Application of MR-based Joint Estimation of Attenuation and Activity Distributions to Clinical non-TOF PET/MR

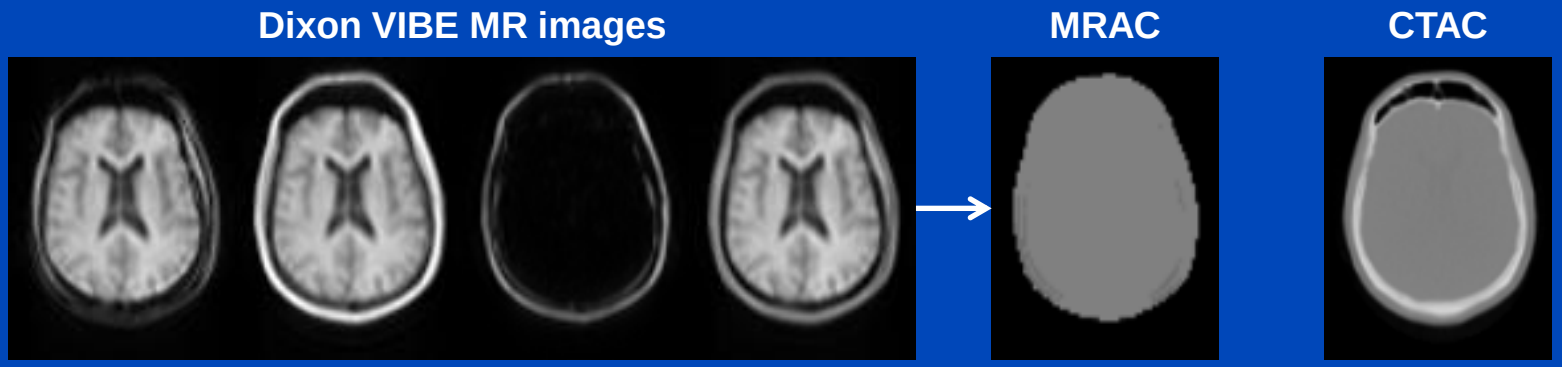
T. Heußer[1], C. M. Rank[1], M. T. Freitag[1], A. Dimitrakopoulou-Strauss[1], H.-P. Schlemmer[1], T. Beyer[2], and M. Kachelrieß[1]

[1]German Cancer Research Center (DKFZ), Heidelberg, Germany

[2]Center for Medical Physics and Biomedical Engineering, Medical University Vienna, Vienna, Austria

dkfz. DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

Introduction



- **Motivation**
  - Standard MR-based attenuation correction (AC) neglects bone attenuation and thus underestimates the activity distribution.
- **Aim**
  - Improve AC for non-TOF PET/MR.
- **Proposed algorithm**
  - Extension of the maximum-likelihood reconstruction of attenuation and activity (MLAA)[1] for non-TOF PET/MR, called MR-MLAA.

[1] J. Nuyts, P. Dupont, S. Stroobants, R. Benninck, L. Mortelmans, and P. Suetens, "Simultaneous maximum a posteriori reconstruction of attenuation and activity distributions from emission sinograms.," IEEE Trans. Med. Imaging 18(5), 393–403 (1999).

MR-MLAA[1]

- **Joint estimation of attenuation and activity**
  - Using PET emission data
  - Incorporating MR-based prior information
- **Iterative approach**
  - Update attenuation and activity in an alternating manner
- **Cost function**

