In-silico bifurcation stenting: plaque composition / bifurcation angle vs plaque shift

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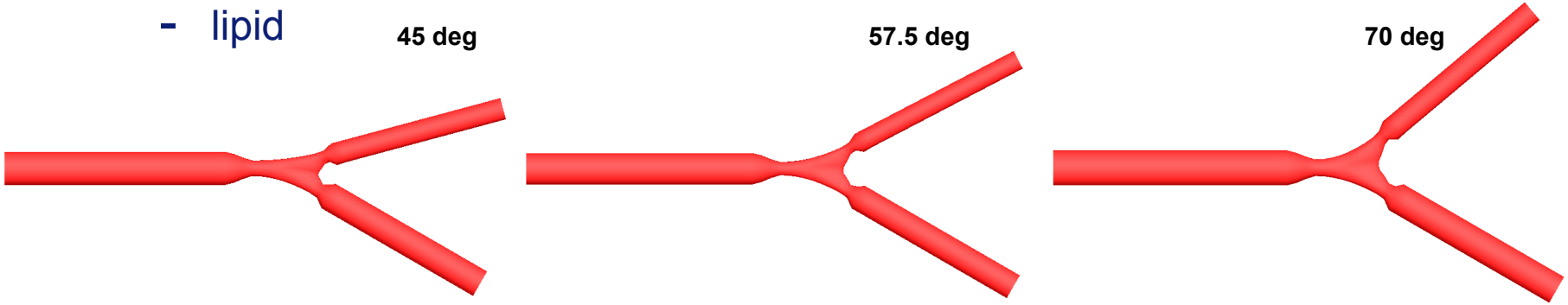
Aim

Erasmus MC

To study the **influence of <u>distal angle / plaque composition</u> on plaque shift / carina shift** because of **provisional stenting**

- ⇨ Create model with plaque included
- ⇨ 3 bifurcation geometries with different distal angles* are investigated
- ⇨ 2 different type of plaques:
  - fibrotic
  - lipid



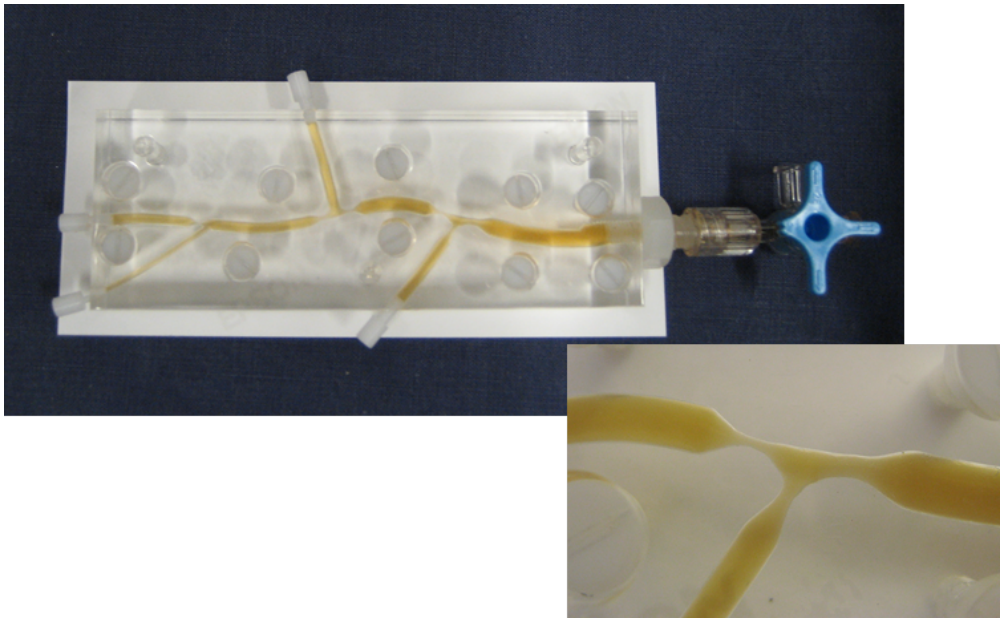
Novel bifurcation phantoms for validation of quantitative coronary angiography algorithms. Girasis C, … Serruys ,Wentzel JJ. CCI, 2011

* ***Distal angle = 57.3° ± 10.0°*** *calculated on LAD, RCA, LCX (mainly LAD, 92.2%) (n = 153 patients) by Elsaban et al. 2013*
Elsaban et al. J Invasive Cardiol 2013; 25:118-122

