A Prototype MR Compatible Positioning Device for Guiding a Focused Ultrasound System for the Treatment of Abdominal and Thyroid Cancer

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ABSTRACT

A prototype magnetic resonance imaging (MRI)-compatible positioning device that navigates a high intensity focused ultrasound (HIFU) transducer is presented. The intended application is to treat eventually tumours in the abdominal and thyroid. The positioning device has 3 user-controlled stages that allow access to various targets using a top to bottom coupling approach. Materials and Methods. The positioning device incorporates only MRI compatible materials such as piezoelectric motors, ABS plastic, brass screws, and brass rack and pinion. Results The MRI compatibility and the accuracy of the system were successfully demonstrated in an open MRI scanner. The robot has the ability to accurately move the transducer thus creating discrete and overlapping lesions in rabbit liver in vivo. This simple, cost effective positioning device can be placed mostly on the structure of an open MRI gantry. Due to the size of this positioning device, the proposed prototype in its current form cannot be used in any closed MRI system. The novelty of this positioning device is the MRI compatible design and its intended application which is the treatment of tumors in the abdominal area using focused ultrasound. This system can be utilized in the future to treat patients with cancer in the liver, kidney, pancreas and thyroid provided that the accuracy of the positioning device is greatly improved.

Keywords: Abdominal, Magnetic Resonance Imaging (MRI), Robot, Thyroid, Ultrasound

1. INTRODUCTION

High intensity focused ultrasound (HIFU) has the potential to induce thermal changes in tissue and therefore it is used extensively for medical applications (Stewart et al 2006). Nowadays HIFU is utilized to selectively heat biological tissues for oncological applications with minimal invasiveness by using magnetic resonance imaging (MRI) to provide, to the

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operator performing the procedure, images of a region within the subject being heated.

HIFU was explored in almost every tissue that is accessible by ultrasound. The following literature represents some examples of some applications explored: eye ablation for the treatment of Glaukoma (Lizzi, 1978), prostate ablation using ultrasound guidance (Chapelon, 1992), liver ablation for the intention to treat cancer (Haar, 1989), brain ablation for the intention to treat cancer (Lele, 1962; Vykhodtseva, 1994) and kidney ablation for oncological applications (Linke, 1973; Hynynen, 1995; Bihrlre, 1994).

In commercial systems (for example, (Chapelon, 1992; Bihrlre, 1994; Hynynen, 2001) HIFU is either guided by ultrasound or MRI. Ultrasonic imaging is the simplest and most inexpensive method to guide HIFU, however MRI offers superior contrast than ultrasound, having the only disadvantage that is more expensive.

In order to treat large areas by creating tissue necrosis the HIFU transducer which has focal beam of few mms should be moved to create overlapping lesions. The positioning device is responsible for this motion and should operate inside the MRI scanner. The use of the positioning device inside MRI scanner may interfere with the RF field and as a result the quality of the images captured could be harmed. Therefore all the components must be non-magnetic materials. Generally the positioning device has to be small to fit the gantry MRI scanners. An MRI compatible robotic system refers to a system that is not hazardous in any way and neither generates any interference to the MRI scanner nor affected by the strong electromagnetic field of the MRI scanner (Gassert, 2008).

The combination of ultrasound and MRI was first cited by Jolesz and Jakab (Jolesz, 1991) in 1991 who demonstrated that an ultrasonic transducer can be used inside a MRI scanner. The idea of using MRI to guide HIFU transducer to achieve necrosis on a tissue was originally introduced in 1993 by Hynynen (1993) and this study showed that lesions produced by HIFU on a canine muscle in vivo inside MRI were clearly visible. Therefore the idea of using MRI to guide a real time non-invasive surgery with HIFU proved to be feasible. Later several studies (Cline, 1992; Hynynen, 1994; Verghese, 2011) showed that the contrast between necrotic tissue and normal tissue is superior when compared with ultrasound imaging and this proves that MRI is an excellent tool for therapy guidance. As a result the use of MRI to guide HIFU systems increased rapidly in subsequent years.

The robotic system of patent by InSightec (Yehezkeli, 2002) uses piezoelectric motors to move the transducer inside an MRI scanner. InSightec produced the system ExAblate 2000 which is the first commercial system for the treatment of uterine fibroids using HIFU with MRI guidance and received the Food and Drug Administration (FDA) approval in 2004. InSightec reported that more than 8,000 patients have been treated with ExAblate system worldwide since 2011 (Thompson, 2011). Furthermore, according to InSightec the ExAblate system can also be used to treat prostate cancer, breast cancer, adenomyosis, and for pain palliation of bone metastases. The ExAblate 2000 system is embedded on the patient’s table which is compatible with the bore of both 1.5 Tesla and 3 Tesla MRI Systems.

Sonalleve MR-HIFU is a commercial HIFU system by Philips Healthcare Philips Healthcare, Netherland (Moonen, 2008). This MR guided robotic system is 5 DoF positioning system and is integrated with the HIFU transducer on the patient’s table. The Sonalleve MR-HIFU system, received the CE mark for clinical use in December 2009, and offers a non-invasive alternative to the traditional surgical treatments for uterine fibroids in women.

Profound Medical Inc. (PMI) is based in Toronto, Canada, and founded in 2008 (Thompson, 2011) focuses in the treatment of prostate cancer. PMI has developed an MRI-compatible ultrasound energy wand to deliver controlled thermal therapy to the regions of the prostate gland via a trans-urethral approach using small unfocused transducer elements.

The MR guided HIFU robotic system proposed by Damianou et al. (Damianou, 2008) has three DoF and is small and portable and it
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www.igi-global.com/article/emotional-prediction-and-content-profile-estimation-in-evaluating-audiovisual-mediated-communication/133283?camid=4v1a

Conclusion
www.igi-global.com/chapter/conclusion/76168?camid=4v1a