23rd CARDIOVASCULAR SUMMIT
TCTAP2018
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Coex, Seoul, Korea

Evolution of Multi-Modal Intracoronary Plaque Imaging

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UniversitätsSpital Zürich

Disclosure

No conflict of interest.

Multi-Modality Intracoronary Plaque Imaging

Sound and light follow the same physical rules of wave propagation

Light

Sound

Boundary conditions are quite different:

Multi-Modality Intracoronary Plaque Imaging

Sound and light follow the same physical rules of wave propagation

Light	Sound

Boundary conditions are quite different:

Higher resolution &

More spectroscopic possibilities

make light better for:

- superficial morphological imaging

- NIRS, Raman, etc.

Higher penetration &

Access to RF signals

make sound better suited for:

- whole plaque imaging

- palpography, elastography, etc

Multi-Modality Intracoronary Plaque Imaging

Clinically Used Approach: Combined NIRS-IVUS

Multi-Modality Intracoronary Plaque Imaging

Clinically Used Approach: Combined NIRS-IVUS

Combined NIR-IVUS Imaging

Laser

Computer with algorithms

Pull-back and rotation device

Catheter

Single use, 3.2 Fr

Dual modality

Spectroscopy – lipid core plaque

IVUS – plaque structure

Nir-Infrared Spectroscopy (NIRS)

Lipid Core Plaque (LCP) Algorithm

- Intracoronary catheter: 3.2F fibre optic catheter
- Spectra processed by algorithm and displayed to user as a chemical image of lipid rich plaque probability (“Chemogram”)

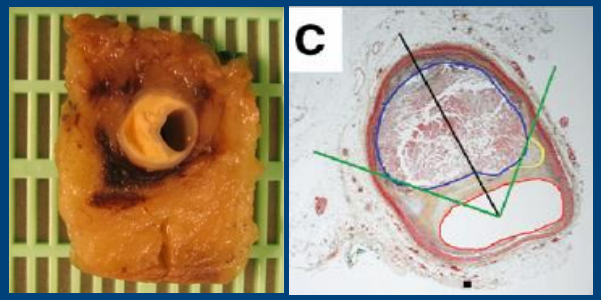
Algorithm Calibration

- 4.2 meters of artery from 33 autopsy hearts.
- Lipid Core Plaque (LCP) defined as:

Fibroatheroma > 200 µm thick

> 60 deg angular extent

Cap < 450 µm thick



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Gardner et al: J Am Coll Cardiol Img 2008;1:638–48)

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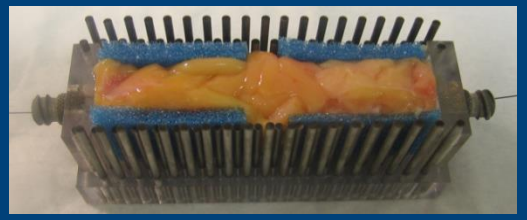
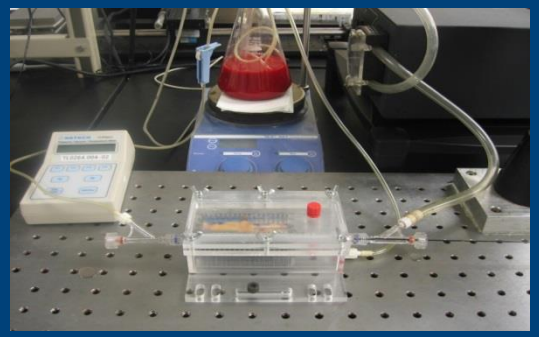
Double Blind Prospective Validation

•5.3 meters of artery from 51 autopsy hearts.





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Nir-Infrared Spectroscopy (NIRS)

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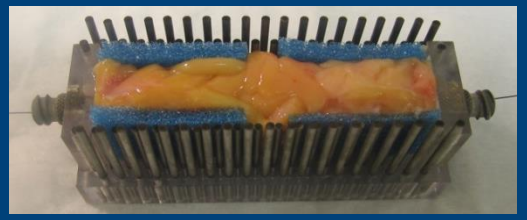
- Intracoronary catheter: 3.2F fibre optic catheter
- Spectra processed by algorithm and displayed to user as a chemical image of lipid rich plaque probability (“Chemogram”)

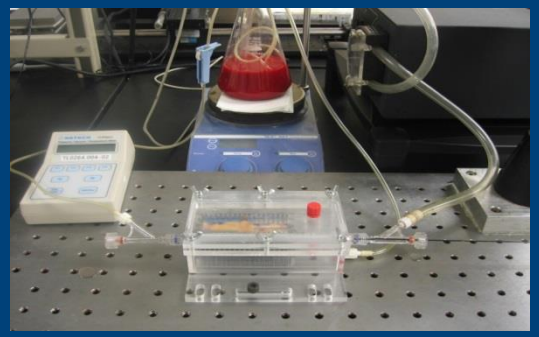
Double Blind Prospective Validation

•5.3 meters of artery from 51 autopsy hearts.

