Cardiac CT for Transcather Aortic Valve Implantation

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For the TAVI,

A unique collaborative experience !

Current Active Devices

Edwards Sapien
Balloon Expandable

Medtronic CoreValve
Self Expanding

Major Uses of CT in TAVI

Patient Selection & Planning

- Ileofemoral Arterial Sytem :
  Size, Calcification, Tortuosity, Plaques
- 3D annular & root morphology & dimensions
- Amounts of calcium in valve
- Annular

During Implantation

- Optimal angle (TF) or puncture site (TA)
- Relationship of annulus to both coronary ostia
- Merging Image during Implantation

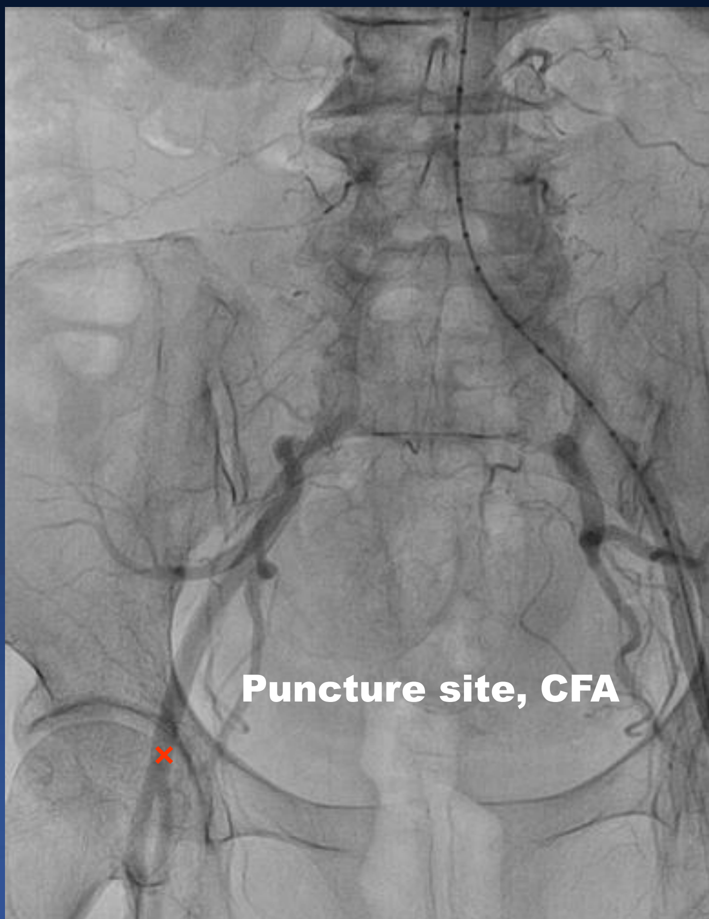
Follow-up

- Post TAVI assessment

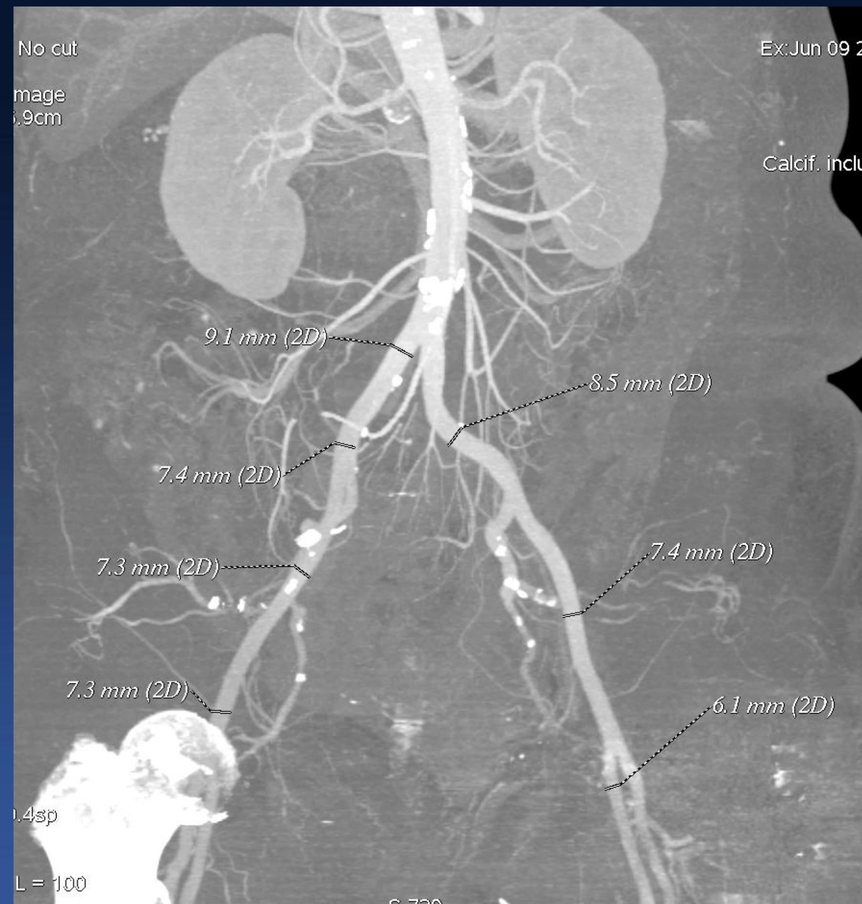
Evaluation of Access Routes

Reduce Vascular Injury

Femoral Artery Puncture under Fluoroscopic Guidance



Initial Ileofemoral Aortography



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Multivariate Predictors of Major Vascular Complications

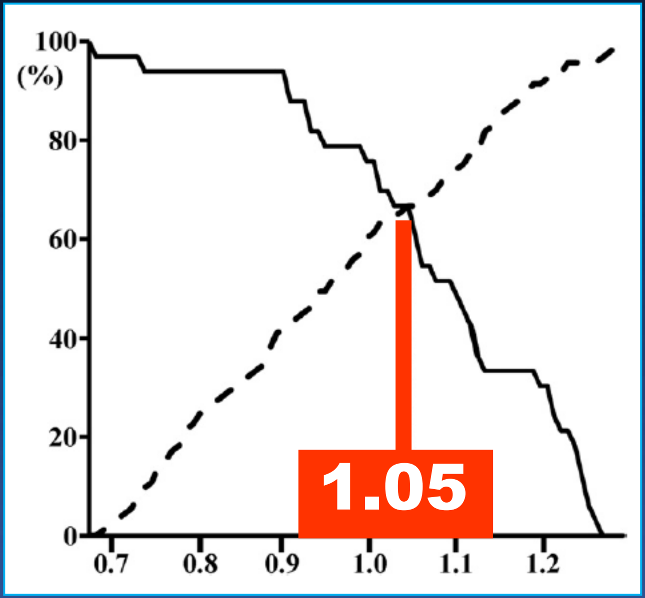
- Sheath to femoral artery ratio (SFAR)* HR: 186.20
- Center experiences, HR: 3.66
- Femoral calcification, HR: 3.44

*SFAR ; the ratio of sheath OD (mm) and minimal femoral artery diameter (mm), measured usually by CTA

Hayashida K, Lefevre T, Chevalier B et al.JACC Intv 2011;4;851-58

SFAR threshold
Predicting Major Vascular Complications

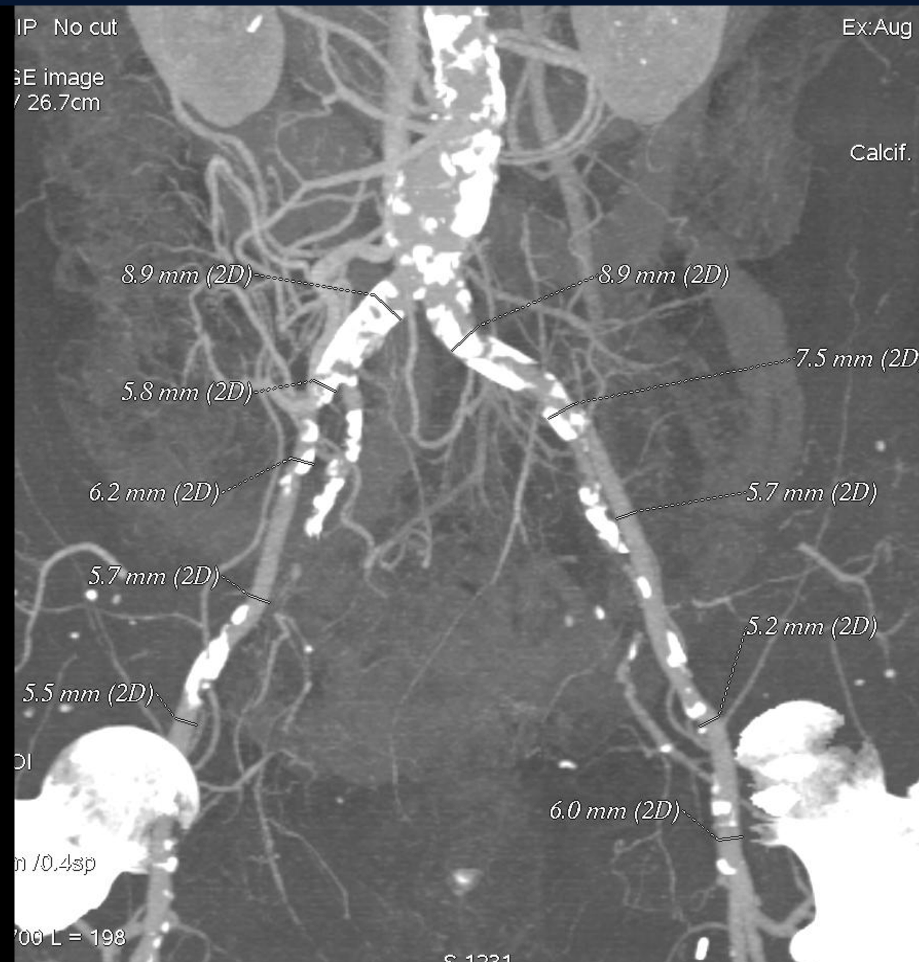
SFAR threshold of 1.05 (AUC 0.723)



Variables	SFAR ≥1.05	SFAR <1.05	P Value
VARC Major	**30.9**	**6.9**	**0.001**
Iliac artery complication	**20.0**	**2.8**	**0.002**
Femoral artery complication	**27.3**	**12.5**	**0.035**
30-day mortality	**18.2**	**4.2**	**0.016**

Hayashida K, Lefevre T, Chevalier B et al.JACC Intv 2011;4;851-58

Baseline Angiography & CT

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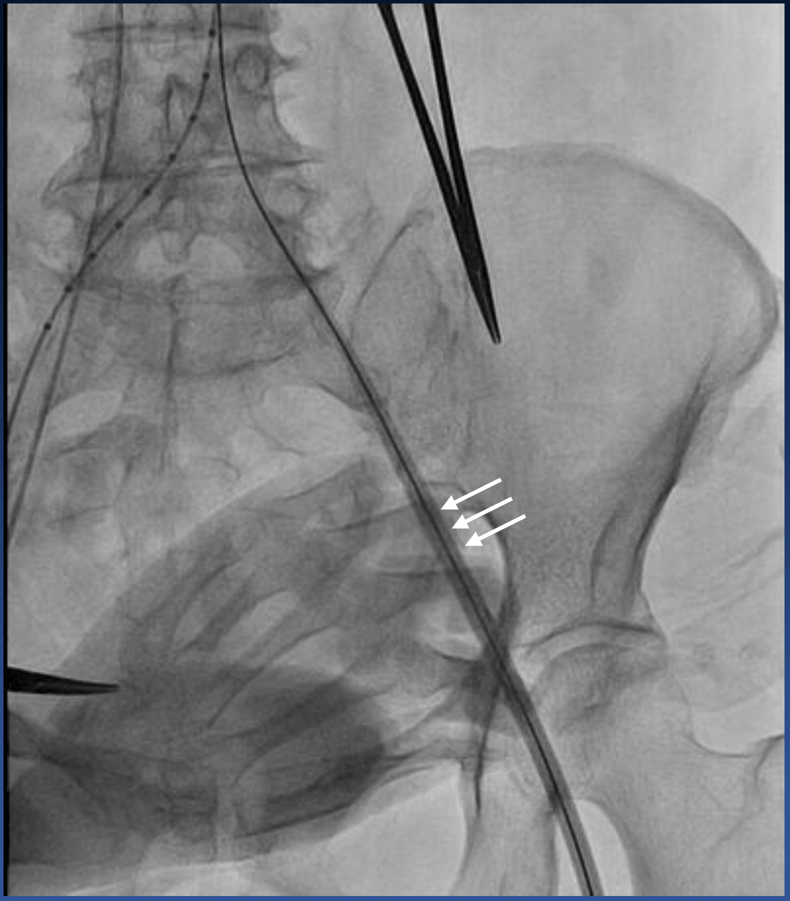
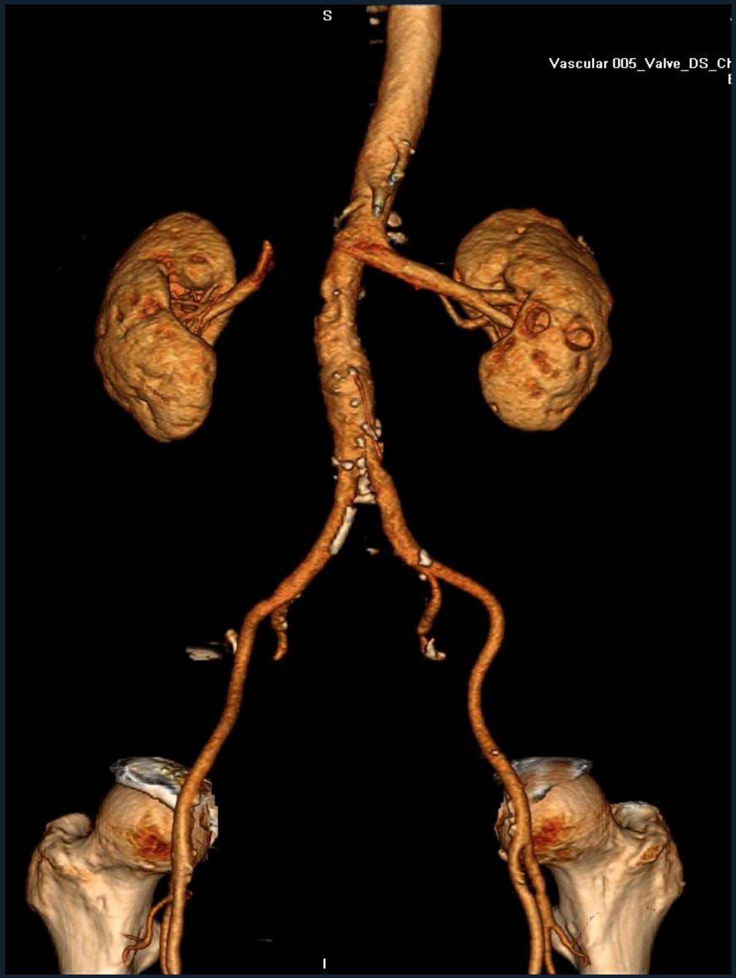
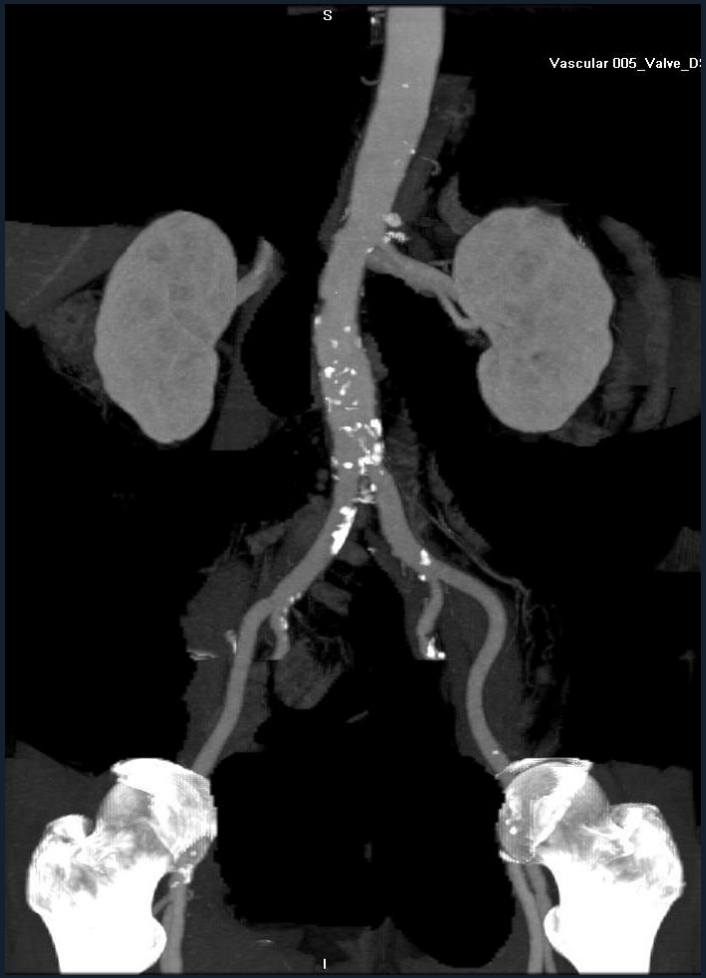
Difficulty in Advancement
Severe calcific small vessel

