TCTAP 2012
Fellowship Course
Bifurcation PCI

Flow at Coronary Left Main Bifurcation After One and Two Stenting

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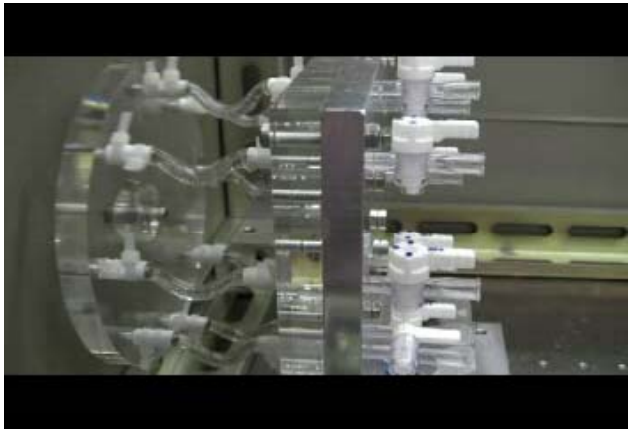
Novel In vitro Methodologies for the Investigation of Practical Performances of Coronary Stents

Flow Visualization

Potential Cause of Thrombosis at Bifurcation

Iwasaki K, AHA Scientific Session 2010

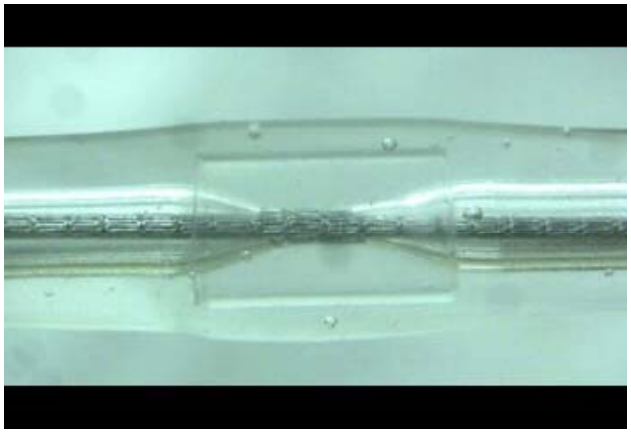
Durability Test



Fracture-Resistant Stent Platform

Iwasaki K, ACC 10'

Stenotic Artery



Optimal Stent Deployment Method

Iwasaki K, AHA Scientific Session 2009

JAMA®

Online article and related content current as of July 7, 2010.

Incidence, Predictors, and Outcome of Thrombosis After Successful Implantation of Drug-Eluting Stents

Ioannis Iakovou; Thomas Schmidt; Erminio Bonizzoni; et al.

JAMA. 2005;293(17):2126-2130 (doi:10.1001/jama.293.17.2126)

Table 2. Univariate Predictors of Cumulative Stent Thrombosis

Variables	Incidence of Stent Thrombosis, No./Total (%)	Hazard Ratio (95% Confidence Interval)	*P* Value
	Categorical Variables		
Premature antiplatelet therapy discontinuation	5/17 (29)	152 (52-442)	<.001
Prior brachytherapy	2/23 (8.7)	7.49 (1.78-31.49)	.006
Renal failure	8/127 (6.2)	11.67 (5.17-26.35)	<.001
Bifurcation with 2 stents	13/336 (3.9)	4.62 (2.22-9.62)	<.001
Bifurcation lesion	18/507 (3.6)	6.50 (3.02-13.98)	<.001
Unprotected left main artery	3/92 (3.3)	0.95 (0.67-1.36)	.81
Diabetes	15/591 (2.5)	3.45 (1.66-7.18)	<.001
Thrombus	1/50 (2)	1.58 (0.21-11.65)	.65
Unstable angina	8/590 (1.4)	1.24 (0.56-2.73)	.58
Male sex	22/1907 (1.2)	0.80 (0.30-2.11)	.66
B2 or C type	21/1698 (1.2)	1.19 (0.48-2.94)	.69
Calcification	4/392 (1)	0.74 (0.26-2.14)	.58
Sirolimus-eluting stent	9/1062 (0.8)	0.50 (0.22-1.10)	0.09

Background

Coronary bifurcation lesions and two stenting at coronary bifurcation are identified as predictors of stent thrombotic events throughout real-world clinical data.

Iakovou, et al. JAMA 293(17), 2126-2130, 2005.

(1) The reason for incidence of stent thombosis after two-stenting has not been well understood yet.

(2) There is little information about influence of one-stent and two-stent at LM bifurcation on flow.

Objective

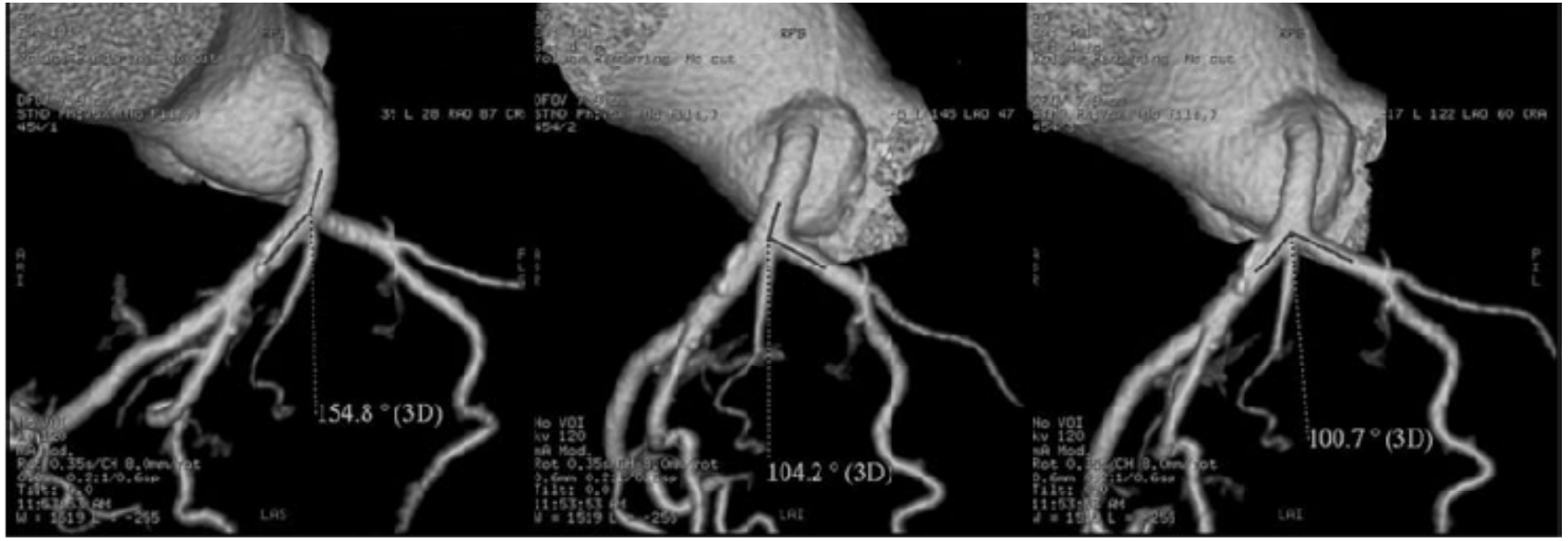
To assess potential flow disturbances after two-stenting and one-stenting in an elastic three-dimensional stenotic bifurcated artery replica, using a physiological circulation simulator

(1) Develop an elastic 3-D stenotic coronary bifurcated replica

(2) Develop a physiological coronary circulation simulator

(3) Investigate influences of two-stent and one-stent at bifurcation on flow characteristics

Kawasaki T, et al. The bifurcation study using 64 multislice computed tomography, Catheter Cardiovasc Interv. 2009;73(5):653-8.



