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Artificial Intelligence Applications for Treatment Planning in IOeRT

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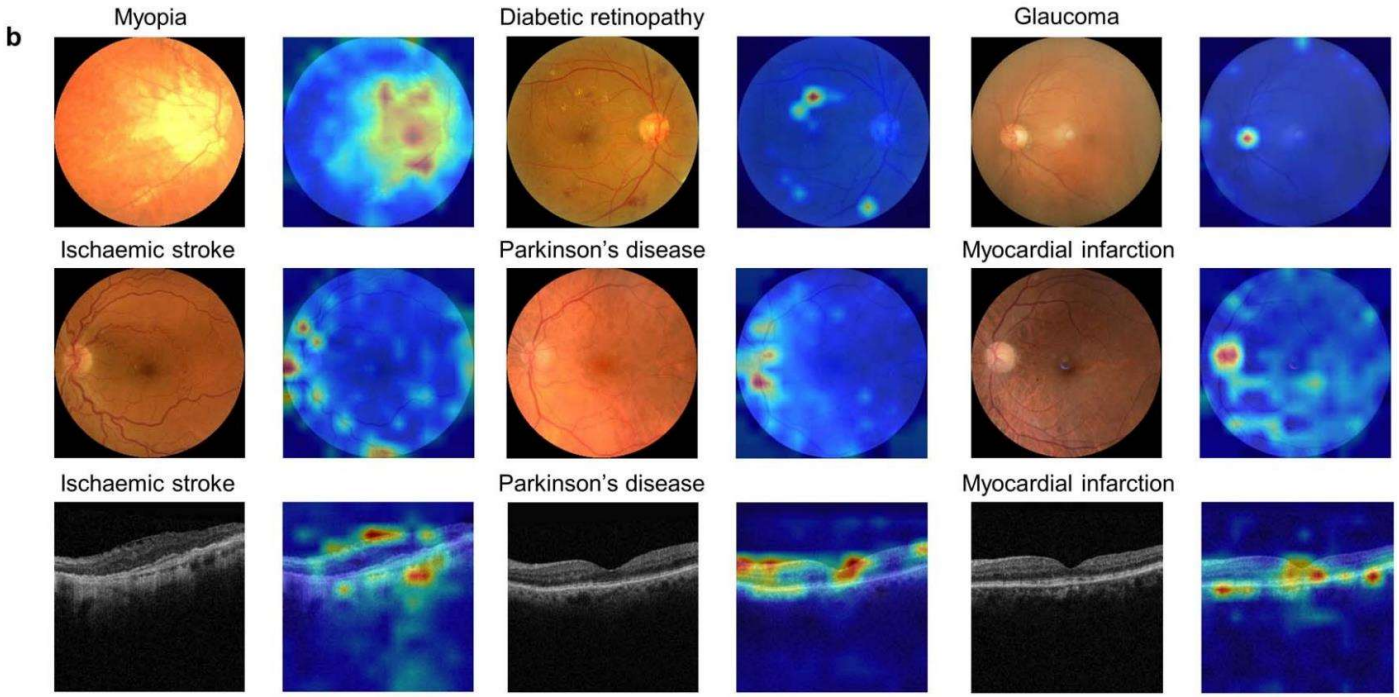
Artificial Intelligence in Medicine



Zhou, Y., Chia, M.A., Wagner, S.K. *et al.* A foundation model for generalizable disease detection from retinal images. *Nature* **622**, 156–163 (2023). https://doi.org/10.1038/s41586-023-06555-x

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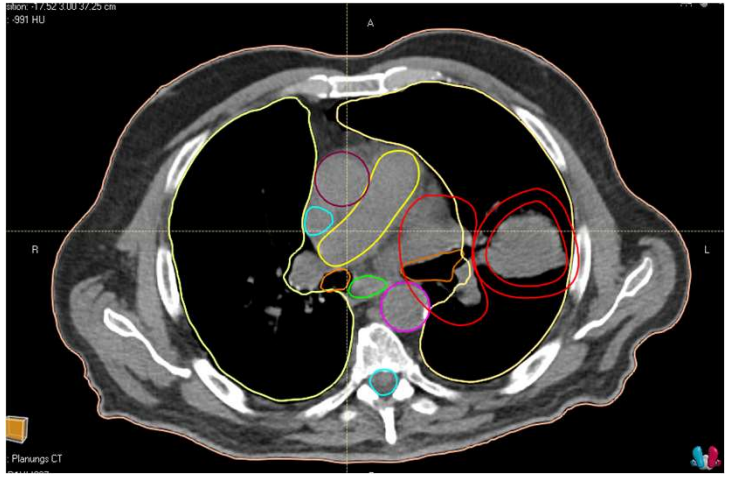
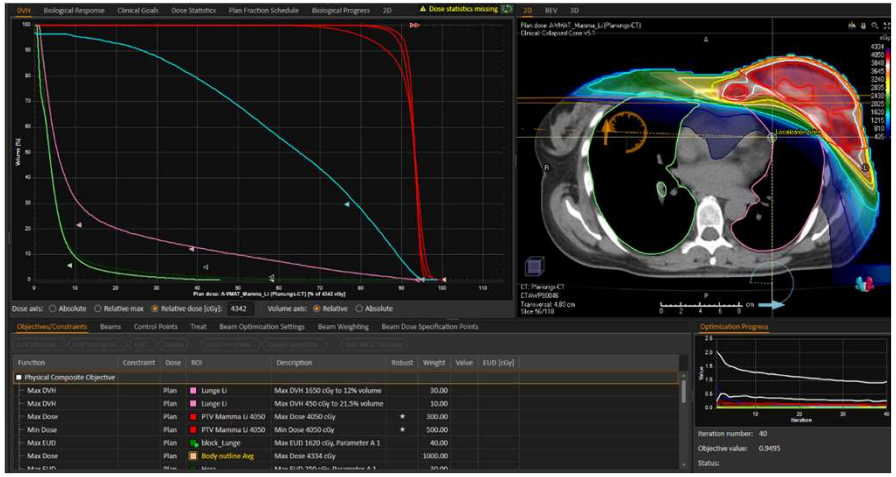
Artificial Intelligence in Radiotherapy



Automatic Segmentation



Automatic Planning

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Artificial Intelligence in IOeRT ???

