Multimodal $^{23}Na/^{1}H$ MR / CT clinical protocol for abdominal application: evaluation of TSC in a gastrointestinal stromal tumor (GIST) patient

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Target Audience

Scientists and clinicians performing abdominal sodium quantification, scientists and clinicians designing multimodal abdominal studies

Purpose

Sodium (^{23}Na) MRI enables in vivo assessment of cell viability and can become a valuable functional biomarker during radiotherapy (1). Linking tissue sodium concentrations (TSC) to cancer development is of high clinical interest since proliferating malignant cells have a higher TSC than healthy tissue due to altered Na^+/H^+ transport kinetics, pH, angiogenesis and increased interstitial space. Patients with gastrointestinal stromal tumors (GIST) have a short life expectancy of 3 years and high risks for metastasing.

We present a multimodal MR/CT clinical protocol for abdominal acquisitions with an application shown on a GIST patient. Abdominal sodium acquisition suffers not only from low signal-to-noise ratios, long scan times and breathing artefacts, but also like all abdominal MR protocols from large field of view (FOV), low transmission efficiencies and inhomogeneous coil sensitivities.

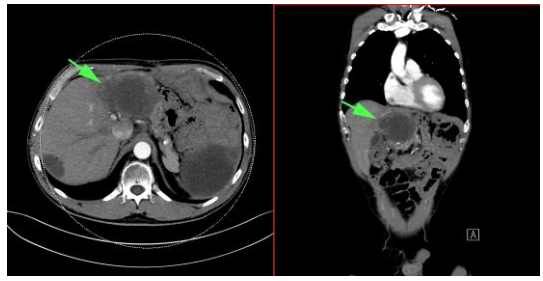

Figure 1 CT thorax and abdominal acquisition. The GIST tumor shows lower HU-values which is visible as a darkening region (largest evaluated tumor indicated by arrow). Axial and coronal slices are shown.

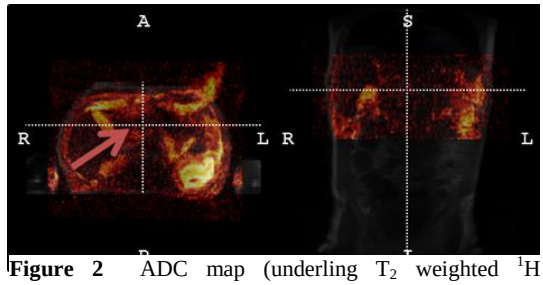

Figure 2 ADC map (underling T_2 weighted ^{1}H acquisition) from GIST tumor region (largest evaluated tumor indicated by arrow) in axial and coronal slice.

Methods

The multimodal protocol consists of CT, ^{1}H and ^{23}Na MR scans. First, CT thorax and abdominal scans were performed. A second-generation dual-source, dual-energy CT with tube voltages of 140 kV and 80 kV scanned 64 abdominal slices. Virtual non-enhanced images and iodine maps representing the iodine related attenuation were calculated. MR acquisitions were performed on a clinical 3T MR system (MAGNETOM Trio, Siemens Healthineers, Erlangen, Germany). Proton imaging was conducted by the system's body coil, allowing for adequate registration to additional acquired ^{1}H MR data. We received anatomical information from MR T_1- or T_2-weighted scans with functional information from diffusion imaging and calculated the apparent diffusion coefficient (ADC). ^{23}Na MR acquisitions were performed using a ^{23}Na 8-channel receive-transmit coil ((2), Rapid Biomedical, Rimpar, Germany) and a density adapted 3D radial UTE sequence (3) with the following parameters: $T_R = 120$ ms, $T_E = 0.7$ ms, FA = 85°, FoV = $(350\ mm)^3$ to image the whole abdominal region, nominal isotropic spatial resolution = $(5\ mm)^3$, projection = 8000 which results in an undersampling factor of 1.6, points on spoke = 384, acquisition time = 16 min. Sodium TSC evaluation was performed for the whole 3D sodium acquisition. Flip angle mapping was conducted by incorporating the phase sensitive pulse pattern (4) inside the density adapted UTE sequence by an additional measurement. Quantification was carried out by matching signal intensities from reference vials. Two reference vials were used. Both contained saline solution, distilled water and were prepared with agarose to achieve a tissue mimicking effect for relaxation times (154 mM ^{23}Na concentration + 2% agarose and 77 mM ^{23}Na concentration + 2% agarose).

A male, 59 years old patient was scanned by the multimodal protocol. He was admitted with suspected diagnosis of stomach GIST tumor. The measurements were approved by the local ethical review committee. Images from all modalities were fused for the clinical evaluation.

Results

In the multimodal measurements, cystic degenerations of the known intrahepatic filiae in the entire left liver lobe and segment 2 were detected (Figure 1). Other increasing cystic degenerated metastases below the left diaphragm thigh were found. There is no evidence of further abdominal filiae, which was confirmed by the ADC map (Figure 2). TSC quantification of the whole 3D volume was performed (Figure 3). Regions of interest were selected in six transversal slices. The evaluated sodium concentration in the whole tumor region is 69.6 mM ± 18.7 mM. High standard deviation arises from the inhomogeneous distribution of sodium concentration in the tumor.

Discussion and Conclusion

Multimodal imaging was successfully performed on a GIST patient. ^{1}H MR scans in the same session as ^{23}Na measurements allow a registration to all clinically acquired proton MR images. Dual energy CT data evaluation suggests that virtual non-enhanced images and iodine maps representing the iodine related attenuation can be used as a surrogate for tumor perfusion and consequently areas of vital GIST. ^{23}Na concentration was successfully evaluated in a GIST tumor. Further TSC quantifications in tumors may provide an additional valuable biomarker to multimodal protocols.

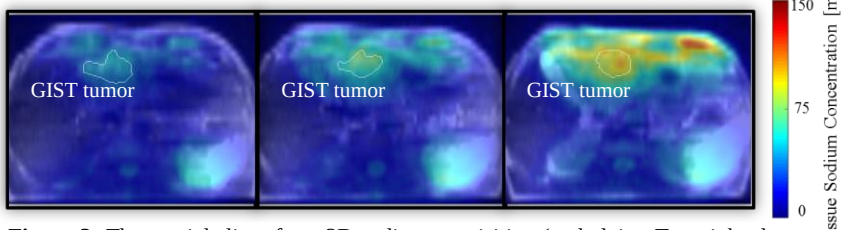

Figure 3 Three axial slices from 3D sodium acquisition (underlying T_2 weighted ^{1}H measurement), quantified by reference vials in tissue sodium concentration. The evaluated GIST tumor is indicated by the white region of interest.

Acknowledgement

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References

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