Impact of Deep Learning-Based PET Image Denoising at Reduced Scan Time on Estimated Lesion Detectability

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1. Introduction

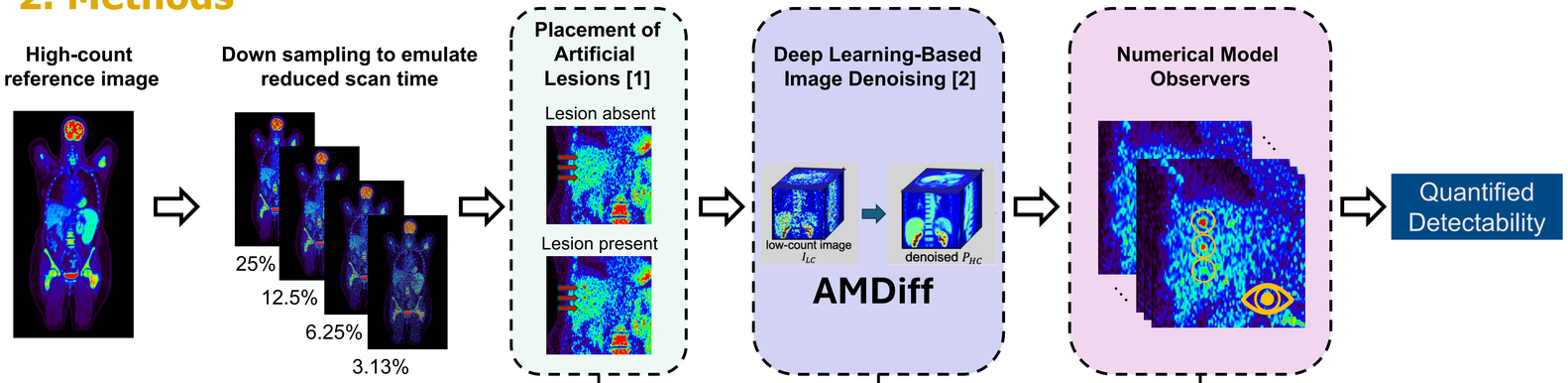
Background

- Lesion detectability is a critical metric in PET imaging, particularly in oncology – impacting diagnostic accuracy and patient outcome
- Growing interest for reduced dose or short-frame/kinetic imaging
- Deep learning (DL)-based PET image denoisers have been proposed to recover image quality from noisy images

Objectives

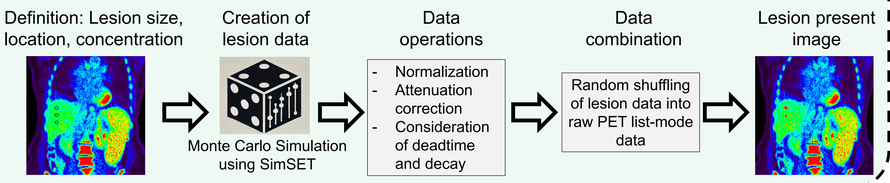
- Evaluation of the impact of DL-based denoisers on computer-estimated lesion detectability using artificially added lesions
- Investigation of the performance at reduced count level
- Comparison to noisy original images under various conditions (lesion contrast, lesion size)

2. Methods



DIANA - **D**etectability **I**nvestigations using **A**rtificial **N**odal **A**dditions [1]

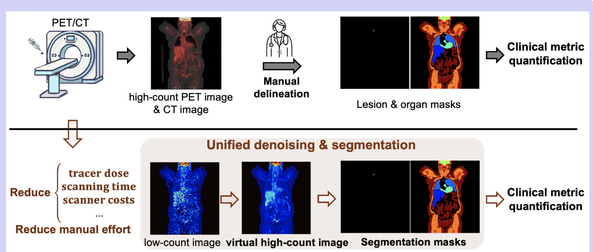
This tool enables the addition of list-mode data from lesions to raw PET data prior to reconstruction



AMDiff [2]

Anatomically and metabolically informed diffusion model

- Unified framework for denoising and lesion segmentation
- Incorporates semantic-informed denoiser and denoising-informed segmenter
- Surpasses stand-alone segmentation or denoising tools



Numerical Model Observer Study

Study design:

