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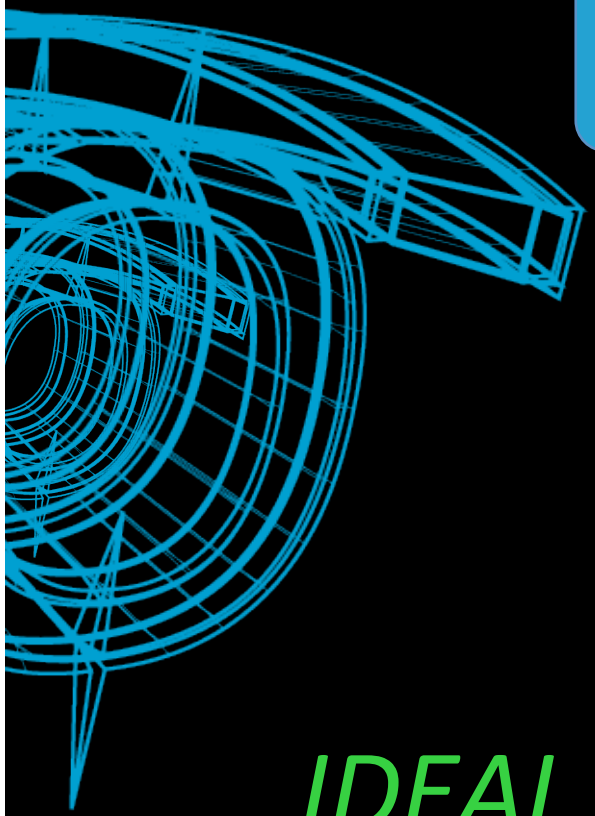

Segmentation of Abdominal Aortic Aneurysms in CT Images Using a Radial Model Approach

I. Macía, J.H. Legarreta, C. Paloc, M. Graña,
J. Maiora, G. García and M. de Blas

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Iván Macía Oliver

Biomedical Applications Dept.
imacia@vicomtech.org

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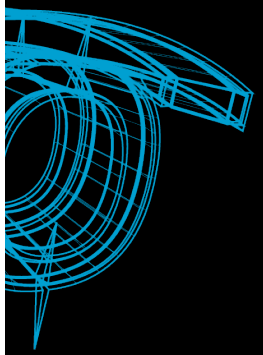
INDICE



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2. In luctus aliquet quam, at porttitor nulla laoreet id.
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7. Curabitur sit amet mi eget nisi sodales ornare.

Introduction

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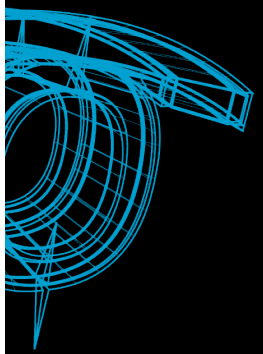

- Abdominal Aortic Aneurysm (AAA)
  - Dangerous condition weakening and dilation of the aortic wall
  - Eventual rupture and possible death if not treated
- Endovascular Aneurysm Repair (EVAR)
  - Non-invasive technique where an endograft serves as a by-pass decreasing pressure in the aortic wall
  - Formation of a thrombus
  - If successful aneurysm size decreases
- Follow-up using CTA
  - Standard screening technique
  - Several exams at one, six and twelve months, then yearly
  - Discard the presence of leaks

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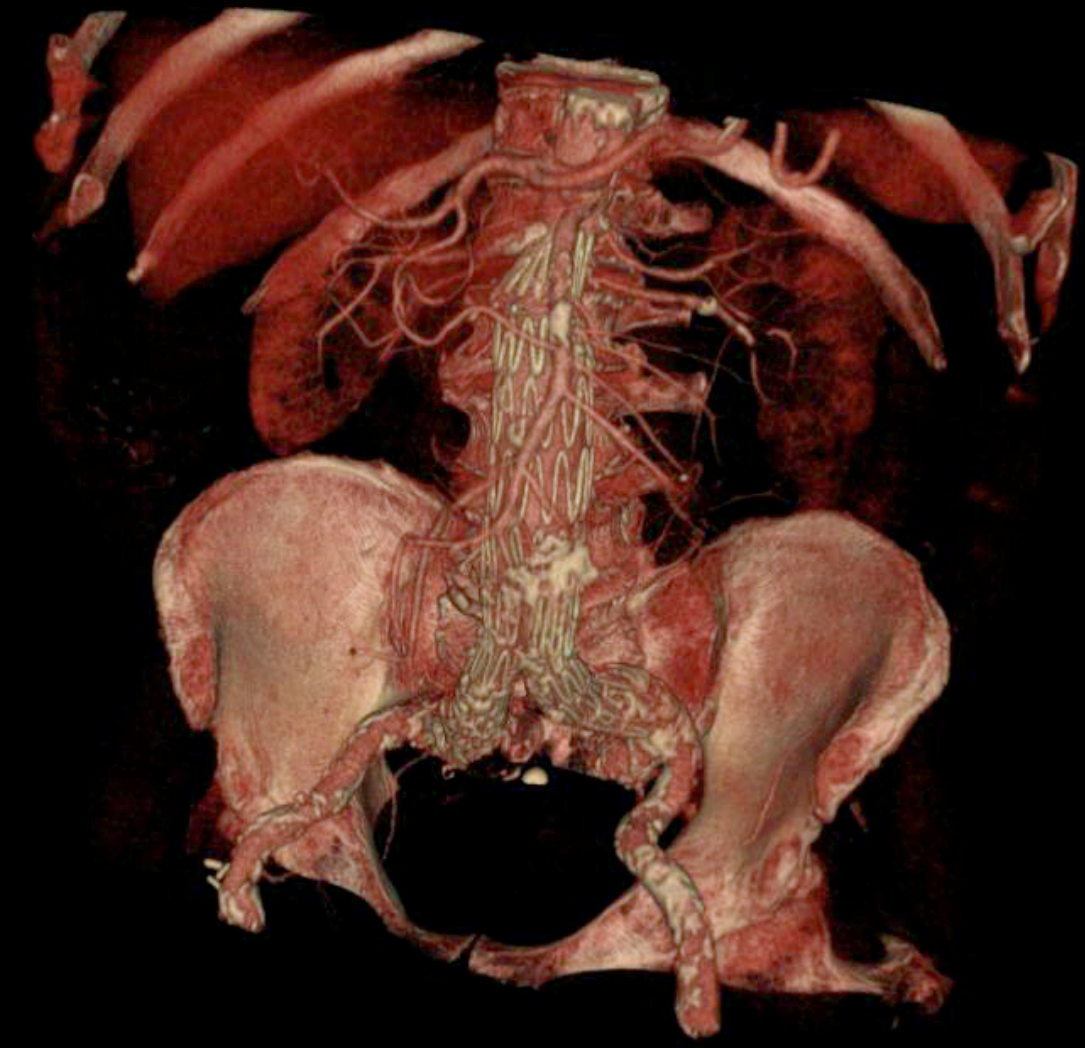