Bifurcation phantom studies

Erasmus MC

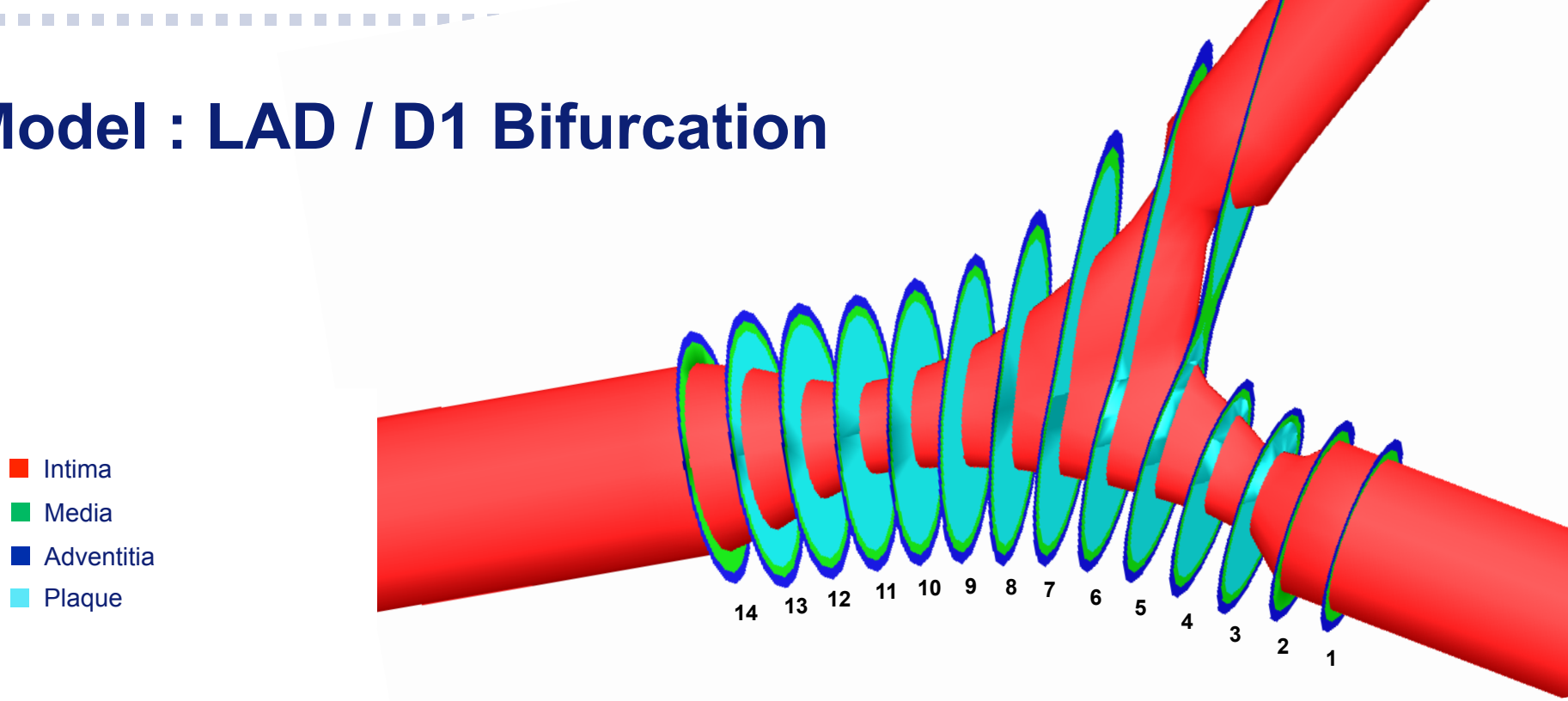
Designed bifurcation phantom



1. Diameter ratio : finet law
2. Length lesion
3. Location MLD
4. Bifurcation angle

Novel bifurcation phantoms for validation of quantitative coronary angiography algorithms. Girasis C, … Serruys ,Wentzel JJ. CCI, 2011

Model : LAD / D1 Bifurcation



Arterial wall thickness (Tzucu 2001, Holzapfel 2005):

intima + media thickness = 0.1 lumen Diameter (healthy)

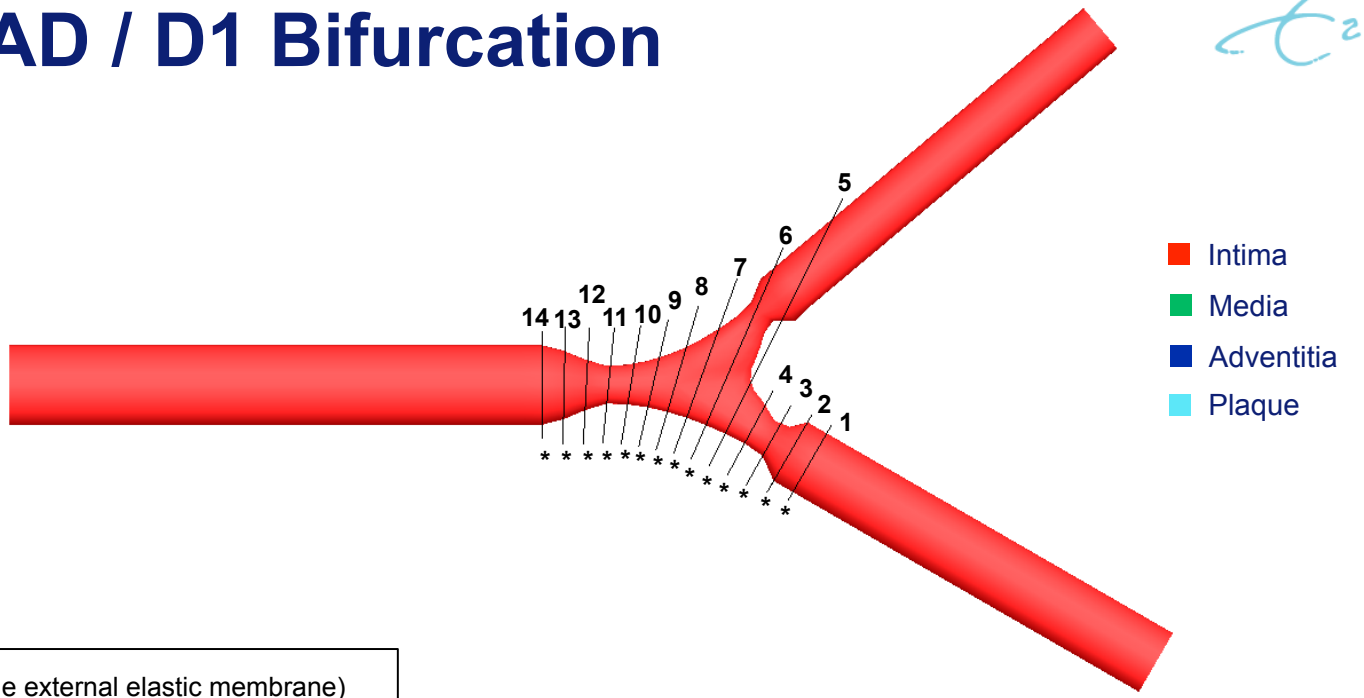
intima thickness/wall thickness = 0.26

media thickness/total wall thickness = 0.35

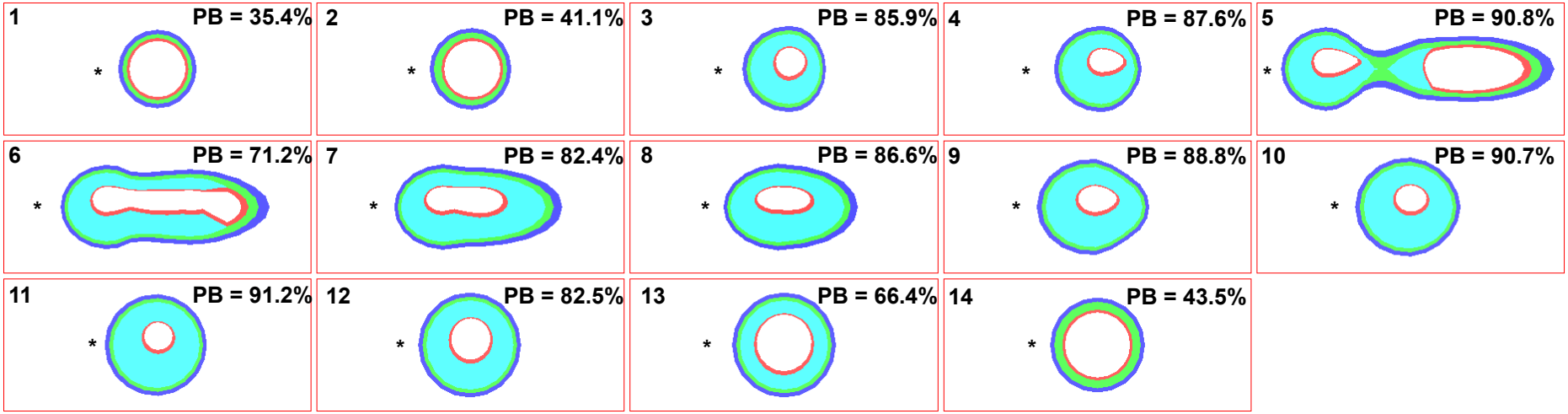
adventitia thickness/wall thickness = 0.39

