# MDCT for Transcatheter Valve Procedures

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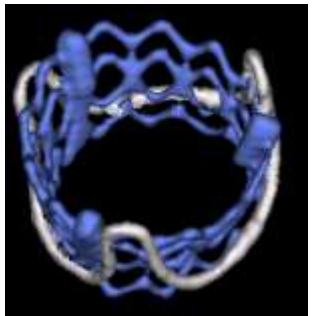


PROVIDENCE
HEART + LUNG INSTITUTE
AT ST. PAUL'S HOSPITAL
New solutions for health

# Disclosures

Speaker's bureau: GE Healthcare and Edwards LifeSciences

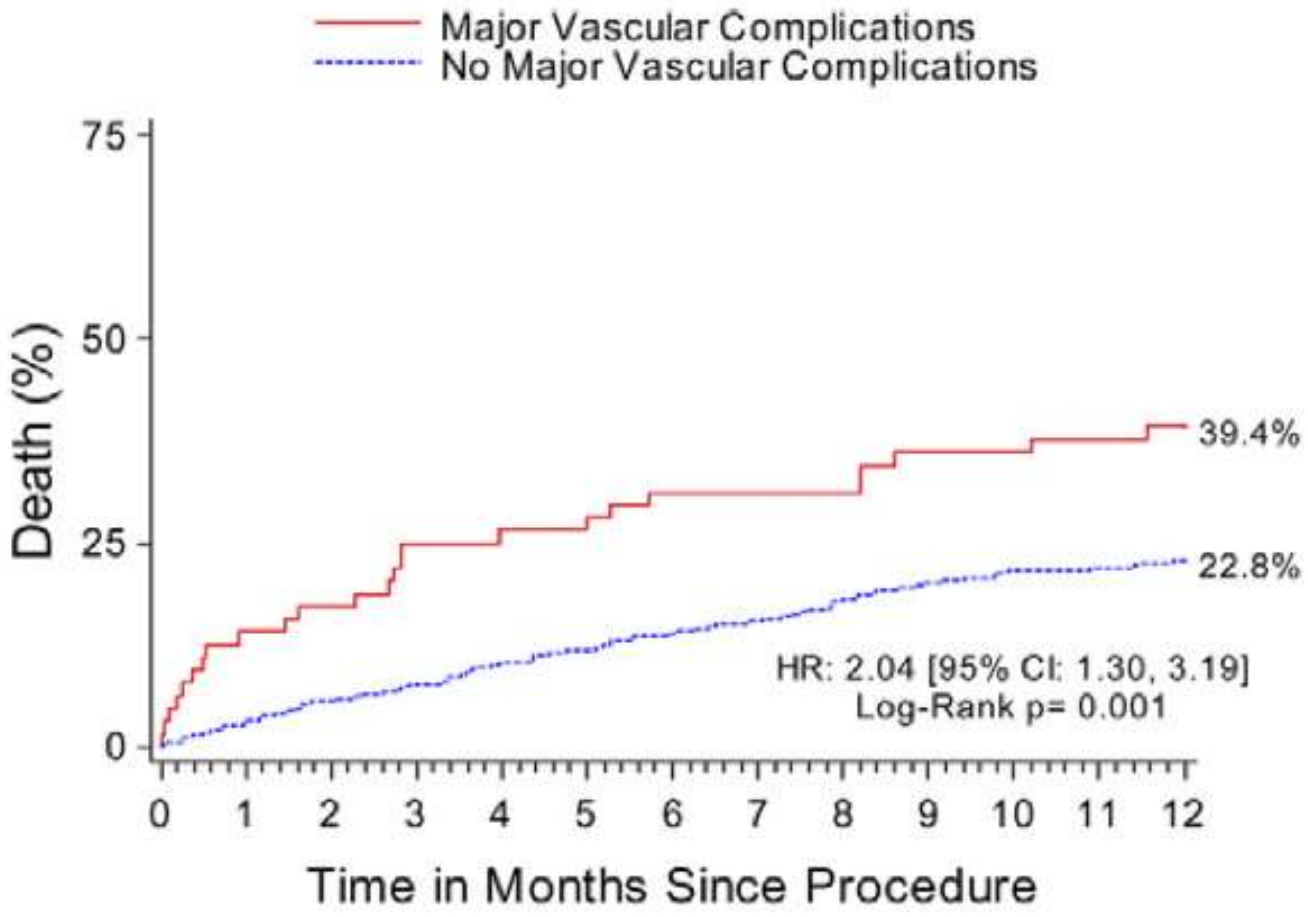
Grant Support- CIHR, NIH, GE Healthcare, Heartflow

Advisory Board- GE Healthcare,
Edwards LifeSciences, Vital Images, Neovasc, Circle CVI

Core Lab- NIH, Edwards Lifesciences, Neovasc, Tendyne

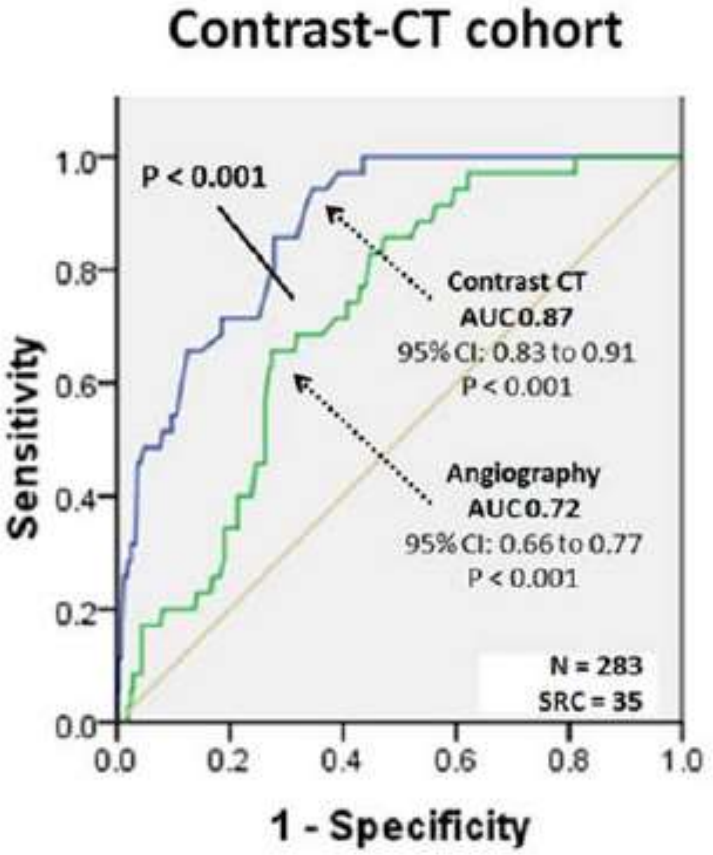
# Vascular Injury

# Major Vascular Complications and Mortality




Genereux, J Am Coll Card 2012; 60(12): 1043-52.

# Contemporary Re-appraisal of SFAR

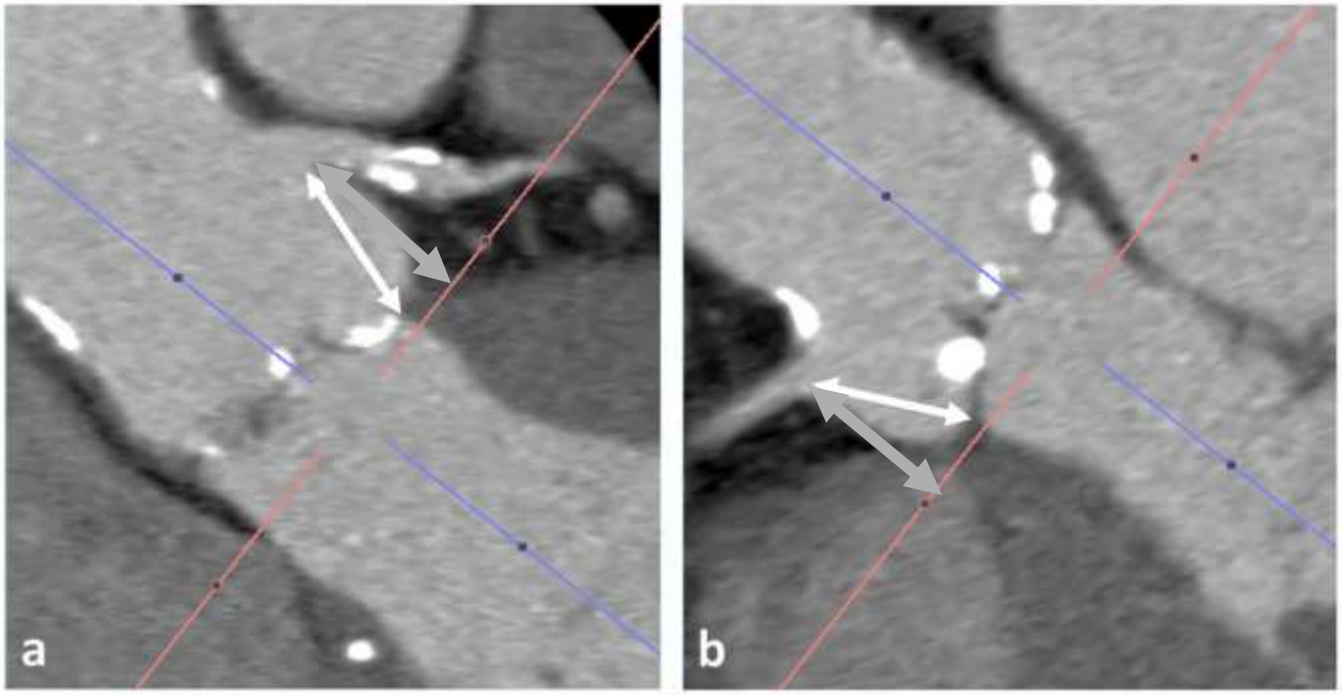



| | Contrast CT ($P$<0.001) | | |
|---|---|---|---|
| | SRC | No SRC | Total |
| SIFAR≥1.12 | 33 (27.7%) | 86 (72.3%) | 119 |
| SIFAR<1.12 | 2 (1.2%) | 162 (98.8%) | 164 |

Source: Okuyama et al Circ Imaging 2014

# Ancillary root measurements & Coronary height

## Coronary artery height




IFU - SAPIEN® - Minimum 10/11 mm

CAVE : Measurements not standardized, „bulky calcifications“

# Anatomical Predictors of Coronary occlusion

## Multi-center register

CLINICAL RESEARCH — Interventional Cardiology

**Predictive Factors, Management, and Clinical Outcomes of Coronary Obstruction Following Transcatheter Aortic Valve Implantation**

Insights From a Large Multicenter Registry

Henrique B. Ribeiro, MD,* John G. Webb, MD,† Raj R. Makkar, MD,‡ Mauricio G. Cohen, MD,§ Samir R. Kapadia, MD,‖ Susheel Kodali, MD,¶ Corrado Tamburino, MD,# Marco Barbanti, MD,†# Tarun Chakravarty, MD,‡ Hasan Jilaihawi, MD,‡ Jean-Michel Paradis, MD,¶ Fabio S. de Brito, Jr, MD,** Sergio J. Cánovas, MD,†† Asim N. Cheema, MD,‡‡ Peter P. de Jaegere, MD,§§ Raquel del Valle, MD,‖‖ Paul T. L. Chiam, MD,¶¶ Raúl Moreno, MD,## Gonzalo Pradas, MD,*** Marc Ruel, MD,††† Jorge Salgado-Fernández, MD,‡‡‡ Rogerio Sarmento-Leite, MD,§§§ Hadi D. Toeg, MD,††† James L. Velianou, MD,‖‖‖ Alan Zajarias, MD,¶¶¶ Vasilis Babaliaros, MD,### Fernando Cura, MD,**** Antonio E. Dager, MD,†††† Ganesh Manoharan, MD,‡‡‡‡ Stamatios Lerakis, MD,### Augusto D. Pichard, MD,§§§§ Sam Radhakrishnan, MD,‖‖‖‖ Marco Antonio Perin, MD,** Eric Dumont, MD,* Eric Larose, MD,* Sergio G. Pasian, MD,* Luis Nombela-Franco, MD,* Marina Urena, MD,* E. Murat Tuzcu, MD,‖ Martin B. Leon, MD,¶ Ignacio J. Amat-Santos, MD,¶¶¶¶ Jonathon Leipsic, MD,† Josep Rodés-Cabau, MD*

