Motorized remote-center-of-motion constraint robot to assist MR-guided microwave thermocoagulation of liver tumors

S. Morikawa[1], N. Hata[2], T. Inubusi[1], K. Demura[1], K. Murakami[1], M. Morita[1], S. Naka[1], Y. Kurumi[1], H. A. Haque[3]

[1]Shiga University of Medical Science, Ohtsu, Shiga, Japan, [2]Brigham and Women's Hospital, Boston, Massachusetts, United States, [3]GE Yokogawa Medical Systems, Hino, Tokyo, Japan

SYNOPSIS

In order to assist MR image guided microwave thermocoagulation therapy of liver tumors, we have developed a motorized robot, which consists of a passive end effecter with two-degree-of-freedom rotation and active XYZ-base stages with three-degree-of-freedom. The remote-center-of-motion constraint of this robot worked properly in the magnet to catch the target from various positions and it is helpful for surgeons to choose optimal puncture route. The design of this robot is also competent for the clinical use in the near future.

INTRODUCTION

In MR-guided microwave thermcoagulation therapy of liver tumors with an open configuration MR system, interactive real-time MR images are utilized for the guidance of puncture (1). The choice of the suitable puncture route, however, is a time-consuming process. Injury of the lung, large vessels and bile ducts must be carefully avoided. The route through the rib cannot be applied. To assist this process, we have developed a portable motorized robot competent for the clinical use. In this paper, the outline and the accuracy of remote-center-of-motion constraint of this robot will be presented.

MATERIALS AND METHODS

An open configuration MR scanner, 0.5 T GE SIGNA SP/i, was used. Spoiled gradient echo images with 14 ms TR and 3.7 ms TE were continuously acquired in the planes interactively controlled with an optical tracking system. The robot consists of a passive end effecter with unconstrained two-degree-of-freedom rotation measured by optical fiber sensors and three-degree-of-freedom active XYZ-base stages with 3 ultrasonic motors (Fig. 1). The target position determined from 3D volume data was instructed to the robot. The motorized 3 base stages kept the needle tip position at the defined point using remote-center-of-motion constraint. The end effecter can be separated from the robot arm. A specially designed hand piece of the optical tracking system (Fig. 2) can be also attached to and detached from the end effecter easily. The accuracy of the remote-center-of-motion was examined by recording the position of the optical tracking system while changing the direction of the effecter around the X and Z axes.

RESULTS AND DISCUSSION

Turning on the switch of the robot inserted into the magnet gap did not cause any adverse effects on MR images. During active movements of the ultrasonic motors, however, substantial noises appeared. We need to wait for the next MR image to monitor new puncture route. More complete shielding of the ultrasonic motors will improve the feasibility of this robot. On the other hand, the robot worked properly in the magnet. The target point was always appeared at the center position of MR images by remote-center-of-motion constraint. Surgeons can easily choose the puncture route by controlling the orientation of the effecter while monitoring continuously acquired MR images. When the effecter was tilted around the X and Z axes, the points determined by the optical tracking system fluctuated a little bit. The root mean square values of the actual positions from the initial one were summarized in Table 1. These values seem to be sufficiently small for the puncture of liver tumors. As the first clinical trial, we are planning to use this robot only for the guidance of the puncture route. After the determination of the route, the hand piece of the optical tracking system will be passed from robot to surgeon. Therefore, the mechanism for easily detachable hand piece is important. Considering of the clinical utilization, the separation of the end effecter will be necessary for the sterilization. Thus, this robot is adapted for the clinical use in the near future after the confirmation of safety issues.

REFERENCES

1. Morikawa S, Inubushi T, Kurumi Y, et al. J Magn Reson Imaging 16: 576-583, 2002.

Table 1 Root mean square values **of the actual positions from the initial one in the 3 axes with various directions of the effecter.** The directions were changed approximately by 5 degrees around the X and Z axes.

	X (mm)	T (mm)	Z(mm)
around X (11 directions)	0.38	0.67	1.74
around Z (14 directions)	1.44	0.62	0.73

Fig. 1 Robot placed in the magnet (left) and outside of the magnet (right).

Fig. 2 Specially designed hand piece of optical tracking system attached to the end effecter.