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Synthetic Magnetic Resonance Image Reconstruction Based on Parametric Weighted Images for Contrast Enhancement at High Field MRI

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The work presented here within describes the development for a technique for Synthetic PArameter-weighted images based on RElaxometry (SPARE) and proof of concept studies to evaluate the validity and potential of the method.

Although the fundamental idea of image synthesis is not a new concept for low magnetic field strengths it has not, to the author's knowledge, been shown at higher field strengths such as 9.4T. It has been shown here that with the aid of quantitative maps we were able to synthesize images corresponding closely with commonly acquired weighted images. Furthermore, as to the Q-maps having high SNR and relate to pure quantitative values, image synthesis allows for higher contrast images when compared to their counterparts. The issue with the traditional method of synthesizing images is the need for a T1 Q-map. This may be impractical in a clinical routine due to the time of acquisition needed for T1-relaxometry. Moreover, the acquisition time of T1 relaxometry extends if more than one slice is needed.

Therefore, besides the "classic" SPARE method using both T1- and T2 Q-maps we have developed two techniques of synthesising images without the need of an acquired T1 relaxometry. Firstly, by substituting the T2 and PD´2 Q-maps back into the equation used for the determination of the T2 Q-maps, and secondly by calculating simulated T1 Q-maps. With the former technique one is able to generated T2- and PD-weighted images. Furthermore, although there is no means of varying TR to weight the image towards T1 (as there is no T1 Q-map), as contrast agent is present in T2 Q-maps at 9.4T, one is able to weight the synthesized image to either enhance or suppress the region where contrast agent has been taken up.

In comparison to this, the method using a SimT1 map increases the spectrum of possible tissue contrasts. We provide evidence that by multiplying the T2 Q-map by a ratio of T1/T2 (the relaxation ratio, RR) one is able to synthesize images which come close to T1-weighted images. This map was given the name SimT1 as it is not the true T1 Q-map, having not actual T1 information but substituted in place of a "true" T1 Q-map in the signal equation. We show that with the proper RR, the resulting relaxation maps correspond closely with a "true" T1 Q-map. The inclusion of this SimT1 map allows the investigator to vary TR and create T1-weighted images. Although this technique has benefits over the other two methods, it must be made clear that the selection of the RR is important for the weighting of the images. That is, due to the differences between different tissue types w.r.t their T1 and T2 relaxation times the same RR may not be suitable for all tissue types. We tested this concept both by means of a phantom study with different concentrations of a contrast agent (modifying the T1 and T2 time) as well as in peripheral nerve imaging. It was shown that due to the large separation of RR (muscle, nerve and fat) a signal gain can be obtained in the nerve while suppressing the signal of the surrounding tissue. We could further show that with a simulated T1 map, the SPARE technique can be extended beyond the spin-echo concept by using the signal equation of an inversion-recovery sequence, which allows for selective suppression of tissues.

Although predominantly tested and proven for 9.4T, we have also demonstrated, as a proof of concept, the use of this technique at 3T and within clinical routine. We could show that with the acquisition of a sequence taking 9min we could synthesize images with a contrast comparable to standard T1- and T2-weighted images, which would take an acquisition time of 20min in total.

From this proof of concept study the results point to the SPARE technique offering a reduced acquisition time, important for claustrophobic or uncooperative patients as well as children. It further allows increase in though put allowing a more economic use of the MR scanner. Most importantly, this technique offers an offline ability to analyze the data and to synthesize the desired contrast in retrospect.