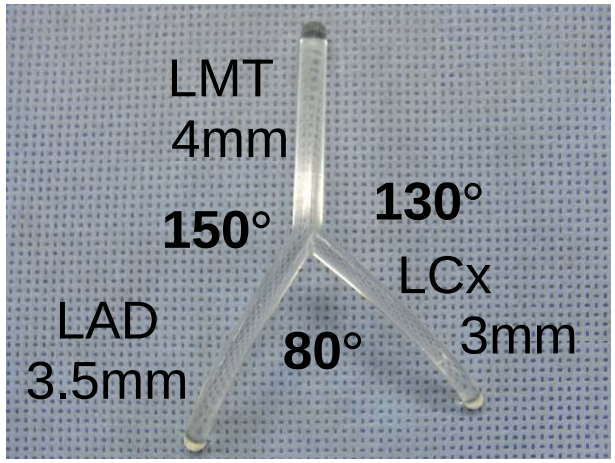
Results of bifurcation angles (n=209)

Bifurcation	Average angle
∠LMT-LAD°	143±13
∠LMT-LCx°	121±21
∠LAD-LCx°	72±22

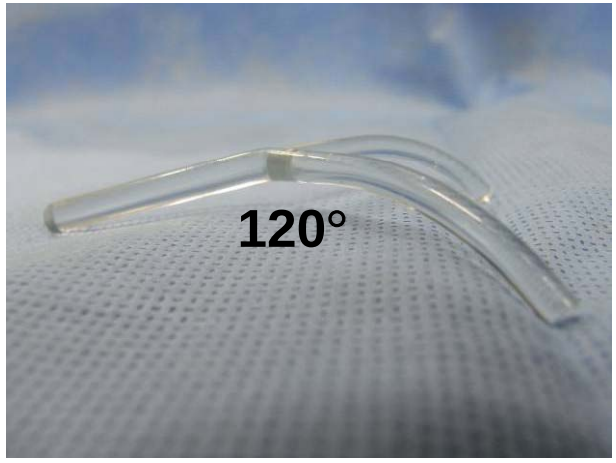
Construction of an Elastic Coronary Artery Bifurcation: Three-Dimensional Model

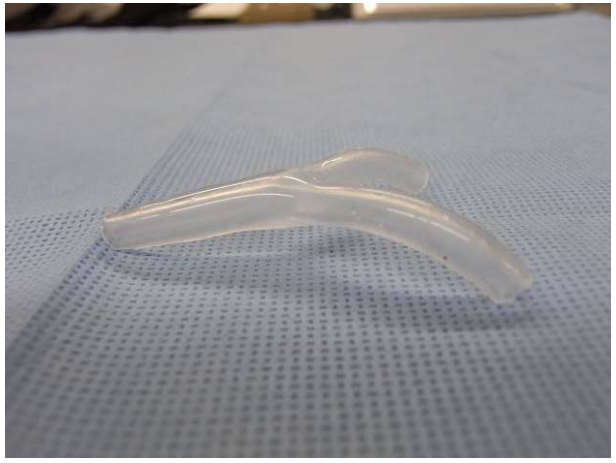
Master Mold **Wax Mold** **Silicone Artery**

Top Views

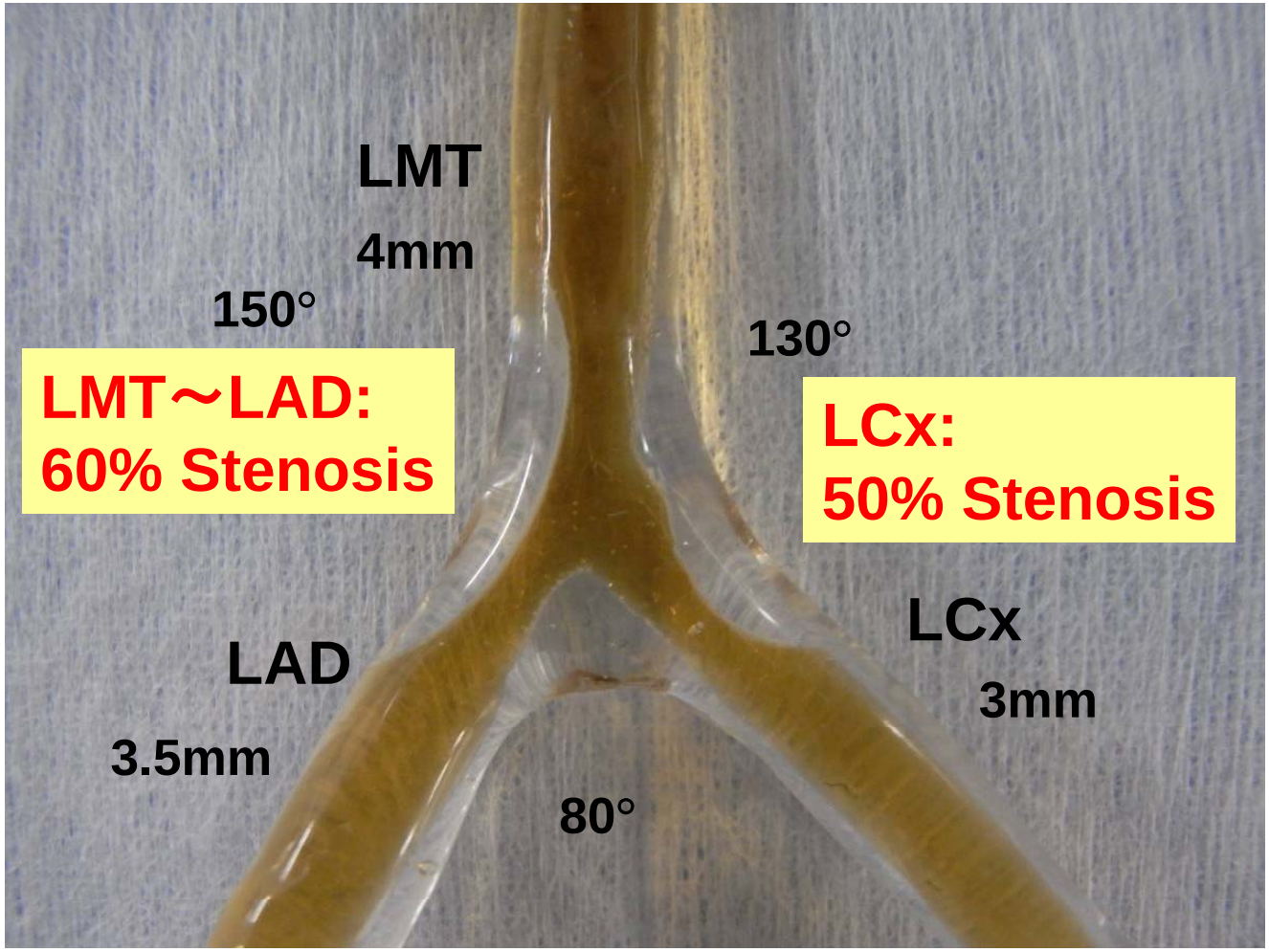


Side Views

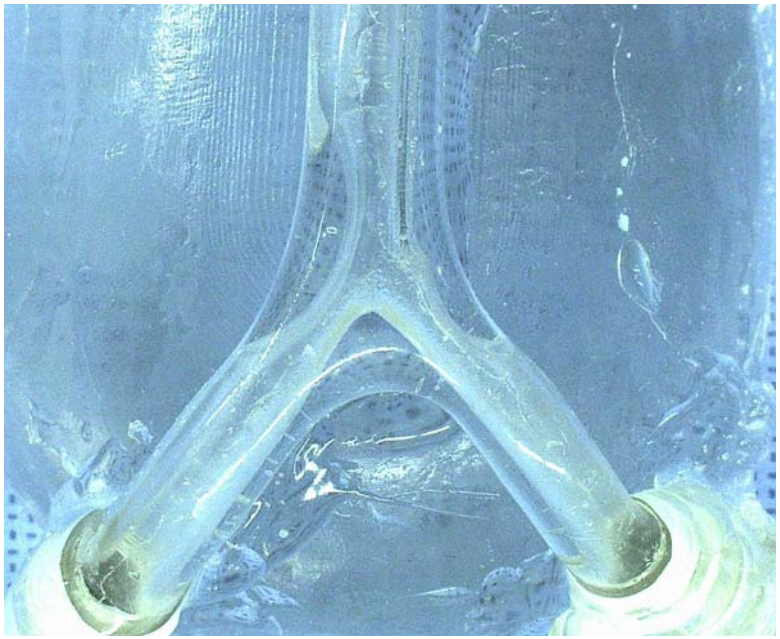




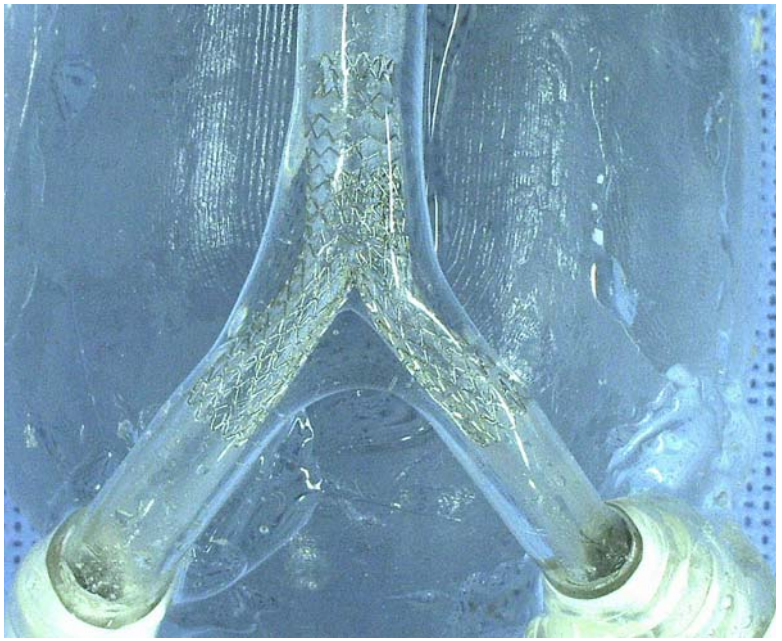
Development of a Stenotic Bifurcated Artery Model :Three-Dimensional Elastic Model



