Clinical feasibility of motion compensation for MR-based thermometry for treatment in the head and neck region using magnetic resonance-guided focused ultrasound

Samuel Pichardo[1,2], Justin Lee[3], and Kullervo Hynynen[4]

[1]*Thunder Bay Regional Research Institute, Thunder Bay, ON, Canada,* [2]*Electrical Engineering & Physics, Lakehead University, Thunder Bay, Ontario, Canada,* [3]*Odette Cancer Centre, Toronto, Ontario, Canada,* [4]*Physical Sciences, Sunnybrook Research Institute, Toronto, Ontario, Canada*

Introduction. Cancer of the head and neck is the sixth most common form of cancer diagnosed in the world[1]. Despite combined modality treatments, 20-55% of patients with locally advanced head and cancer will develop local recurrence with overall survival of approximately 40-60%. There remains a need for therapeutic strategies which can improve loco-regional control and provide symptom relief while limiting treatment duration and side effects. We propose to use Magnetic resonance image (MRI) guided high intensity focused ultrasound (MRgHIFU) as an adjuvant therapy to radio-therapy for the treatment of recurrent head and neck tumours. A previous pre-clinical study[2] using a porcine model showed the importance of artifacts in MR-based temperature calculation and a method was developed and tested to compensate this source of noise. This paper presents the first results of using this method in a clinic context with patients with primary cancer in the neck area. **The target audience** includes research groups in the areas of interventional MRI, MRgHIFU, and therapy of head and neck cancer.

Methods. A protocol to perform imaging in the neck area of patients showing primary neck cancer was approved by the institutional Research Ethics Board. Four (4) subjects were imaged at the middle section of the neck area using a 3T Achieva scanner (Philips Healthcare). Subjects were positioned on an MRgHIFU system Sonalleve V2 (Philips Healthcare) that was modified for head and neck applications. The head and neck of the subject was immobilized using a mold built with a foaming agent (AC 250, Alpha Craddle). A custom-made water bag was used as a coupling medium between the acoustic window in the MRgHIFU system and the neck area. The surface coils used for abdominal MRgHIFU (HIFU SENSE coils, Philips Healthcare) were used for imaging. Thermometry maps were calculated using method based water-proton resonance frequency shift[3] and multi-baseline classified by pencil beam navigator displacement[2]. A T1-weighted 3D acquisition were acquired for tumour localization with the following MRI parameters: FOV = 320 × 320 mm^2, voxel size = 0.5 mm, slice thickness = 2.5 mm, slice separation = 1.25 mm, TE/TR = 2.3/3.5 ms, flip angle = 7°, acquisition matrix = 256 × 183, ETL = 1, NEX = 1. A supplementary T1-weighted 3D acquisition with same parameters was performed in the upper lung region for placement of the pencil beam navigator. For temperature monitoring, four (4) single-slice stacks were positioned as follows: stacks 1, 2 and 3 at coronal, sagittal and transverse orientations, respectively, centered on the HIFU focal spot; stack 4 was user-defined with coronal orientation to monitor post-focal region. MRI parameters were as follows: FOV = 400 × 400 mm^2, voxel size = 2.08 mm, slice thickness = 7 mm, TE/TR = 16/48 ms, flip angle = 18°, acquisition matrix = 192 × 191, reconstruction matrix = 192, ETL = 11, NEX = 1, dynamic time = 3.07 s. Thermometry values were only considered in the regions of the images that showed a temperature uncertainty less than 2°C. Peak-peak ($T_{SA\text{-}p.p.}$) and DC bias ($T_{SA\text{-}DC}$) of temperature were measured in *focal* and *non-heated* regions of interest (ROIs). The *focal* ROIs in the coronal stack was a central circular region with 16-mm of diameter. Elliptical regions with a small diameter of 16 mm and a large diameter of 34 mm at center of image were placed at sagittal and transverse stacks. *Non-heated* regions were tissue regions outside the *focal* zones. Drift in thermometry caused by the variations of the magnetic field over time was corrected using the following 2nd-order spatial-temporal compensator[4]

