C. The value of CT before percutaneous aortic valve replacement

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Learning objectives

- Cardiac valve diseases are an important public health problem, with an increasing incidence strongly linked to the increasing age of the Western population.
- The most frequent valve disease is aortic stenosis, for which percutaneous aortic valve replacement (PAVR) is currently evolving as an alternative therapy in high-risk patients.
- Nevertheless, careful evaluation of all aspects of this new approach is still required to avoid uncontrolled diffusion.
- Imaging plays a key role in selecting patients who may be eligible for PAVR, focusing on the evaluation of leaflet anatomy, severity of valve dysfunction, haemodynamic consequences and potential problems in the access route.
- While echocardiography is commonly used for both the anatomical and functional evaluation, multidetector CT (MDCT) has important intrinsic advantages providing state-of-the-art 3D imaging with a high spatial resolution over a large anatomic coverage.

During this poster, we will discuss:

- the advantages and disadvantages of MDCT compared with other imaging modalities.
- The relevant anatomy of the aortic valve and annulus will be reviewed, with emphasis on correct alignment of the imaging planes, and its implications for correct reporting of the necessary measurements targeted at the clinicians’ need.
- Furthermore, MDCT scan protocol design will be reviewed, focusing not only on optimal implementation of common scan parameters but also on the need of ECG-triggering and its consequences.
- Finally, we will present the current status of evidence on using MDCT in PAVR procedures, and discuss future challenges and perspectives.
SECTION I: UNDERSTANDING THE PROBLEM

* Severe aortic valve stenosis is the most frequent valvular disease in Europe. It almost exclusively affects the elderly population, with about 2-3% over age 75 having severe aortic stenosis. When symptomatic, it is associated with a high degree of mortality. Furthermore, it’s a progressive disease which must be treated (Fig. 1 on page 7).

* Surgical valve replacement has been the treatment of choice for many years (Fig. 2 on page 7). Unfortunately, not every patient can have surgery for a variety of reasons (Fig. 3 on page 8). However, since severe aortic valve stenosis is a progressive & fatal disease, an alternative approach for this patient group is needed.

SECTION II: UNDERSTANDING THE PROCEDURE

* The alternative approach consists in replacing the diseased aortic valve with a prosthetic valve using an endovascular or transapical approach to deliver the device (Fig. 3 on page 8, Fig. 4 on page 9).

* The procedure is referred to as **TAVI**: Trancatheter Aortic Valve Implantation or **PAVR**: Percutaneous Aortic Valve Replacement

* Currently, there are two devices made by different manufacturers (Fig. 4 on page 9, Fig. 5 on page 10). On one hand, there is the SAPIENS valve from Edwards Lifescience, which is a balloon-expandable valve. Alternatively, Medtronic manufactures the COREVALVE, which is a self-expandable valve.

* These prosthetic valves comes in different sizes, to accommodate a range of diameters of the of aortic root 'annulus' in different patients (Fig. 6 on page 11).

* Therefore, there is a **pre-operative technical selection** (Fig. 7 on page 12): the size of the patient's aortic 'annulus' has to be within the available size ranges of the prosthetic devices. The better the device fits, the less risk for pre- and post-procedural complications.

* These complications include (among others) paravalvular regurgitation, prosthesis migration and embolic stroke.

* Furthermore, the endovascular access route has to be investigated for sufficient vessel size to accommodate the transportation of the device, the presence of obstructive
stenosis, extensive arterial calcifications and other potential access problems (Fig. 8 on page 13).

SECTION III: UNDERSTANDING THE RELEVANT ANATOMY

* The procedure takes place in the aortic root, which extends from the end of the left ventricular outflow tract (LVOT) to the sino-tubular junction (Fig. 9 on page 14).

* The aortic root contains the aortic valve leaflets within the sinus of Valsalva. The ‘annulus’ is a term often used to indicate a supposedly circular insertion site of the aortic valve leaflets (Fig. 10 on page 15).

* However, three important observations have to be made here:

1. The aortic root, and therefore the aortic valve within it, has a double-oblique orientation (Fig. 11 on page 16, Fig. 12 on page 17).
2. The morphology of the aortic root varies: it is most circular at the level of the sino-tubular junction, but becomes more clover-leaf shaped at a mid-sinusal level, and very often further evolving into an oval shape at the root base (Fig. 13 on page 18).
3. The insertion site of the aortic valve leaflets is not circular, but resembles a crown extending from the sino-tubular junction to the crossing with the LVOT (Fig. 13 on page 18).

