Investigation of the Impact of MR Hardware Attenuation on TOF and non-TOF PET/MR Images

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Aim

The aim of this simulation-study is to investigate the impact of ignoring the attenuation from MR hardware during PET reconstruction and considering different hardware attenuation coefficients and reconstructed objects. Results are given with and without TOF information.

Introduction

Neglecting the effect of attenuation due to MR hardware on the acquisition of PET data in PET/MR scans can lead to underestimation of activity [1], [2]. However, the impact of using the wrong attenuation estimate is likely to depend on the acquisition details.

Materials & Methods

Simulations Analytical, using "SIRF" [5] and "STIR" [6], [7] for the PET modelling; no randoms, scatter or measurement noise were simulated

Phantoms and Attenuation

Hardware	Phantom
Headphones (0.006 cm^{-1})	Uniform cylinder (att.: 0.0916 cm^{-1})
Headphones (0.015 cm^{-1})	Uniform cylinder (att.: 0.0916 cm^{-1})
Headphones (0.015 cm^{-1})	Uniform cylinder (att.: 0.0 cm^{-1})
Headphones (0.015 cm^{-1})	Brainweb data (Fig. 1 a) and b))
MR-Coil (Fig. 1c)	Uniform cylinder (att.: 0.0916 cm^{-1})
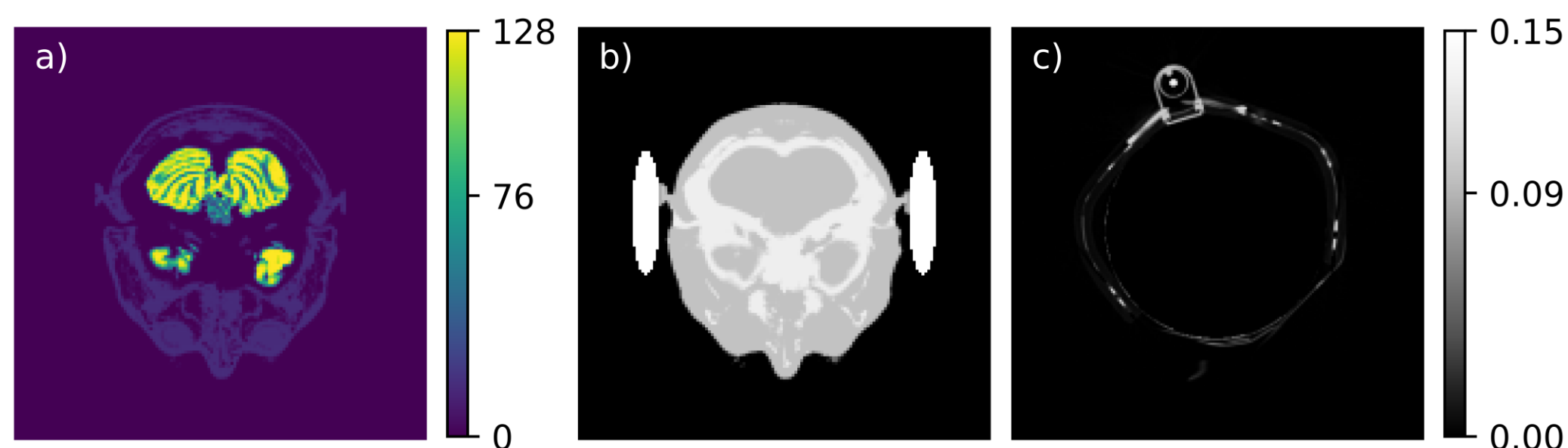
Fig. 1 a) Activity and b) attenuation images of the brainweb data used. Activity ratios roughly correspond to an FDG scan in a). c) Attenuation image of the multichannel MR coil used in simulations.

Scanner geometry

non-TOF: Biograph mMR (Siemens Healthineers)

TOF: biograph Vision 600 (Siemens Healthineers), TOF resolution: 214 ps

Reconstructions att. corrected OSEM reconstructions. Reconstructions using incorrect μ-maps excluding HW were compared to reference reconstructions using correct μ-maps including the HW attenuation.

Results

The mean error over the region of interest (ROI) is negative for all simulation settings as expected due to the undercorrection for attenuation. Nevertheless, the analysis showed that the error varied significantly for the different simulation setups, see Table I.

