Automated and Robust Organ Segmentation for 3D-based Internal dose Calculation

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Abstract

Purpose: In this work we address image segmentation within dosimetry using deep learning and make three main contributions: a) to extend and op- timize the architecture of an existing Convolutional Neural Network (CNN) in order to obtain a fast, robust and accurate Computed Tomography (CT) based organ segmentation method for kidneys and livers; b) to train the CNN with an inhomogeneous set of CT scans and validate the CNN for daily dosimetry; c) to evaluate dosimetry results obtained using automated organ segmentation in comparison to manual segmentation done by two independent experts.

Methods: We adapted a performant deep learning approach using CT-images to calculate organ boundaries with sufficiently high and adequate accuracy and processing time. The segmented organs were consequently used as binary masks for further convolution with a point spread function to retrieve the ac- tivity values from quantitatively reconstructed SPECT images for ”volumet- ric”/3D dosimetry. The retrieved activities were used to perform dosimetry calculations considering the kidneys as source organ.

Results: The computational expenses of the algorithm was adequate enough to be used in clinical daily routine, required minimum pre-processing and per- formed within an acceptable accuracy of 93 . 4% for liver segmentation and of 94 . 1% for kidney segmentation. Additionally, kidney self-absorbed doses calcu- lated using automated segmentation differed 6 . 3% from dosimetries performed by two medical physicists in 8 patients.

Conclusion: The proposed approach may accelerate volumetric dosimetry of kidneys in molecular radiotherapy with 177Lu-labelled radio-pharmaceuticals such as 177Lu-DOTATOC. However, even though a fully automated segmen- tation methodology based on CT images accelerates the organ segmentation and performs with high accuracy, it does not remove the need for supervision and corrections by experts, mostly due to misalignments in the co-registration between SPECT and CT images.

Trial registration: EudraCT, 2016-001897-13. Registered 26.04.2016, www.clinicaltrialsregister.eu/ctr-search/search?query=2016-001897-13

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the latest manuscript can be downloaded and accessed as a PDF.