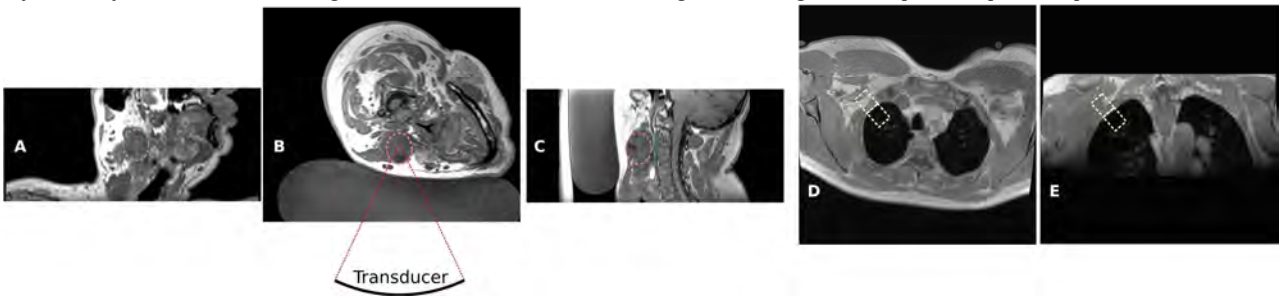

Figure 1. Coronal (A), transverse (B) and sagittal (C) images of target zone, where tumour location is encircled. Relative position of transducer is shown in B. Transverse (D) and coronal (E) images of upper region of lungs where location of pencil beam navigator is shown.

Results. Figure 1 shows T1-W treatment planning images showing tumour location and position of pencil beam navigator. Subjects were imaged for temperature monitoring for 5 minutes. Total time of procedure (including positioning, planning and temperature monitoring) was 45 minutes in average. Figure 2 shows overlay of thermal maps for subject #3 on magnitude images of dynamic scan showing temperature estimation with and without motion compensation. Including all patients and imaging slices, the average (±s.d.) of $T_{SA\text{-}p.p.}$ and $T_{SA\text{-}DC}$ in the in the *focal* zone was, respectively, 2.4(±1.2) ºC and 0.4 (±0.2) ºC with motion compensation and 3.1(±1.5) ºC and 0.41 (±0.3) ºC without. In the *non-heated* area, these values (in the same order) were 0.6(±0.5) ºC and 0.1 (±0.13) ºC with motion compensation and 1.2(±0.3) ºC and 0.15 (±0.15) ºC without.

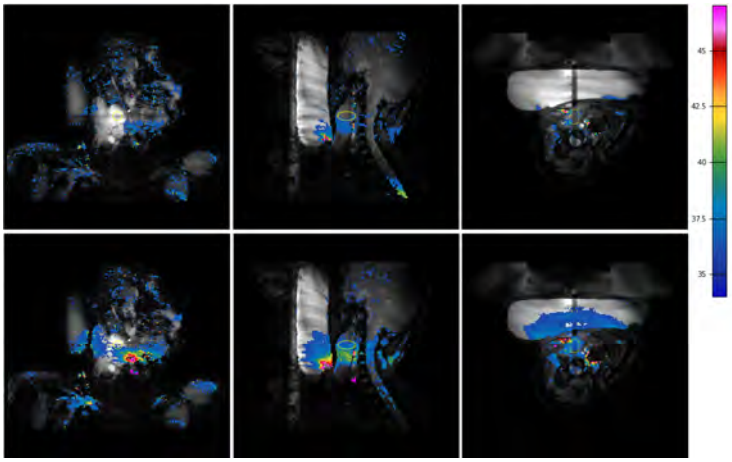

Figure 2. Overlay of thermal maps on magnitude images on coronal (left), sagittal (center) and transverse (right) planes with (top row) and without (bottom row) motion compensation. Temperature below 38 degrees was masked. Region of interest of focused ultrasound are encircled by a yellow line.

Discussion and Conclusions.

Motion compensation with multi-baseline images indexed by displacement measured at the upper lung translated in a reduction of the peak-peak amplitude and DC bias in measured MR-based temperature. Remaining artifacts were observed by spontaneous swallowing by patient and other involuntary small motion. Future study will evaluate reducing these artifacts by combining the present method with in-plane pixel displacement techniques.

References: [1] Hunter KD *et al.*, *Nat Rev Cancer.* 2005, **5**(2):127. [2] Pichardo *et al.*, accepted for publication in *Int J Hyperthermia* on Oct 2014. [3] Ishihara *et al.*, *Magn Reson Med.* 1995, **34**(6):814. [4] El-Sharkawy *et al*. *Magn Reson Mat Phys Biol Med.* 2006, **19**:223