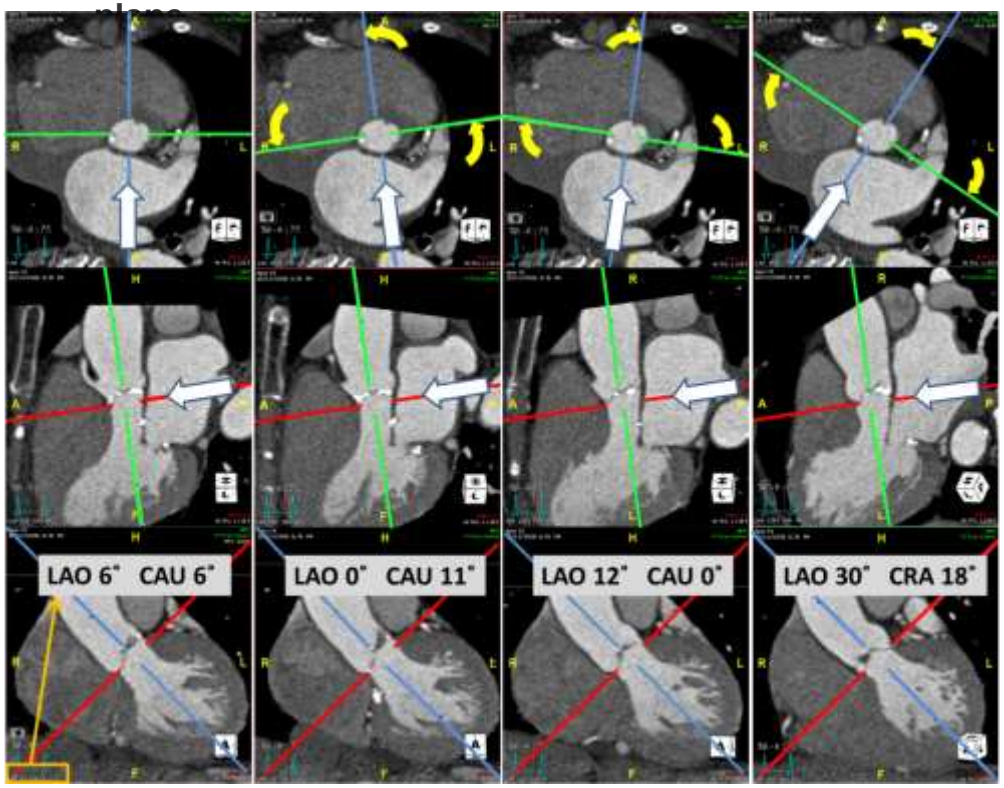
*Quebec City, Quebec, Toronto, Ottawa, Hamilton, Ontario, and Vancouver, British Columbia, Canada; Los Angeles, California; Miami, Florida; Cleveland, Ohio; New York, New York; Catania, Italy; Sao Paulo, and Porto Alegre, Brazil; Valencia, Oviedo, Madrid, Vigo, La Coruna, and Valladolid, Spain; Rotterdam, the Netherlands; Singapore; St. Louis, Missouri; Atlanta, Georgia; Buenos Aires, Argentina; Cali, Colombia; Belfast, Northern Ireland; and Washington, DC*

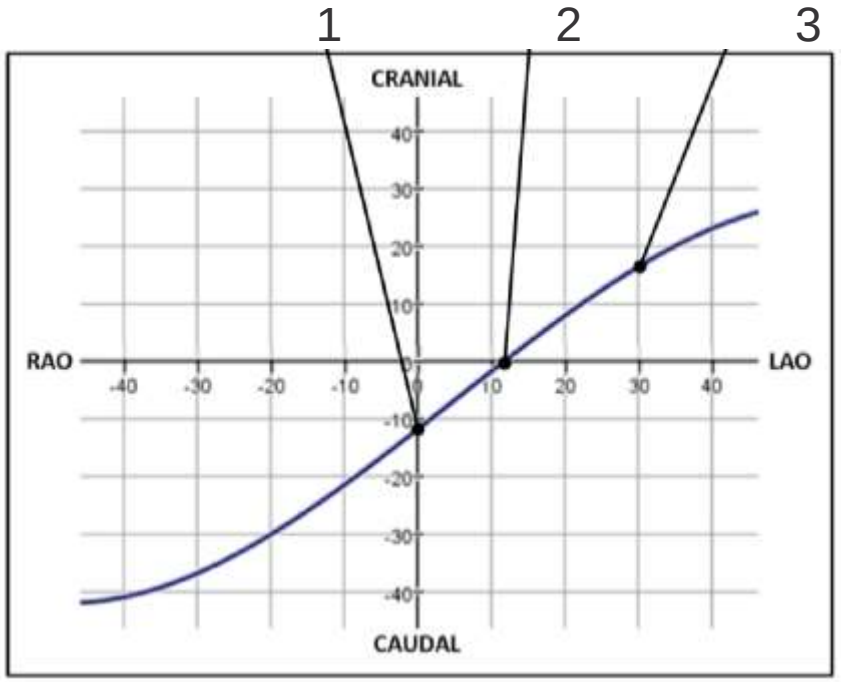
- 44/6688 (0.66%)
- Predominantly LM
- More common in
  - Women
  - Balloon-expandable TAVI
  - Valve-in-Valve

- **LMH**:
  - 10.6±2.1mm vs. 13.4±2.1mm
  - <12mm – in obstruction 86%
  - <12mm – controls 26%
- **SOV**:
  - 28.1±3.8mm vs. 31.9±4.1 mm
  - <30mm – in obstruction 71%
  - <30mm – controls 33%
- **LMH** <12mm and **SOV** <30mm
  - obstruction 68%
  - controls 13%

