Simultaneous Reconstruction of Attenuation and Activity for non-TOF PET/MR Using MR Prior Information

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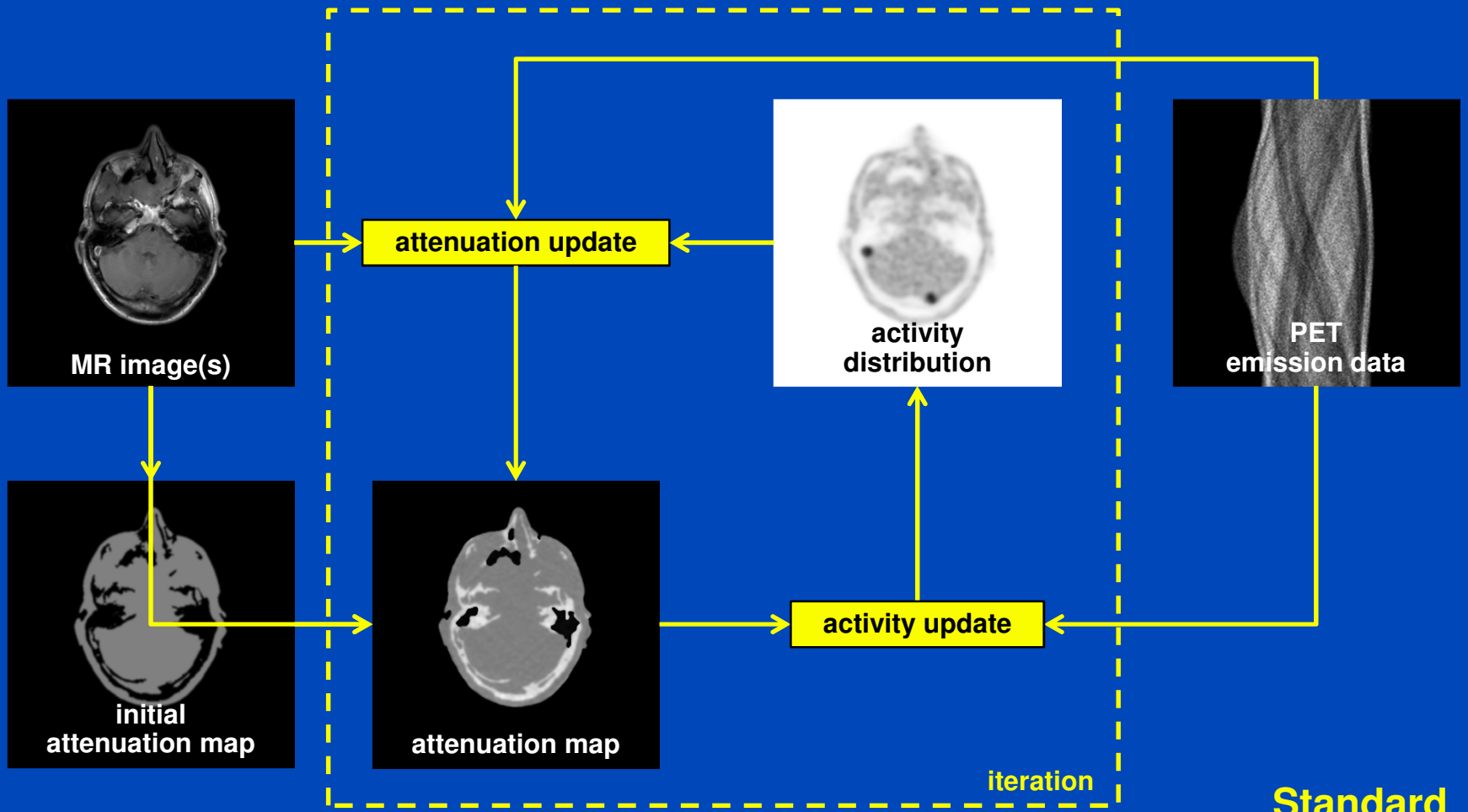
Introduction

- **Motivation**
  - Standard MR-based attenuation correction (AC) neglects bone attenuation and thus underestimates the activity distribution.
- **Aim**
  - Improve AC for non-TOF PET/MR by simultaneous reconstruction of attenuation and activity distributions from PET emission data using MR prior information.
- **Proposed algorithm**
  - The presented algorithm is an 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).