This image was generated with the assistance of AI.

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GOAL:

Closing the gap in treatment planning between teletherapy and IORT by leveraging machine learning to streamline the time-consuming process of 3D image-based IORT treatment planning.

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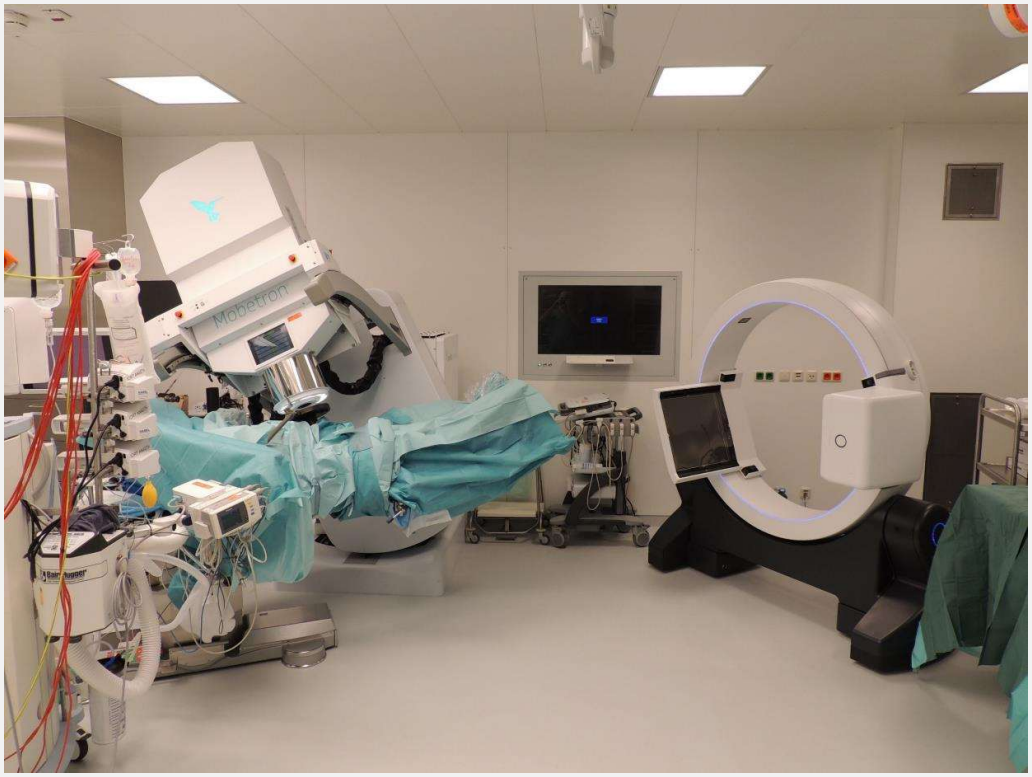
Imaging Ring



3D imaging device in operating room:

- Mobile Cone beam CT (CBCT)

  (Imaging Ring-m, medPhoton)
- CBCT scan in treatment position during IOeRT

Automatic Contouring IORT

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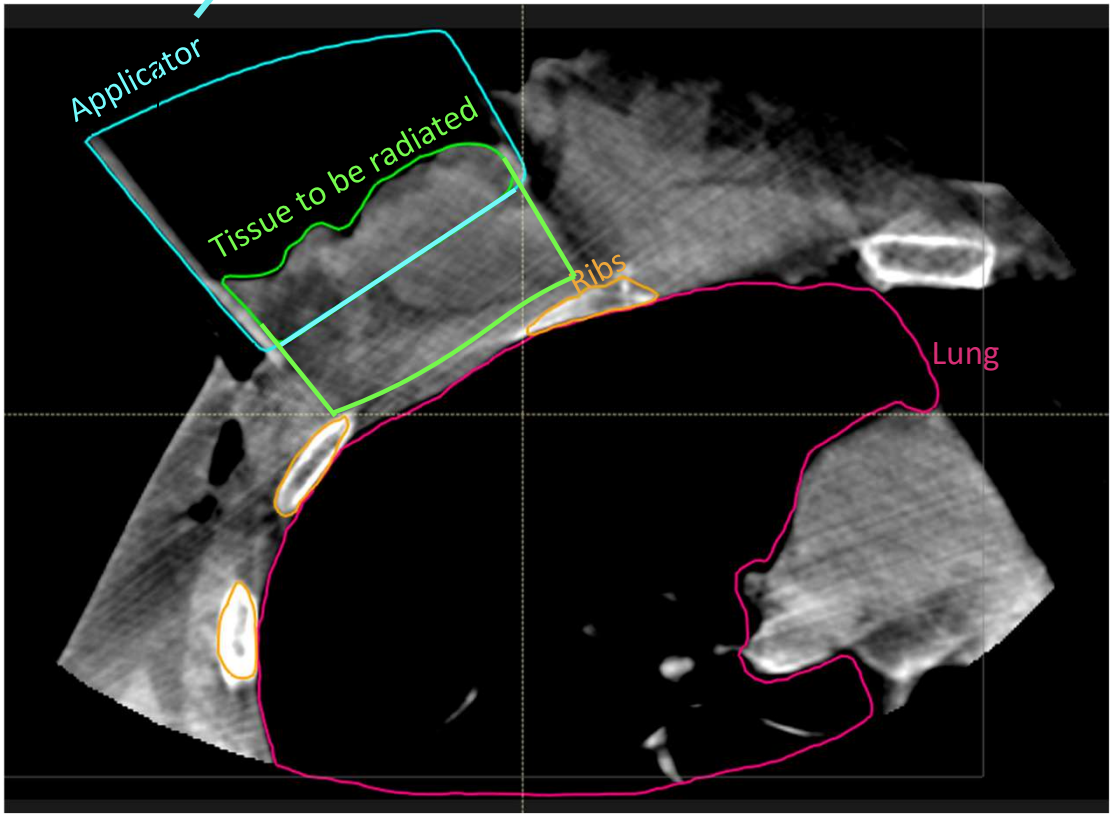
- Contours necessary for 3D dose estimation
- Manual segmentation very time-consuming
- Tight time schedule in an operative setting