Volume Render of CTA of patient treated with EVAR

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INTRODUCTION

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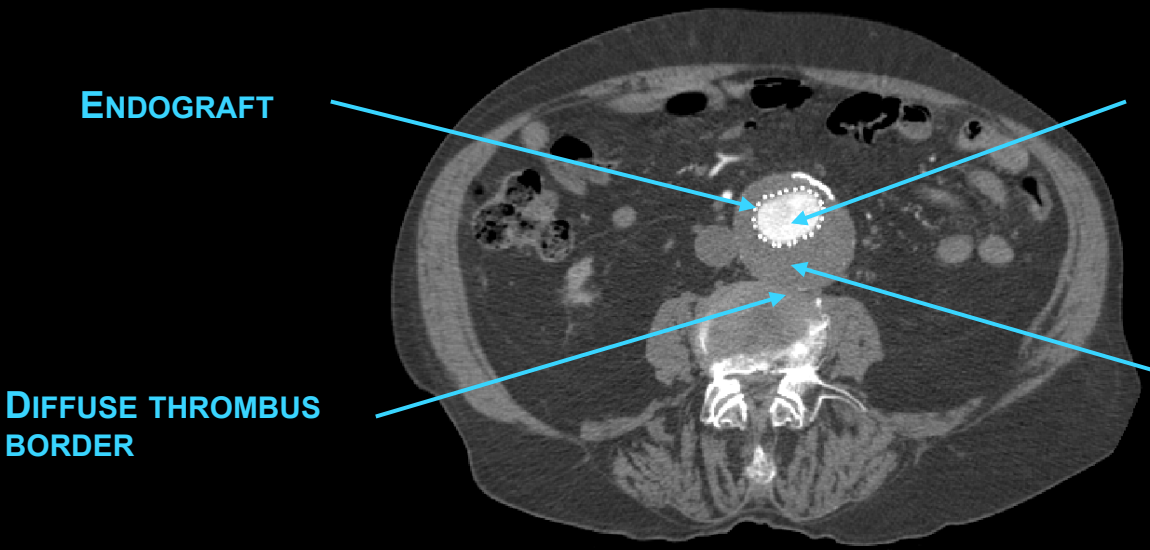
- Segmentation of AAA
  - Delineation of AAA manually is very time consuming
  - (Semi)Automatic segmentation required routinely
  - Segmentation of lumen is relatively easy due to contrast
  - Segmentation of thrombus is very challenging: little contrast with respect to adjacent structures



