Deep Learning-Enabled Automated Hotspot Detection from ^{18}F-DCFPyL (PyL-PSMA) PET/CT in Metastatic Prostate Cancer

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Background

- PyL-PSMA PET/CT hybrid imaging is one of the most promising tools for the detection and diagnosis of metastatic prostate cancer
- Accurate quantification with minimal manual effort requires:
  - Automated detection of hotspots in the PET image
  - Computation of Standard Uptake Values (SUV) in reference organs

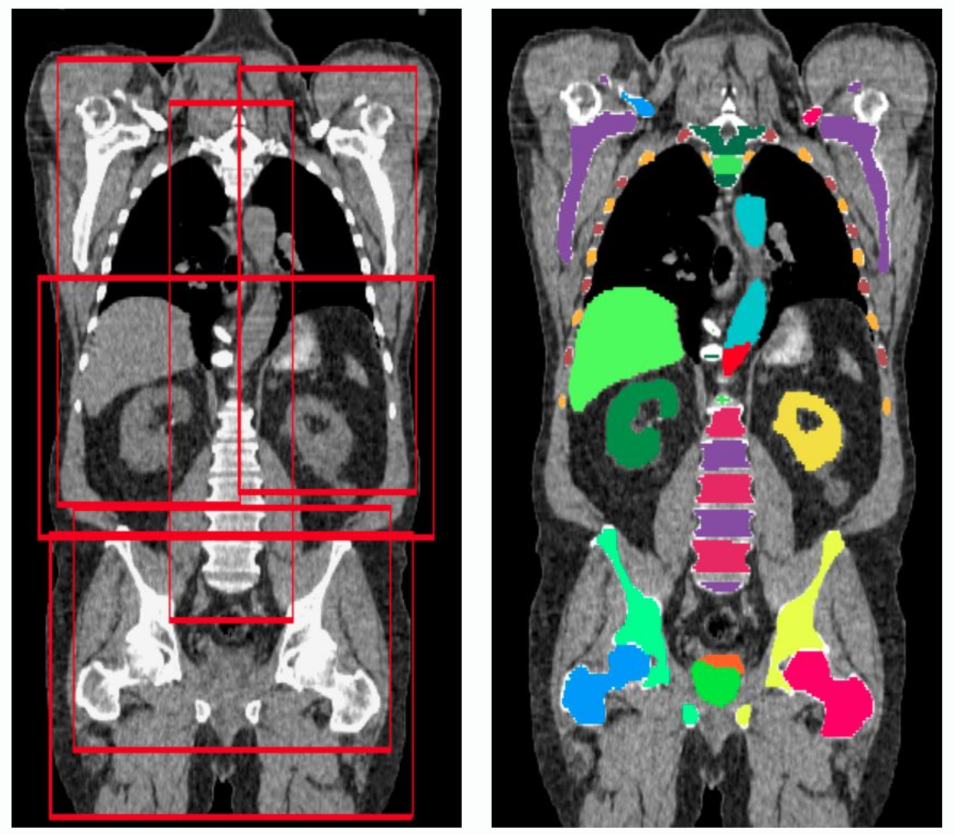
Objectives

- Automated detection of hotspots in bone and in the pelvic region that may represent metastases
- Automatic segmentation of liver and aorta (thoracic part), for reference SUV computation

Data

A data set from the PyL Research Access Program was used for hotspot detection algorithm development. The data set consisted of 157 PET/CT scans annotated for bone metastases (114 w/o metastases, 11 w/ > 3 metastases) and 66 scans annotated for regional lymph node metastases (40 w/o metastases, 6 w/ > 3 metastases).

Methods



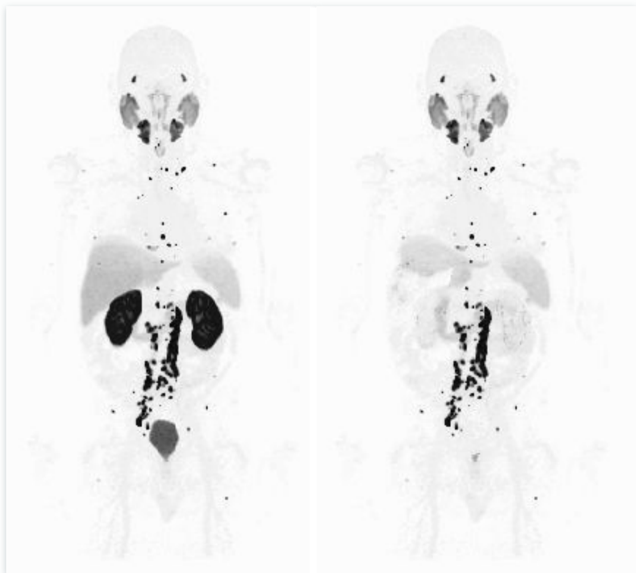
Neural network output

Deep neural networks applied to the the CT image give:

