CT substitutes derived from SPIRiT and CG-SENSE reconstructed images

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Purpose: Images resembling CT image can be derived from MR images acquired using sequences with ultrashort echo time (UTE) (1). These artificial CT images (s-CTs) may be used as substitutes for real CT images in radiotherapy dose planning and PET attenuation correction. However, with a total imaging time of six minutes (2) for a FOV of 256x256x256 mm³ the method would be time consuming to use for attenuation correction in PET/MR if multiple bed positions are needed. To reduce scan time non-cartesian parallel-imaging reconstruction methods may be employed. We investigate the quality of substitute CT images derived from MRI images reconstructed with CG-SENSE (3) and SPIRiT (4) for accelerations factors of 3, 6, 10 by comparing them to convolution gridding (5).

Method: Two volunteers were scanned with a dual echo (TE = 0.07 ms and 3.76 ms) 3D radial UTE sequence with TR = 6 ms for both a 10° and a 30° flip angle resulting in four 3D isotropic image volumes per volunteer. 65,000 radial spokes were acquired for each echo and flip angle combination which corresponds to a factor two over-sampling compared to the earlier method (1). The data was then isotropically subsampled into sets of 30k and 10k radial spokes for convolution gridding and 10k, 5k and 3k radial spokes for CG-SENSE and SPIRiT. Convolution gridding, CG-SENSE and SPIRiT were then used to reconstruct images. These images were finally converted into substitute CT images. The substitute CT images derived from all 65k spokes were used as reference for evaluation of the reconstruction methods.

Table 1. Mean absolute deviation of voxel values in Hounsfield units (HU) for s-CT images reconstructed with different methods and sampling densities compared to an s-CT derived from gridding reconstruction with 65k spokes.

Number of radial spokes	Gridding	CG-SENSE (10 iter.)	CG-SENSE (40 iter.)	SPIRiT (10 iter.)	SPIRiT (40 iter.)
30,000	21				
10,000	71	68	148	76	68
5,000	127	74	141	92	74
3,000	156	84	123	107	85

Results: The mean absolute deviation between the s-CT derived from the full dataset and the s-CTs derived from images reconstructed with different sampling densities and reconstructions methods is listed in table 1. The quality of s-CT derived from gridding reconstruction deteriorates rapidly below 10k spokes. For both CG-SENSE and SPIRiT good quality s-CT were obtained for as few as 3000 spokes. However, for CG-SENSE the result is better for 10 iterations than for 40, while the quality for the SPIRiT s-CTs is better for 40 iterations. Samples of s-CT are shown in figure 1.

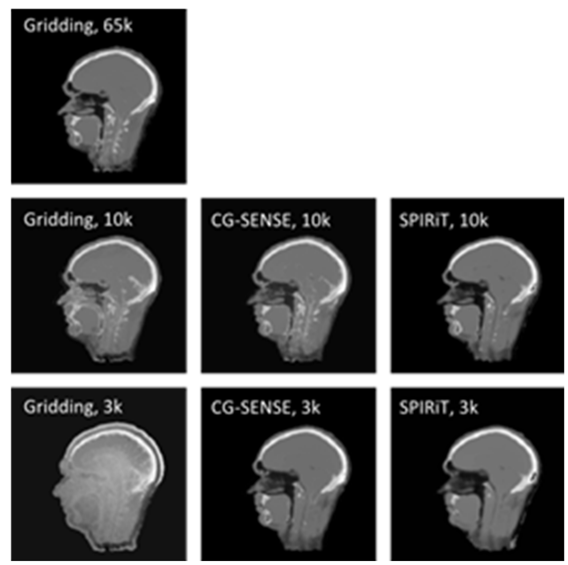

Figure 1. Sample slices of s-CT images derived from gridding, CG-SENSE and SPIRiT reconstruction with different sampling densities.

Discussion: The deviation found in s-CTs reconstructed with CG-SENSE and SPIRiT are small compared to those deviation found between CT and s-CT images (~140 HU (1)). Thus it is be possible to accelerate the scan time 10 times from 6 min to 40 s when imaging the head. The reduced CG-SENSE images quality for 40 iterations could be caused by noise amplification as the method start to diverge. The convergence of SPIRiT reconstruction is more stable.

Conclusions: Both SPIRiT and CG-SENSE enables reduction in scan-time with maintained s-CT quality compared to gridding reconstruction. These methods make s-CT based attenuation correction feasible for PET/MR applications using multiple bed positions.

References: **1.** A. Johansson et al., Med Phys 38(5), 2708-2714 (2011). **2.** A. Johansson et al., Med Phys 39(6), 3283-3290 (2012). **3.** K. P. Pruessman et al., Magn Reson Med 46, 638–651 (2001). **4.** M. Lustig, J. et al, Magn Reson Med 64, 457–471 (2010). **5.** P. J. Beatty et al., IEEE Trans Med Imag 24(6) 799-808 (2005).