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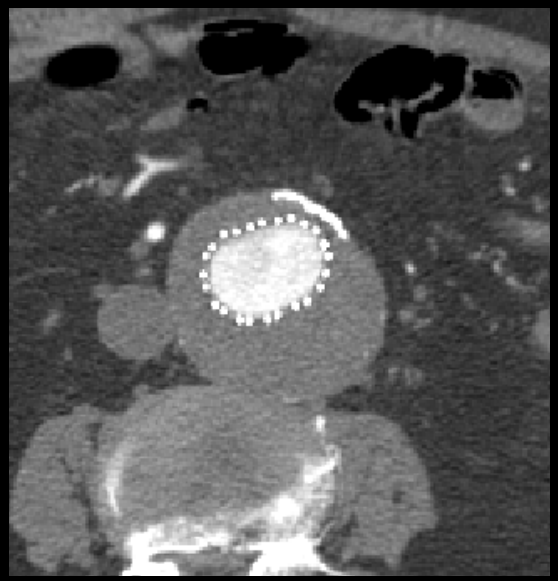
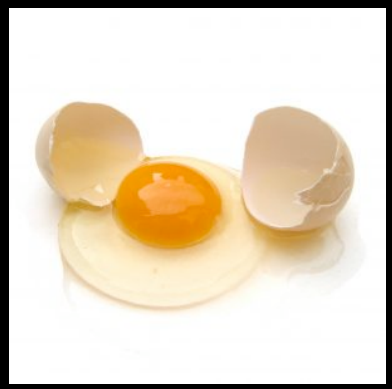
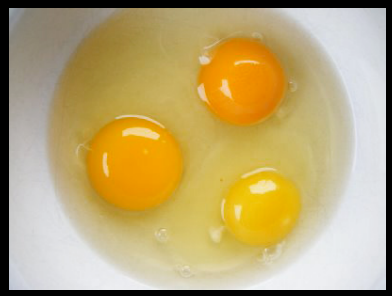
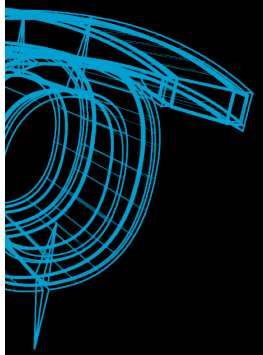
- Simile with raw egg
  - Lumen ≈ Yolk : strong borders, easy to segment
  - Thrombus ≈ White : border confuses with adjacent structure/ egg
  - Endograft ≈ shell







Lumen Segmentation



- Lumen is usually a starting point for thrombus segmentation
  - Approximates inner thrombus boundary (not considering endograft)
  - Allows calculation of aorta centerline
- 3D region-growing based algorithm
  - Select two seed points on the centerline determining the VOI in axial direction
  - Iterative process:
    - Calculate mean and variance in a neighborhood from a single seed point
    - Select connected points within this confidence interval
    - Calculate new mean and variance for current region
    - ...
  - Segmentation refined by morphological closing

Lumen Segmentation

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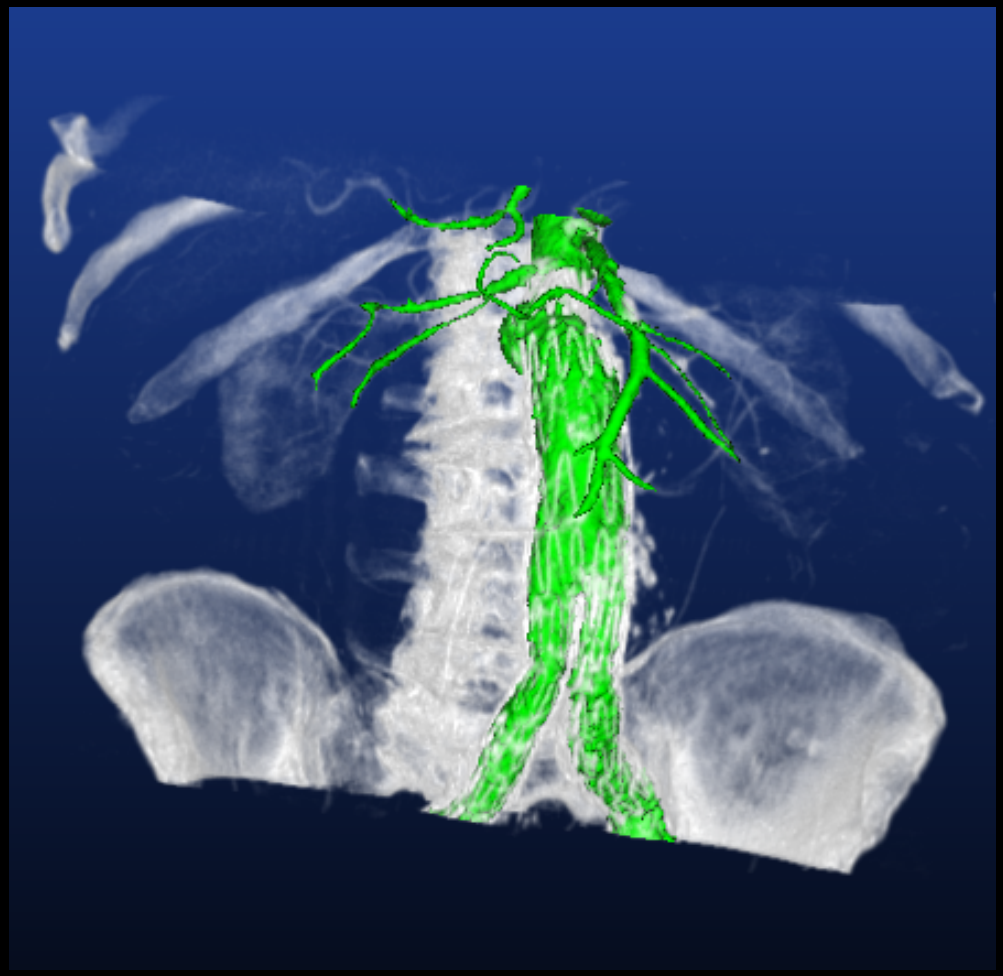