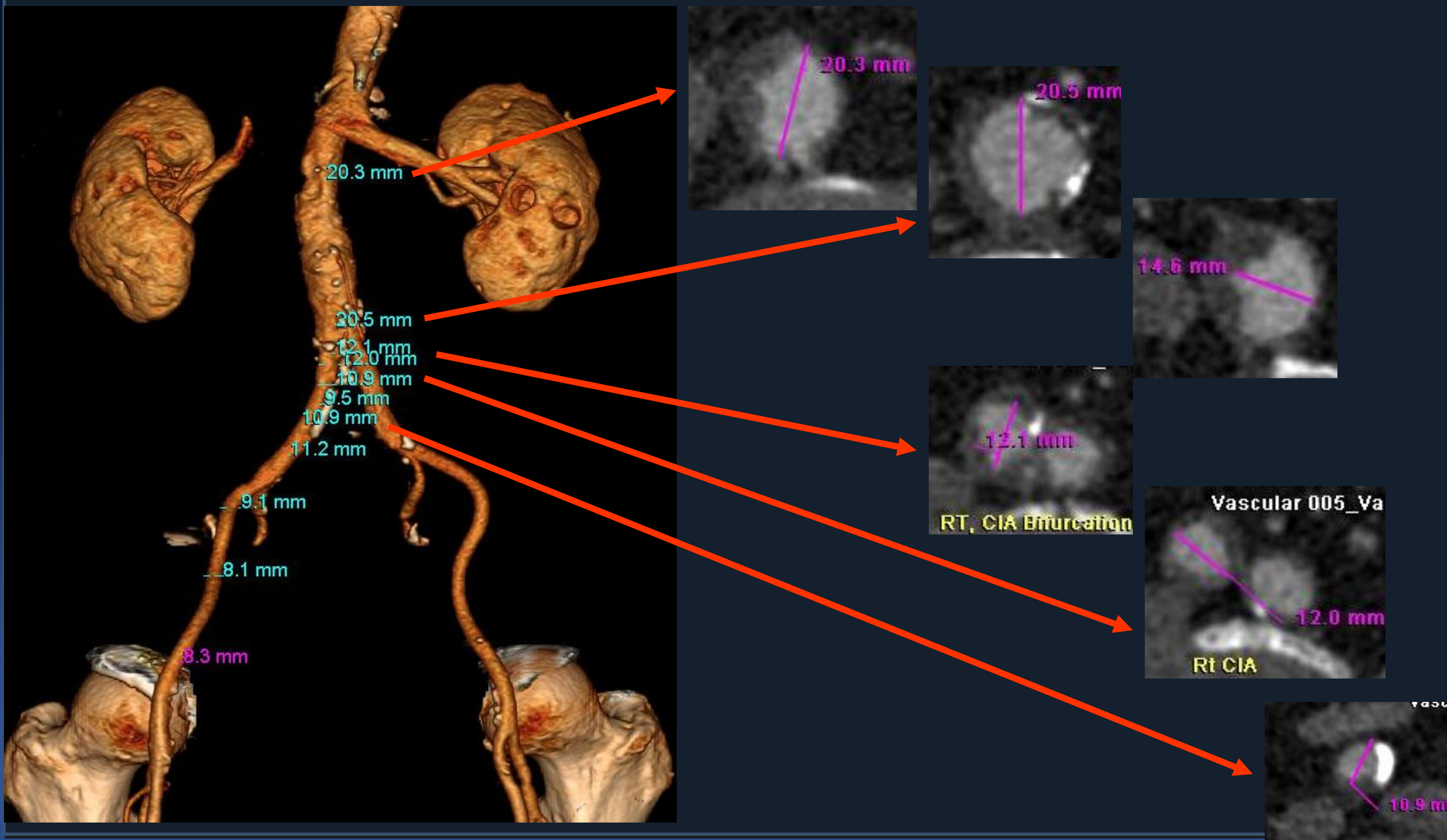


Ileofemoral Artery Evaluation





Ileofemoral Artery Evaluation



Size Measure, Calcium distribution, Tortuosity,,,

CT Screening Can Help Reduce Vascular Injury Rates

Variables	2009	2010	P value
MDCT Screening	44%	69%	<0.01
Ultrasound-guided puncture	0	37%	<0.01
Sheath size >19F	40%	2%	<0.01
Expandable sheath	12%	18%	0.33
MLD < external sheath diameter	77%	30%	<0.01
All vascular complications	32%	9%	<0.01

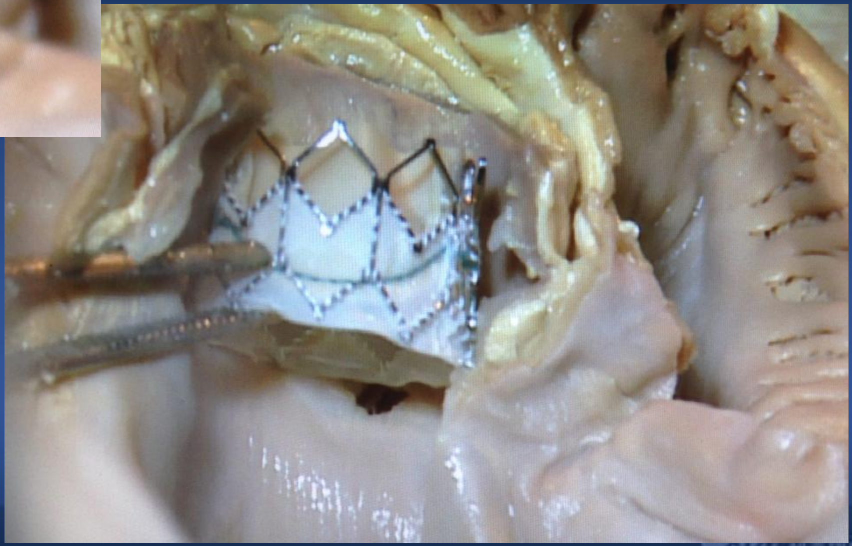
Toggweiler et al. JACC 2012

Annulus sizing

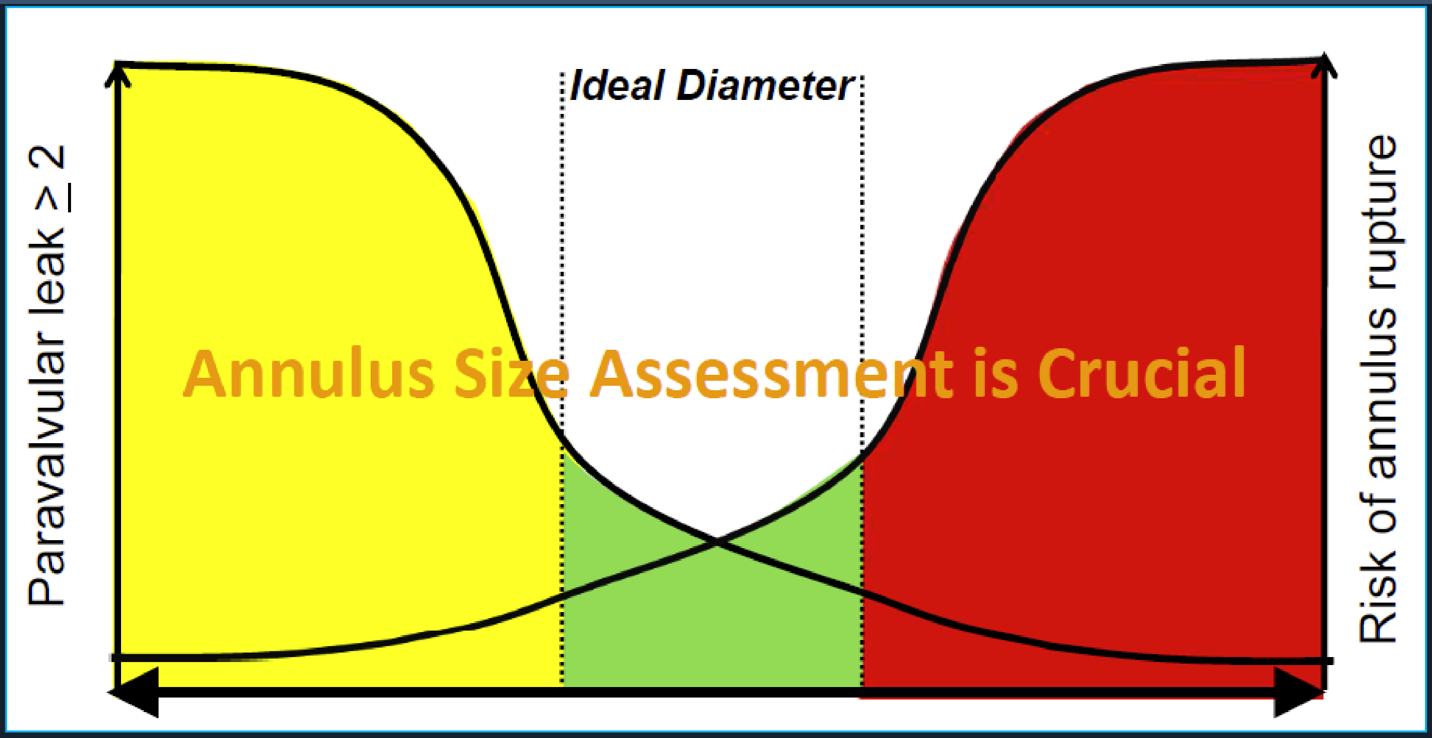
Cannot be emphasized enough…

For successful procedure
& reduce complications

Aortic Annulus:
Difficult to understand



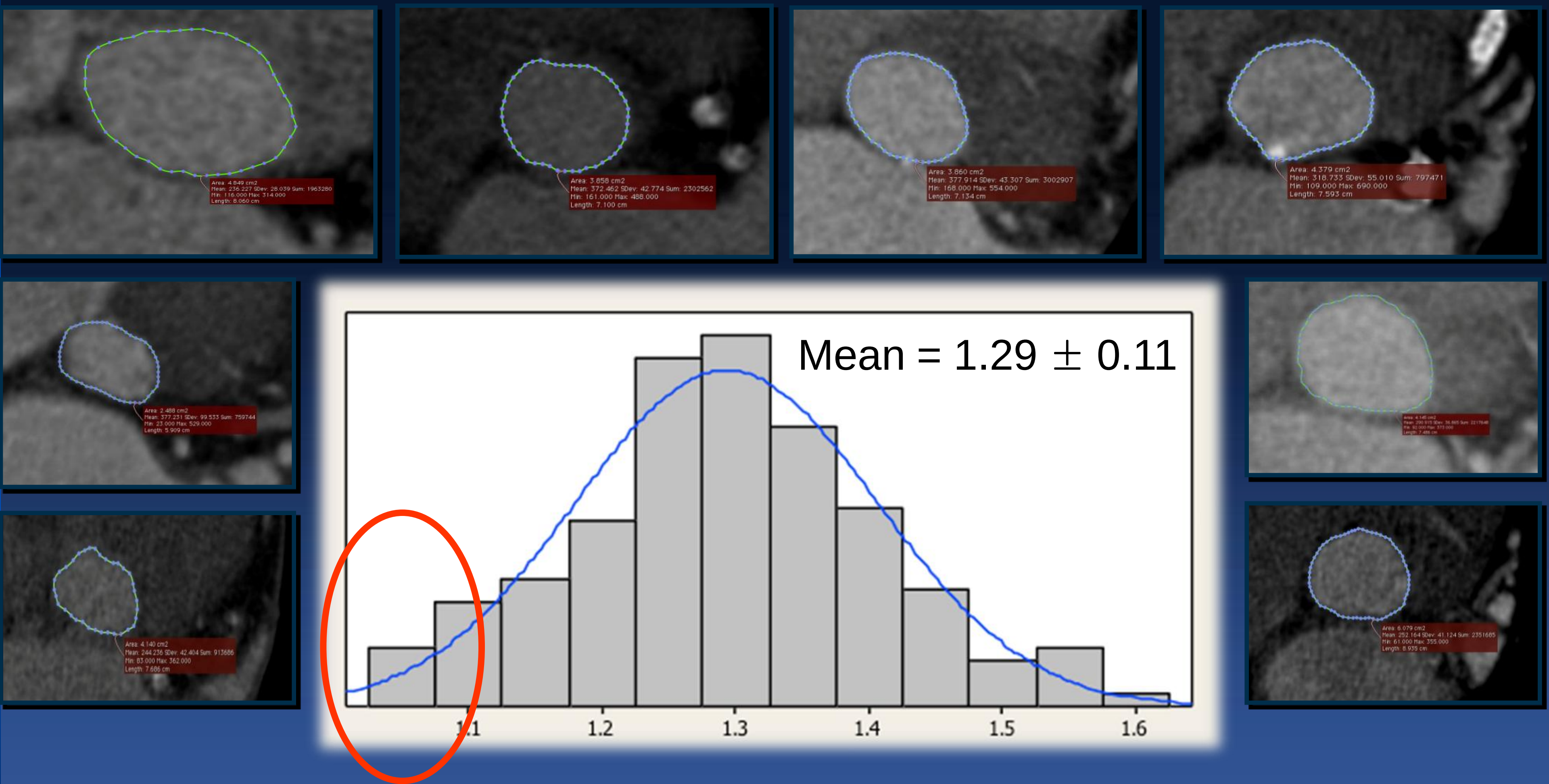
PPM or Rupture vs. PVL



% undersizing *0* *10-15%* *% oversizing*

Adapted from Thierry Lefevre; London Valves, 2012

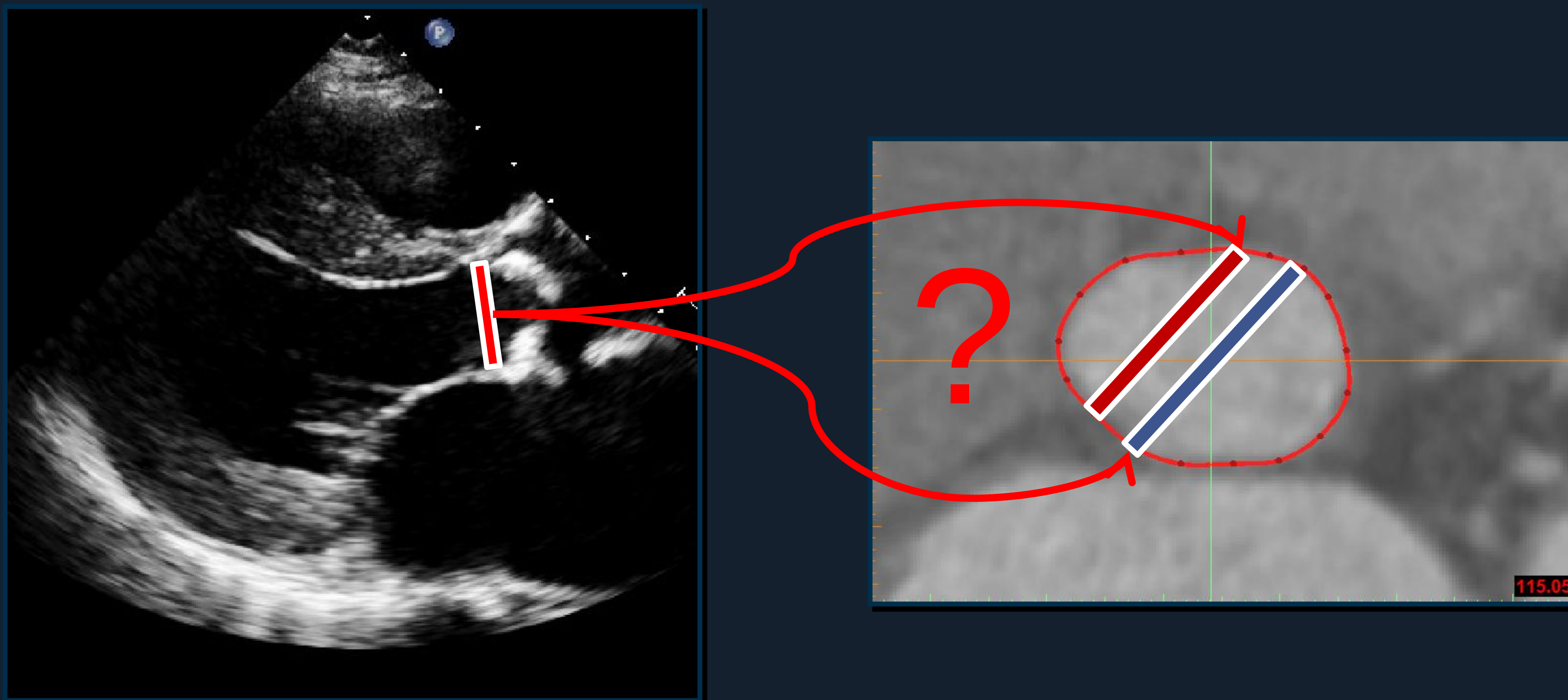
Aortic Annulus on CT



Circular Annulus is Very Small Proportion

Distribution of D_{max}/D_{min} from 164 TAVI patients
Courtesy of Dr. Piazza and Prof. Lange, German Heart Center, Munich Germany

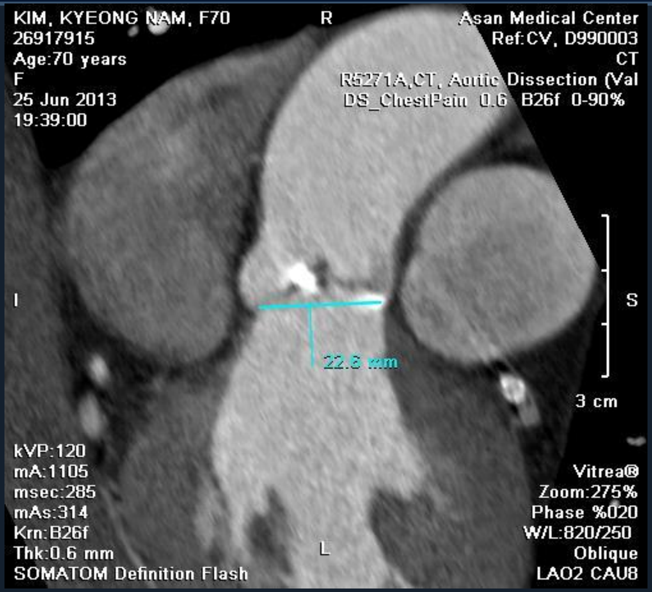
A Limitation of 2-D Image



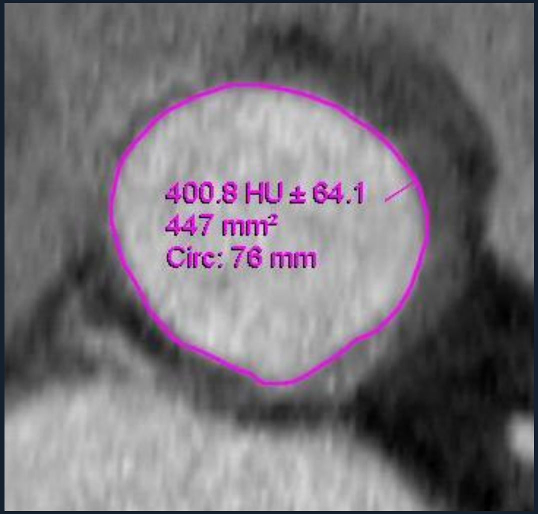
It is possible a true diameter is not measured due to the imaging plane acquired

Piazza N, et al. *Circ Cardiovasc Intervent*. 2008;1:74.