Workflow



Standard MR-based AC

Prior Information

- **Cost function**

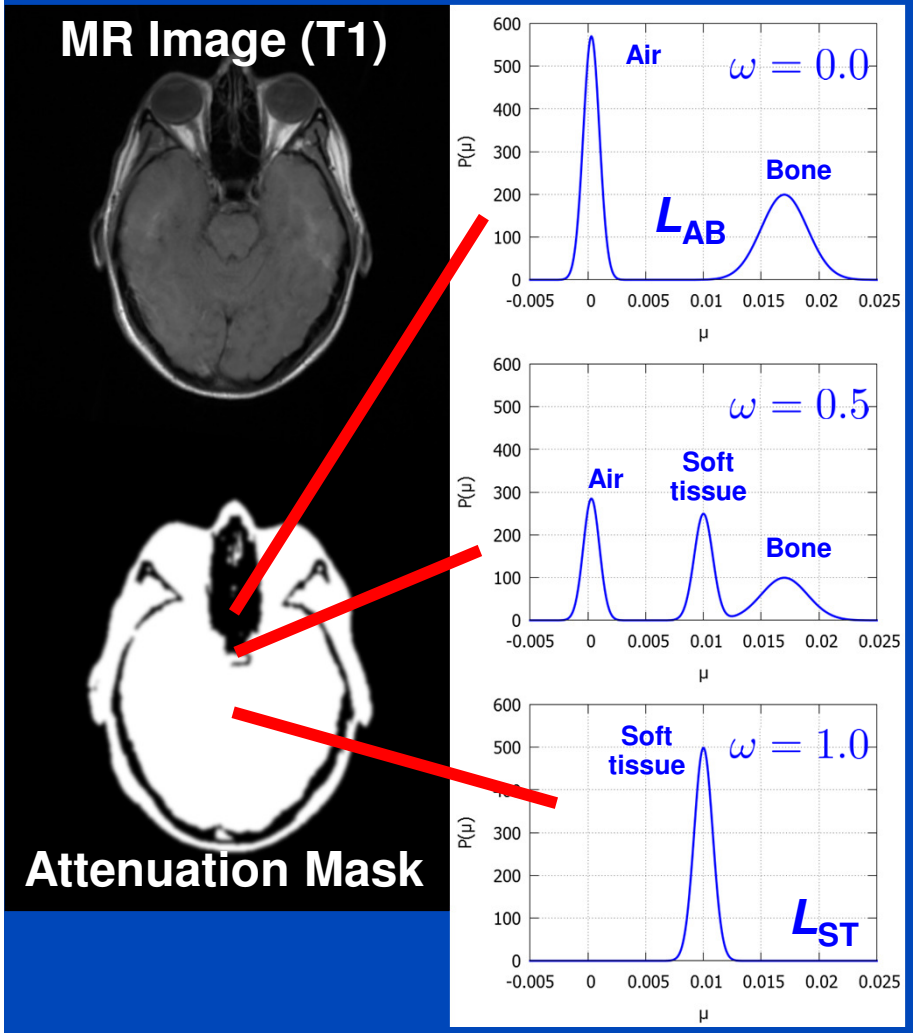
$$C(\boldsymbol{\lambda}, \boldsymbol{\mu}) = L(\boldsymbol{\lambda}, \boldsymbol{\mu}) + L_{\mathrm{S}}(\boldsymbol{\mu}) + L_{\mathrm{I}}(\boldsymbol{\mu})$$

λ Activity

μ Attenuation

- **Log-likelihood *L***
  - Probability for acquiring the measured data given *λ* and *μ*.
- **Smoothing prior L_S**
  - Favors smooth attenuation map.
- **Intensity prior L_I**
  - Voxel-dependent Gaussian-like probability distribution of pre-defined attenuation coefficients, e.g., for soft tissue, air, bone, etc.

