Hybrid Decision Support System for Endovascular Aortic Aneurysm Repair Follow-Up

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An overview of the medical problem (I)

What is an abdominal aortic aneurysm?

○ An abdominal aortic aneurysm (also known as AAA) **is a localized dilatation (ballooning) of the abdominal aorta, exceeding the normal diameter (50% increase over normal aorta diameter or 3 cm of enlargement).**
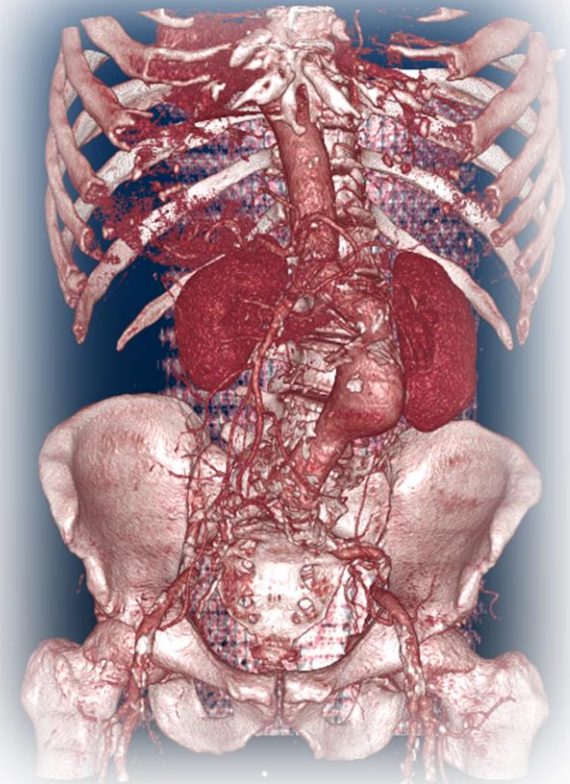
Source: *Stanford Computer Graphics Laboratory*

AAA affected patient. Volume render

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Surgical repair of AAAs

○ **Natural behaviour is to grow larger**.

○ Survival rate to rupture is less than 10%.

○ Two **surgical repair techniques:**

    ❑ **Open Repair (OR)**: The weakened (ballooned) portion of the aorta is replaced with a stent graft that is matched to the normal aorta and sewn in place.

    ❑ **Endovascular Aneurysm Repair (EVAR)**: A stent graft is inserted through the femoral arteries in order to exclude the bulge from blood circulation. A catheter serves as a guide.
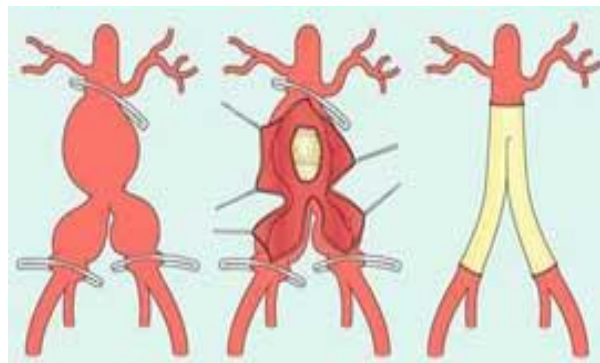
Source: Hallet et al.: *Comprehensive Vascular and Endovascular Surgery*, 2004 Elsevier Ltd.

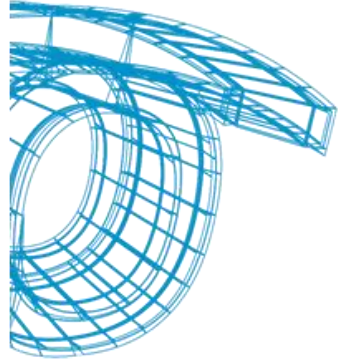AAA treatment with a modular Quantum (*CORDIS, Johnson & Johnson*) stent graft