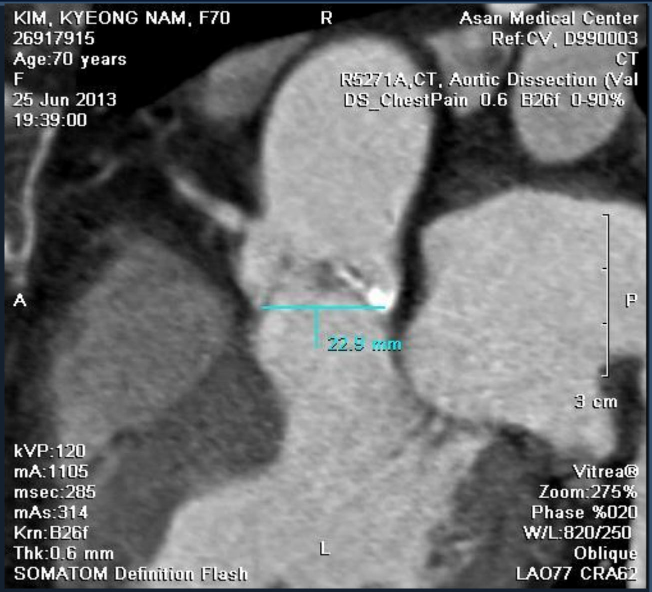
Aortic Annulus on MSCT



Coronal Image

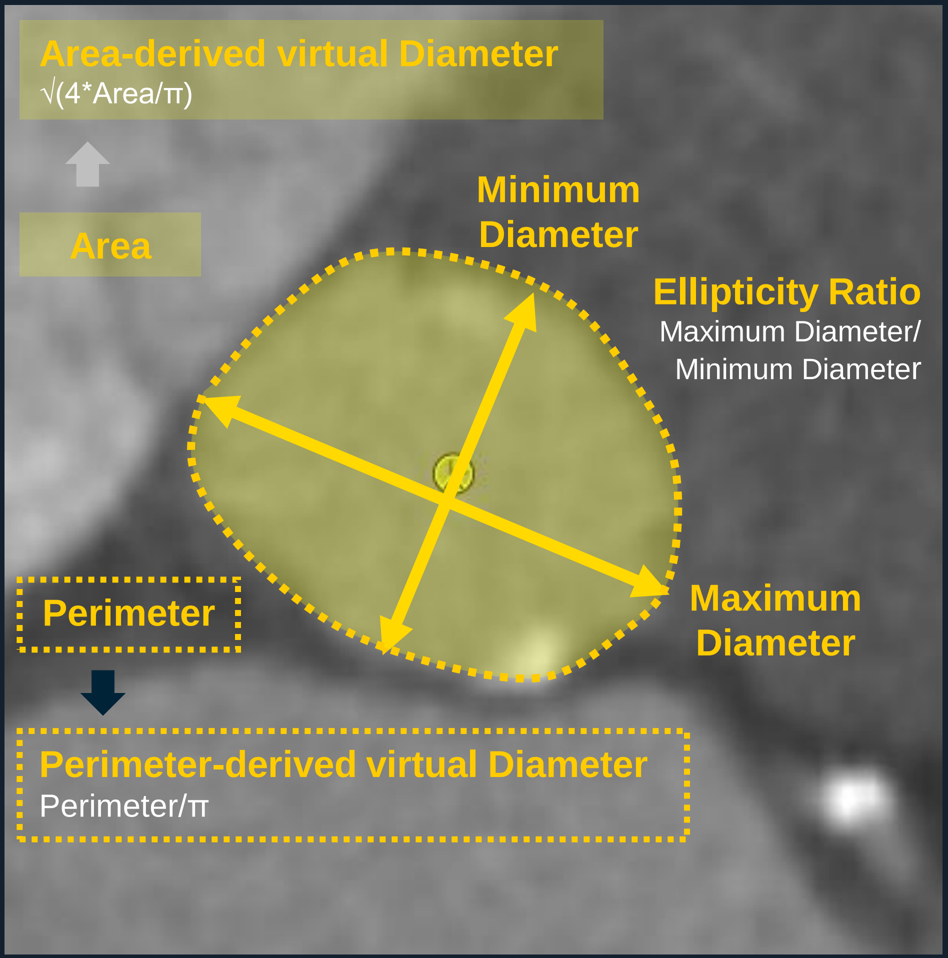


Basal Ring



Oblique Sagittal Image

New CT Parameters



Reliability Comparison

TEE vs. CT Variables

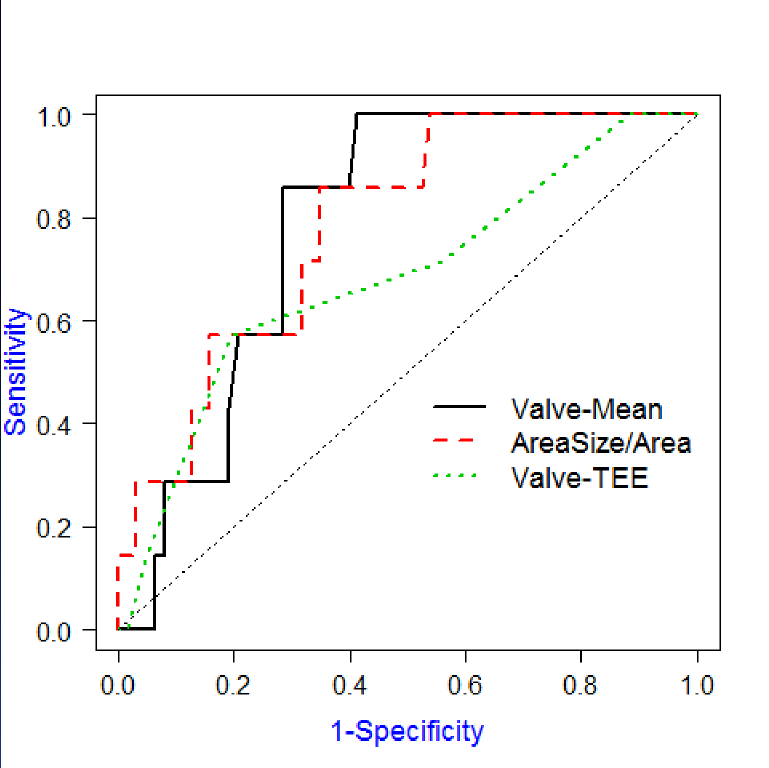
(N=30, Preliminary AMC Data)

TEE						
by ICC (1)						
(2)	0.51 (0.40-0.62)	0.93 (0.84-0.97)	0.95 (0.88-0.97)	0.96 (0.89-0.99)	0.93 (0.83-0.96)	0.95 (0.86-0.98)

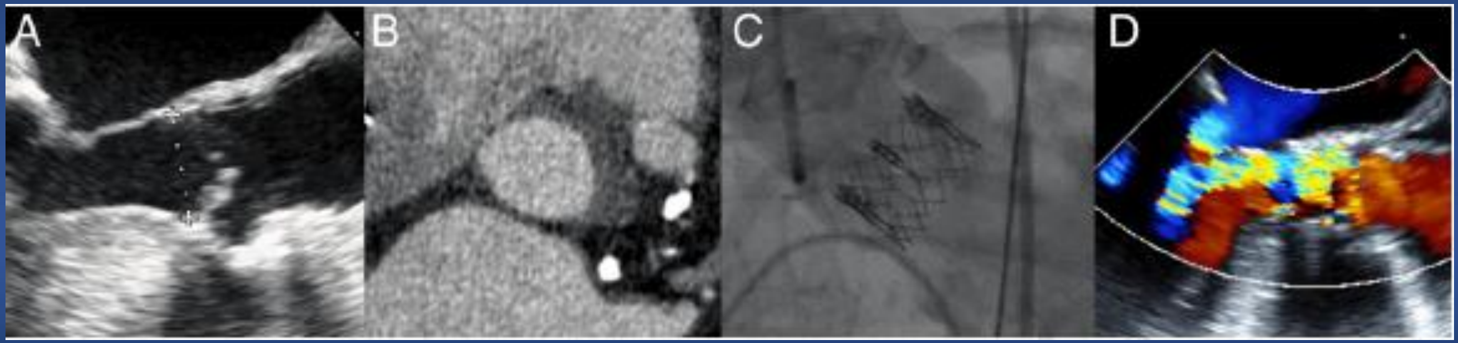
CT measurements for annulus are usually larger than TEE measurements. CT perimeter & area measurements are most reproducible.

ICC ; Intraclass correlation coefficient

CT Measures Can Predict PVL

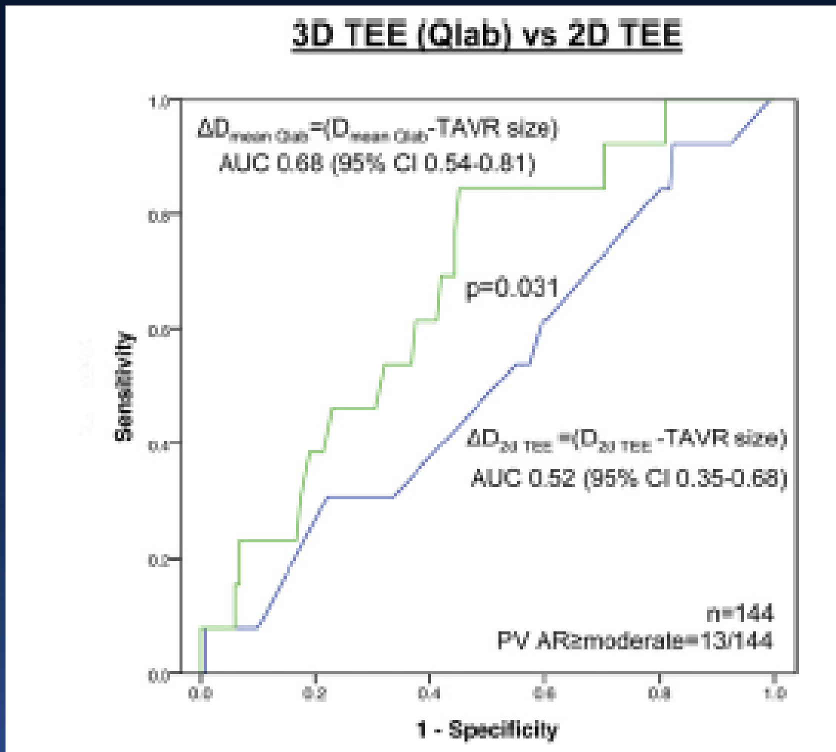


- Valve stent diameter – Mean annular diameter$_{CT}$ = AUC 0.84
- Valve stent diameter – Area-derived annular diameter$_{CT}$ = AUC 0.86
- Valve stent area/ Annular area$_{CT}$ = AUC 0.87

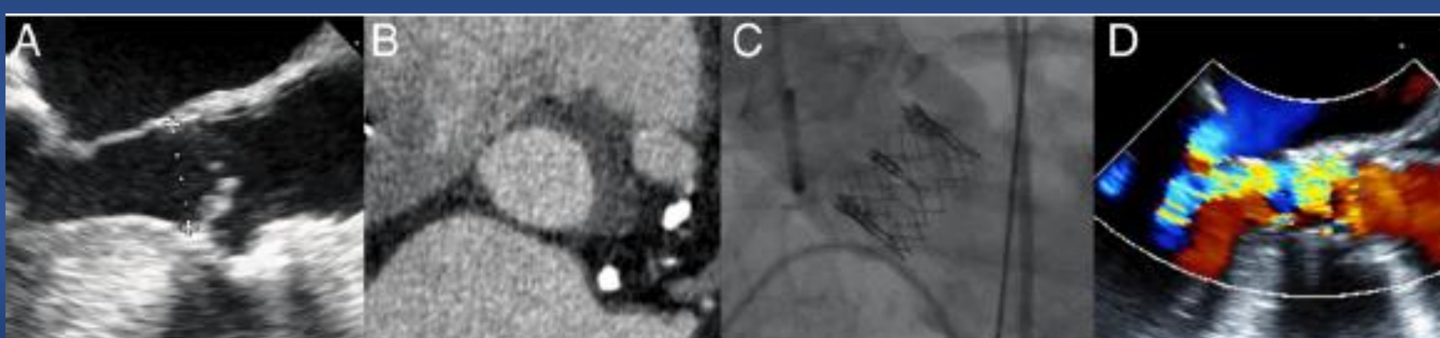


Willson et al. JACC 2012

CT Annular Measures Appear more Predictive than 3-D Echo for PVL

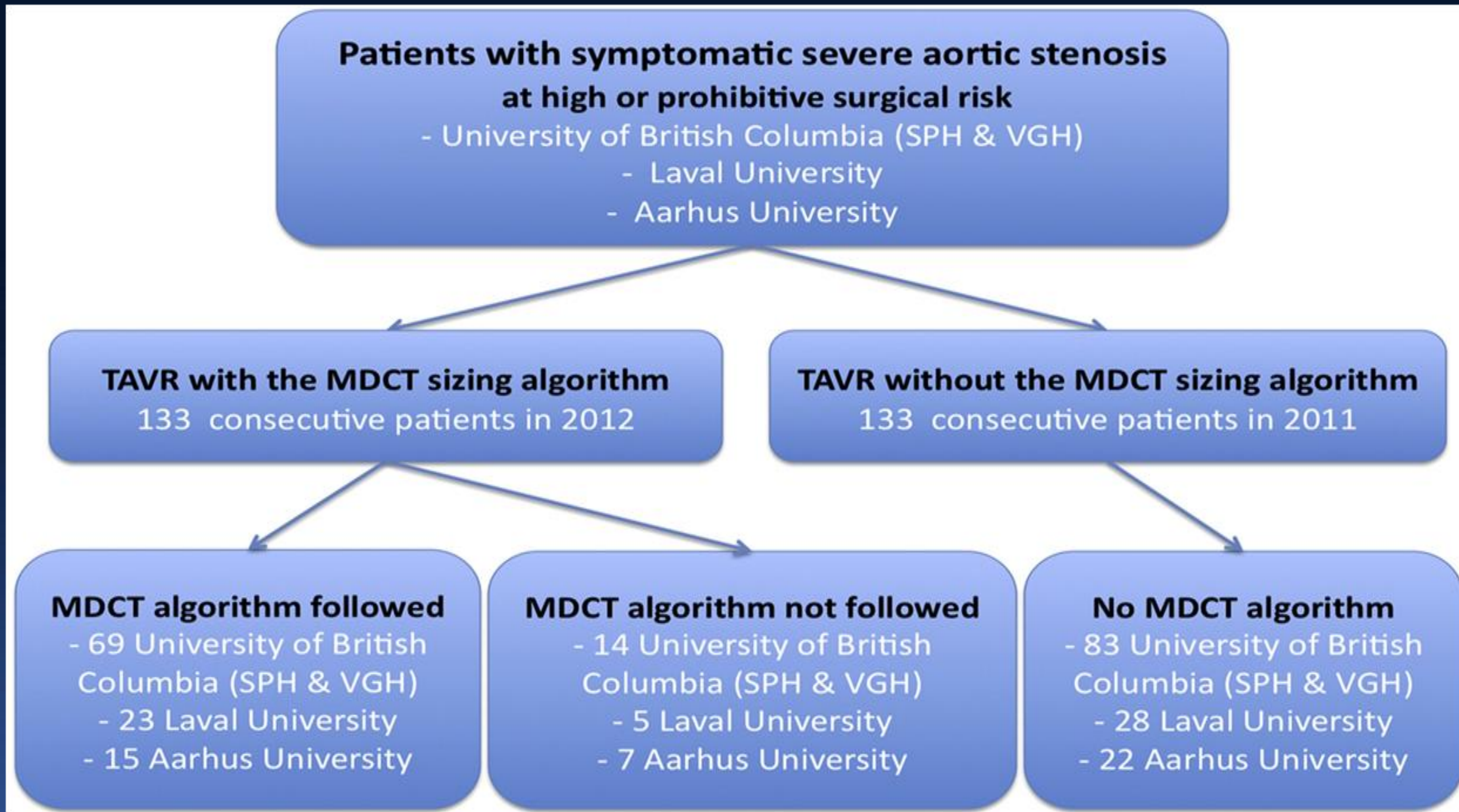


- CT Dmean – Annulus AUC = 0.82
- 3D TEE Mean – Annulus AUC = 0.68
- 2D TEE AUC = 0.52



Jilaihawi et al. JACC 2013

CT vs. Echo in Sizing: Edwards



PVL (>mild) : CT (7%) vs Echo (17%) p=0.032

PVL, Severe : CT (0%) vs Echo (6%) p=0.013

Binder et al JACC 2013

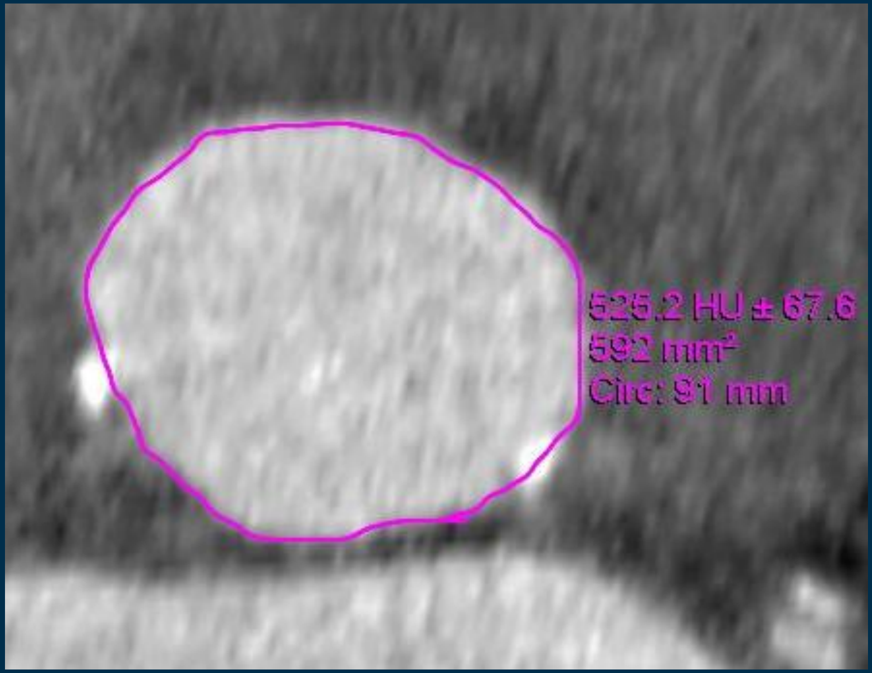
Stretching Index

$$\frac{\text{Device Perimeter (Calculated)}}{\text{Measured CT Perimeter}}$$

Asian CoreValve Registry, in submitting

Stretching Index Examples

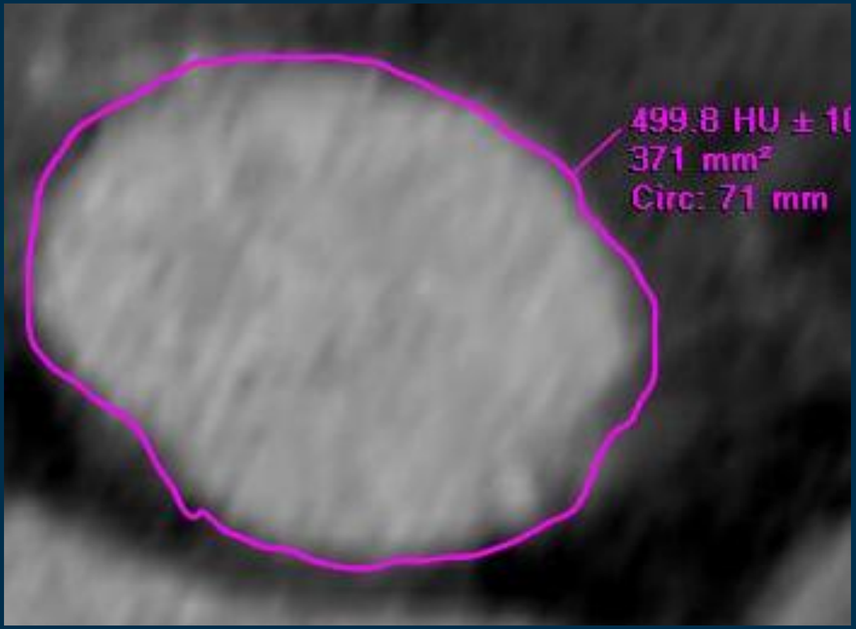
31 mm, No PPM



= 1.07

Avg. Diameter 26 mm (81.6 mm)

