3D reconstruction of coronary bifurcations using fusion of IVUS and MSCT

Jolanda Wentzel

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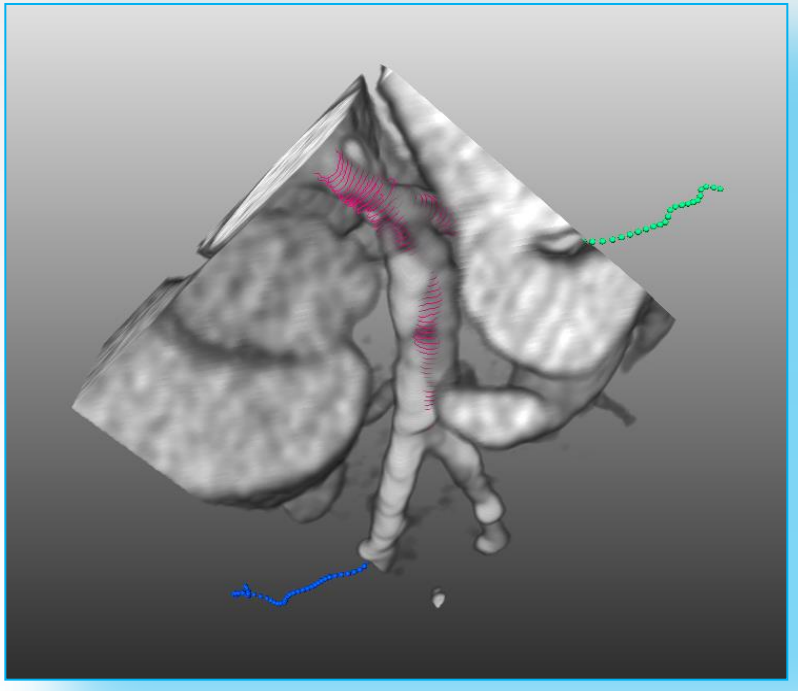


9th European Bifurcation Club meeting - London, UK - 18th & 19th October 2013

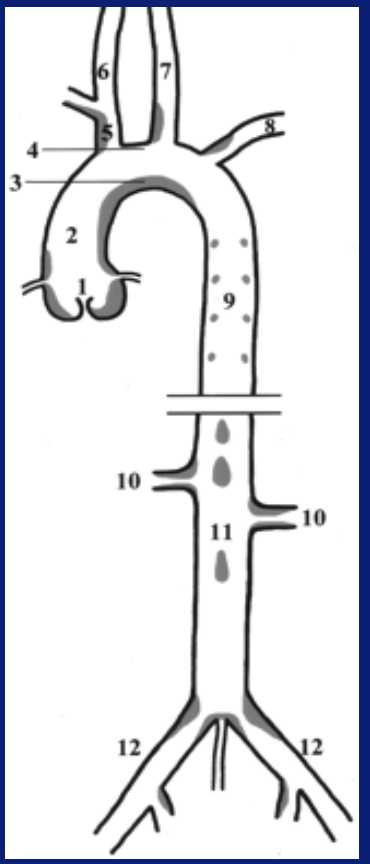
Wall shear stress (WSS)

Despite systemic risk factors, atherosclerosis is localized at specific places in the vascular bed

Low wall shear stress (~1 Pa) is the localizing factor

Wall shear stress is the friction force of the blood along the vessel wall

Also in the progression of atherosclerosis WSS might be an important factor



Bron: Vanderlaan- ATVB ‘04

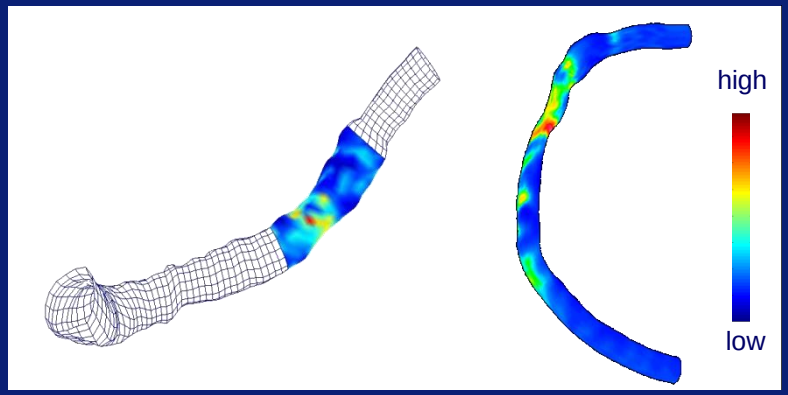
Modeling

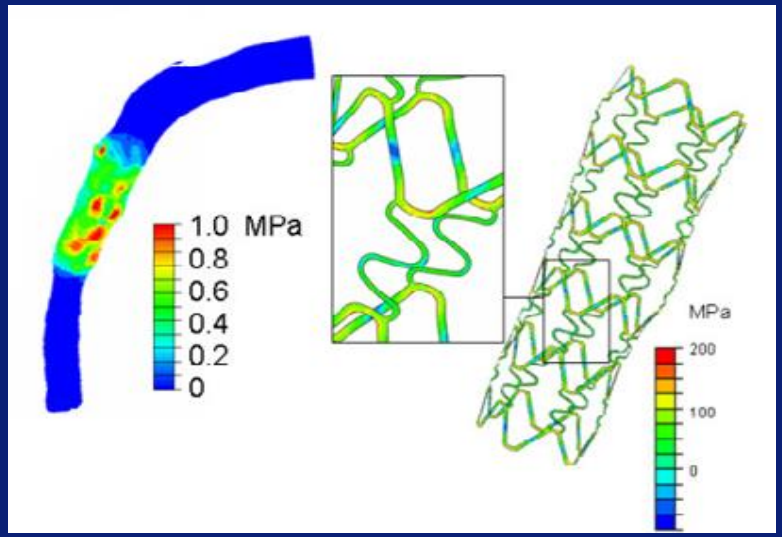
Modeling of

- Shear stress
- Wall stress
- Stent deployment

requires geometry

of lumen and vessel all





3D reconstruction based on fusion MSCT and IVUS

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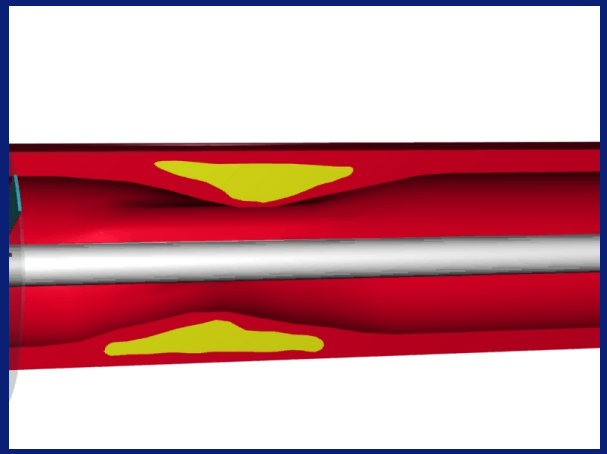

