Seminar

CTPA segmentation to calculate biomarkers for pulmonary embolism risk stratification

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Pulmonary Embolism (PE)

3rd leading cause of death in Europe

Blood cloth (thrombus) blocking pulmonary arteries

- systemic hypotension

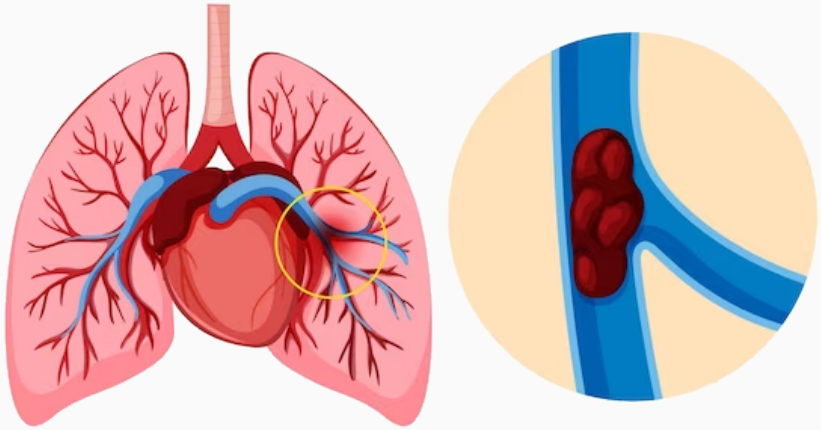

Figure 1: Pulmonary embolism (https://fr.freepik.com/photos-vecteurs-libre/embolie)

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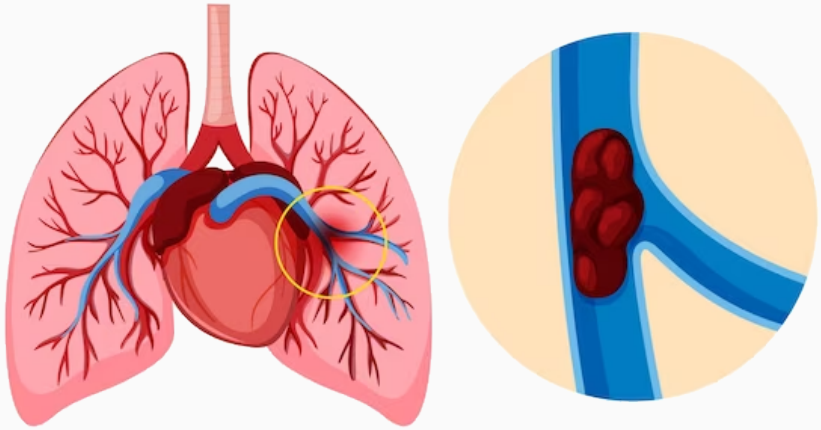

Figure 1: Pulmonary embolism (https://fr.freepik.com/photos-vecteurs-libre/embolie)

Need to quantify the severity of the PE

Current PE risk stratification

Categories of risk of death after 30 days [1]

- low, intermediate, and high
- determines the patient's management protocol and treatment [2]

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Biomarkers [3]

- functional biomarkers
  - protein levels in the blood linked with heart failure
- morphological biomarker
  - right-to-left ventricle (RV/LV) diameter ratio

PERSEVERE

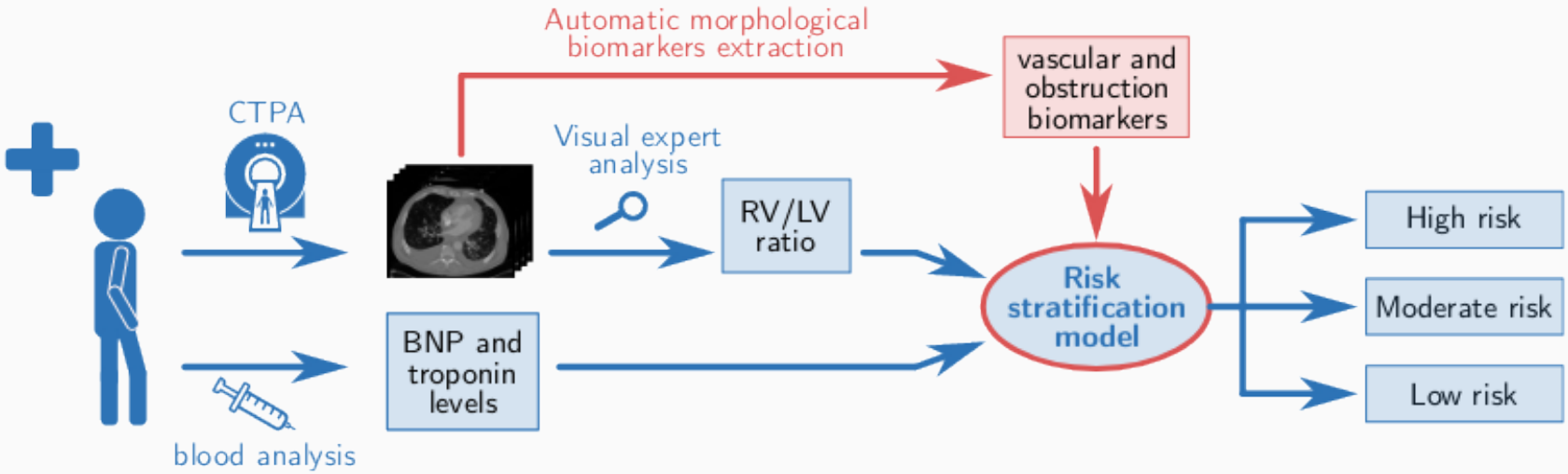

Figure 2: Current PE patient prognosis evaluation procedure in blue, and the modification proposed in the PERSEVERE project in red. [3]