Plaque burden > 40% at location of lumen narrowing (Glagov 1987)

Model : LAD / D1 Bifurcation



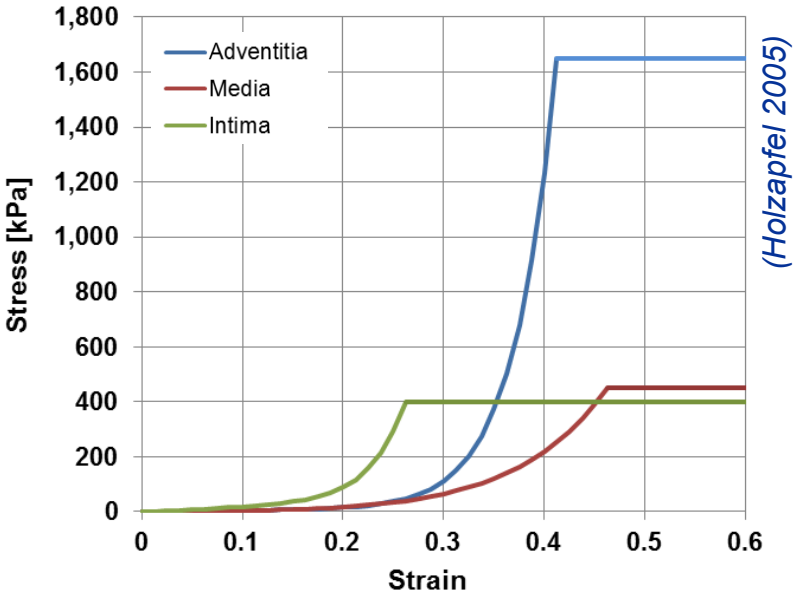
PB = Plaque burden (up to the external elastic membrane)



Computer simulations
Mechanical properties of plaque components

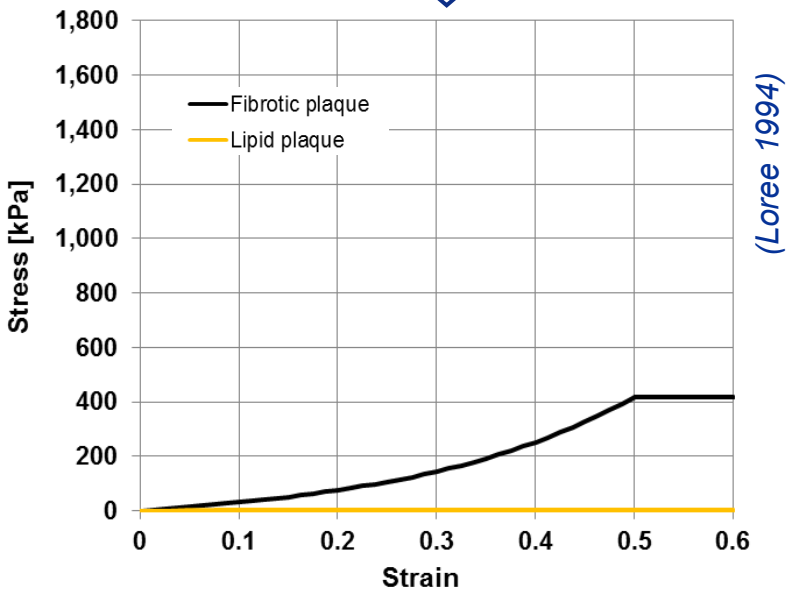
Arterial wall

Isotropic hyperelastic behavior with ideal plasticity to mimic vessel damage



Fibrotic / Lipid plaque

Isotropic hyperelastic behavior with ideal plasticity to mimic plaque rupture

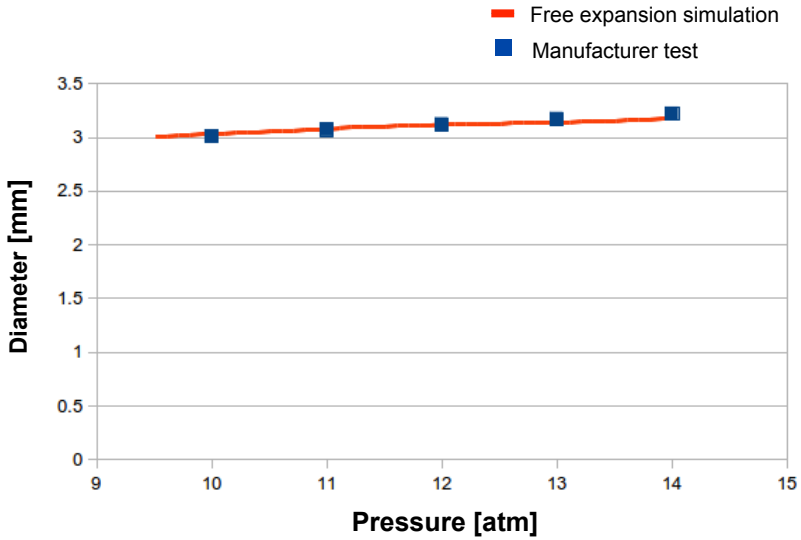


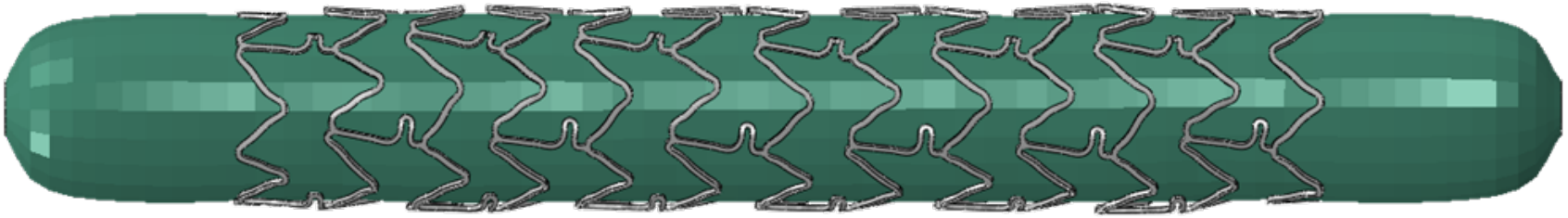
Loree et al. J Biomech, 1994; 2: 1995-204
Holzapfel et al. Am J Physiol Heart Circ Physiol, 2005; 289: H2048-H2058

Methods :Computer simulations
Stent and balloon

- **Multi-Link 8** (Abbott Laboratories, Abbott Park, IL, USA)
  - Bare-metal stent, Co-Cr alloy
  - Size: 3x18 mm

