoagulation therapy of liver tumor assisted by the robot. A surgeon and the robot are facing each other on both sides of the patient in the magnets.

Fig. 2 A display of our navigation software. The upper left 2 windows are real-time MR images in 2 perpendicular planes and lower left 2 windows are reformatted images from 3D data in the corresponding planes. The tumor area is shown in red. In the 3D display (upper right), tumor volume is shown in yellow and the treated volume is shown in blue.