•The algorithm prospectively identified **Lipid Core Plaques** with an **ROC area of 0.80** (95% CI: 0.76-0.85).

• The **lipid core burden index** (LCBI) detected the presence or absence of any fibroatheroma with an **AUC of 0.86** (95% CI:0.81-0.91).





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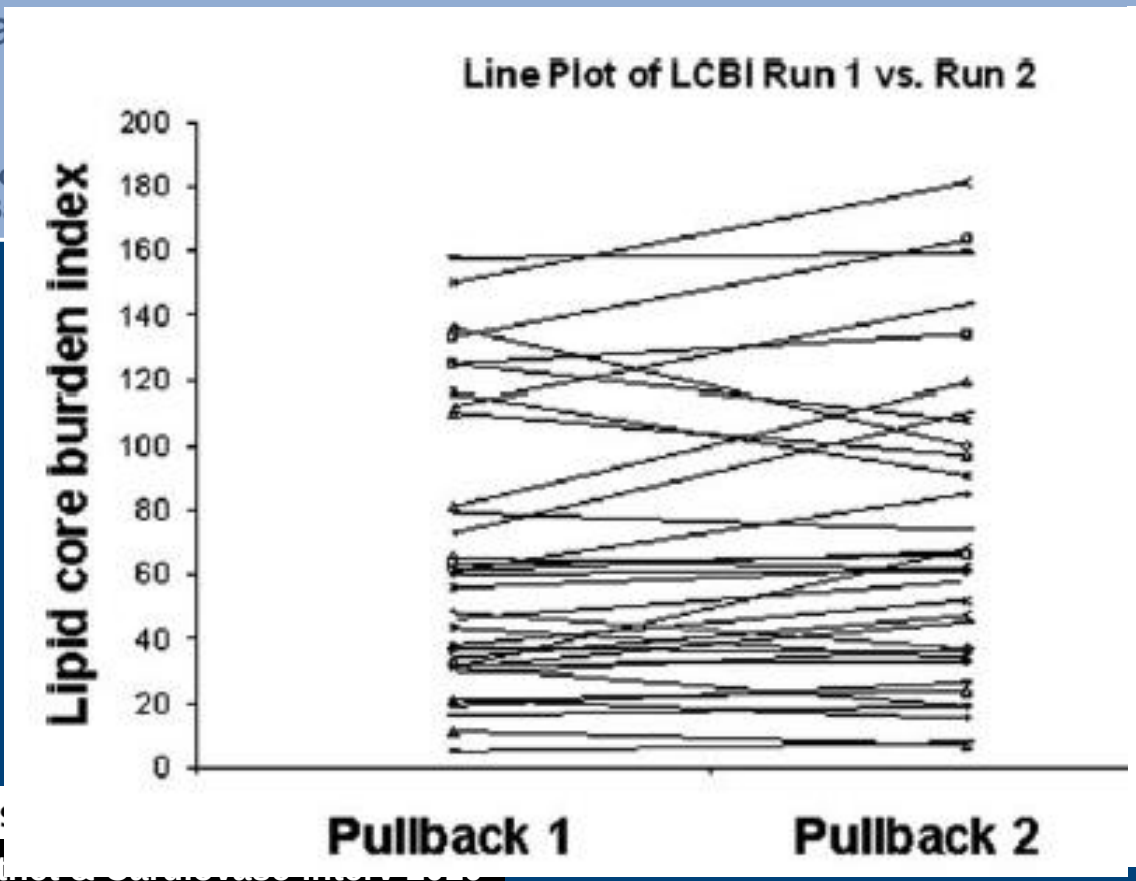
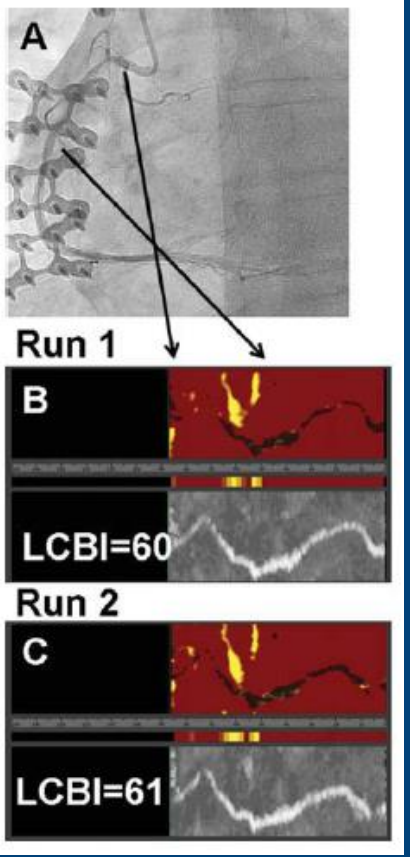
Nir-Infrared Spectroscopy (NIRS)
Reproducibility In-Vivo