# Fluoroscopy angulation prediction

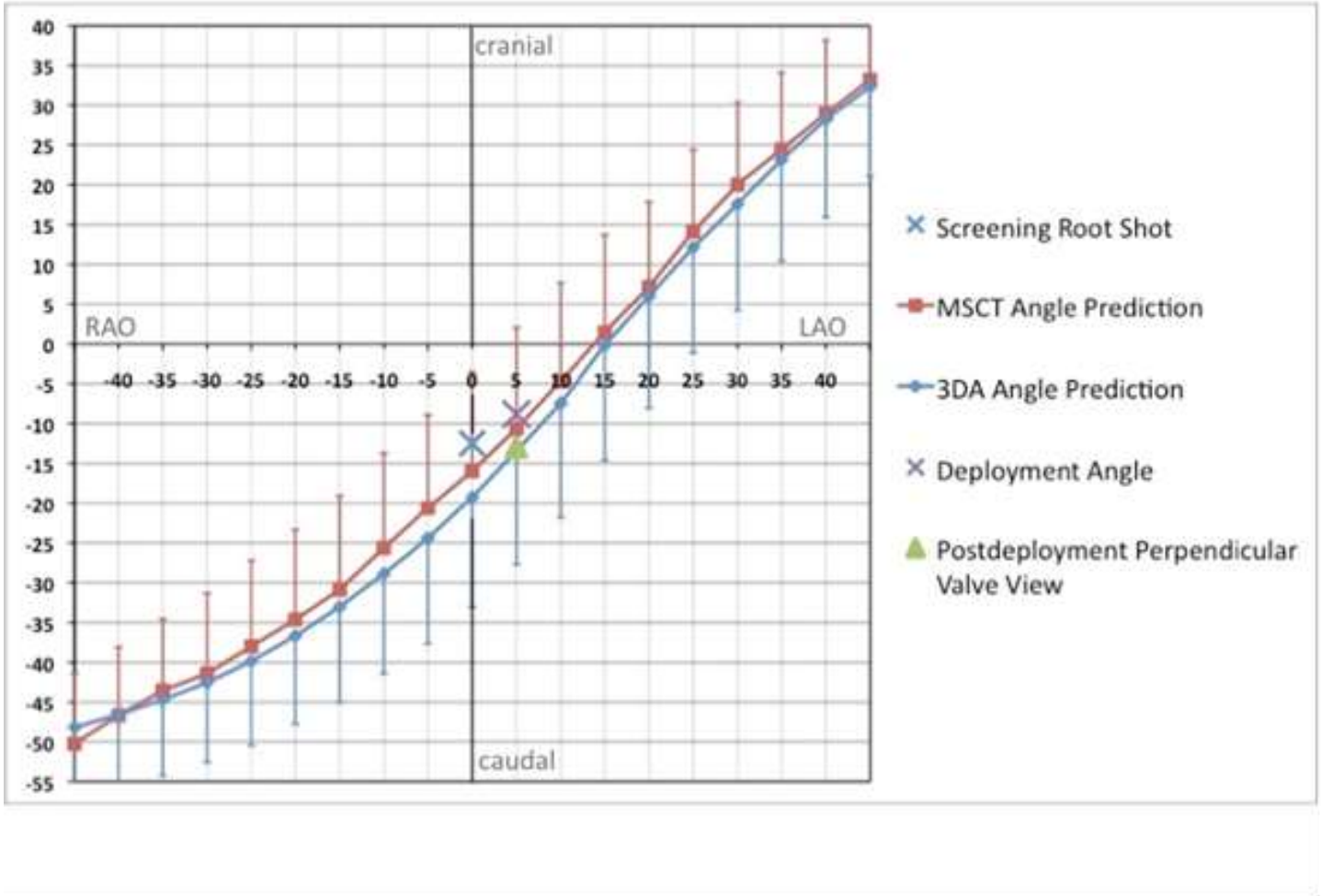
## Line of perpendicularity




Blanke, Leipsic *Radiology 2013*

# MDCT vs 3-D Angio CT for Angle Prediction

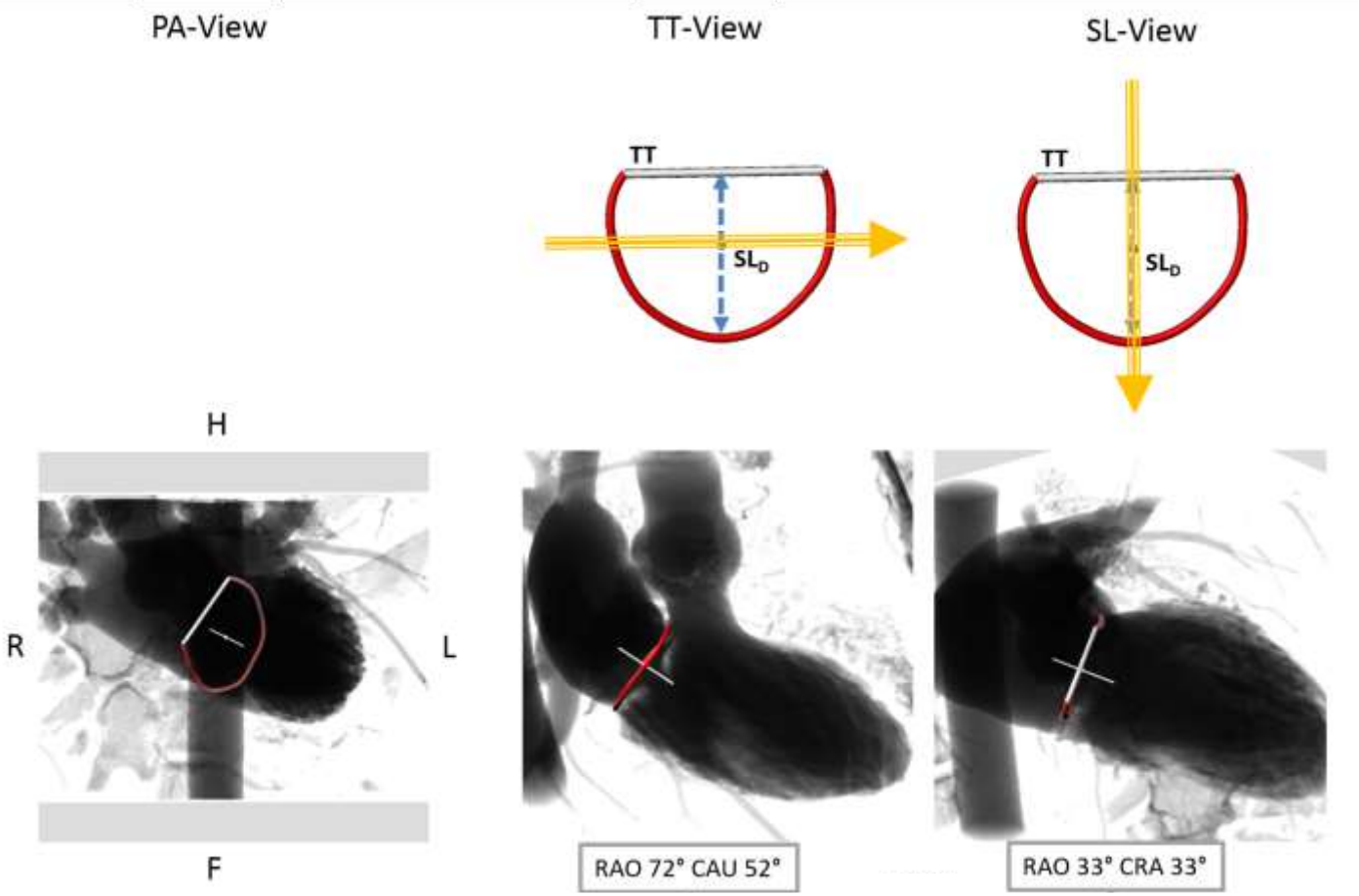



Source: Binder et al. TCT 2011 , Circ Interventions April 2012

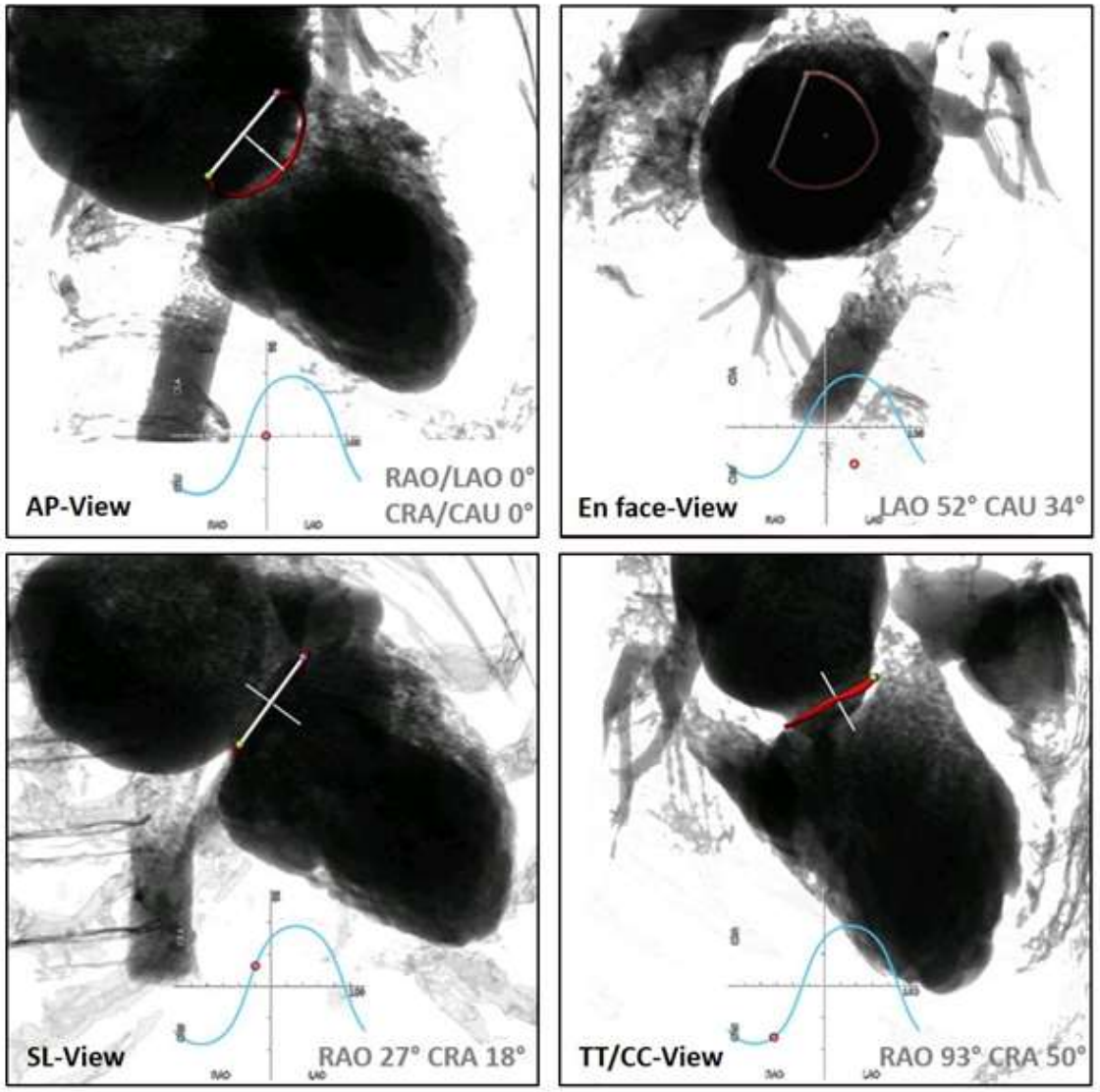
# Assist with co-planar angle prediction