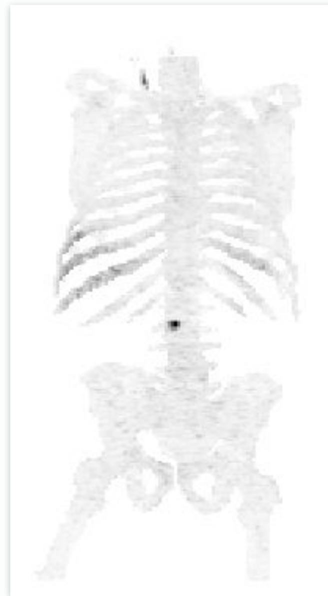
- A localization of regions of interest
- A semantic segmentation of relevant organs and bones in those regions, which are merged to a joint segmentation of the CT image

The segmentation is transferred to the PET image space. Averages of the intensities in the aorta (thoracic part) and the liver respectively can be used as reference SUV's.

The segmentation in PET space is also used to define regions for abnormal hotspot search, and to suppress intensities pertaining to urinary bladder, liver and kidney. Abnormal hotspots are found using blob detection algorithms.



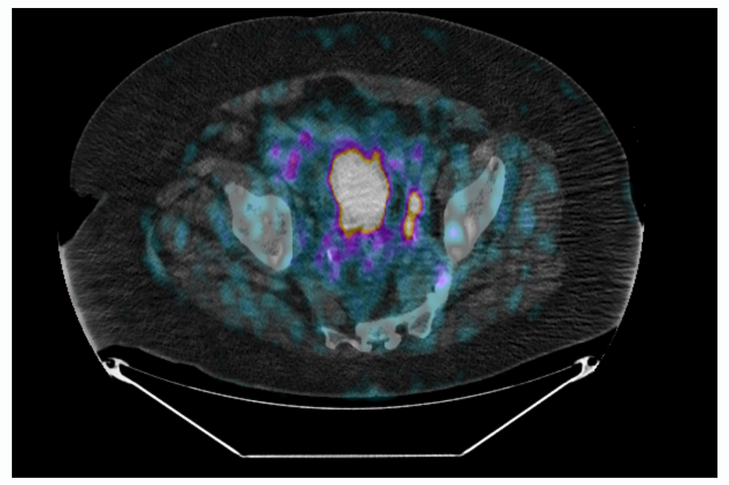
Maximum intensity projection (MIP) before and after suppression. The suppression-corrected PET is used for malignant lymph node search.