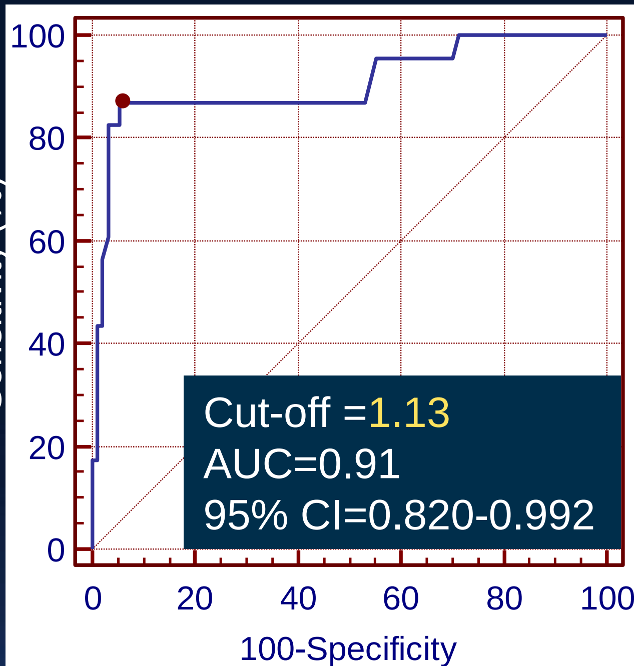
26 mm, PPM



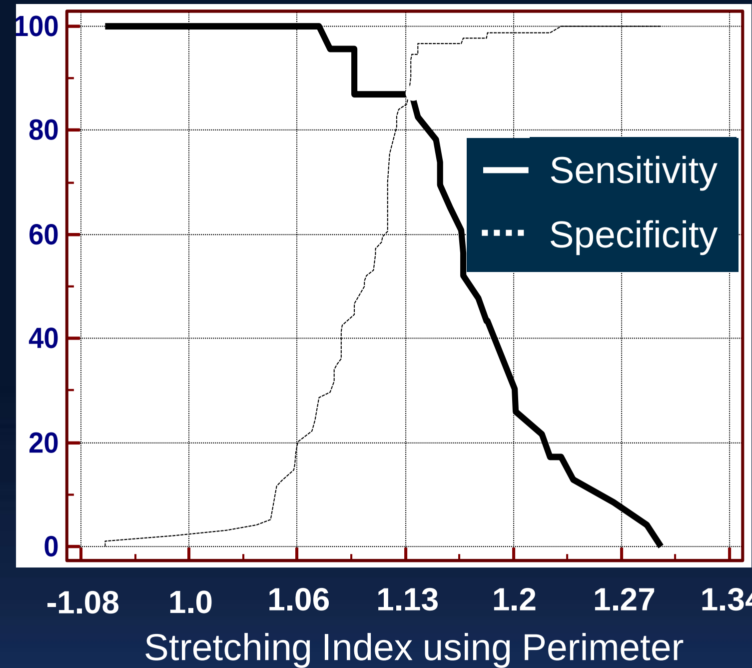
= 1.15

Avg. Diameter 19.6 mm (62.8 mm)

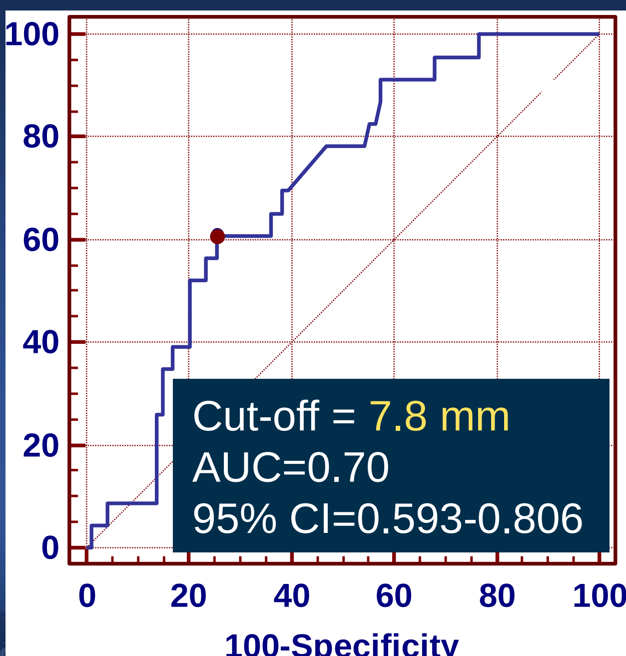
Stretching Index vs. PPM



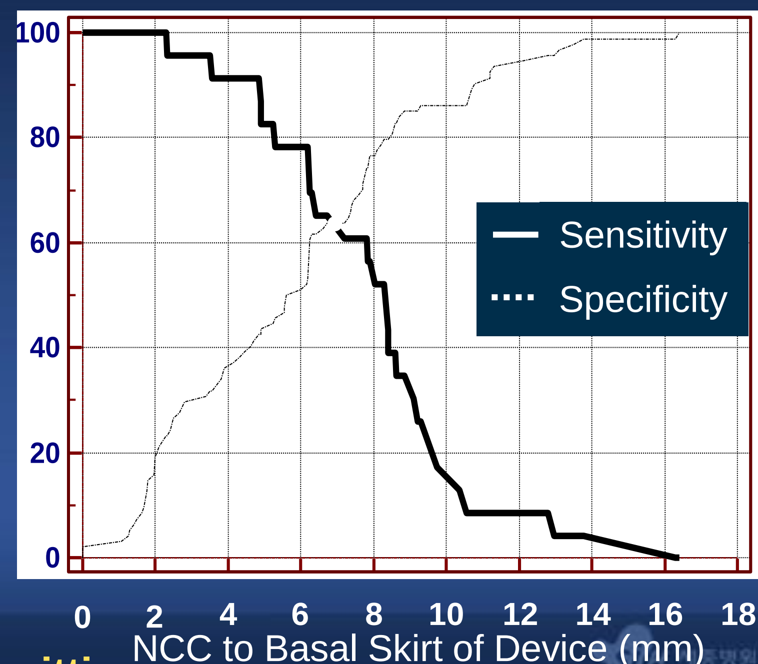
Sensitivity 86.96%
Specificity 94.68%
PPV 80%
NPV 96.74%
Accuracy 93.2%



Depth vs. PPM

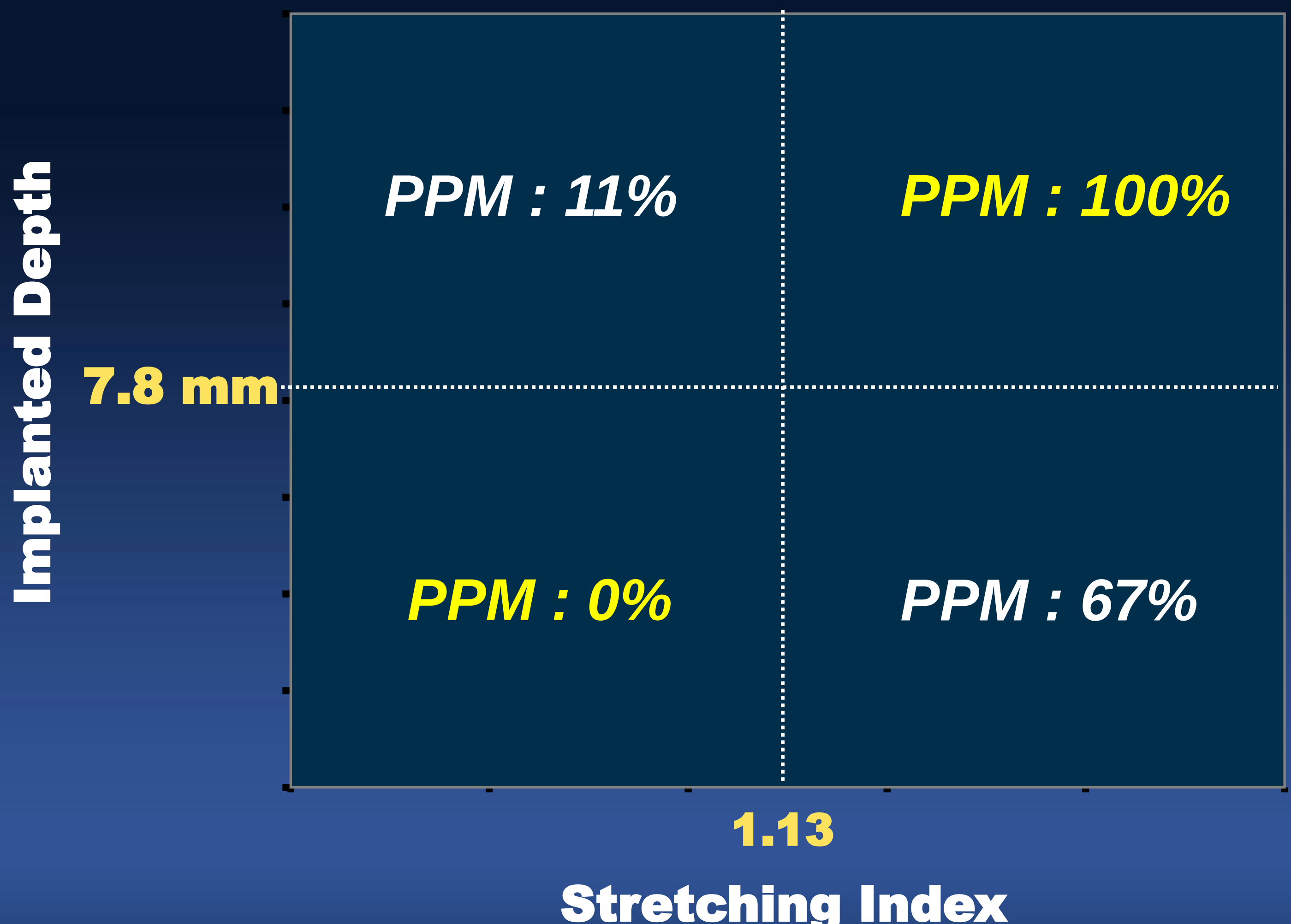


Sensitivity 60.87%
Specificity 74.47%
PPV 35.14%
NPV 87.5%
Accuracy 70.94%



Asian Registry, in submitting

Best Combination for Prevention of Permanent Pacemaker



Logistic regression $p<0.0001$, AUC 0.97, 95% CI=0.94-0.99

Predictors of aortic root rupture

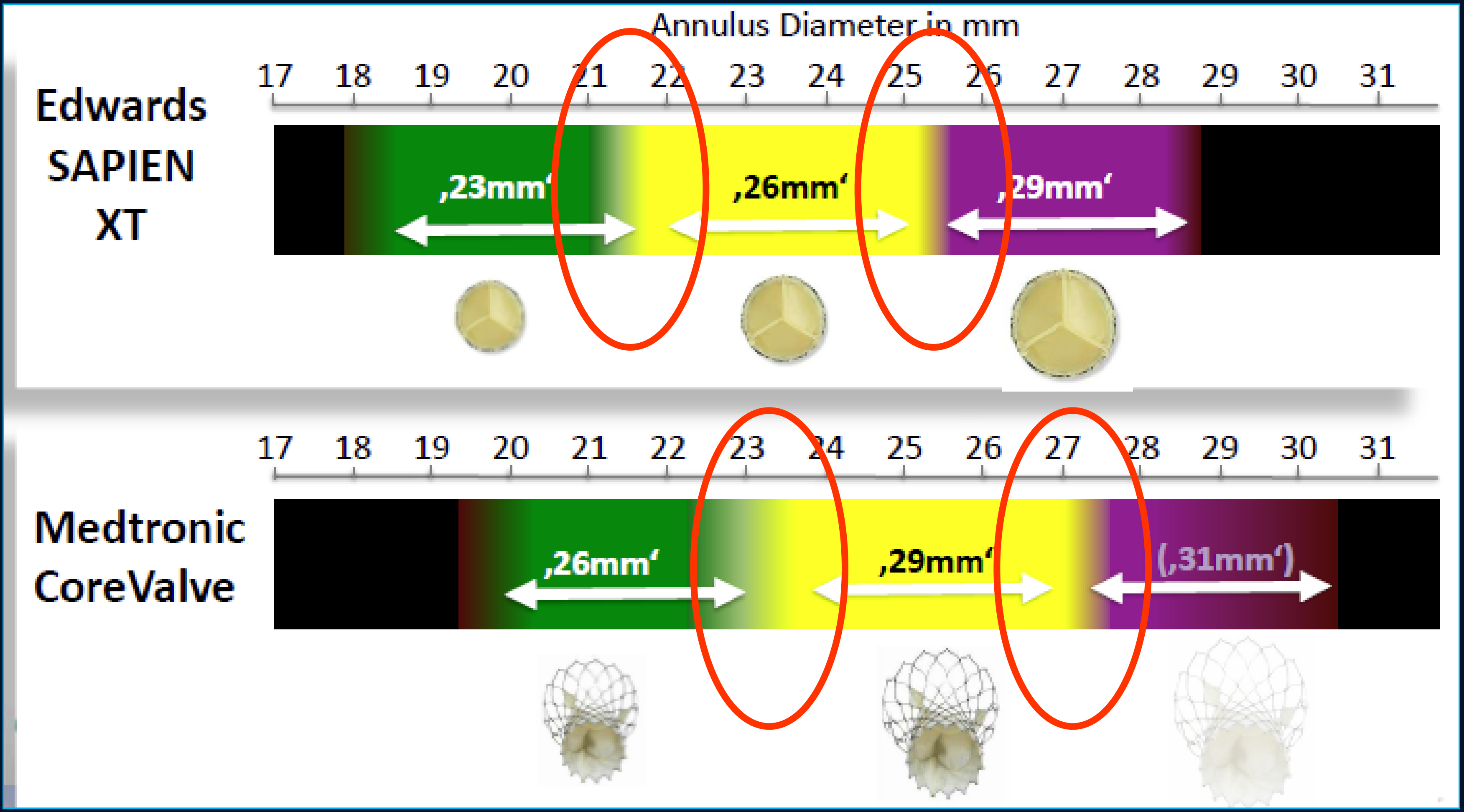
	Univariate		Multivariable	
	Odds Ratio (95%CI)	P value	Odds Ratio (95%CI)	P value
LVOT calcifications moderate/severe	6.03 (2.35-15.45)	<0.001	12.45 (2.97-52.15)	0.001
Prosthesis oversizing ≥ 20%	8.76 (3.19-24.09)	<0.001	23.17 (4.77- 45.71)	<0.001
Balloon post-dilation	9.00 (2.59-22.08)	0.001	10.40 (1.54-30.46)	0.016

Adjusted for gender, MDCT annular area, MDCT LVOT area, presence of MDCT LVOT moderate to severe calcification, presence of MDCT aortic valve moderate to severe calcification, presence of prosthesis oversizing ≥20%, MDCT SV maximal diameter, and balloon post-dilation.

Barbanti et al. Circulation 2013

Annular Sizing for TAVR

Measurement of Annulus Dimensions



CT Sizing for CoreValve

Valve Size	Diameter	Perimeter	Cover Index
31mm	29mm	91.1	6.45%
31mm	28mm	88	10.30%
31mm	27mm	84.8	12.90%
31mm	26mm	81.7	16.13%
29mm	27mm	84.8	6.90%
29mm	26mm	81.7	10.30%
29mm	25mm	78.5	13.80%
29mm	24mm	75.4	17.20%
26mm	23mm	72.3	11.50%
26mm	22mm	69.1	15.40%
26mm	21mm	66	19.20%
26mm	20mm	62.8	23.10%

Derived from Medtronic

CT Sizing for Edwards Valve

Annular Area (mm^2)	Edwards valve size (mm)
230 - 300	20
310 - 320	20 or 23
330 - 400	23
410	23 or 26
420 - 510	26
520	26 or 29
530 - 660	29

We need Additional Measurements

Kasel et al. JACC Imaging 2013

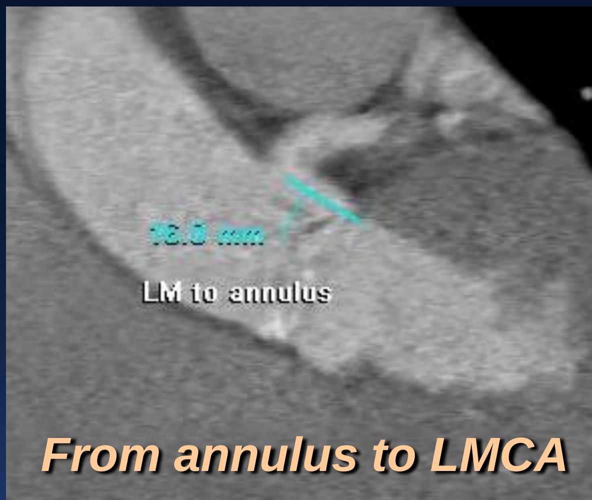
Impact of Underfilling on Expansion In Vitro

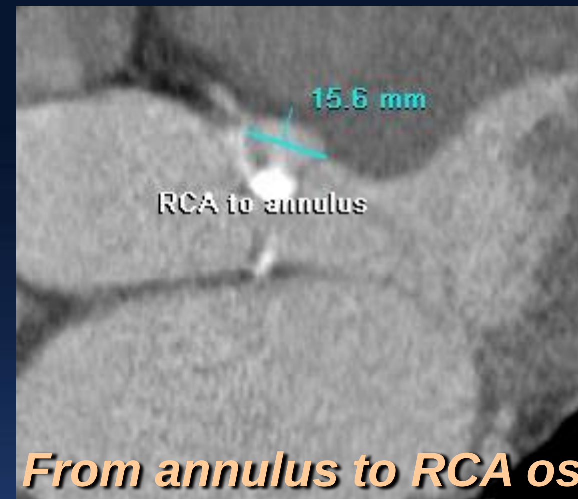
	Balloon volume	1 ml underfilled	2 ml underfilled	3 ml underfilled	4 ml underfilled
Novaflex					
20-mm THV	11 ml	-9.1%	-18.2%*	-27.3%*	-36.4%*
23-mm THV	17 ml	-5.9%	-11.8%	-17.6%*	-23.5%*
26-mm THV	22 ml	-4.5%	-9.0%	-13.6%	-18.2%*
29-mm THV	33 ml	-3.0%	-6.1%	-9.1%	-12.1%
Ascendra					
23-mm THV	16 ml	-6.3%	-12.5%	-18.8%*	-25.0%*
26-mm THV	20 ml	-5.0%	-10.0%	-15.0%	-20.0%*
29-mm THV	30 ml	-3.3%	-6.7%	-10.0%	-13.3%