Figures

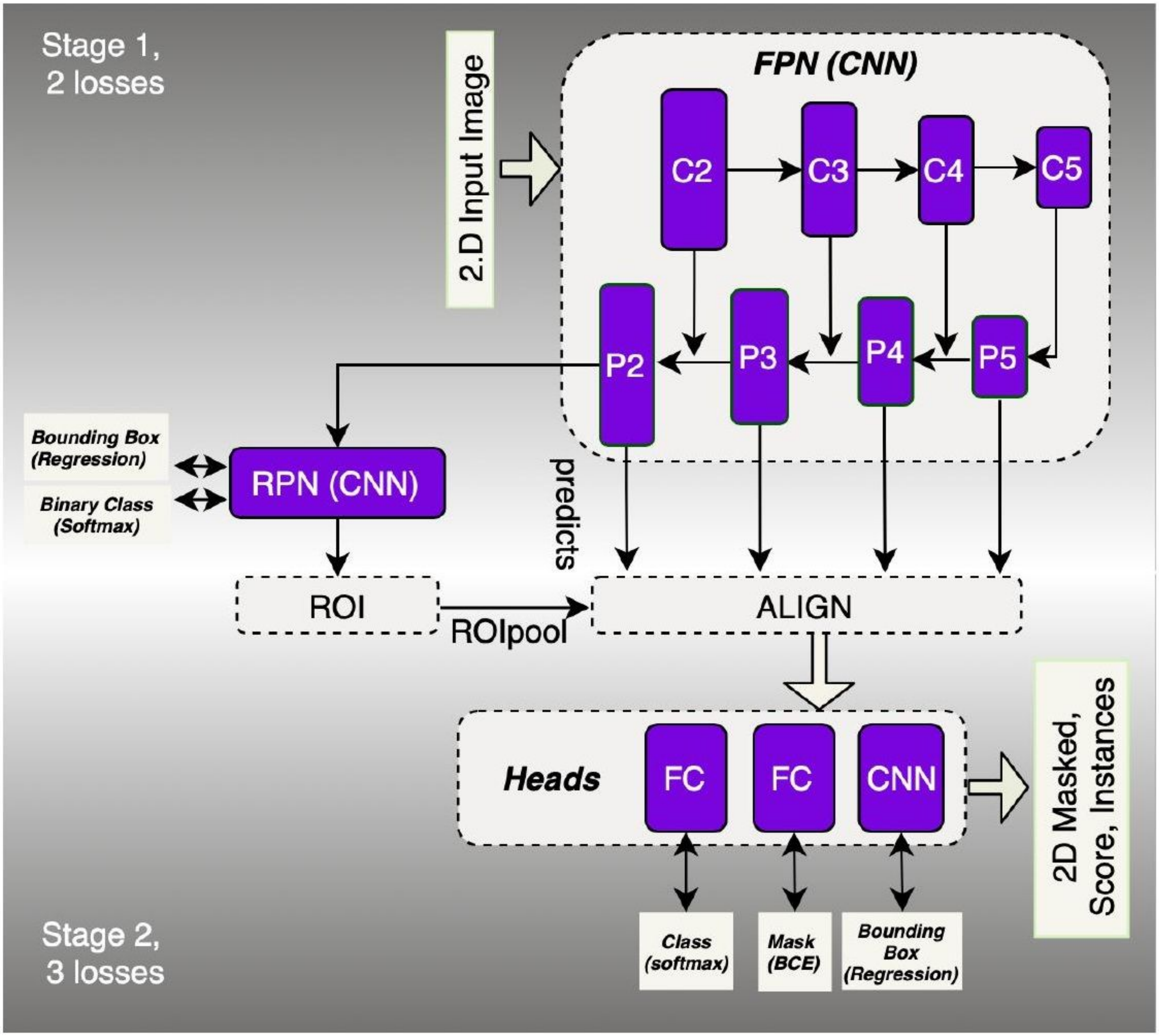
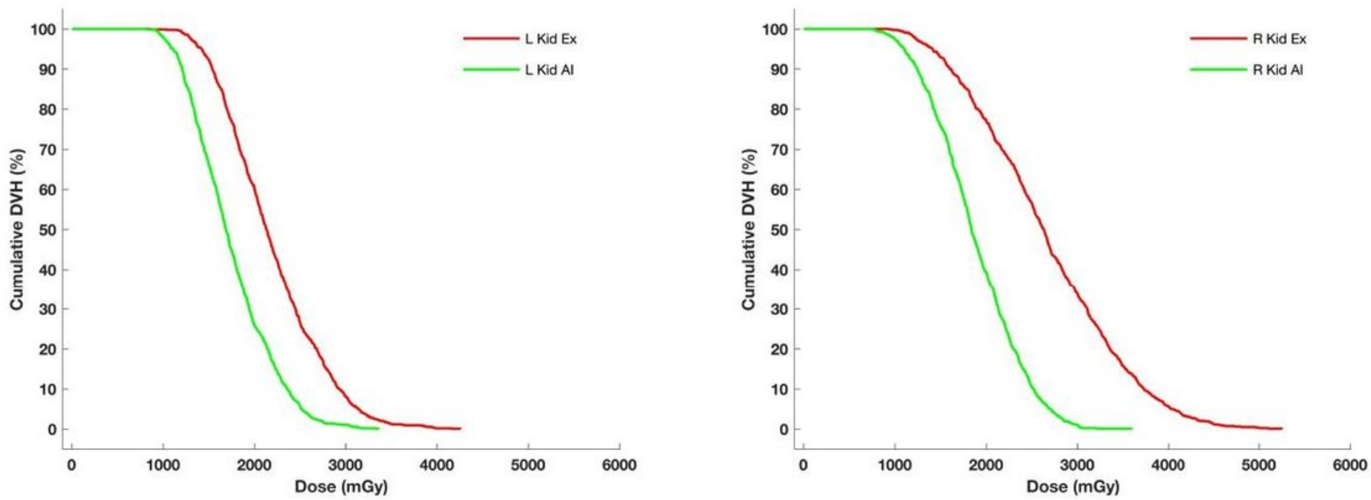