PERSEVERE

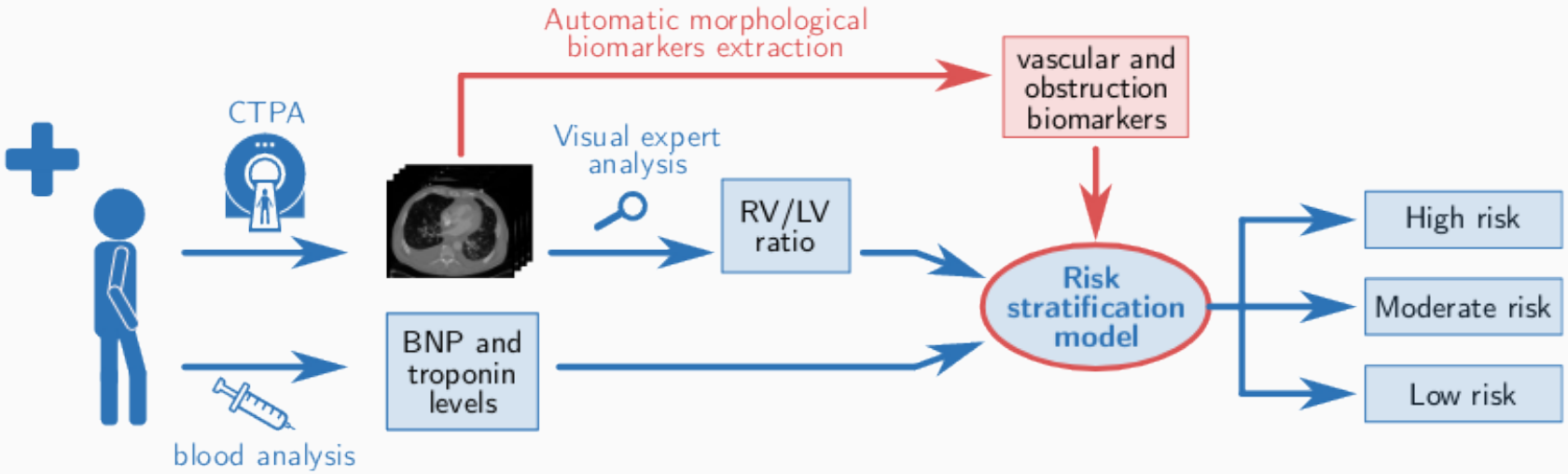

Figure 2: Current PE patient prognosis evaluation procedure in blue, and the modification proposed in the PERSEVERE project in red. [3]

Our work focused on the RV/LV ratio

Why the RV/LV ratio ? [4] [5]

PE prevents part of the lungs from oxygenating the blood

- RV pumps blood to the lungs
- RV pumps harder to oxygenate the same amount of blood
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RV/LV ratio > 1 $\Rightarrow$ PE

How is the RV/LV ratio is measured ?

Slices where the ventricles are the largest

Ideally measured on echography [3]

- no known risk
- synchronized to heart rate
- not accessible in initial stage of PE

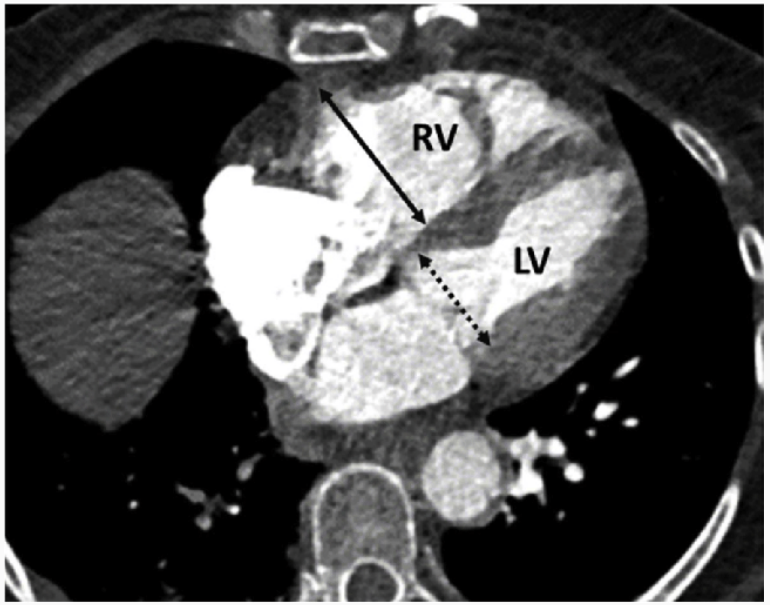

Figure 3: RV/LV diameter measurements on CTPA [6]

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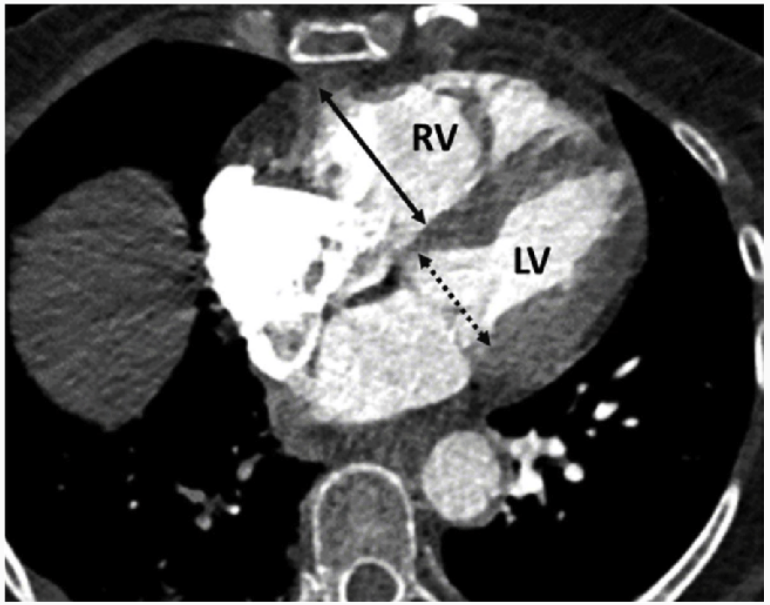

