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A robust motion compensation algorithm for volumetric MR-temperature monitoring during micro-wave ablation of liver tumor in patients.

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Introduction: Micro-wave tumor ablation (MWA) in the liver could benefit from magnetic resonance guidance that enable real-time temperature and lesion size monitoring during the energy delivery [1]. Nevertheless, motion of abdominal organs causes significant challenges [2] and can be addressed either by synchronizing the acquisition with the physiological motion or by acquiring continuously the acquisition and compensating for the effect of displacement on magnitude and phase images using additional image processing method [3]. In such context, local intensity changes during MWA ablation (due to changes in tissue properties with heating) may be interpreted as motion and lead to local erroneous displacement vector fields, which can compromise MR temperature mapping. We investigate the use of a novel motion compensation algorithm [4, 5] during liver tumor ablation. The performance of the method was retrospectively evaluated on experimental images under gated conditions.

Methods: Patient: The study was performed at the University Hospital of Munich and was approved by the local health authorities. The patient underwent MWA procedure to ablate a primitive liver tumor. During the procedure, the patient was under general anesthesia and was continuously cared by medical staff. Ablation device: An AveCure micro-wave system (MedWaves, San Diego, USA) was used to perform the ablation. A 14-gauge large antenna was used. Ablation duration was set to 10 minutes. A stack of 13 contiguous slices (no slice gap) was acquired dynamically (350 repetitions) on a 1.5T MRI scanner (Magnetom Aera, Siemens Healthineers, Erlangen, Germany) during the exhalation phase using a gradient-echo echo planar imaging (EPI) sequence (TR/TE=2070/18ms). The acquisition was performed under respiratory gating using a cushion positioned in the patient abdomen. Temperature, thermal dose monitoring and lesion size was computed retrospectively using 3 workflows: a) standard phase subtraction (gold standard), b) *conventional H&S* motion compensation [6], c) *PCA-based H&S* motion compensation [4]. The impact of flow field, temperature and lesion volume size error were compared using maximal endpoint error (EE) of the displacement in the heated area for a time frame, RMSE of the temperature elevation during the ablation and Bland Altman plot.

Results and conclusion: An intensity signal decrease of 50% was observed in the vicinity of the needle. The maximal EE was in the range of 1-3 mm with *conventional H&S* and of 0.1-1 mm with *PCA-based H&S*. The flow field distortion estimated using *conventional H&S* optical-flow resulted in temperature errors up to 30°C while *PCA-based* method result in temperature error lower than 5°C. The 95% uncertainty for lesion size evolution (every ten frames) was reduced using the *PCA-based H&S* (Fig. 1), but a more limited impact on the thermal dose and corresponding lesion estimation was found due to the ablation duration. Under gated conditions, the performances of the proposed algorithm in term of motion field, temperature and lesion size accuracy outmatch the *conventional H&S* algorithm. Acquisition under free breathing are being evaluated.

Reference: [1] Gorny K.R. et al. Phys Med. 2019. [2] Kägebein U. et al. Topics in Magnetic Resonance Imaging, 2018. [3] Roujol S. et al. MRM, 2010. [4] Denis de Senneville B., et al. IEEE Trans. Med. Imaging, 2015. [5] Toupin S. et al, Physics in Medicine & Biology, 2017. [6] Horn B.K. and Schunck B.G. Artif. Intell. 1981.

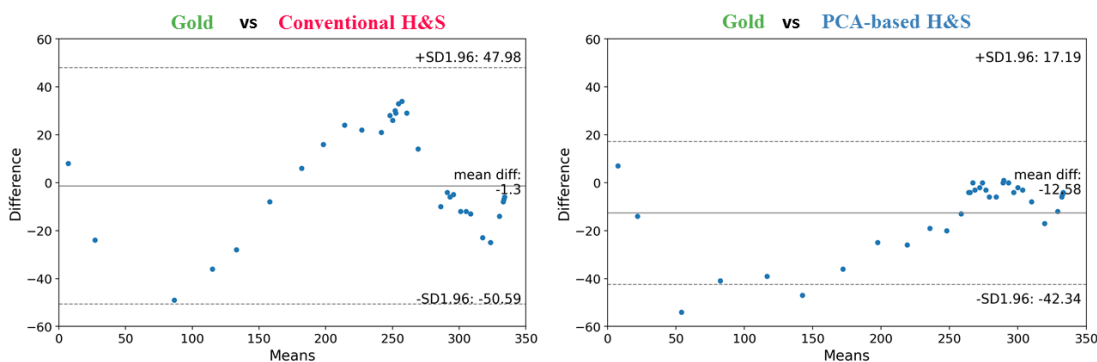


Figure 1 : Comparison of the lesion size evolution in voxel (every ten frames) between the gold standard with *conventional H&S* or with *PCA-based H&S*.