Figure 1

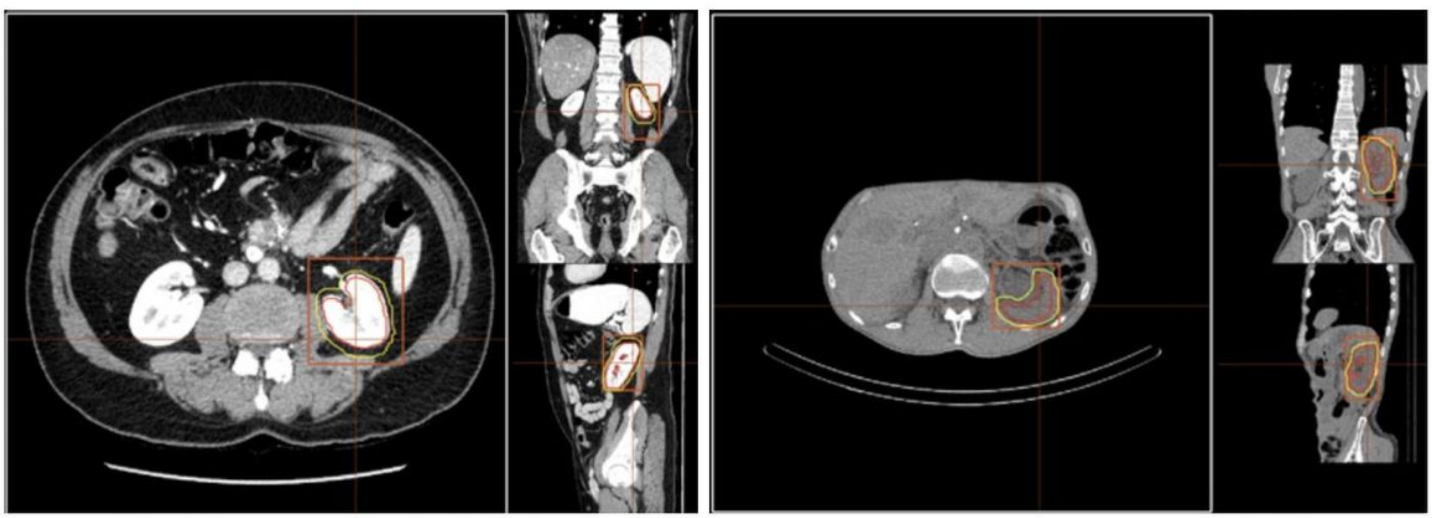
Mask-rcnn structure consists of two stages. The object of interest in the input image is artificial wrapped into boxes, binary classified and fine tuned. These boxes are then fed into the second stage of the network to be further fine-tuned to better fit the area where the object is located and multiclassified. Pixels inside the best box is then binary classified to generate the mask. In this image, RPN stands for regional proposal network, FPN stands for feature pyrimid network, RoI for region of interest and ALIGN is the RoIAlign mechanism. The head section is where 3 separate networks (two FCs, i.e. fully connected neural network and one CNN) generate the output. The rectangular boxes connected to the RPN box and Heads box indicate the type of loss functions.