Mini-Crush Stenting in the Stenotic Bifurcation Model



Stenotic Bifurcation



Post-Stenting

1. LMT～LCx: Driver 3.0mm × 18mm

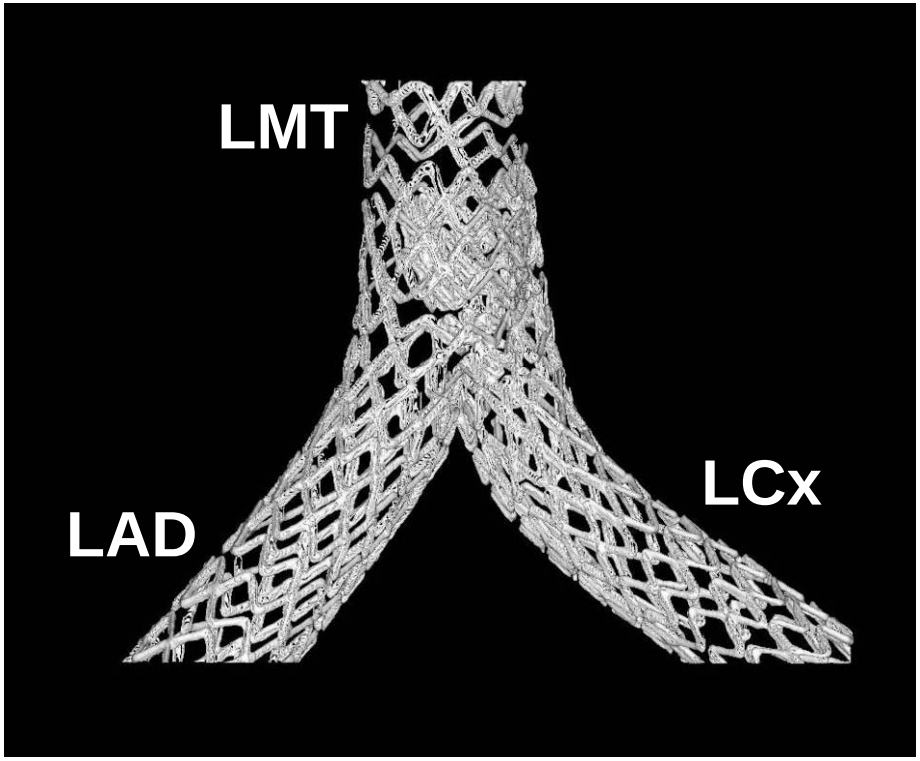
2. LMT～LAD: Driver 3.5mm × 24mm

3. LMT～LCx: QUANTUM MAVERICK 2.0mm × 15mm

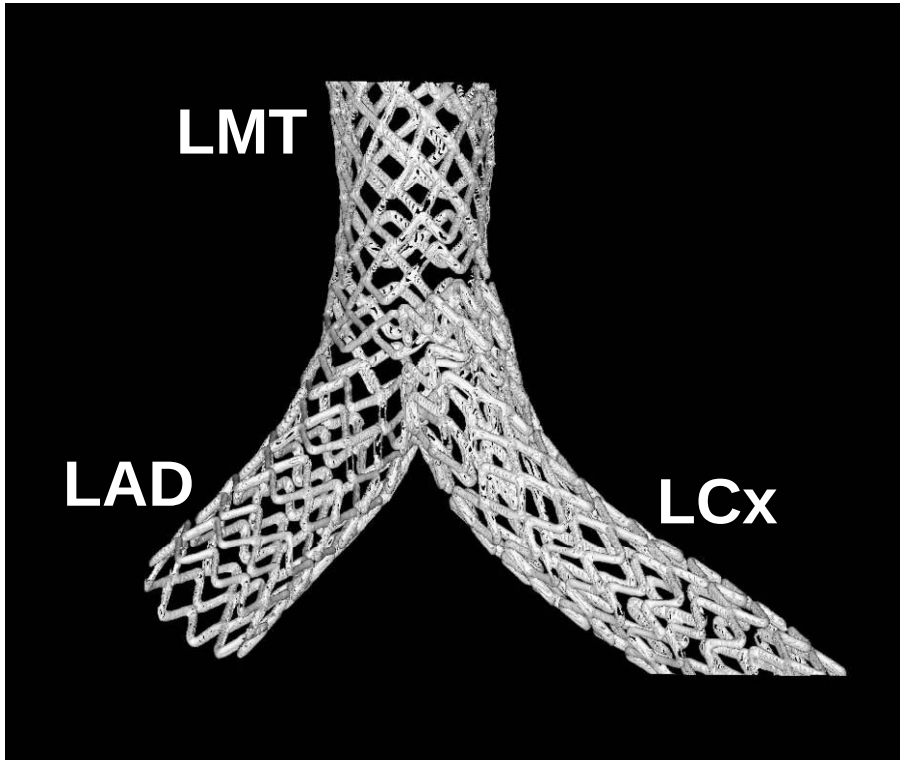
4. Final KBT: Simultaneous Kissing Balloon Post-dilation

Micro-CT Images after Two Stenting in the Elastic Stenotic Bifurcated Artery Replicas

