Intra-operative angiographic images for Transcatheter Aortic Valve Implantation: extraction of quantitative data to support computer-based simulations

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Outline

1 Transcatheter Aortic Valve Implantation (TAVI)
   - procedure description

2 Intra-operative angiography
   - technical aspects
   - employment for TAVI
   - angiographic aspect of aortic root

3 Matlab program to support computer-based simulations
   - data extraction form angiographic images
   - program description
Transcatheter Aortic Valve Implantation (TAVI): innovative and promising technique for the treatment of aortic stenosis

- calcified leaflets with reduced motion
- death within 2 years from diagnosis
- replacement of the valve required

Features of the procedure:

- biological valve mounted onto a stent
- stent crimped into a sheath
- self/balloon-expandable device
- minimally invasive
- alternative to surgery
- over 50,000 cases since 2002

Angiography is employed to guide the whole procedure
Aims

Aims of the thesis:

1. full understanding of angiography employed to perform TAVI
   - review of the literature
   - collaboration with Istituto Clinico Sant’Ambrogio (ICSA)
     - two interventions attended and angiographic images provided

2. use of angiographic images to support computer-based simulations of TAVI
   - pre-processing: realistic reproduction of the specific intervention
   - post-processing: validation to test predictive accuracy

3. development of a program within Matlab environment
   - semi-automatic data extraction from angiographic images
Angiography: principles

- Standard imaging technique to visualize blood vessels and heart chambers

- Technical aspects:
  - interaction Xrays-body forms the image
  - 2D image of a 3D object
  - projection of the structures crossed by the beam
  - different angles available
  - contrast agent required
Angiography: support to TAVI

- **Gold standard** to support the whole procedure
  - **pre-operative**: anatomical measurements
  - **intra-operative**: placement and deployment of the valve
  - **post-operative**: register early outcomes
- **Most crucial step**: **positioning**
  - angiography mandatory to achieve suitable implantation
Angiography: anatomical landmarks

- **Constitutive elements** of the aortic root are used as **anatomical markers** to guide the implantation of the device
  - sinuses of Valsalva
  - sinotubular junction
  - ventriculo-arterial junction
  - aortic annulus

- **Assessment of aortic root under angiography important for data extraction**
Computer-based simulation of TAVI

- Computer-based models are engineering tools for simulation of TAVI procedure
  - **case specific**: patient, device, position of implantation
  - future employment in the field of **predictive medicine**

- Intra-operative angiographic images can support the development of the simulations
  - several images available for each intervention
  - possibility to gain information about the implantation

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**Applications:**

1. **pre-processing** to gain realistic reproduction of the specific case
2. **post-processing** to test the predictive accuracy

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*Figure:* computational simulation developed by Morganti et al.
Program for data extraction

Program developed within Matlab environment

- support to the pre-processing phase of the simulations
  - provide position of the implanted valve within the root
  - simulated device implanted in the same position of the real
- semi-automatic tool to gain quantitative information about implantation
- data extraction from intra-operative angiographic images provided by ICSA

Features of the program:

- intuitive Graphical User Interface (GUI)
- minimal interaction with the user
- user not required to be familiar with angiography
- guided procedure
- measurements semi-automatically arranged
- two device configurations implemented
Program: loading step

- **Graphical User Interface (GUI):**
  - interactive window
  - buttons and panels for the images
  - Matlab code is executed when the button is pressed

- The selected angiographic image is loaded to perform measurements

- **Sketch of aortic root with device**
  - guide the user in all the step of the procedure
Program: support to pre-processing

- The program is developed to support pre-processing phase of TAVI simulations.

- Data extracted from the images used to set-up the simulations:
  - realistic placement of the crimped device within the root

- Required information:
  - quantitative
  - easily implemented in the simulations
  - univocally identify device position
  - not redundant
Program: data extraction

- **Data extraction in semi-automatic fashion**
  - measurements arranged by the program

- **Matlab Image Processing Toolbox**
  - cross-hair on the image
  - user picks the required points
  - selected points appear on the image
  - possibility of repositioning
  - coordinates of each point

- **Calculations**
  - measurements performed using algebraic considerations
  - extracted data stored in a text file
Support to post-processing

- **Post-processing phase**: validation of the simulation to test predictive accuracy

- Data extracted from angiographic images of expanded device
  - stent profile
  - depth of implantation
  - stent diameters at different heights
Conclusions and future developments

► Conclusions

- Intra-operative angiography gold standard to guide TAVI
- Data extraction from angiographic images to support computer-based simulations
  - pre-processing phase
  - post-processing phase
- Matlab program for data extraction
  - images provided by ICSA
  - 2 device configurations implemented
  - analysis performed on 4 patient
- The program is just one step towards predictive medicine

► Future developments

- Extracted data have to be implemented to set-up the simulation
- Validation of the simulations has to be performed
Thank you!