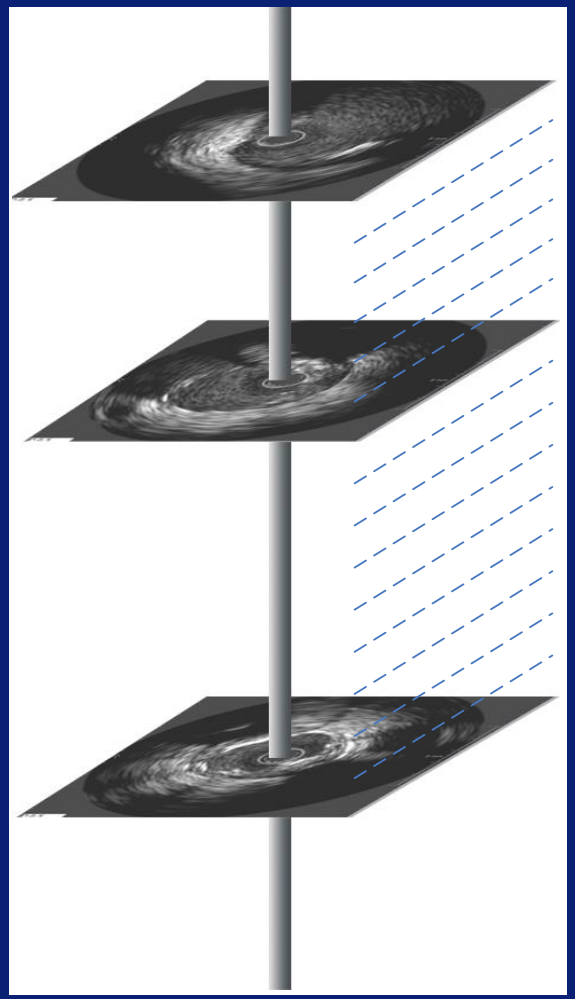

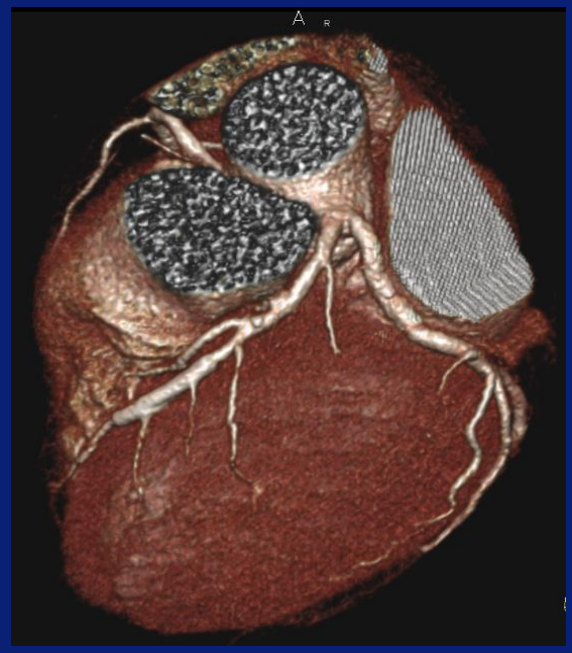

Intravascular ultrasound provides lumen and wall information

3D Shape of lumen

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Centerline determination

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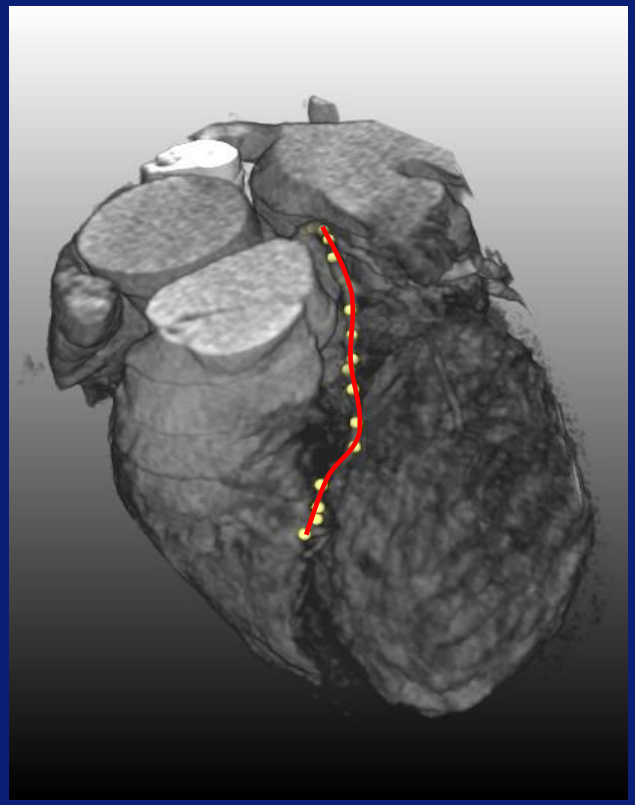
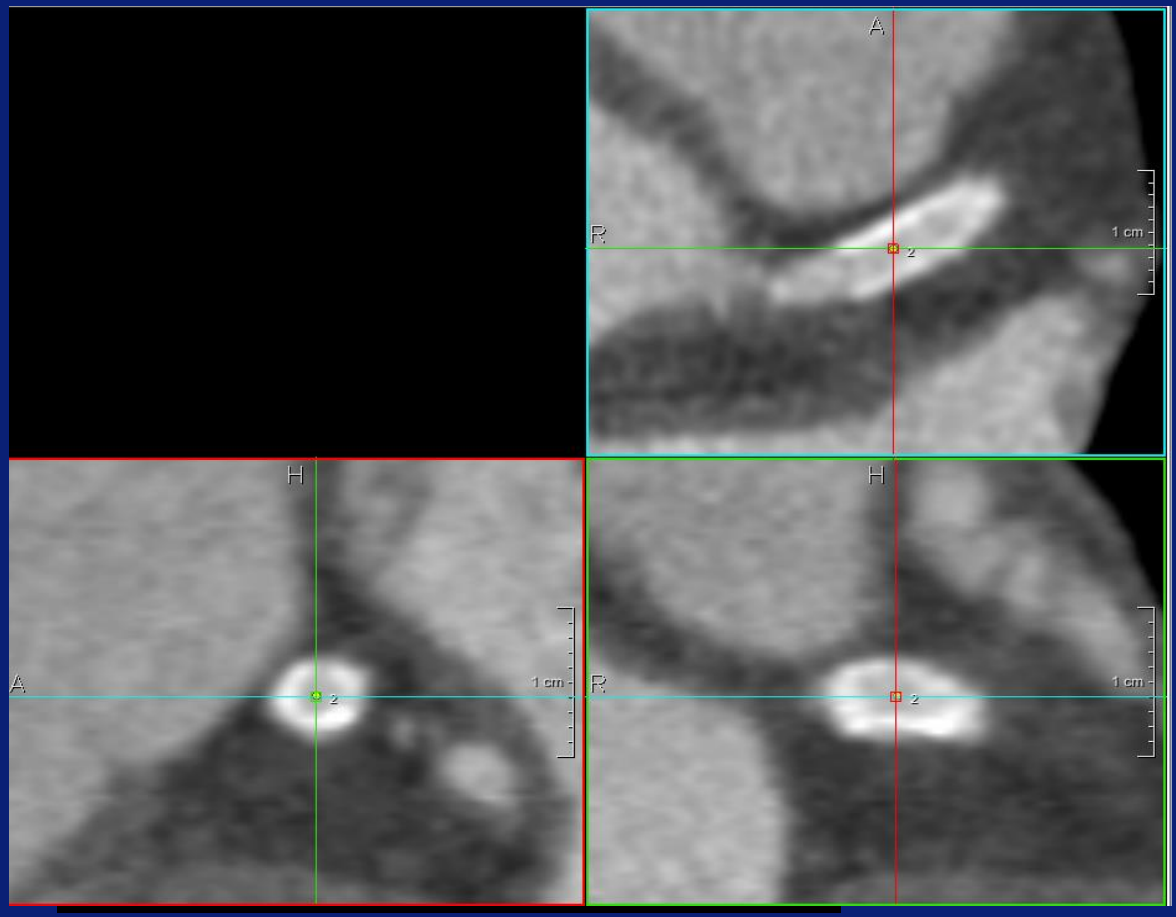
Centerline in MSCT





IVUS-MSCT registration

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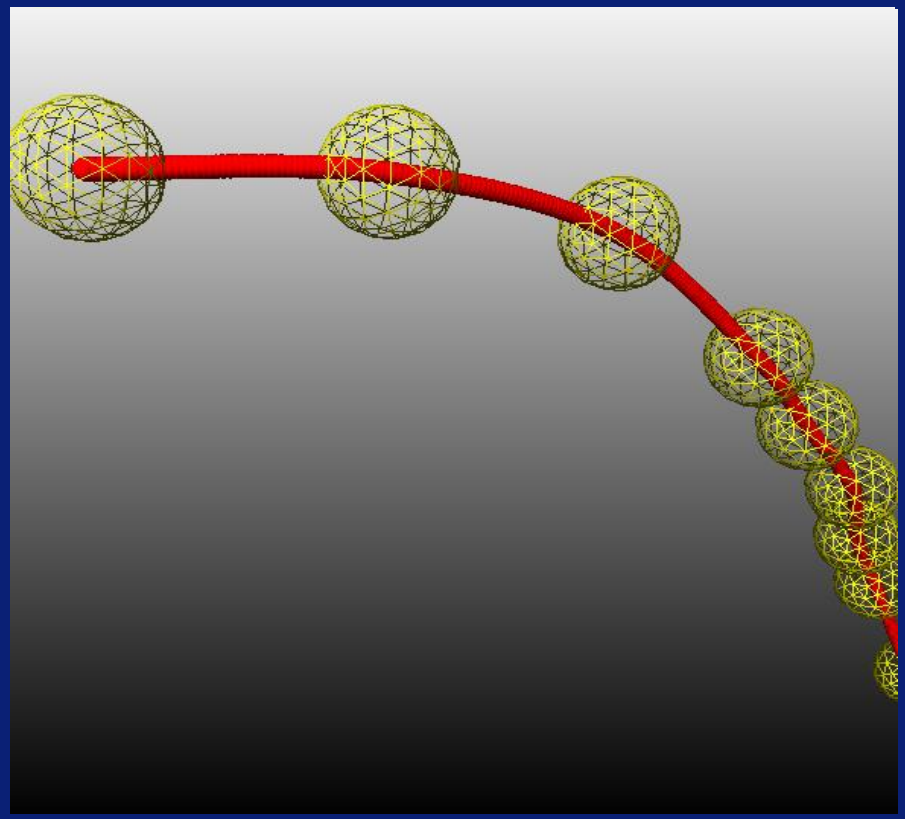
Reconstruct cross-sections

- Smooth centerline
- Resample equidistant
- Distance = 0.2 mm
- Perpendicular



3D reconstruction : registration & IVUS orientation

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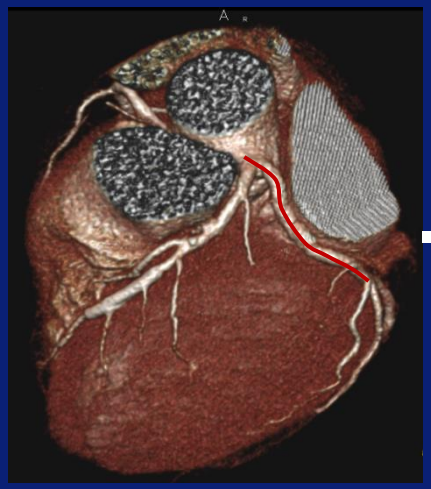

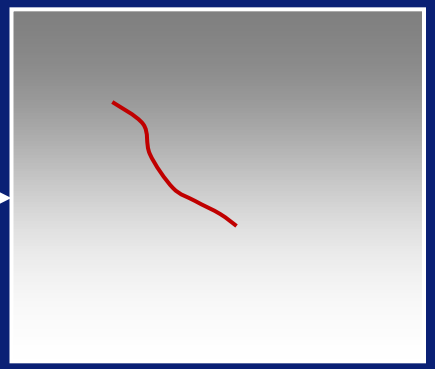

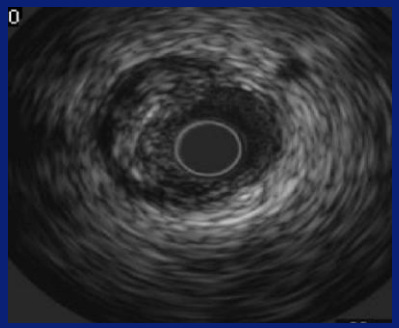

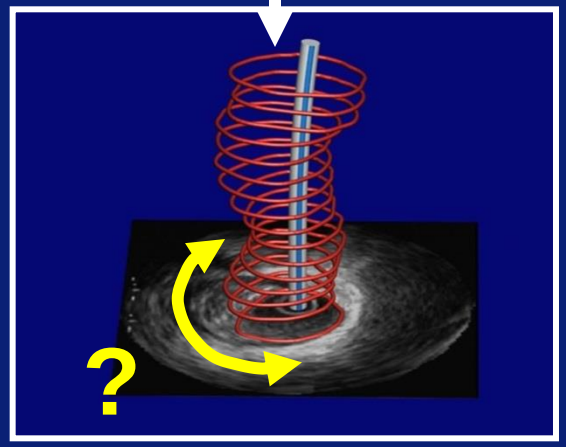

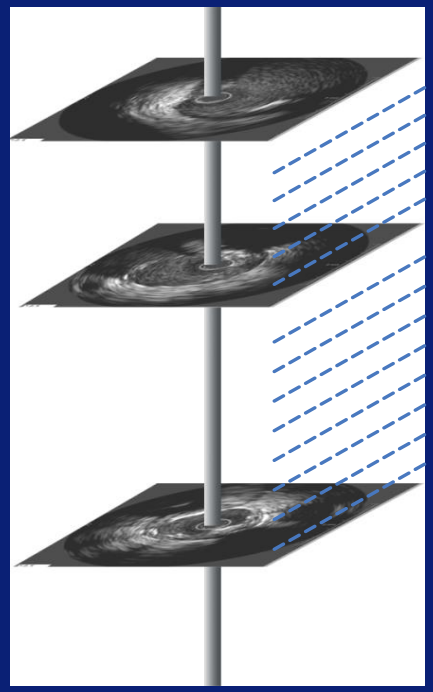

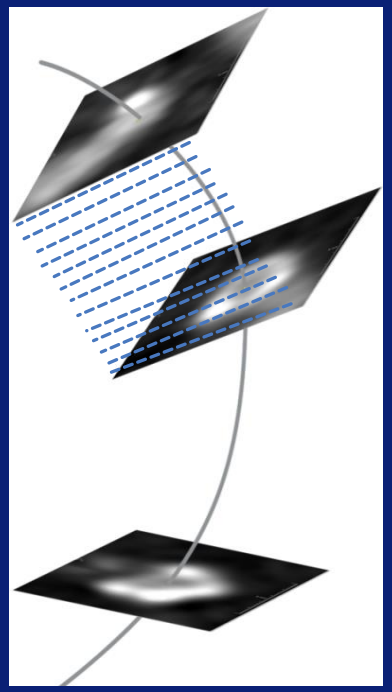

compare

Van der Giessen et al. Int J Cardiovasc Imaging 2010

IVUS-MSCT registration / rotation

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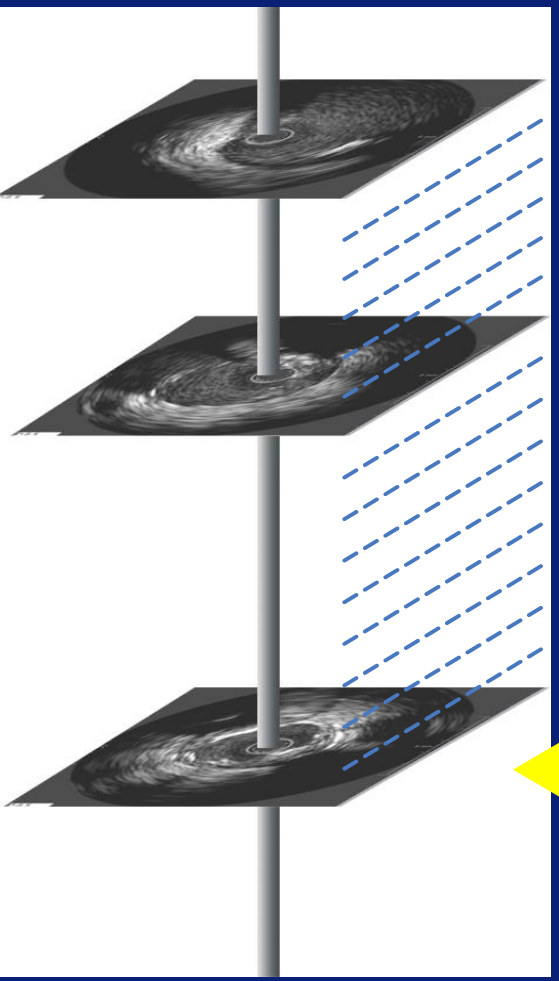