Figure 3: RV/LV diameter measurements on CTPA [6]

In clinic, the patients undergo a CTPA exam in 90% of cases [3]

CTPA (Computed Tomography Pulmonary Angiography) (1/2)

CT scan + injection of contrast dye + X-Ray [7]

- enhance the visibility of the pulmonary arteries

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Advantages [7]

- assess other cardiopulmonary conditions
- availability in the majority of hospitals
- non-invasiveness

CTPA (Computed Tomography Pulmonary Angiography) (2/2)

Disadvantages [7]

- dangerous radiations
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How to improve the RV/LV ratio ?

Our proposition

Measure the volumetric RV/LV ratio instead of the diameter RV/LV ratio

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Need segmentations of the RV and LV…

Segmentation

Classifying every voxel of an image as either belonging to the background or a region of interest

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- error-prone due to the lack of experience and eye fatigue
- inter-observator and intra-observator variability

PERSEVERE's Dataset

No ground truth of ventricles

- No other CTPA dataset of ventricles annotated
  - Most research on PE is focused on segmentations of thrombus and pulmonary vascular tree

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CTPA of 431 patients of multiple PE risk categories

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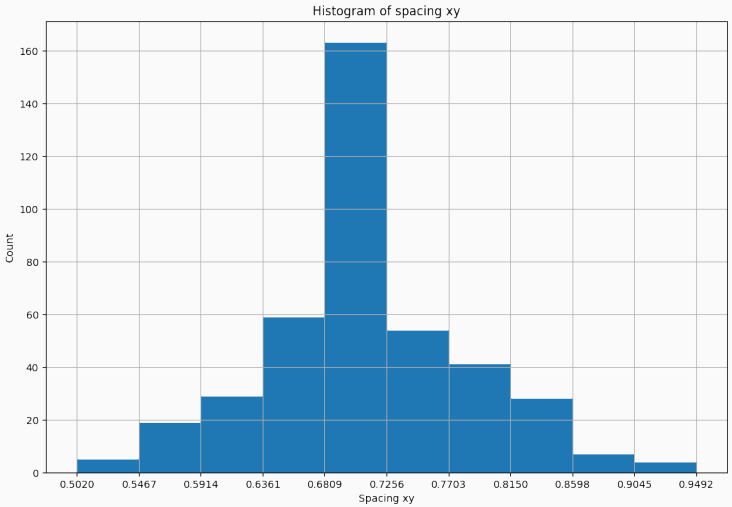
CTPA of 431 patients of multiple PE risk categories

Multiple scanners with different parameters

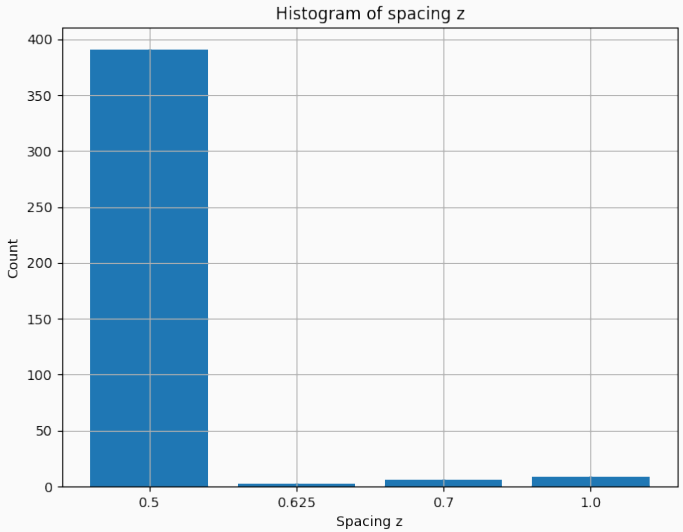
- **different sizes, resolutions and spacing**

Dataset Resampling

Resampling with the most occurring spacing values and nearest neighbour interpolator



(a) Spacing XY



(b) Spacing Z

Figure 4: Histogram of the dataset spacing

Localisation of the ventricles

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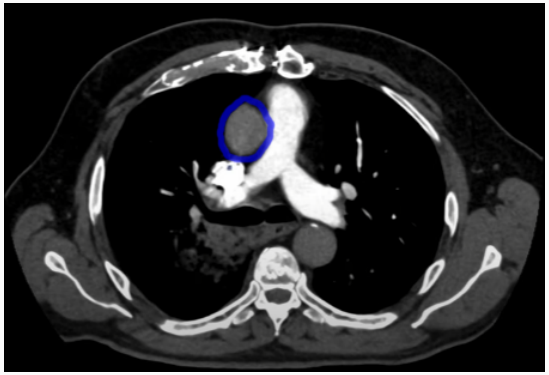

(a) blue: ascending aorta

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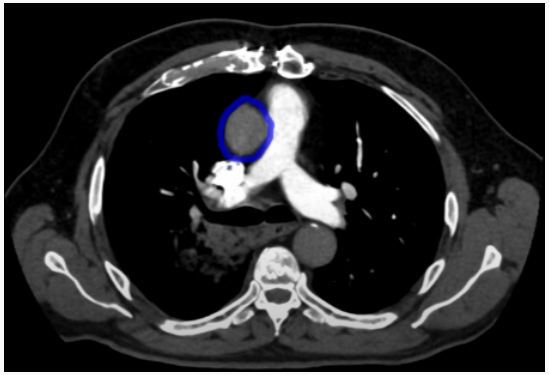

