DEVELOPMENT OF AN IMAGING SYSTEM FOR THE CHARACTERIZATION OF THE THORACIC AORTA.

Juan Antonio Martínez Mera

Centro Singular de Investigación en Tecnoloxías da Información

Universidade de Santiago de Compostela

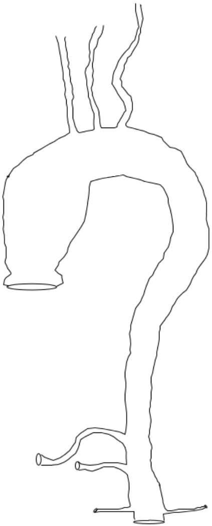
10 de abril de 2014

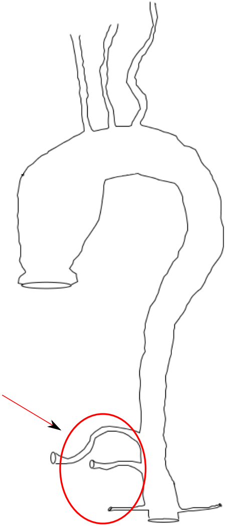
USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

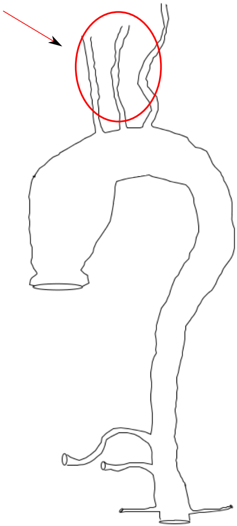
CAMPUS VIDA CAMPUS DE EXCELENCIA INTERNACIONAL

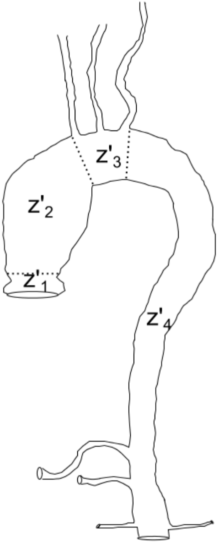
CiTIUS Centro Singular de Investigación en Tecnoloxías da Información

The aorta is the main artery of the body, is the larger vessel throughout the body and is characterized by a thick elastic wall.





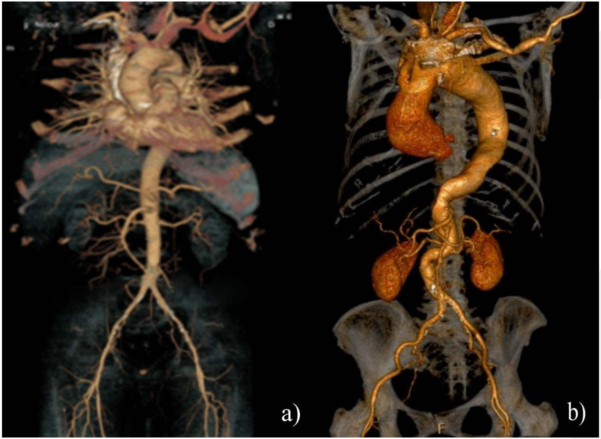



Z'3
Z'2
Z'1
Z'4

The thoracic aorta can be affected by different diseases:

- Dissection
- Atherosclerosis
- Aortitis
- Aneurysm

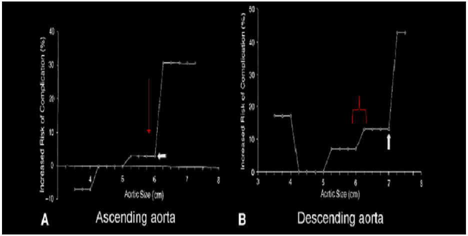
....

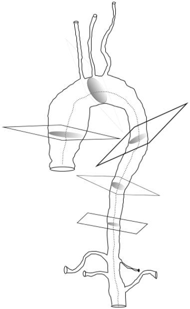


An aneurysm is local and permanent dilation of a portion of the vessel.
This pathologic process affects the wall.

- The aortic aneurysm is the most common pathology.
- Its incidence is de 6/100.000.
- Risk of rupture 74 %.
- Its mortality ratio is 90 %.
- It is a degenerative disease.