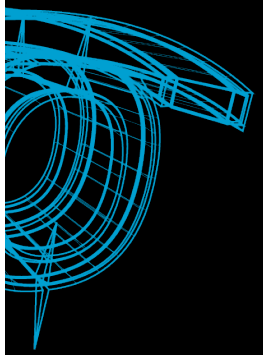

Centerline Extraction

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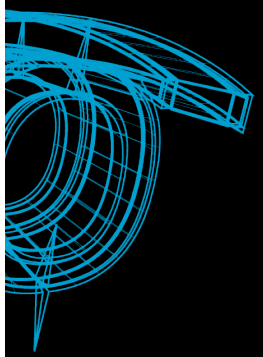

- Lumen centerline
  - Obtained as the centroid of the lumen region at each slice
  - Approximates the morphological skeleton of the whole aorta
- Centroid calculation
  - At each slice there are several connected components
  - Select nearest centroid to previous slice and discard the rest
- Algorithm

```
1: initialization of region: center line in first processed slice
2: iterative process: for all slices in 3D image do
3:         identify connected components
4:         for components in slice do
5:                 compute candidate centroids
6:                 compute Euclidean distances to centroid in previous slice
7:         end for
8:         keep nearest candidate centroid
9: end for
```

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Thrombus Segmentation

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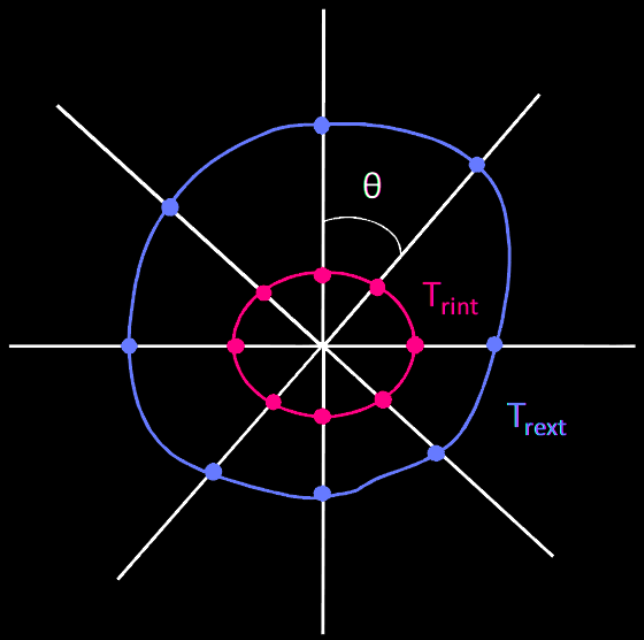
- The VOI around the lumen centerline can be expressed in cylindrical coordinates

$$\Psi = \Psi(r, \theta, z)$$

- Model the thrombus internal and external contour as a radial function at each slice with orign on the centerline



$$T_{rint} = \Psi_{rint}(\theta, z)$$
$$T_{rext} = \Psi_{rext}(\theta, z)$$

Thrombus Segmentation

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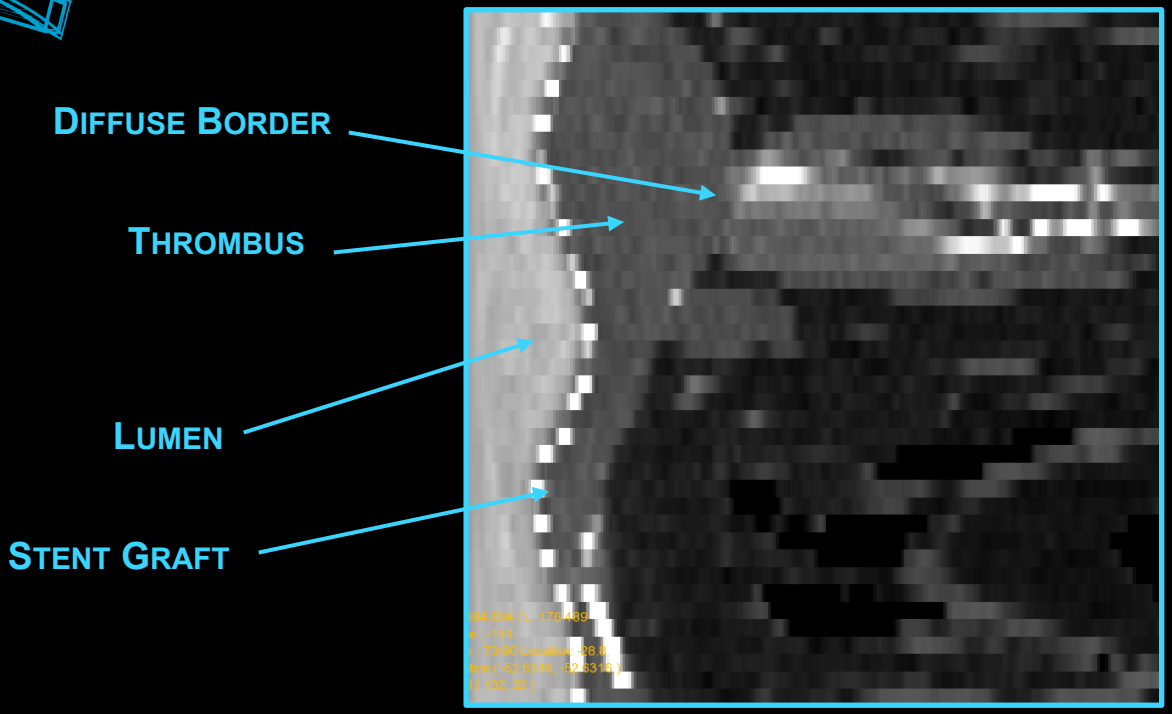
- Resample each slice from cartesian to polar coordinates
  - Left origin is centerline point
  - The VOI is now a wide tube instead of a rectangular prism
  - Natural reference system for radial analysis