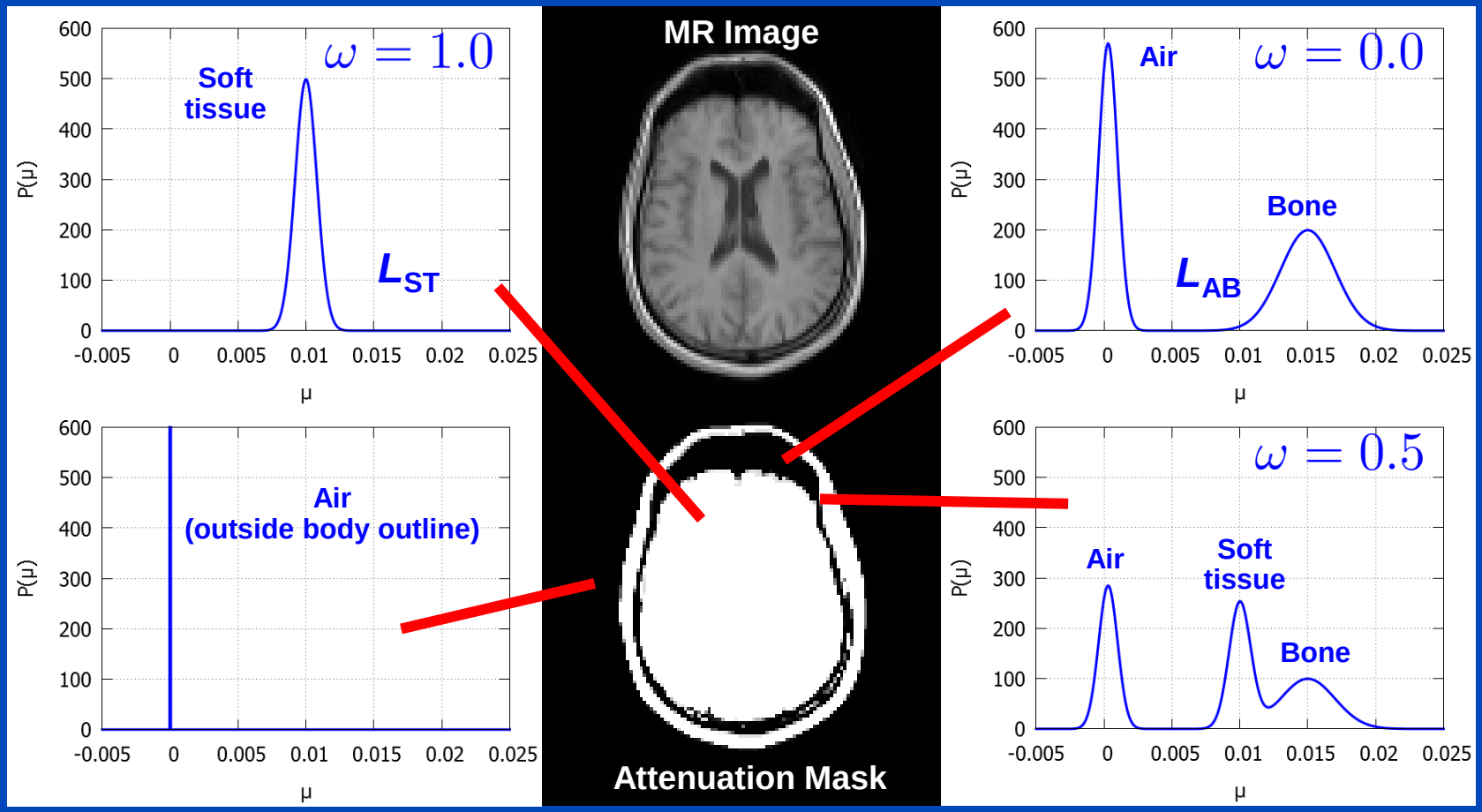
$$C(\boldsymbol{\lambda}, \boldsymbol{\mu}) = \underbrace{L(\boldsymbol{\lambda}, \boldsymbol{\mu})}_{\text{Log-likelihood}} + \underbrace{L_{\mathrm{S}}(\boldsymbol{\mu}) + L_{\mathrm{I}}(\boldsymbol{\mu})}_{\text{Prior terms}}$$

$\boldsymbol{\lambda}$ = activity
$\boldsymbol{\mu}$ = attenuation

- **Intensity prior L_{I}**
  - **Voxel-dependent** Gaussian-like probability distribution of pre-defined attenuation coefficients, e.g., for soft tissue, air, bone
  - Derived from diagnostic T1-weighted MR image

[1] T. Heußer, C.M. Rank, M.T. Freitag, A. Dimitrakopoulou-Strauss, H.-P. Schlemmer, T. Beyer, and M. Kachelrieß, "MR-Consistent Simultaneous Reconstruction of Attenuation and Activity for non-TOF PET/MR," *IEEE Trans. Nucl. Sci.*, in press.