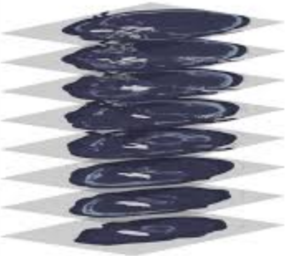
When there is an aneurysm?





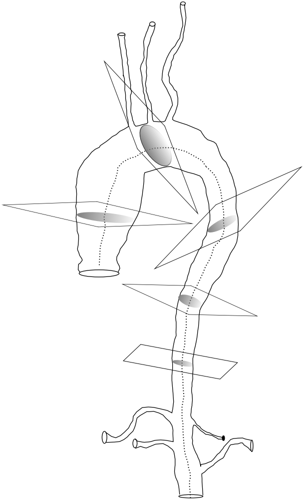
- The diameter of the aorta should not exceed a maximum diameter of 5.5 cm in the ascending aorta.
- For the descending aorta (5.5 - 6.0 cm).
- The diameters have to be calculated in the normal planes to the wall of the vessel.

To diagnose a patient in the hospital:



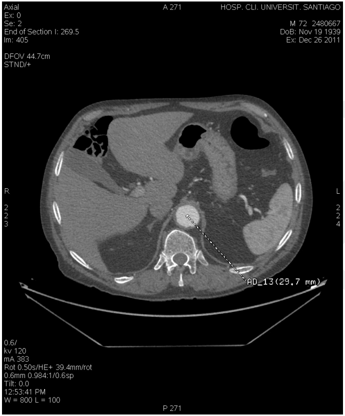
The patients are scanned with a CT. We obtain several images from inside the patient.

To check if a patient has an aneurysm a commercial software (General Electric)is used. This comercial software calculates the normal diameters.



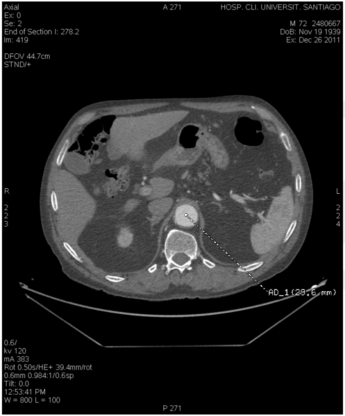
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



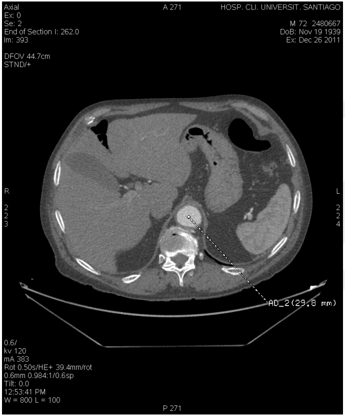
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



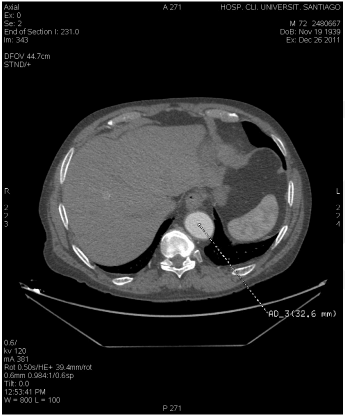
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



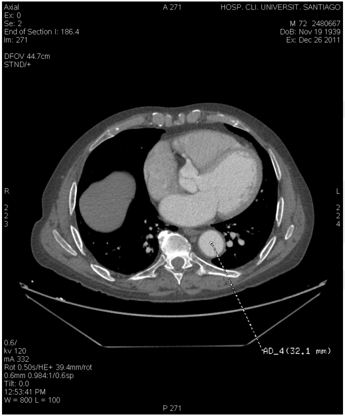
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



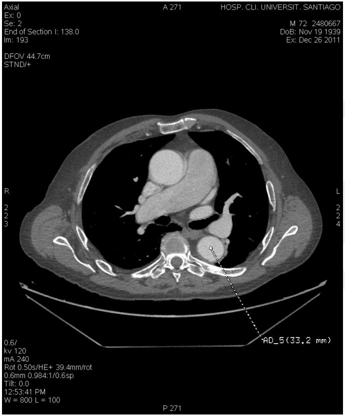
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