* The annulus as an anatomic structure therefore does not really exists!

* What is relevant for a TAVI or PAVR procedure is the morphology and diameters of the aortic root at a level located at the most basal insertion site of the aortic valve leaflets. It is here that the prosthetic devices are going to get anchored to the aortic root wall.

SECTION IV: CT & THE INTERVENTION

* Before the procedure, we need to know if:

* the base of the aortic root has a diameter within the ranges applicable for the available devices. Currently, this means that the aortic ‘annulus’, or as explained, the diameter at the basal insertion site of the aortic valve leaflets must be between 18-29 mm.

* there are no access problems or any other anatomic objections for the procedure (Fig. 14 on page 19)

* Historically, ultrasound (both transthoracic and trans-esophageal) is almost invariably used as the first imaging screening tool to determine technical patient eligibility.
* However, ultrasound is by nature a 2D imaging tool. Furthermore, the sonographer assumes a circular-shaped aortic root base, as such measuring and reporting only one diameter. Finally, this diameter is often not along the true long axis of the aortic root base, but sometimes measured along a rather arbitrary chosen line at the aortic root base (Fig. 15 on page 20).

* CT, as an intrinsic 3D imaging tool, does provide the exact aortic root morphology (Fig. 16 on page 21). This has several implications:

1. given the often oval shape of the aortic root base, CT often delivers a minimum & maximum diameter. These diameters are different (almost always larger) to the single ultrasound measurement, and can therefore not be easily compared (Fig. 17 on page 22, Fig. 18 on page 23)
2. basically, CT and ultrasound measure as such different things. With this in mind, it is obvious that CT cannot be used as a tie-breaking technique when the ultrasound measurement is inconclusive.

* Different scanning techniques can be used, depending on the required information (Fig. 19 on page 24)

**SECTION V: OTHER MEASUREMENTS & OBSERVATIONS**

* the prosthetic device is going to be deployed during an angiographic procedure. Therefore, the resulting image is a 2D angiographic projection.

* For successful device deployment, in this image the three sinuses of Valsalva (and as such the three basal insertion points of the leaflets) need to aligned in the same plane for correct device placement. The angulation of the angiographic tube has therefore to be correctly placed (Fig. 20 on page 25).

* In order to facilitate this angulation, CT can pre-operative provide the best LAO/RAO and CRA/CAU angulation in order to have optimal alignment of the aortic root base along a straight line (Fig. 21 on page 26).

* Other CT observations that can be made:

1. the extend and location of aortic leaflet calcification (Fig. 22 on page 27). This may be associated with conduction disturbances after device deployment, as these post-procedurally displaced calcifications may induce electrophysiogical changes along nearby located conduction paths.
2. the distance from the left aortic leaflet basal insertion to the left main, in order to avoid the very rare instance of ostial occlusion due to a displaced leaflet (Fig. 23 on page 28)
3. the size and morphology of the ventricular septal wall. A hypertrophic wall may theoretically complicate device deployment (Fig. 24 on page 29).

4. the angulation between the aortic root and the left ventricle. A sharp angulation may implicate a technically more challenging procedure (Fig. 24 on page 29).

SECTION VI: THE BOTTOM LINE

* TAVI/PAVR is here to stay, and will become more & more popular

* more devices are currently being developed to accommodate more patients

* Therefore, technical selection will become increasingly important.

* CT and ultrasound are different things, and therefore different rules and selection criteria apply.

* CT can provide more information more than the aortic root base diameter

* more studies are needed to further investigate these criteria and understand fully the place of CT in the pre-procedural management.
Aortic stenosis is a progressive disease, which must be treated. It is the most frequent valvular disease in Europe and affects the elderly population. It is common for individuals over 75 to have severe aortic stenosis. When symptomatic, it is associated with a high degree of mortality. It is a progressive disease, and symptomatic aortic valve stenosis is a severely debilitating disease.

Fig. 1: Aortic stenosis is a progressive disease, which must be treated.
Fig. 2: Without surgery, there is a fast & steady decline

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Fig. 3: Not everyone can have surgery, therefore an alternative approach is needed.

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Fig. 4: Different access routes are possible.

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The Concept

- At this time, two types of transcatheter valves are available

**SAPIEN Valve**
Balloon expandable

*Edwards Lifescience*

**COREVALVE**
Self expandable

*Medtronic*

**Fig. 5:** Two prosthetic devices are commercially available.

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**Patient selection**

- These valves can accommodate different aortic ‘annulus’ sizes

![Diagram showing range of applicable aortic ‘annulus’ sizes along prosthetic devices.