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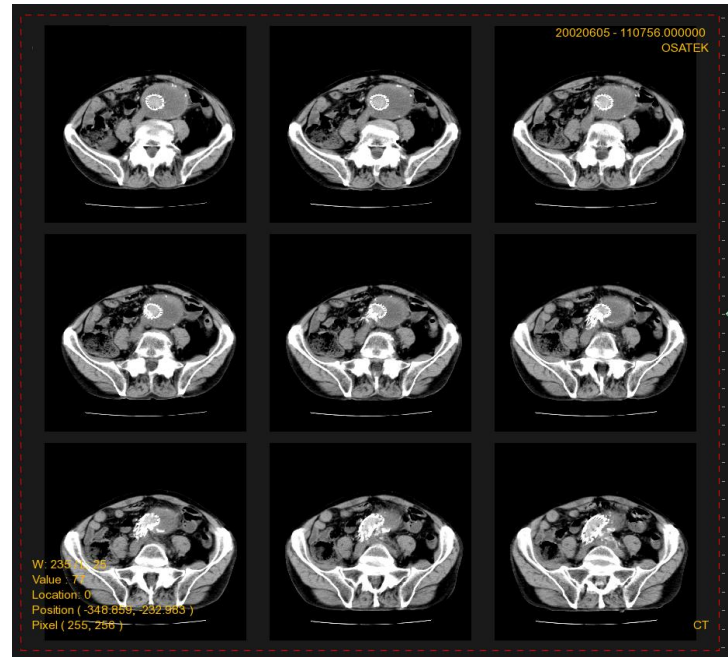
Where do the biomedical engineers come up?

○ A successful outcome of EVAR means bulge shrinking; after EVAR AAAs may shrink or *may not.*

○ Screening is **necessary.**
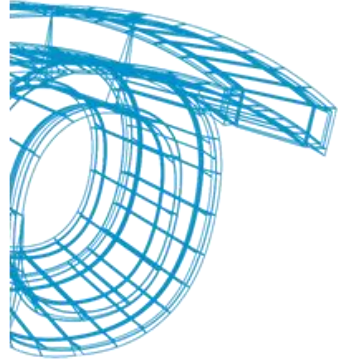
EVAR undergone AAA affected patient. 3x3 mosaic view. CT imaging

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Where do the biomedical engineers come up?

What is an endoleak or leak?

Some leaks
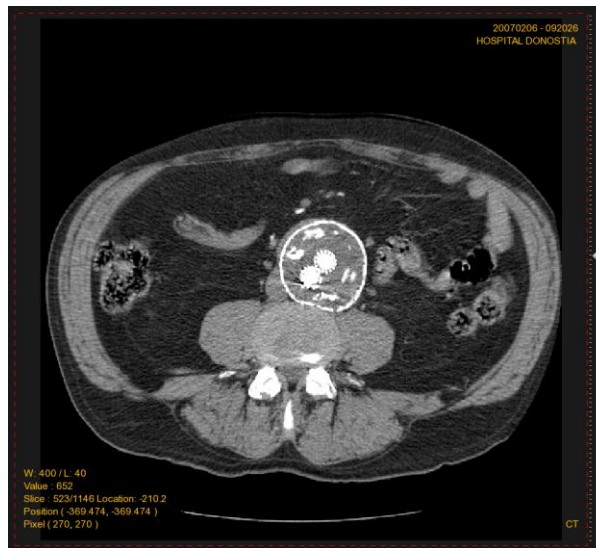
One leak
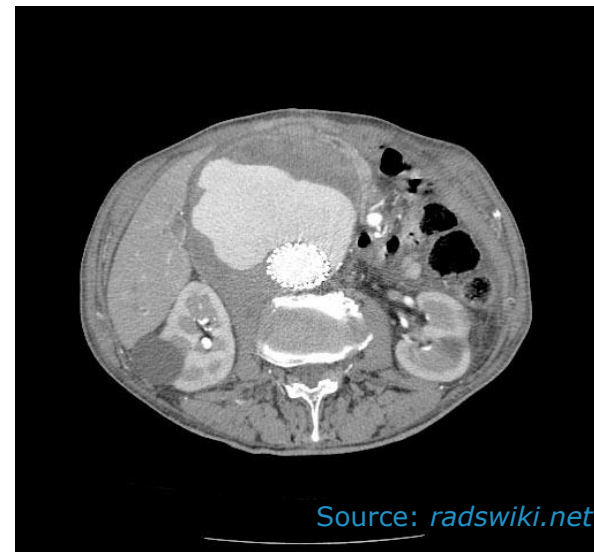
Source: *radswiki.net*

