Assessment of renal function after conformal radiotherapy and intensity modulated radiotherapy by functional 1H-MR-imaging and 23Na-MR-imaging.

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Introduction:

Adjuvant radiochemotherapy improves survival of patients with locally advanced gastric cancer. Conventional 3-dimensional conformal radiotherapy (3D-CRT) results in ablative doses to a significant amount of the left kidney, while image-guided intensity-modulated radiotherapy (IG-IMRT) provides excellent target coverage with improved kidney sparing. Functional magnetic resonance imaging at 3.0T including blood oxygenation-level dependent-imaging (BOLD), diffusion-weighted imaging (DWI) and ^{23}Na-imaging was used to evaluate renal status after radiotherapy with 3D-CRT or IG-IMRT.

Method and Materials:

All measurements were performed on a 3.0 Tesla clinical whole-body MR scanner (MAGNETOM TimTrio 32x102, Siemens Healthcare Sector). For signal reception a dedicated sodium-tuned cardiac coil with 8 coil elements (Rapid Biomedical) was used. It consists of two identical halves with a transmit loop and four receive-only channels each. The coil was tightly fixed around the volunteers and covered a coronal field-of-view of 320 x 320 mm^2. Beside both kidneys, standardized 0.6% and 0.9% NaCl-dilutions including 2% agarose were covered in the field-of-view serving as calibration phantoms [2].

For adjusting the inhomogeneity of the coil a priori, a homogeneous sodium phantom was measured as reference. According to this reference, all images of the volunteers were corrected. For the sodium concentration map, a density adapted 3D radial trajectory was used for acquisition with the following parameters: TR = 120ms, TE = 0.55ms, flip angle = 85°, FOV = 320 x 320mm^2, readout length per spoke = 20ms, projections = 8000 resulting in a total scan time of 16min. The isotropic spatial resolution was 5mm.

Beside T2w morphological sequences, axial DWI images (TE = 87.3ms; TR = 4435ms; b-values = 0-800; spatial resolution=0.6 x 0.6x 5mm^3) and 2D-GRE-BOLD images (12xTE = 5-48.7ms; TR = 106ms; spatial resolution = 0.5 x 0.5x 4mm^3) were acquired. Mean values/standard deviations for [^{23}Na], ADC- and R2*-values were calculated for upper/middle/lower parts of both kidneys. Cortico-medullary ^{23}Na-concentration gradients were calculated for the linear increase (10mm from the cortex to the medulla) in mmol/l/mm. Paired-t-test were used to find significant differences between the different renal parts.

After institutional review board approval and informed consent, 4 disease-free patients (3 male, 1 female; median age 65 years; 2 after 3DCRT with chemotherapy based on INT0016 (5-FU/leukovorin) and 2 after IMRT with intensified chemotherapy (capecitabine/oxaliplatin) within the MARGIT/AIO study; FU for all patients >5ys) underwent the above-described MR protocol. The radiation doses for the patients were for 3DCRT: mean right kidney dose (MRKD) 5.3Gy, mean left kidney dose (MLKD) 28.8Gy, mean dose to cranial third of left kidney 42Gy. IMRT: MRKD 8.9Gy, MLKD 22,73Gy, dose to most of the renal cortex <10Gy.

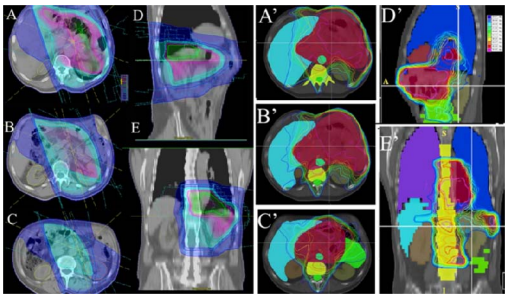

***Figure 1**. Overview of dose parameters to both kidneys (right panel: 3D-CRT; left panel; IG-IMRT).*

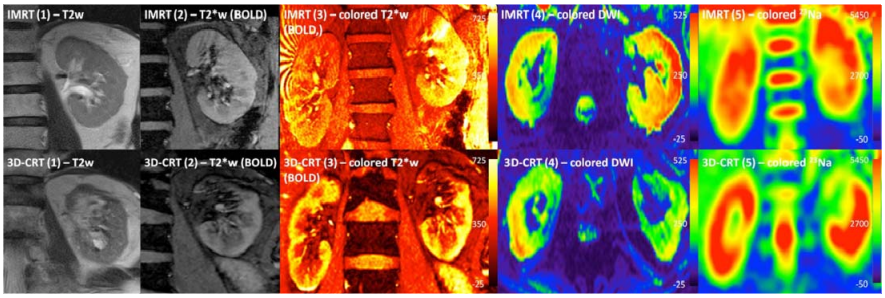

***Figure 2**. This panel shows the morphological (T2w) and the functional images (T2*w, DWI, ^{23}Na) for the IG-IMRT- (upper row) and for 3D-CRT-patients (lower row). The alterations of the left cranial part in 3D-CRT-patients can be depicted in the lower row.*

Results:

All data were successfully acquired. IG-IMRT patients showed no morphological alterations and nonstatistically differences for comparison of ADC- and R2*-values in all renal parts. Mean cortico-medullary ^{23}Na-concentration gradient matched with values for healthy volunteers. Results were similar in 3D-CRT patients for the non-irradiated right kidney and middle/caudal part of the left kidneys (p = 0.056 – p = 0.962). The cranial part of the left kidney was atrophic and presented significantly reduced ADC-, prolonged R2*-values and significant reduced ^{23}Na-concentration (p = 0.001 – p = 0.033).

Conclusion:

Functional MRI at 3.0T seems feasible for investigation of post-radiotherapeutic renal changes. Marked morphological/functional effects were observed in high-dose areas (3DCRT) while no alteration in kidney function was observed in IG-IMRT patients who received lower doses of radiation.

References:

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