Thrombus Segmentation

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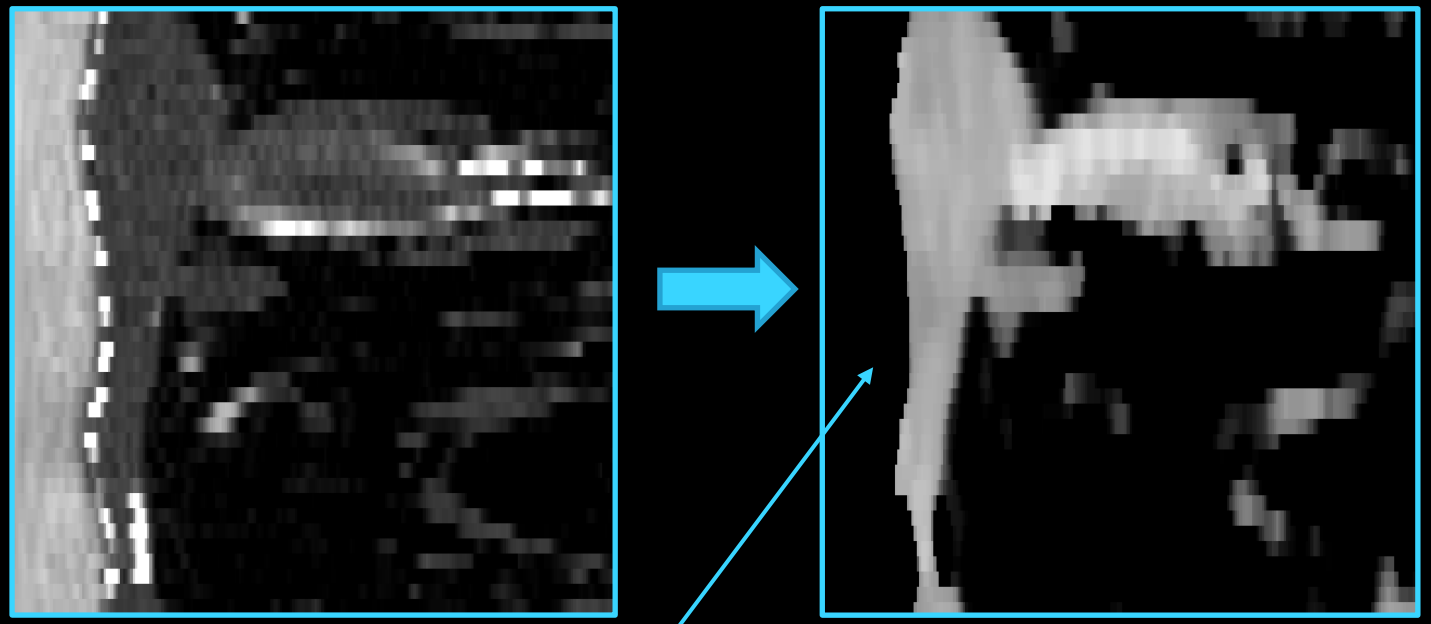
- Pre-processing
  - Remove noise using median filtering
  - Threshold above 150 HU to a background value of -100 HU
    - Removes lumen and endograft on the left side
    - Makes the thrombus the brightest structure closest to the centerline



Removed Lumen and Stent

Thrombus Segmentation

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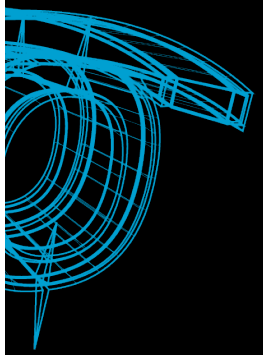

- Local analysis based on two concepts
  - Radial Connected Component (RCC): connected component on a row of a slice in polar coordinates
  - Slice Connected Component (SCC): connected component on a slice in polar coordinates
  - Stored used run-length encoding
- The basic idea is to filter the CCs in order to keep only those that are part of the thrombus, based on
  - *A priori* knowledge: thrombus is brightest structure closest to centerline
  - Spatial coherency: thrombus is a connected structure whose radius varies smoothly
- Main problem is identifying the external thrombus radius

THROMBUS SEGMENTATION

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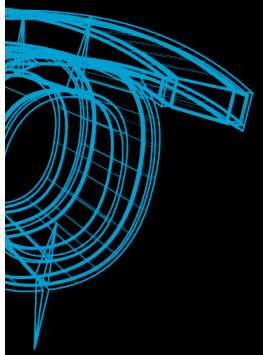
- First create RCCs by row-by-row analysis of slices
  - Current membership criterion is difference from mean < 20 HU
  - During the process lumen radius is identified (first RCC with -150 HU as set before)



```
1: Initialization of region: center line in first processed slice
2: Iterative process: for all polar slices do
3: for all rows in current polar slice do
4:         create new RCC and insert first voxel in row
5:         for all voxels in current row do
6:                 if ( intensity(voxel) Intensity range(RCC) ) then
7:                         insert voxel in current RCC
8:                 else
9:                         create new RCC and insert current voxel
10:                end if
11:                calculate and store lumen external radius for the row
12:                end for
13:        end for
14: end for
```