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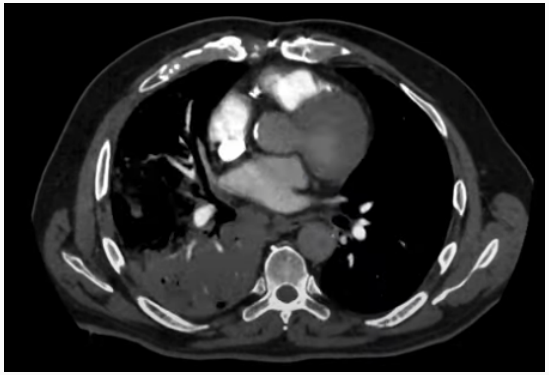
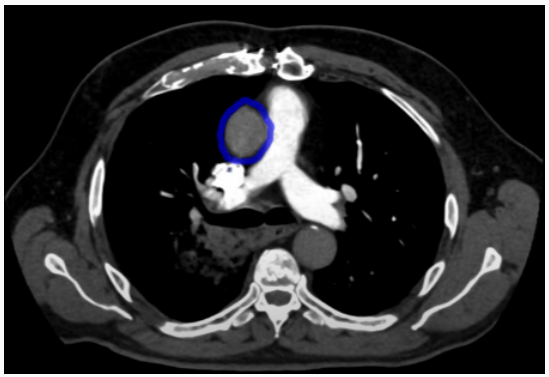


(b) Slice where the ascending aorta is connected to the LV

Localisation of the ventricles



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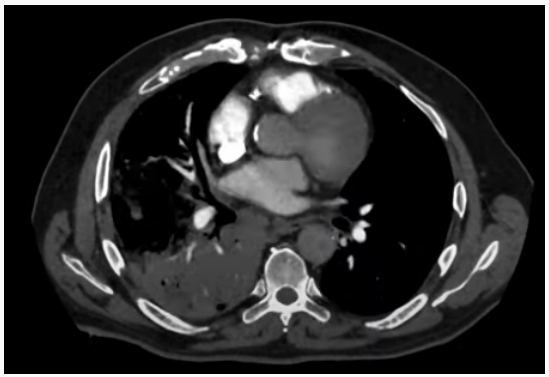

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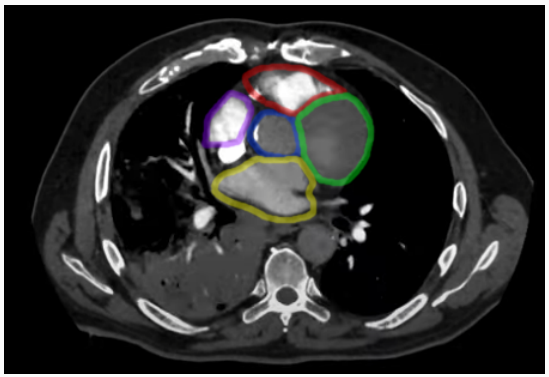


(c) blue: ascending aorta ; green: LV ; red: RV; yellow: left atrium; purple: right atrium

Figure 5: Localisation of the ventricles (https://youtu.be/8WUgH4WHlLE?si=uk5pXg1hqpcg8VJl&t=1111)

Limits of the ventricles (1/2)