Implementation of an artificial neural network (ANN) to segment:

- Tube, tissue within tube, lung, ribs

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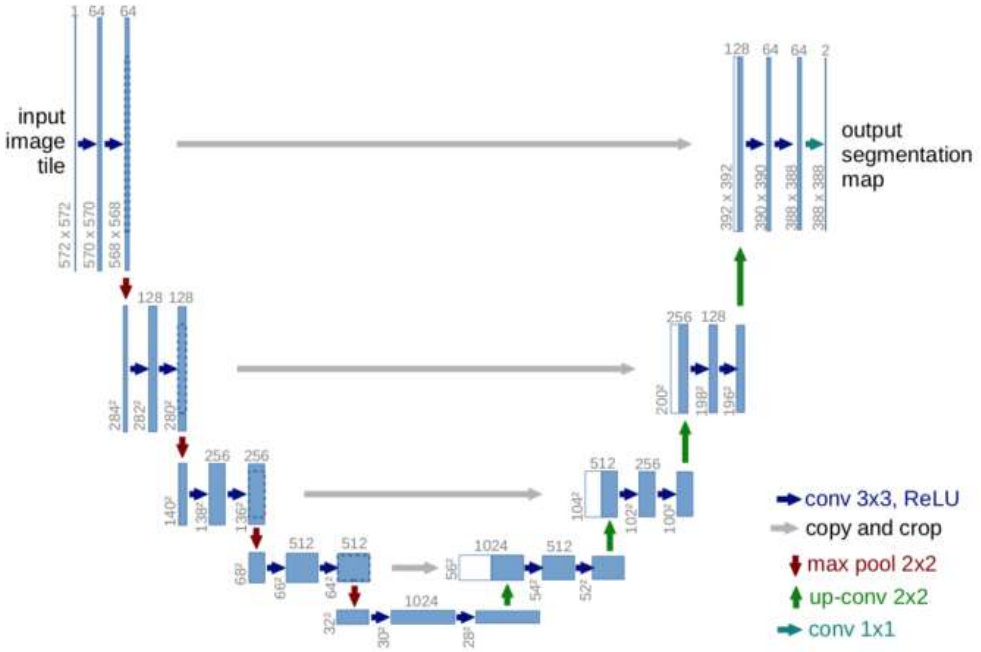
U-Net



+ Captures fine-grained spatial features.
+ Designed for tasks where precise delineation of organ boundaries and local anatomical details is essential.

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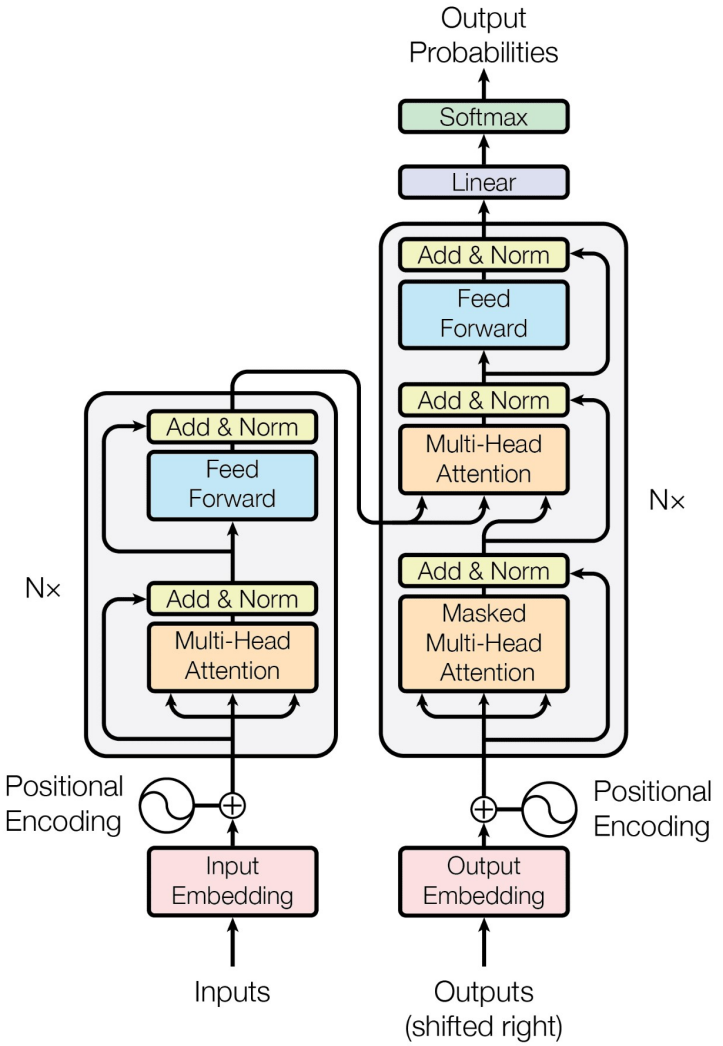
Ronneberger 2015, U-Net: Convolutional Networks for Biomedical Image Segmentation