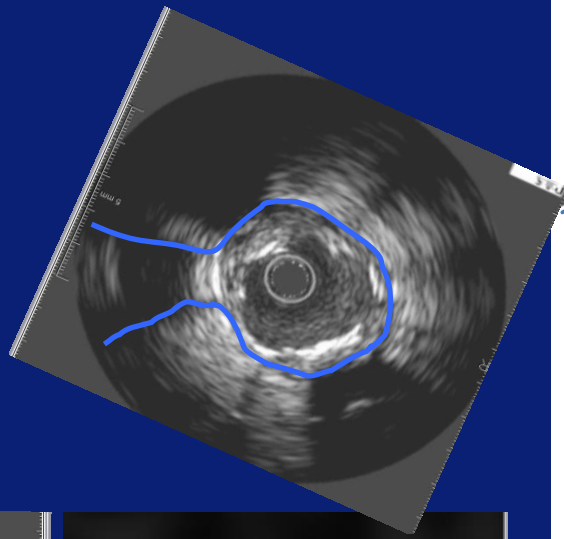

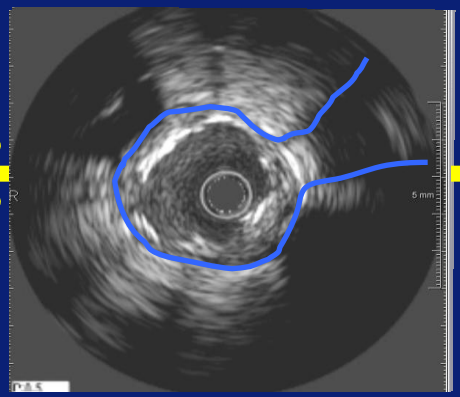

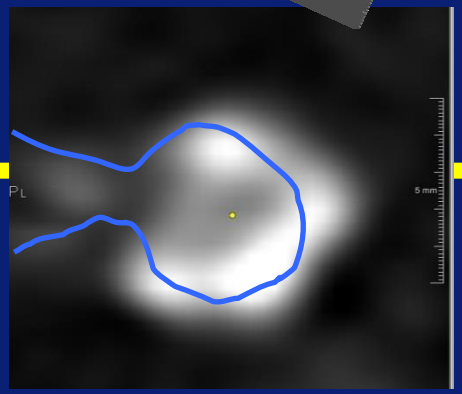

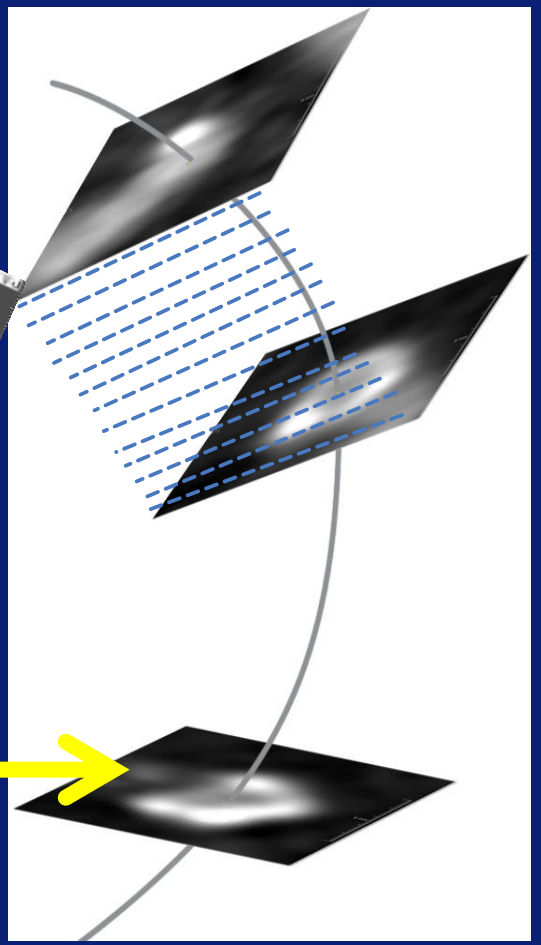

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IVUS-MSCT registration / rotation

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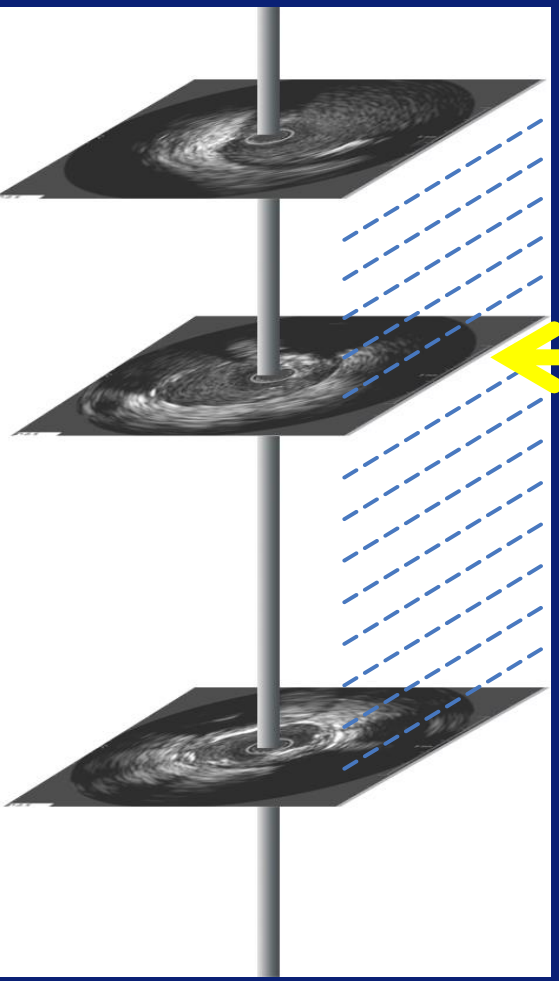

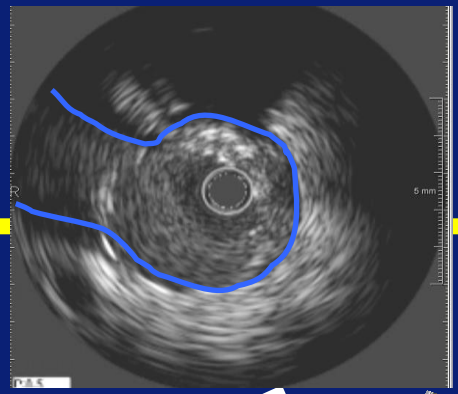

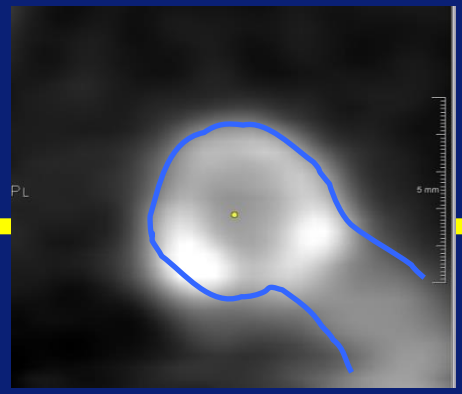

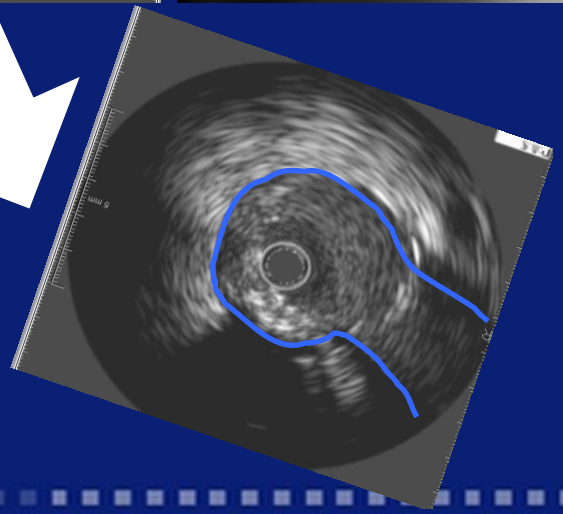

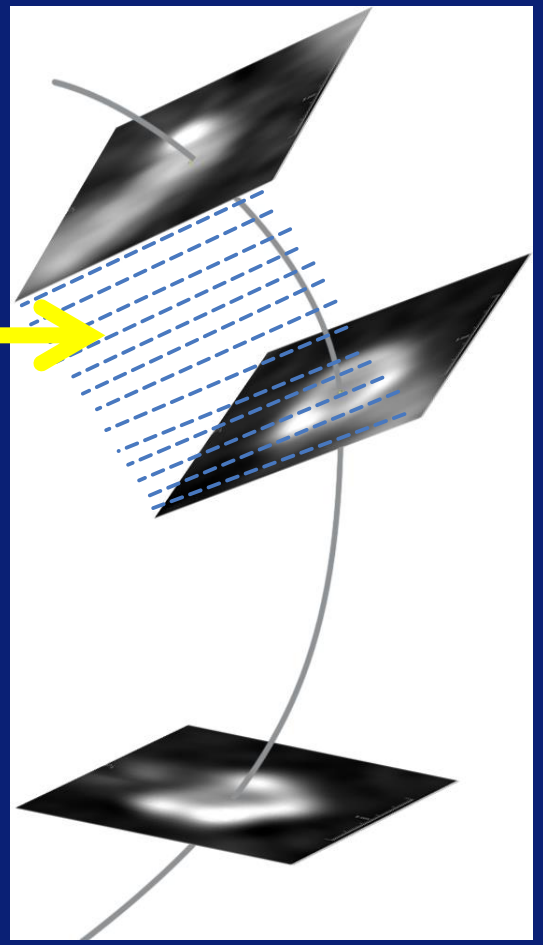

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IVUS-MSCT registration / rotation

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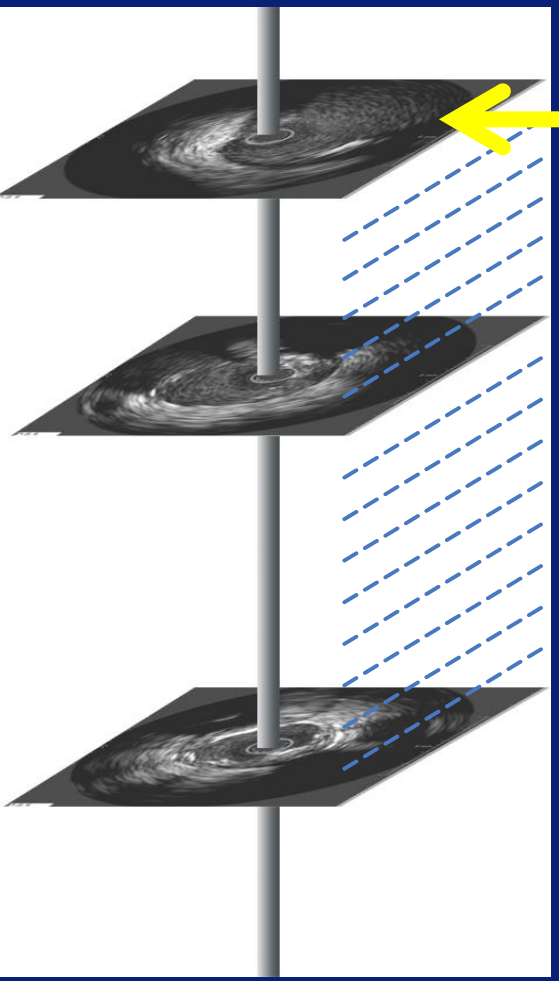

