Quality Assurance Testing of Clinical MRgFUS System

K. R. Gorny[1], G. K. Hesley[1], N. J. Hangiandreou[1], J. P. Felmlee[1]
[1]Radiology, Mayo Clinic, Rochester, Minnesota, United States

Introduction

Magnetic Resonance guided Focused Ultrasound Surgery (MRgFUS) is an emerging technique, rapidly gaining acceptance as a non-invasive alternative to surgical treatment of uterine fibroids. Magnetic Resonance (MR) imaging of the patient is used to plan the treatment and guide the focused ultrasound (FUS) treatment. FUS sonications are used to treat the fibroid by rapidly raising local tissue temperatures to levels sufficient to ablate tissue [1]. MR images acquired during treatment are used to measure and display temperature maps superimposed with anatomical images providing real-time treatment evaluation [2]. Since MRgFUS is a therapy device designed to thermally ablate tissue, it is essential that adequate quality assurance tests, using homogeneous tissue mimicking phantoms, are routinely performed. However, MRgFUS is a relatively new technique and, at present, very little published work exists addressing this issue [3].

Methods and Materials

Our tests were performed on ExAblate® 2000 MRgFUS system (InSightec, Haifa, Israel) using uniform tissue mimicking phantoms provided by the vendor. In ExAblate® 2000 the temperature maps can be obtained in three orthogonal MR scan planes: coronal, axial, and sagittal. The coronal scan plane is that which is perpendicular to the propagation of ultrasound (US) pulses in these experiments. To assess the precision of temperature measurements, we performed a series of 30 identical sonications for each of the scan planes, using nominal slice thickness of 5mm and treatment parameters similar to those used in clinical studies. In a second set of tests, we measured the temperatures in the three planes for 3, 5, and 7mm slice thicknesses, for 5 available US beam focal size diameters. At each slice thickness a set of 5 sonications was performed for each plane, for each focal size. In a third set of “reciprocity” tests, the temperatures in the coronal plane were measured while systematically varying acoustic output and sonication duration keeping the deposited acoustic energy constant at 1700J. At each output level, 5 independent temperature measurements were collected. The reciprocity tests were repeated using the MRgFUS system before and after repair of water leakage in the FUS transducer.

Results

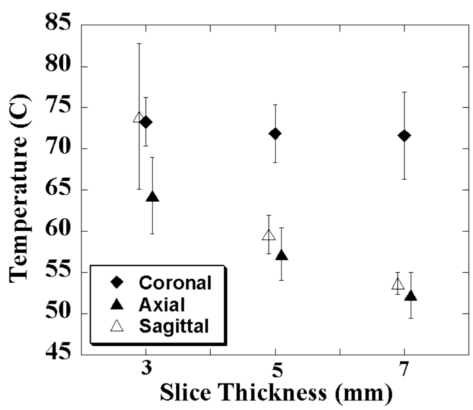

Figure 1: Temperature in three scan planes versus slice thickness.

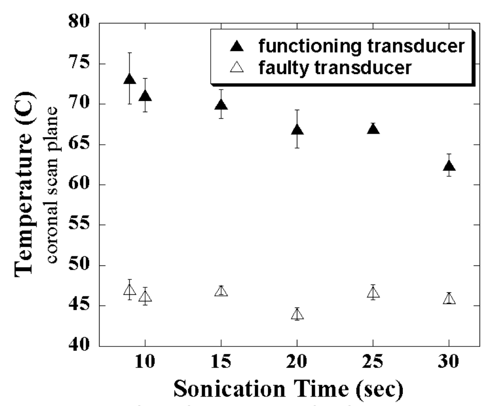

Figure 2: Reciprocity tests. Sonication energy = 1700J.

We show a systematic difference between temperatures measured in the coronal and both the axial and sagittal scan planes. The average measured temperatures were 74.6 ± 1.8°C in the coronal, 57.5 ± 2.2°C in the sagittal and 52.5 ± 1.7°C in the axial scan planes, respectively. As shown in Figure 1, the temperature differences diminish with decreasing slice thickness demonstrating that this discrepancy can be attributed to partial volume effects. The temperature differences also diminish with increasing focal spot diameter. Reciprocity test data are displayed in Figure 2. For the properly functioning transducer the measured coronal plane temperatures decrease with increasing sonication time, an effect that is a result of heat dissipation in the TM phantom. For the faulty transducer, the temperatures are significantly lower and independent of sonication time.

Conclusions

While it is equally important to monitor temperatures in the coronal and axial or sagittal scan planes during patient treatments – we show that the coronal scan plane is least affected by partial volume effects. We also demonstrate the importance of routine QA tests for MRgFUS systems, where the reciprocity test has been employed to detect instances of FUS transducer problems prior to patient care.

References

[1]. Sapareto S. A., Dewey W.C., Int. J. Radiat. Oncol. Biol. Phys. **10** (6), 787-800, 1984
[2]. Vitkin I.A., *et al*, Med. Phys. **24** (2), 269-277, 1997
[3]. Wu T., Felmlee J.P., J. App. Clin. Med. Phys. **3** (2), 162-167, 2002