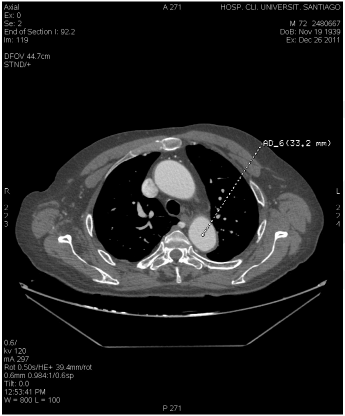
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



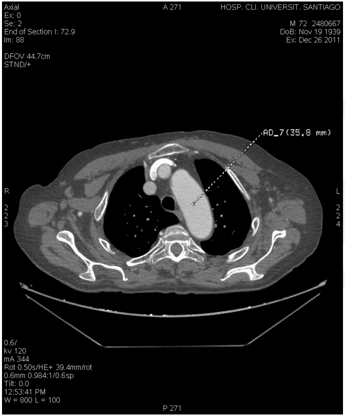
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



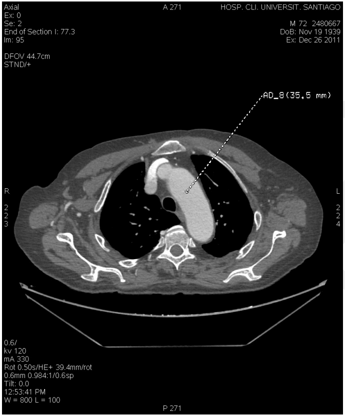
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



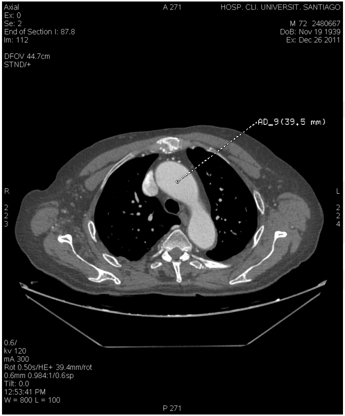
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



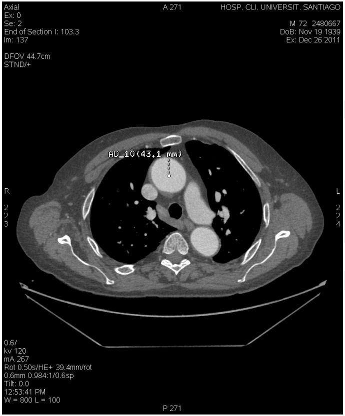
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



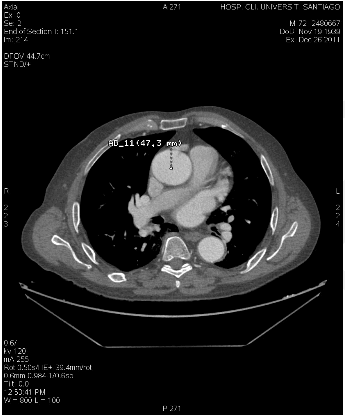
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points



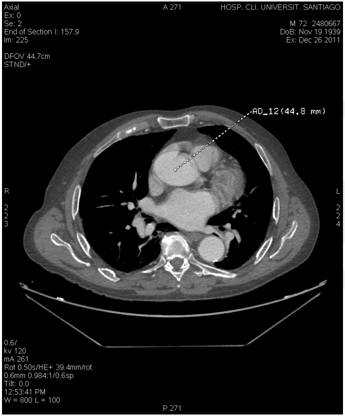
But this comercial software has several drawbacks:

- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points

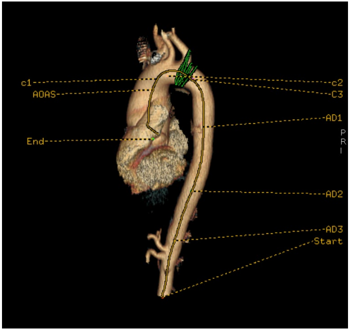


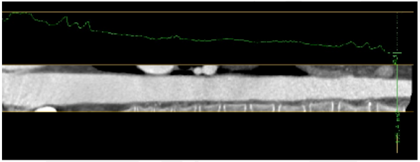
But this comercial software has several drawbacks:

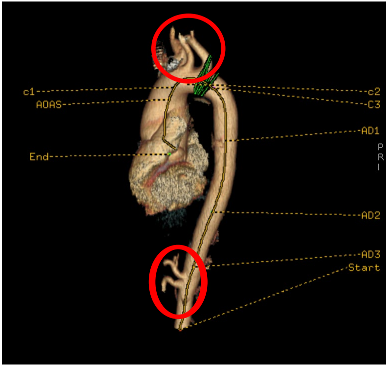
- The specialist must indicate several points within the vessel.
- The radiologist uses about 20 minutes to analyze a case.
- The result may depend on where the radiologist put the initial points