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Thrombus Segmentation

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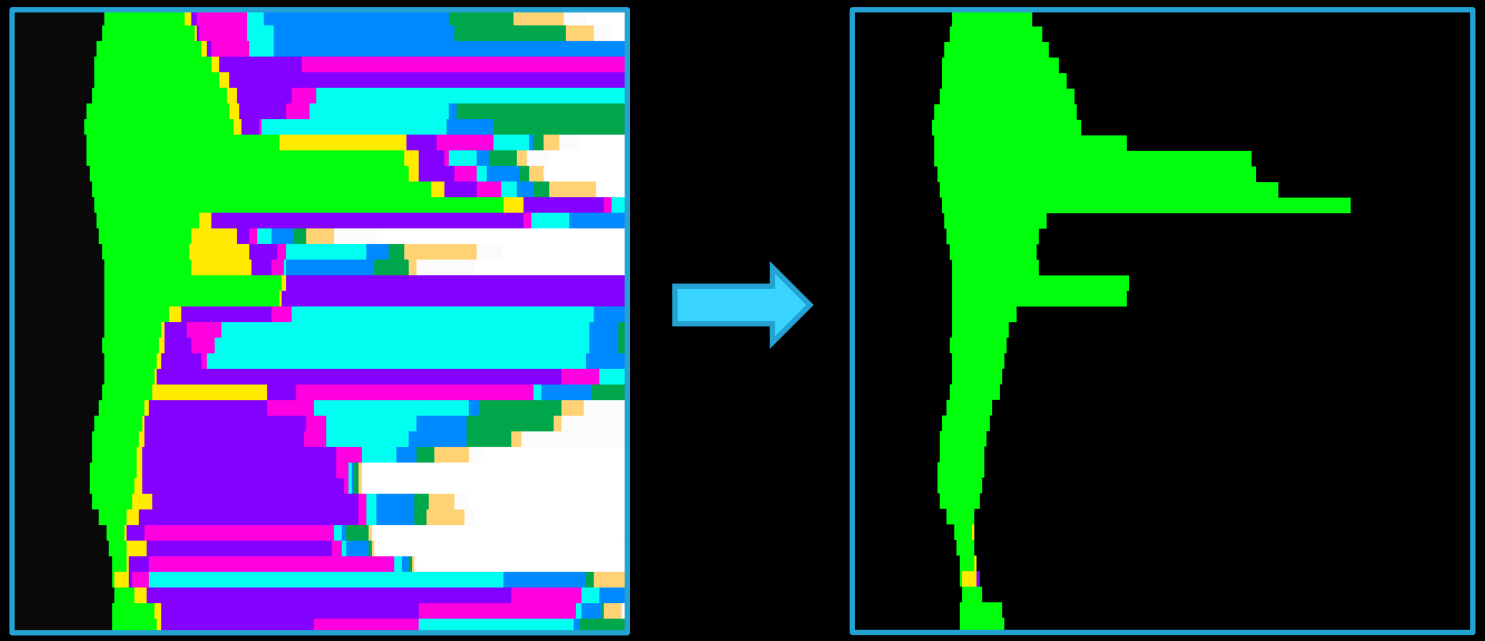
- Filter RCCs with conservative criteria
  - Remove RCCs outside 0-200 HU range
  - Remove RCCs > 5 mm. away from external lumen radius
  - Should work for most datasets (more validation needed)



Thrombus Segmentation

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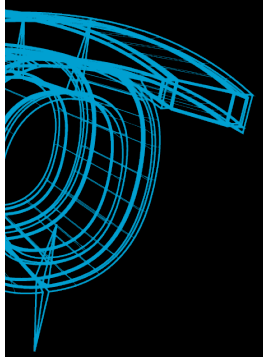

- Now create SCCs for each slice
  - SCCs are connected groups of RCCs (referenced)
  - Use same membership criteria as with RCCs
- Filter SCCs (and contained RCCs):
  - By size: remove SCCs with less than 10 voxels (typically noise)
  - By position of centroid:
    - Calculate median value of centroid of remaining RCCs on a slice
    - Calculate centroid of each SCCs
    - Compare SCC centroid with median value for the slice and if > 20 mm. remove it
- From remaining RCCs calculate for each row of each slice:
  - Internal thrombus radius (T_{rint}): start index of first RCC
  - External thrombus radius (T_{rext}): end index of last RCC