- **Balloon:**
  - Modeled as a straight tube using Kiousis approach*
  - Calibrated using the manufacturer compliance chart from 10 atm to 14 atm (nominal pressure = 10 atm, burst pressure = 18 atm)

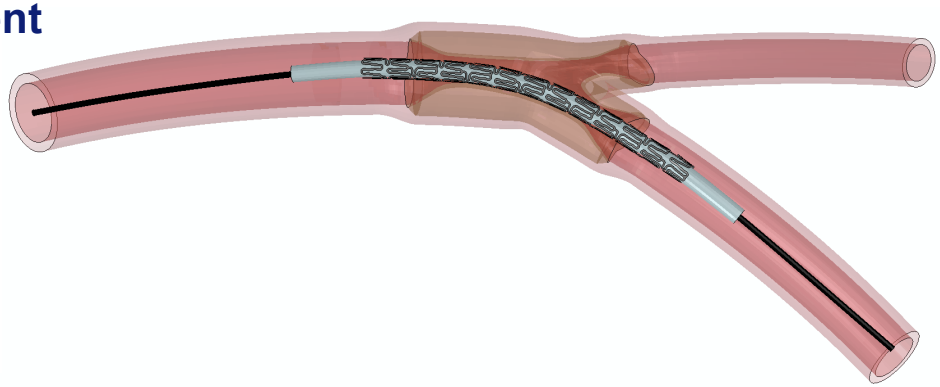




Kiousis et al. Int J Num Methods Eng, 2008; 75:826-855

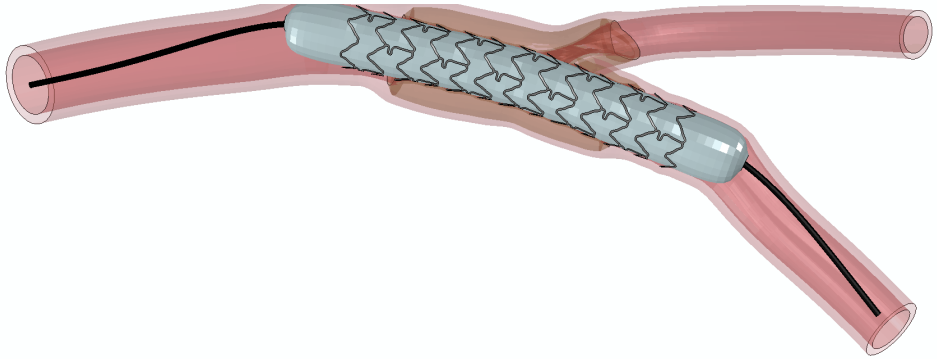
Computer simulated provisional stenting

1. **Insertion of 3x18mm Multi-Link 8 stent**

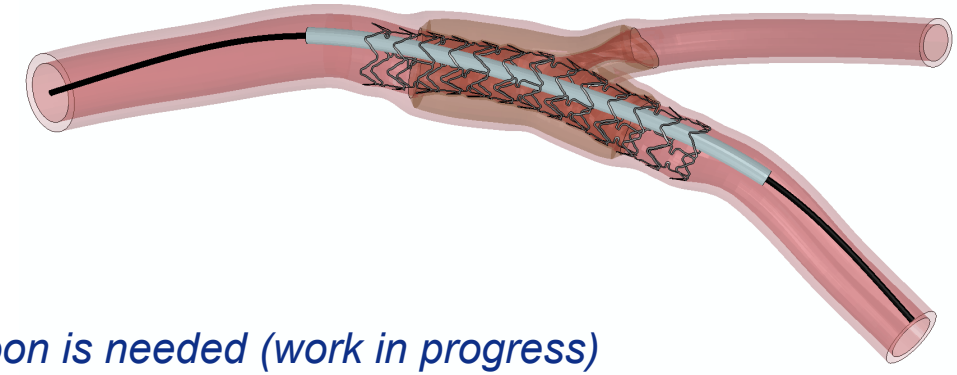


2. **Balloon expansion at 14 atm**

   (Final diameter = 3.22 mm)



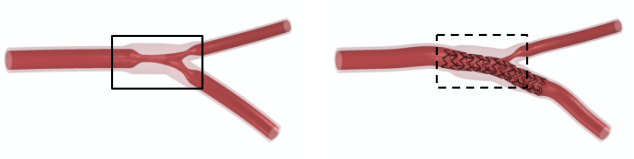
3. **Final configuration after balloon deflation**

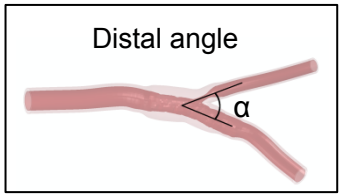


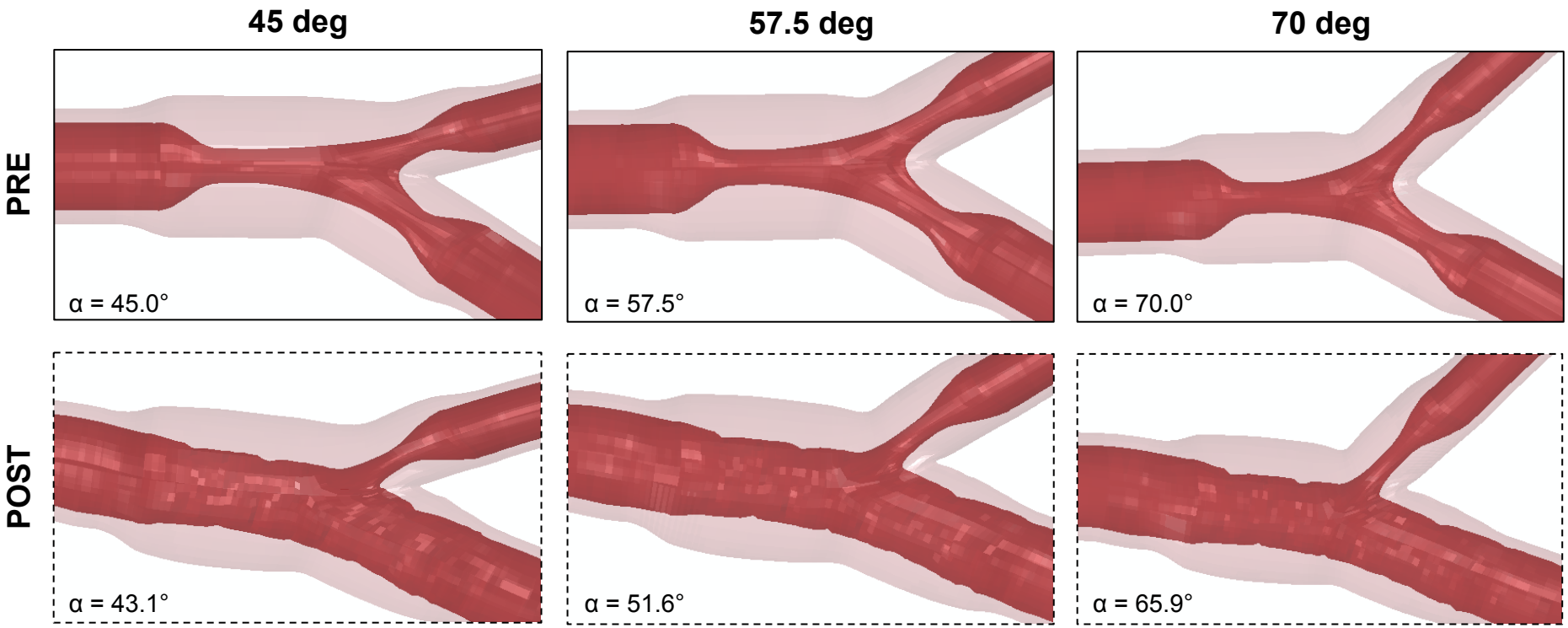
Note: *Post-dilatation with a 3.5x12 balloon is needed (work in progress)*