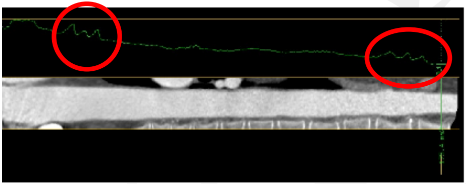


After, the specialist approves several windows of the comercial program and gets this graph. Finally the specialist have to check if this chart is correct, and remove from the graph the branches of the aorta.

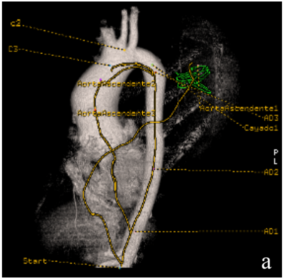


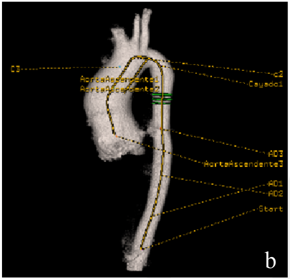



c1
AOAS
End
c2
C3
AD1
P
R
I
AD2
AD3
Start



The results may be differents in the same clinical case.



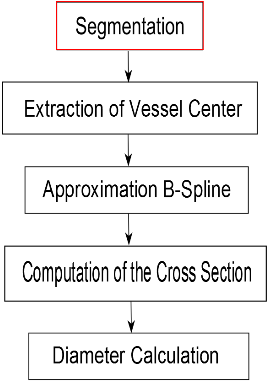


Aim

- Develop a system to segment and analyze the thoracic aorta.
- Without intervention of the specialist.
- System that provides reproducible results that can not get a specialist.

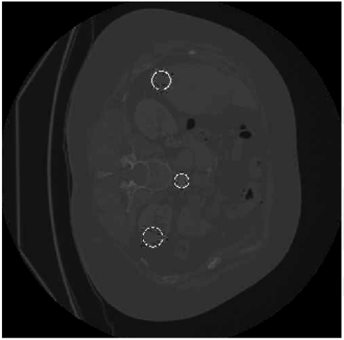
Method

- The method is based on the following steps:



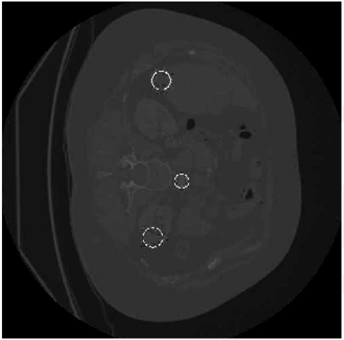
Method

We apply the Hough transform to determine the correct position of the thoracic aorta.



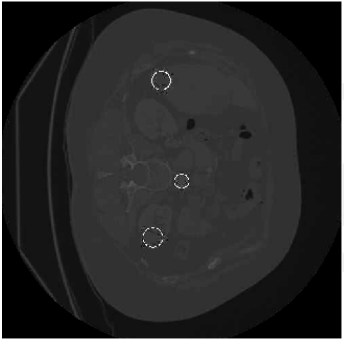
Method

The Hough transform was applied at the most caudal slice of the descending aorta.



Method

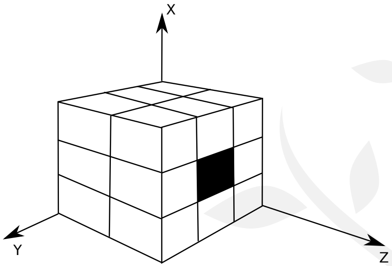
In this area, a slice's approximate shape is a circle. The Hough transform enables pre-set shapes to be found in an image. Hough transform involves convolving a circular mask with the image given.



Method

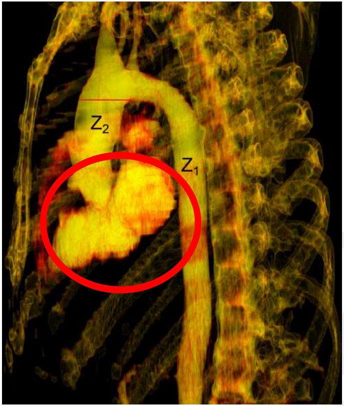
Volumetric region-growing technique is used to segment the section Z_1

This volumetric region growing consists of the use of the 17 pixel neighbors corresponding to the previous and current slices for the calculation of the mean and variance.