Mini-Crush Stenting

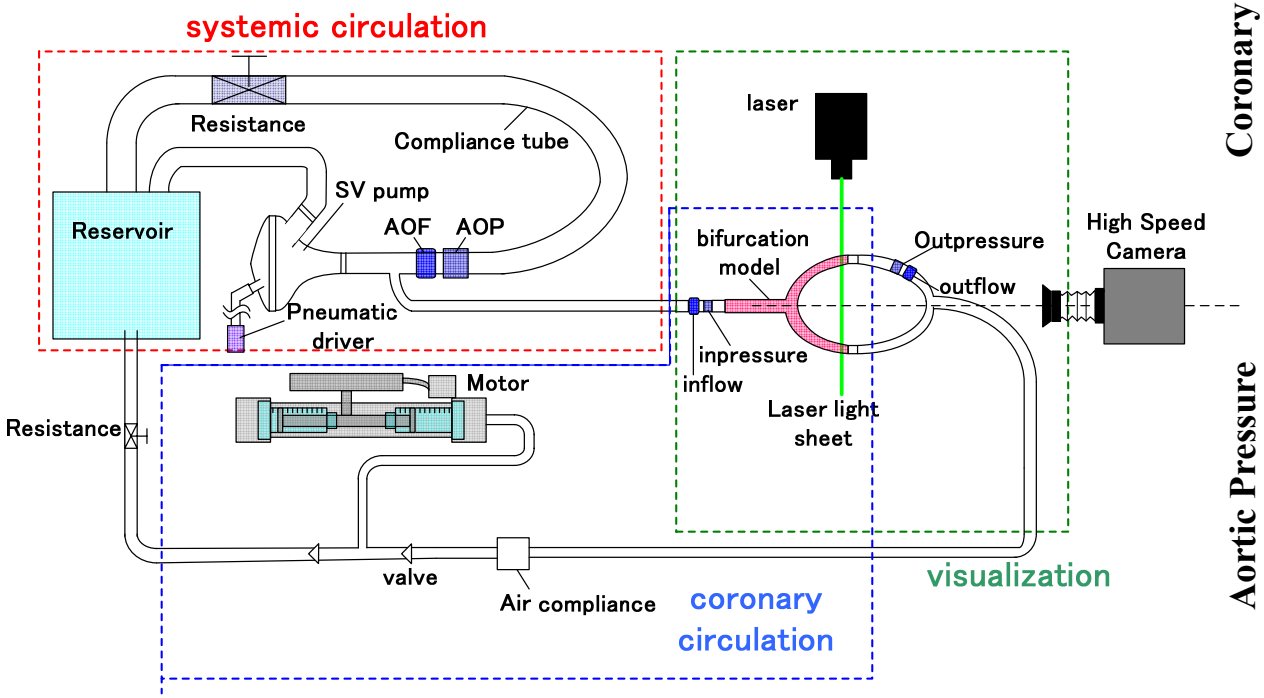


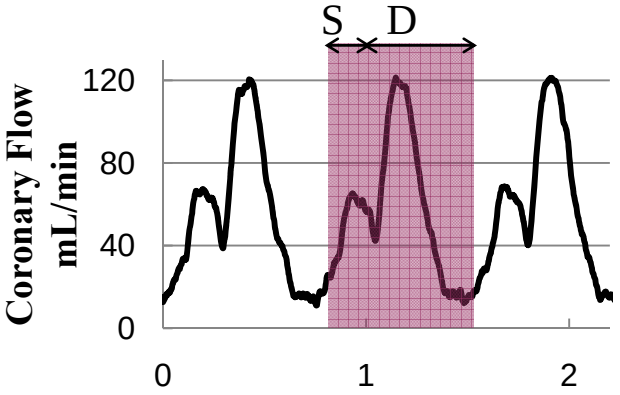
Modified-T Stenting

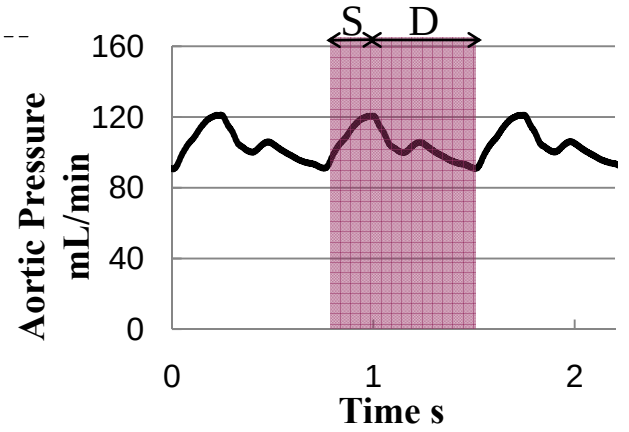


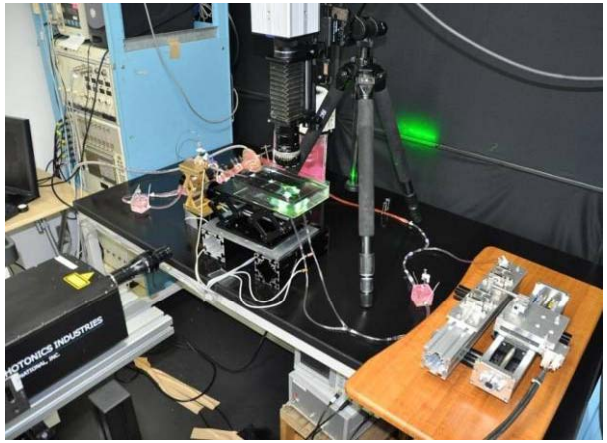
Coronary Circulation Simulator for Flow Visualization at Bifurcation

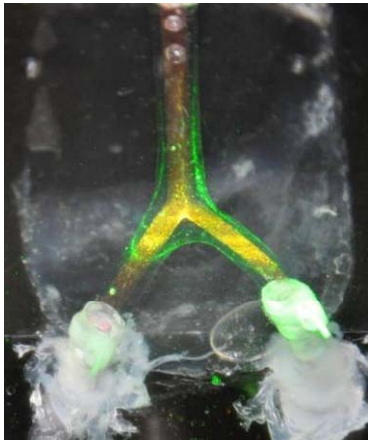
Coronary Circulation Simulator





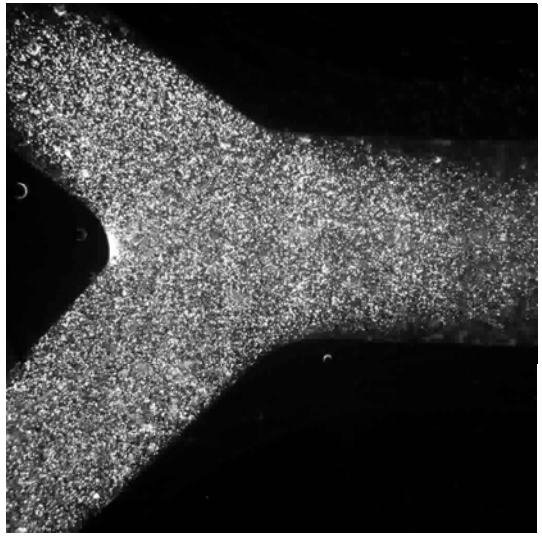




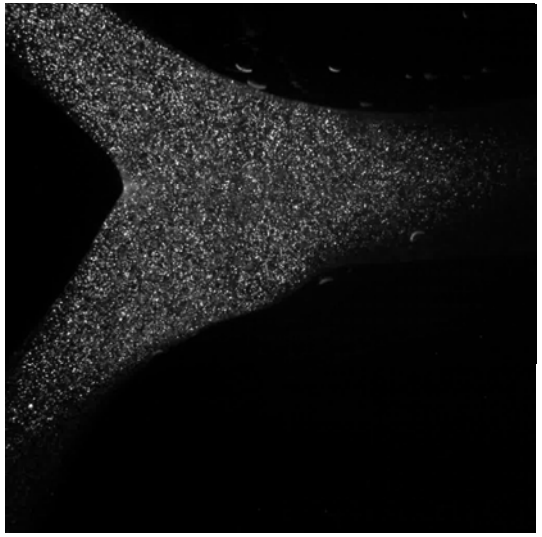


Mean flow rate	55mL/min
Flow ratio	50%:50%
Pressure	120/80mmHg
Heart rate	80bpm
Working fluid	Glycerol solution (1.1g/cm^3,4.0cP)
Seeding particle	Fluorescent particle(1.1g/cm^3,13μm)
Time resolution	500Hz
Space resolution	170μm

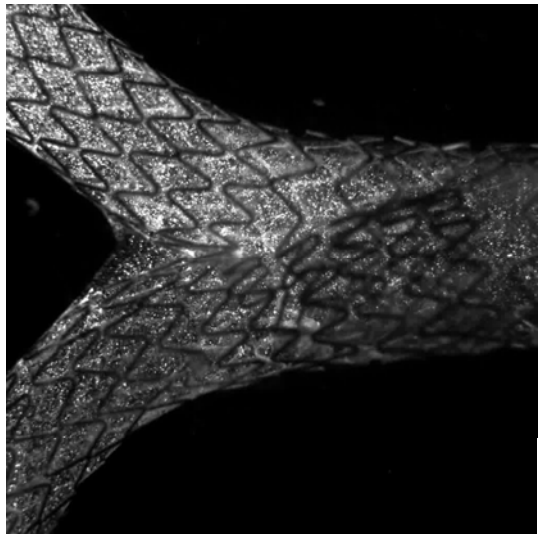
Flow Observation at Coronary Artery Bifurcation