Results – fibrotic plaque

- **Geometrical configuration pre/post**

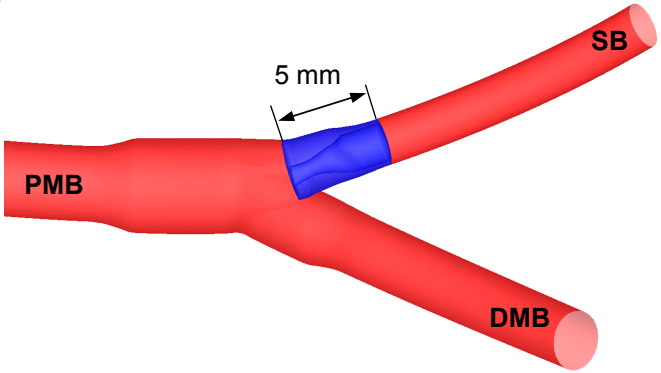




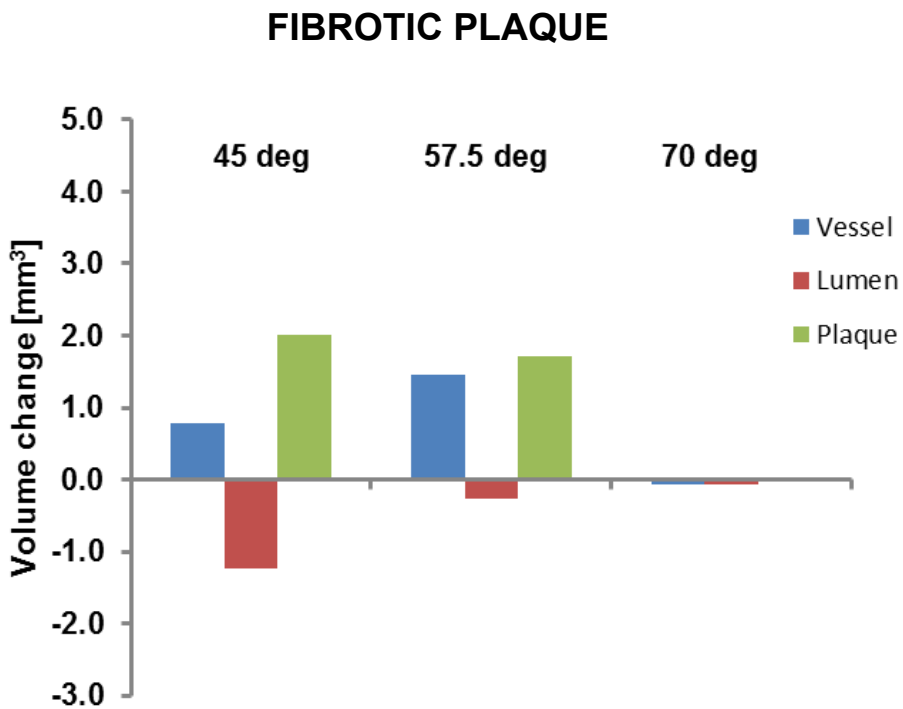


- **Distal angle decreases after stent deployment**
- **Lumen shape of side branch is effected**

Results: plaque shift



- **Volumetric analysis**



SB ostial compromise = lumen volume decrease in the SB ostial segment after MB stenting

Plaque shift = plaque volume increase in the SB ostial segment after MB stenting

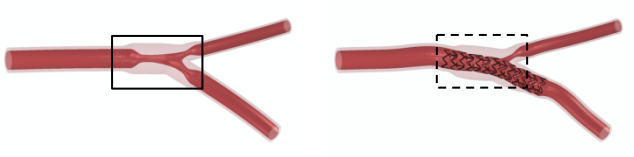
Carina shift = vessel volume decrease in the SB ostial segment after MB stenting

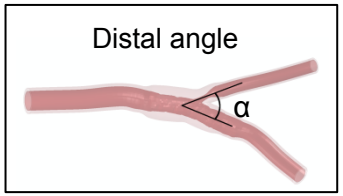
- SB lumen : Distal angle ↑↑ ⇨ SB ostial compromise ↓↓
- SB plaque : Distal angle ↑↑ ⇨ Plaque shift ↓↓ (absent with distal angle = 70°)