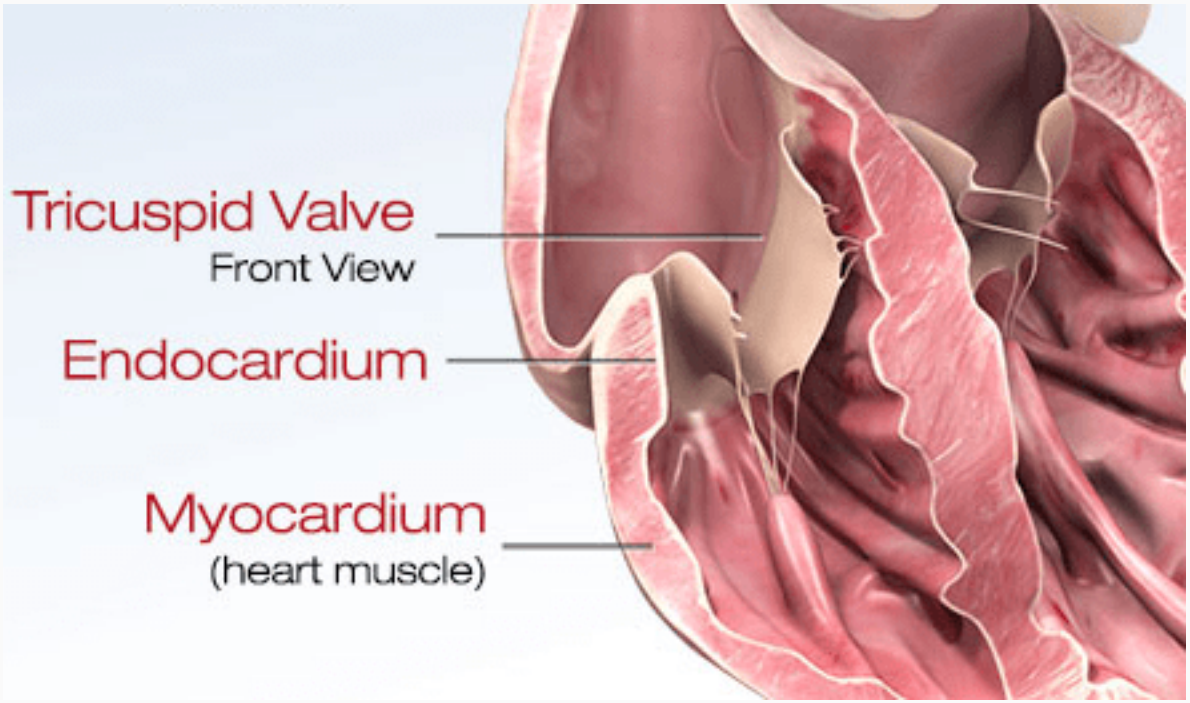
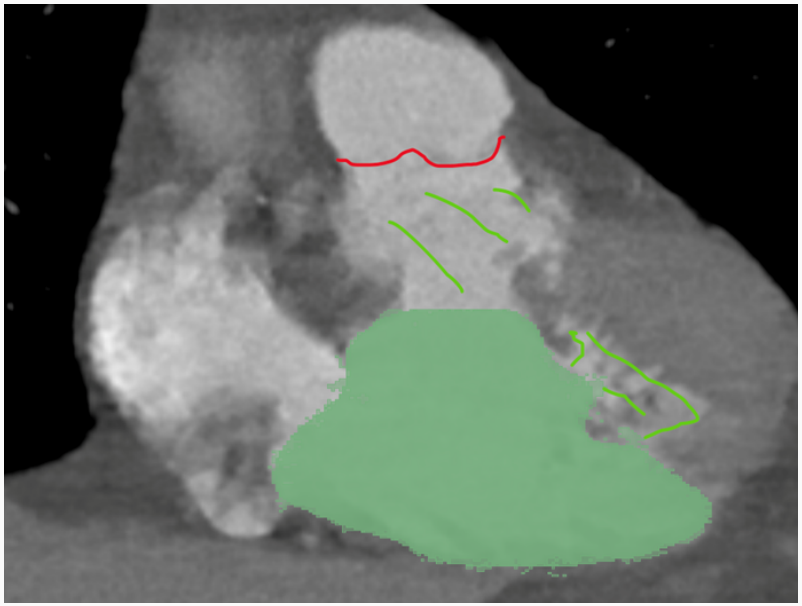
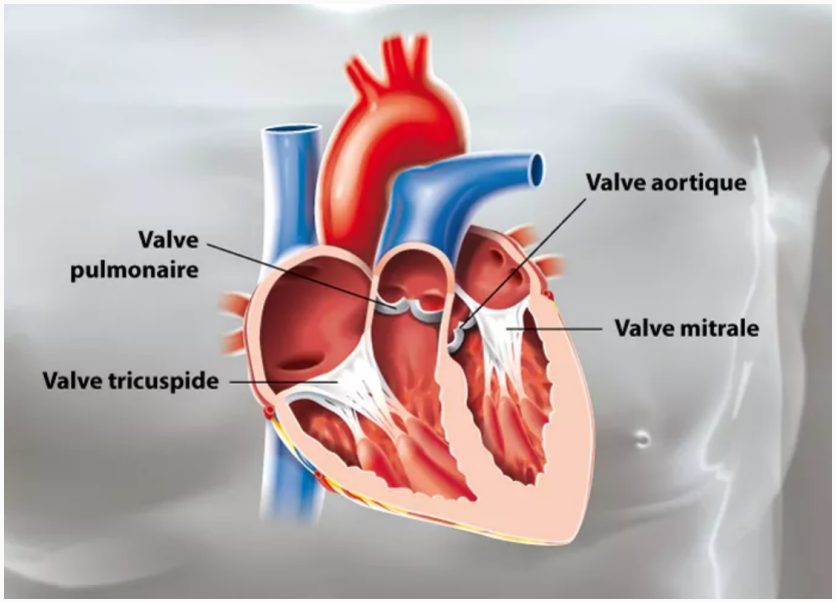


Figure 6: Heart wall layers
(https://www.heart.org/en/health-topics/myocarditis)

Limits of the ventricles (2/2)



(a) LV segmentation and markers for upper limit



(b) Pulmonary valves (https://www.ramsaysante.fr/vous-etes-patient-en-savoir-plus-sur-ma-pathologie/valves-cardiaques)

Figure 7: Segmentation correction : LV upper limit

Start of our segmentations

No specialized model exists to segment ventricles on CTPA and no ground truth

- **We started with manual segmentation**

Start of our segmentations

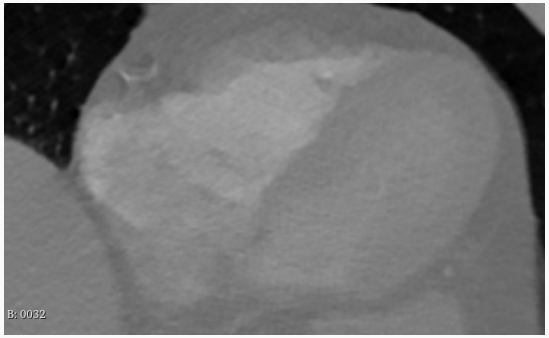
No specialized model exists to segment ventricles on CTPA and no ground truth

- **We started with manual segmentation**

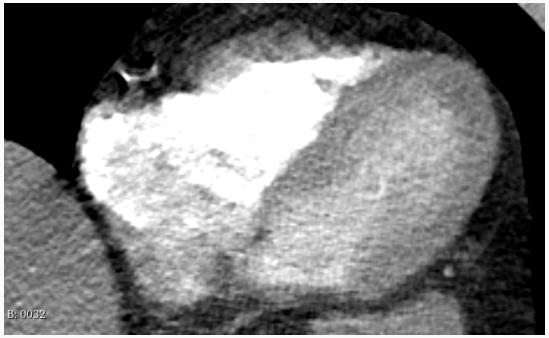
3DSlicer (https://www.slicer.org/)