Intensity Prior L_I



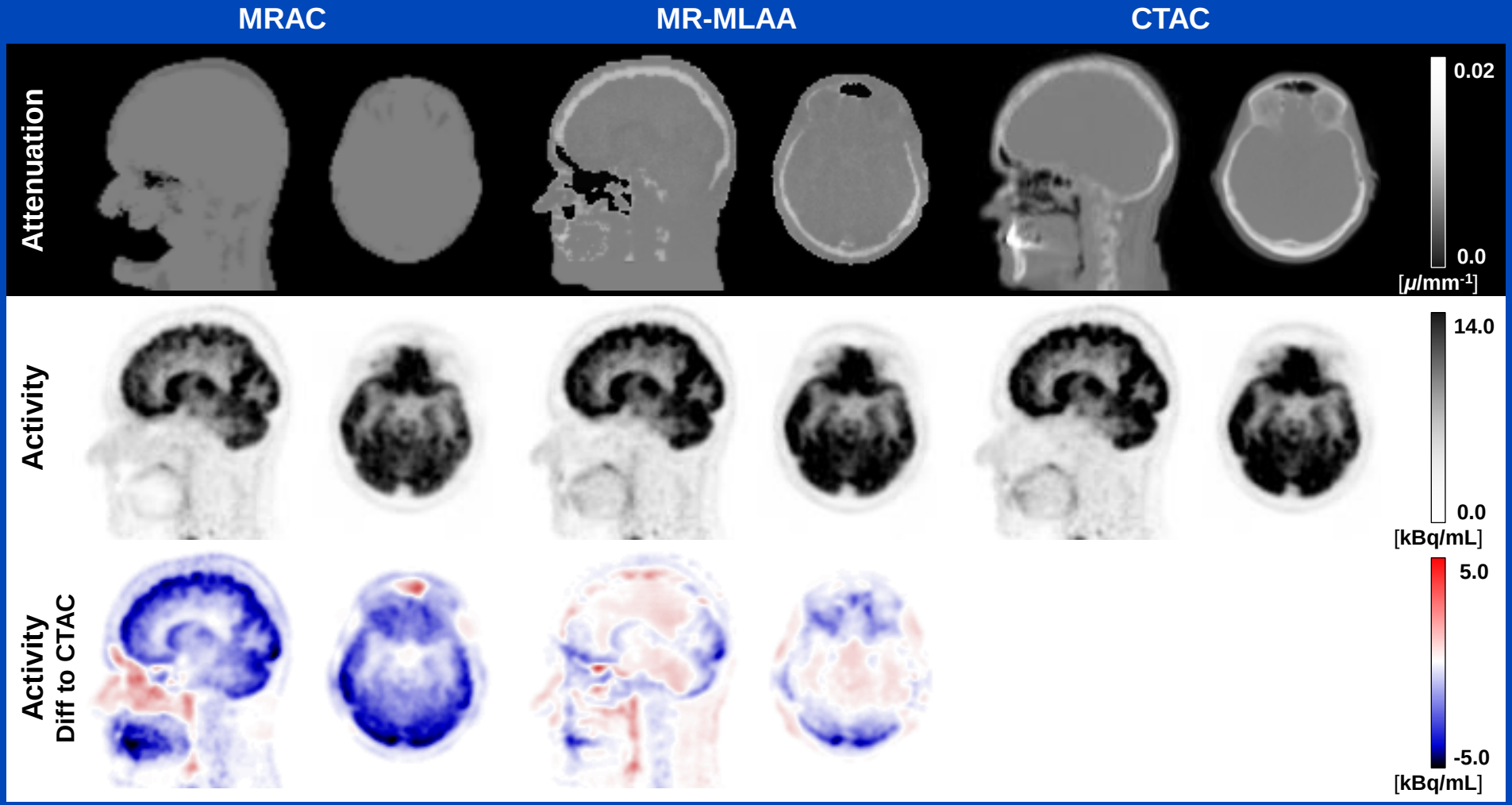
$$L_{\mathrm{I}}(\boldsymbol{r}) = \omega(\boldsymbol{r})\beta_{\mathrm{ST}}L_{\mathrm{ST}} + (1-\omega(\boldsymbol{r}))\beta_{\mathrm{AB}}L_{\mathrm{AB}}$$

dkfz.