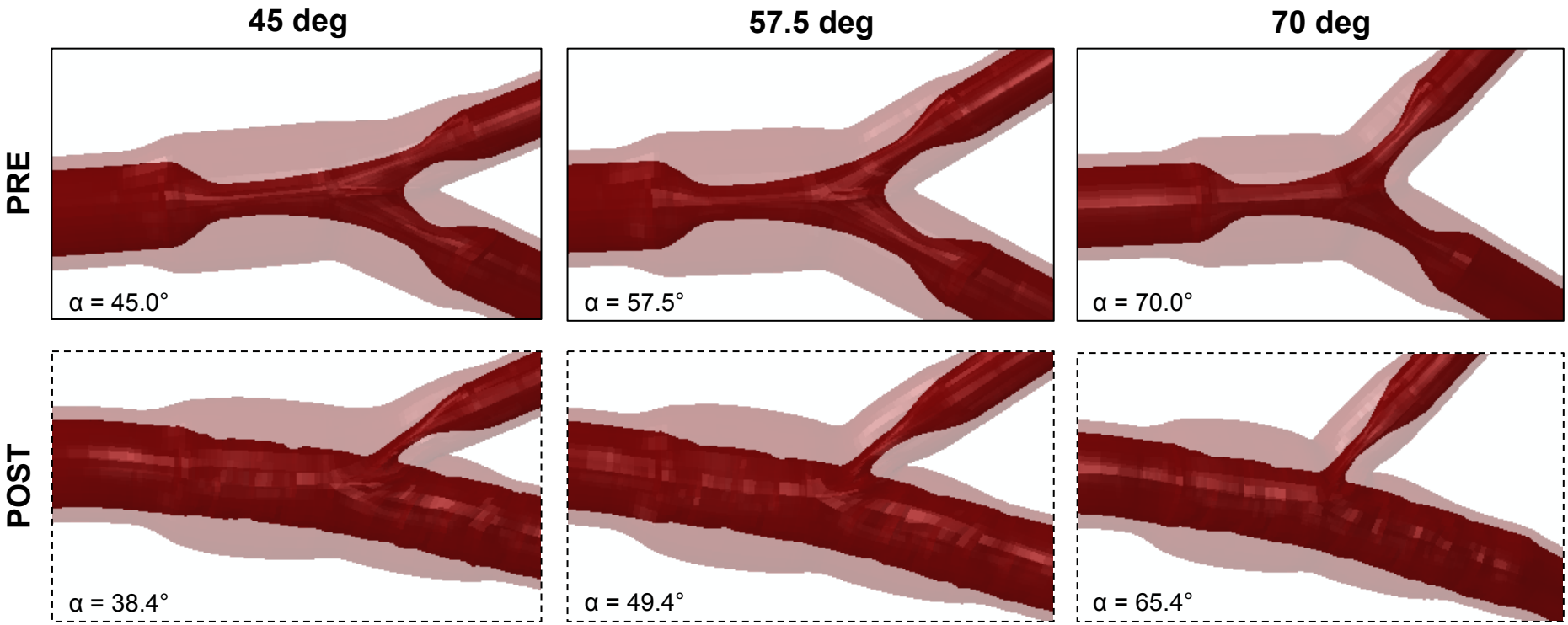
Distal angle ↑↑ ⇨ Area Polygon of confluence ↑↑ ⇨ Plaque shift ↓↓

Results – lipid plaque

- **Geometrical configuration pre/post**



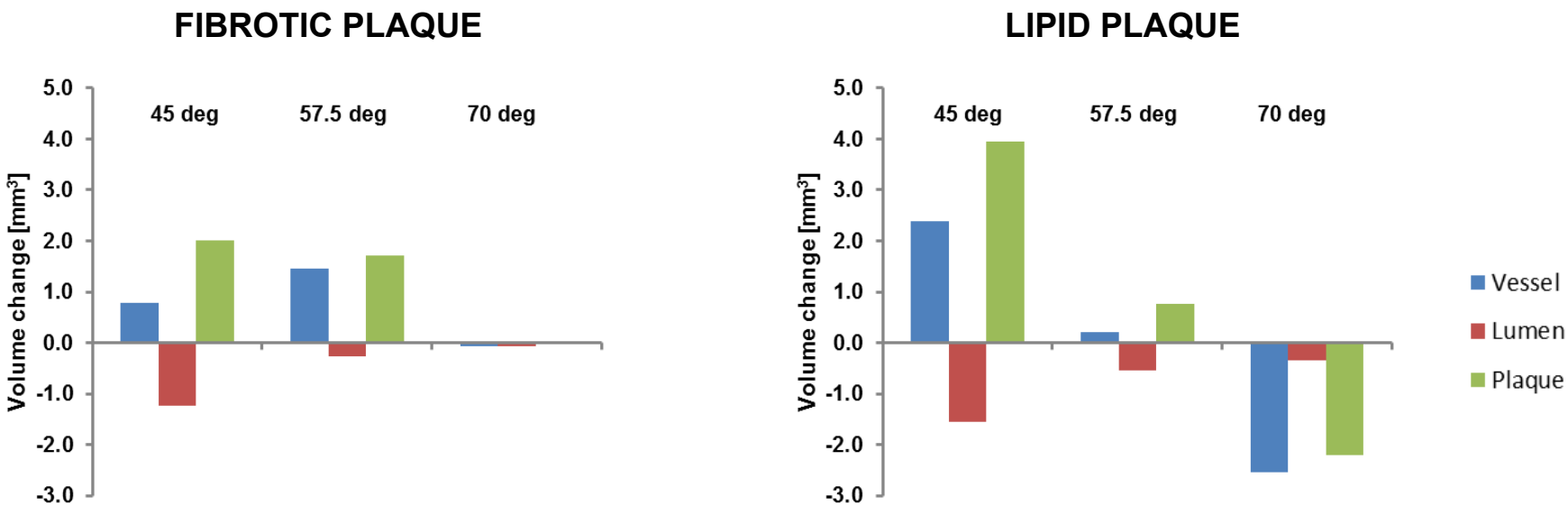




- **Distal angle decreases after stent deployment**
- **Lumen shape of side branch is effected**
- **The decrease of distal angle is greater in the lipid cases than the fibrotic cases**

Results: plaque shift

- **Volumetric analysis**



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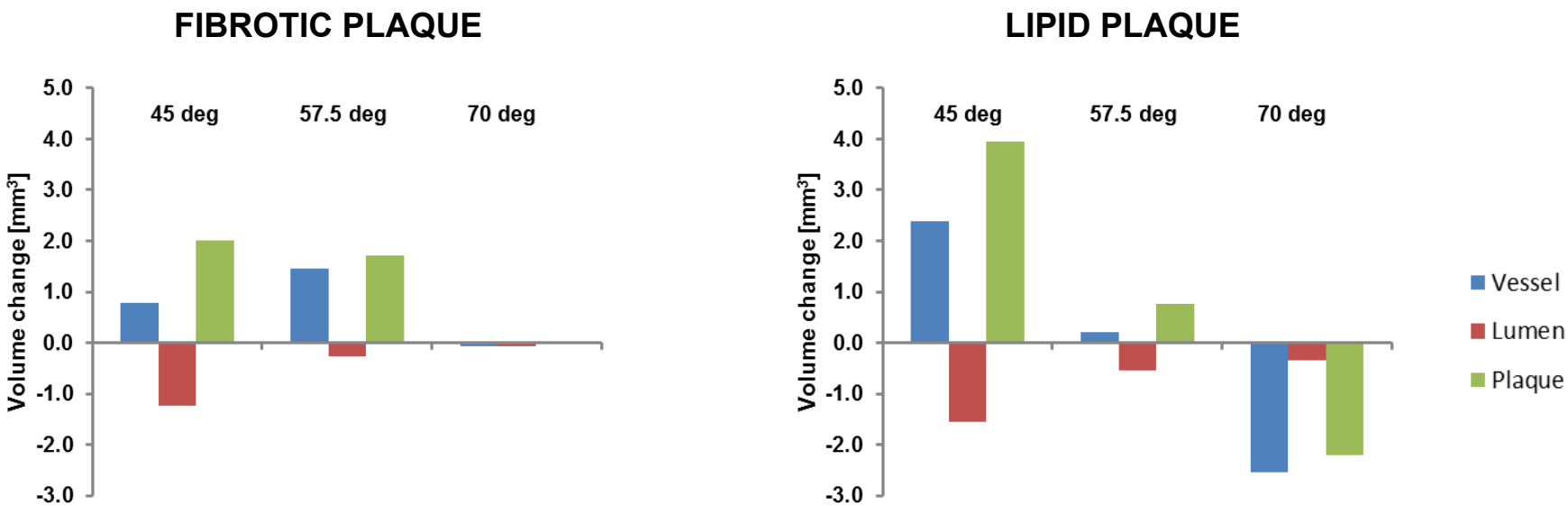
- SB lumen : SB ostial compromise and plaque shift more severe in **lipid** cases
- SB plaque : Carina shift present only in the **lipid** case with **distal angle = 70°**
- **Lumen size of side branches marginally changes after stenting but lumen shape is effected**