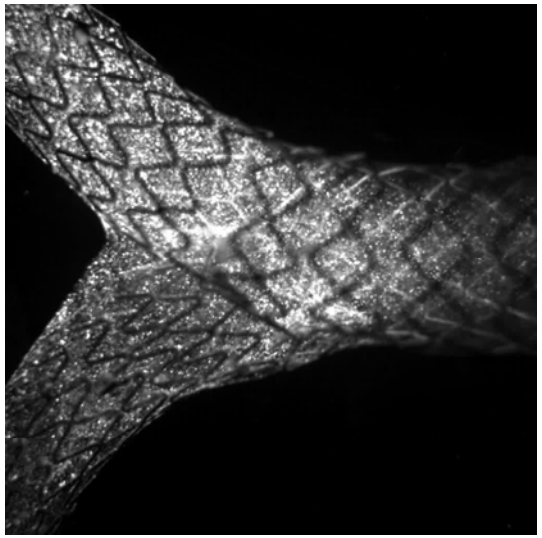
Normal Bifurcation



Stenotic Bifurcation



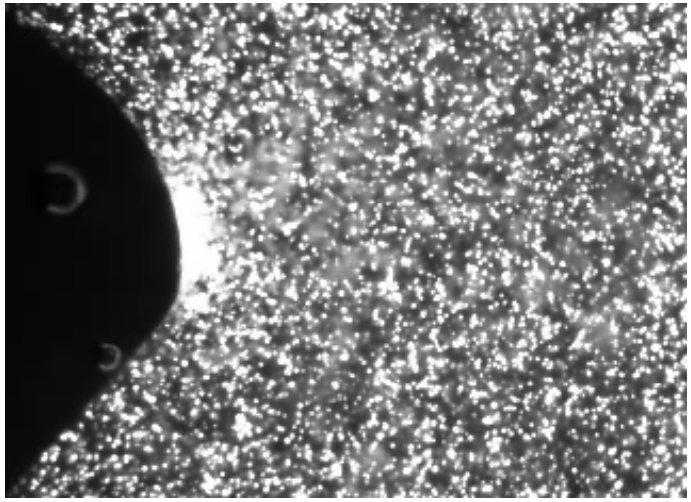
Mini-Crush Stenting



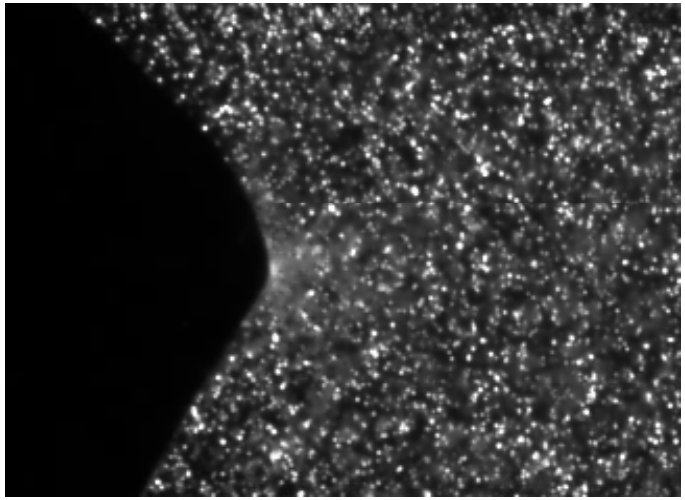
Modified-T Stenting

Flow Observation at Bifurcation [High Magnification]

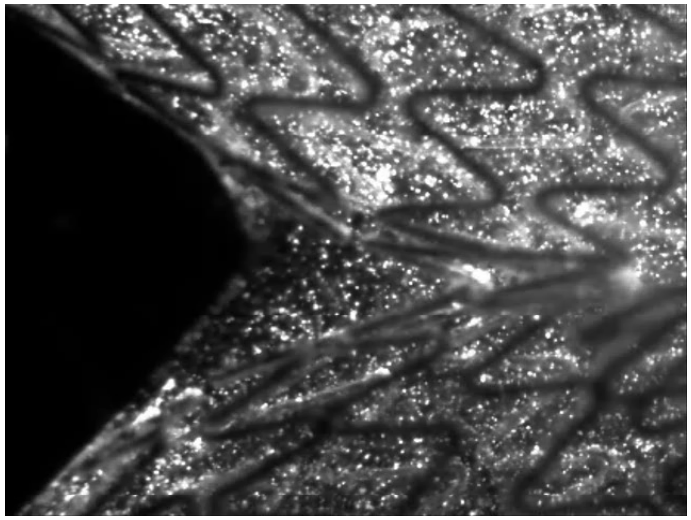
Carina



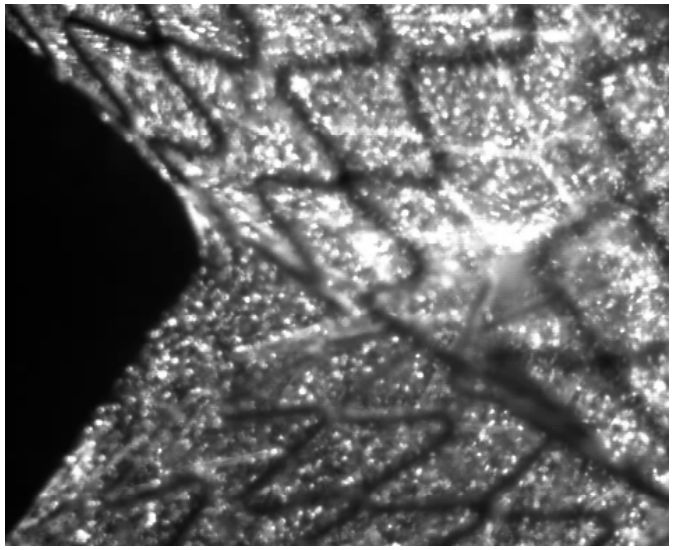
Normal Bifurcation



Stenotic Bifurcation

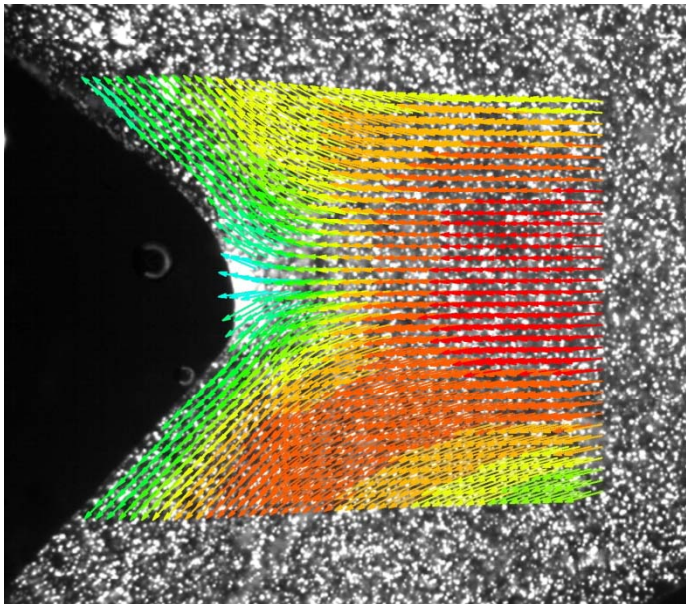


Mini-Crush Stenting

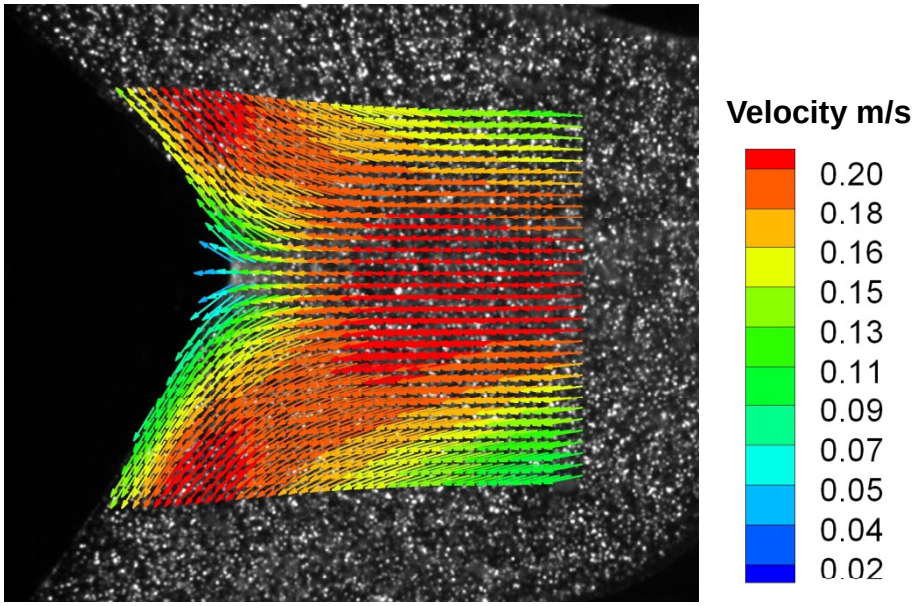


Modified-T Stenting

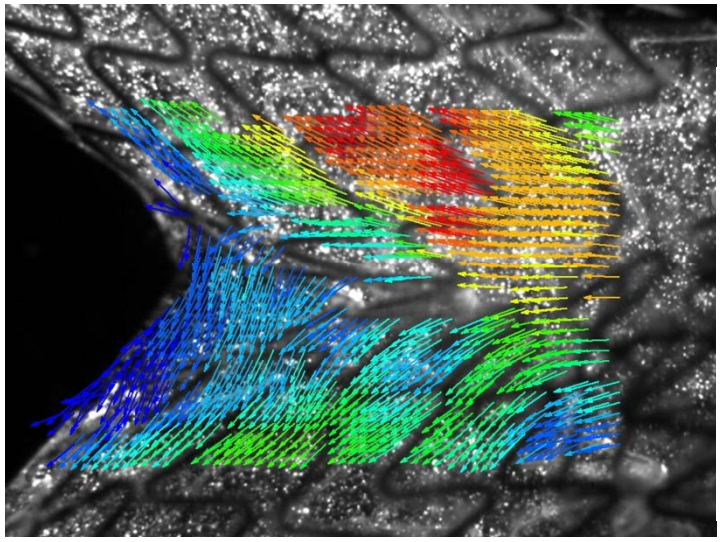
Comparison of Flow Velocity Distributions at Carina