Intensity Prior L_I



- Use the MR image to create a mask defining air/bone and soft tissue.
- Smooth mask.
- Define intensity prior L_I as linear combination of air/bone intensity prior L_{AB} and soft tissue intensity prior L_{ST}:

$$L_I = (1-\omega)\beta_{AB}L_{AB} + \omega\beta_{ST}L_{ST}$$

ω Voxel-dependent weighting factor, based on attenuation mask

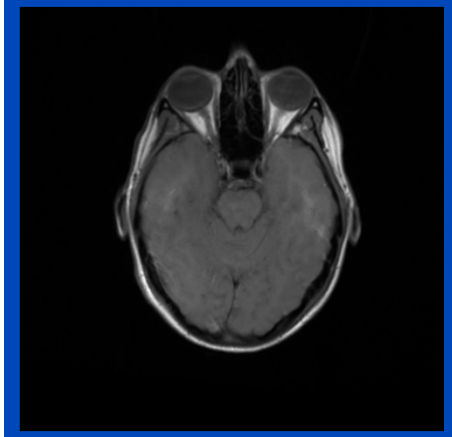
β_{AB}, β_{ST} Global weighting factors

Experiments

- Simulate 2D PET emission data accounting for
  - Poisson noise.
  - attenuation.
- Perform reconstructions using
  - the true attenuation for AC (ground truth).
  - standard MR-based AC (MRAC).
  - MR-consistent reconstruction of attenuation and activity (MR-MLAA).
- Quantitative Evaluation
  - Measure relative mean activity in ROIs corresponding to simulated lesions.
    - » Lesion 1: A_1
    - » Lesion 2: A_2