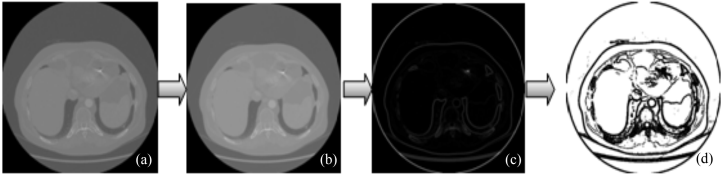
The transition from section Z_1 to section Z_2 is characterised by a increase in the size of the segmented region. This region can be approximated by an ellipse in which one of the foci will be used to segment the section Z_2.

Algorithm based on level set is used to segment the section Z_2

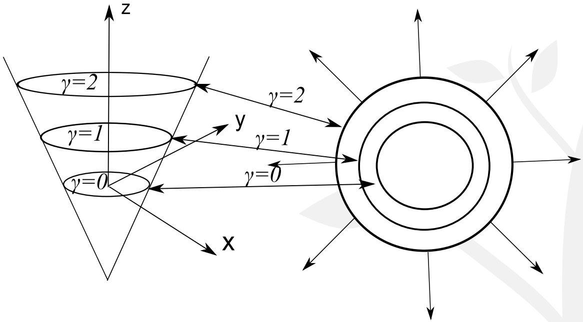


We use level set algorithm, because the aorta is connected to the heart, which is filled with blood. For this reason, the boundary between the heart and the aorta is fuzzy.

We applied a pre-processing stage to enhance the border of the image, and next applied a level set algorithm.

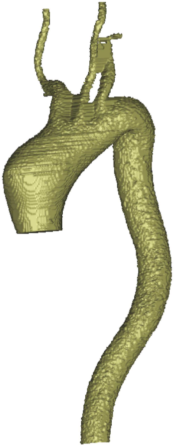


The basic idea underlying level set can be stated as follows: Given a 2*D* closed curve, its representation by a single 2*D* function is not possible. A solution consists of using a 3*D* function intersected by a plane at a given height.



Method

So, we obtain this result of the segmentation on a clinical case with hybrid method of segmentation.




Computer Aided Surgery

http://informahealthcare.com/csu
ISSN: 1092-9088 (print), 1097-0150 (electronic)

Comput Aided Surg, Early Online: 1–9
© 2013 Informa UK Ltd. DOI: 10.3109/10929088.2013.816978

informa healthcare

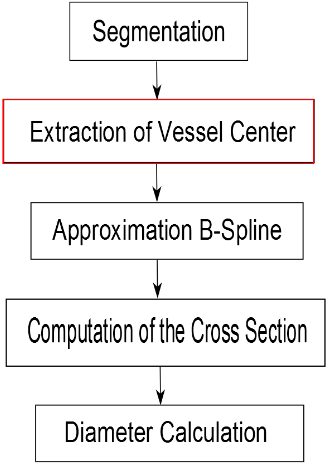
BIOMEDICAL PAPER

A hybrid method based on level set and 3D region growing for segmentation of the thoracic aorta

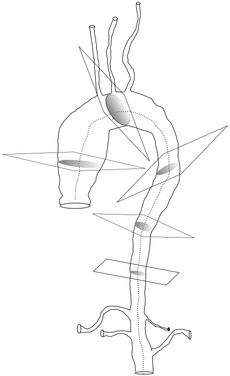
Juan Antonio Martinez-Mera[1], Pablo G. Tahoces[1], José M. Carreira[2], Jorge Juan Suárez-Cuenca[3], and Miguel Souto[2]

[1]Centro Singular de Investigacion en Tecnoloxias da Informacin (CITIUS), University of Santiago de Compostela, Santiago de Compostela, Spain, [2]University Hospital Complex of Santiago de Compostela (CHUS), Santiago de Compostela, Spain, and [3]University of Santiago de Compostela, University of Santiago de Compostela, Spain

Method


Segmentation
Extraction of Vessel Center
Approximation B-Spline
Computation of the Cross Section
Diameter Calculation

Once we have the segmentation of the aorta, we need to calculate the normal plane of the vessel. For this reason, we need to calculate the vessel centerline.