- Standard for open source visualisation and segmentation software for medical images

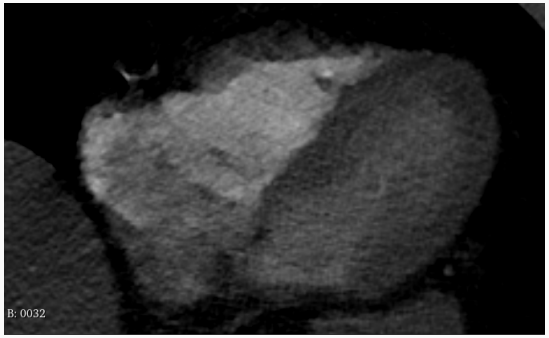
Abdominal window (1/2)



(a) Default window



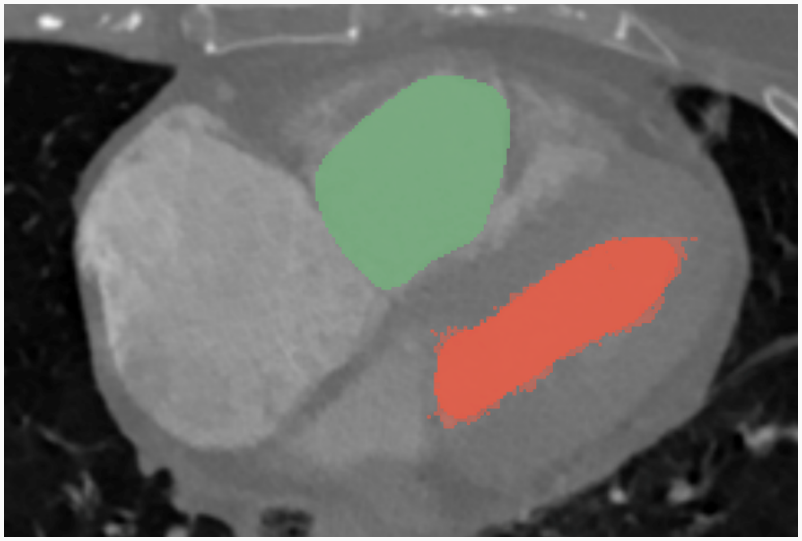
(b) Abdominal window preset



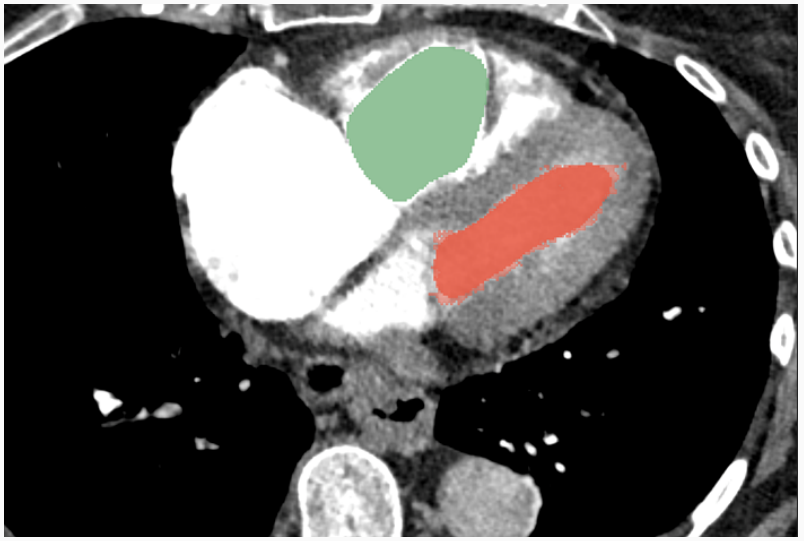
(c) Manually adapted window

Figure 8: Different 3DSlicer windows used for segmentation

Abdominal window (2/2)



(a) Segmentation on default window



(b) Same segmentation on media intestinal window

Figure 9: Same segmentation on different windows

Other tools

- Threshold tool
  - to limit the range of Hounsfield units that can be painted on

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- Threshold tool
  - to limit the range of Hounsfield units that can be painted on
- Growing regions tool
  - seeds for ventricles and seeds for limits
  - propagation of seeds in the neighbouring voxels
  - sensitive to intensity variations