**Prediction of fluoroscopy angulation**

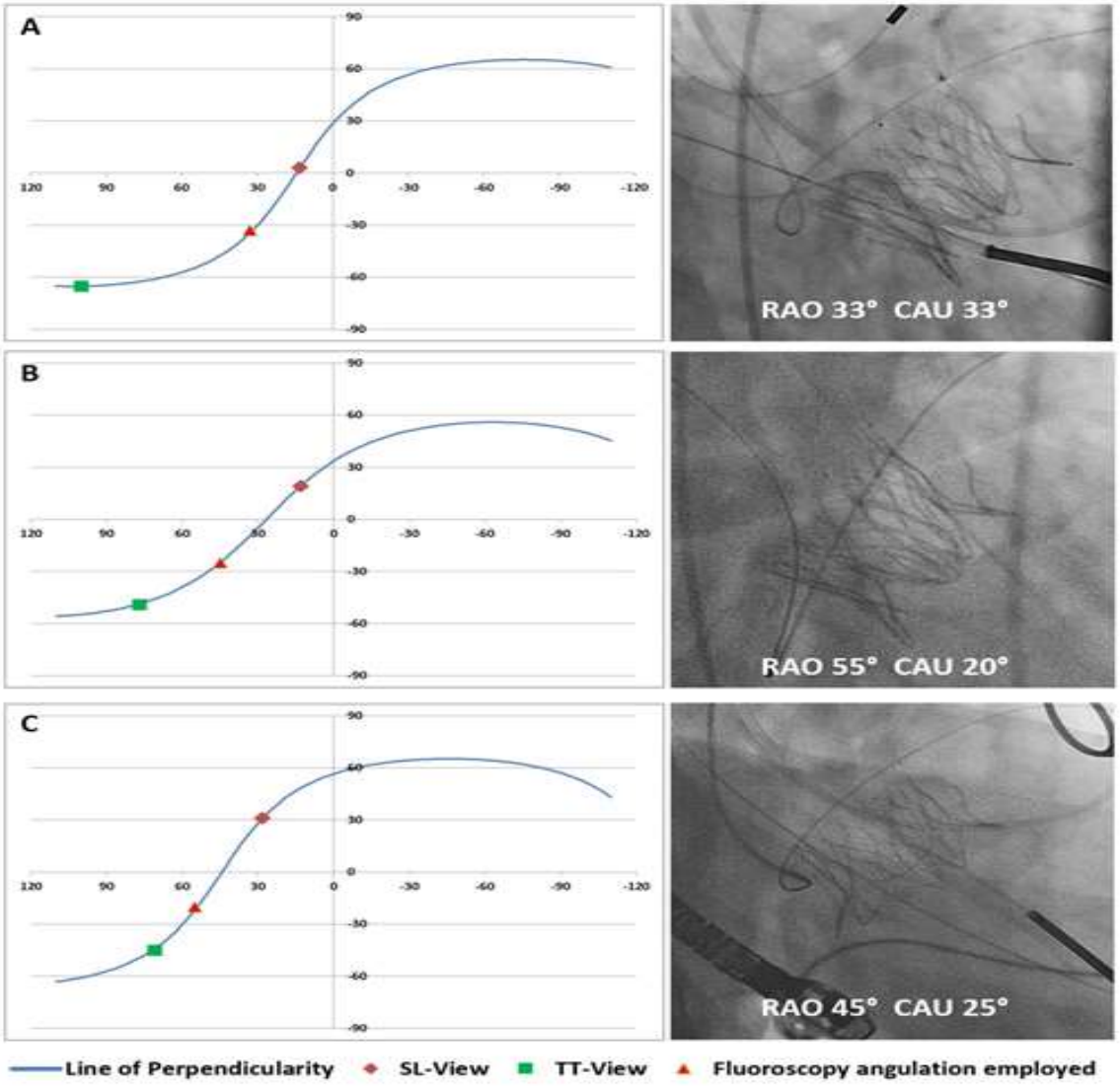
- Corresponding LAO/RAO and CRA/CAU



# Only some angles are feasible in the hybrid OR



# Clinical Implications for TMVI

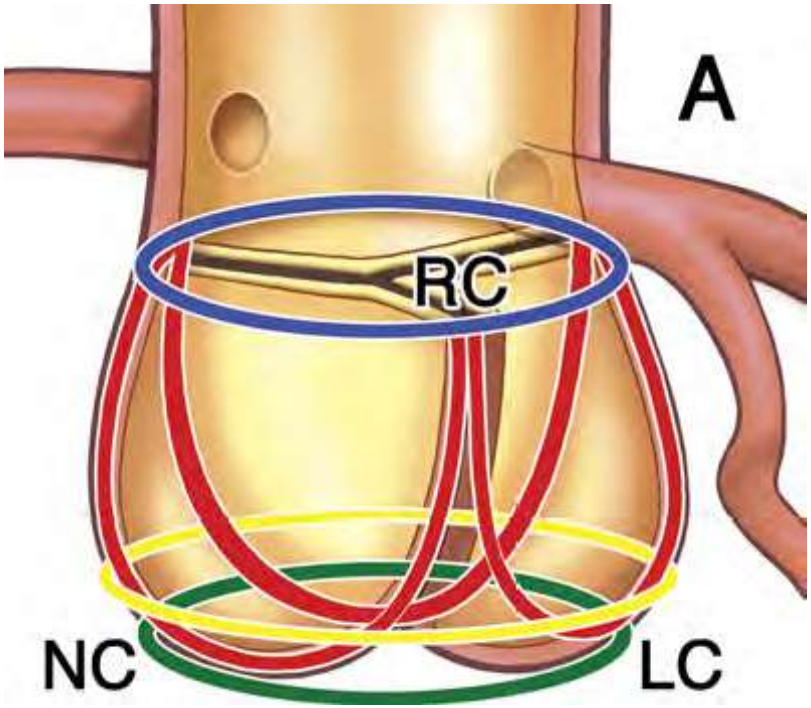


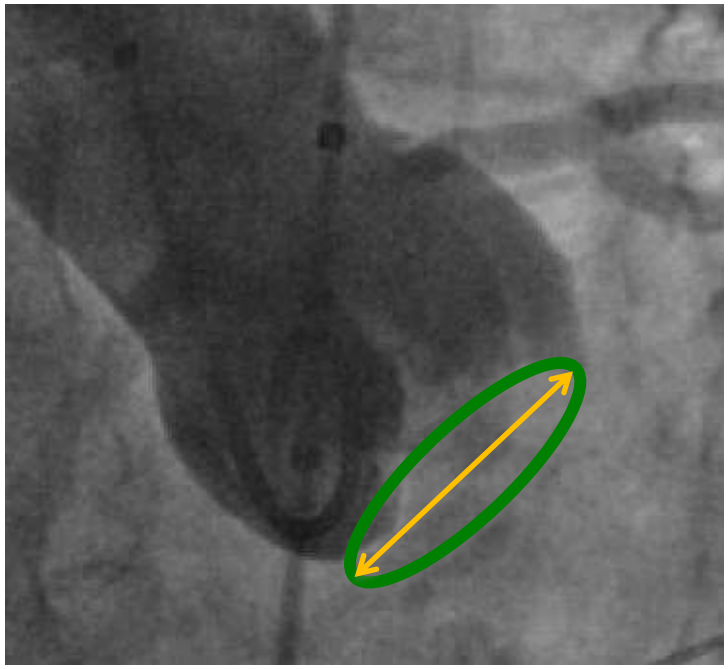



Source: in press JCCT

# MDCT for Annular Sizing and THV Selection

# The Virtual Basal Ring



**Sinotubular junction**

**Aortic leaflets**

**Aortic Annulus**

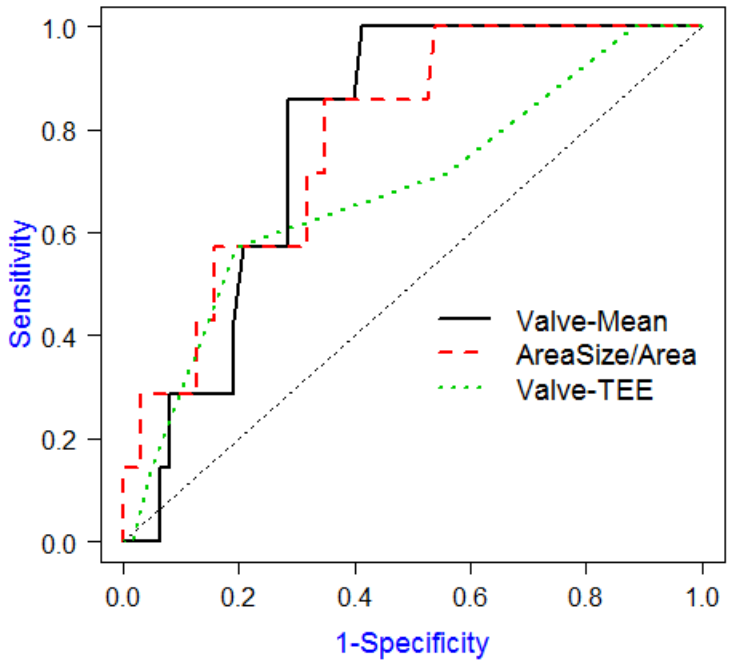
**Aortic Annular Diameter**

RC = Right coronary cusp; NC = Non-coronary cusp;
LC = Left coronary cusp

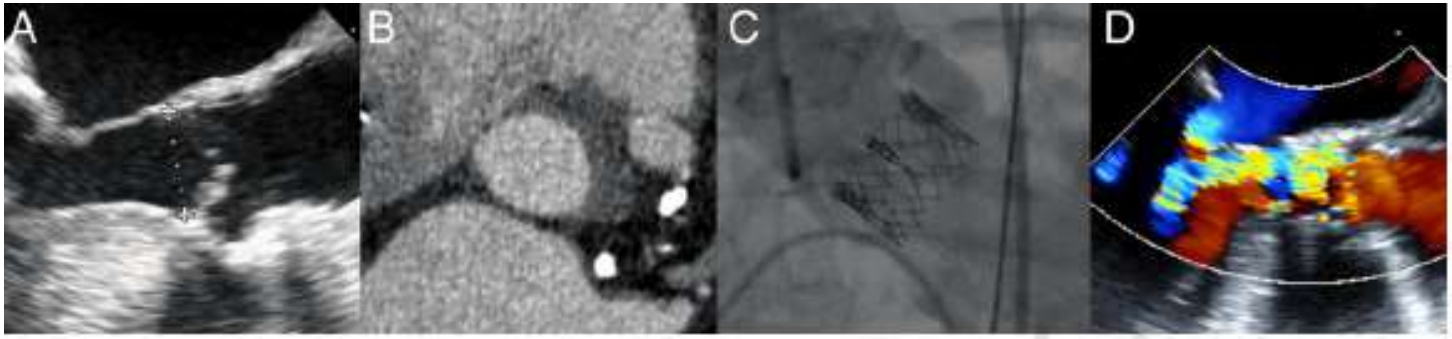
**Source:** Leipsic et al JACC Img April 2011

# Area Measurements Can Predict Significant PV Leak

# CT Annular Measures Can Predict PV Leak




- Valve stent diameter – Mean annular diameter$_{MDCT}$ AUC 0.84
- Valve stent diameter – Area-derived annular diameter$_{MDCT}$ AUC 0.86
- Valve stent area/ Annular area$_{MDCT}$ AUC 0.87