Results: plaque shift

- **Volumetric analysis**



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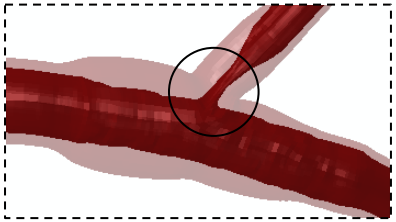
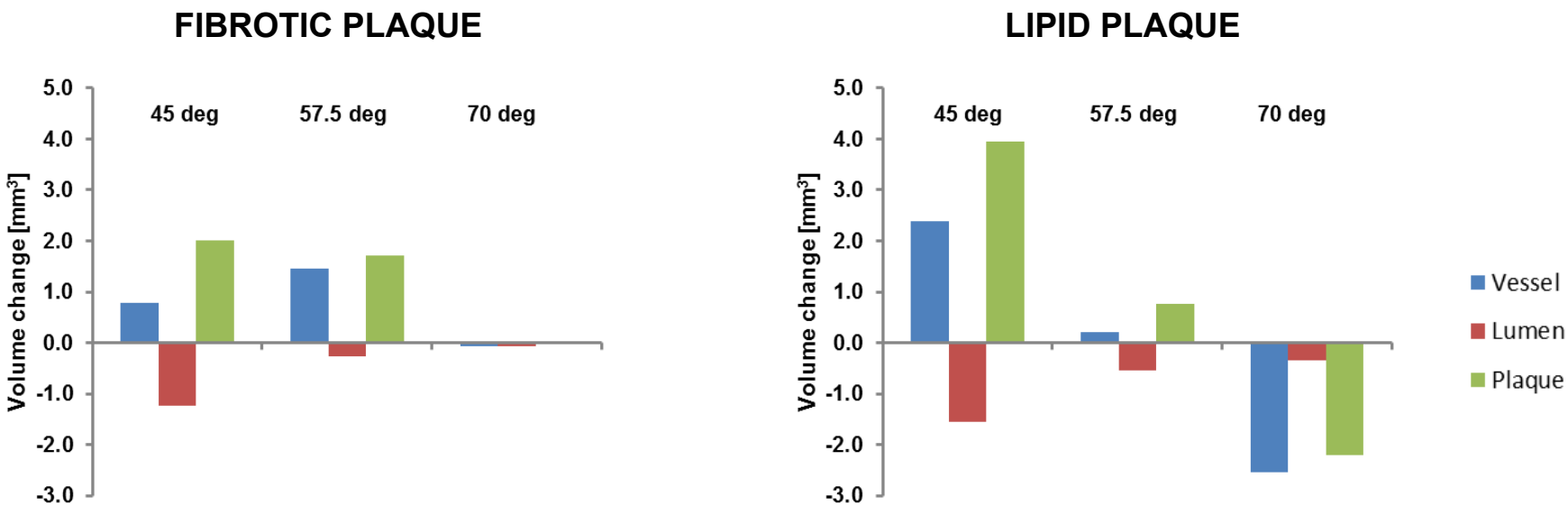


Results: plaque shift

- **Volumetric analysis**



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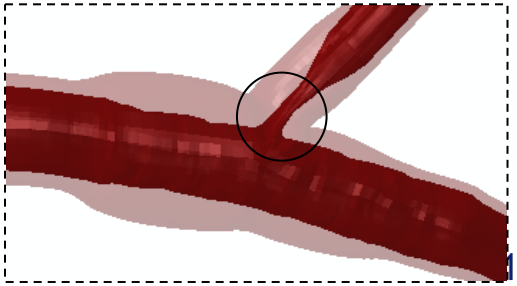
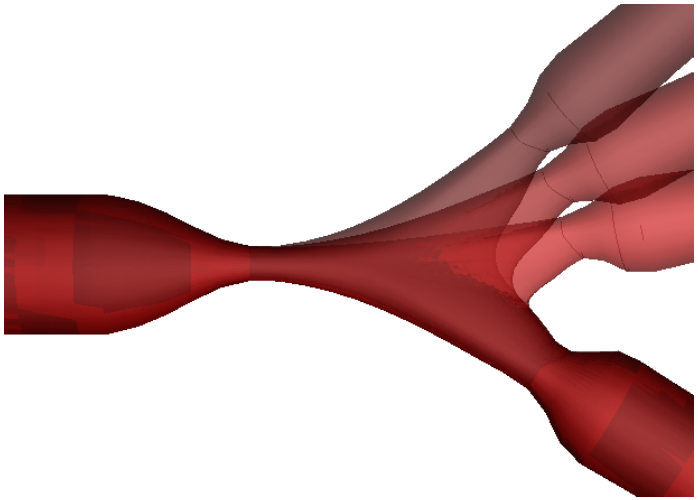


Conclusions/Discussion (I)

- Development coronary bifurcation model including plaque dimensions

- Quantification of plaque shift by volumetric analysis → same order of magnitude as Xu et al. Circ cardiovasc int 2012

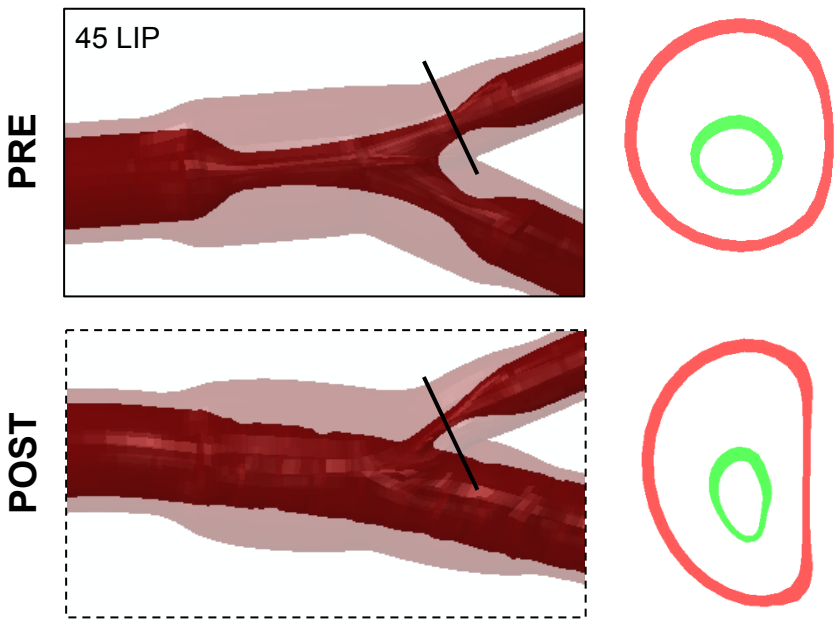
- Plaque shift depends on plaque composition and bifurcation angle
  - The largest plaque shift in lipid rich plaque
  - The largest plaque shift in small bifurcation angle



