Feasibility of MR thermometry in pancreas

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Introduction The average life expectancy of patients diagnosed with pancreatic cancer is only a few months, mainly because of the late stage at diagnosis and the lack of an efficient therapy. Only 15-20% of the patients are eligible for surgical treatment with curative intent. Alternative treatments such as radiation and chemotherapy are mainly used for pain palliation[1]. MRI guided High Intensity Focused Ultrasound (HIFU) might become a new tool for the non-invasive image-guided treatment of pancreatic cancer. Firstly, HIFU can be used to ablate locally (non-resectable) small malignant tumors[2]. In addition, HIFU can be used to induce local hyperthermia over a prolonged time. Hyperthermia is one of the most efficient sensitizers to radiotherapy and systemic chemotherapy[3]. Furthermore, hyperthermia has shown to increase the perfusion of pancreatic tumors and promote drug penetration into tumors. Finally, hyperthermia can be used for local drug delivery using temperature-sensitive liposomes[4]. For all these applications accurate MR temperature measurements are essential. To date, the most commonly used method for performing MR thermometry is the proton resonance frequency shift (PRFS) based method. The objective of this study was to investigate the accuracy of PRFS based thermometry in the pancreas in volunteers. We looked at the temperature accuracy during breath hold as well as during free breathing with multi-base line motion correction.

Material & Methods *Image acquisition*: All experiments were performed on a MR-HIFU system (Philips Sonalleve MR-HIFU V2, Philips Healthcare, Vantaa, Finland) integrated with a clinical 1.5-T MRI scanner (Achieva, Philips Healthcare, Best, The Netherlands). Volunteers (n = 3) were positioned supine. First, an anatomical T2-weighted image (TR = 596 ms, TE = 81 ms, voxel size = 1x1x3 mm^3) was acquired for planning the position of the thermometry slice. Next, single slice Gradient Echo (GE) images were acquired dynamically during breath hold (100 dyns in 13.6 sec) and free breathing (450 dyns in 60.5 sec). Relevant scan parameters: TR = 44.4 ms, TE = 18.7 ms, FA = 20, voxel size = 2.5x2.5x5 mm^3, dynamic scan time = 130 ms. The image slice was placed coronal and parallel with the vertebra such that out of slice pancreas motion was minimal. Temperature maps were calculated from the phase image information in the GE-image.

Image processing: MR-images were co-registered to a common reference position using an optical-flow based image registration algorithm applied on anatomical information [5]. For the free breathing images, motion related errors in PRF-based MR thermometry were corrected using a multi-baseline (MBL) approach as follows: Phase perturbation with motion was analyzed in a pre-treatment step performed prior to the intervention. A complete set of N reference magnitude together with the co-registered phase images were collected in a pre-recorded look-up table (N=40). During the intervention, the phase image of the look-up table acquired with the corresponding organ position was selected with an inter-correlation coefficient computed for magnitude image, and then used as a reference for temperature computation, as explained in detail by [6].

Statistical analysis: The temperature standard deviation was computed in a voxel-by-voxel basis over the entire dynamic scan in a region of interest that only includes the pancreas. This region of interest was drawn manually.

Results Figure 1 shows a boxplot with the temperature standard deviation in the pancreas during breath hold and during free breathing (after correction for motion related errors using a MBL approach) in three volunteers. The median temperature standard deviation for all cases was about 2-3 degree Celsius. In all volunteers the median temperature stability was lower during breath hold. In figure 2 the temperature standard deviation maps for all three volunteers are shown. A homogenous temperature standard deviation can be observed in the complete pancreas except for the voxels at the edge of the pancreas.

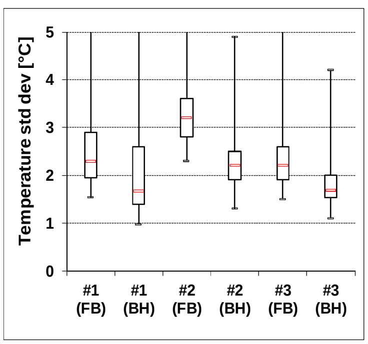

Figure 1: Boxplot that show the temperature standard deviation in the pancreas of three volunteers during free breathing (FB) and breath hold (BH). Temperature levels values corresponding to the minimum (lowest point), first quartile (lower box limit), median (red line), third quartile (higher box limit) and maximum (highest point) of the distribution of temperature standard deviation in the ROI.

Discussion & conclusion Temperature mapping is feasible in the pancreas. The accuracy of temperature mapping is high enough for guiding HIFU ablations, because 2-3 degrees of temperature mismatch is not critical at these high temperatures. However, for guiding HIFU-induced hyperthermia treatments higher temperature accuracy is necessary, because 2-3 degrees of temperature mismatch corresponds to no effect or thermal damage. In this study temperature maps were acquired in the body of the pancreas. However, 66% of the pancreatic tumors are in the head region of the pancreas. Tumors in this region are even difficult to recognize on high resolution anatomical images and therefore thermometry might be extra challenging. To conclude, MR-HIFU may be an alternative treatment option for a sub-group of patients with pancreatic cancer.

References [1]Li et al., Lancet, 2004, [2]Hynynen et al., JMRI, 2011, [3]Wust et al., The Lancet oncology, 2002, [4]Grüll et al., JCR, 2012, [5]Horn et al. Artif Intel 1981, [6]Roujol et al., Magnetic Resonance in Medicine, 2010

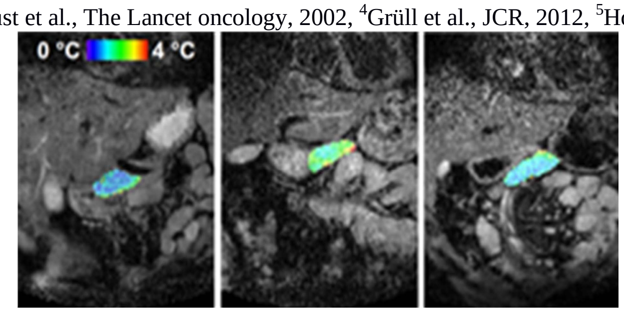

Figure 2: Temperature stability obtained in the pancreas of the three volunteers. The standard deviation of the temperature was computed on a voxel-by-voxel basis over the entire experiment.