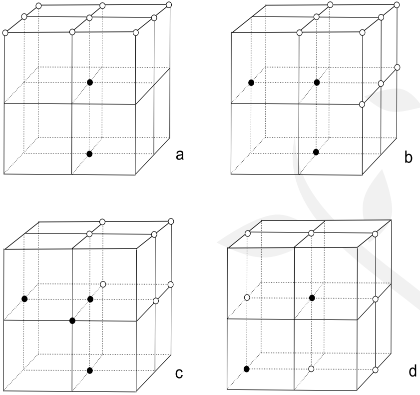


Method

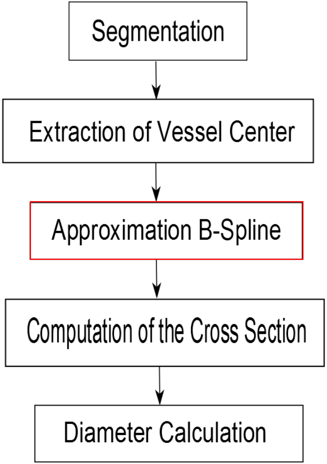
The centerline is extracted using two different techniques:
In sections descending aorta and ascending aorta, the centerline is calculated using the center of mass of the segmented region on each slice.

$$CMX = \frac{\sum_{i=0}^{i=N} GL_i \cdot x_i}{GL_i} \quad CMY = \frac{\sum_{i=0}^{i=N} GL_i \cdot y_i}{GL_i} \tag{1}$$

In aortic arch iterative erosion of volumetric image data is applied. This erosion process involves four basic templates. Black symbol are object to be eroded and white symbol is the background. The result to erode corresponds to the centerline of the aortic arch.

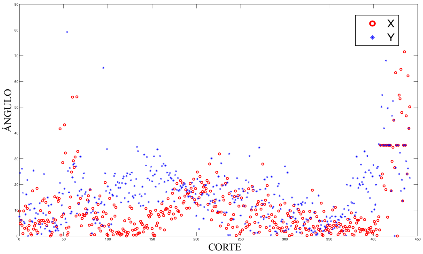


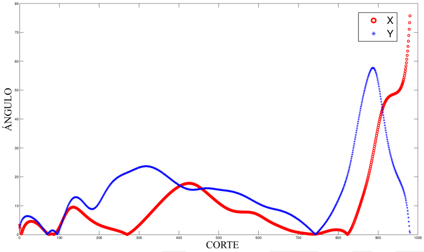
Method


Segmentation
Extraction of Vessel Center
Approximation B-Spline
Computation of the Cross Section
Diameter Calculation

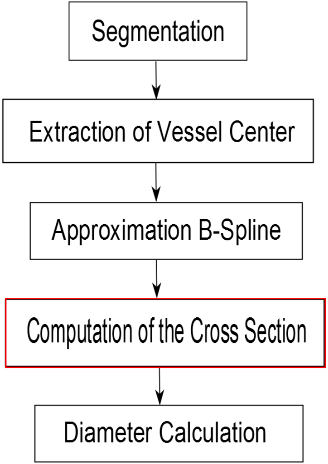
Method

The points calculated in the previous step are interpolated to smooth the centerline. (B-Splines)



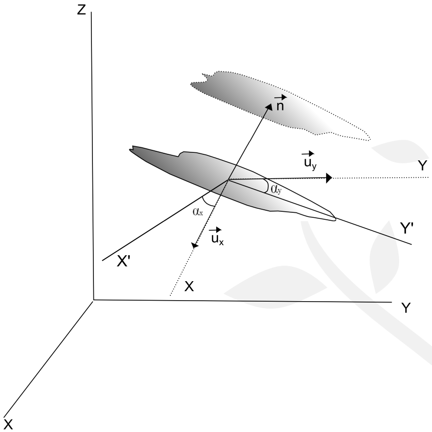


Method

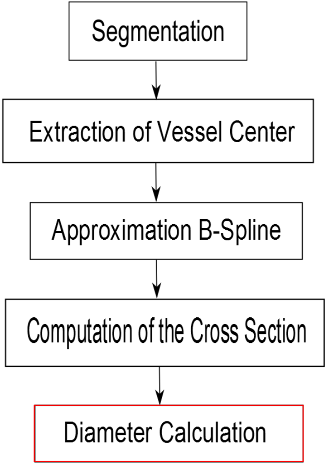

Segmentation
Extraction of Vessel Center
Approximation B-Spline
Computation of the Cross Section
Diameter Calculation

Method

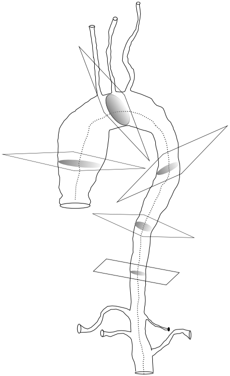
The points of the centerline are used to determine the normal vectors corresponding to the cross-sections at each point on the line.