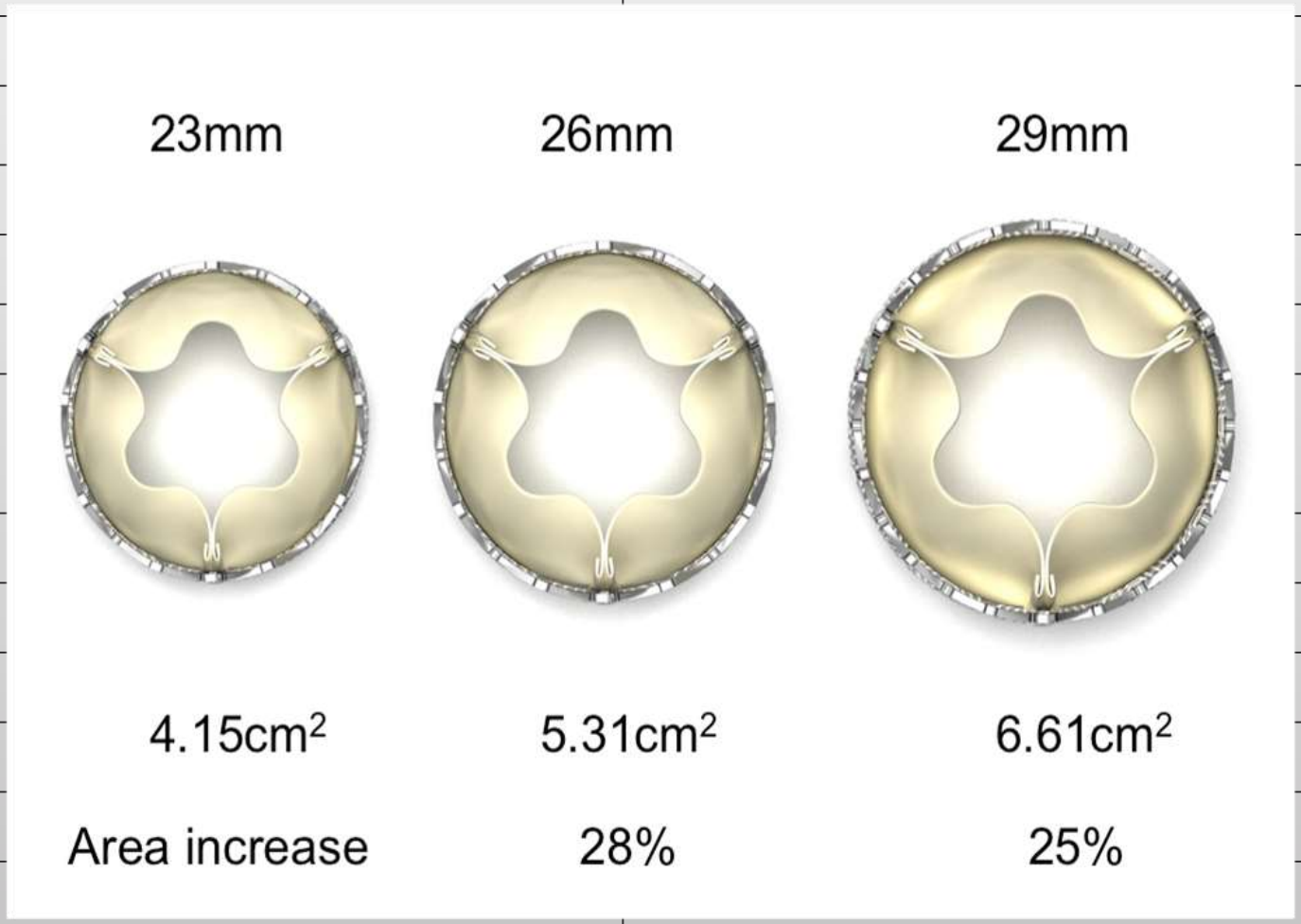



Willson et al. JACC 2012

# MDCT Can Provide Reproducible and Robust Sizing Recommendations

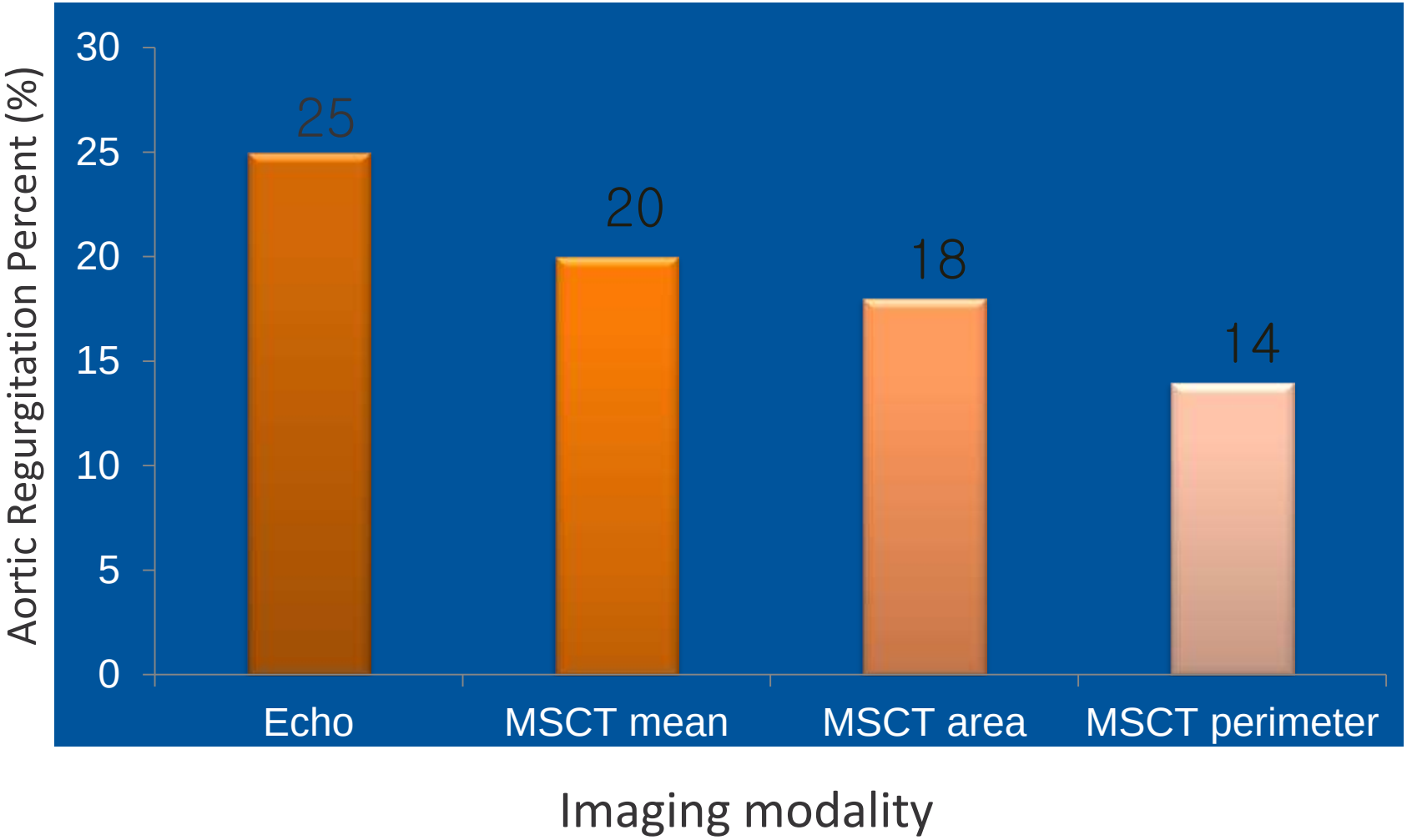
# Vancouver MDCT Sizing Guidelines

| Annular Area ($mm^2$) | 26mm SAPIEN XT THV |
|---|---|
| 520 | 2.1 |
| 530 | 0.2 |




Source: RSNA 2012
Willson et al JCCT

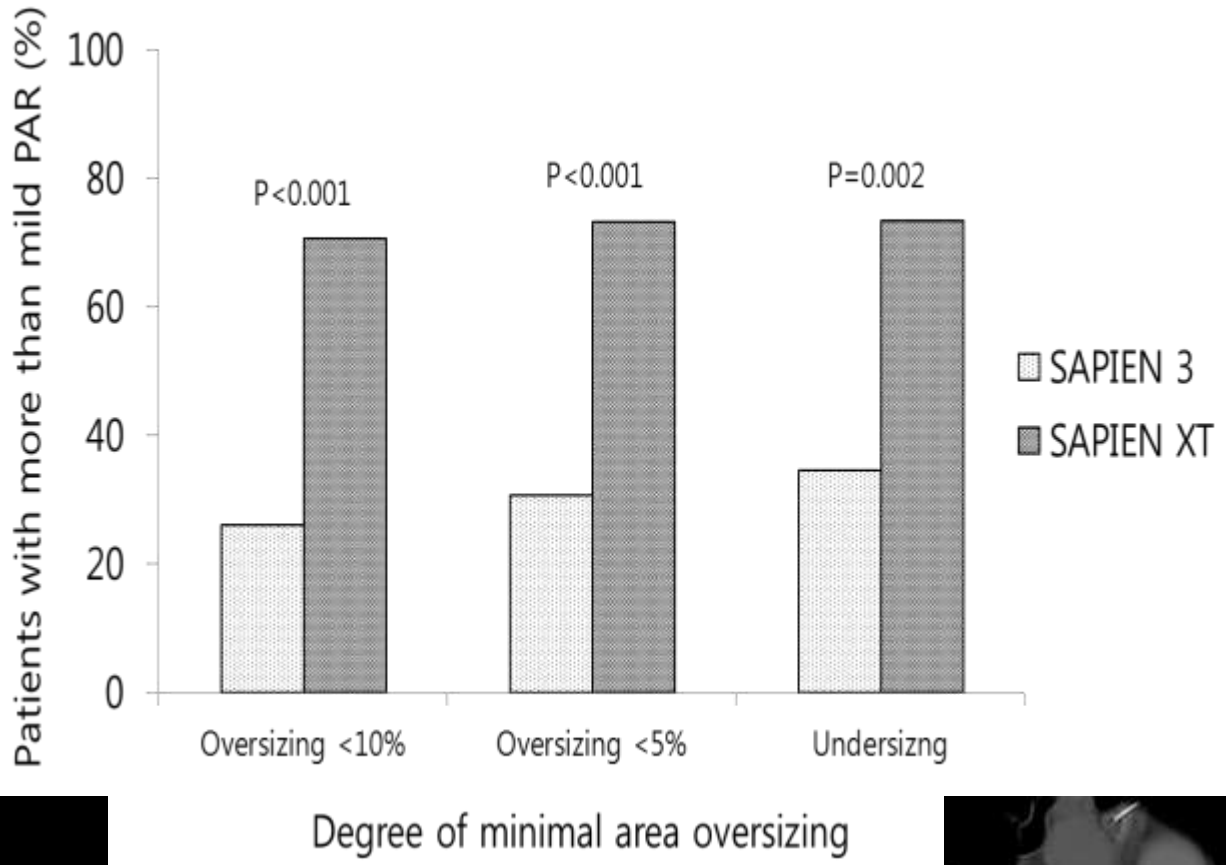
# Comparison of MSCT Annulus Measurements



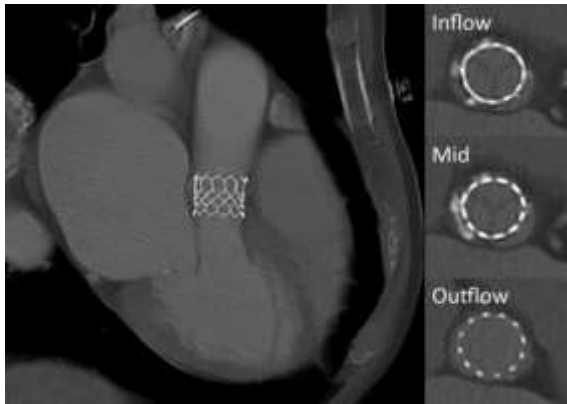

Retrospective analysis suggests that perimeter would have the lowest % of patients with AR ≥ 2

Source: Slide courtesy of Dr N Piazza

# Different Sizing Algorithms for Different Valves




Source: Yang et al ACC 2014, JACC Int in press



# Different Sizing Algorithms for Different Valves

## SAPIEN 3

**It may not always be possible to implant the larger THV size for borderline annulus diameters. Consider the smaller THV in the following special situations:**

- Severe annulus calcification
- Narrow root and low coronary ostia
- Narrow sinotubular junction
- Mitral annular calcification
- Porcelain aorta
- Bulky leaflet and low coronary ostia

**If/when outside of recommended range:**

1) Reference alternative sizing modalities (echocardiography, balloon sizing)
2) Consider the following factors in valve size selection
   - Clinical: very advanced age, corticosteroids, chest radiation, extensive calcification, calcium extending into the LVOT, etc

**Bold** = recommended Sealing Zones relate only to valves that are deployed with nominal volumes

| 3D Area-derived Diameter (mm) | | 20.0 | 20.2 | 20.5 | 20.7 | 21.0 | 21.1 | 21.4 | 21.7 | 22.0 | 22.3 | 22.6 | 22.8 | 23.0 | 23.1 | 23.4 | 23.7 | 23.9 | 24.0 | 24.2 | 24.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3D Annular Area ($mm^2$) | | 314 | 320 | 330 | 338 | 346 | 350 | 360 | 370 | 380 | 390 | 400 | 410 | 415 | 420 | 430 | 440 | 450 | 452 | 460 | 470 |
| % Annular Area Over (+) or Under (-) Nominal by 3D CT | 23 mm | 29.3 | 26.9 | 23.0 | **20.1** | **17.3** | **16.0** | **12.8** | **9.7** | **6.8** | **4.1** | **.5** | **-1.0** | **-2.2** | **-3.3** | **-5.6** | -7.7 | -9.8 | | | |
| | 26 mm | | | | | | | | | | | 9.8 | 26.6 | 25.1 | 23.6 | **20.7** | **18.0** | **15.3** | **14.8** | **12.8** | **10.4** |
| | 29 mm | | | | | | | | | | | | | | | | | | | | |

**ALL VALUES PRESENTED ARE BASED ON NOMINAL/RECOMMENDED INFLATION VOLUMES.**

**SYSTOLIC MEASURES ARE RECOMMENDED**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24.5 | 24.7 | 25.0 | 25.2 | 25.5 | 25.7 | 26.0 | 26.2 | 26.4 | 26.5 | 26.7 | 26.9 | 27.2 | 27.4 | 27.6 | 27.9 | 28.0 | 28.1 | 28.3 | 28.5 | 28.8 | 29.0 | 29.2 | 29.4 | 29.5 | 29.6 | 29.9 | 30.1 | 30.3 |
| 470 | 480 | 490 | 500 | 510 | 520 | 530 | 540 | 546 | 550 | 560 | 570 | 580 | 590 | 600 | 610 | 615 | 620 | 630 | 640 | 650 | 660 | 670 | 680 | 683 | 690 | 700 | 710 | 720 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **10.4** | **8.1** | **5.9** | **3.8** | **1.8** | **-0.2** | **-2.1** | **-3.9** | **-4.9** | -5.6 | -7.3 | -8.9 | | | | | | | | | | | | | | | | | |
| | | | 29.8 | 27.3 | 24.8 | 22.5 | **20.2** | **18.9** | **18.0** | **15.9** | **13.9** | **11.9** | **10.0** | **8.2** | **6.4** | **5.5** | **4.7** | **3.0** | **1.4** | **-0.2** | **-1.7** | **-3.1** | **-4.6** | -5.0 | -5.9 | -7.3 | -8.6 | -9.9 |

# From Theoretical to Practical

# Cross-Sectional Computed Tomographic Assessment Improves Accuracy of Aortic Annular Sizing for Transcatheter Aortic Valve Replacement and Reduces the Incidence of Paravalvular Aortic Regurgitation

Hasan Jilaihawi, BSc (Hons), MBChB,* Mohammad Kashif, MD,* Gregory Fontana, MD,† Azusa Furugen, MD, PhD,* Takahiro Shiota, MD,* Gerald Friede, BS, MS,* Rakhee Makhija, MD,* Niraj Doctor, MBBS,* Martin B. Leon, MD,‡ Raj R. Makkar, MD*

**Table 5** Comparison of Outcomes Related to Prosthesis Sizing With TEE- and CT-Guided Approaches

| Outcomes | All Studied Patients (n = 136) | 2D TEE-Guided Annular Sizing (n = 96) | Cross-Sectional CT-Guided Annular Sizing (n = 40) | p Value |
|---|---|---|---|---|
| PV AR | | | | 0.001 |
| None | 41 (30.1) | 23 (24) | 18 (45) | |
| Trivial or mild | 71 (52.2) | 52 (54.1) | 19 (47.5) | |
| Mild-moderate | 9 (6.6) | 8 (8.3) | 1 (2.5) | |
| Moderate | 12 (8.8) | 10 (10.4) | 2 (5) | |
| Moderate-severe | 3 (2.2) | 3 (3.1) | 0 | |
| Severe | | 0 | 0 | |
| PV AR > mild | 24 (17.6) | 21 (21.9) | 3 (7.5) | 0.045 |
| Need for bail-out valve-in-valve | 1 (0.7) | 1 (1) | 0 | 0.52 |
| Annular rupture | 1 (0.7) | 1 (1) | 0 | 0.52 |
| Prosthesis instability (rocking) | 1 (0.7) | 1 (1) | 0 | 0.52 |
| Peri-procedural mortality | 4 (3) | 3 (3.2) | 1 (2.5) | 0.82 |