Anatomic Implications for TAVI Imaging

- The aortic annulus is clearly a complex structure and requires imaging that can take into account its elliptical and irregular shape
- Single diameter sizing methods can provide misleading results
- 3D imaging can provide a more accurate representation of the aortic annulus

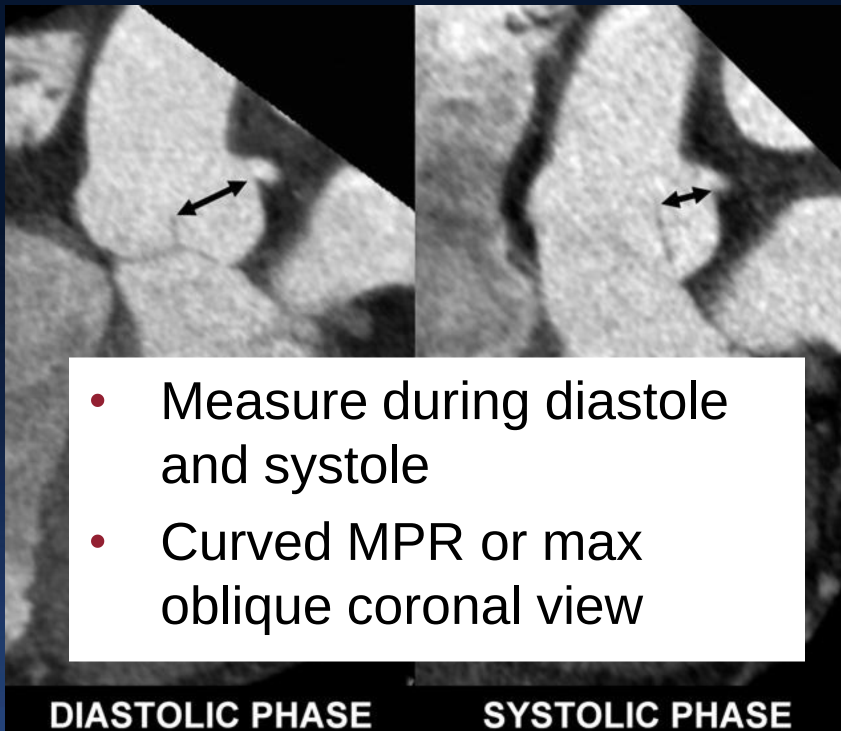
Aortic Root Anatomy and Distances

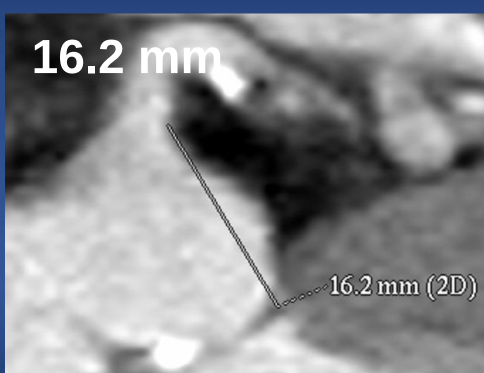


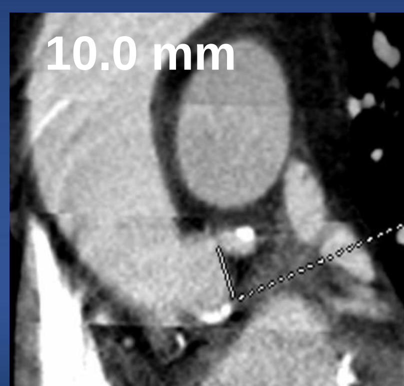


	Width	Height	For annulus diameter	Height of skirt
Edward SAPIEN XT™	23mm	14.3mm	18-22mm	10.1/7.74mm
	26mm	17.2mm	21-25mm	11.4/8.67mm
CoreValve Revalving™	26mm	53mm	20-23mm	12mm
	29mm	55mm	23-27mm	12mm

Left main height





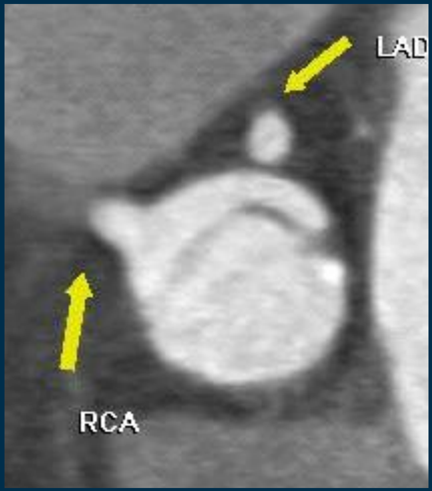


Potential Mechanisms of Coronary Ostial Obstruction

1. **Impingement** of ostia by THV support structure
2. **High positioning** of sealing cuff
3. **Embolization** of atheroma, calcium, thrombus, air or vegetation
4. **Oversizing** of THV
5. **Dissection** of aortic root
6. **Displacement** of native aortic leaflets towards coronary ostia

Recommended annulus to ostial height: > 10 mm for Sapien 23 and > 11 mm for Sapien 26

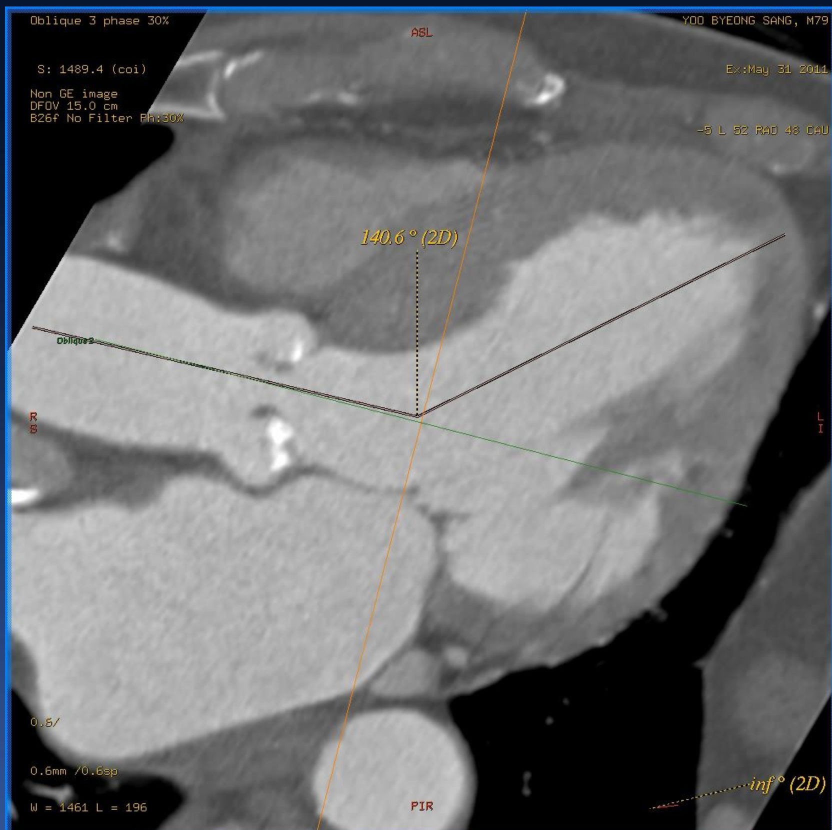
Coronary Height



Bicuspid AV

Right Coronary Artery

Navigator For Transapical Approach



Direction of Puncture or Wire

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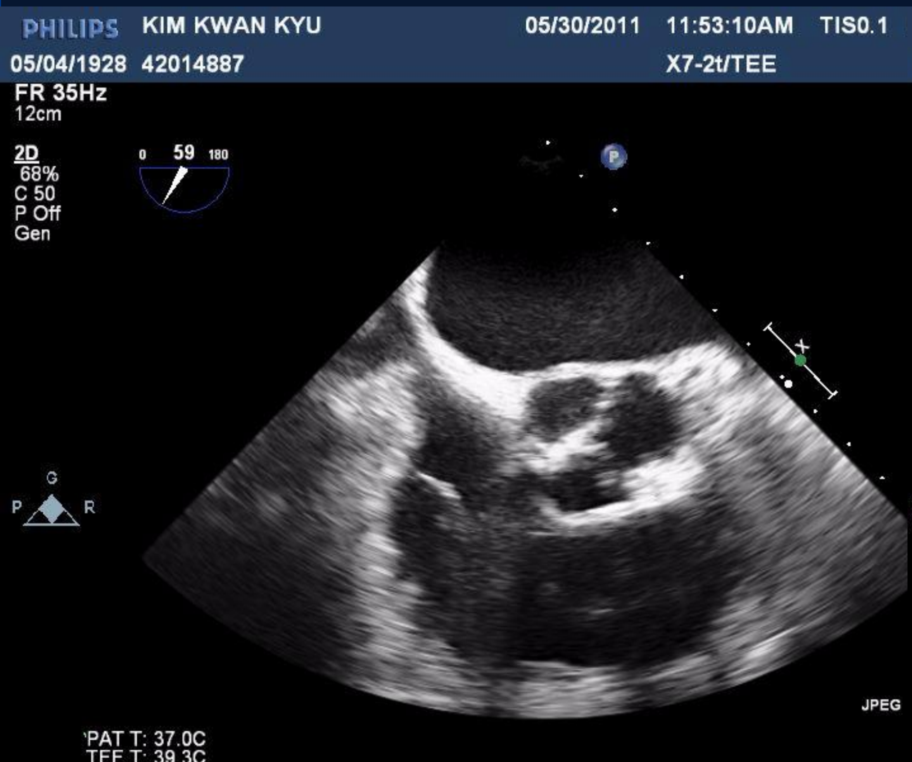
Aortic Valve Morphology & Amount of Calcium

Scanty calcium

Heavy eccentric calcium

Echocardiographic findings

Calcificated structure is enemy of Echo



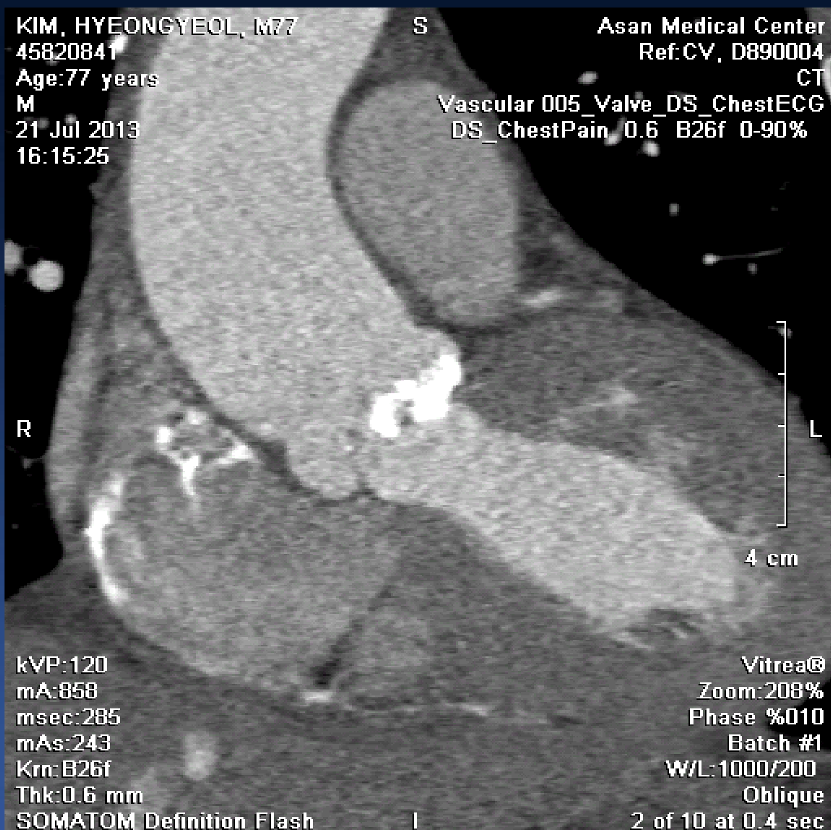
TEE

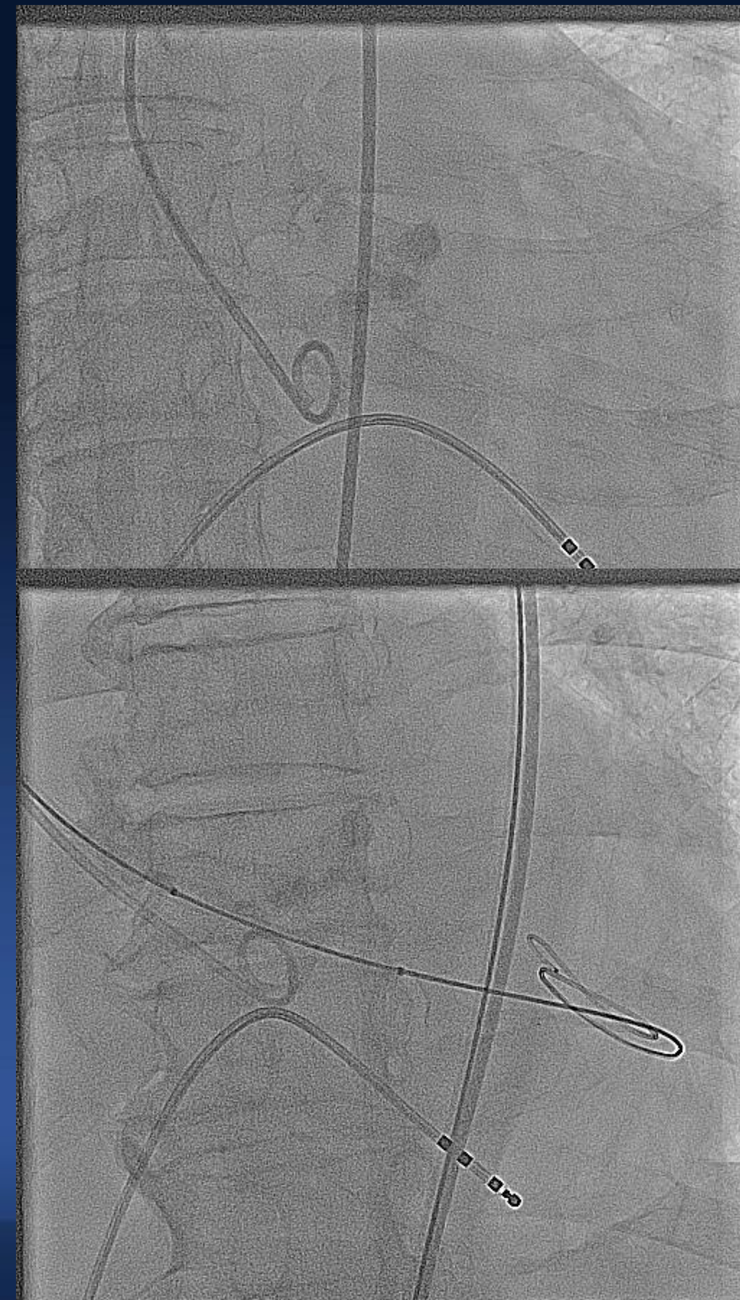
TTE

Amount of Cuspid Calcification

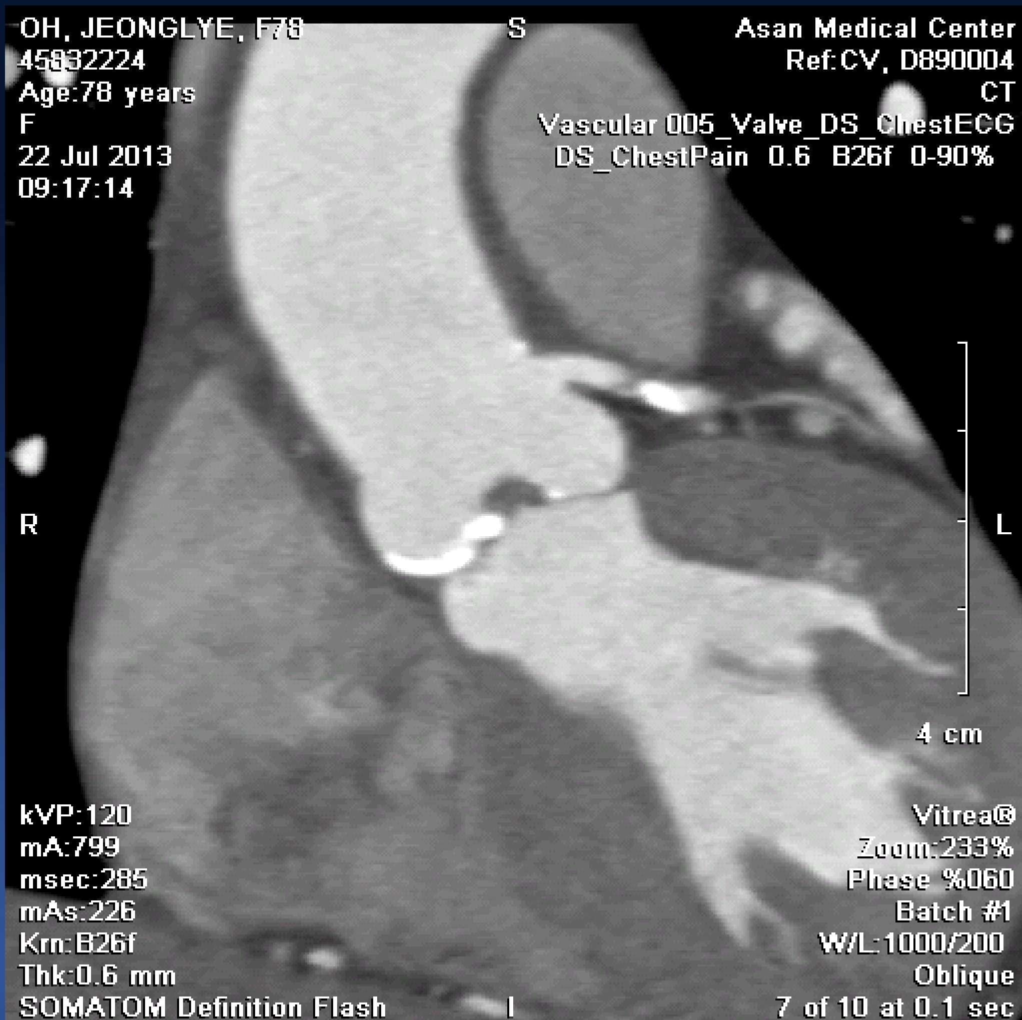
Scanty of Calcium **Heavy Eccentric Calcium**

