Increased applicability of a manipulator to assist MR guided microwave ablation of liver tumors and clinical experiences of 14 cases

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INTRODUCTION

We have developed a motorized MR-compatible manipulator with a remote-center-of-motion (RCM) control to assist MR guided microwave ablation of liver tumors[1)] and started clinical studies using it. Our preliminary experiences of the initial two cases have been reported at the previous ISMRM meeting in Toronto[2)]. The manipulator was designed to puncture liver tumors from the anterior abdominal wall and liver tumors in the lateral segment were selected as the initial two cases. In such a situation, however, the manipulator could be applied only to some limited cases. In order to increase the applicability of this manipulator, we have developed several types of adaptors for the hand piece. The improvements of the manipulator and our experiences of 14 clinical cases are presented in this study.

MATERIALS AND METHODS

An open configuration MR scanner, 0.5 T GE SIGNA SP/i, was used. The manipulator consists of a passive end effecter with 2-degree-of-freedom rotation and active XYZ-base stages with 3-degree-of-freedom translation using 3 ultrasonic motors, and chases the preset target point with a synergetic virtual RCM control. A hand piece of an optical tracking system was also fixed to the end effecter and controlled the image planes for real-time MR images. Four types of adaptors have been developed to puncture liver tumors from the lateral side of the patients (Fig. 1). Accordingly, the control systems of the manipulator and the optical tracking system were modified to use these adaptors. This manipulator has been used in 14 clinical cases of MR image guided microwave ablation of liver tumors. A summary of the cases is shown in Table1.

Table 1 Summary of the cases

No.	Age/Sex	Origin	No. of lesion	Location	Diameter (mm)	
1	64 F	colon	1	S3	20	
2	54 M	HCC	1	S3	12	
3	63 M	stomach	1	S5	30	
4	84 F	HCC	1	S5	30	
5	60 M	HCC	2	S5, S8	20, 7	Th
6	56 F	intestine	1	S7	35	
7	82 M	HCC	1	S8	25	Th
8	76 M	HCC	1	S7	35	
9	70 M	colon	4	S4x2, S6x2	20,25,15,20	Th
10	50 M	colon	2	S4, S8	17, 10	Th
11	74 M	HCC	1	S7	15	
12	74 M	colon	1	S6	10	
13	62 M	HCC	2	S6x2	20,12	
14	62 M	HCC	2	S8x2	15,15	Th

HCC: hepatocellular carcinoma; Th: Thoracoscopy(+)

RESULTS AND DISCUSSION

The virtual RCM control worked properly with either adaptor. Calibration between the magnet and manipulator coordinates was required only once at the beginning of the procedure and the adaptor could be easily changed during the procedure without calibration. These adaptors enabled to puncture liver tumors in various locations of the right lobe. As a result, all the tumors shown in table 1 could be successfully punctured using the manipulator and no complication has been experienced. In 5 of the 14 cases, tumors were punctured through the diaphragm with thoracoscopic assistance (Fig. 2, 3). The adaptors were used in all cases except for the initial 2 cases. In this procedure, multiple punctures and ablations are usually required. Our navigation software can record the parts of already ablated regions and we could set the sequential target points for the manipulator at the untreated part of the tumor on this software. The manipulator directly received this information and immediately led the surgeon to the next target point. The manipulator was quite helpful for the accurate treatment and substantially reduced the stress and workload of the surgeons. At the initial stage, suitable cases were selected for the use of this manipulator, but after the Case 3, this manipulator was used in all cases of MR guided microwave ablation of liver tumors.

In conclusion, these adaptors increased the applicability and feasibility of the manipulator. Now, this manipulator is effectively and routinely used in MR guided microwave ablation of liver tumors at various locations..

REFERENCES

1. Hata N, et al. J Magn Reson Imaging 27:1130-1138, 2008.
2. Morikawa et al. Proc ISMRM, Toronto, 2008. (abstract 3010)

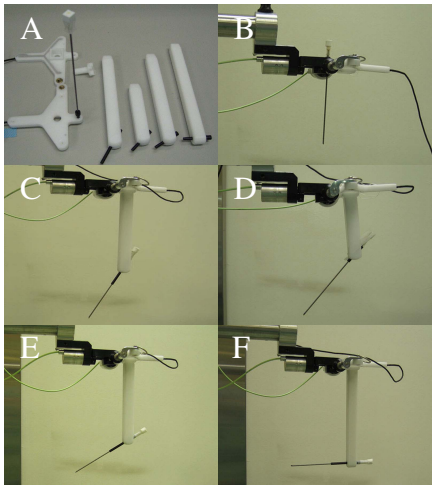

Fig. 1 Adaptors for the puncture from lateral side. A hand piece of the optical tracking system was modified to attach adaptors (A). Without (B) and with adaptors for 30° (C), 45° (D), 60°(E), and 90° (F) angled punctures.

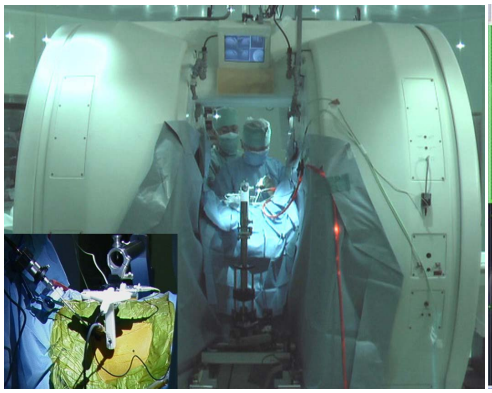

Fig. 2 A case of MR-guided microwave ablation of liver tumors. A surgeon in the magnet is using both the manipulator and thoracoscope. Thoracoscope and an electrode of microwave inserted to the patient.

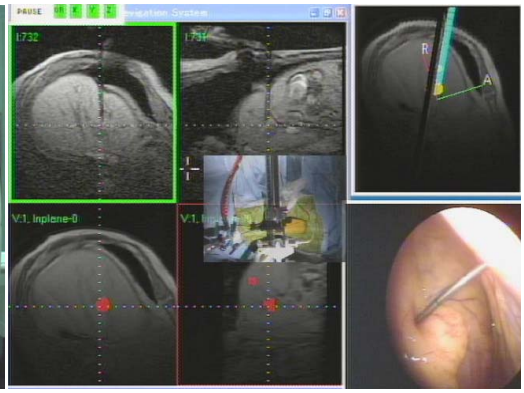

Fig. 3 A display of our navigation software for the surgeon, Real-time and reformatted images in 2 perpendicular planes are displayed in combination with a thoracoscopic image.