Segmentation of a high risk patient's ventricles

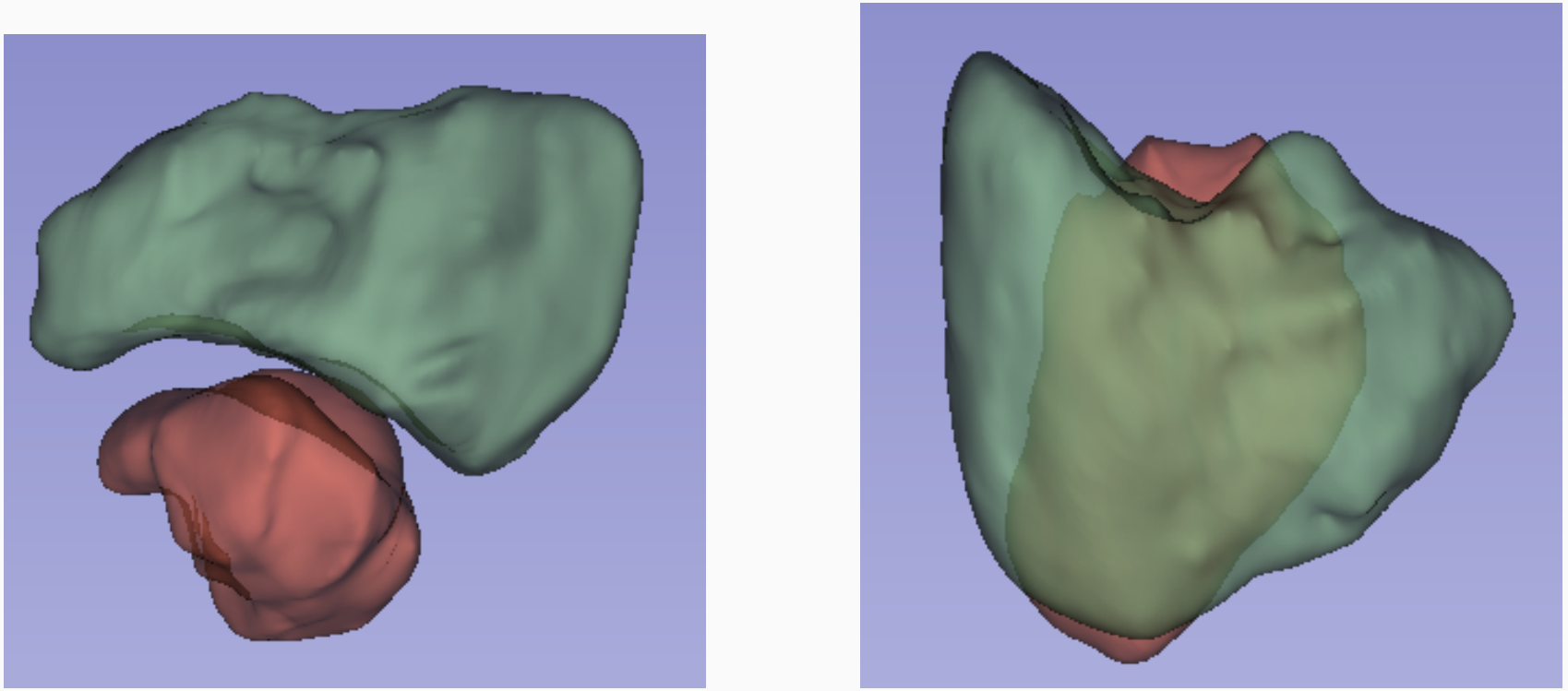

Figure 10: Segmentation of a high risk patient's ventricles
RV: green ; LV : red

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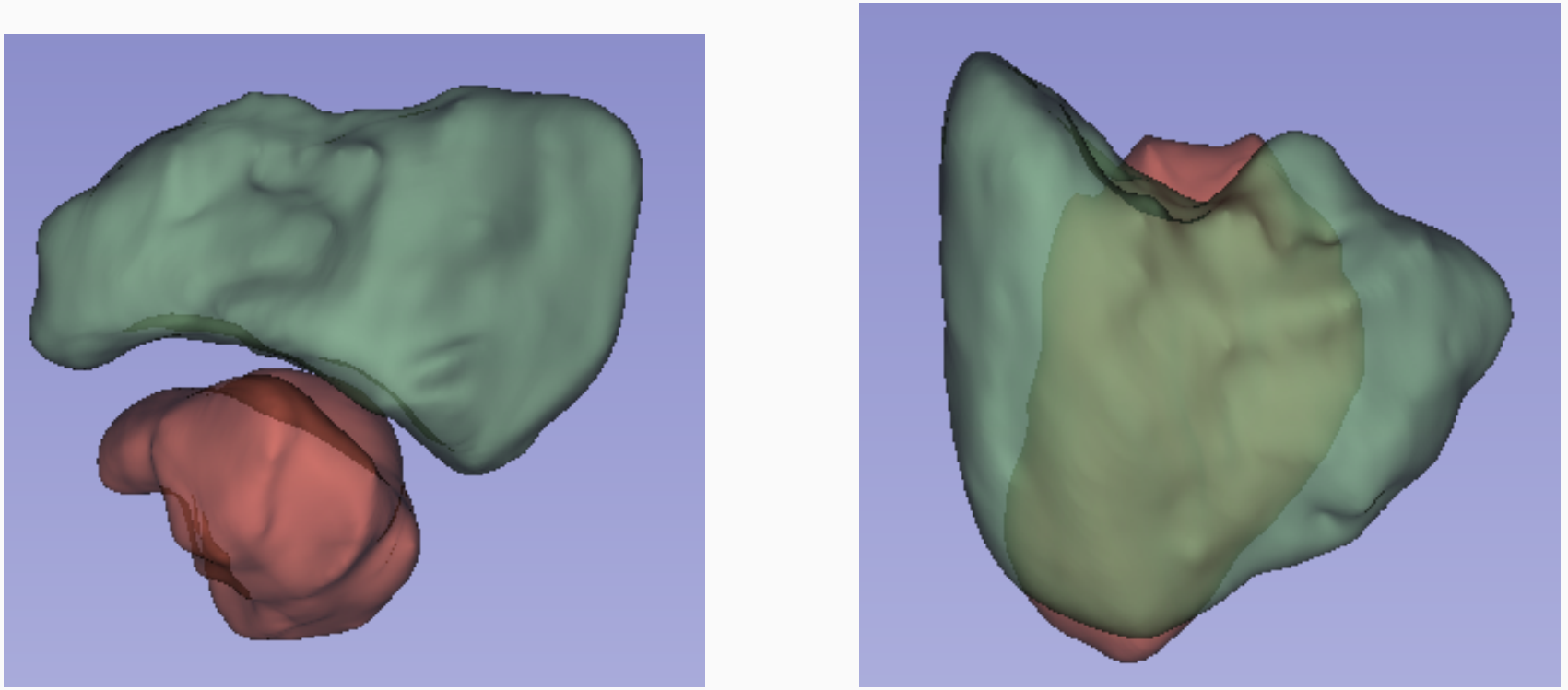