Method

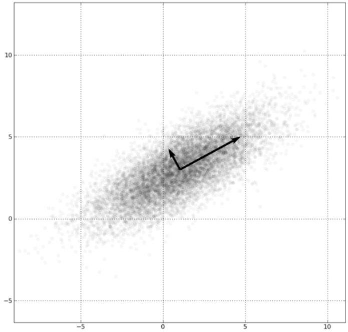

Segmentation
Extraction of Vessel Center
Approximation B-Spline
Computation of the Cross Section
Diameter Calculation

Once normal planes are calculated. Variance-covariance matrix of these planes is calculated too.



Method

The eigenvalues of the matrix are the vectors that indicate the orientation of the principal axes. Thus, to obtain the value of maximum and minimum diameters, we compute the size of segmentation in these directions.



Method

To determine real dimensions of a vessel diameter, we applied a scale factor.

- The distance between the slices of the acquisitin system used.
- The different dimensions of the voxel.
- *PCA* is calculated in two dimensions and the vectors must be transformed to $3D$.

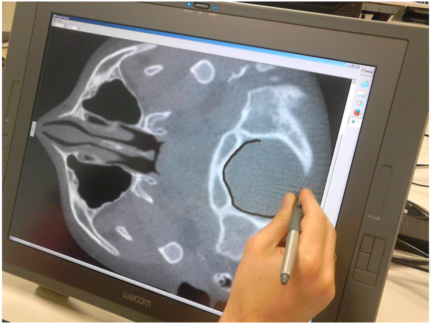
Results

The results have been divided into:

- Segmentation results
- Diameter results.

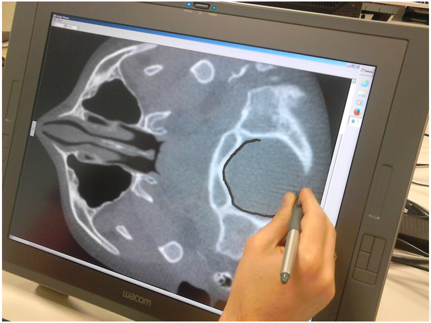
Segmentation Results

Manual segmentation was considered the **gold standard** to compare with automatic method. Manual segmentation was performed by two expert vascular radiologists in clinical cases. Database was made of 32 clinical cases y 14.128 images.

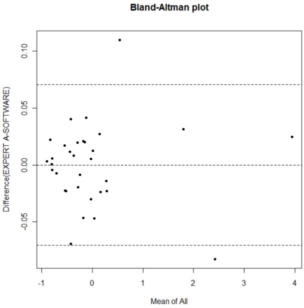


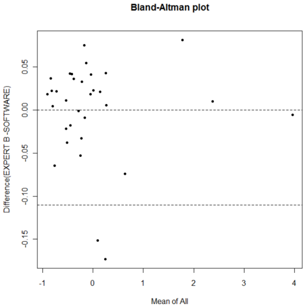
Segmentation Results

Manual segmentation was performed in a graphics tablet equipped with software and a light pen for manually tracing borders.



Segmentation Results





Only 5 % cases in both plots exceeded the confidence interval ($\pm$ 1.96σ).

There were no statistically significant differences.

The *DSC* factor was calculated to check the overlapping areas :

$$DSC = 2\frac{A \cap B}{A \cup B} \tag{2}$$

$$DSC_{error} = 2\frac{\mid V(A) - V(B) \mid}{V(B)} \tag{3}$$

DSC=0 indicated that the two areas or volumes did not overlap, *DSC*=1.0 indicated complete overlap.

Expert	Asc.	Arch	Desc.	Mean
A	96.15 %	94.75 %	94.76 %	95.22 %
B	94.54 %	92.88 %	91.82 %	93.08 %

Pearson coefficient and Intraclass coefficient were calculted to check the segmentation.