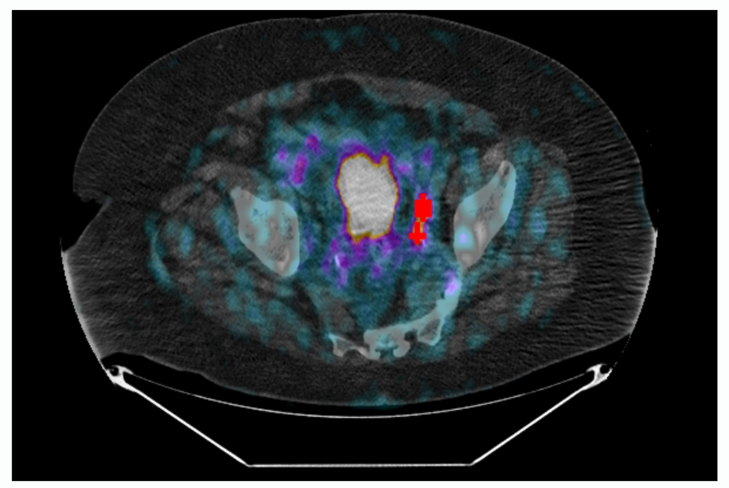


MIP of masked bone intensities, that are used for detection of bone metastases

Results

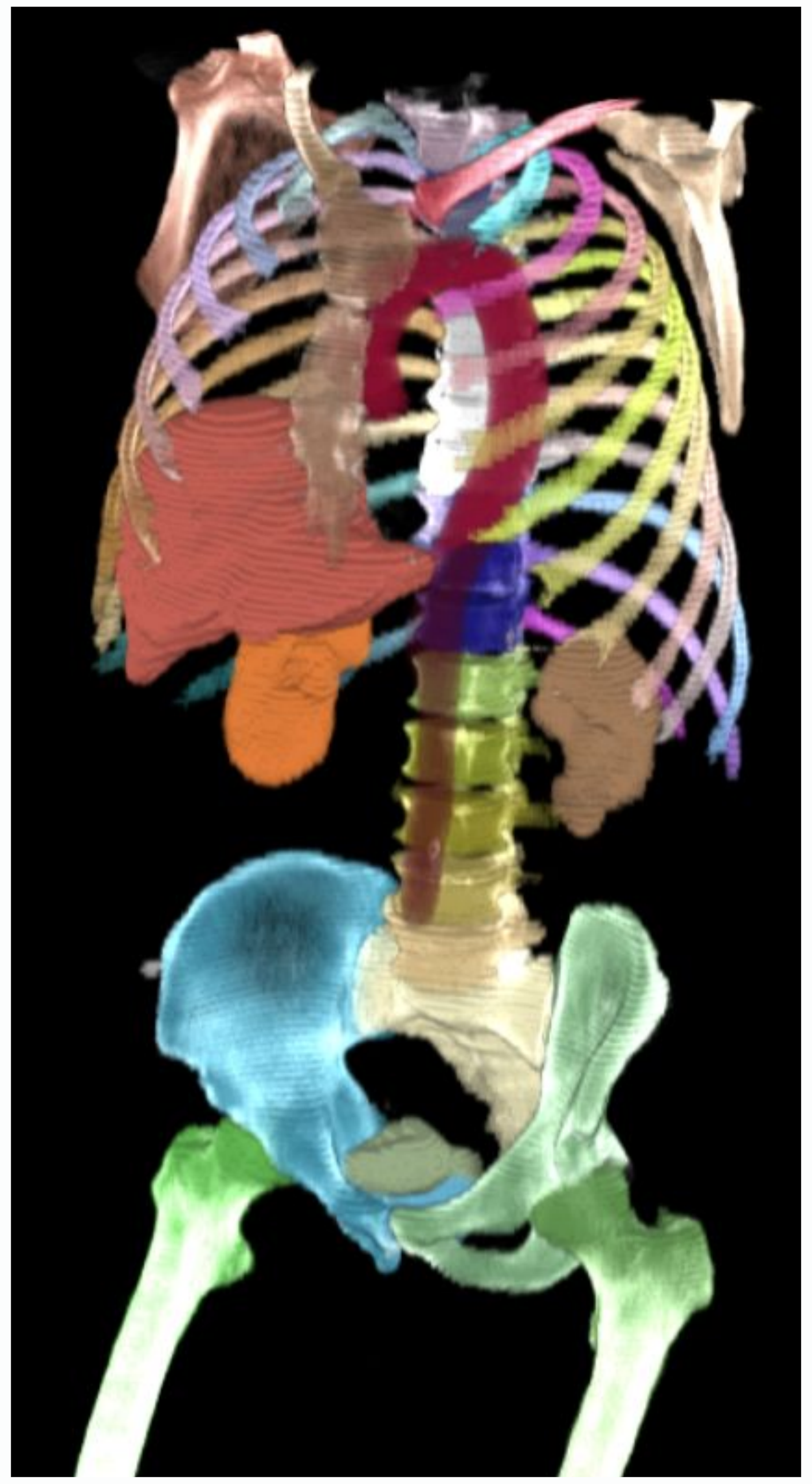
The bone detection algorithm found 97% of all annotated bone metastases, with an average 109 hotspots per scan. The lymph node detection algorithm found 96% of all annotated regional lymph node metastases with on average 32 hotspots per scan.





Right, top: *PyL-PSMA PET/CT fusion image*

Right, bottom: *Regional lymph node metastases automatically detected by the algorithm*



Deep learning semantic segmentation of 52 bones and 7 soft tissue organs

The deep learning semantic segmentation has been trained to segment 52 bones and 7 soft tissue organs that are used for hotspot detection or as reference. As an example, 140/37 manually segmented livers were used for training/development, similarly 61/14 aortas.

In a test set of ten images not used in training and development, liver had Dice 0.97 ±0.01 and aorta had Dice 0.91 ±0.05.

Conclusion

The study demonstrated the utility of deep learning based semantic segmentation for automated hotspot search and computation of reference SUV's in PyL-PSMA PET/CT images. Future work includes assessing precision of automatically quantified values such as SUV_{max} and volume to further optimize the hotspot detection algorithm.

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