Vaswani et al., 2017, Attention is all you need

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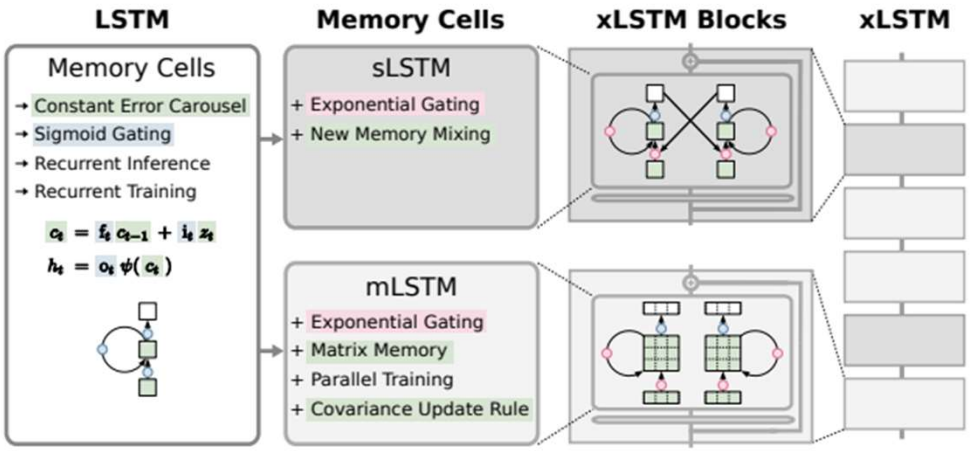
Transformer

+ Self-attention mechanism to capture long-range dependencies and global context in medical images.
+ Understanding of relationships between anatomical structures across an entire medical image is crucial.

xLSTM

+ Type of Recurrent Neural Network
+ „Memory Cell“ to remember information over long sequences
+ Good at capturing long-term dependencies in data



Beck…Hochreiter et al., 2024, xLSTM: Extended Long Short-Term Memory

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IDEA:

Combination of U-Net and Transformer Network and U-Net and xLSTM to enhance quality of CBCT segmentation.

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RayStation
Script

CT / CBCT

For all ROIs
= IORT Structures

ResNet18 (pretrained)
5-fold cross validation

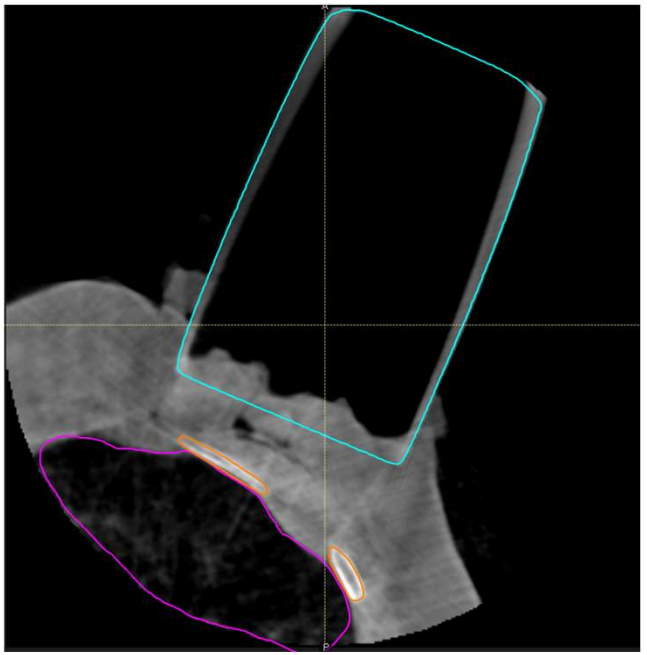
Model 1: CT Slice Classification
Is the ROI located on this slice?

Yes?

Choice between
U-Net and **U-Net+Transformer**
and U-Net+xLSTM

Model 2: CT Slice Segmentation
Segmentation of this ROI on this slice

RT Struct Dicom file with new structures loaded to RayStation



RayStation

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Transfer Learning needed for U-Net und U-Net+Transformer

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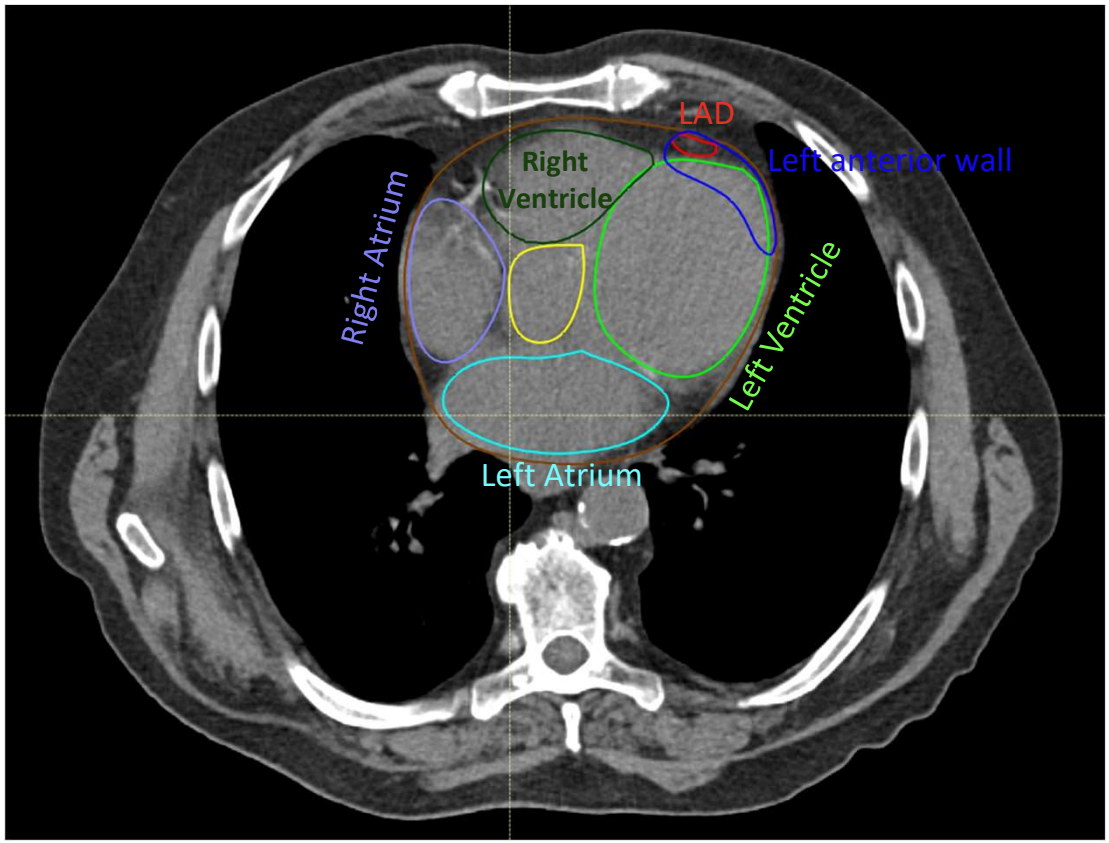
Issue:

Bad image quality of mobile CBCT due to artifacts and variable field of view size

Approach:

- ANN for auto segmentation of heart regions
- Good quality CT images
- Heart regions contours based on knowledge
- Dataset size: 85 patients



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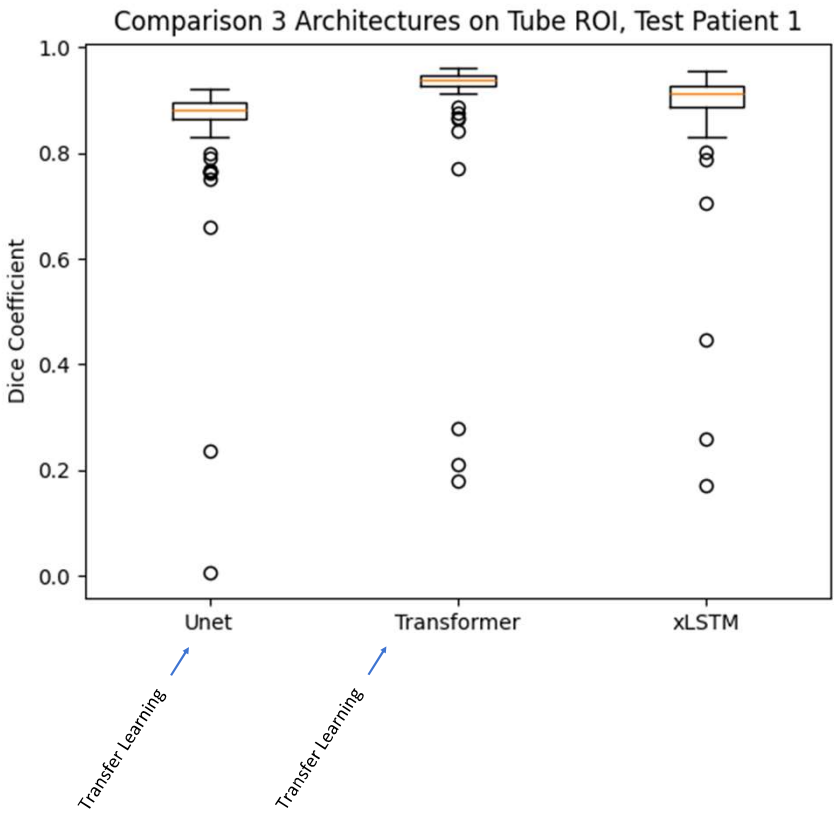
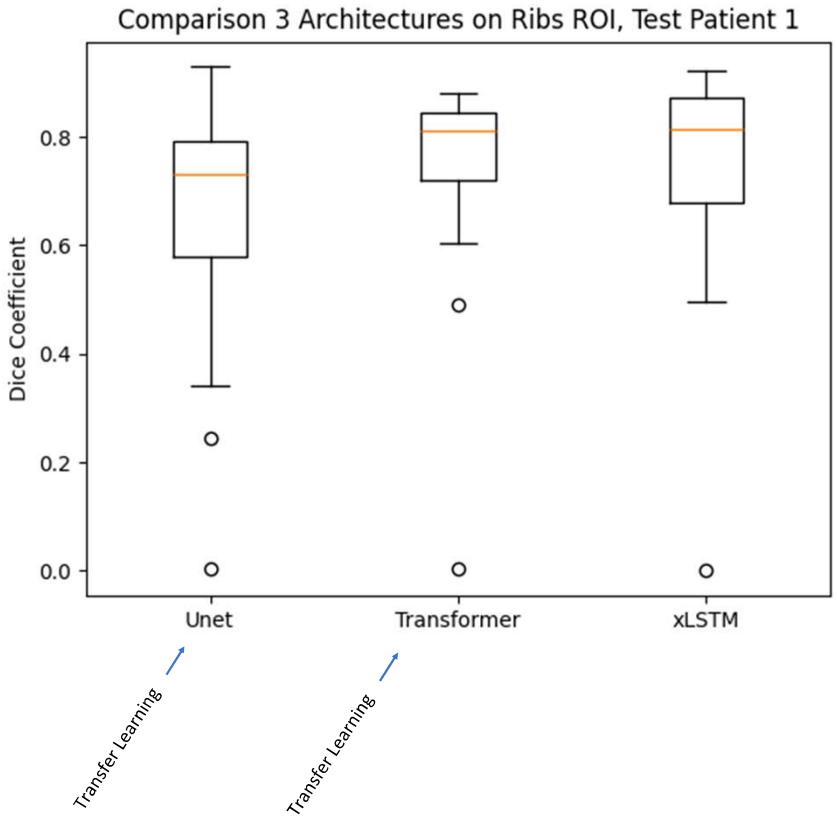
Test Patients Results – Tube, Ribs