# Impact of CT sizing on TAVR outcomes

The Impact of Integration of a Multidetector Computed Tomography Annulus Area Sizing Algorithm on Outcomes of Transcatheter Aortic Valve Replacement: A Prospective, Multicenter, Controlled Trial

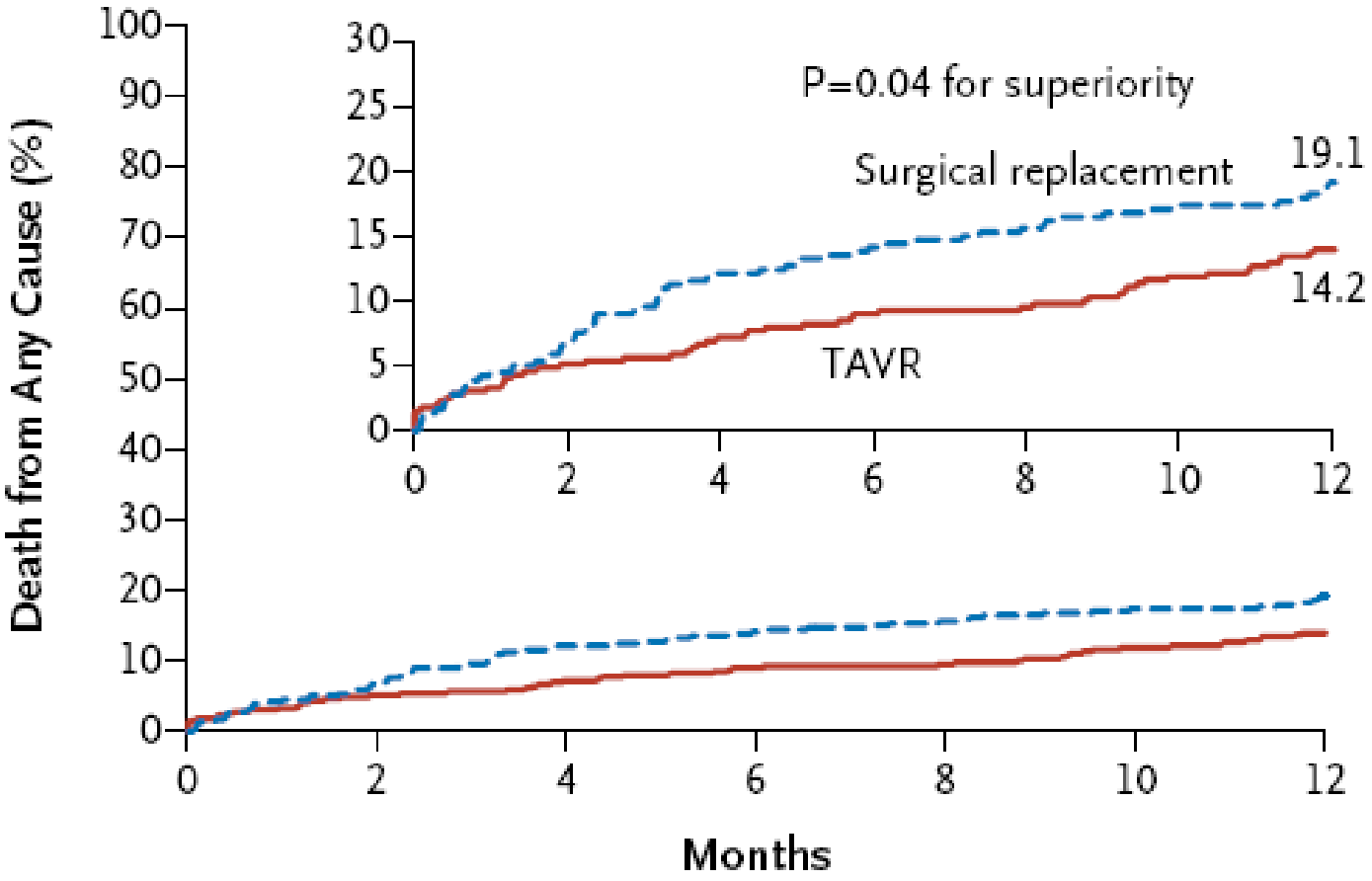
**Short Title:** Computed Tomography Area Sizing for TAVR

Ronald K. Binder[1], MD; John G. Webb[1], MD; Alexander B. Willson[1], MBBS; Marina Urena[2], MD; Nicolaj C. Hansson[3], MD; Bjarne L. Norgaard[3], MD; Philippe Pibarot[2], MD; Marco Barbanti[1], MD; Eric Larose[2], MD; Melanie Freeman[1], MBBS; Eric Dumont[2], MD; Chris Thompson[1], MD; Miriam Wheeler[1], MBChB; Robert R. Moss[1], MD; Tae-hyun Yang[1], MD; Sergio Pasian[2], MD; Cameron Hague[1], MD; Giang Nguyen[1], MD; Rekha Raju[1], MD; Stefan Toggweiler[1], MD; James K. Min, MD[5]; David A. Wood[4], MD; Josep Rodés-Cabau[2], MD; Jonathon Leipsic[1], MD.

- 266 patients in the trial
- 133 patients underwent TAVR with the MDCT sizing algorithm recommendation and 133 patients without the algorithm
- PVL> mild was present in 5.3% in the MDCT group and in 12.8% in the control group (p=0.032)
- Composite of in-hospital death, aortic annulus rupture and PVL> moderate 3.8% in the MDCT group and in 11.3% in the control group (p=0.020)

Source: JACC Jun 2013

# CT Sizing helps optimize outcomes with Self Expanding Prosthesis




Source : Adams et al NEJM 2014

# Preventing Annular Injury with MDCT

# Annular rupture

**Anatomical and Procedural Features Associated with Aortic Root Rupture During Balloon-Expandable Transcatheter Aortic Valve Replacement**

Marco Barbanti, Tae-Hyun Yang, Josep Rodés-Cabau, Corrado Tamburino, David A. Wood, Hasan Jilaihawi, Philipp Blanke, Raj R. Makkar, Azeem Latib, Antonio Colombo, Giuseppe Tarantini, Rekha Raju, Ronald K. Binder, Giang Nguyen, Melanie Freeman, Henrique B. Ribeiro, Samir Kapadia, James Min, Gudrun Feuchtner, Ronen Gurtvich, Faisal Alqoofi, Marc Pelletier, Gian Paolo Ussia, Massimo Napodano, Fabio Sandoli de Brito, Jr., Susheel Kodali, Bjarne L. Norgaard, Nicolaj C. Hansson, Gregor Pache, Sergio J. Canovas, Hongbin Zhang, Martin B. Leon, John G. Webb and Jonathon Leipsic

| | Study group (n = 31) | Uncontained rupture (n = 20) | Contained rupture (n = 11) | P value |
|---|---|---|---|---|
| **Mortality** | 48.4% | 75.0% | 0.0% | <0.001 |
| **Cardiovascular mortality** | 45.2% | 70.0% | 0.0% | <0.001 |
| **Disabling stroke** | 12.9% | 10.0% | 18.2% | 0.447 |
| **Life-threatening bleeding** | 45.2% | 60.0% | 18.2% | 0.049 |

Source: Barbanti et al. Circulation July 2013

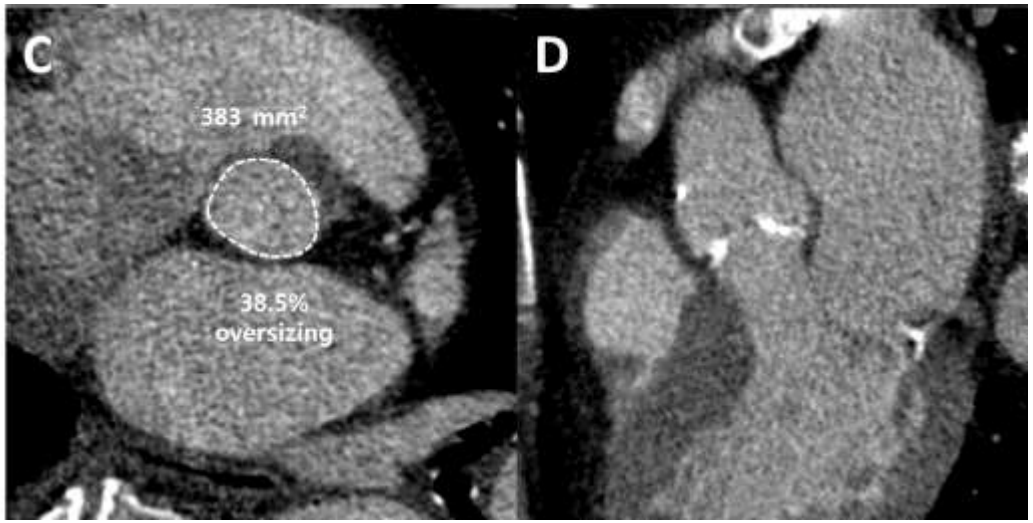
# Annular Rupture May not Be Random- Insights from MDCT

| | Univariate | |
|---|---|---|
| **Predictors of aortic root rupture** | Odds Ratio (95%CI) | P value |
| **LVOT calcifications moderate/severe** | 10.92 (3.23-36.91) | <0.001 |
| **Prosthesis oversizing ≥ 20%** | 8.38 (2.67-26.33) | <0.001 |

Source: ACC 2013 and Circulation July 2013

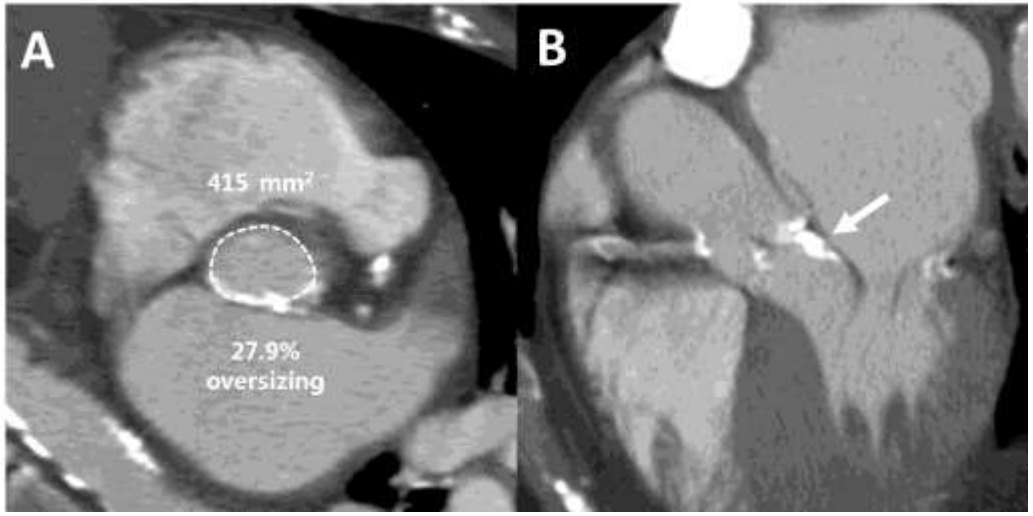
# Case examples

*Significant oversizing (>20%) is possible…Just do it in the right patient!*




**Case example #1**

- ❑ 26-mm SAPIEN XT
- ❑ 38.5% oversizing
- ❑ No LVOT calcification
- ❑ Uneventful TAVR!