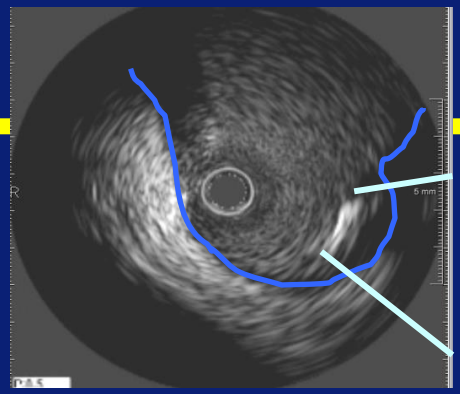

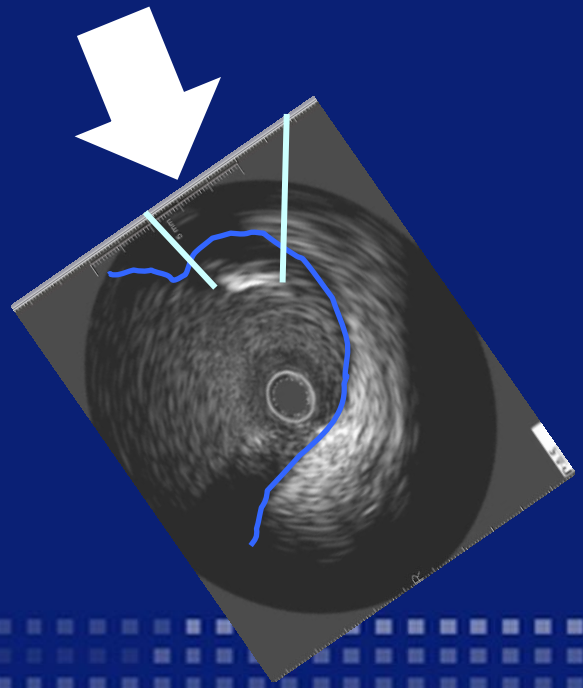

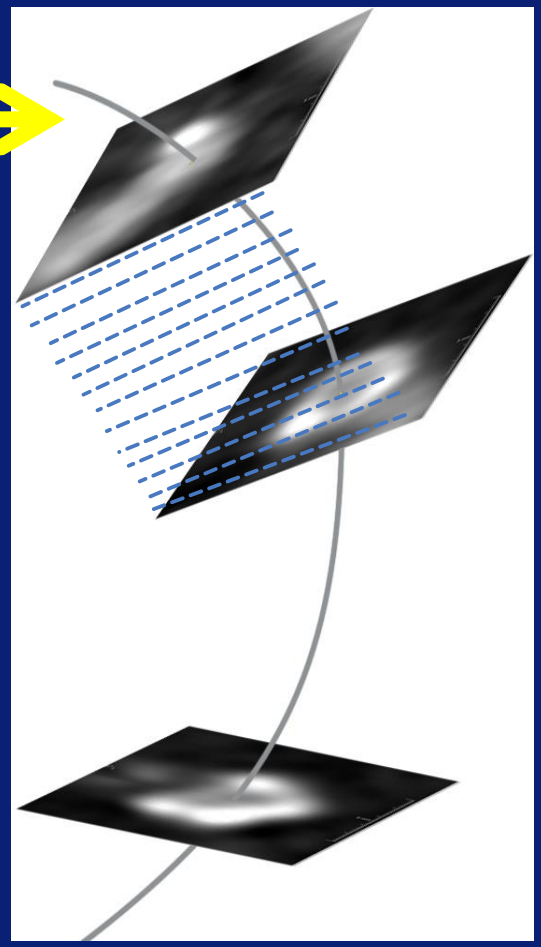

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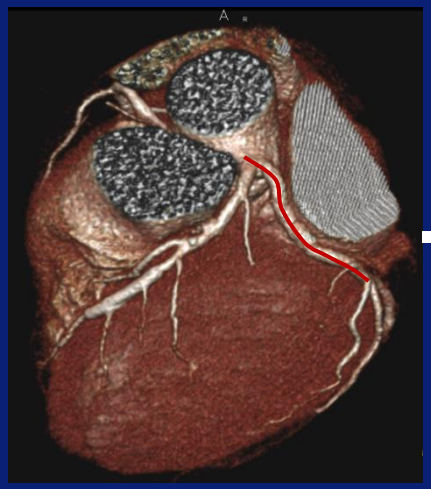
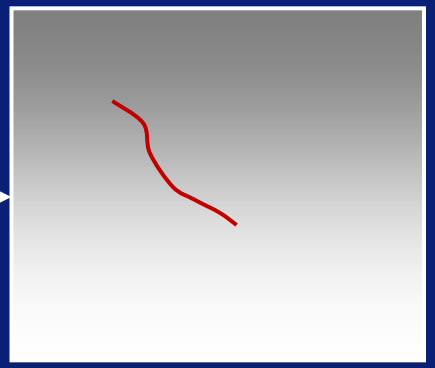
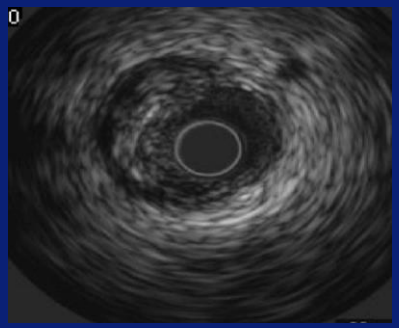
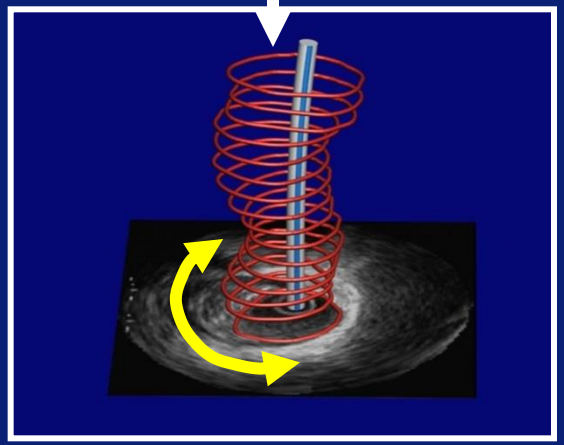
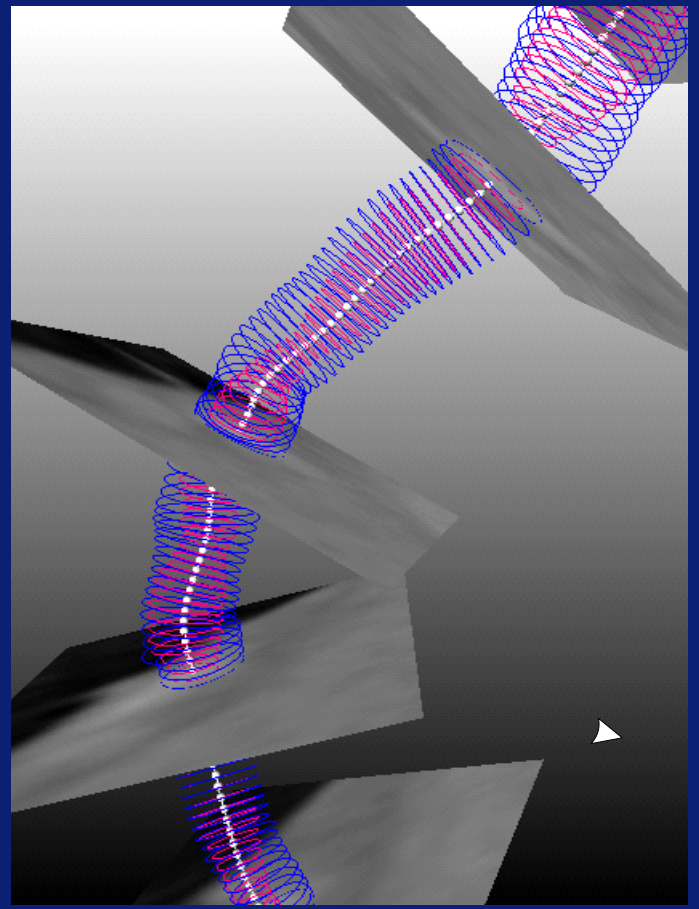