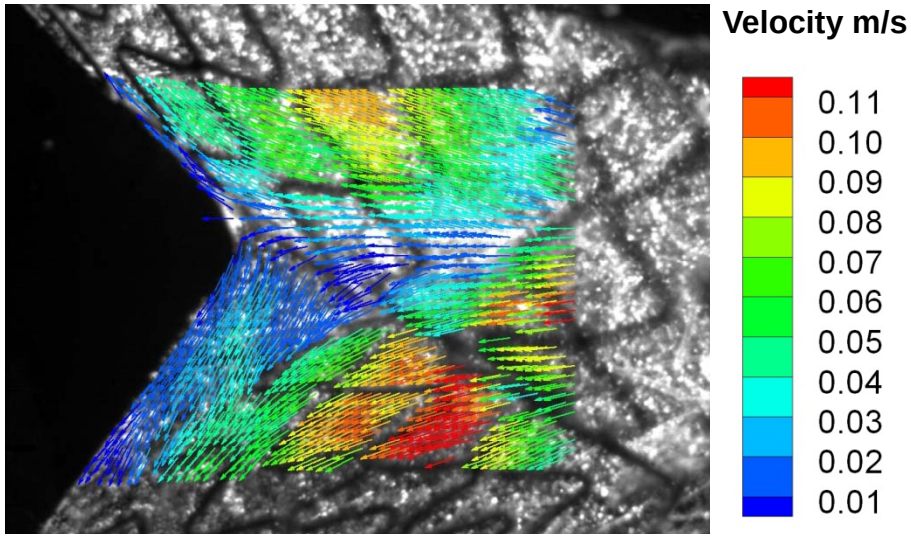
Normal Bifurcation



Stenotic Bifurcation

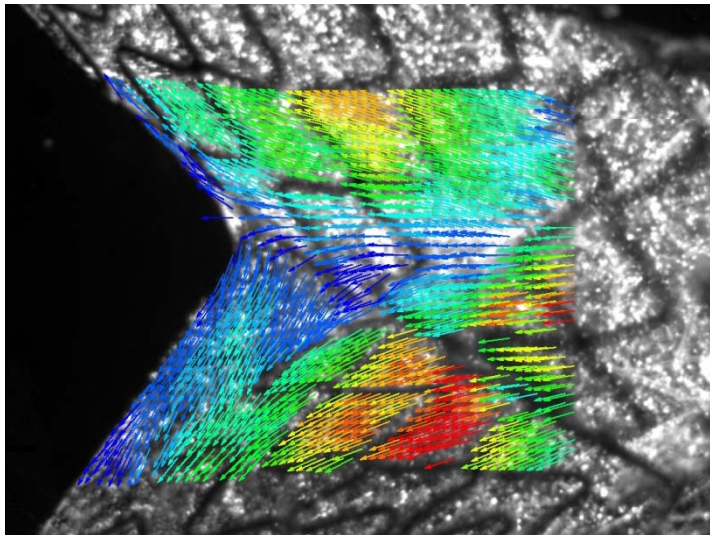


Mini-Crush Stenting

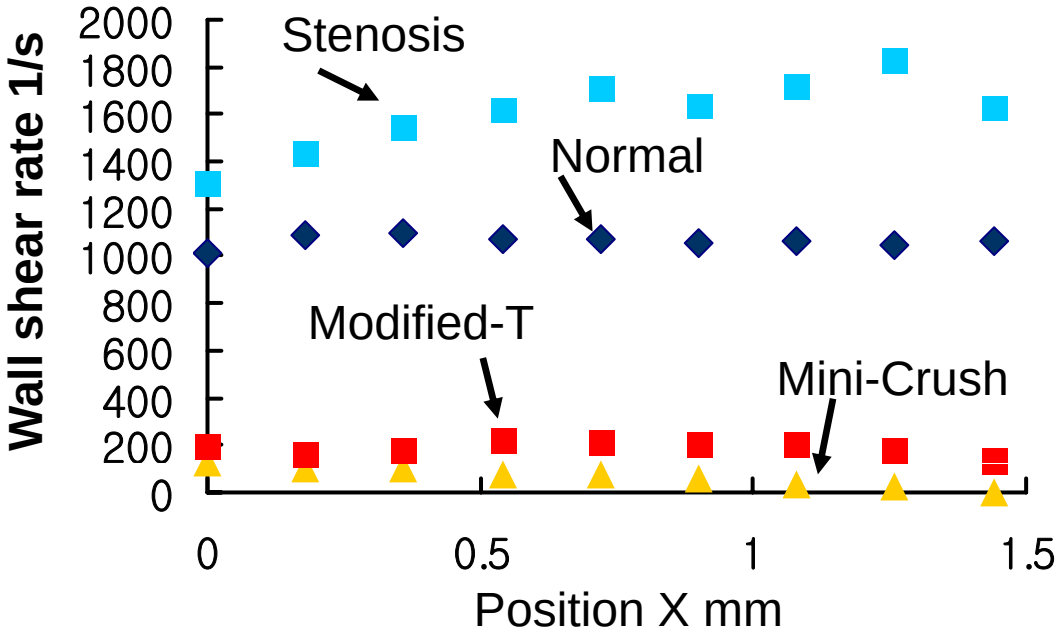


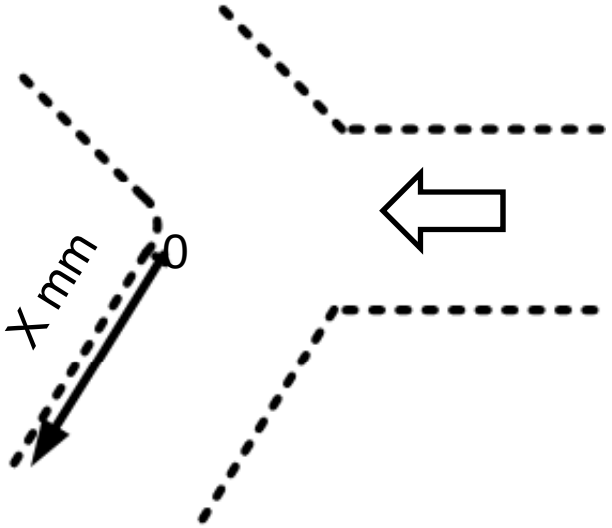
Modified-T Stenting

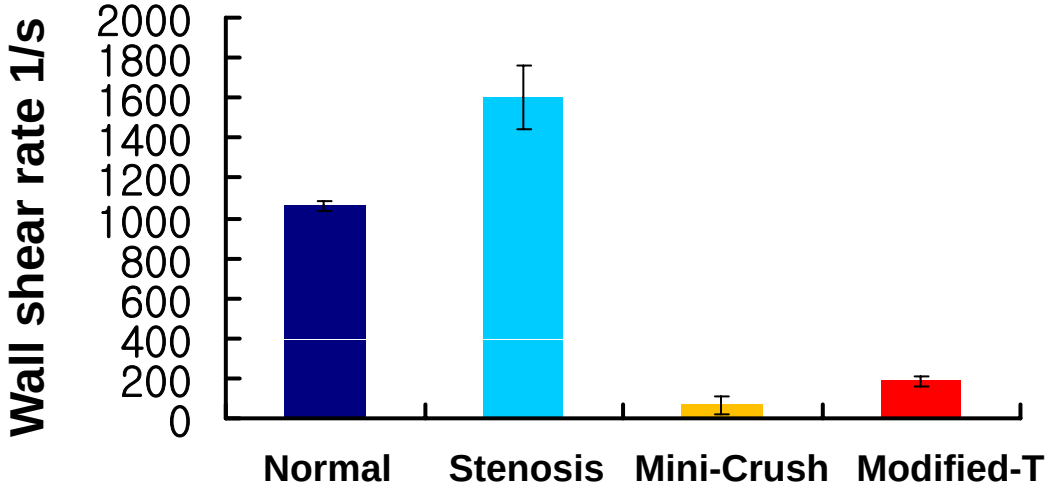
Comparison of Wall Shear Rate along Arterial Wall: from Carina Tip to Downstream