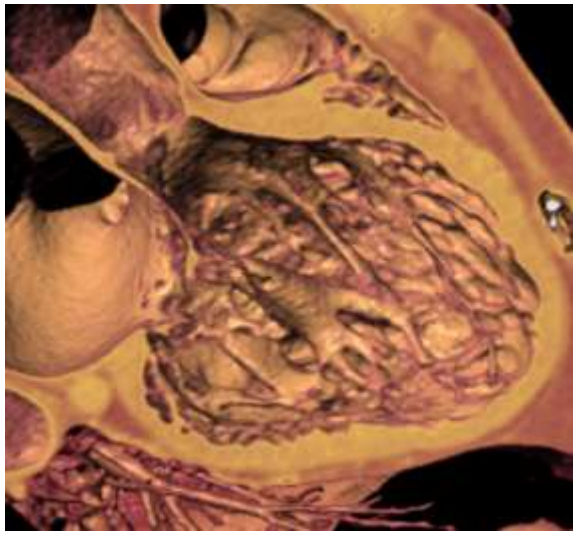

**Case example #2**

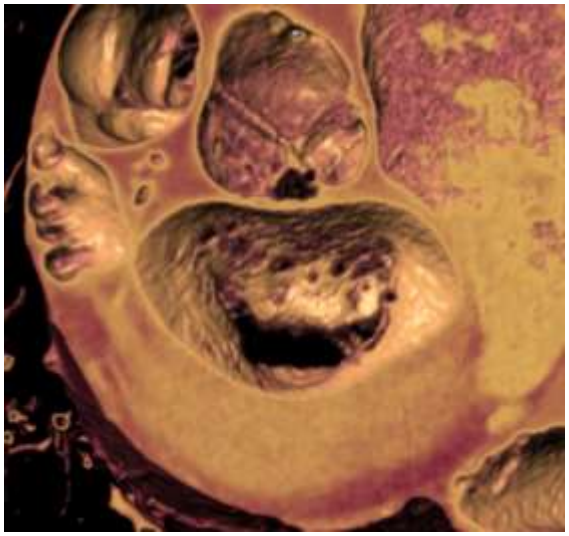
- ❑ 26-mm SAPIEN XT
- ❑ 27.9% oversizing
- ❑ Severe LVOT calcification
- ❑ Annular rupture!

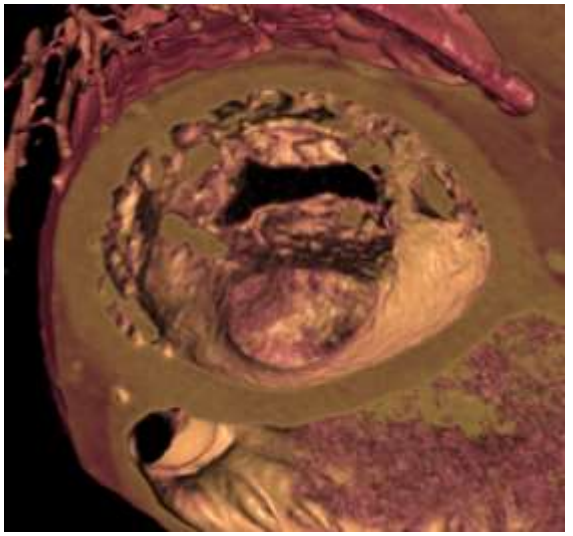
# Transcatheter Mitral Valve Implantation (TMVI)

## Requirements

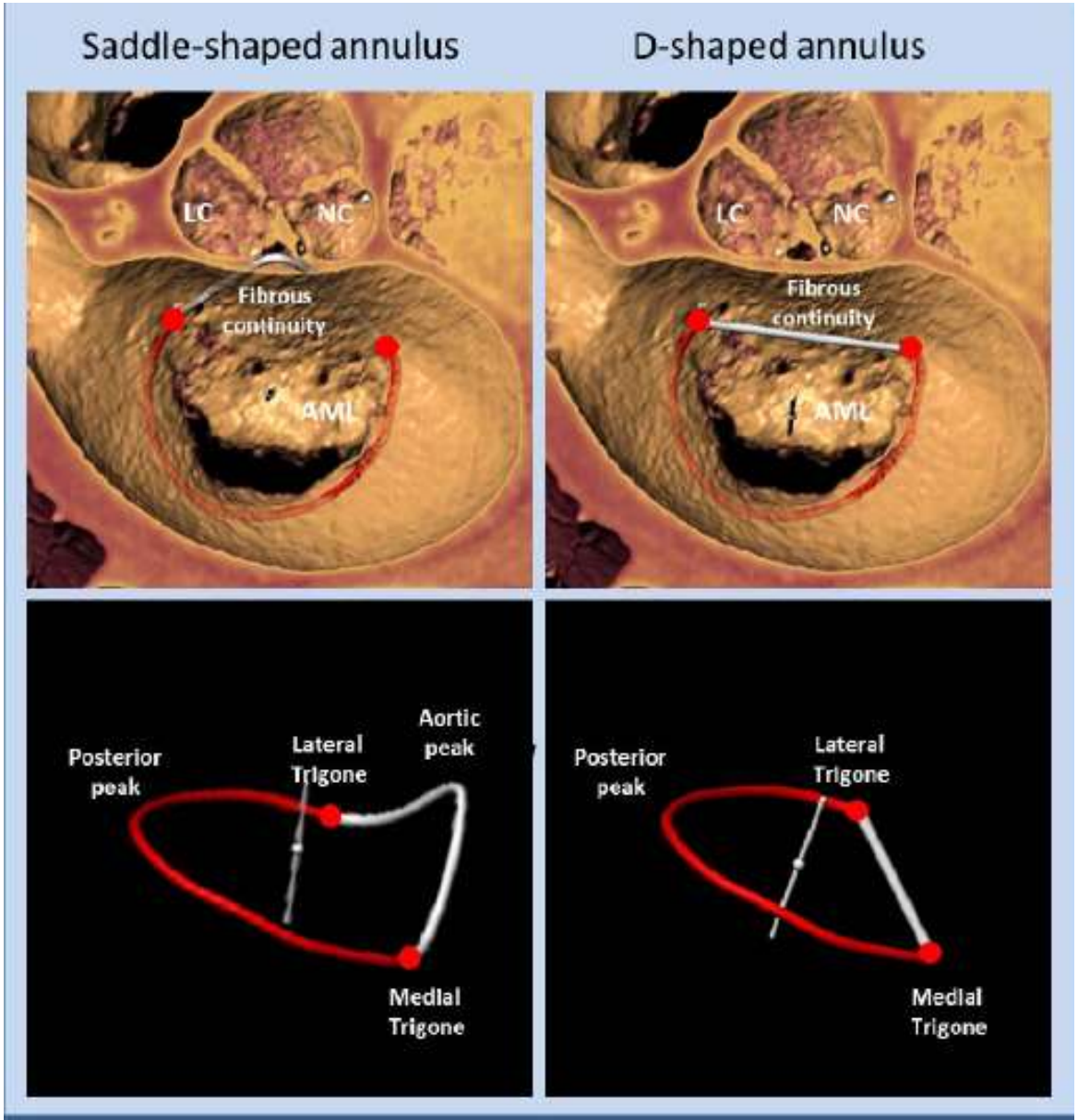
1. Secure position preventing migration
2. Minimize paravalvular leakage
3. Avoid LVOT obstruction