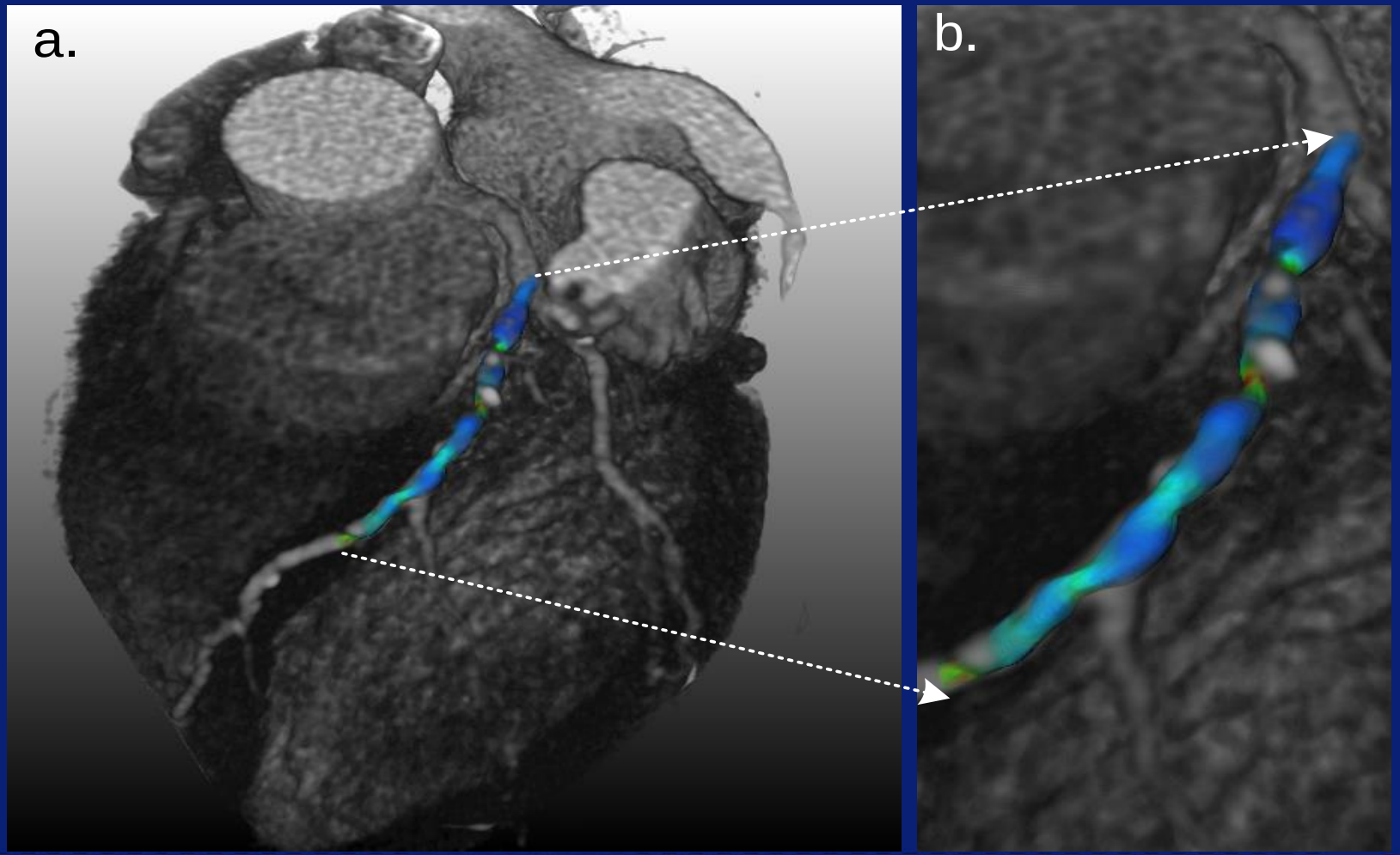




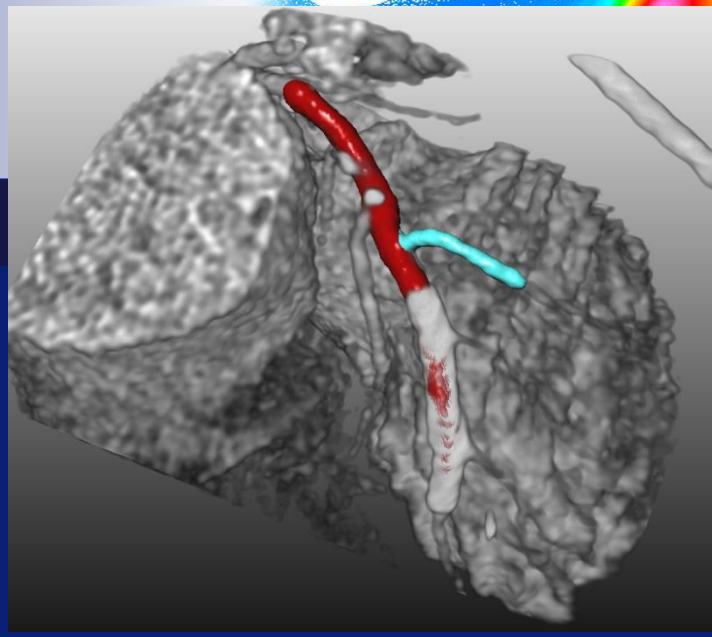


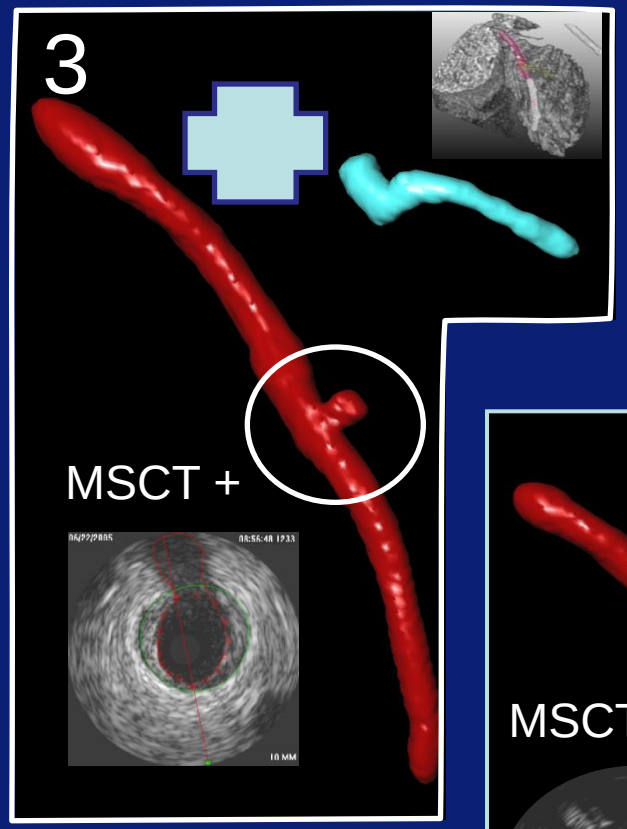


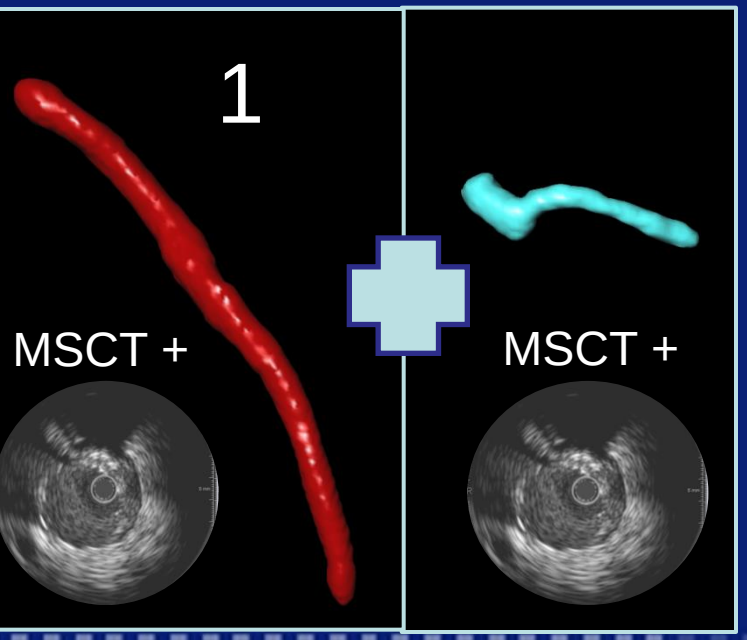
3D: WSS calculations

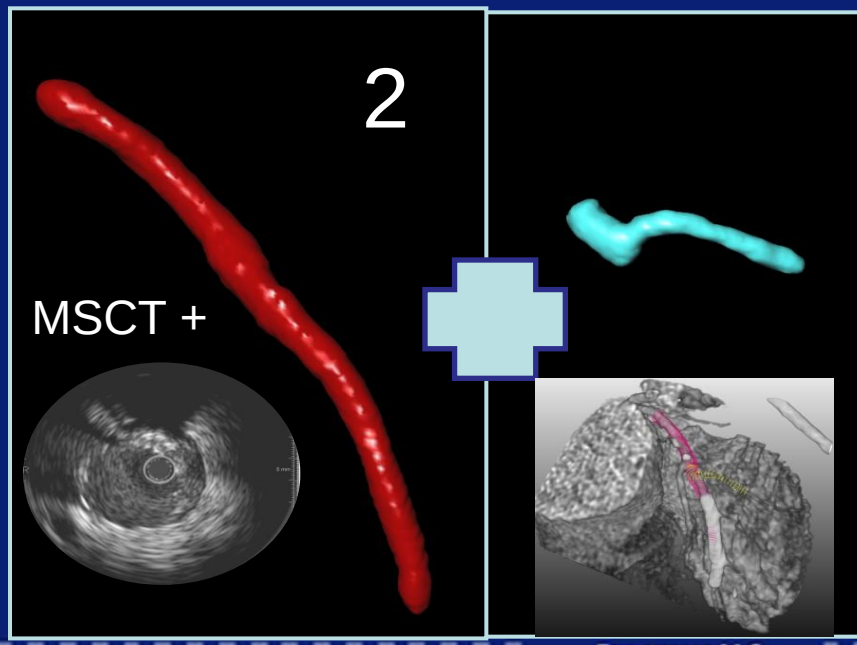


Bifurcations : 3 approaches









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Approach 1: both branches IVUS

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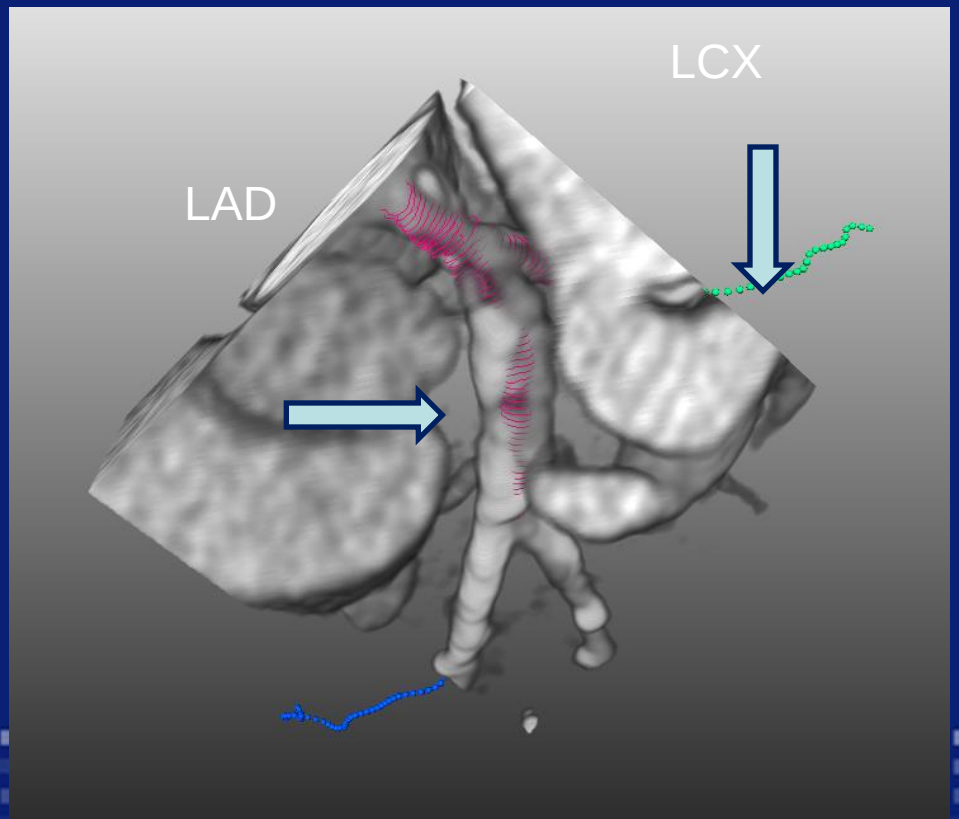
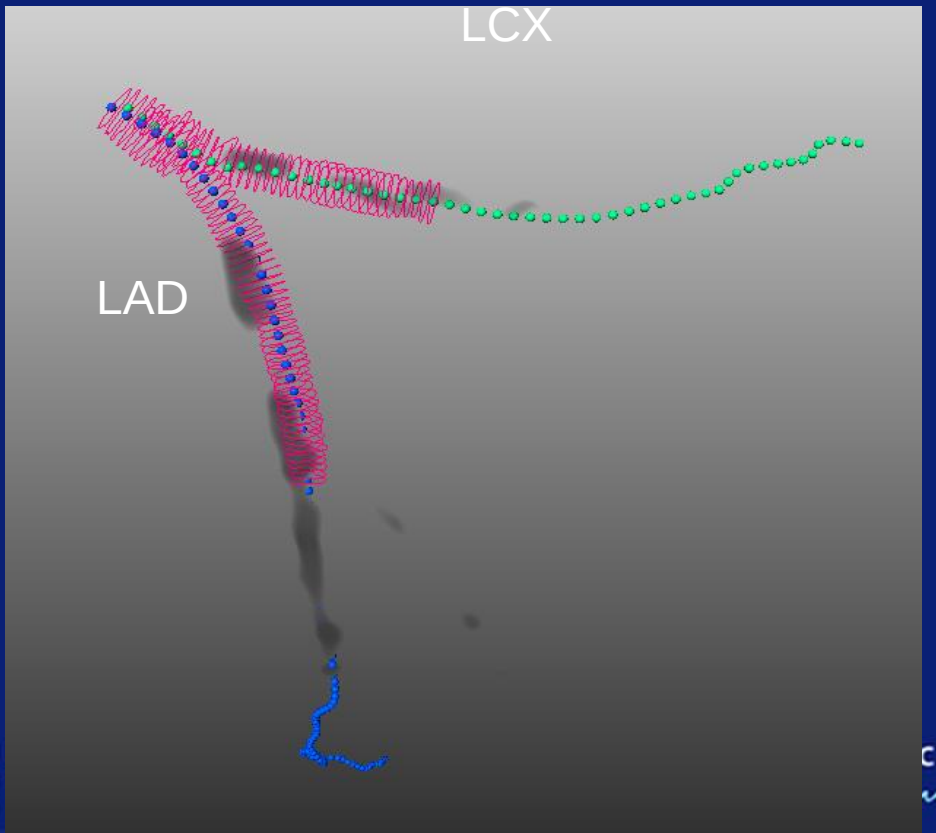
Left main bifurcation

Information available for 3D reconstruction :
angiograms, CT, IVUS of both branches, OCT





Approach 1: both branches IVUS

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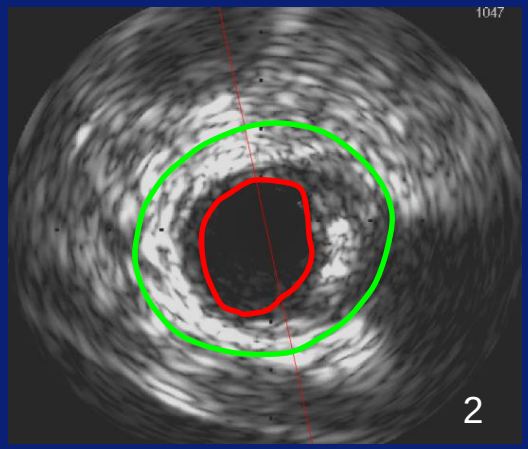