Heavy Eccentric Calcium



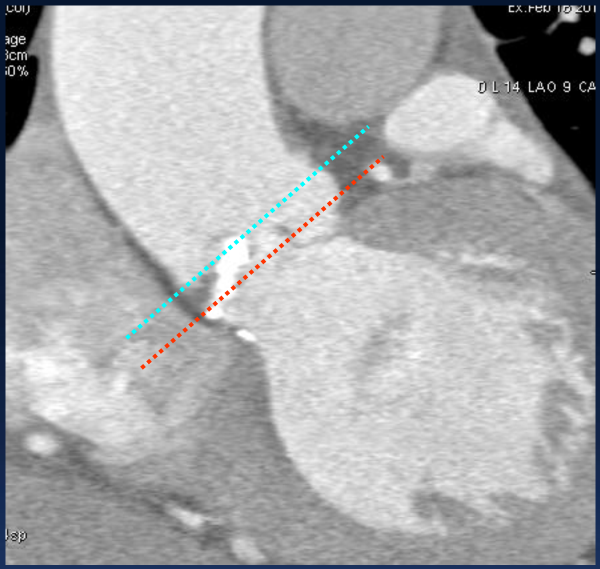


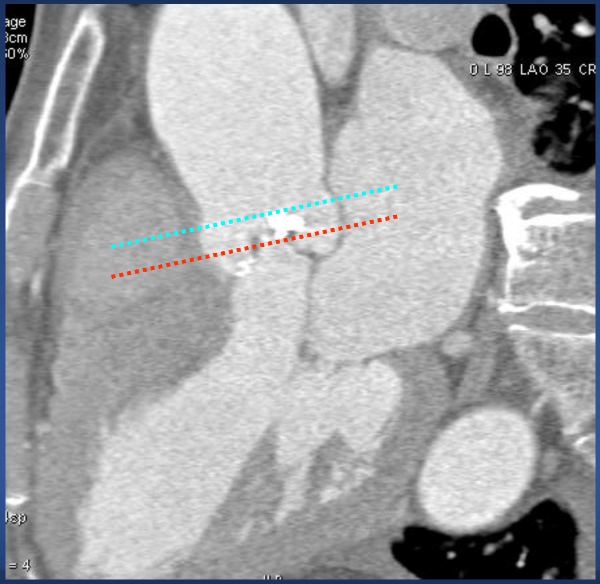
Heavy Eccentric Calcium

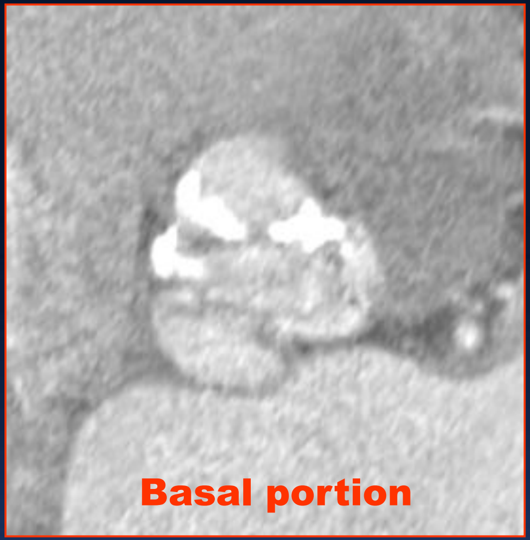


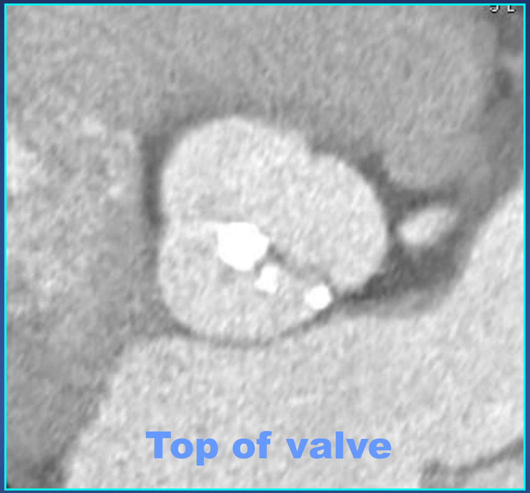
23 mm Edward Valve

Heavy Eccentric Calcium: Extent



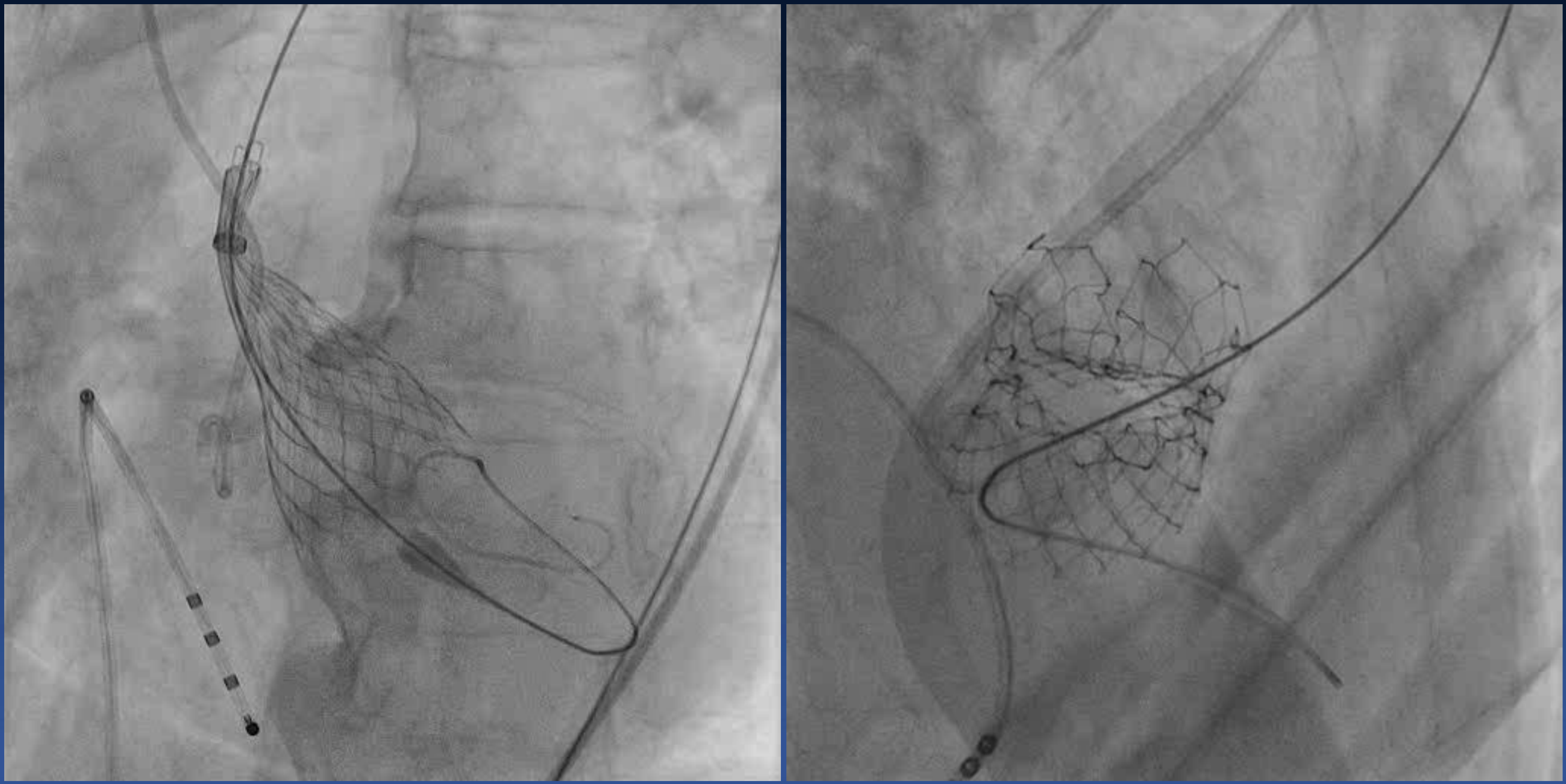




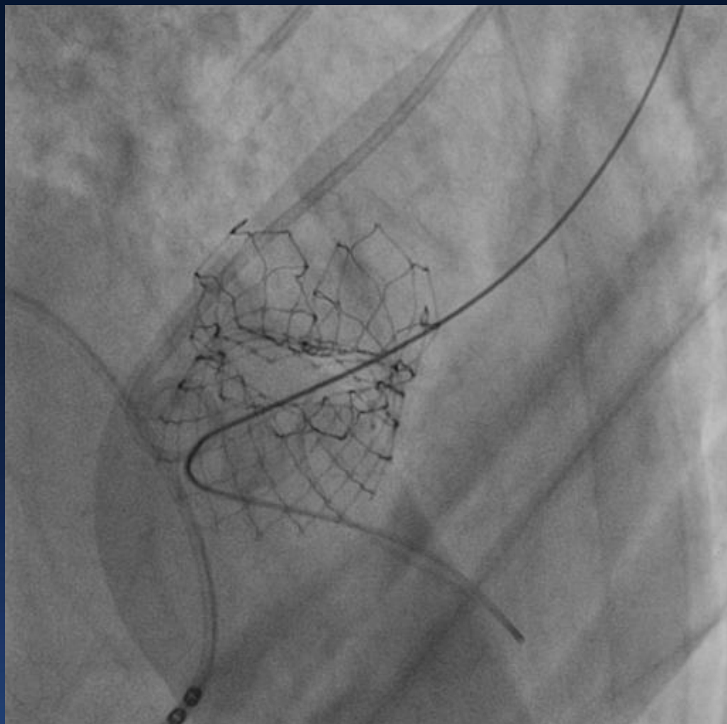


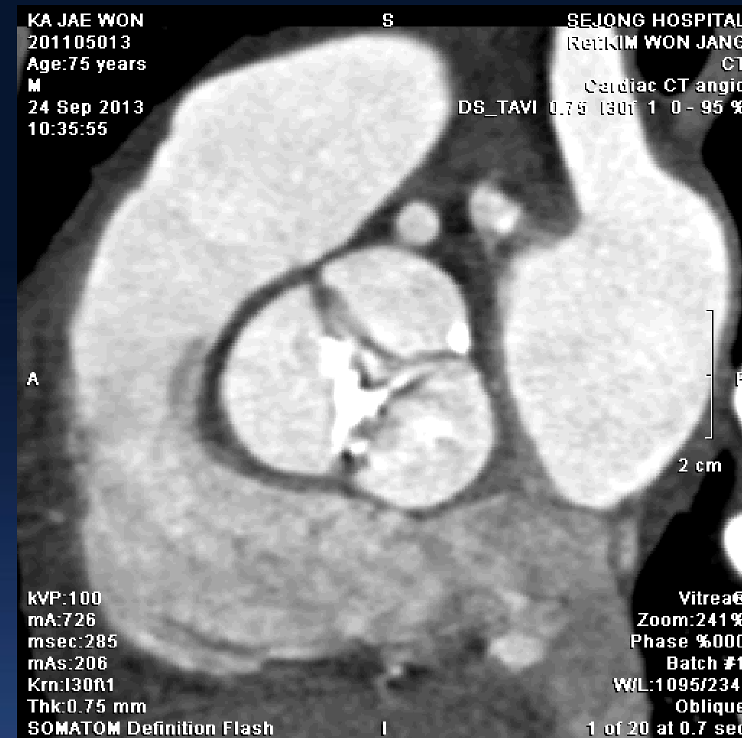
Made by Adw 4.5, GE healthcare system

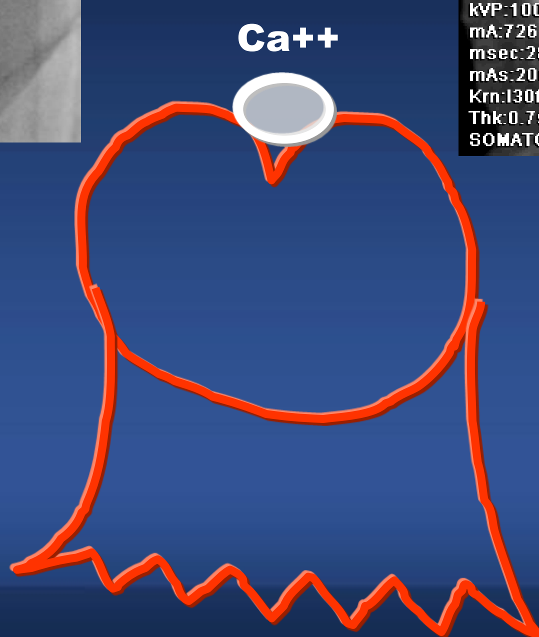
Folded Valve



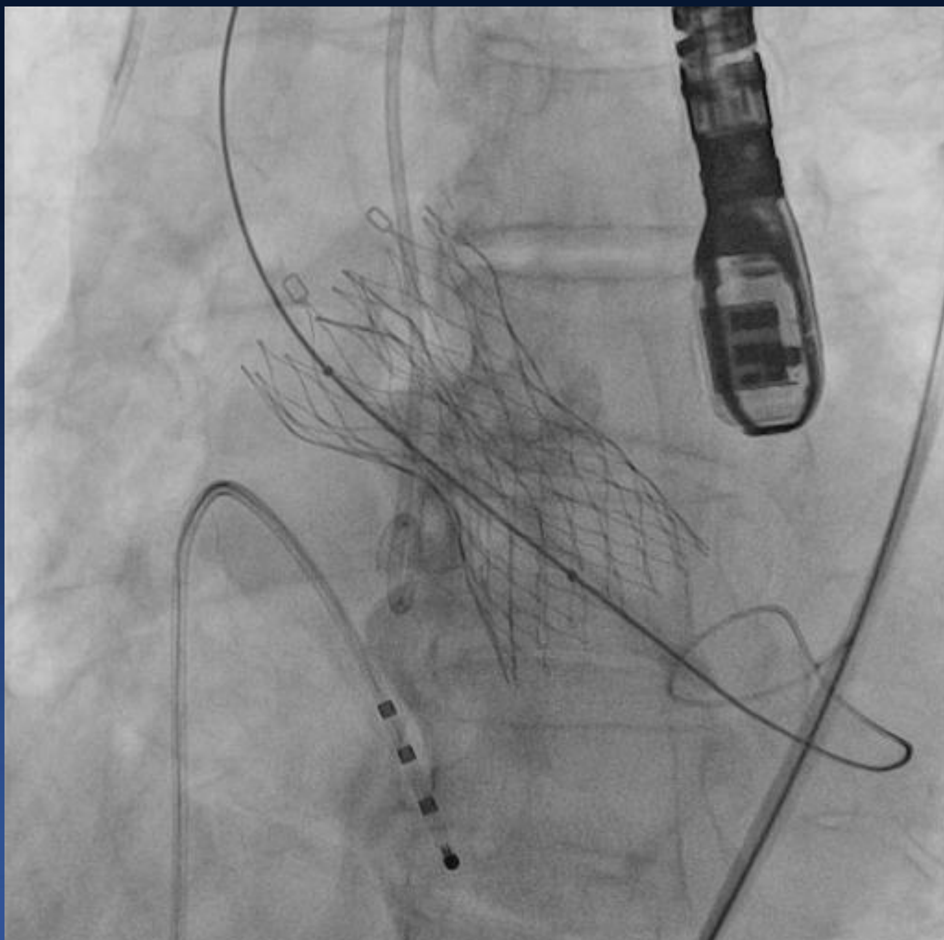
Folded Valve

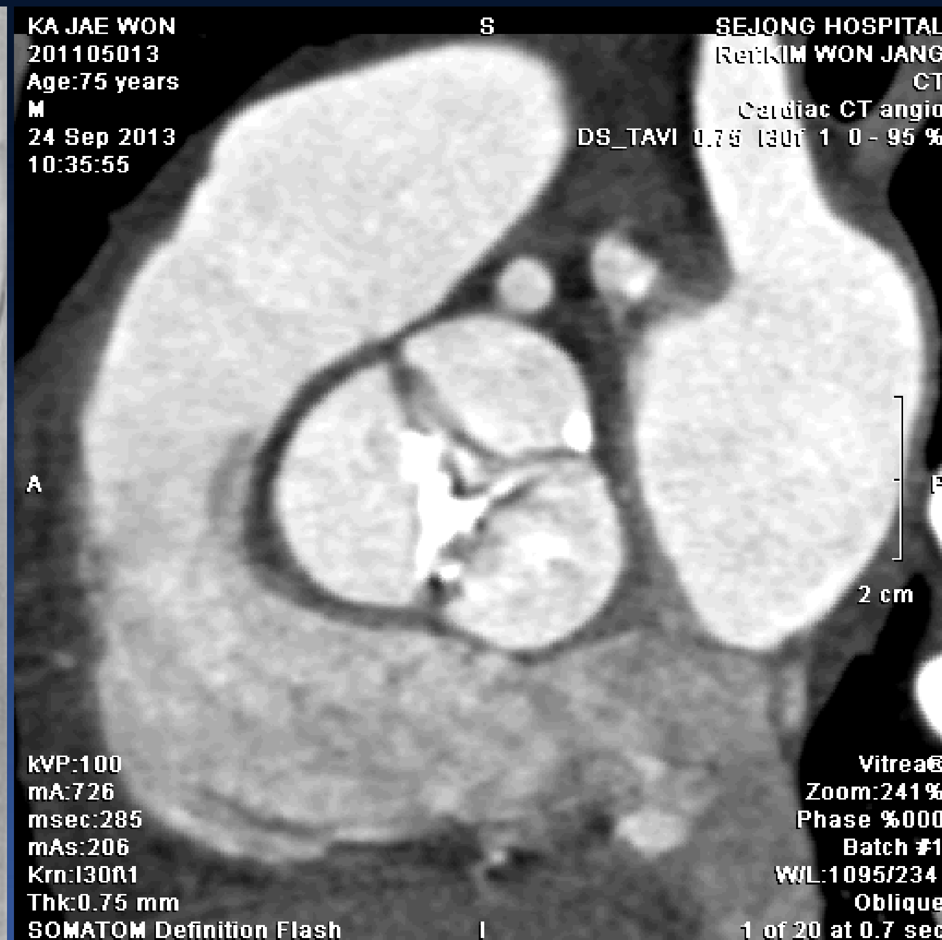




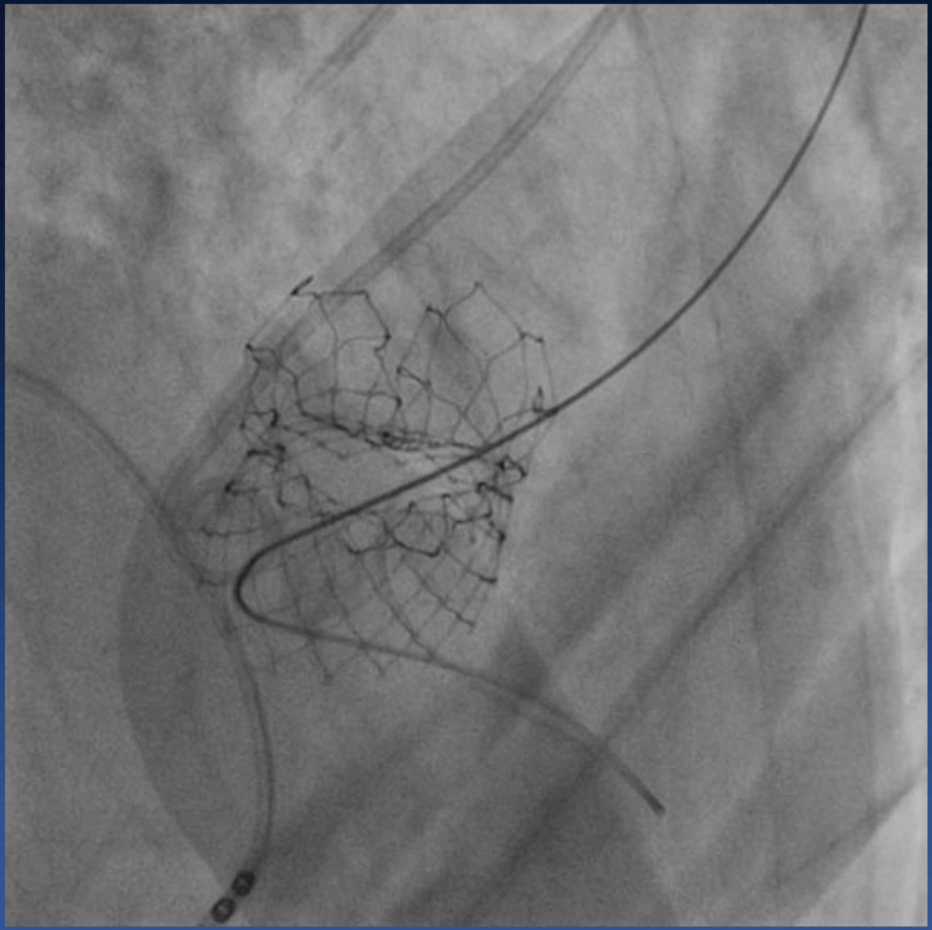


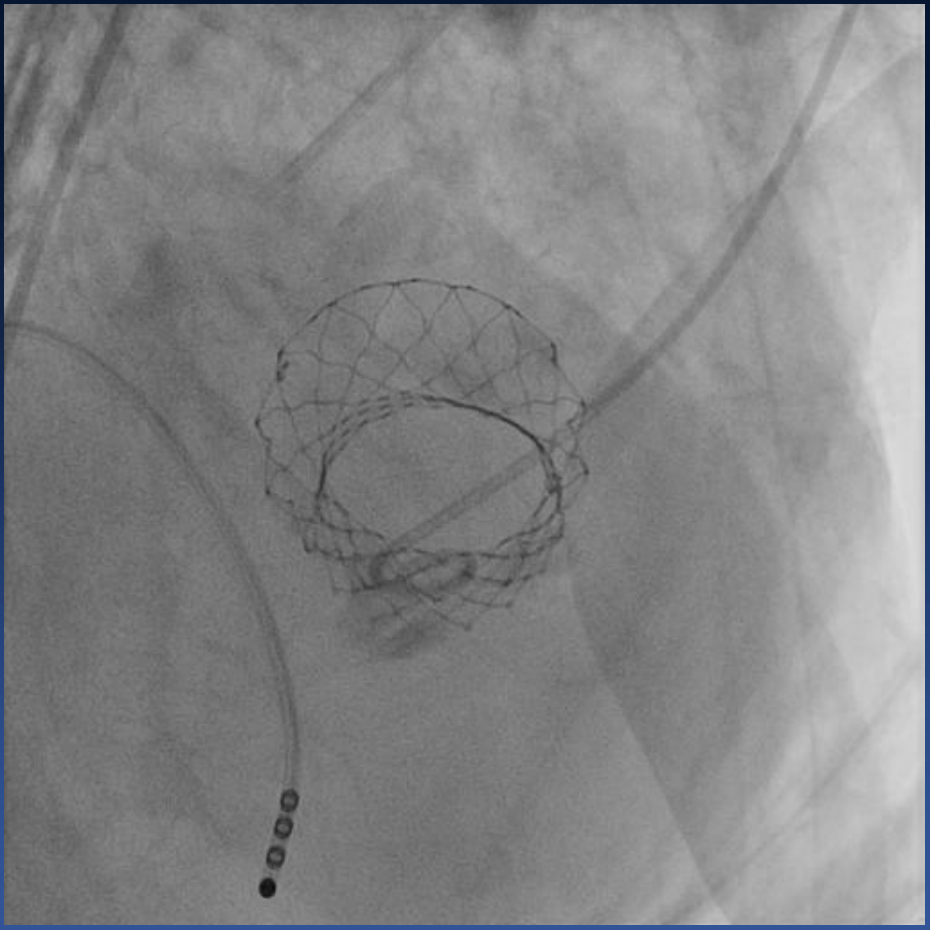
Folded Valve





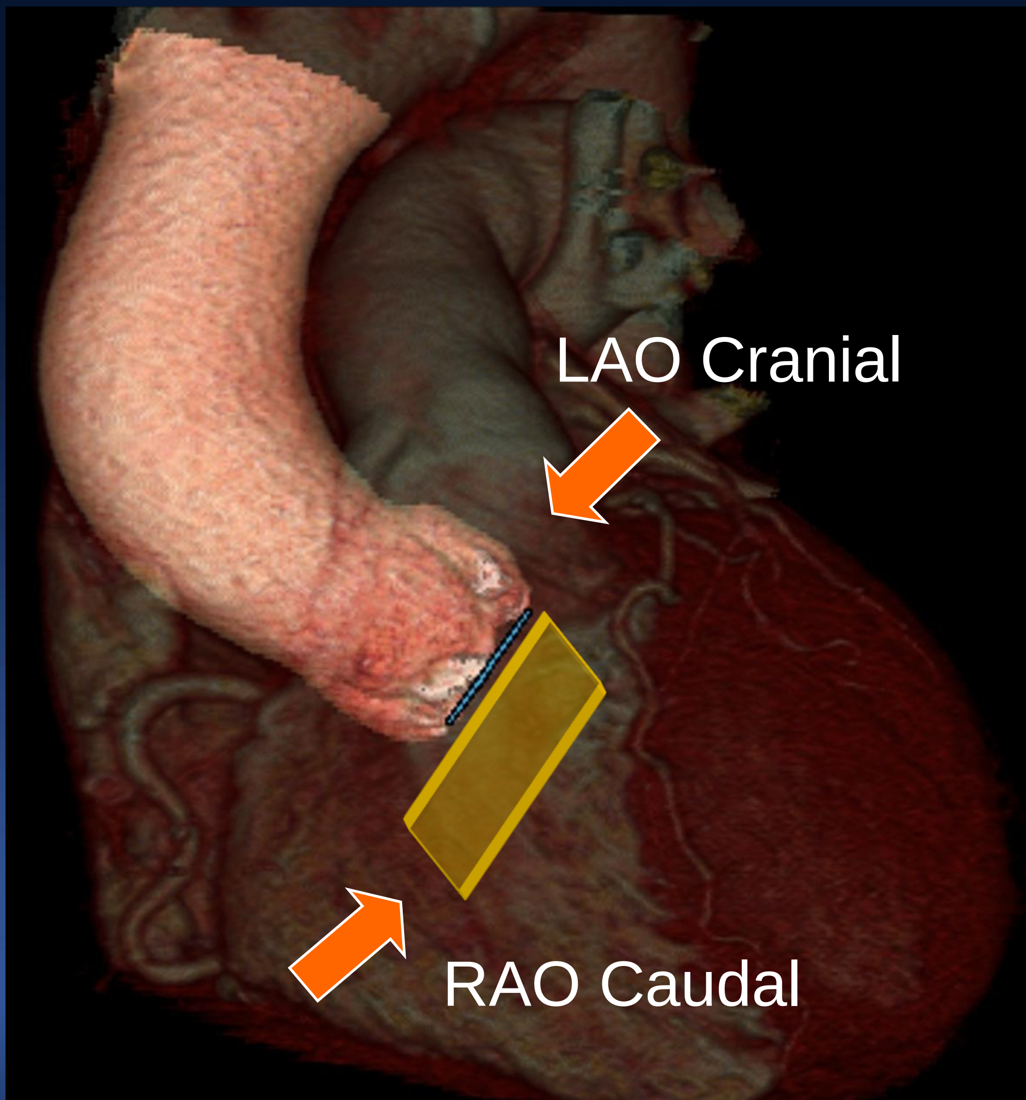
Folded Valve

