# Fast Double-Echo EPI Pulse Sequence for Thermal Focal Spot Localization During MR-guided Regional Hyperthermia Treatment

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## Introduction

Regional hyperthermia is used as a supplementary therapy during cancer treatment. During hyperthermia the cancer tissue is heated moderately to temperatures between 39-45° C to improve chemotherapy and radiotherapy effect [1, 2]. The temperature of the cancerous and healthy tissue during regional hyperthermia is typically monitored with temperature probes inserted into catheters.

MR thermometry with the proton resonance frequency (PRF) method allows for a non-invasive temperature monitoring, and often conventional gradient echo techniques (FLASH) are used to measure the phase changes during heating. In this work, a double echo segmented EPI sequence for MR thermometry during regional hyperthermia was developed for faster volumetric temperature measurements. With segmented EPI the localization of unwanted thermal focal spots would be faster, and the hyperthermia procedure could be made safer and more reliable.

## Materials and Methods

Hyperthermia experiments were performed with a clinical hyperthermia unit (BSD 2000 3D MRI, BSD medical corporation, Salt Lake City, UT) with SIGMA-Eye applicator that consists of 24 antennas, which operate at 100 MHz with maximum power of 1800W (75W per antenna). MR images were obtained using a 1.5T MR system (Siemens Magnetom Symphony).

A segmented double gradient echo EPI sequence (DEPI) was developed for the PRF temperature mapping. Two echoes are required to compensate for tissue conductivity changes during heating [3]. The sequence was tested during a hyperthermia experiment in a dedicated MR gel phantom containing 1.3% NaCl. The following parameters were used for DEPI temperature mapping: $TE_1$ = 5 ms, $TE_2$ = 20 ms, TR = 129 ms, slice thickness = 10 mm, EPI factor = 5, bandwidth = 750 Hz/px, $\alpha$ = 15°, matrix = 125×128, FOV = 500×500 mm$^2$, acquisition time = 5.5 s, 5 slices. For comparison, data were also acquired with a double echo FLASH sequence in an interleaved manner during heating, and the temperature in the gel phantom was monitored with Bowman [4] temperature probes (diameter = 1.1 mm, accuracy 0.2°). The following parameters were used for the FLASH sequence: $TE_1$ = 5 ms, $TE_2$ = 19 ms, TR = 600 ms, slice thickness = 10 mm, bandwidth = 260 Hz/px, $\alpha$ = 50°, matrix = 128×128, FOV = 500×500 mm$^2$, acquisition time = 76 s, 25 slices.

The DEPI sequence was tested during hyperthermia treatment of a 45y old male patient with a diagnosed myxoid liposarcoma localized in the lower left leg. Again, the double echo FLASH sequence was interleaved with the DEPI data acquisition. To calculate temperatures, at first, phase difference images were calculated for each time step: $\Delta\varphi = \varphi(TE_2) - \varphi(TE_1)$. Temperature maps were then calculated from MR phase difference images, using the well-known PRF equation $\Delta T = \frac{\Delta\varphi(T) - \Delta\varphi(T_{ref})}{\gamma \alpha B_0 \Delta TE}$, where $\Delta\varphi(T)$ is the phase difference at temperature $T$, and $\Delta\varphi(T_{ref})$ is the reference phase difference before the heating, $\alpha = 0.01$ *ppm/°C* is the PRF thermal coefficient, and $\Delta TE = TE_2 - TE_1$. An additional field drift correction was applied by subtracting data from fat/oil bags region, surrounding the healthy, much less heated leg (see Fig. 1A).

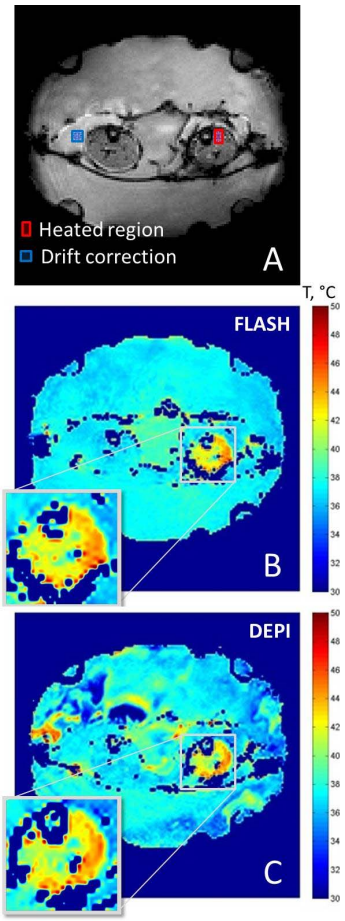


*Fig. 1: A. Position of ROI's during calculation. B, C. Comparison of temperature maps calculated from FLASH (B) and DEPI (C).*

## Results and Discussion

Figure 2A shows a comparison of the temperatures calculated from both DEPI and FLASH sequences and measured by one temperature probe. The maximum difference between the temperature measured by thermometer and calculated from two different sequences does not exceed 0.7°C.

Figure 1B and 1C show comparison of temperature maps during hyperthermia treatment of the patient (the corresponding magnitude image is shown in Fig. 1A). The DEPI temperature map shows a more inhomogeneous background in the water bolus of the hyperthermia applicator surrounding the patient's legs, because segmented EPI acquisitions are more sensitive to motion. In the tissue, however, the heat distribution is clearly seen in both images (Fig 1B and 1C). In Fig. 2B the temperature time course is shown for both sequences. The maximum temperature deviation is 1.0°C. The larger difference at the beginning of the treatment is due to the fact that initially the temperature changes very fast and the two sequences are not measured at the same time.

These preliminary data show that DEPI temperature mapping can be used for temperature monitoring during a hyperthermia treatment. Motion sensitivity needs to be further reduced which will be achieved by introducing flow compensation and pre-saturation of the water in the bolus. DEPI is faster than FLASH by the EPI factor (here: 5), which can be extended in this example to 7 or 9 (depending on the readout bandwidths). The higher acquisition speed of DEPI can be exploited at the beginning of the treatment to localize focal RF hot spots in the body of the patient, which can be avoided by careful re-adjustments of the transmitted phases of the hyperthermia unit. Additionally, the saved time can be used to increase resolution, to increase the spatial coverage or to include additional functional measurements during treatment.

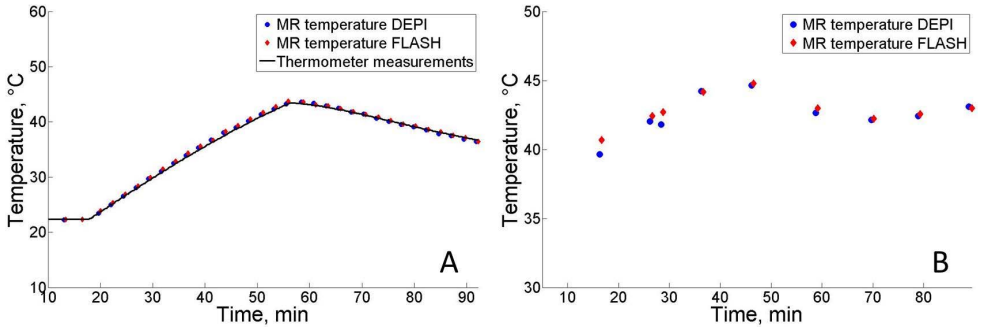


*Fig.2: A. Phantom experiment, temperature measured with thermometer and calculated from two sequences, as a function of time. B. Patient experiment, temperature calculated from two sequences, as a function of time.*

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## References

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