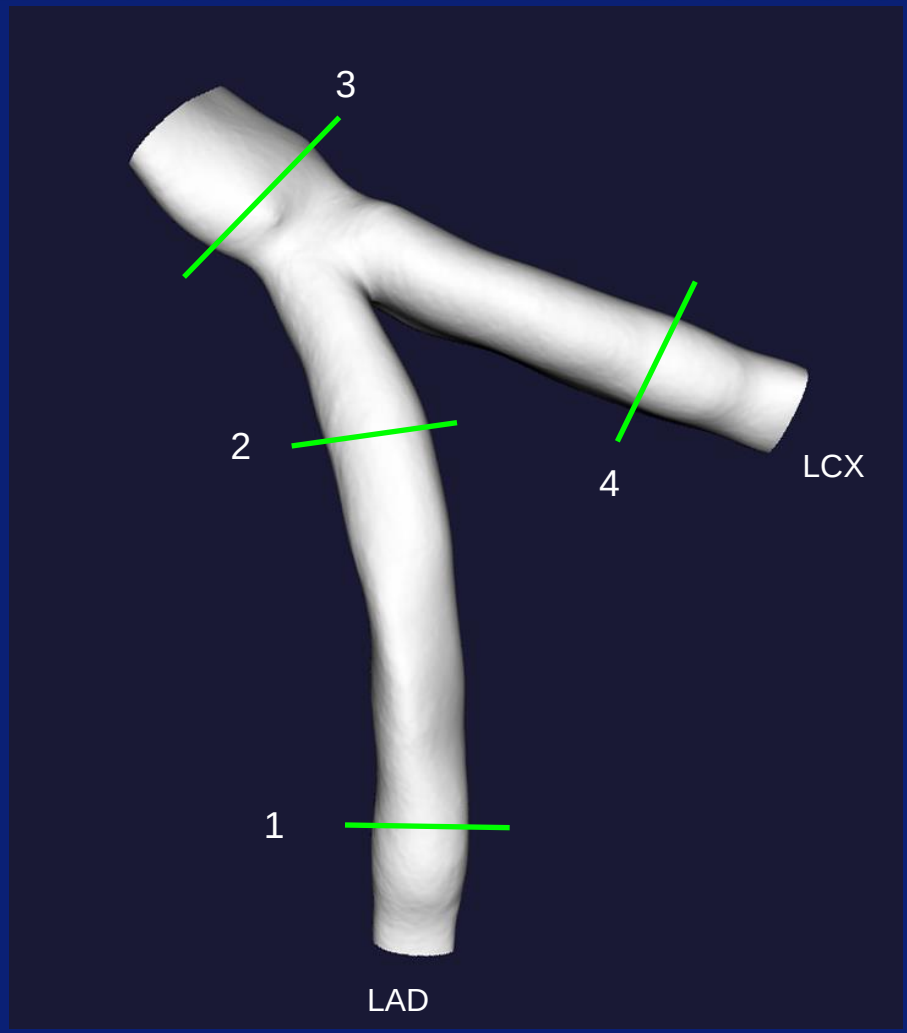

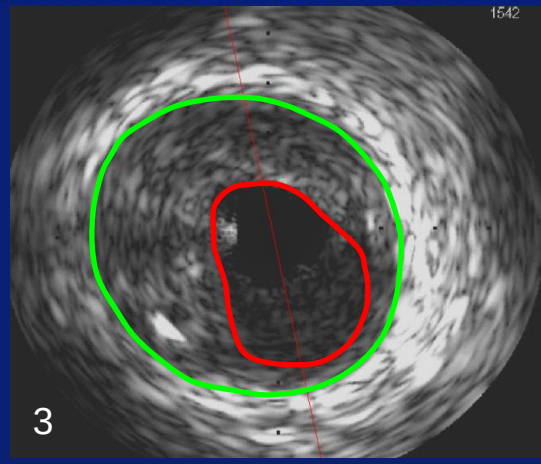

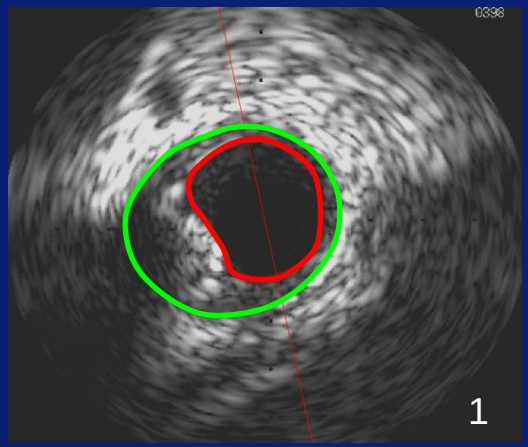

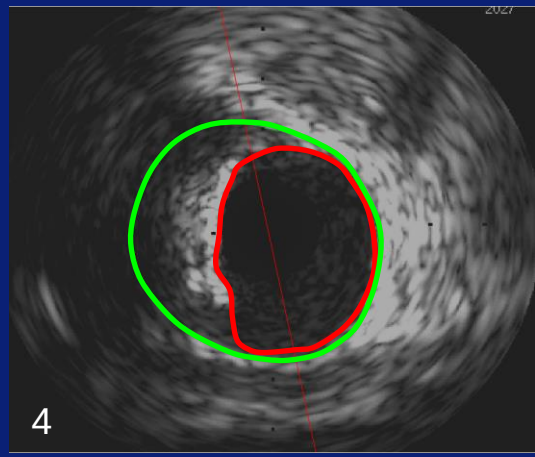

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Approach 2: one branche IVUS, one CT

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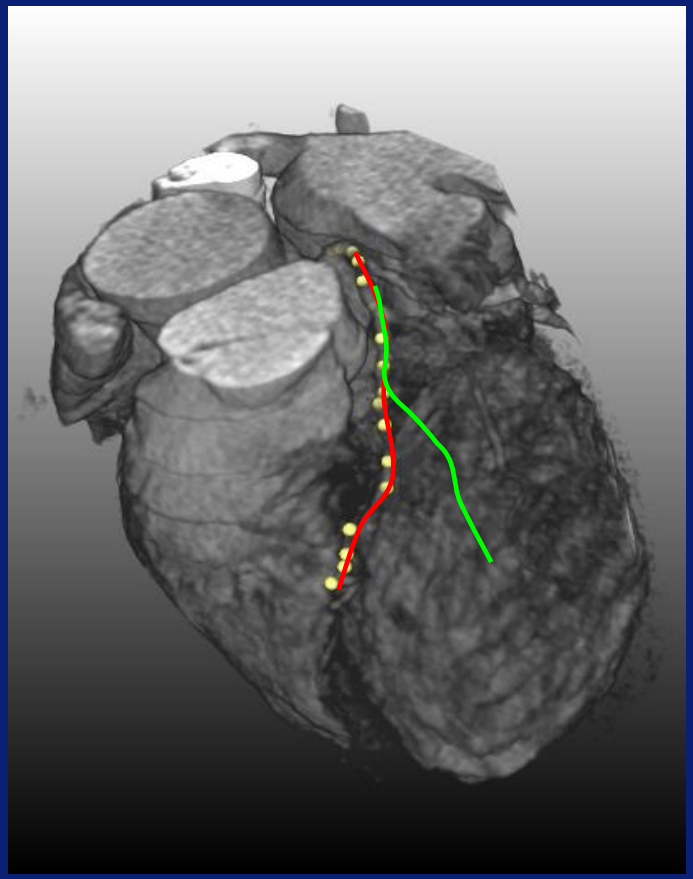
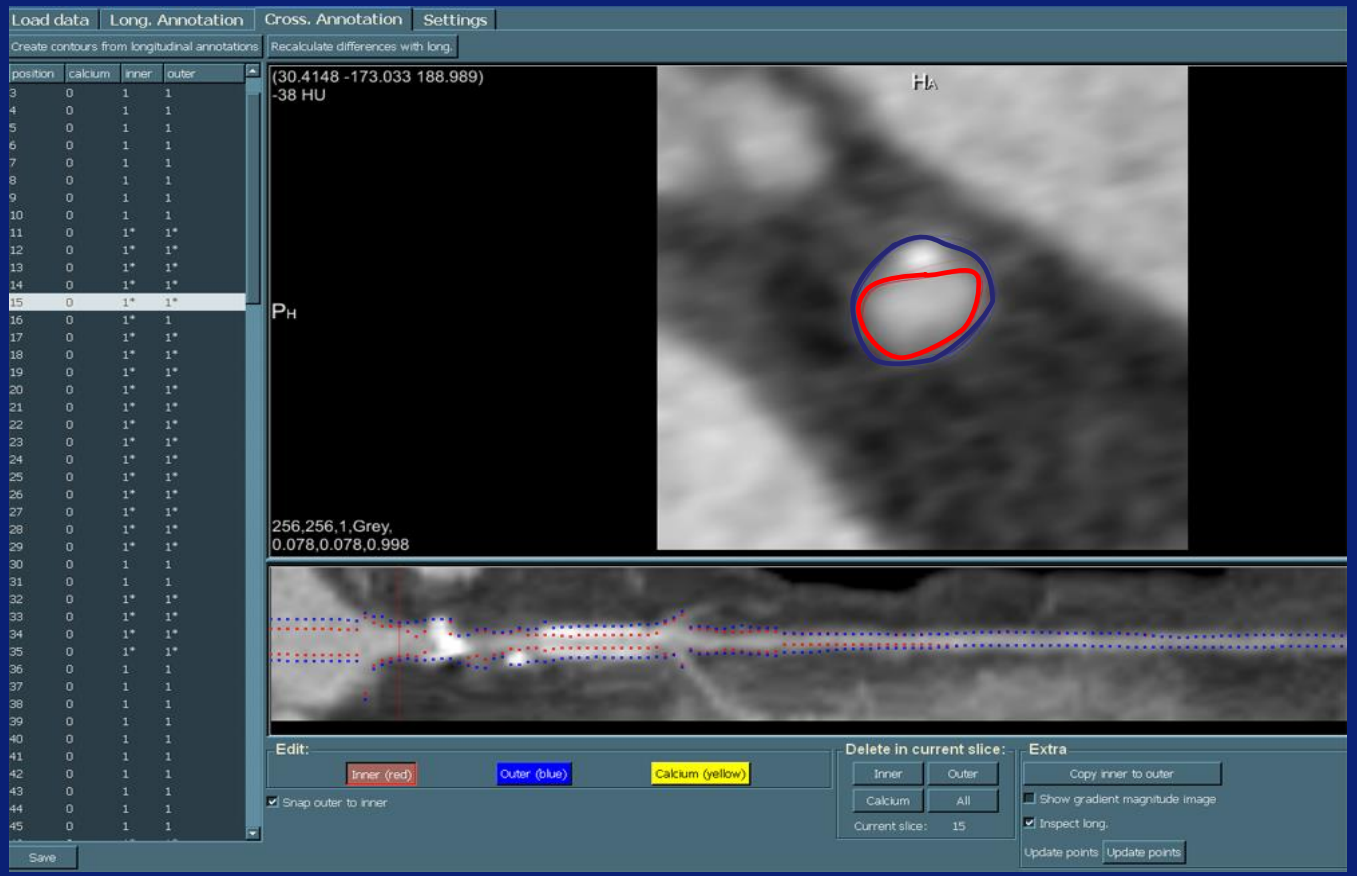
MSCT Side Branch centerline and lumen segmentation





Erasmus MC

Approach 2: one branche IVUS, one CT

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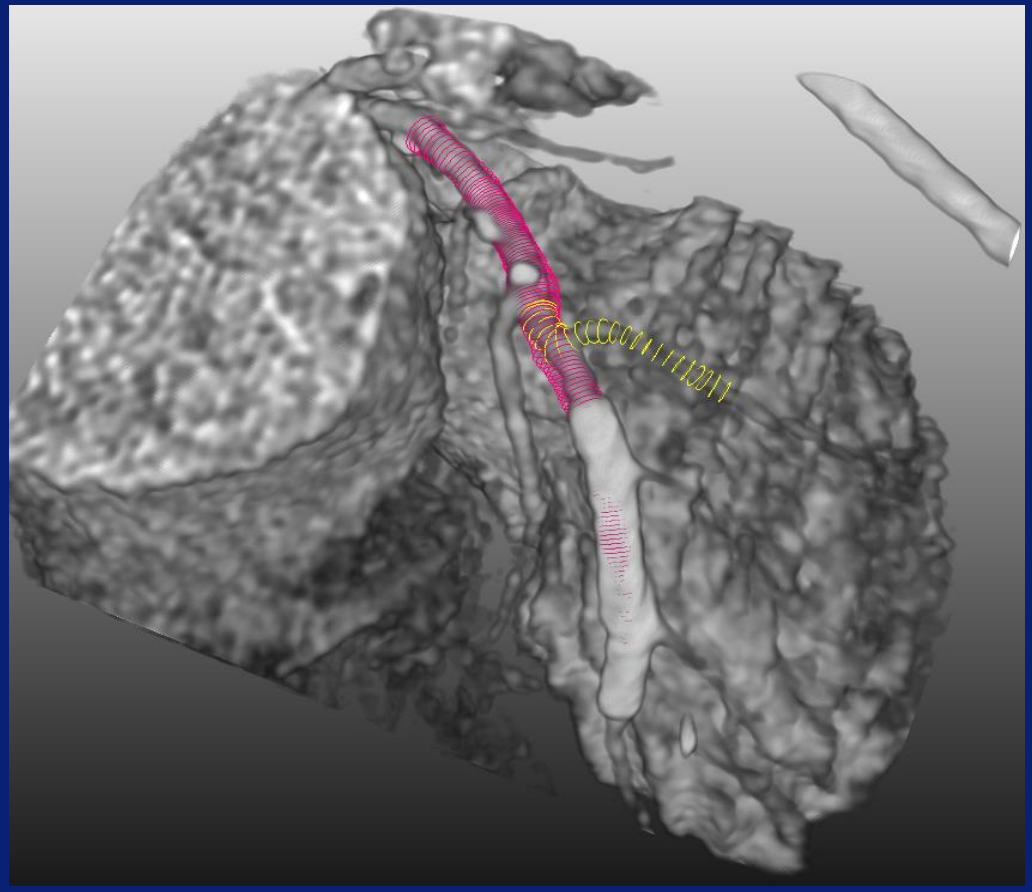