	Mean [%]	Std Dev [%]	Min [%]	Max [%]
foam, w cyl, non TOF	-1.3	1.4	-8.2	0.9
PVC, no cyl, non TOF	-23.3	20.3	-99.5	39.6
PVC, w cyl, non TOF	-23.1	35.9	-87.0	125.4
PVC, w cyl, TOF	-23.7	6.6	-54.2	0.0
coil att. w cyl non TOF	-8.9	7.1	-56.2	12.1
coil att. w cyl TOF	-9.4	4.0	-37.8	0.1
BW, non TOF-grey m.	-0.9	3.2	-22.1	9.5
BW, non TOF-white m.	-0.2	1.9	-17.6	13.5
BW, non TOF-bone	-2.2	10.5	-67.4	61.3
BW, TOF-grey m.	-0.9	3.1	-16.4	0.2
BW, TOF-white m.	-0.5	2.2	-14.6	0.2
BW, TOF-bone	-1.0	3.3	-25.0	1.8

Table I Relative errors for MLEM reconstructions without known HW μ-maps w.r.t reconstructions with known HW μ-maps.
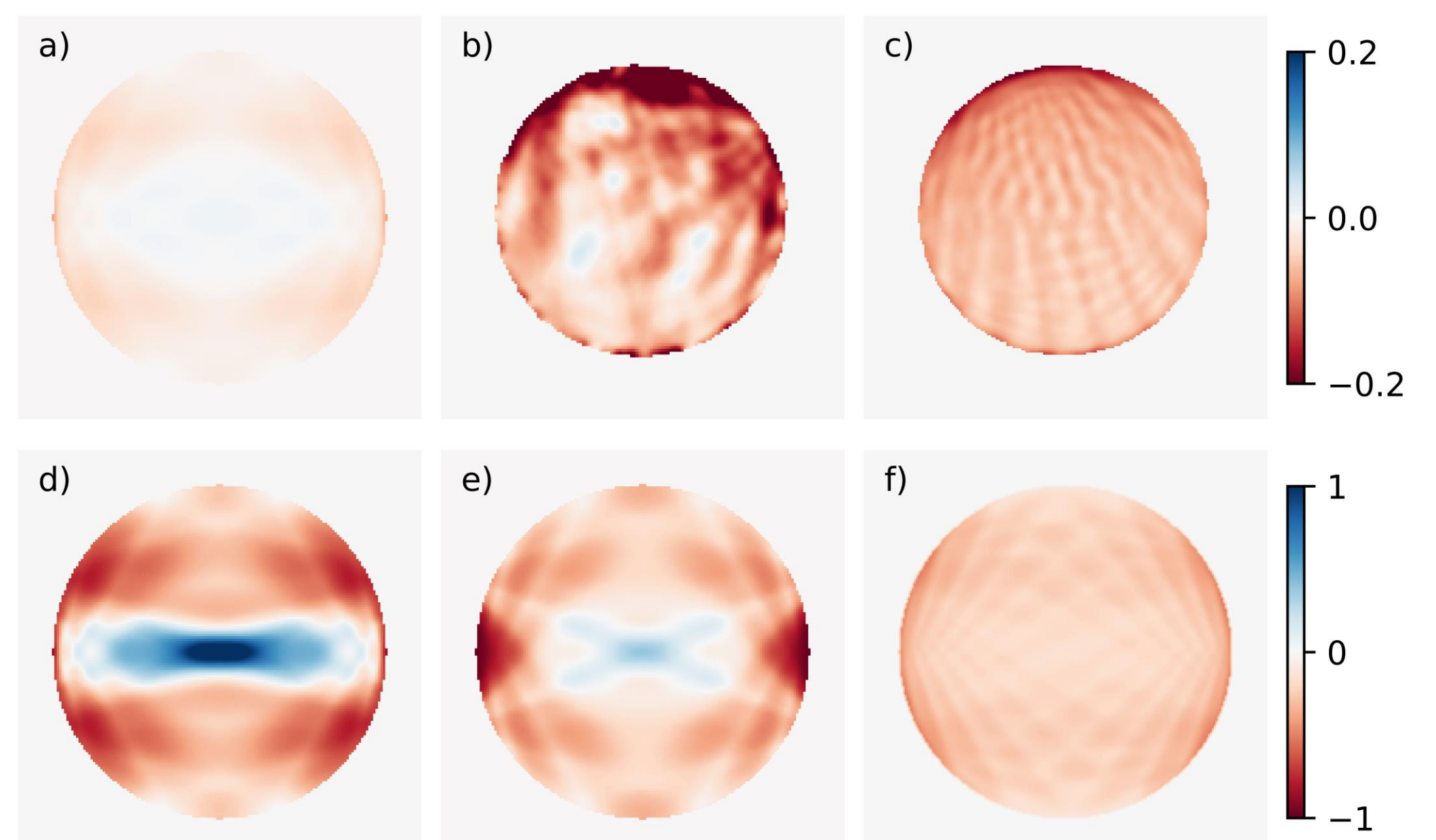