Mini-Crush Stenting







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Pathological Findings at Bifurcation Lesions

The Impact of Flow Distribution on Atherosclerosis and Arterial Healing After Stent Implantation

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Frank D. Kolodgie, PHD,* Renu Virmani, MD*

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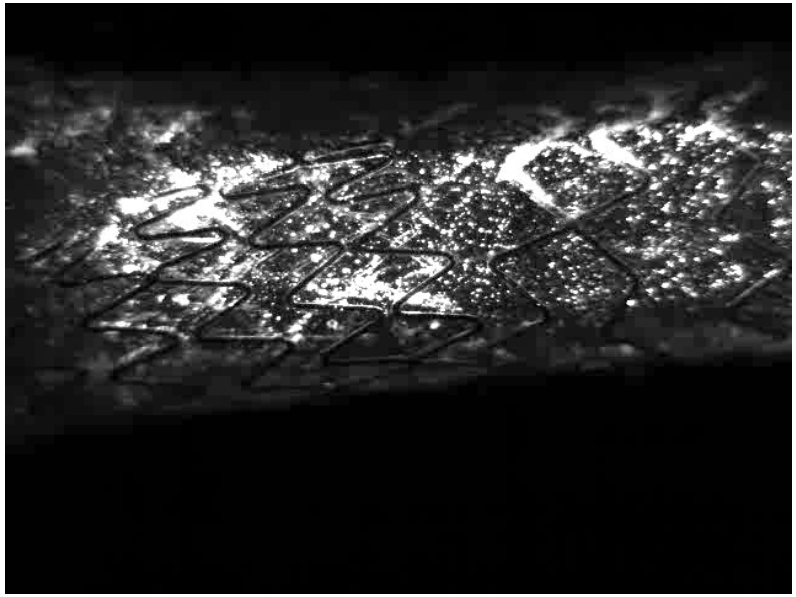
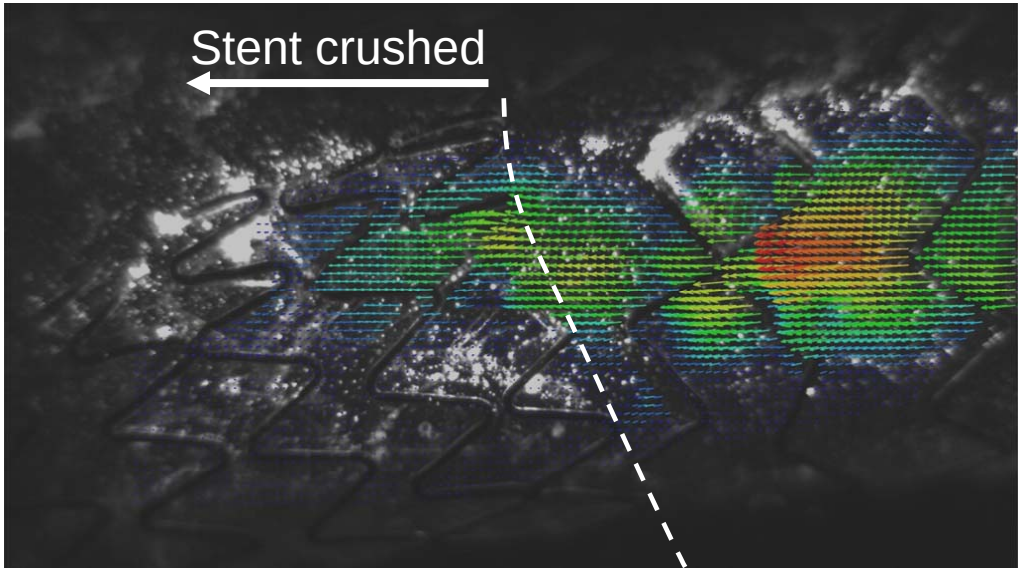
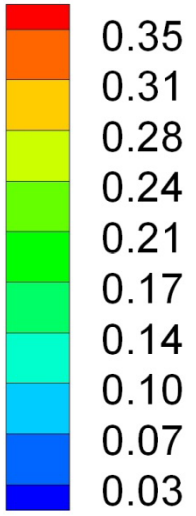
Table 2 Morphometric Comparison Between Flow Divider Versus Lateral Wall In DES and BMS

	DES (12 Lesions, 17 Stents)			BMS (14 Lesions, 18 Stents)			p Value for DES vs. BMS	
	Flow Divider	Lateral	p Value	Flow Divider	Lateral	p Value	Flow Divider	Lateral
Neointimal thickness (mm)	0.07 (0.03–0.15)	0.17 (0.09–0.23)	0.001	0.26 (0.16–0.73)	0.44 (0.17–0.67)	0.25	0.0002	0.004
Fibrin deposition (% struts)	60 (21–67)	17 (0–55)	0.01	8 (0–33)	3 (0–21)	0.21	0.008	0.19
Uncovered struts (% struts)	40 (16–76)	0 (0–15)	0.001	0 (0–21)	0 (0–0)	0.10	0.004	0.38

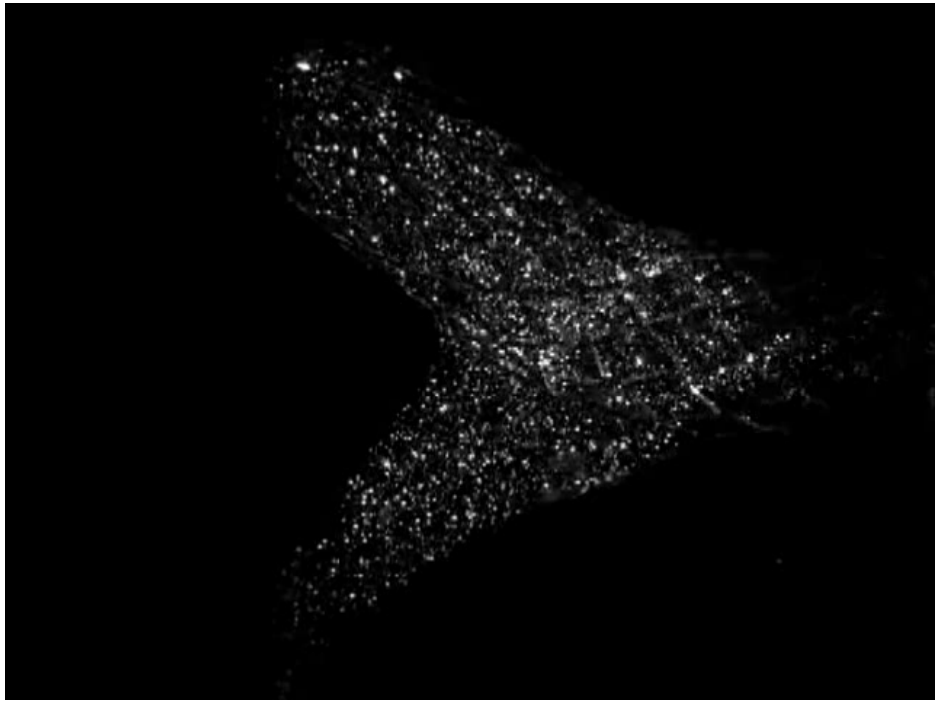
Distinct Slow Flow Velocity at the Crushed Lesion