Thrombus Segmentation

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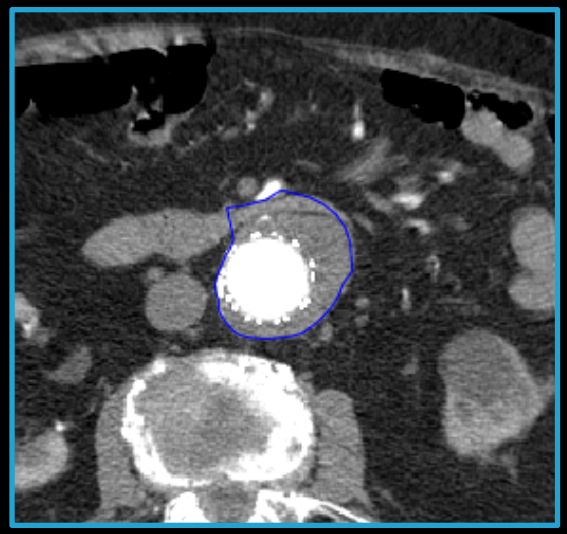

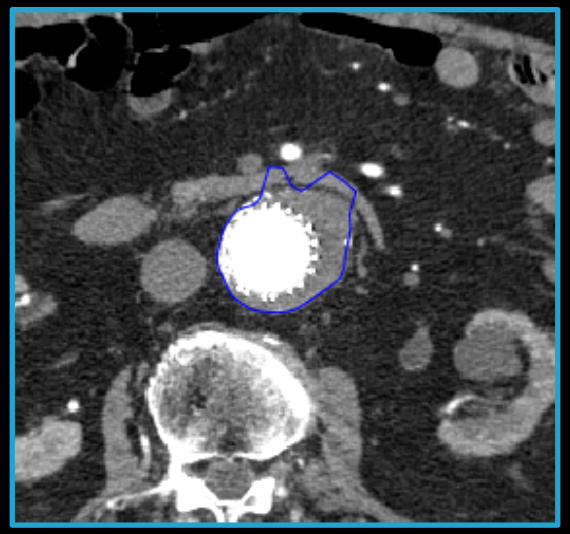

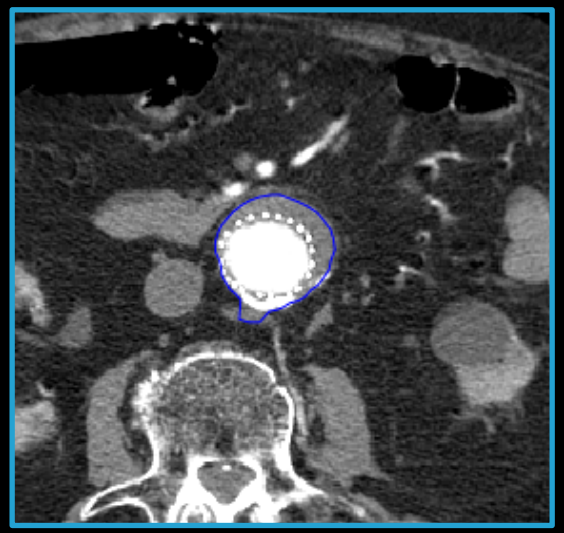

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Thrombus Segmentation

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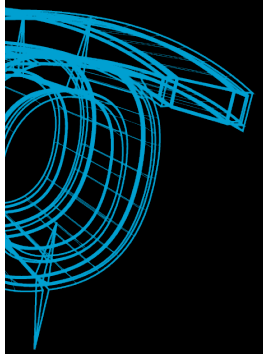
- Problem: the thrombus leaks on adjacent structures with similar intensity values
  - Seen as discontinuities in calculated external radius
  - Thrombus radius should be smooth at each slice



- Solution:
  - Impose a continuity criteria:
    - Identify discontinuities
    - Recalculate their radius by interpolation

Thrombus Segmentation

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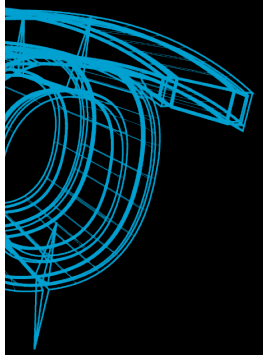