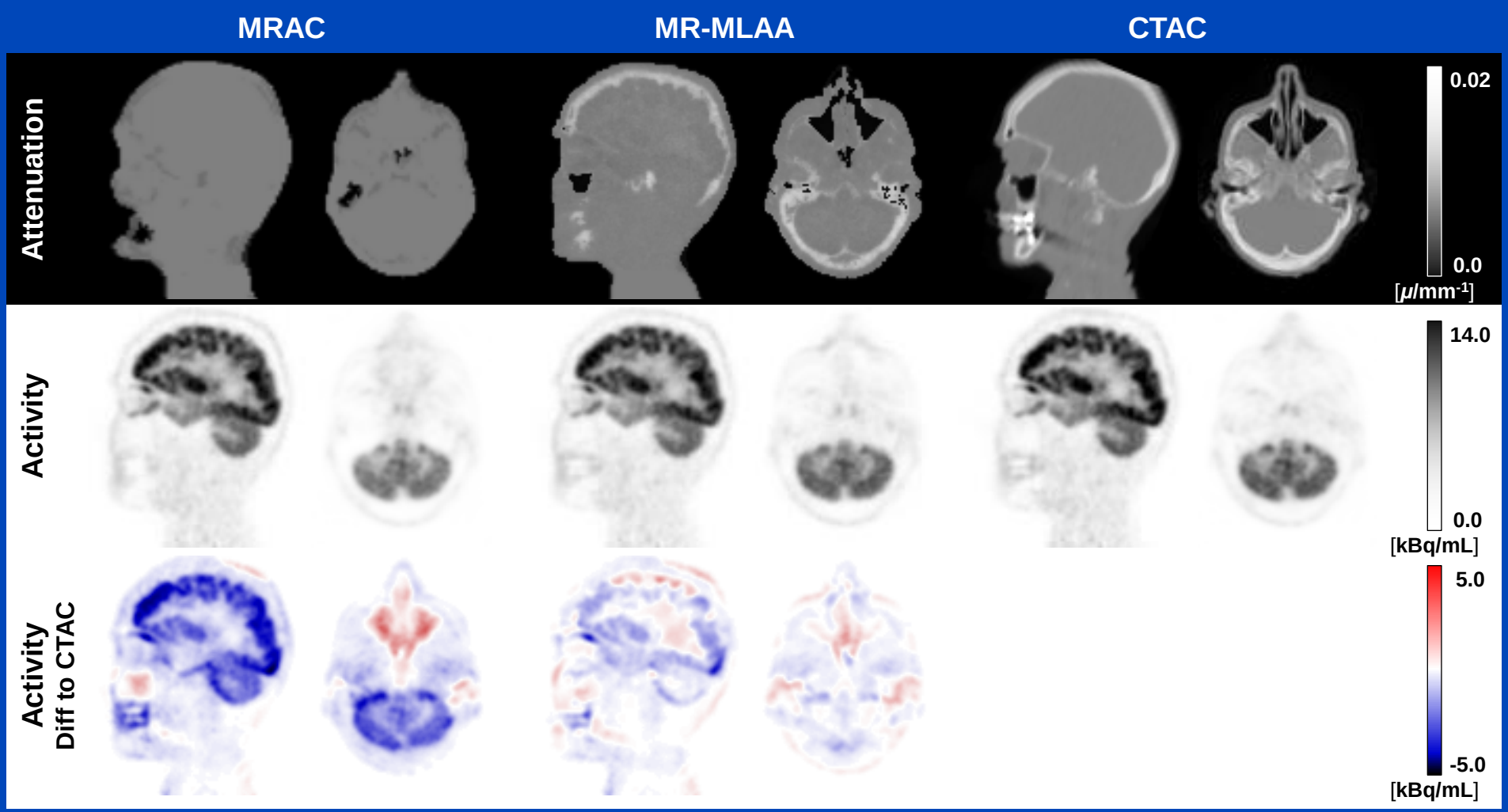
Experiments

- Clinical non-TOF ^{18}F-FDG-PET/MR data of the head region acquired with a Siemens Biograph mMR
- Perform OSEM reconstructions using
  - 3 iterations
  - 21 subsets
  - Gaussian post-smoothing (σ = 2.0 mm)
- Attenuation correction
  - MRAC: standard MR-based AC
  - MR-MLAA: proposed method
  - CTAC: CT-derived AC

Results: Patient 1



Results: Patient 2



Conclusion

- **MR-MLAA reduces activity underestimation compared to standard MR-based AC.**
- **Five patients, activity evaluated in full brain:**
  - **MRAC: 10.7 % activity underestimation**
  - **MR-MLAA: 3.4 % activity underestimation**
- **Drawbacks**
  - **Local activity over- or underestimation due to tissue misclassifications (air/bone)**
  - **Increased computational demand due to iterative approach**

Thank You!

The 4th International Conference on

Image Formation in X-Ray Computed Tomography

July 18 – July 22, 2016, Bamberg, Germany

www.ct-meeting.org

Conference Chair

Marc Kachelrieß, German Cancer Research Center (DKFZ), Heidelberg, Germany

This presentation will soon be available at www.dkfz.de/ct.

This work was supported by the Helmholtz International Graduate School for Cancer Research, Heidelberg, Germany.

Parts of the reconstruction software RayConStruct-IR were provided by RayConStruct® GmbH, Nürnberg, Germany.

dkfz.