U-Net+xLSTM on Test Patients – Ribs, Tube

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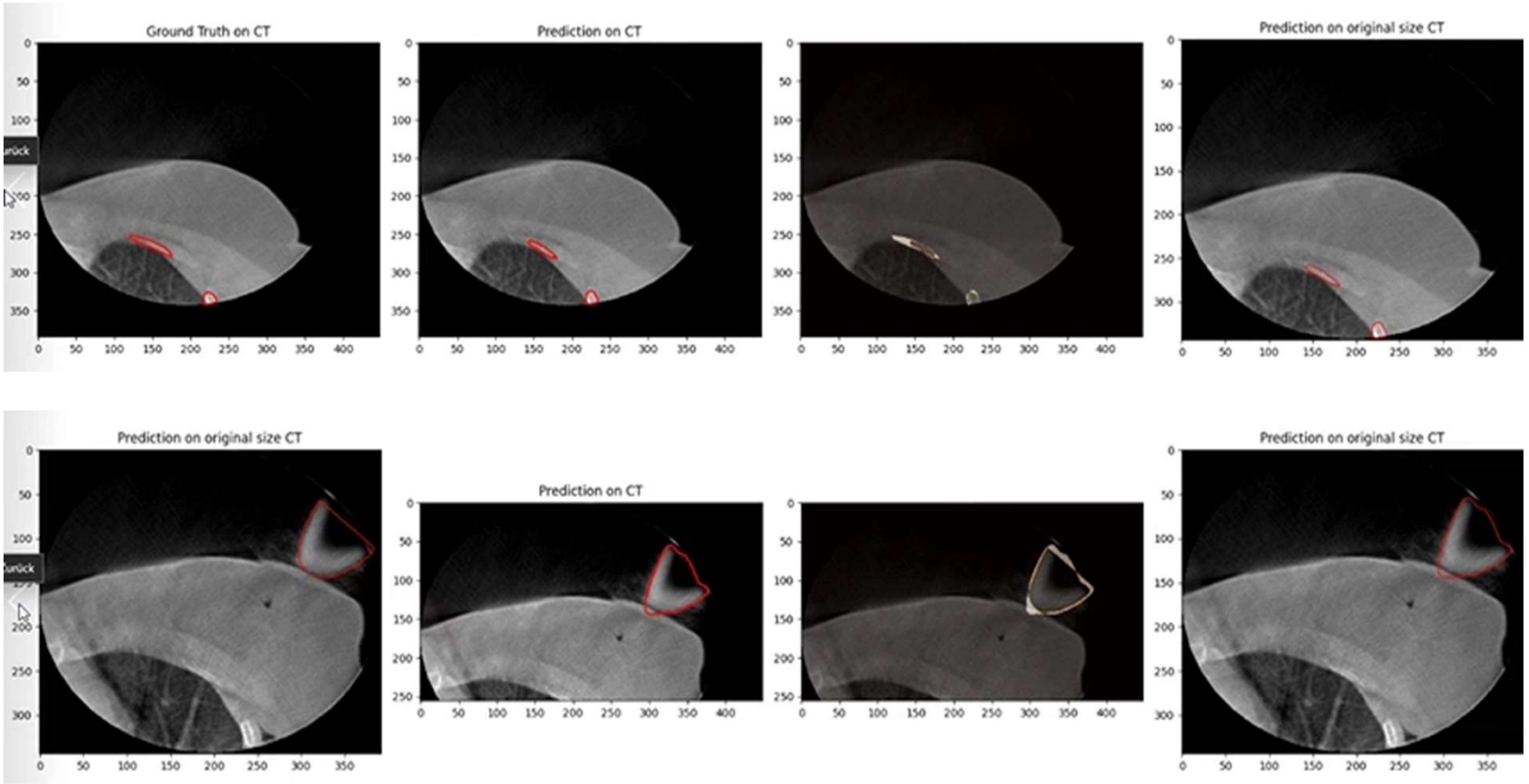

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U-Net on Test Patients – Ribs, Tube

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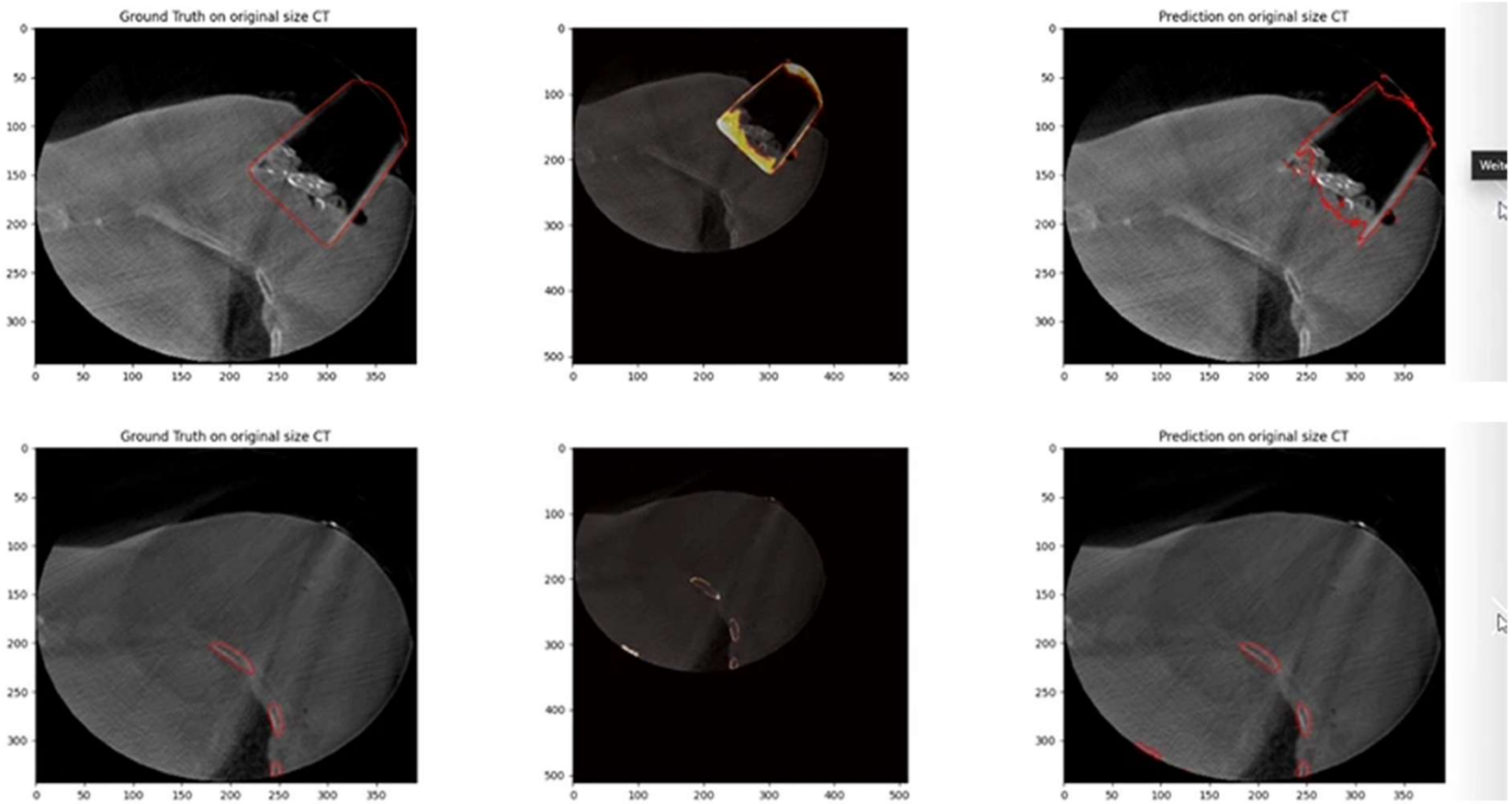