- Pearson coefficient was greater than 0,9 for each section of the aorta by radiologist *A* and 0,8 for radiologist *B*.

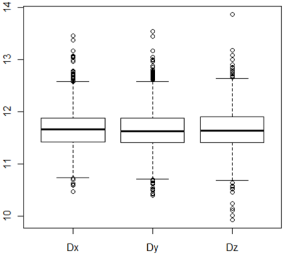
- Intraclass coefficient was between 0,8 and 0,85 in all regions of the aorta for each segmentation.

Diameters Results

- To check the results of diameters we designed this phantom to test the rotational invariance.

Results Diameters

Phantom images were obtained by CT at different spatial projections (X,Y,Z).

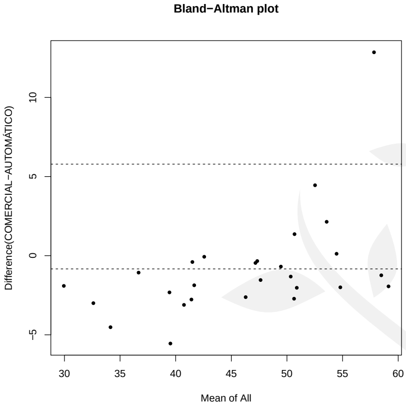


Axes	Average distance	Confidence interval
D_x	11,65	11,64-11,66
D_y	11,64	11,63-11,65
D_z	11,65	11,64-11,66

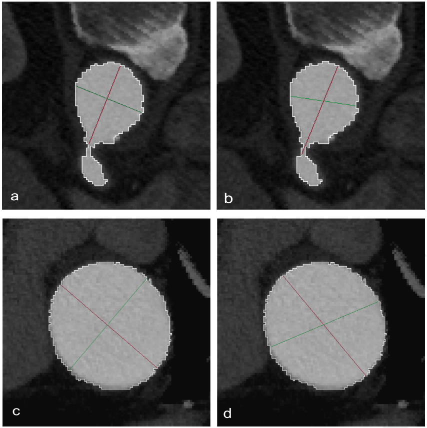
No statistically significant differences were found between the three subsets.

Results Diameters

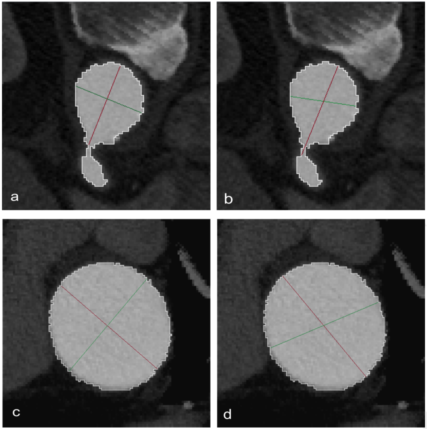
The diameter of the aorta was calculated with the two methods (the proposed and the commercial) in different clinical cases.



No statistically significant differences were found.

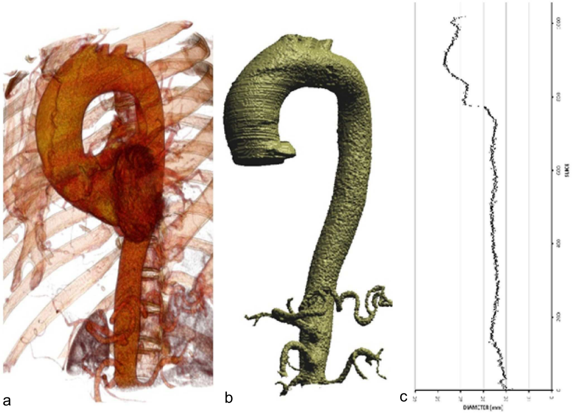


- Maximum and minimum diameters were calculated in a normal section. • Pictures a)c) were calculated by PCA, and the diameters of the pictures b)c) were calculated with multidirectional analysis.



PCA method avoids the branches of thoracic aorta.

Clinical case/ the volumetric reconstruction of segmentation/ graph of diameter.



Conclusions

- Alternative to manual segmentation.
- Highly reproducible, while manual segmentation is not reproducible.
- The method developed automates the calculation of the diameter of the aorta.
- Shown the potential of PCA for determination of diameters, and to prevent lateral branches.

final

Se acabo