- Lesions placed in the liver of a human subject
- 3 different noise levels with 8 image representations each
- Lesion to liver background-ratio 3:1 and 5:1
- 3 different lesion diameters: 4mm, 6mm, 8mm

Non-Pre-Whitening Matched Filter

- Observer response variable λ_i for an input image f_i with lesions present (i=1) or absent (i=0)
- $\lambda_i = (< f_1 > - < f_0 >) \cdot f_i$
- $< f_i >$ is the average image of its class

SNR

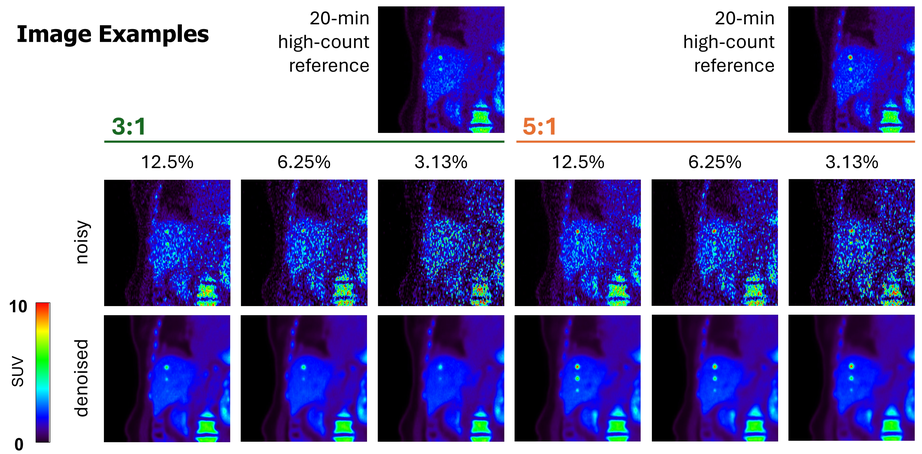
- Measures how reliable a signal can be distinguished from the absence of a signal
- $\mathrm{SNR} = \sqrt{\frac{(<\lambda_1> - <\lambda_0>)^2}{0.5 \cdot \mathrm{Var}(\lambda_1) + 0.5 \cdot \mathrm{Var}(\lambda_0)}}$

Area under the Receiver Operating Characteristic Curve (AROCC)

- Related to SNR: $\mathrm{AROCC} = \frac{1}{2} + \frac{2}{2} \cdot \mathrm{erf}(0.5 \cdot \mathrm{SNR})$
- Returns a value between 0.5 (no detectability) and 1.0 (maximum detectability)

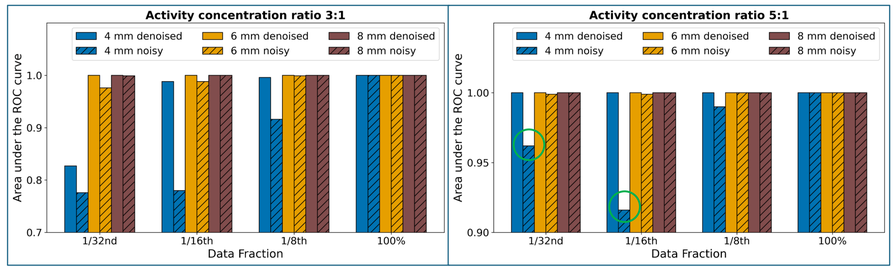
3. Results

Image Examples



→ **Improved lesion conspicuity on denoised images**

Lesion Detectability



→ **AROCC is consistently higher than on original noisy images throughout all lesion sizes and noise levels**

→ Caveat: high statistical noise: inconsistent AROCC (see circles in right figure)

4. Conclusion

Summary and Conclusion

- The developed framework allows for reproducible in-vivo lesion quantification
- The investigated DL-based denoiser enhances lesion detectability for both contrast ratios (3:1 and 5:1) and across all noise levels and lesion sizes

Next Steps

- Randomizing lesion size, number and location
- Increased data sizes for consistent and statistically significant results
- Use of more advanced metrics like the Channelized Hotelling Observer

Get more info here:

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References
[1] R. Bayerlein, et al. (2024) 10.1109/NSS/MIC/RTSD57108.2024.10657528; **[2]** M. Xia, et al. (2025) arXiv:2503.13257