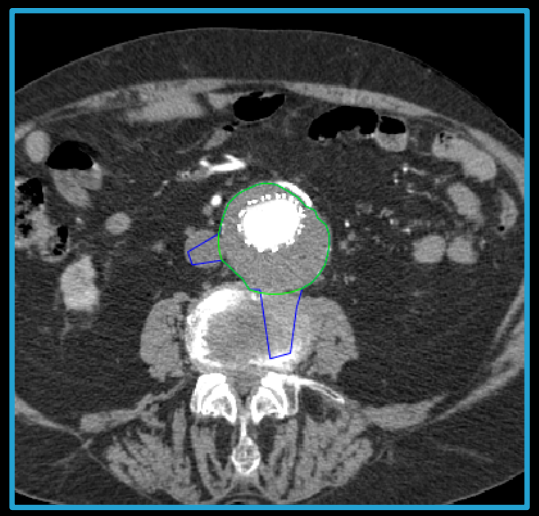

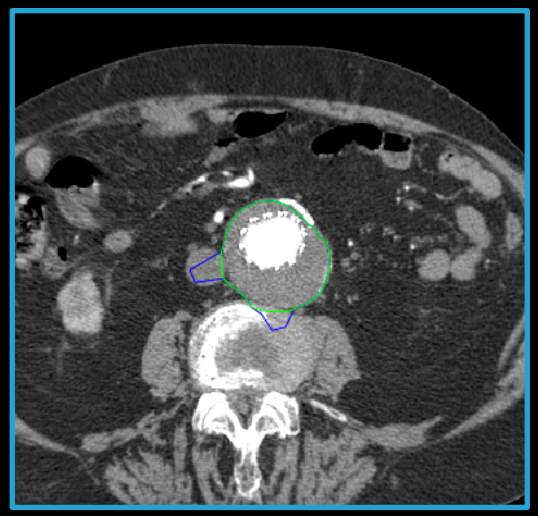

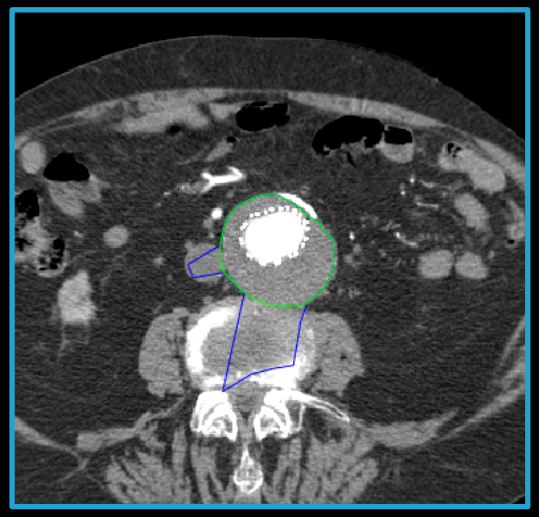

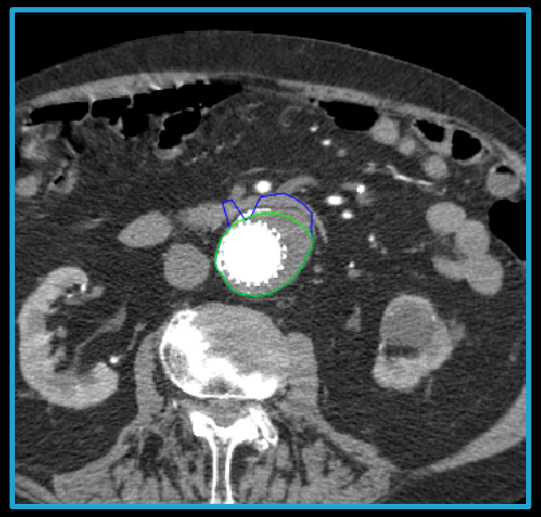

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Results and Discussion

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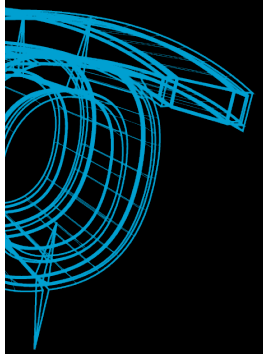
- Preliminary work: method not validated but promising

- Initial results:
  - Lumen segmentation and centerline extraction is accurate and efficient.
  - Good estimation of thrombus contour in places where other algorithms fail due to leakage on adjacent structures
  - The thrombus external radius is sometimes underestimated
  - Very fast method!



CONCLUSIONS

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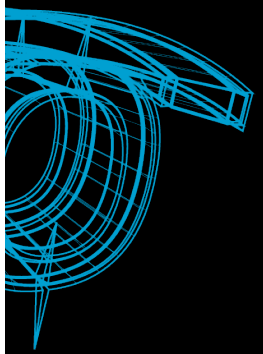

- Novel technique for semi-automatic segmentation of AAAs from CTA images:
  - Lumen is obtained using a region growing-based algorithm followed by centerline extraction
  - Centerline is origin of a polar representation of the input slices
  - Thrombus contours modeled as radial functions
  - Radial function for the external radius obtained by local and slice-level analysis of CCs an a priori knowledge of the location, size and intensity of the thrombus.
- Advantages:
  - The algorithm does not depend on any user-defined contour or initial manual segmentation
  - User interaction is minimal
  - Very fast

Conclusions

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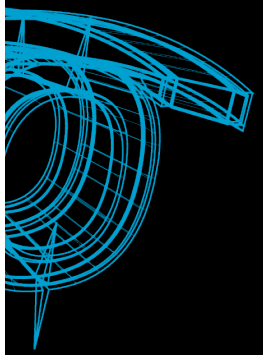
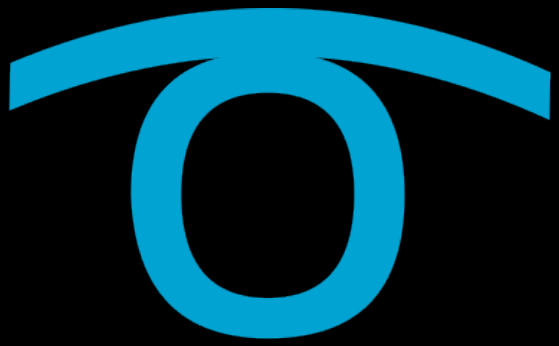
- Promising results on real datasets
  - Accurate segmentations are obtained in areas where it is difficult to distinguish the thrombus from adjacent structures
- Future work
  - Need further validation
  - Need to fine-tune or remove parameters
  - Improve thrombus model



THANK YOU FOR YOUR ATTENTION!



www.vicomtech.org
info@vicomtech.org

Iván Macía Oliver
Biomedical Applications Dept.
imacia@vicomtech.org