(a) Left Kidney (b) Right Kidney

Figure 2

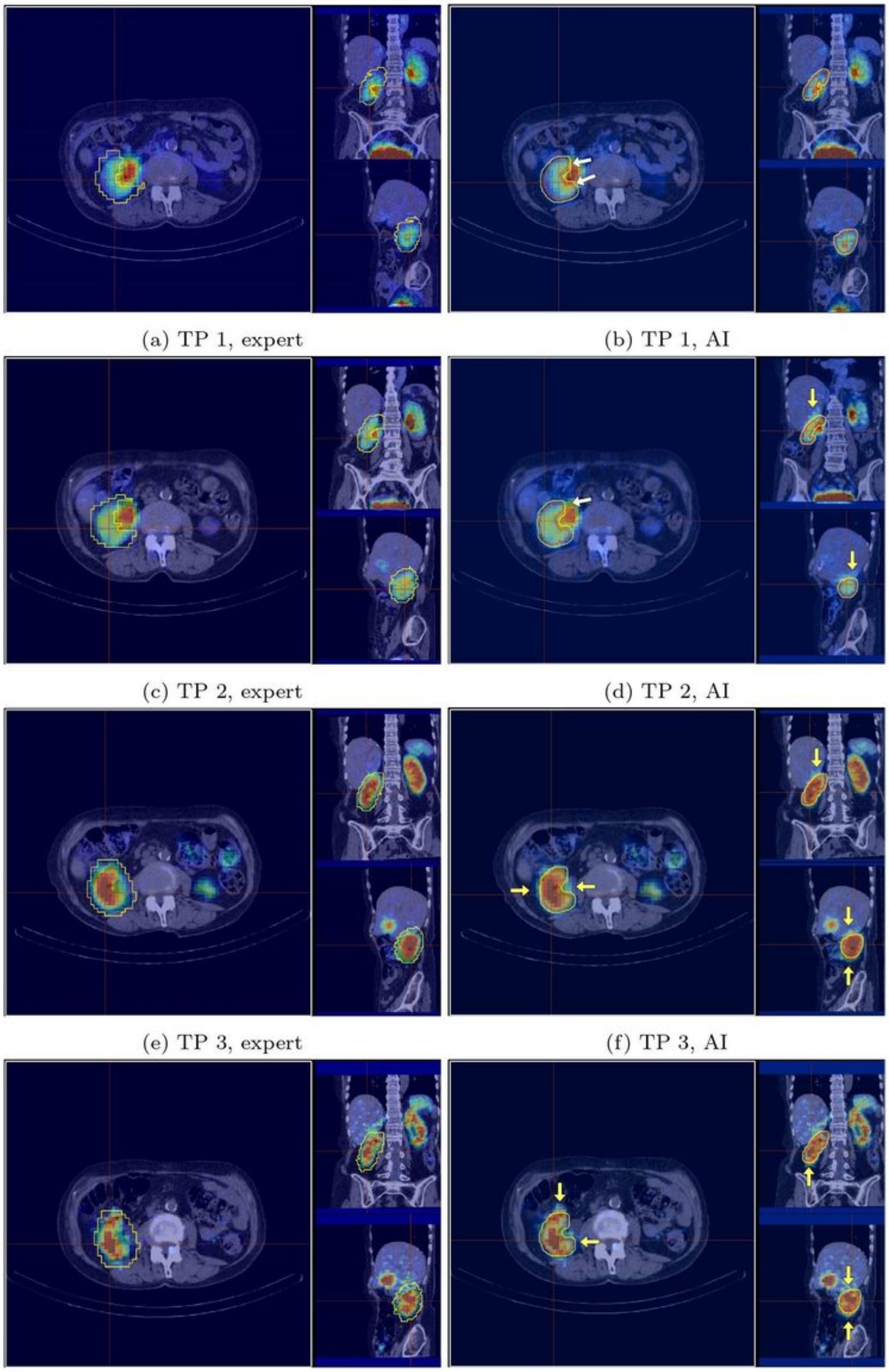
Dose volume histograms of left and right kidneys for patient 7 with the highest error margin. Red line represent the dose calculations based on expert segmentation and the green lines the corresponding dose based on the AI segmentation.



(a) Segmentation on contrast-enhanced CT (b) Segmentation on low-dose CT

Figure 3

Segmented left kidney along axial, sagittal and coronal axis using the AI . The segmentation boundaries on an constrast-enhanced CT are highlighted with red contour on the left-hand side and on a low-dose CT on the righthand side. The red rectangle corresponds to the bounding box used in kidney detection by the algorithm and the yellow contour is the 3 mm expanded region for activity retrieval from the SPECT images based on the CT segmentation.



(a) TP 1, expert (b) TP 1, AI

(c) TP 2, expert (d) TP 2, AI

(e) TP 3, expert (f) TP 3, AI

(g) TP 4, expert (h) TP 4, AI

Figure 4

Comparison of the VoI segmentation for patient 7 of the right kidney based on the two different methodologies. Left: segmentation performed by expert 2 . Right: segmentation when using the AI. The red contours illustrates segmentation on CT while the yellow contours show activity segmentation. Underestimated activity areas by the AI algorithm are pointed by a yellow arrow and overestimated activity areas by a white arrow.