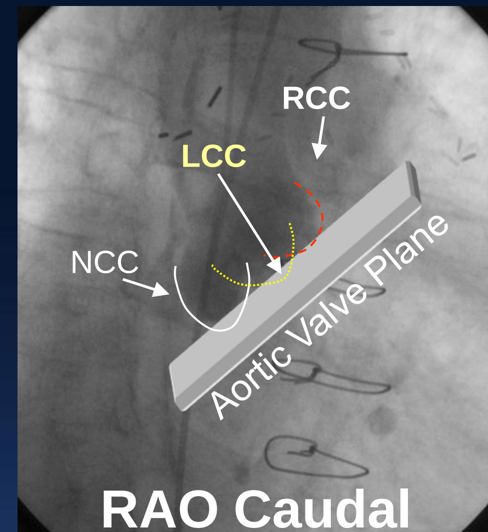


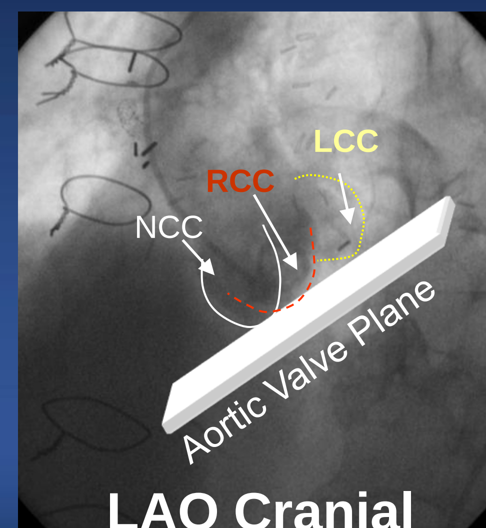


Valve positioning

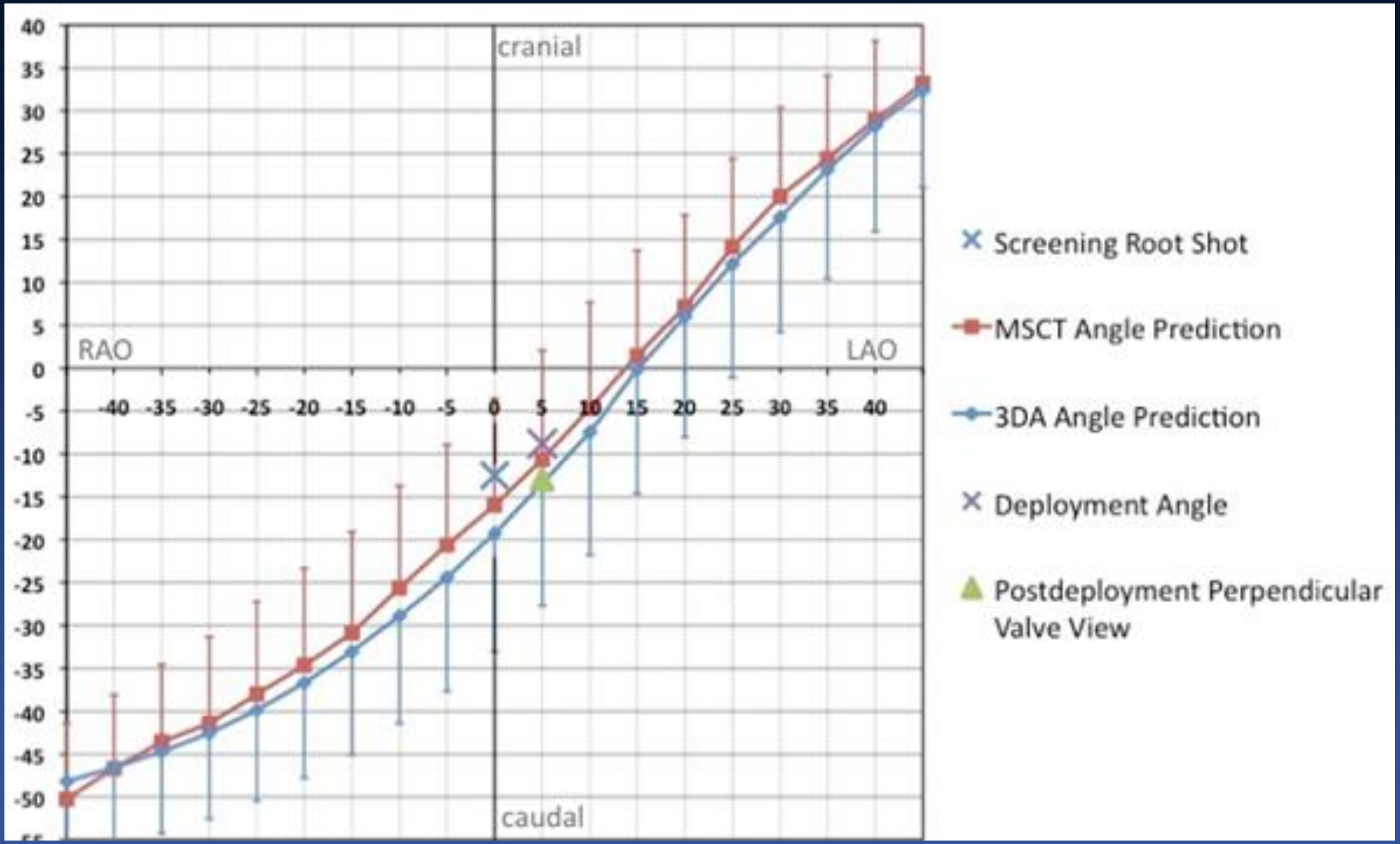
Aortic Valve Plane by CT Scan





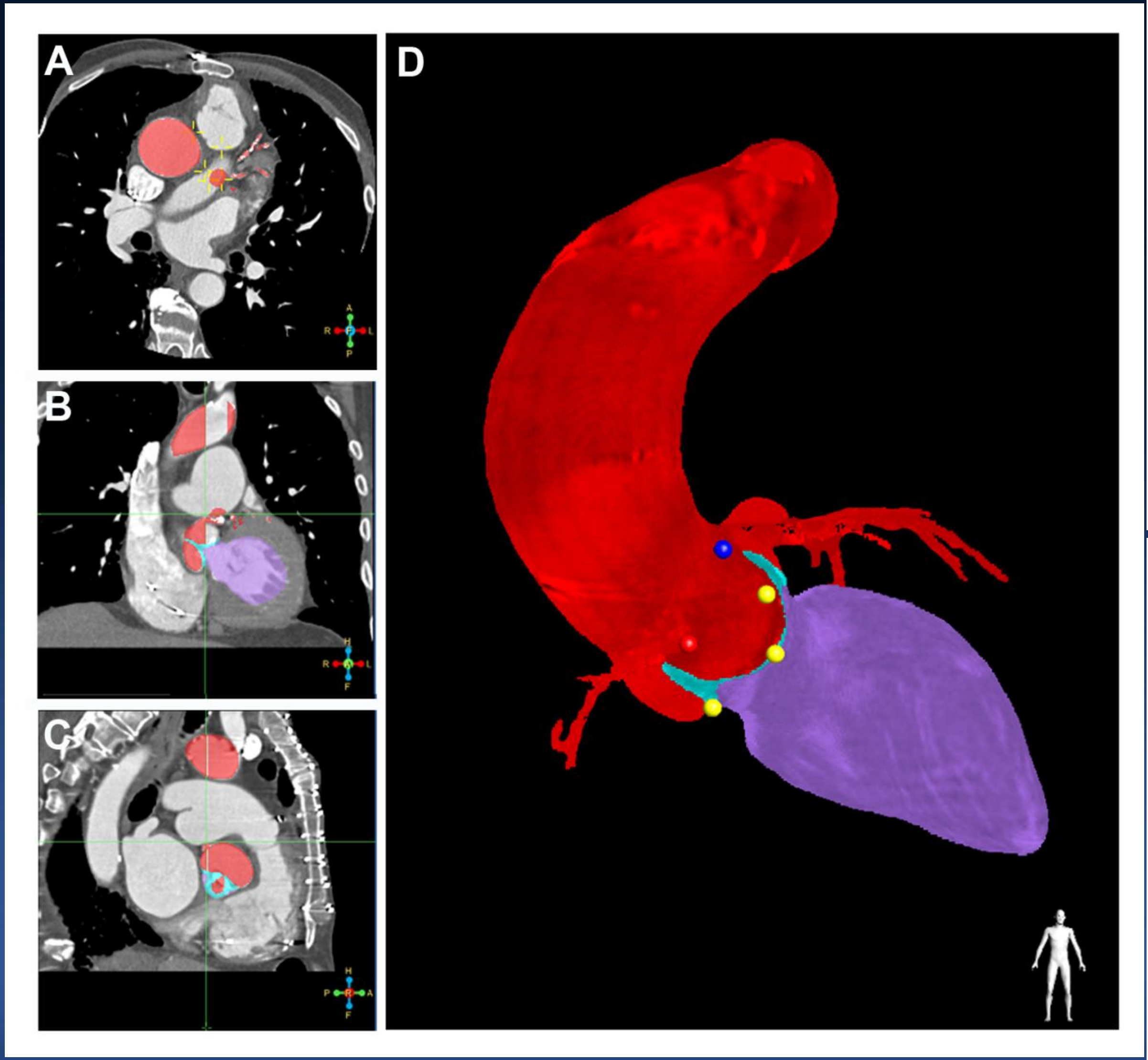


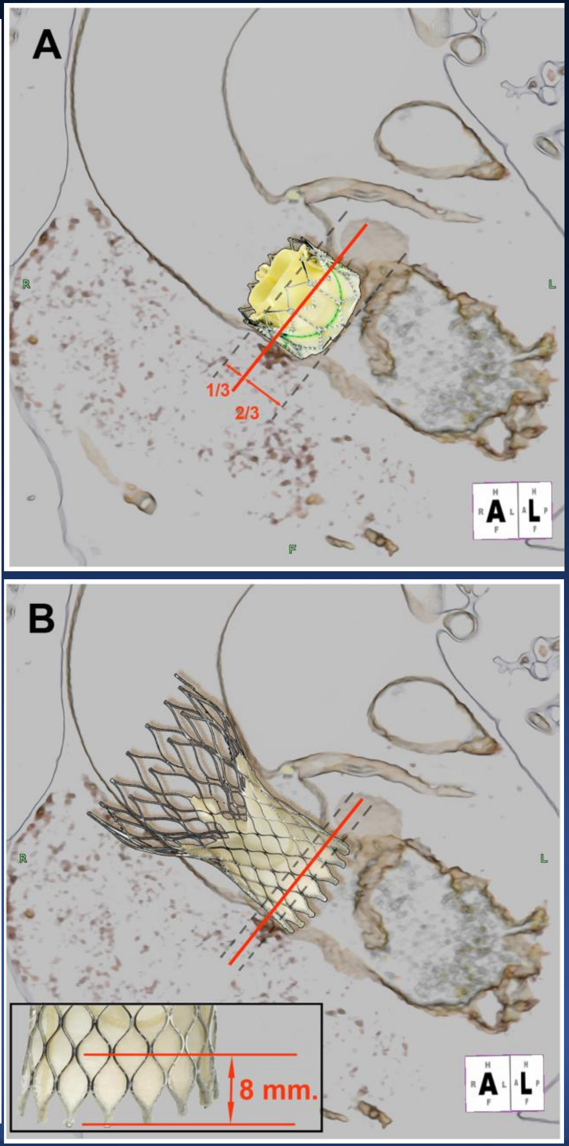
CT vs 3-D Angio CT for Angle Prediction



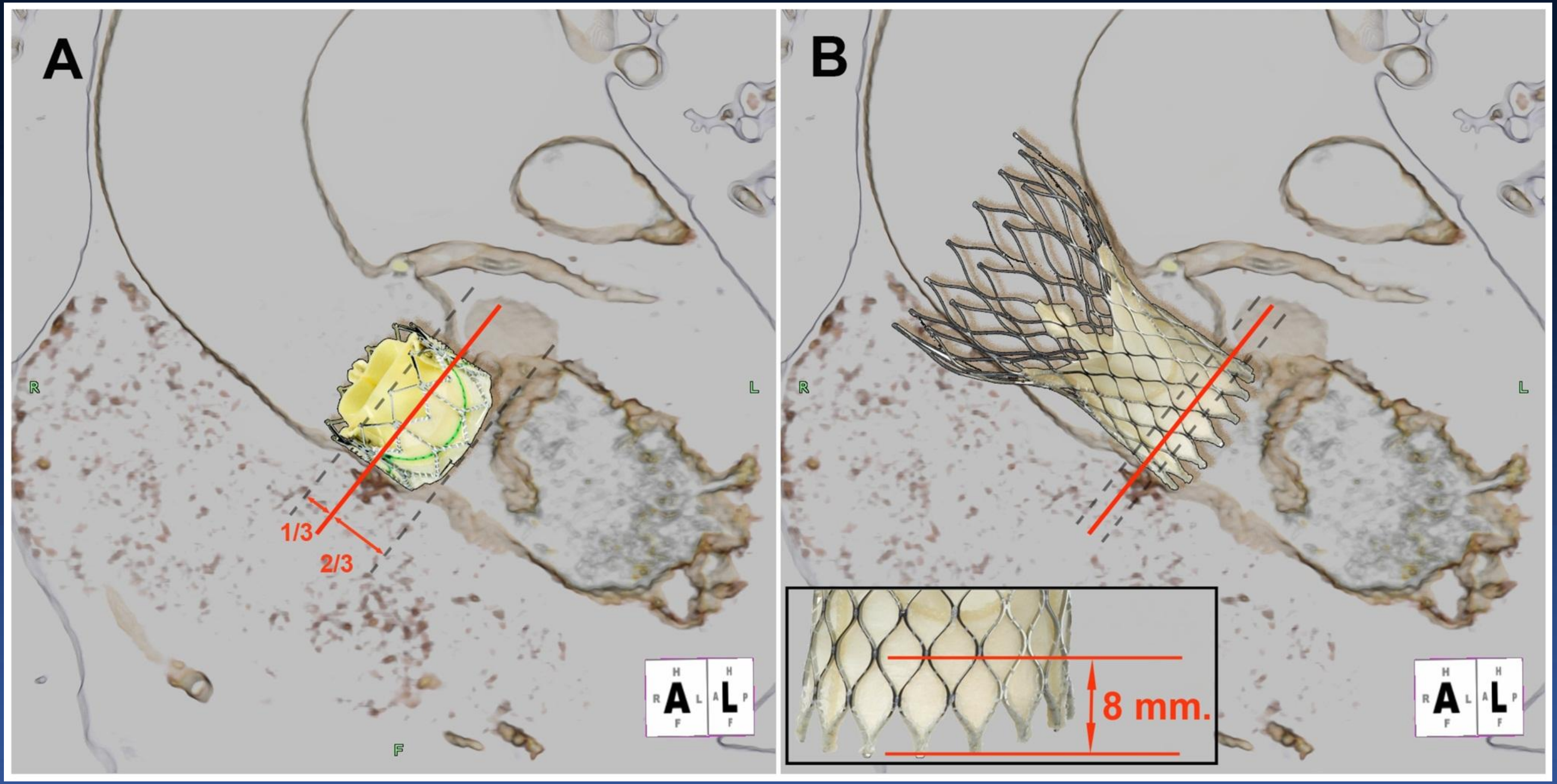
Binder et al. TCT 2011 , Circ Interventions April 2012

Valve Placement



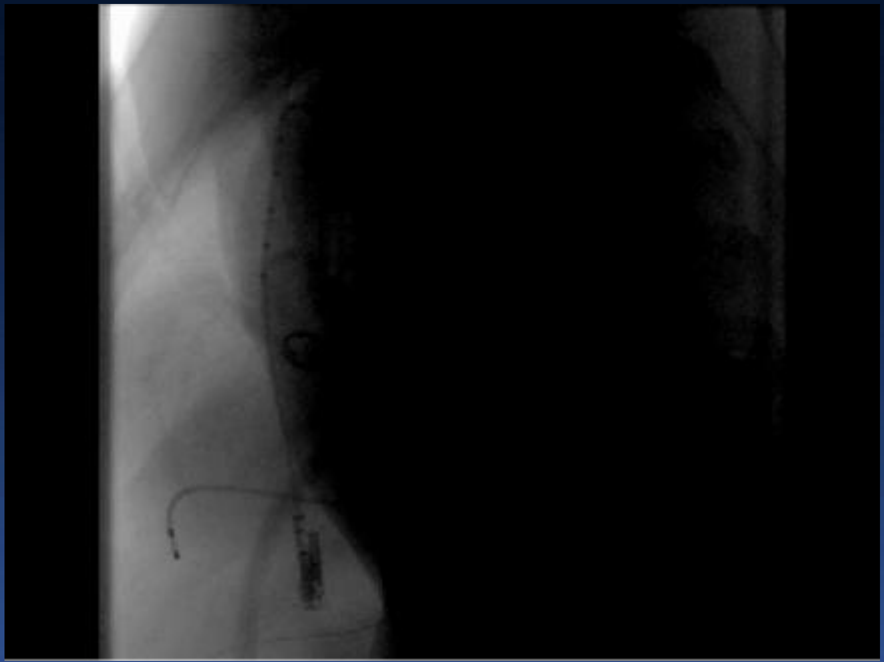


Assisting with Valve Positioning



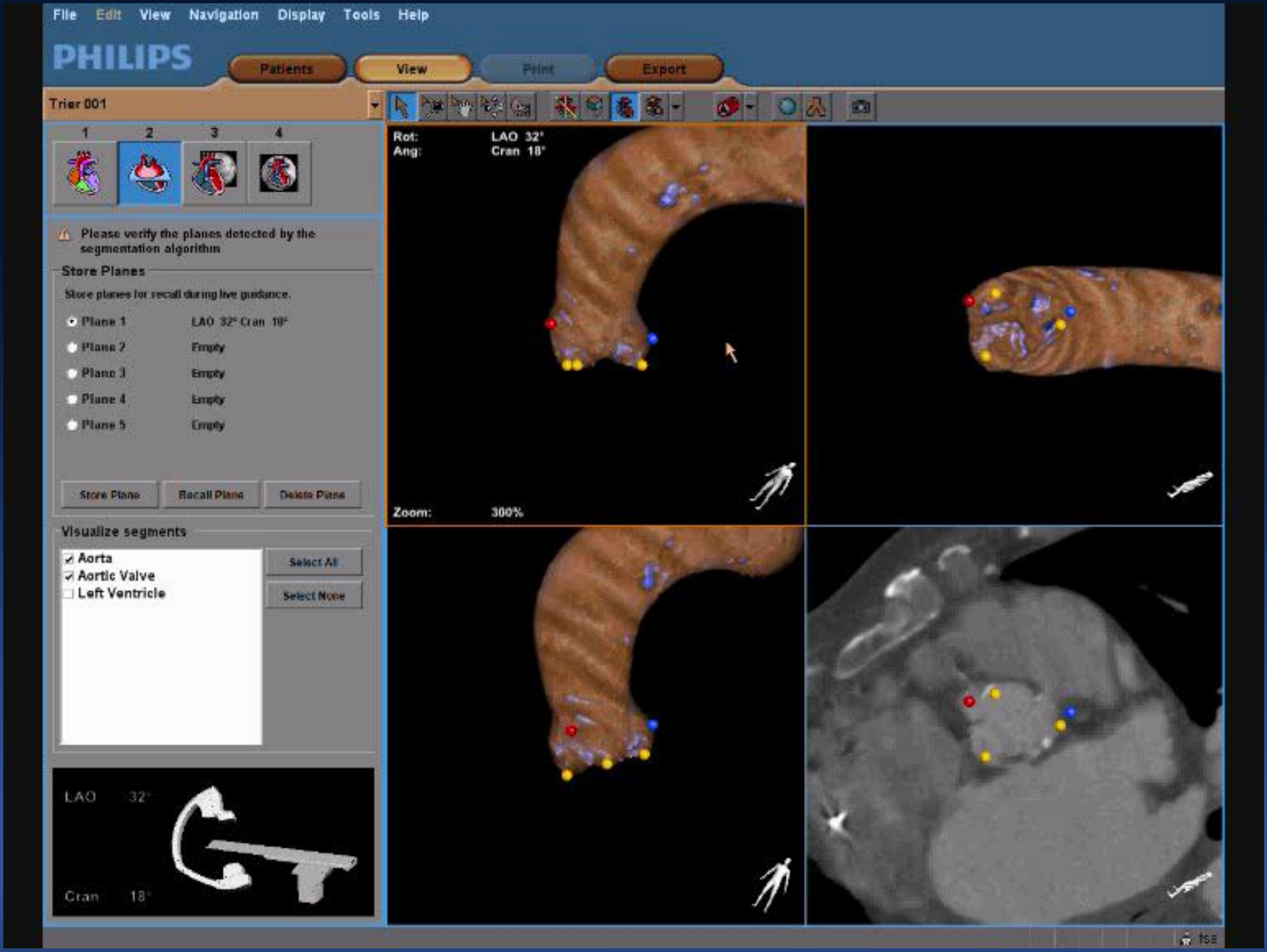
Courtesy of Dr C Ruiz

DynaCT Image Acquisition with rapid pacing



Courtesy Siemens Systems

Merged Imaging Tools



Philips Heart Navigator

Valve deployment under DynaCT

Edwards SAPIEN

CoreValve