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U-Net+Transformer on Test Patients – Ribs, Tube

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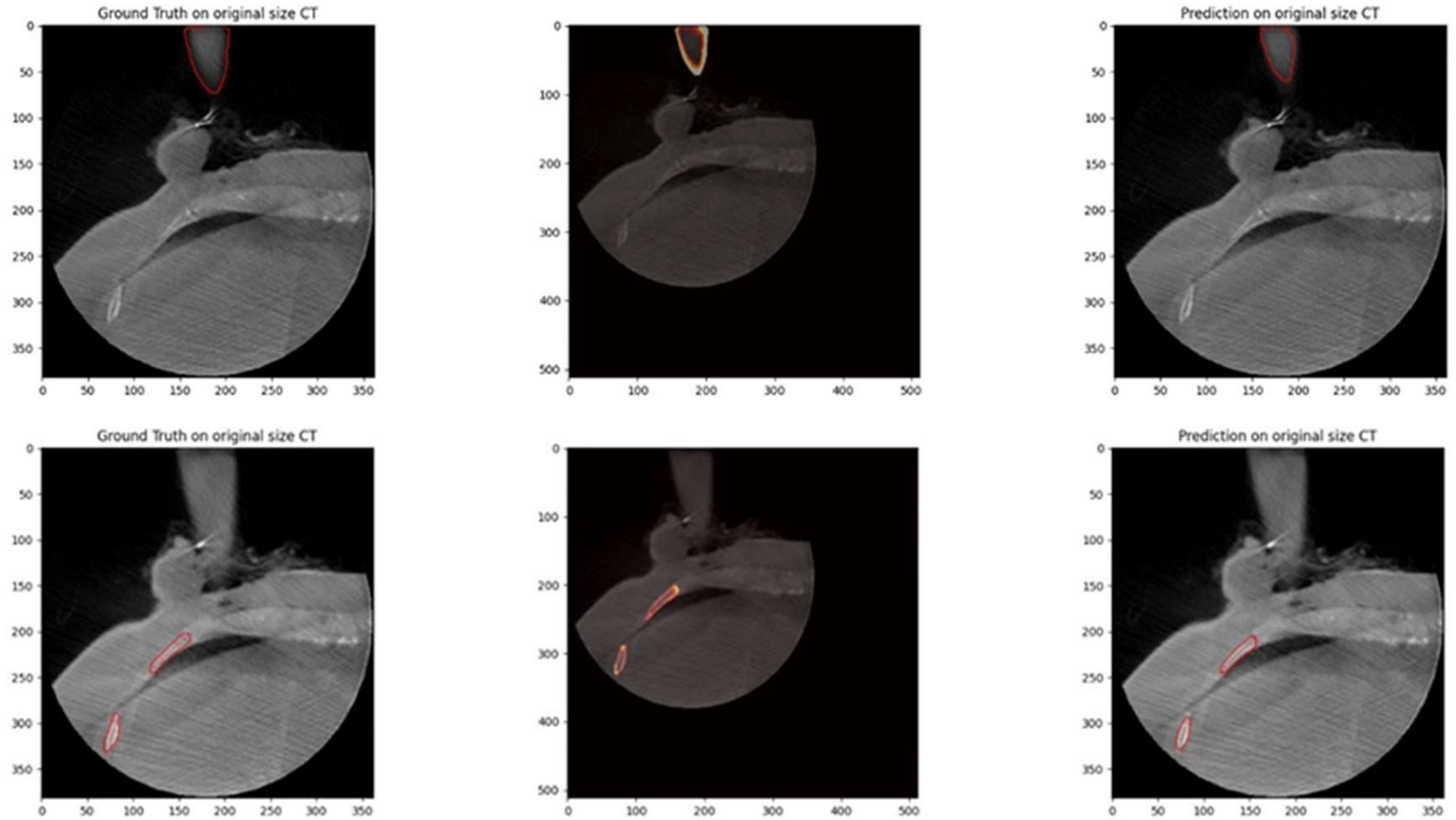