Fig. 2 Relative error images of reconstructions with different att.: a) foam, non-TOF; b) MR-coil, non-TOF; c) MR-coil, TOF d) PVC att. non-TOF; e) PVC att. no cylinder att., non-TOF and f) PVC att., TOF
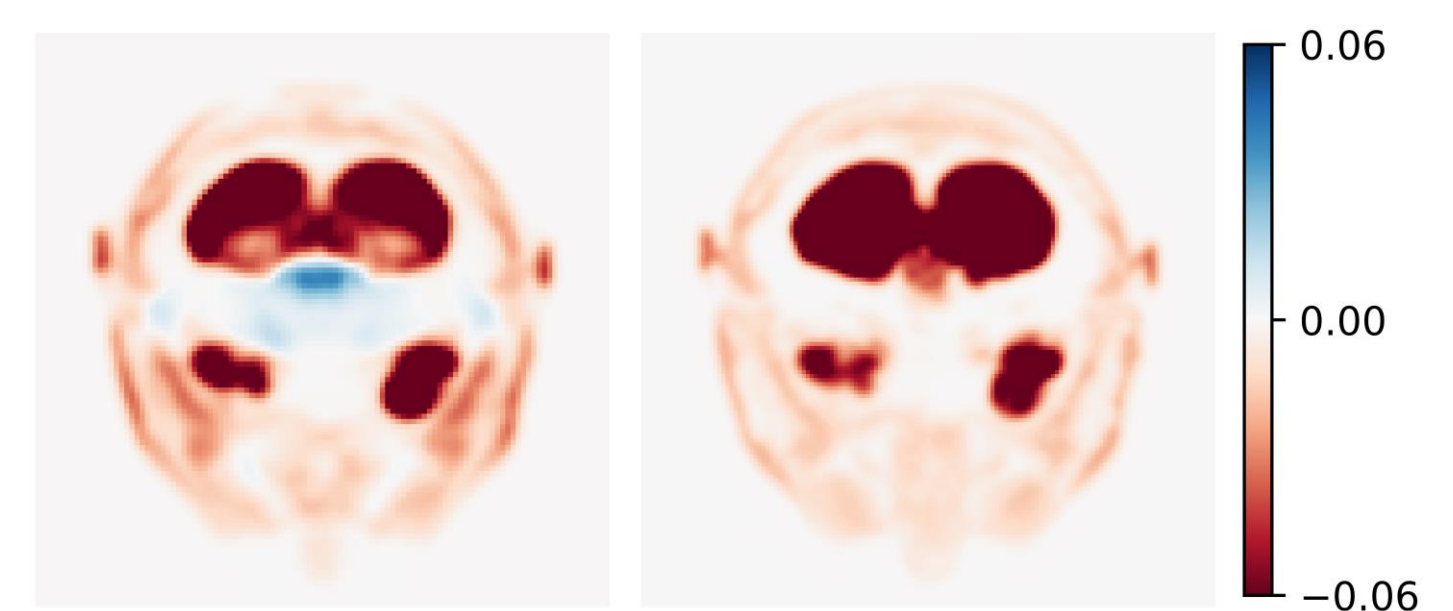
Fig. 3 Difference images of reconstructions of brainweb data including headphones made of PVC, normalized to the maximum activity value of the ground truth. a) non-TOF; b) TOF.

Discussion

The magnitude of the error and the geometrical structure of the error image is strongly dependent on HW attenuation as well as the phantom attenuation. TOF strongly affects the structure of the relative error but does not decrease its mean for the cylinder data.

References

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