○ As many as 36% of patients with bulge growth do not show leaks (EUROSTAR record http://www.eurostar-online.org).

○ **Only the presence of leaks and the size of the aneurysm are taken into account for evolution assessment.**

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Objectives

○ The development of an integrated hybrid platform which encompasses

❑ Heterogeneous data sources

❑ Visualization tools

❑ Segmentation and registration tools

❑ Aneurysm morphometry information

❑ Aneurysm rupture risk prediction after EVAR procedure

in order to build **a system capable of proposing a computational process/model to predict EVAR outcome.**

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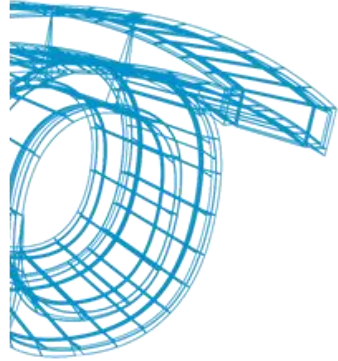research alliance

System components
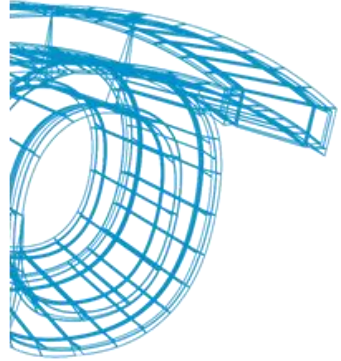
○ 3 stages

  ❑ Pre-operative