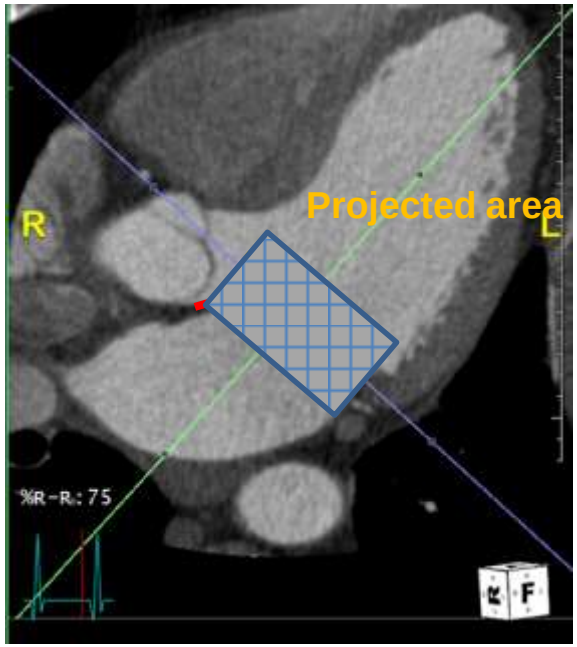


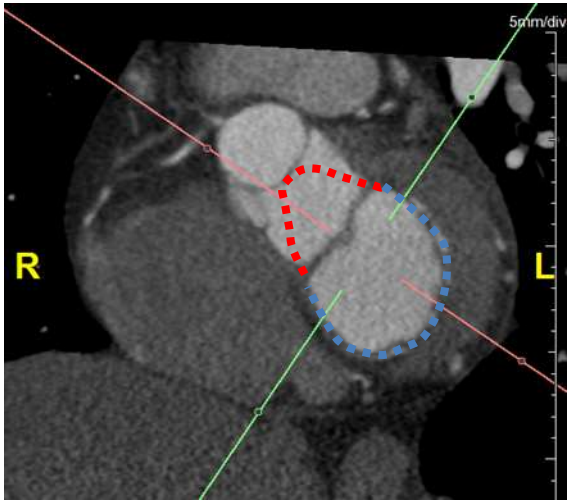


# Re-thinking the Mitral Annulus



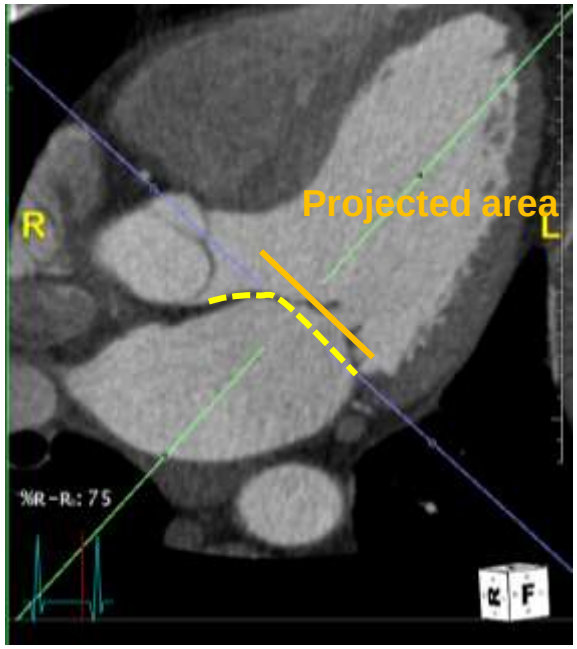
# Mitral Annulus in the context of TMVI

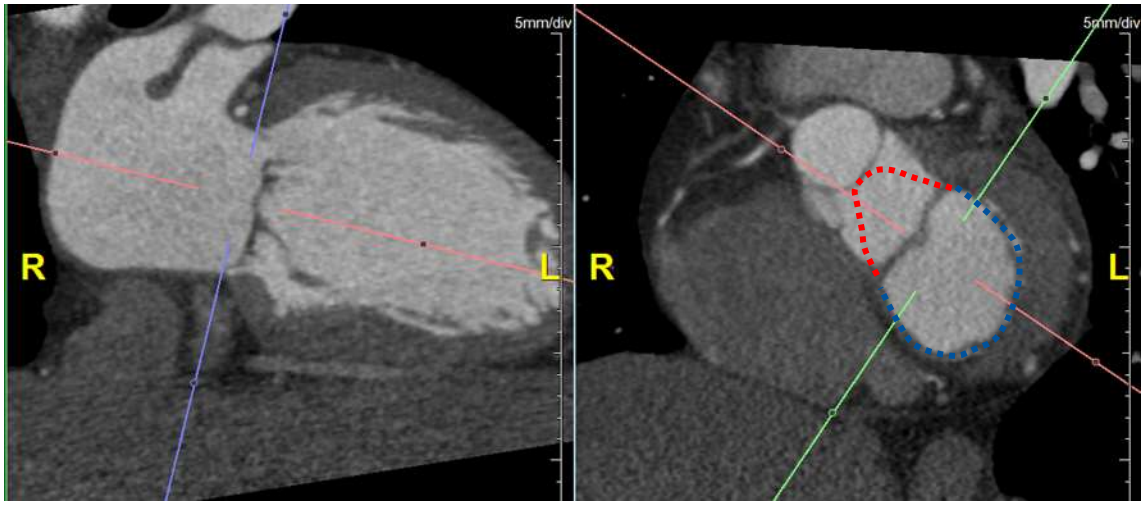



Source: Blanke et al JCCT 2014 and in press JACC Imaging 2015

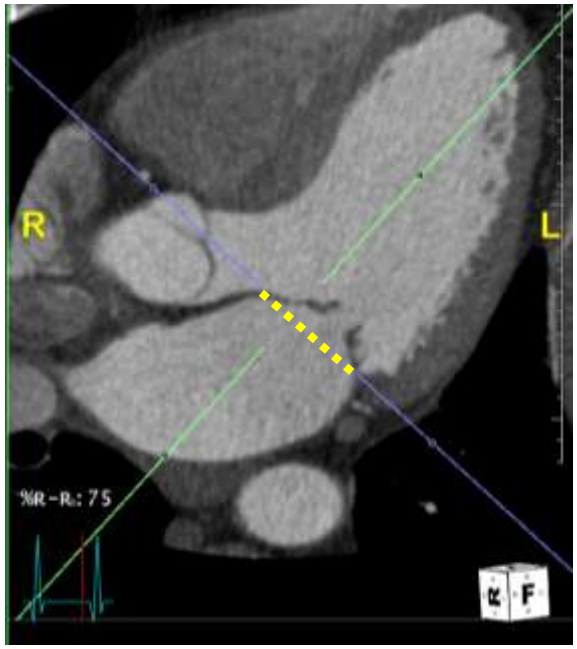
# Saddled Annulus

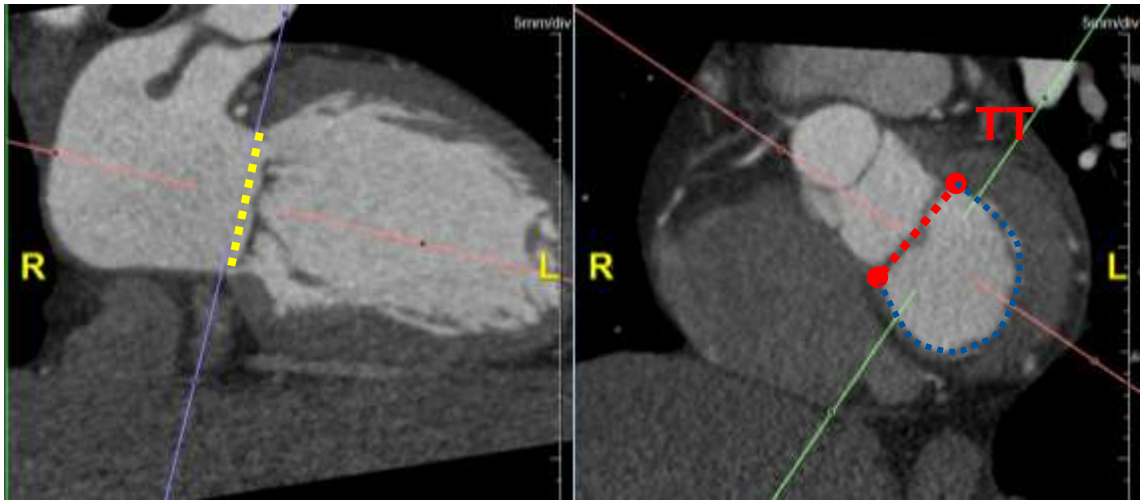



Traditional Method for Mitral Annular Assessment

# “unsaddled” annulus



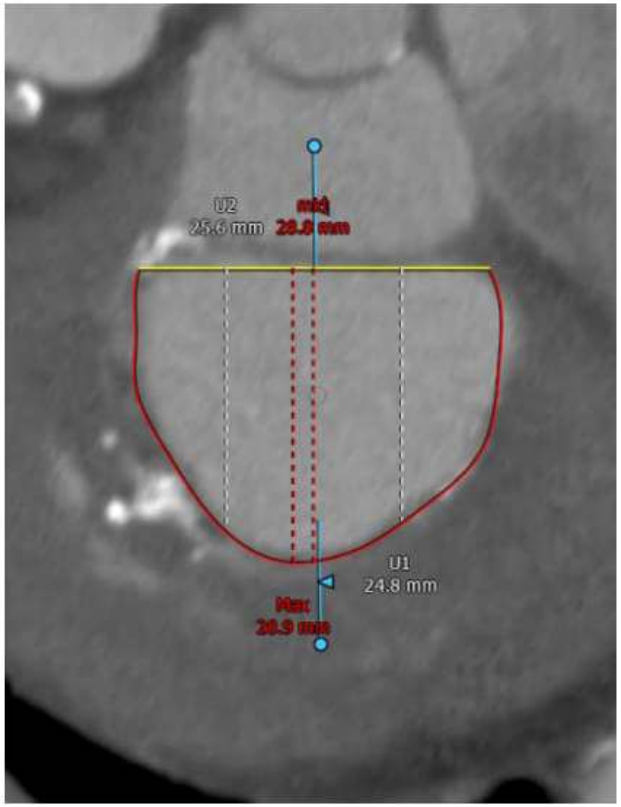
# Conformational similarities with an implanted device in vivo

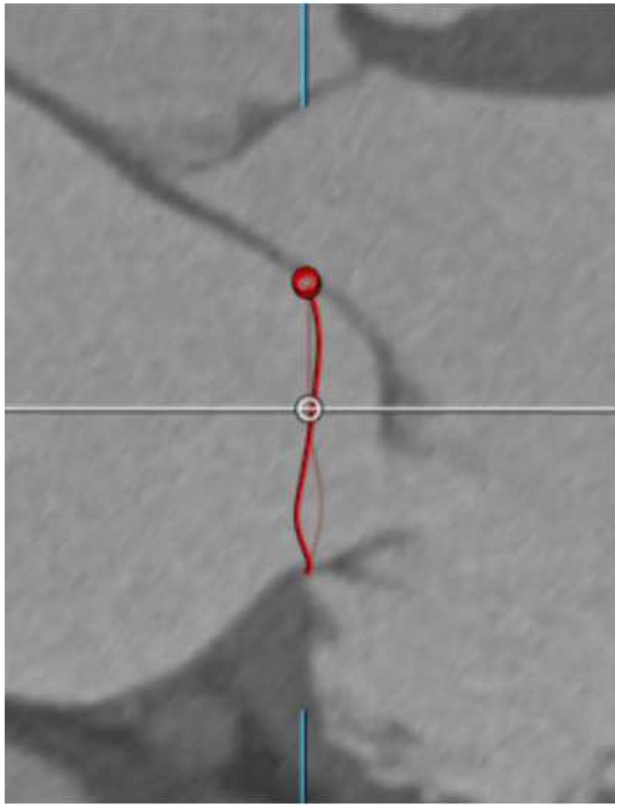
Source: Cheung et al. JACC 2014

# Impact on Sizing and Device Selection

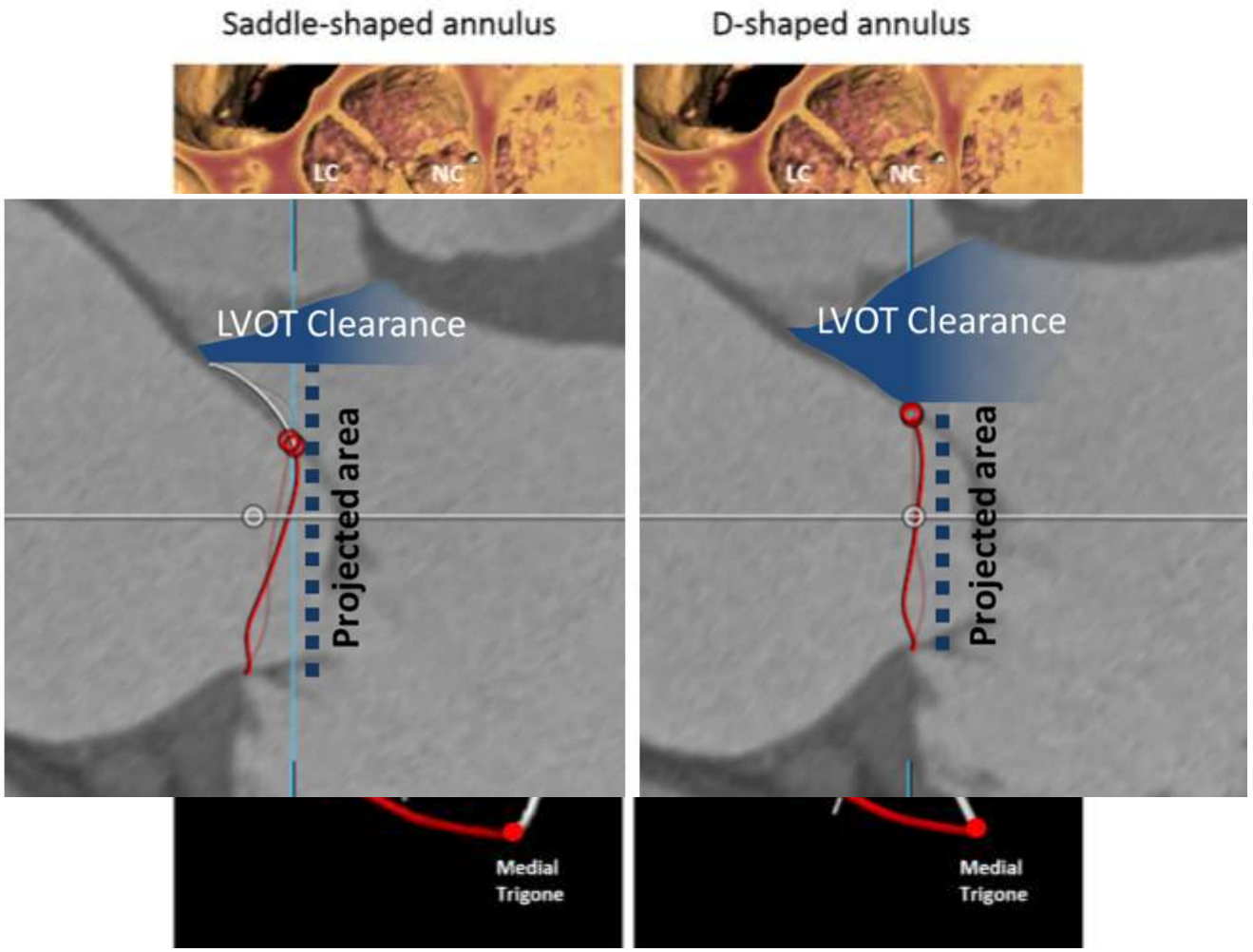
**D-shaped annulus**

| | |
|---|---|
| Area | 8.5 $cm^2$ |
| 3D-Perimeter | 111 mm |
| 2D-Perimeter | 110 mm |
| TT | 34 mm |
| SL | 29 mm |



# Implications for Sizing and LVOT Clearance




Source: Blanke et al in press JACC Imaging

# Conclusions

- MDCT is now well established as an important tool for annular sizing
- Allows for the discrimination of those patients historically at risk for annular rupture, coronary occlusion and PAR
- Field is moving from historical device selection based on sex or 2 D measurements to a truly individualized approach to THV selection
- Growing role in the assessment of risk of coronary occlusion in valve in valve procedures