Catheterization and Cardiovascular Interventions 76:359–365 (2010)

Reproducibility of Near-Infrared Spectroscopy for the Detection of Lipid Core Coronary Plaques

Subhash B





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Garcia et al. Cat

Nir-Infrared Spectroscopy (NIRS)

Reproducibility In-Vivo

Catheterization and Cardiovascular Interventions 76:359–365 (2010)

Reproducibility of Near-Infrared Spectroscopy for the Detection of Lipid Core Coronary Plaques and Observed Changes After Coronary

Subhash

	Mean number of LCPs pullback 1	Mean number of pullback 2	Median number of LCPs pullback 1	Median number of LCPs pullback 2	Spearman's rho for number of LCPs (*P*-value)	Intraclass correlation coefficient for number of LCPs (95% confidence intervals)
Definition 1	1.06 ± 1.0	0.94 ± 0.9	1	1	0.827	0.756 (0.572, 0.868)
Definition 2	1.61 ± 1.3	1.64 ± 1.0	1	1	0.79	0.774 (0.6, 0.878)
Definition 3	1.94 ± 1.1	1.97 ± 1.0	2	2	0.698	0.72 (0.516, 0.847)
Definition 4	0.61 ± 0.7	0.61 ± 0.8	0.5	0	0.75	0.814 (0.666, 0.901)
Definition 5	1.17 ± 0.9	1.08 ± 0.9	1	1	0.871	0.883 (0.783, 0.939)
Definition 6	1.47 ± 0.9	1.47 ± 0.8	1	1	0.717	0.666 (0.436, 0.815)
Definition 7	0.25 ± 0.4	0.28 ± 0.5	0	0	0.709	0.689 (0.469, 0.828)
Definition 8	0.67 ± 0.8	0.72 ± 0.7	1	1	0.761	0.788 (0.623, 0.886)
Definition 9	1.06 ± 0.9	1.17 ± 0.8	1	1	0.732	0.773 (0.598, 0.877)
Panel B						
Definition 1	4.75 ± 5.4	4.58 ± 5.1	4	3	0.892	0.882 (0.781, 0.938)
Definition 2	10.36 ± 9.3	10.28 ± 8	9	8	0.853	0.771 (0.595, 0.876)
Definition 3	17.03 ± 11.8	17.25 ± 12.3	15.5	16.5	0.886	0.821 (0.677, 0.905)
Definition 4	3.94 ± 5.36	3.61 ± 5.23	2	0	0.817	0.913 (0.836, 0.955)
Definition 5	9.25 ± 8.6	8.89 ± 8.1	8	8	0.82	0.764 (0.585, 0.873)
Definition 6	16.14 ± 11.5	15.69 ± 12.6	15.5	15	0.717	0.804 (0.649, 0.895)
Definition 7	2.44 ± 4.5	2.81 ± 5.2	0	0	0.835	0.868 (0.757, 0.931)
Definition 8	6.47 ± 7.4	7.31 ± 8.2	6	6	0.794	0.793 (0.631, 0.889)
Definition 9	13.72 ± 12	14.36 ± 13	13	14	0.845	0.811 (0.66, 0.899)