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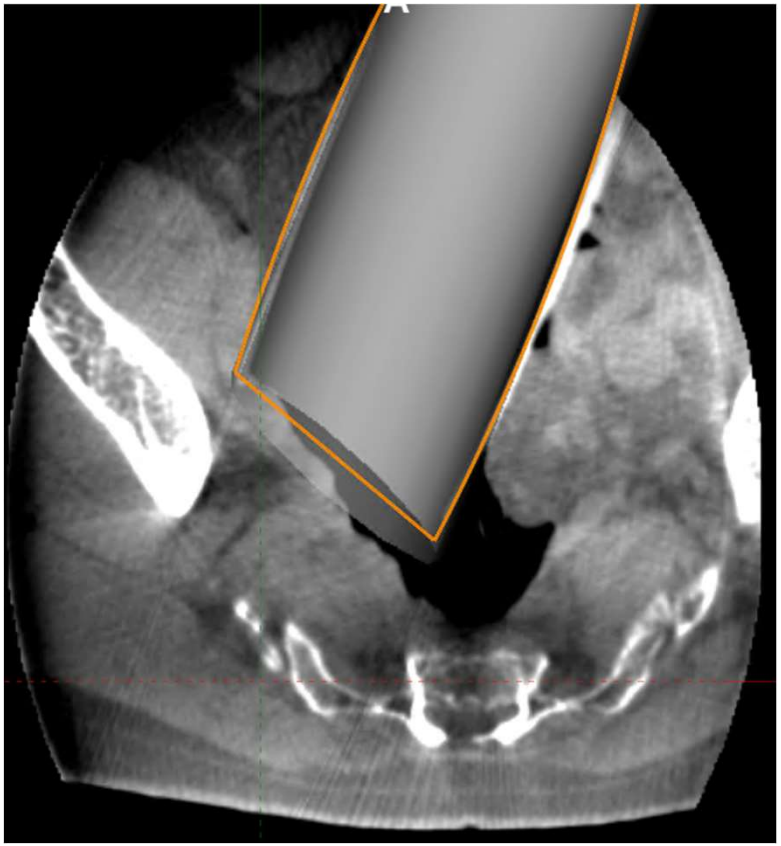
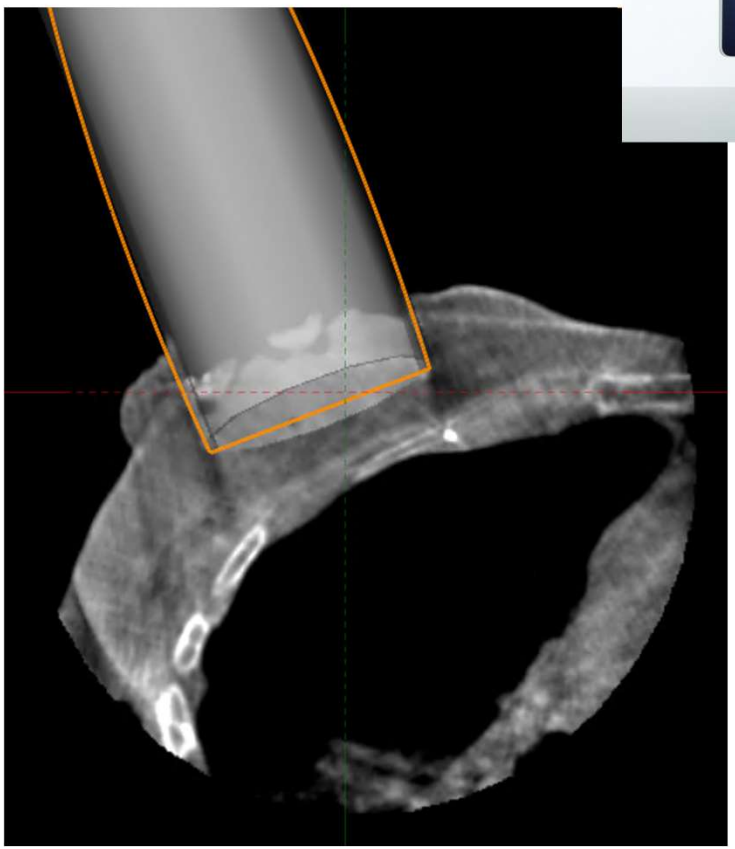
Possible positioning of radiotranslucent applicator





in treatment planning software Radiance

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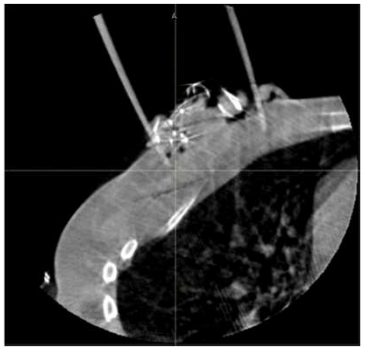
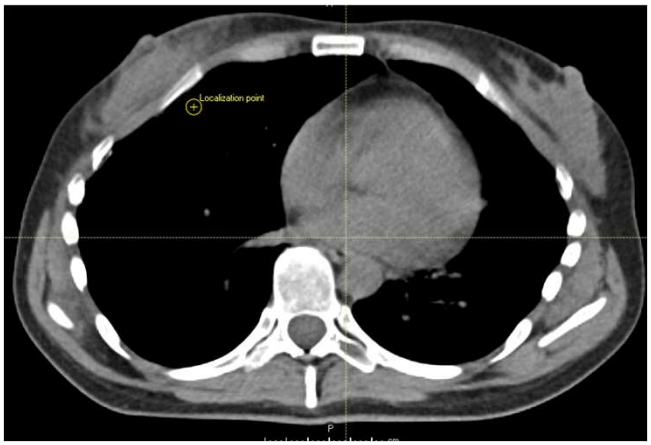
Deformable Image Registration (DIR) and Dose Accumulation using AI





DIR with AI → Dose Accumulation

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The synergy of artificial intelligence, advanced image processing and computational methods can allow for a 3D model-based adaptive treatment planning within the limited time frame of an operative setting.

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Thank you!

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