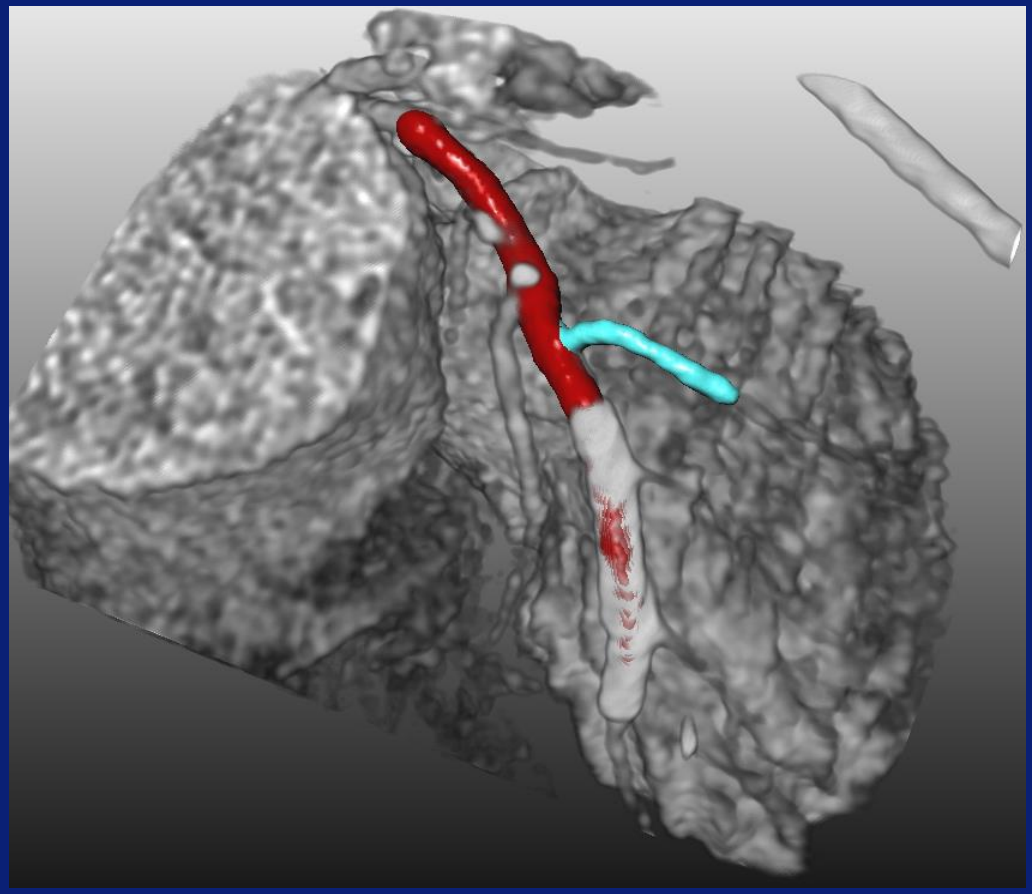

IVUS contours

CT contours

Erasmus MC

Approach 3: one branche IVUS, one CT
Optimize CT segmentation

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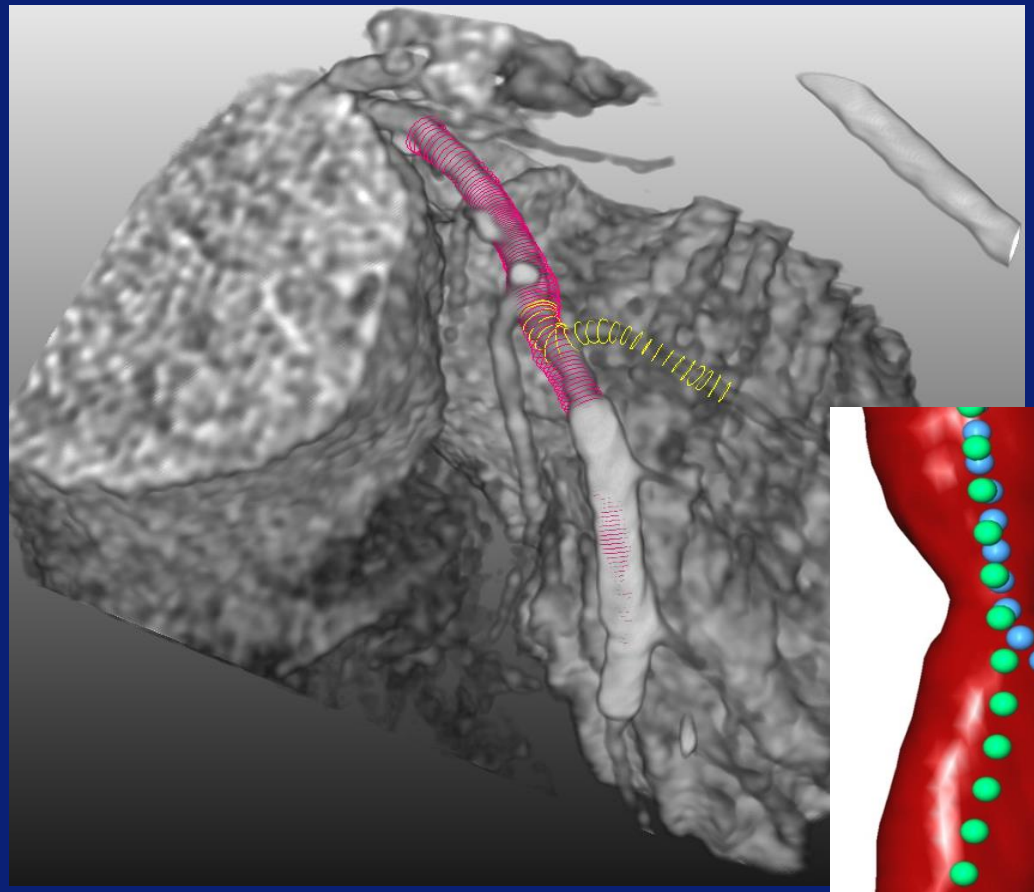

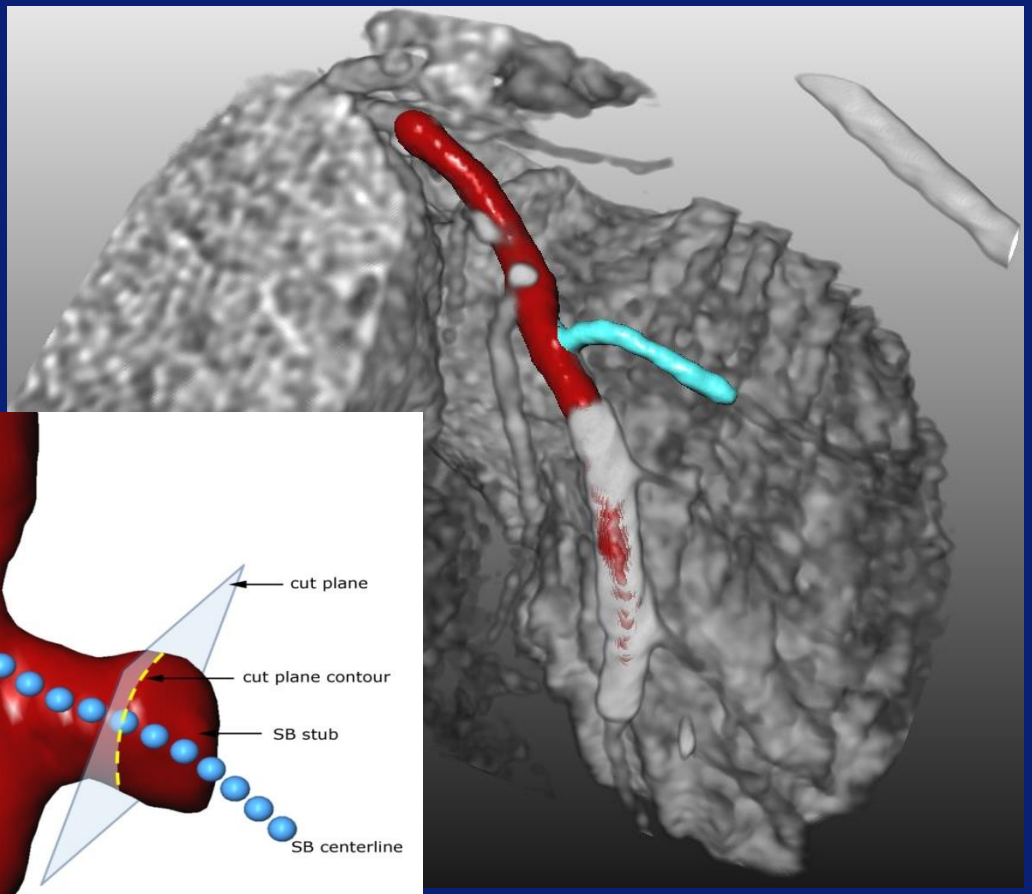

IVUS contours

CT contours

Comparison approach 2 & 3: 4 examples

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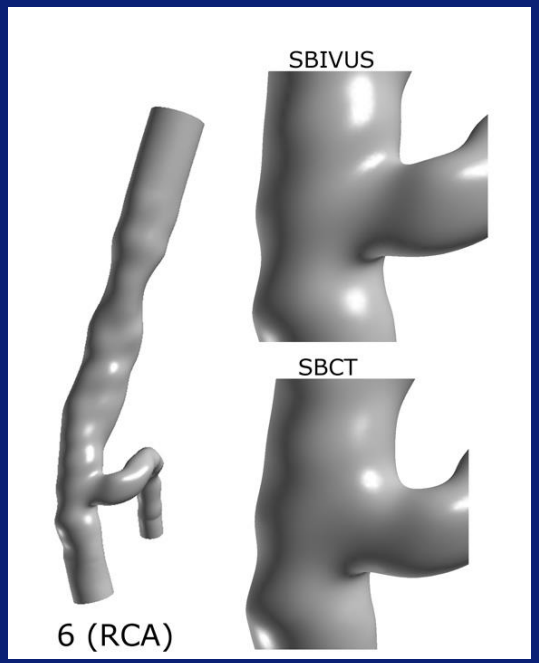
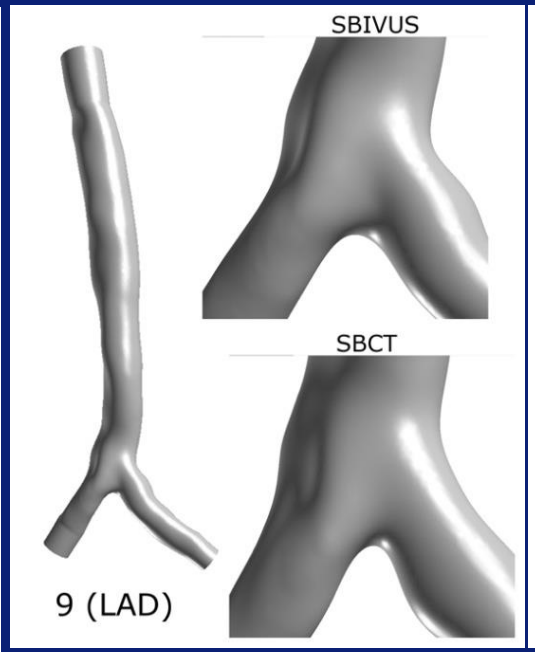
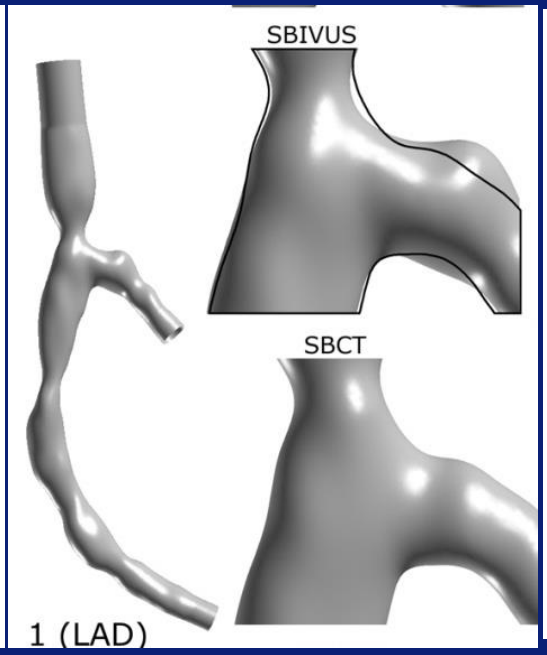
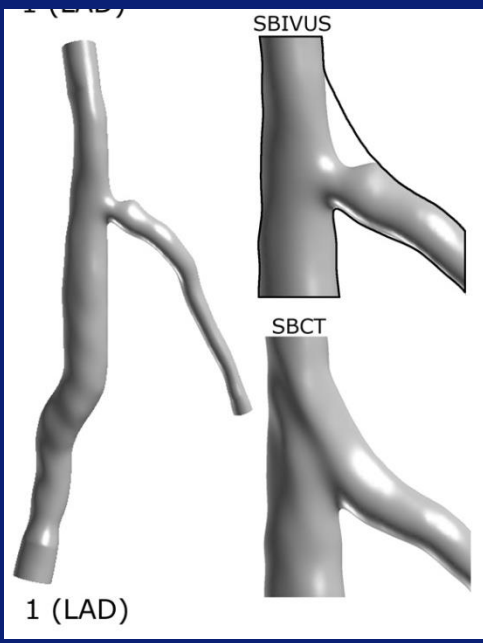
10 bifurcations were 3D reconstructed using approach 2 & 3
Distance between surface only 0.06 mm