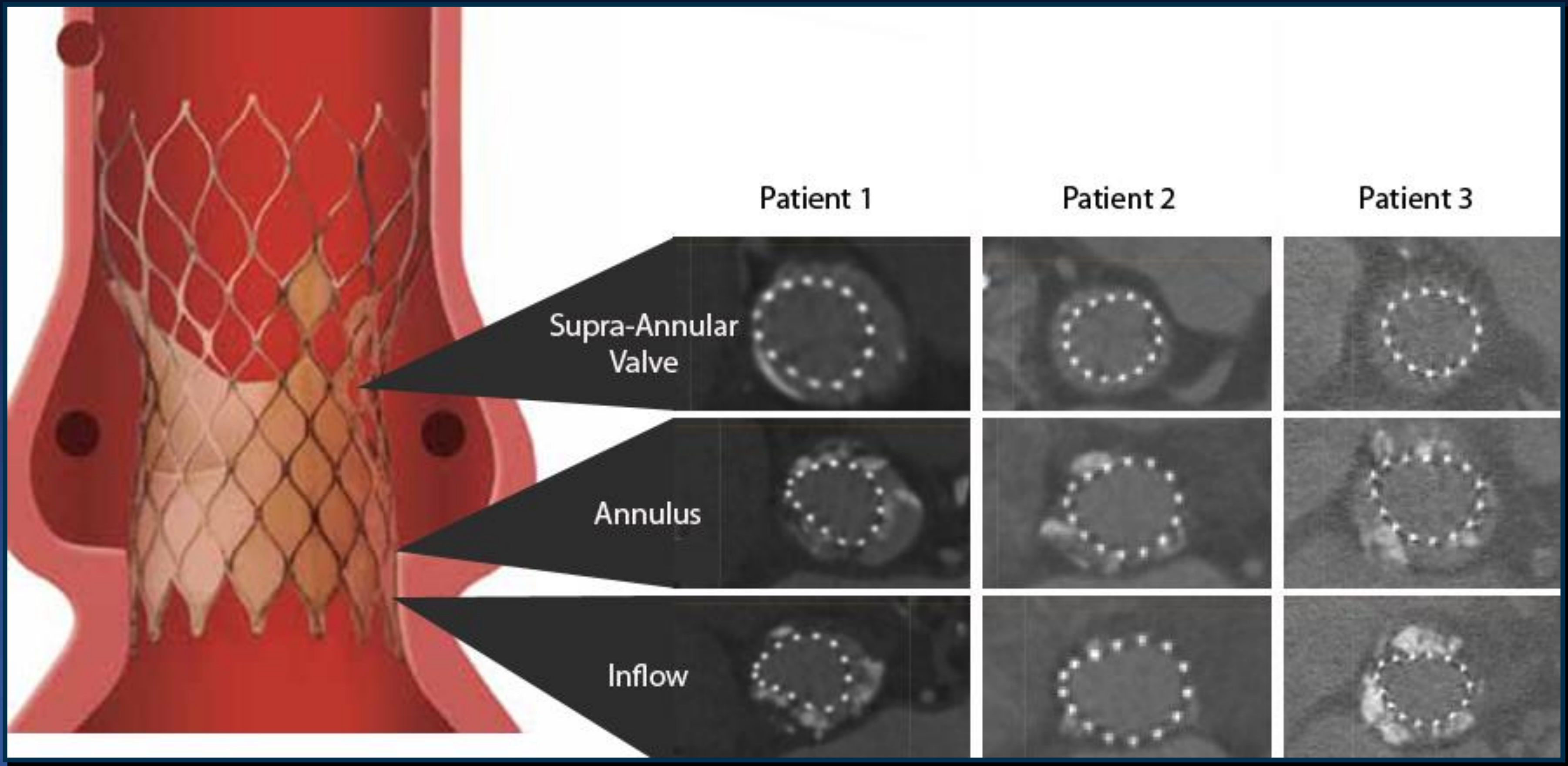
Courtesy by Alois Nöttling Siemens

Courtesy by Brockmann German Heart Center Munich

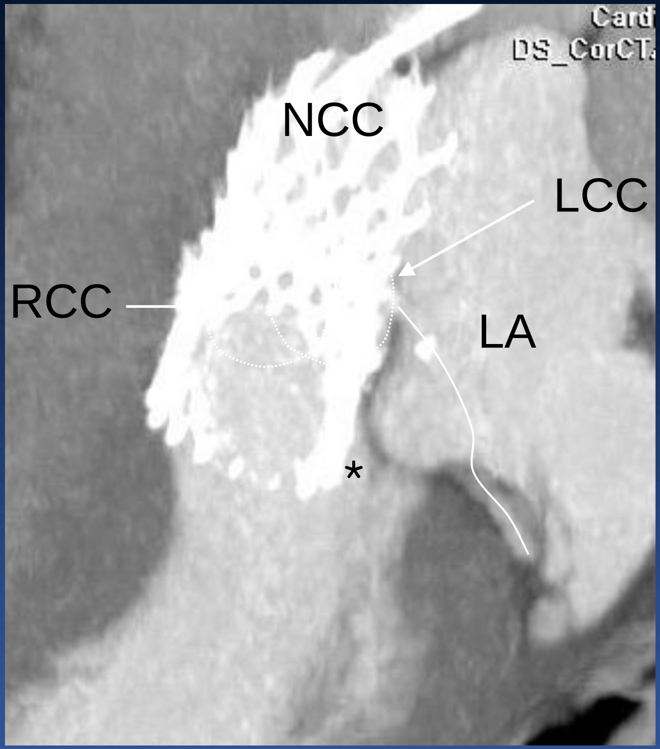
Follow up evaluation

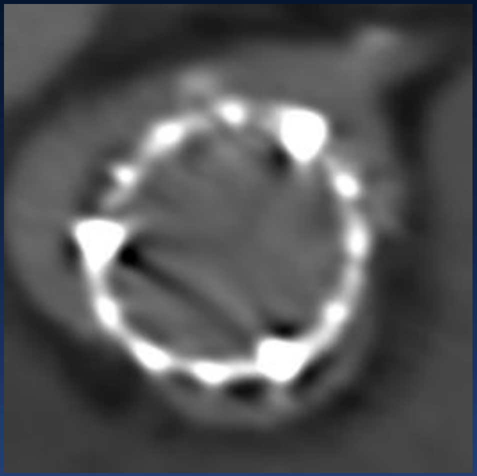
Examples of Conformability

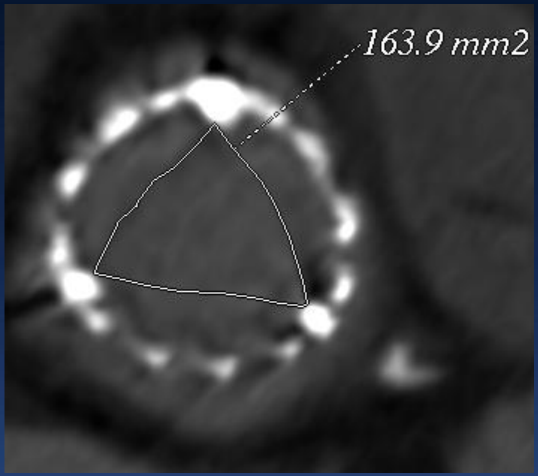
CoreValve Cases



Follow Up Image







No Valve Migration, Fracture, Circumferentiality

Deep Implantation, but No PPM
No contact in Node

Roles of CT in TAVI

- Ileofemoral Arterial Sytem :
  Size, Calcification, Tortuosity, Plaques
- 3D annular & root morphology & dimensions
- Amounts of calcium in valve
- Annular Sizing
- Relationship of annulus to both coronary ostia
- Optimal angle (TF) or puncture site (TA)
- Merging Image during Implantation
- Post TAVI assessment