In terms of available prostheses, a patient is eligible with an ‘annulus’ Ø of 18-29 mm.

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**Fig. 6:** Range of applicable aortic ‘annulus’ sizes along the prosthetic devices.

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Goal of CT

• Measurement of the aortic root components
  • LVOT & basal leaflet insertion (‘annulus’) 
  • Aorta sinus 
  • Position of ostia of coronary arteries relative to the aortic root 
  • Position & extend of leaflet calcifications 

• Determination of the best imaging plane of aortic sinuses 
  • Reduce of contrast in search for best coaxial angles during actual procedure 

• Examination of access route & co-morbidity 
  • Can we get through using an endovascular approach to the aortic root? 
  • Presence of extensive atherosclerosis, calcification, stenosis,… 
  • Is there previously unsuspected co-morbidity & other incidental findings 

Fig. 7: Goal of pre-operative CT imaging.
Fig. 8: A pronounced arterial kinking or obstructive stenosis indicate an important access problem, which could challenge the technical feasibility of the procedure.
Fig. 9: The different components of the aortic root.

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Fig. 10: The myth of the aortic annulus.

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**Fig. 11:** The aortic root, and therefore also the aortic valve, has a double-oblique orientation.

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**Fig. 12:** The aortic root has a double-oblique orientation.

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Fig. 13: The changing shape of the aortic root and crow-shaped insertion site of the aortic valve leaflets.

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Incidental findings

- It’s an old population
  - Statistically, important non-cardial incidental findings are likely
  - Their presence may influence & complicate the decision for procedure
  - Large anatomic coverage of CT is an important factor in screening

- Ben-Dor et al *
  - 259 patients referred for CT pre-TAVI
  - Significant incidental findings in 34,3 %
  - Malignancy in 4,2%
  - Important peripheral vascular disease found in 37,8 %
  - 19,1% as such excluded for transfemoral approach!

* Ben-Dor et al. Utility of radiologic review for noncardiac findings on multidetector computed tomography in patients with severe aortic stenosis evaluated for transcatheter aortic valve implantation. Am J Cardiol. 2010

Fig. 14: Incidental findings during pre-operative CT imaging.

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**Fig. 15:** On ultrasound, the true morphology of the aortic root base is not correctly appreciated, as such often leading to an incorrect/incomplete measurement.

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Fig. 16: CT delivers a true 3D view of the aortic base root, which cannot be compared with a 2D ultrasound diameter. In this figure, different 2D measurements (simulating US measurements) are given, illustrating the difference between a CT and an ultrasound measurement.

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Fig. 17: Be careful when comparing US with CT measurements

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Fig. 18: US measures a 2D diameter, which is not always the largest diameter along the true long axis of the aortic root base.

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Fig. 19: Depending on the required information and the available scanner (especially scan speed), different approaches can be used.
The angulation of the basal plane

- In search for the optimal projected viewing angle

Fig. 20: During device deployment, the three basal insertion sites of the aortic valve leaflets must be aligned in the same plane.

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Fig. 21: CT can predict the best LAO/RAO and CRA/CAU angulation for the angiography tube in order to achieve correct alignment of the aortic leaflet insertion sites.

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Other measurements

- Aortic leaflet morphology calcifications
  - Often extensive leaflet calcifications present in patients with aortic valve stenosis
  - Distribution of calcium may be linked to conduction disturbances
  - Extensive calcifications further complicate accurate measurement on CT & US

Fig. 22: Extensive aortic valve calcifications may induce post-procedural electrophysiological disturbances.

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Other measurements

• Relation between leaflets & coronary ostia
  • Large leaflet & short distance to ostium of LM & RCA may lead to ostial occlusion*
  • Nevertheless, large range in distance has been reported: 7.1 – 21.7 mm! **

Fig. 23: A short distance between the left aortic valve leaflet insertion and the left main ostium may indicate a risk of ostial occlusion after device deployment.

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**Other measurements**

- Placement of the aortic valve prosthesis
  - The angulation between the aortic root & the left ventricle may vary
  - Inadequate angulation means a technically more demanding procedure
  - Shape & thickness of the left ventricular wall can also be evaluated

**Fig. 24:** Both the angulation between the aortic root & the left ventricle as the shape of the septal ventricular wall may influence the technical difficulty of the procedure.

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