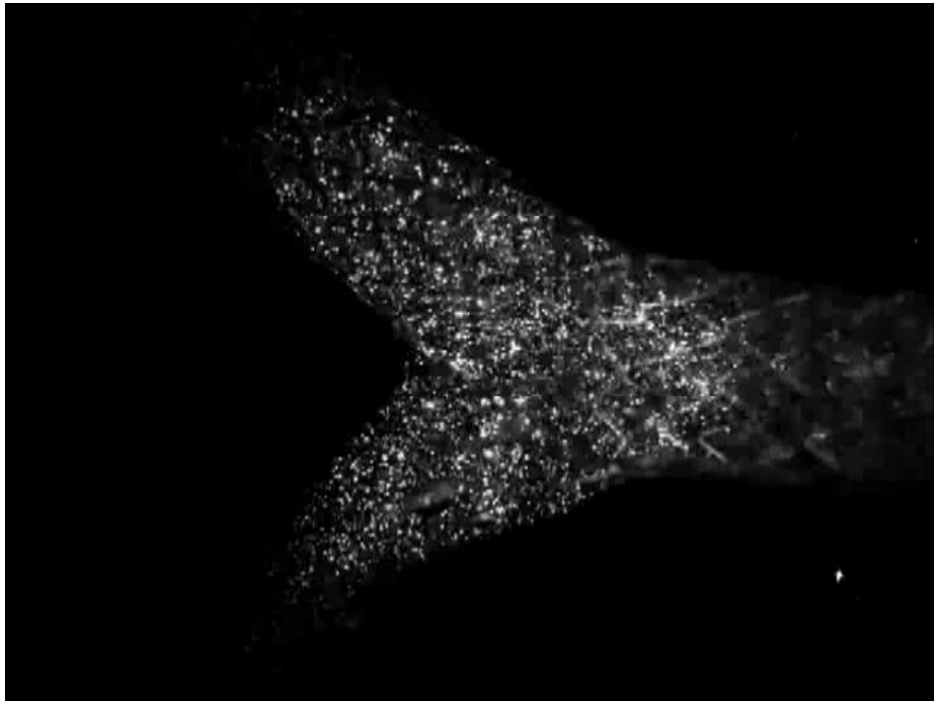




Flow at Bifurcation: One stent with/without KBI

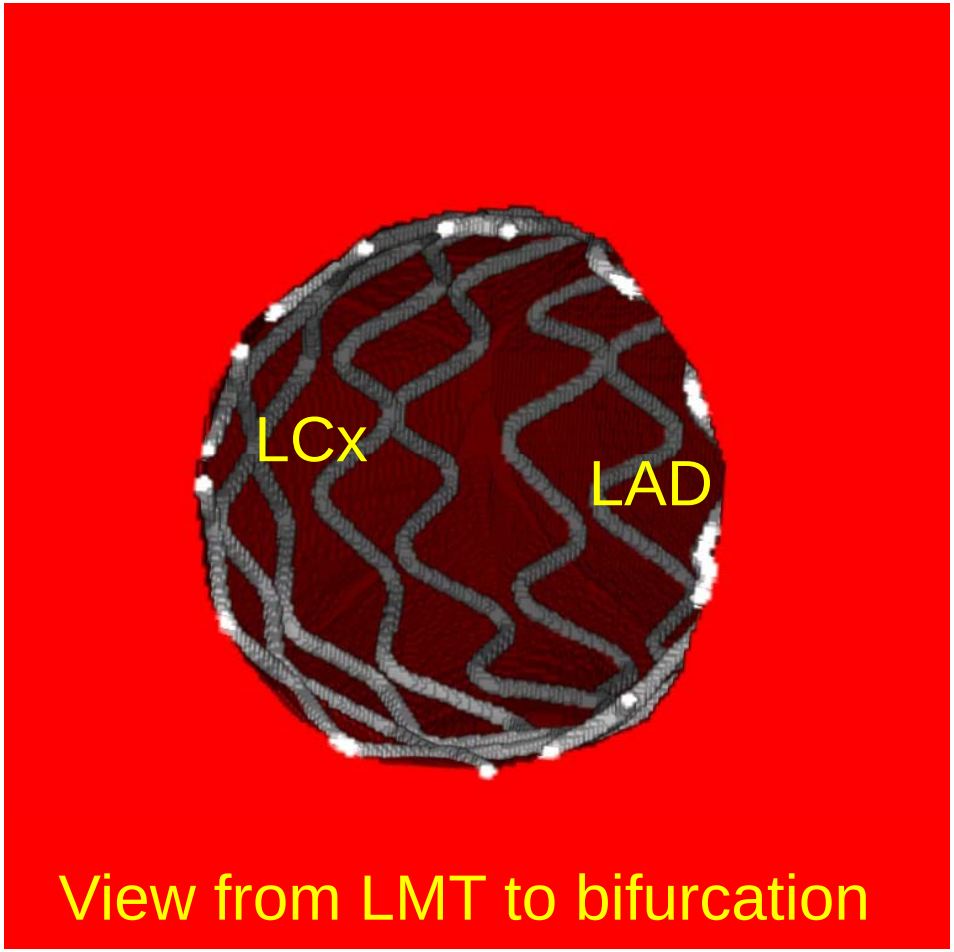


One-stent (Non KBI)

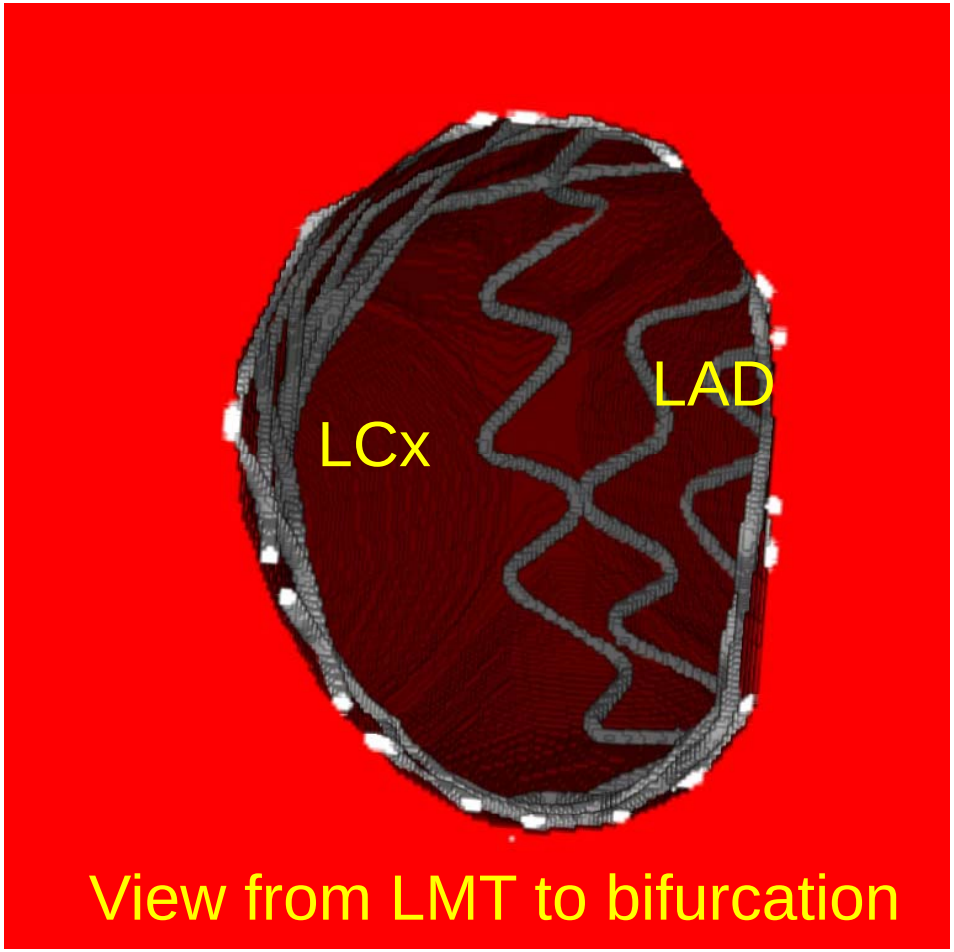


One-stent plus KBI

Flow Tract Observation using Micro CT



One-stent (Non KBI)



One-stent plus KBI

Flow Tract Observation using Micro CT

One-stent (Non KBI)

One-stent plus KBI

Summary

(1) In vitro pulsatile flow study using elastic three-dimensional stenotic bifurcated artery replica demonstrated that two stenting at coronary bifurcation yielded distinctly slow flow region at carina.

(2) When mini-crush stenting was performed, distinct slow flow velocity region was observed between the crushed two independent stents.

(3) Influence of stent struts in flow domain especially after one stenting on stent thrombosis should be further investigated.

(4) These data would partially give an explanation of higher incidences of thrombotic events at bifurcation after two stenting.

Acknowledgements

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(1) Health Science Research Grant (H20-IKOU-IPAN-001) from Ministry of Health, Labour and Welfare, Japan

(2) “Promotion of Environmental Improvement for Independence of Young Researchers” activities under the Special Coordination Funds for Promoting Science and Technology provided by the Ministry of Education, Culture, Sports, Science and Technology, Japan.