## Evaluation of PRFS MR Thermometry in the Human Prostate Gland at 3.0T for Transurethral Ultrasound Therapy

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**Introduction:** Current treatments for localized prostate cancer are effective, but can result in significant long-term sexual, urinary and bowel complications. MRI-controlled transurethral ultrasound therapy is a minimally-invasive image-guided prostate treatment method that is being developed to address this issue. With this technique, multi-planar temperature measurements obtained with proton resonance frequency shift MR thermometry are used to control the spatial extent of heating delivered from a multi-element ultrasound device inserted in the urethra. Successful treatment depends on reliable temperature feedback with a temporal resolution of a few seconds (1). In this work, the spatial, temporal and temperature resolution of a segmented gradient echo (GE) EPI sequence as applied to PRF shift thermometry, as well as its distortion properties, were evaluated in healthy human volunteers at 3T in order to determine its feasibility for MRI-controlled transurethral prostate therapy.

**Methods:** This study was approved by our Institutional Research Ethics Board, and all participants (11 healthy males, age range 23-58 years) provided written informed consent. Eleven sets of multi-slice oblique-axial GE EPI thermometry images covering the entire prostate gland were obtained using a Philips SENSE XL 16-channel torso array on a 3T MR imaging system (Achieva, Philips Healthcare, Best, Netherlands). The range of acquisition parameters for the thermometry images (see Table) was chosen to evaluate the influence of TE, EPI factor and voxel size on the temperature accuracy and distortion properties of the sequence. For each scan, 20 dynamic image sets were obtained, consisting of 9 slices with thickness/gap=5.3mm/-.3mm and a 256mm field of view. Temperature time series were calculated according to the PRD shift method (2) using the first 5 dynamic scans as a baseline. Temperature stability was evaluated based on temperature standard deviation (SD) maps, which show for each pixel the temperature standard deviation over time. These maps are indicative of the temperature uncertainty over time and across the prostate gland. The evaluation of spatial distortion as a function of EPI factor used the phase-based method described previously by Zeng et al (3).

| | TR (ms) | TE (ms) | EPI factor | Voxel size (mm) | Dynamic Time (s) |
|---|---|---|---|---|---|
| Influence of TE | 180 | 7 | 9 | 2.00x2.00 | 6.55 |
| | 180 | 10 | 9 | 2.00x2.00 | 6.55 |
| | 180 | 15 | 9 | 2.00x2.00 | 6.55 |
| | 180 | 20 | 9 | 2.00x2.00 | 6.55 |
| | 180 | 25 | 9 | 2.00x2.00 | 6.55 |
| Influence of EPI Factor | 137 | 15 | 5 | 2.00x2.00 | 8.00 |
| | 132 | 15 | 9 | 2.00x2.00 | 4.77 |
| | 130 | 15 | 13 | 2.00x2.00 | 3.42 |
| | 129 | 15 | 17 | 2.00x2.00 | 2.87 |
| Influence of Voxel Size | 132 | 15 | 9 | 1.45x1.45 | 6.14 |
| | 132 | 15 | 9 | 1.14x1.14 | 7.18 |

**Results**: Figures 1a and1b show an anatomical image and a typical temperature SD map of the same prostate slice. The map indicates that the temperature SD is very small for most pixels in the prostate. Temperature SD trends were evaluated quantitatively using ROI's drawn in the prostate, avoiding artifacts due to motion or air in the rectum. It was found that temperature SD did not exceed 1$^{o}$C for any of the parameter choices in the above Table. For example, Figure 1c shows that the temperature SD increased with decreasing voxel size. The different colours indicate results for seven volunteers. There is clearly a tradeoff between spatial resolution and temperature accuracy, which is due to the decreased SNR in magnitude in images with small voxels. It was also found that temperature SD increased monotonically with <u>decreasing</u> TE (Fig 1c) and with <u>increasing</u> EPI factor (not shown). In the both cases, the cost of greater temperature stability was longer dynamic scan times. The distortion analysis showed that the geometrical distortion increased slowly with EPI factor, but never exceeded 1mm for ROI's within the prostate.

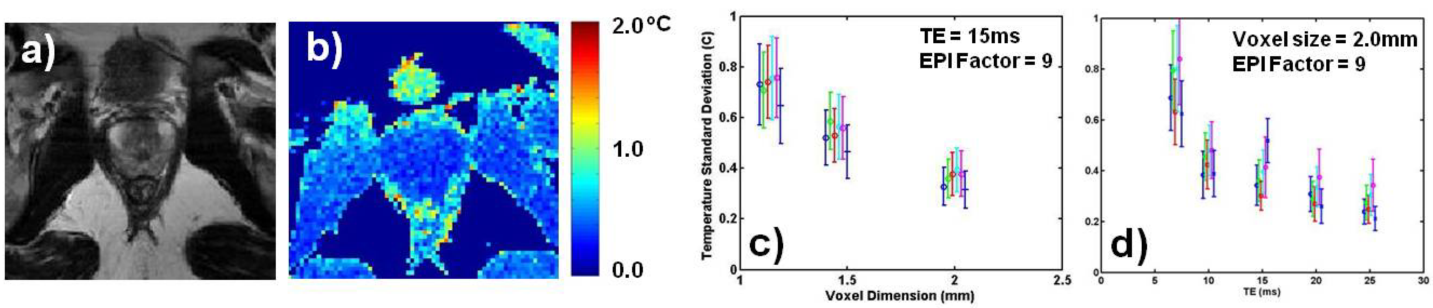


***Figure 1:*** *a) Anatomical image and b) typical temperature SD map of the same slice of the prostate gland. Variation of temperature SD with (c) voxel size and (d) TE, averaged over the prostate for 7 volunteers (represented by different colours).*

**Discussion:** For all sets of scan parameters and for all volunteers, the temperature standard deviation within the prostate was less than 1$^{o}$C, while the distortion was less than 1mm. Thus segmented GE EPI sequences are very appropriate for use in prostate thermometry at 3T. Scan parameters must be chosen which strike a balance amongst competing quantities such as temperature accuracy, acquisition time, spatial resolution and the degree of geometric distortion. For focal thermotherapy, it is especially important that multi-slice thermometry with voxels as small as 1mm is feasible with reliable temperature stability.

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**References:** 1) Chopra R et al, Phys Med Biol. 2006;51:827-44 2) Ishihara Y et al, Magn Reson Med 1995;34:814-823
3) Zeng H et al. Magn Reson Med. 2002;48:137-146.