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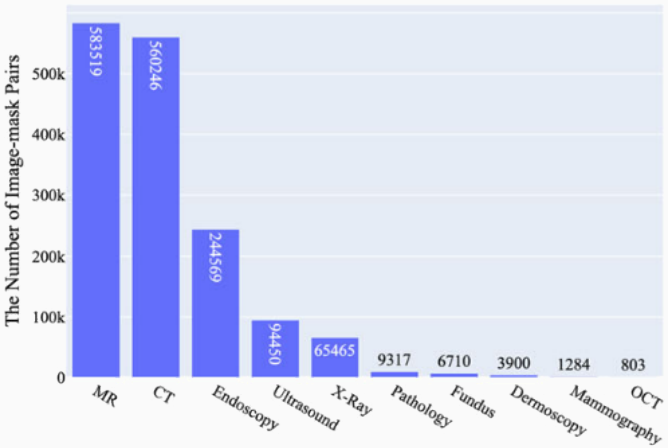
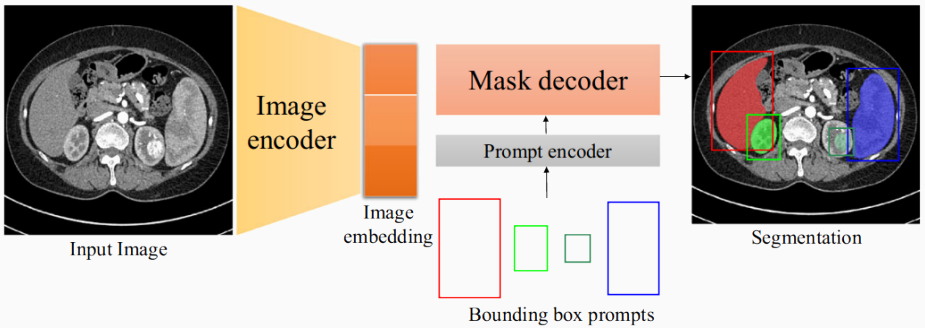
It took approximately 5 hours...

MedSAM [9]

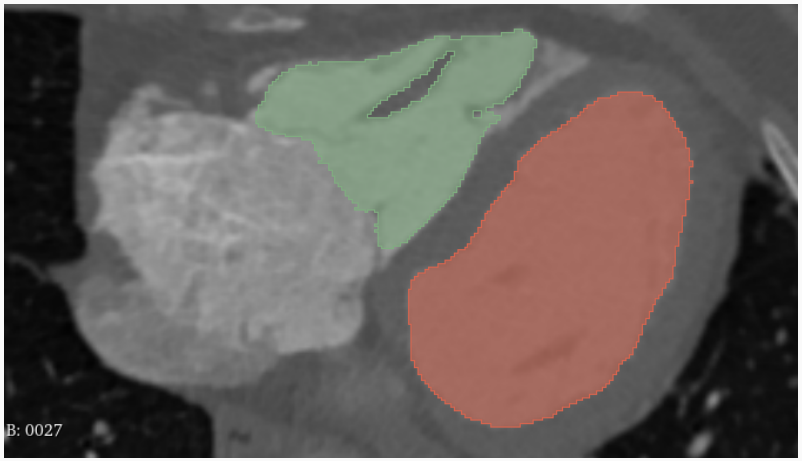


(a) Modality distribution of MedSAM's dataset [8]

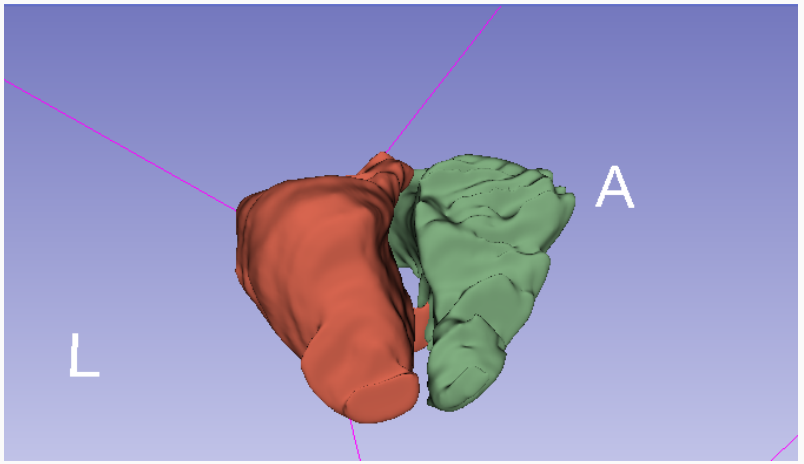


(b) Architecture of MedSAM [8]

MedSAM 3DSlicer plugin (https://github.com/bowang-lab/MedSAMSlicer) [9]



(a) MedSAM segmentation slice in the axial view



(b) MedSAM segmentation in 3D view

Conclusion

- Main contribution : 8 segmentations

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- Resampling of the PERSEVERE dataset

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- Main contribution : 8 segmentations
- Resampling of the PERSEVERE dataset
- Refactoring of a repository aimed at facilitating the experimentation of vascular segmentation models

Future work

Finish the manual segmentations needed by the radiologist to evaluate the correlations

After the review and corrections of the segmentations

- Experiment multiple methods and model architectures to automatically segment ventricles on CTPA

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[1] Stavros V et al. Konstantinides. **“2019 ESC Guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS)”.** In: *European heart journal* (2020). DOI: 10.1093/eurheartj/ehz405.

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[8] Jun Ma et al. **“Segment anything in medical images”.** In: *Nature Communications* (Jan. 2024). DOI: 10.1038/s41467-024-44824-z.

[9] Jun Ma et al. **“Segment anything in medical images”.** In: *Nature Communications* (2024). DOI: 10.1038/s41467-024-44824-z.