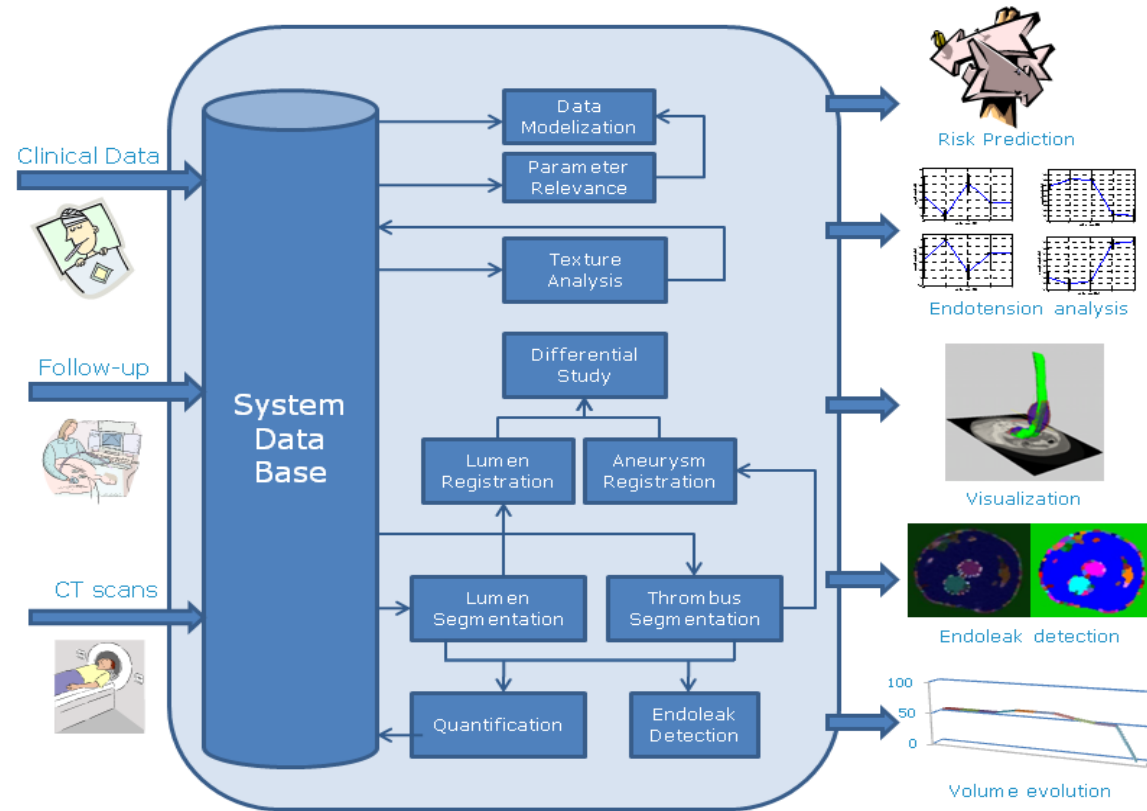
  ❑ Intra-operative

  ❑ Post-operative

○ 5 subsystems

  ❑ Segmentation system

  ❑ Endoleak detection system

  ❑ Registration and visualization system

  ❑ Texture analysis

  ❑ Risk prediction by *a priori* knowledge

System components

System components

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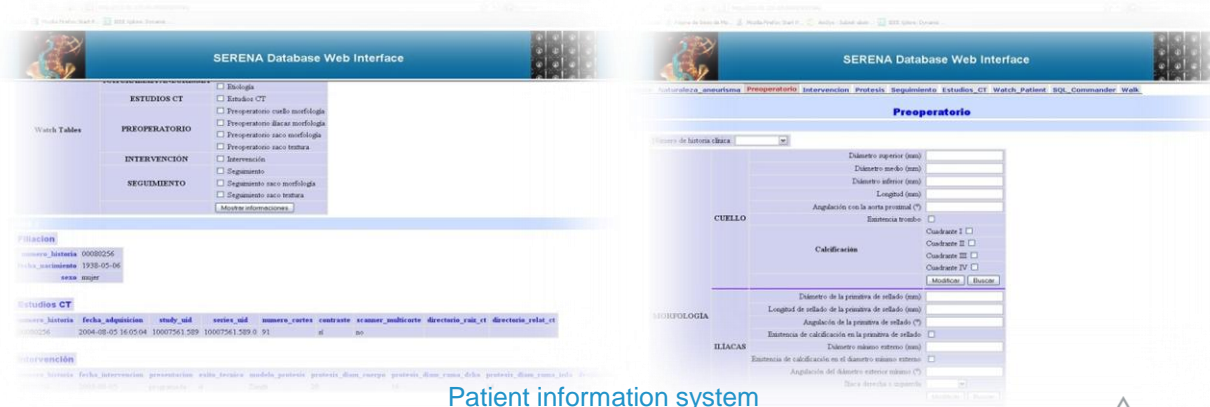**vicomtech**

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System components

○ Input Data

❑ EVAR undergone patients' data

❑ Patients are considered to belong to one among three groups:

- Favorable evolution
- Unfavorable evolution with visible endoleaks
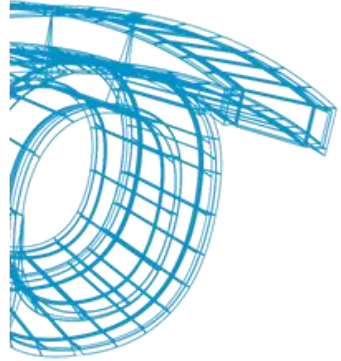- Unfavorable evolution without visible endoleaks

○ A Web-based information system centralizes data related to the presence and evolution of EVAR-treated AAAs.

