

Feasibility of using Magnetic Resonance-guided High Intensity Focused Ultrasound (MRgHIFU) to perform ablative and hyperthermia interventions in the neck area: A preliminary *in vivo* study.

Samuel Richardson^{1,2} and Kullervo Hynynen¹

¹Physical Sciences, Sunnybrook Research Institute, Toronto, ON, Canada, ²Electrical Engineering, Physics, Lakehead University, Thunder Bay, ON, Canada

Introduction. Tumours in head and neck represent a challenge in oncology because the important presence of critical organs in that area. A more targeted treatment is desired to reduce risks of morbidity. This paper presents preliminary results to establish the feasibility of performing ablation and hyperthermia treatments in the neck area with Magnetic Resonance-guided High Intensity Focused Ultrasound (MRgHIFU) using an acute pig model. The target audience includes research groups in the areas of interventional MRI, MRgHIFU, and therapy of head and neck cancer.

Methods. Six 17-18-kg pigs were treated in the eomohyoid muscle at the middle section of the neck area. The protocol was approved by the local animal care committee (AUP 121). Experiments were performed using an MRgHIFU system Sonalleve V2 (Philips Healthcare) and a 3T Achieva scanner (Philips Healthcare). Animal was under anesthesia (Isoflurane 2%) during the procedure using a respirator with a breathing rate of 20 breaths per minute and a breathing volume of 200 mL. The head and neck of the pig was immobilized using a mold built with a foaming agent (AC 250, Alpha Cradle, North Canton, OH, USA). A custom-made water bag was used as a coupling medium between the acoustic window in the MRgHIFU system and the neck area. Thermometry maps were calculated using a technique based on the water-proton resonance frequency shift¹. Baseline temperature was measured with an optic fiber inserted in the gluteus muscle. After procedures were completed and prior to euthanasia, contrast enhancement imaging was performed using a gadolinium-based agent (Magnevist, Bayer). Lesion volume was calculated with contouring of lesions on contrast images using the Osirix software package.

Hyperthermia. The right side of the neck (Fig 1) was treated with hyperthermia with a target temperature of 41 °C during 30 minutes. A target region of 16-mm diameter and 34-mm in length was used to cover the muscle region. First 3 pigs were treated using the automatic control algorithm included in the standard Sonalleve software (V3.1.1010.343). The remaining 3 pigs were treated with a manual control of the sonication using real-time toolboxes for the control of the MRgHIFU system and MR scanner². In both groups, ultrasound frequency was set to 1.2 MHz. In the group using the manual control the acoustic power was controlled by the user and drift in thermometry caused by the static magnetic field was corrected using a 2nd order spatial-temporal compensator³.

HIFU lesions. The left side (Fig 1) of the neck was treated with a cluster of individual HIFU lesions, each with a diameter of 8 mm and a length of 20 mm. Duration of

exposure of was set to 20 s and frequency to 1.2 MHz. The standard Sonalleve software (V3.1.1010.343) was used to induce the HIFU lesions.

Results. **Hyperthermia.** Table 1 shows the average over time of the measured temperature based on the type of control used. Temperature was measured in the focal regions on coronal and sagittal plans, and in the pre-focal zone on the sagittal plan. Compared to the automatic method, the user-controlled approach managed to deliver temperatures closer to the target goal of 41°C with inferior peak temperatures. Noise in the images was observed by respiratory motion in the caudal-cranial direction. With the automatic algorithm, initial power was set to 40W, which was later modulated without user intervention. In the user-controlled algorithm, power was initially set to 20 W and power has to be increased up to 50W to sustain the hyperthermia level. After 30 min of exposure, the required time of temperature to return to baseline values ranged

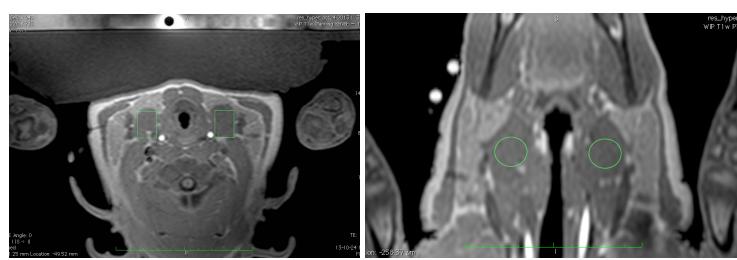


Figure 1. Transverse (left) and coronal (right) plans of the middle section of the neck where treatments regions are shown by green contours. HIFU lesions were performed on the left side of the neck and hyperthermia on the right side of the neck

Plane / Method	Average temperature		Peak temperature		from 100 to 200 s.
	Automatic	Manual	Automatic	Manual	
Focal coronal	37.3±2.6	40.3±1.8	44±4.5	42.6±0.5	
Focal sagittal	38.5±2.7	39.6±1.4	52±9.8	42.5±1.8	
Pre-focal sagittal	37.8±3	41±0.7	54±6.6	45±3.4	

Table 1. Average and peak temperature (°C, ± s.d.) over central 20 min of treatment in the focal and prefocal regions of the treatment using the automatic and manual methods.

Lesion formation. As shown in Table 1, three (3) experiments were conducted with a target power level of 110W and the 3 remaining with a power level of 140W. The number of individual lesions ranged from 4 to 12 to cover the target zone with an expected treated volume ranging from 3.52 to 10.56 mL. Experiments with a power of 110W showed very low success rate when compared to high power. One experiment at 140W developed post-focal region in the adjacent muscle. Nevertheless, the lesion volume observed in contrast imaging was inferior to the planned volume for all experiments. Exposures located in proximity of the carotid artery were unable to produce lesions regardless the applied power.

# exp	# Lesions	Power (W)	Expected Volume (mL)	Volume D30 (mL)	Volume D240 (mL)	C.I. Volume (mL)
1	7	100	6.16	0.1	0.02	0.08
2	11	110	9.68	1.5	0.7	0.64
3	4	110	3.52	0.6	0.08	0.018
4	12	140	10.56	6.6	2.6	9.4
5	4	140	3.52	1.2	0.3	0.4
6	9	140	7.92	5.8	2.5	1.8

Table 2. Parameters and measured volume for HIFU lesion experiments.

Thermal dose volume was calculated at thresholds of 30 (D30) and 240 (D240) min at 43°C from thermal maps. C.I.= contrast-imaging.

correction algorithm. Results indicated that it is feasible to both induce lesions and sustain hyperthermia levels in the neck area using MRgHIFU.

References:

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