Patient 1

MR Image

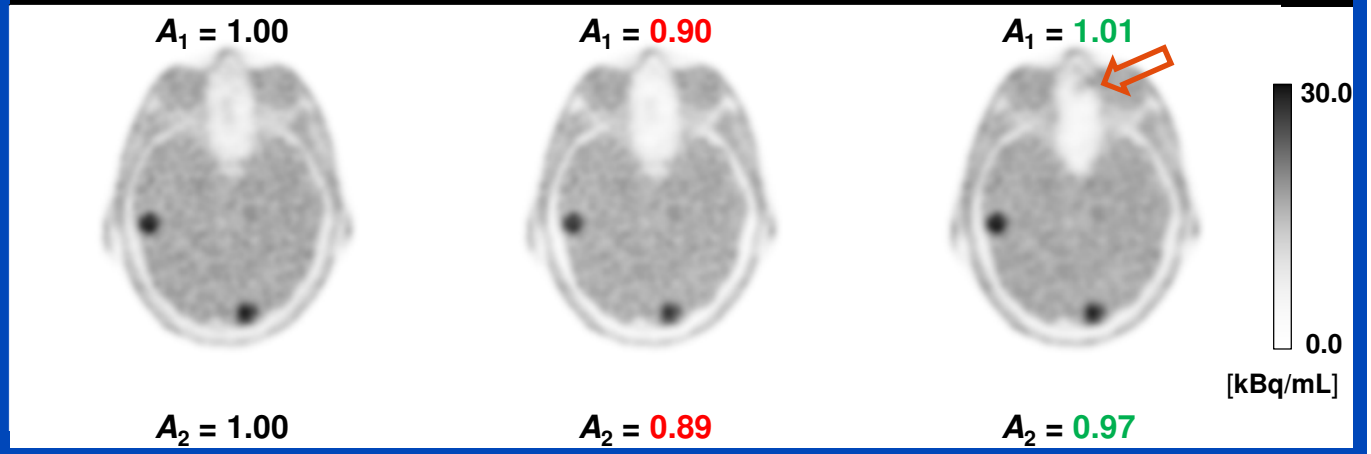


Attenuation Mask

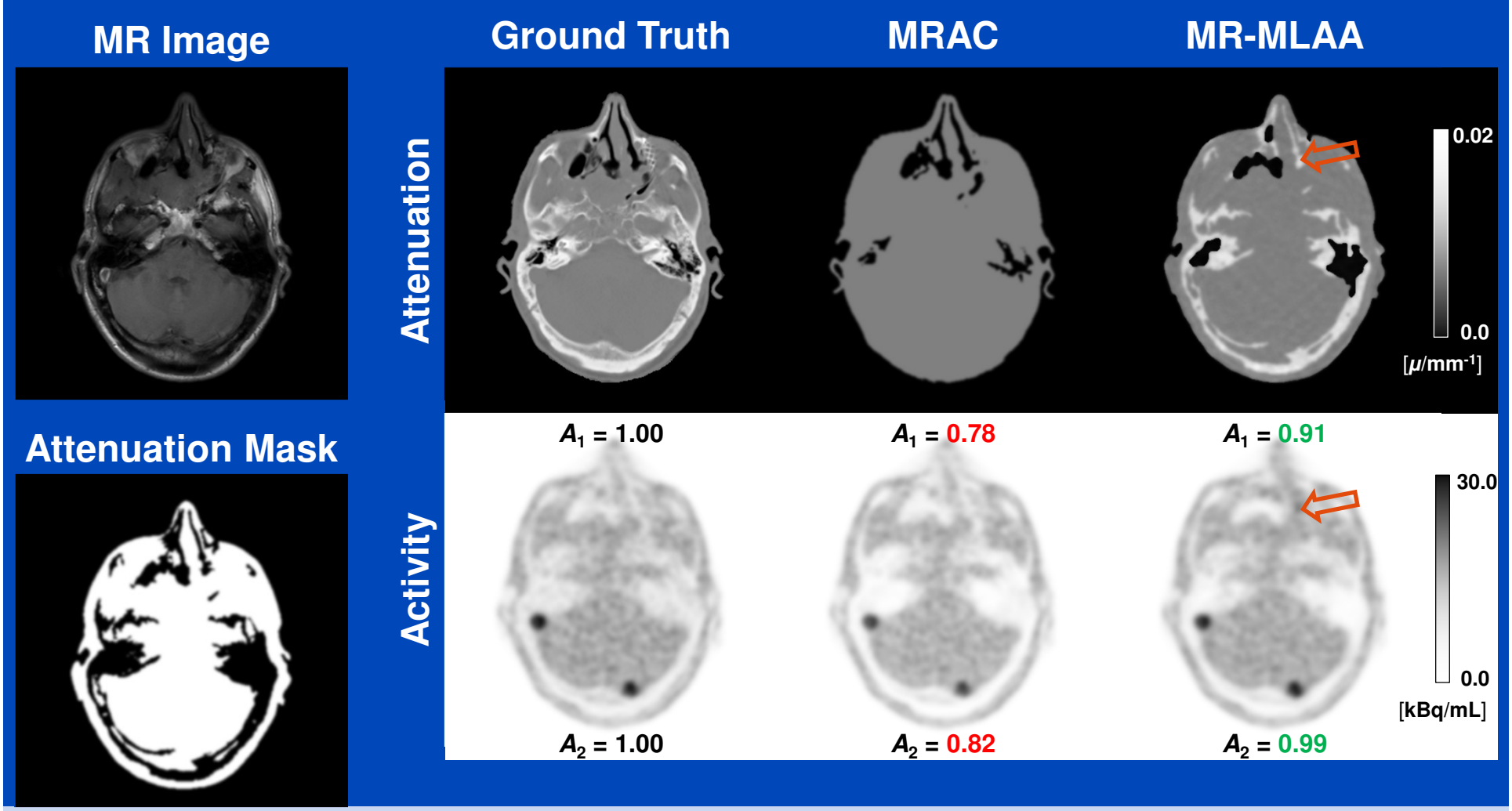
Ground Truth | MRAC | MR-MLAA

Attenuation

Activity



Patient 2


MR Image
Ground Truth
MRAC
MR-MLAA
Attenuation
0.02
0.0
[μ/mm-1]
Attenuation Mask
A1 = 1.00
A1 = 0.78
A1 = 0.91
Activity
30.0
0.0
[kBq/mL]
A2 = 1.00
A2 = 0.82
A2 = 0.99

Conclusion

- Underestimation of activity in the lesions can be significantly reduced using MR-MLAA compared to standard MR-based AC.
- Some misclassifications
  - Bone instead of soft tissue or air.
  - Air instead of bone.
- Potential improvements
  - Sophisticated segmentation technique to create attenuation mask from MR image(s).
  - Additional prior information, e.g., from non attenuation-corrected (NAC) images.
  - …

Thank You!

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

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