Patient information system

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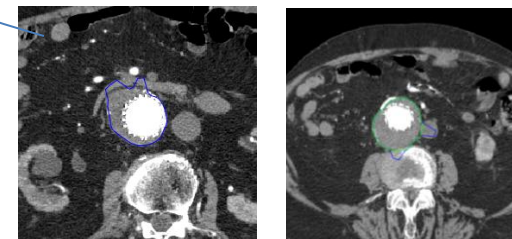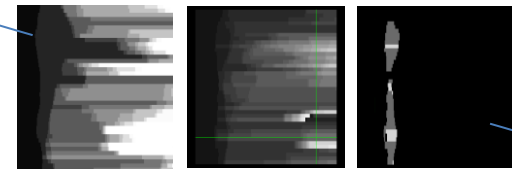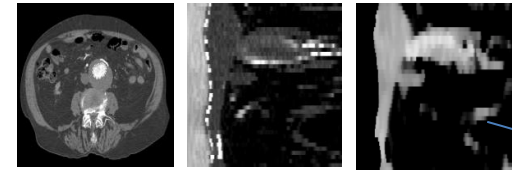
Segmentation subsystem

○ **Interest**: automatically determine the boundaries of the (thrombus of the) AAA

❑ Dimensions of the aneurysm

❑ AAA evolution at a glance

○ **Difficulty**: thrombus boundaries are ambiguous at some points

○ **Premise**: contrast-enhanced CT

○ **Method**

❑ Semi-automated 3D radial model

❑ First step: lumen segmentation

❑ Second step: centerline extraction

❑ Third step: thrombus segmentation

Thrombus segmentation process

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Endoleak detection

○ **Interest**: main known cause for aneurysmatic bulge growth after EVAR.

❑ Detection is based on visual inspection of CT scans

❑ Time consuming

○ **Premise**: contrast-enhanced CT

○ **Method**:

❑ Detection of type II endoleaks

❑ Based on a Multilayer Perceptron (MLP) Artifical Neural Network (ANN)

❑ Input: output of the segmentation subsystem

❑ AAA labelling using a Topological Grayscale Watershed Transform

❑ Feature extraction and correlation analysis in order to get a reduced dimensionality

❑ The MLP takes the reduced version of the vector and determines whether a connected component belongs to a type II endoleak
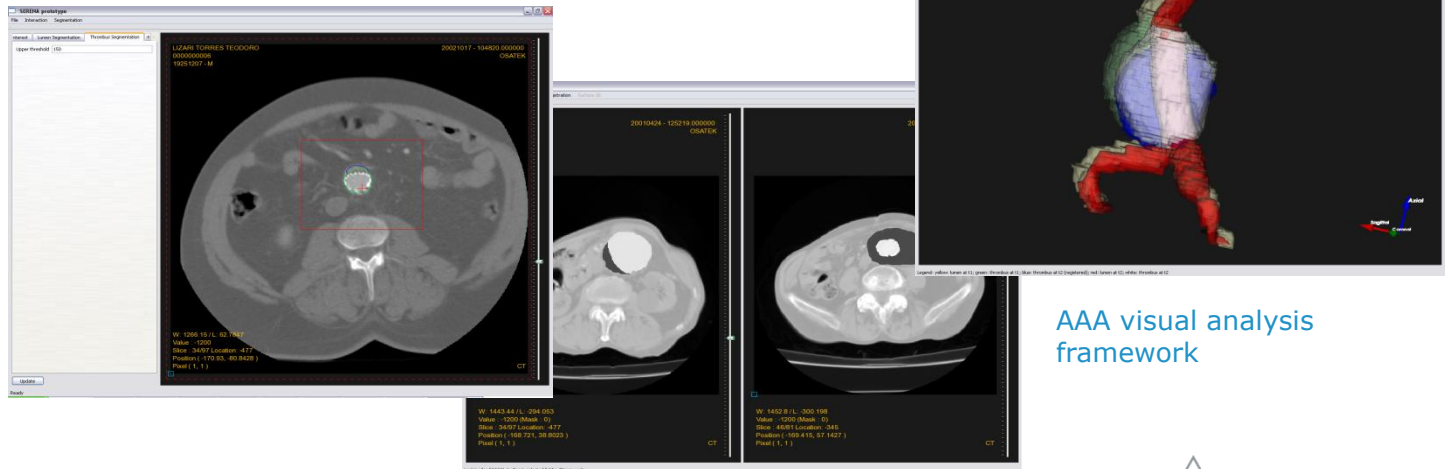
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Registration and visualization
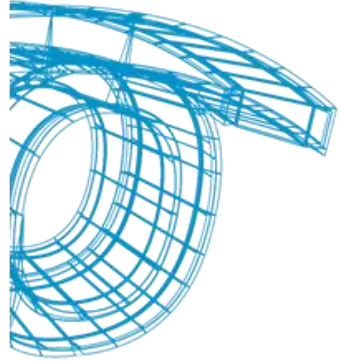
○ **Interest**: visualization of a given AAA along the time in the same scene.