Approach 3







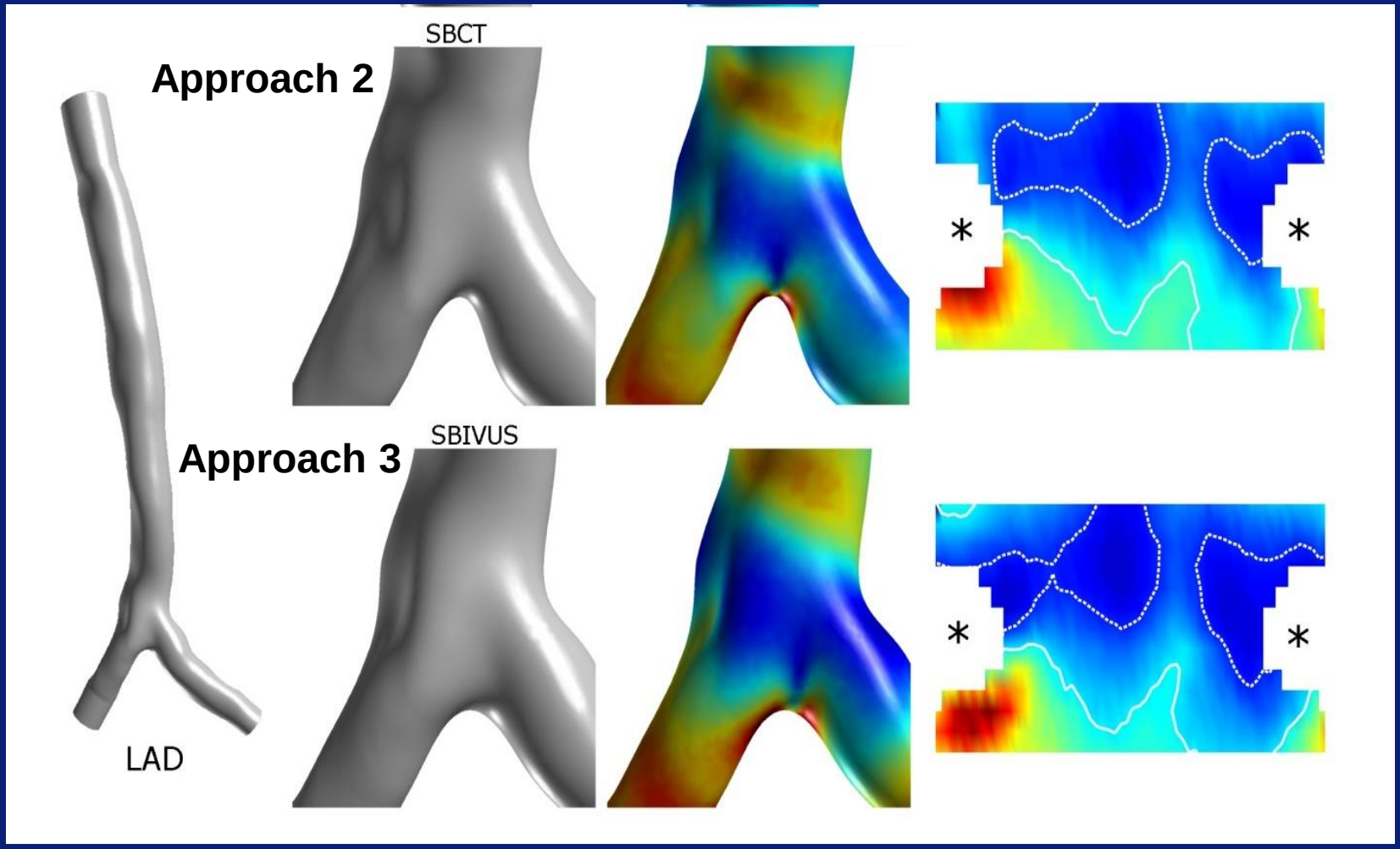


Approach 2

Gijsen et al, accepted in J. Biomechanics

Erasmus MC

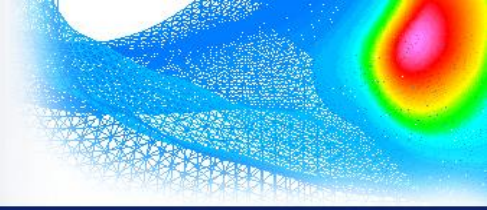
Shear stress in bifurcations



Low shear stress <25%

High shear stress >75%

Compare approach 2 & 3



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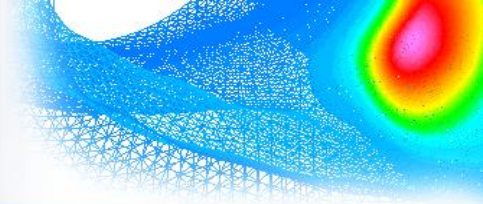
LOW SHEAR STRESS AREA (mm^2)					HIGH SHEAR STRESS AREA (mm^2)			
bifurcation	SBCT	SBIVUS	COLOC	%	SBCT	SBIVUS	COLOC	%
1	12.8	12.2	7.07	60	13.1	12.5	9.1	69.5
2	11.3	11	9.2	81	11.5	11.4	8.3	72.6
3	10.2	10.2	7.6	70.6	11.4	11.3	7.5	65.6
4	7.2	7.1	5.3	74.3	10.7	10.6	8.7	81.7
5	8.7	8.7	7	79.5	9.6	9.7	8.4	87.5
6	16.2	16.2	18.73	85.7	16.4	16.5	13.1	79.9
7	12	11.5	8.1	67.6	11.5	12.1	9.2	80.2
8	15.9	16.2	11.5	72.5	15.3	15.3	12	78.3
9	12.8	12.6	10.6	82.8	14.9	15.1	13.4	89.8
10	16.2	16.6	12.6	77.8	16.8	16.3	9.9	58.7

Shear stress: 0.99±0.49 0.9±0.35 **75±7.7%** **Shear stress: 2.17±1.2 2.38±0.36** **76.4±7.7%**

Erasmus MC

Requirements / (dis) advantages



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	Approach 1 IVUS & IVUS	Approach 2 IVUS & CT	Approach 3 IVUS & CT/IVUS
IVUS pullback in main branch	x	x	x
IVUS pullback in & SB	x	-	-
Wall thickness available in main branch & SB	x	-	-

Requirements IVUS :

1. 2 sidebranches present
2. Full bifurcation region visualized
3. Continues pullback

CT-medina

Medina

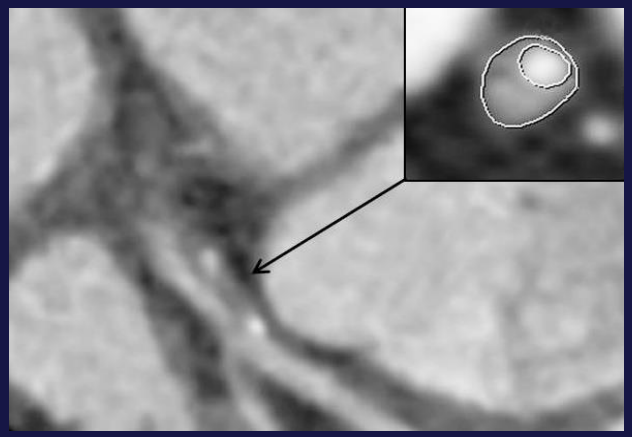
1 ,0 ,0

DS>50%

0 ,0 ,0

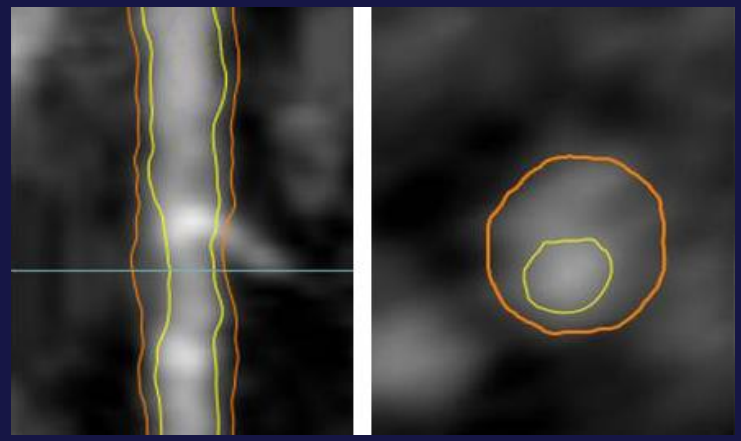
DS<50%

CT-
Medina



1* ,0 ,0

plaque burden>70%
DS>50%



0* ,0 ,0

plaque burden>70%
DS<50%

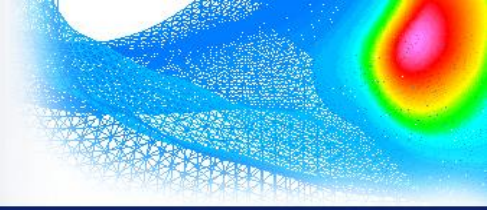
CT-medina : 18% reclassified

39 bifurcations of out 26 patients

Re-classification of bifurcation lesions into a CTCA combined classification scheme	
Medina Classification	**CT medina (≥50% lumen diameter reduction and plaque burden ≥70%)**
0.0.0 (n=36)	**→ 0.0.0 (n=32)**
	→ 0.0*.0 (n=1)
	→ 0.0.0* (n=1)
	→ 0*.0*.0 (n=2)
1.0.0 (n=1)	**→ 1*.0*.0* (n=1)**
1.1.0 (n=2)	**→ 1*.1*.0 (n=1)**
	→ 1*.1*.0* (n=1)
CTCA: computed tomography coronary angiography	

E Papadopoulou et al, submitted

Conclusion



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- Fusion of IVUS and CT is suitable to 3D reconstruction coronary bifurcations
- 3 approaches were discussed, from which IVUS in both side branches is preferred since wall information is present for both branches.
- Alternative approach (2 & 3) can be used for the lumen but gives no information on the wall in the side branch
- A new CT-medina classification provides information on the plaque burden additional to the lumen and could serve as help for decision making for treatment.

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