Changes in ultrasonic images of tissue damaged by high intensity focused ultrasound in vivo

Feng Wu, Zhi B. Wang, Zhi L. Wang

Institute of Ultrasonic Engineering in Medicine, Chongqing Medical University, Chongqing 400046, P.R. of China

Abstract: In order to clarify the effects of high intensity focused ultrasound (HIFU) on the liver in vivo, the morphological changes in a large animal model were detected by ultrasonic image. One region of the liver was selected as a target tissue by ultrasonic imaging. Then, using the method of focal planes, the target part of the liver was resected by ultrasound-monitored HIFU with a 1.6MHz extracorporeal spherical-bowl transducer. Ultrasonic images of liver at the selective region were acquired before, immediately, and consecutively after HIFU treatment. The big difference of ultrasonic image at the selective damage of liver in vivo before and after HIFU treatment was detected by diagnostic ultrasound. It was observed immediately after focused extracorporeal pyrotherapy. Sharp changes in ultrasonic image were also detected by consecutive monitoring after treatment. These results suggest that as a method to detect necrosed tissue, the ultrasonic image may also be used as an indicator of morphological changes after HIFU treatment.

INTRODUCTION

As a new therapy characterized by local treatment of tumor, High Intensity Focused Ultrasound (HIFU) has been undergoing great progress in recent years. With its physical properties, HIFU can produce hyperthermal effect and cavitation. And without operation it can cause immediate destruction to deep tissue with little effect upon those around. In our laboratory B-mode ultrasound scanner was used to select precisely the deep-seated tissues to be treated with HIFU. In order to clarify the effects of HIFU on tissue in vivo, some studies were designed to detect morphological changes of the tissue damaged by HIFU with MR imaging and CT. Based on studies on changes in ultrasonic echoic images of lesioned tissues, our study explored the feasibility of utilizing diagnostic scanner in monitoring and quantifying the effects of focused thermotherapy.

MATERIALS AND METHODS

Animals After 12 hours of starvation, depilation, degasificoton, and derosinaton were performed on skin areas of upper abdomen after 28 pigs receiving intra-abdominal anesthesia with 3% pentobarbital sodium (30mg/kg). Using B-mode ultrasound to diagnose the HIFU sonicated tissue structure of the swine’s left liver lobe under the xiphoid, the correlation between localization or the depth size of ablative lesions receiving hyperthermia treatment and the adjacent tissues was determined.

HIFU Therapeutic Unit Computer controlled, the unit is capable of moving in X, Y, Z directions and automatically positioning and treating target tissues. The therapy transducer was developed on the basis of lens focussing theory with a volume of 1.1mm×1.1mm×4mm, a frequency of 1.6MHz, a focal length of 120mm, and an output acoustical power of 4920W/cm².

HIFU Sonication Two focal planes received HIFU sonication. A single pulse lasted 3 seconds, with an interval of 2 seconds between two pulses. The therapy transducer was shifted to a new focal plane after comple-
tion of sonication on one plane. During the interval between each two pulses, the ultrasonic imaging system was employed to collect ultrasonic images that were to be stored in a computer. The computer automatically compared changes in ultrasonic image pre and post-treatment. Within 4 weeks posttherapy, Color and Pulsed Doppler Ultrasound was regularly used to retrace the changes in ultrasonic images and blood perfusion of damaged liver tissues.

RESULTS

Relations between acute tissue damage of in vivo miniswine liver and ultrasound images Changes in ultrasonic images of the preselective liver tissues were seen immediately after a single pulse of HIFU. The changes were mainly shown in increased echoes of damaged tissues. The area of damaged liver tissues expanded with the increase of pulse times, and the enhanced echoic area of B-mode ultrasound also extended. Ultrasound scanner was used to calculate the area of damaged liver tissues following HIFU sonication. The abdomen was cut open after anesthesia, and the area of swine liver tissues damaged by HIFU was examined. The lesion was found to be a constitution of three parts: the central area of pale acute coagulating necrosis ring of congestive area, and an area of subacute necrosis in between. The ratio between the total area of lesion and that calculated by B-mode ultrasound was 3:1; a proportion of 1.5:1 was found between the area of acute coagulating necrosis and the increased echoes with diagnostic ultrasound.

Changes in ultrasonic images of the liver tissues damaged by HIFU A day after HIFU sonication, echoes of the damaged liver tissues were found to be gradually weakening, but the margin was vague. Within 1-3 days echograms did not change much but were still stronger than those observed in normal liver tissues. More significantly, the margin became gradually clear. 7 days later gradual shrinking of damaged liver tissues was witnessed. The echoic level entered a new low and even lower than that of the normal liver tissues. On the 28th day, the lesion was only 30% of that observed on the first day.

DISCUSSION

As a minimally invasive surgery, HIFU has been proven by most animal experiments to be able to play an important role in resection of deep-seated tumors in vivo. High demands, therefore, must be put on the effectiveness and safety. In recent years, the rapid development of imaging technology has made it possible to use diagnostic ultrasound scanner as a tool of pretreatment positioning and treatment monitoring. The apparatus we developed boasts synchronous functions of tissue damaging and ultrasonic imaging and is able to meet the needs of both preclinical large animal experiments and clinical trials. It is essential that the sonication access and target area be determined with diagnostic ultrasound scanner before treatment. Special concern should be given to organs adjacent to the liver, especially to the stomach full of air. Draw out the gastric air if necessary. During the interval between two pulses in our experiment, diagnostic ultrasound scanner was used to take sonograph of the target area. This enabled us to learn about the effectiveness and ensured the safety of HIFU treatment. The obvious ultrasonographical changes of the target area indicated that diagnostic scanner was important in detecting the therapeutic effect of HIFU. Computer controlled, the diagnostic ultrasound scanner could finish collecting information within seconds. Such a short time exerted little impact on therapy time. The timely monitoring of therapeutic effect ensures the safety and effectiveness of ultrasonic sonication. In comparison with the target area in vivo, the area of increased echogenicity was found to be highly relative to the area of actual lesions. Besides, rules in the changes of ultrasonic imaging of damaged liver tissues were also explored. These findings provided significant laboratory data for the observation of pathological change in tumor ablation with HIFU.