○ **Method**:

❑ A medical imaging visualization tool

❑ Incorporates a DICOM explorer

❑ Incorporates segmentation

❑ Incoporates registration

❑ Incorporates an isosurface volume rendering

AAA visual analysis framework

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Texture analysis
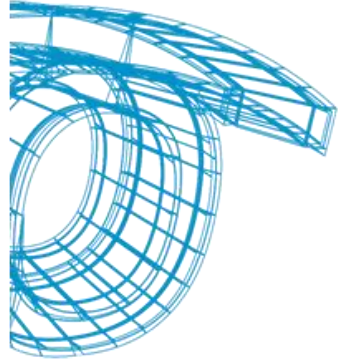
○ **Interest**: discovery of the mechanism of growth of an AAA in the absence of endoleaks.

❑ Medical team's hypothesis

○ **Method**:

❑ Starting point: ground-truth classification

• Favorable evolution
• Unfavorable evolution with visible endoleaks
• Unfavorable evolution without visible endoleaks

❑ Statistical texture analysis based on Gray Level Spatial Dependency Matrix (GLSDM)

❑ Parameters' variance is compared in order to classify a patient

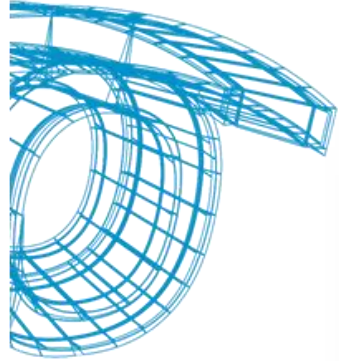**visual interaction communication technologies**

Risk prediction by *a priori* knowledge

○ **Interest**: build a Clinical Decision Support System (CDSS).

- ❑ CDSS on the need of reintervention

- ❑ Pre-operative evaluation: which intra-operative parameters have an impact on the evolution?