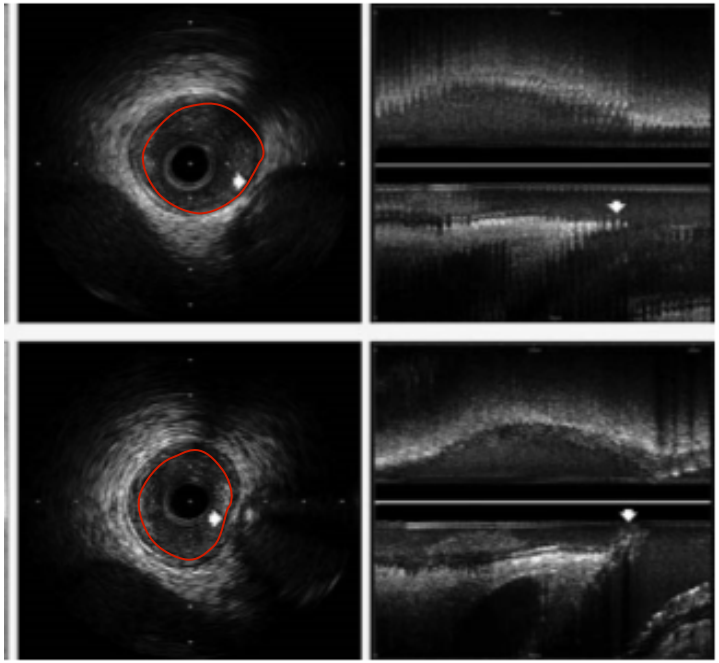
Conclusions/Discussion (I)

- **Lumen size of SIDE BRANCH does marginally change --> more influence on lumen shape**

Simulation



Xu et al. 2012



Xu et al. Circ Cardiovasc Interv, 2012; 25 657-662

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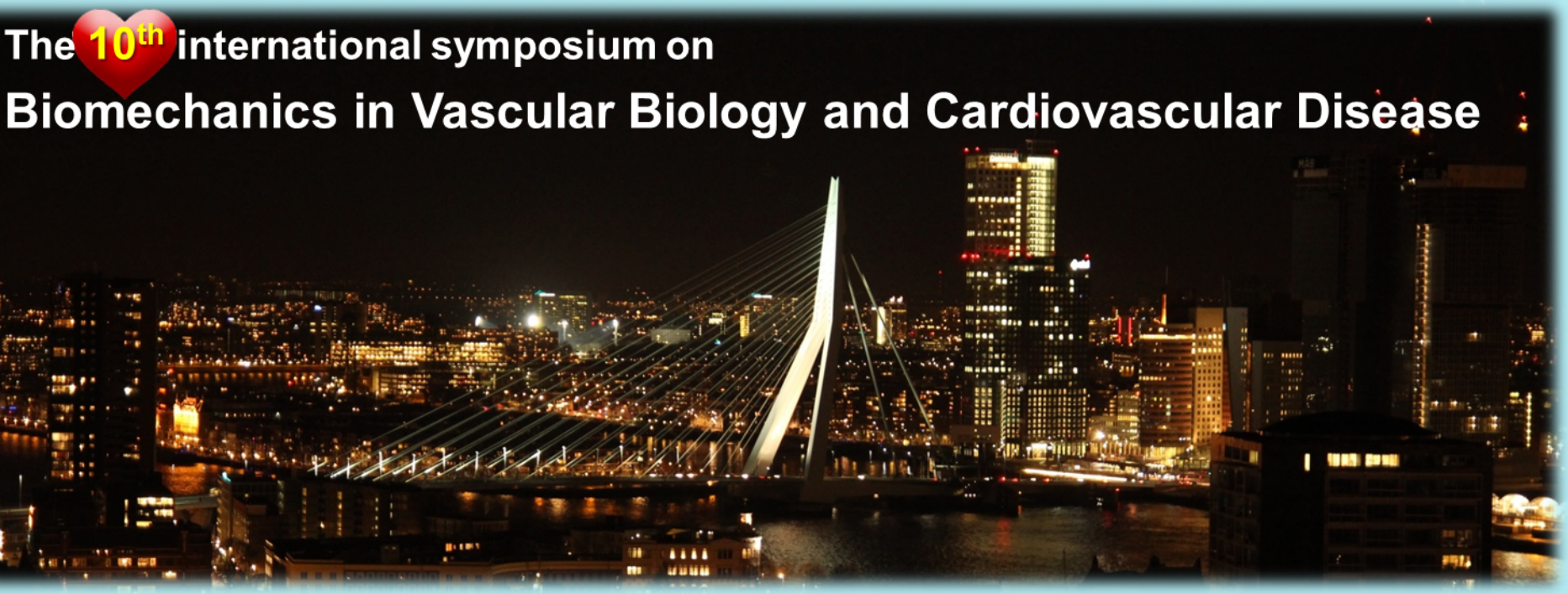

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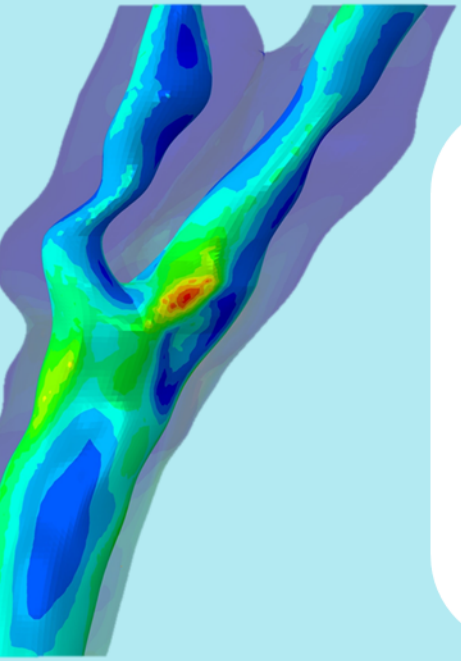

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