Intelligent Medical Robots based on Physical Model of Human Tissue

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Abstract — Mechanical engineering is a crucially important area to promote collaboration between medical and engineering fields. We introduce here our contribution for proactive activities for a healthier society with intelligent medical robots based on physical model of human tissue.

I. INTRODUCTION

Facing an elderly dominated society, Robot Technology (RT) is expected to play an important role in medical areas. It is important for robot control to use mechanical properties of human body, such as material mechanics, dynamics, thermodynamics and fluid dynamics. Therefore, we have developed medical robots which are controlled using this information, such as soft tissue stiffness, organ thermal conductivity. This means, that we transform knowledge acquired by the surgeons through experience into mechanical quantitative properties. In our group, we work in close cooperation with medical institutions. Based on these considerations, we briefly introduce here a robotic system to assist in needle insertion therapy for RFA.

II. NEEDLE INSERTION ROBOT

The use of minimally invasive procedures for breast tumor diagnosis and treatment, such as catheter insertion, needle biopsy and radiofrequency ablation (RFA), is steadily increasing. Accurate needle insertion requires solving the problems of tissue deformation and target displacement. Therefore, we have been developing a robotic needle insertion manipulator [1] and method with physical model to improve the precision of needle insertion. Our research group has been developing a FEM-based viscoelastic and nonlinear deformable model of the liver, as well as a probability-based model of puncture conditions. We also reported in this article was to develop a planning method to determine the needle insertion path into the liver using the deformable model and the puncture conditions. Specifically, the planning method provides for evaluating the expected value of needle placement accuracy and choosing a robust insertion path for a variety of puncture conditions.

III. RADIO FREQUENCY ABLATION THERAPY

Radio frequency ablation (RFA) is an important modality to treat cancers and is been used increasingly over the past few years. However, it is difficult for operators to control precisely the formation of coagulated areas because of the limitations of medical imaging modalities. To overcome this limitation, we proposed previously a model-based robotic ablation system that can create the required size and shape of coagulation zone based on the dimensions of the tumor. At the heart of such a robotic system is a precise temperature distribution simulator for RF ablation. We also evaluated the accuracy of a temperature-dependent thermal conductivity model with our initial constant thermal conductivity numerical simulation liver model. The results of both simulators we compared against the temperatures obtained during RFA in vitro experiments. The liver model that used the temperature dependence of thermal conductivity did not result in a large increase of simulation accuracy compared with the temperature-independent model in the temperature range achieved during clinical RF ablation [3].

Figure 2. Comparison of appearance between actual liver and model [3].

REFERENCES