- ❑ Follow-up evaluation: which follow-up parameters have an impact on the evolution?
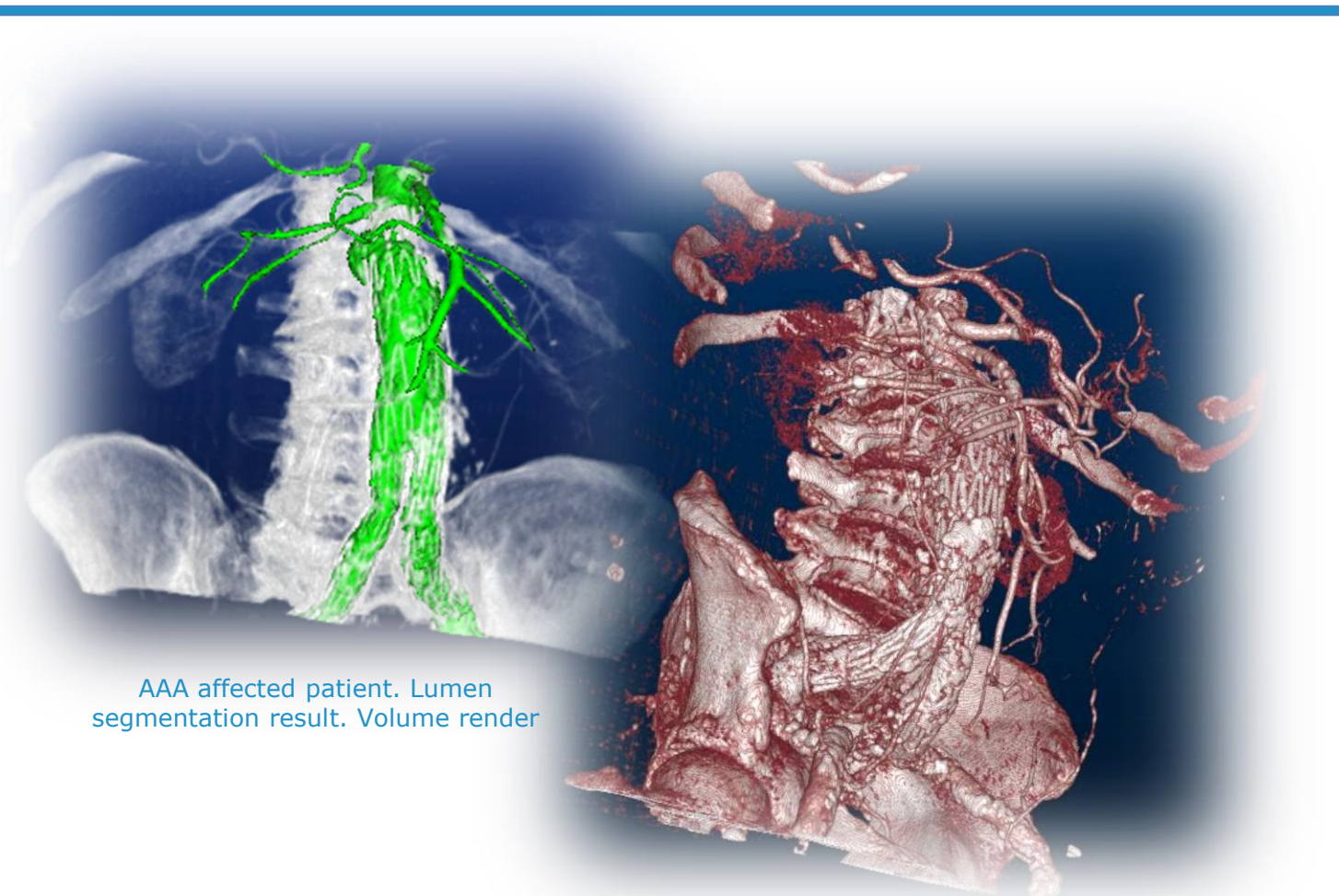
○ **Method**:

- ❑ Statistical modelling of clinical information

- ❑ First step: statistical (manual) variable selection/filtering

- ❑ Second step: Artificial Neural Network (ANN) to analyze nonlinear data

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Results and Discussion

AAA affected patient. Lumen segmentation result. Volume render

AAA affected patient. Volume render

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Results and Discussion

○ Segmentation algorithm

  ❑ Feasibility of the scheme

  ❑ Reasonable computational time

  ❑ Stability issues to be resolved

○ Endoleak detection

  ❑ An average of 95% correctly classified labels for type II endoleaks

○ Registration and visualization

  ❑ Medical image viewer adapted to AAA visual analysis

  ❑ AAA evolution at a glance

○ Texture analysis

  ❑ Patients can only be split into favorable and unfavorable evolution

○ Multivariable analysis (Risk prediction by *a priori* knowledge)

  ❑ Little results, although some reflect the ground truth

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Conclusions and Future Work

○ First steps towards a hybrid computer aided system to help in AAA evolution assessment after EVAR.

○ **Conclusions**

❑ New segmentation scheme

❑ Semi-automatic type II endoleak classification

❑ Hybrid approach

○ **Future Work**

❑ Curved Planar Reconstruction

❑ Improvement of segmentation scheme

❑ Quantification of algorithms' accuracy

❑ Validation and integration into the services' workflow

❑ Surgical planning?

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