Garcia et al. Cathet & Cardiovasc Interv 2010

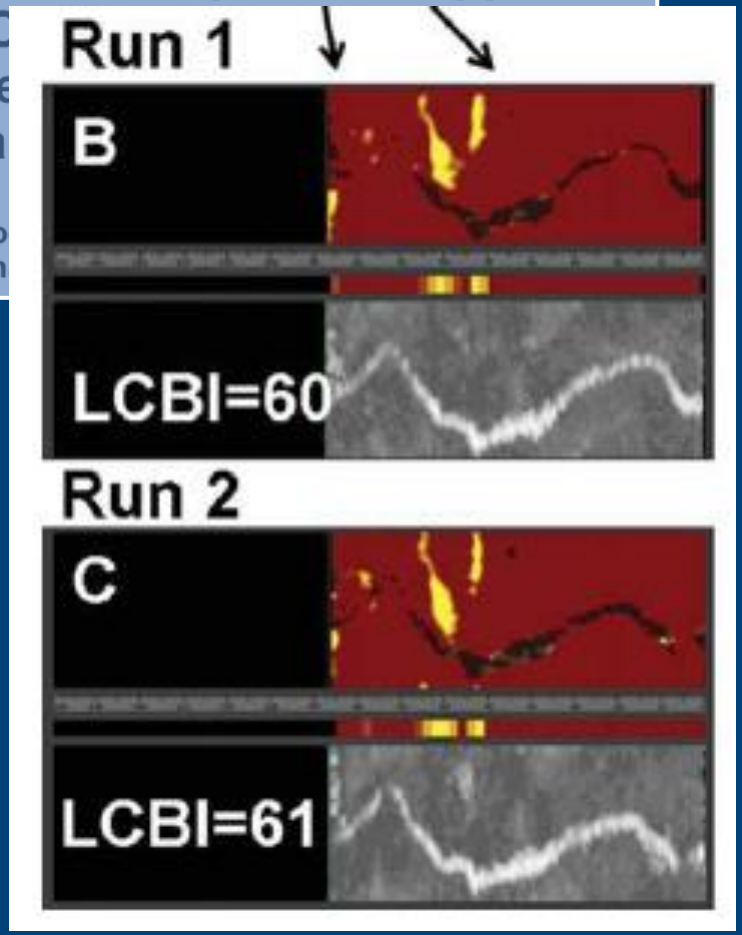
Nir-Infrared Spectroscopy (NIRS)

Reproducibility In-Vivo

Catheterization and Cardiovascular Interventions 76:359–365 (2010)

Reproducibility of Near-Infrared Spectroscopy for the Detection of Lipid C and Observed Change Stent Impla

Bobby A. Garcia,[1,2] BA, Frances Woo
Subhash Banerjee,[1,2] MD, FACC, FSCAI, and Emm



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Garcia et al. Cathet & Cardiovasc Interv 2010

Nir-Infrared Spectroscopy (NIRS)

Combination with Ultrasound

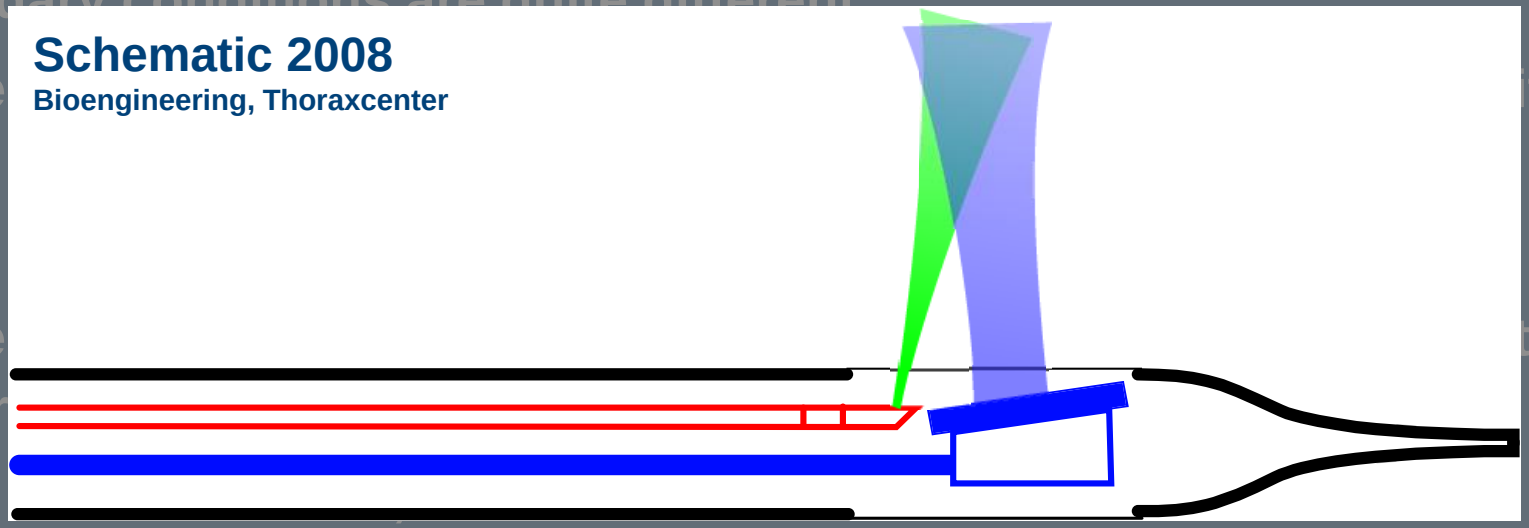
Sound and light follow the same physical rules of wave propagation

Boundary conditions are quite different

Highe ited for:

Highe t better

for



Both sound and light are suited for tissue characterization.

Combination catheters might offer the benefits of both

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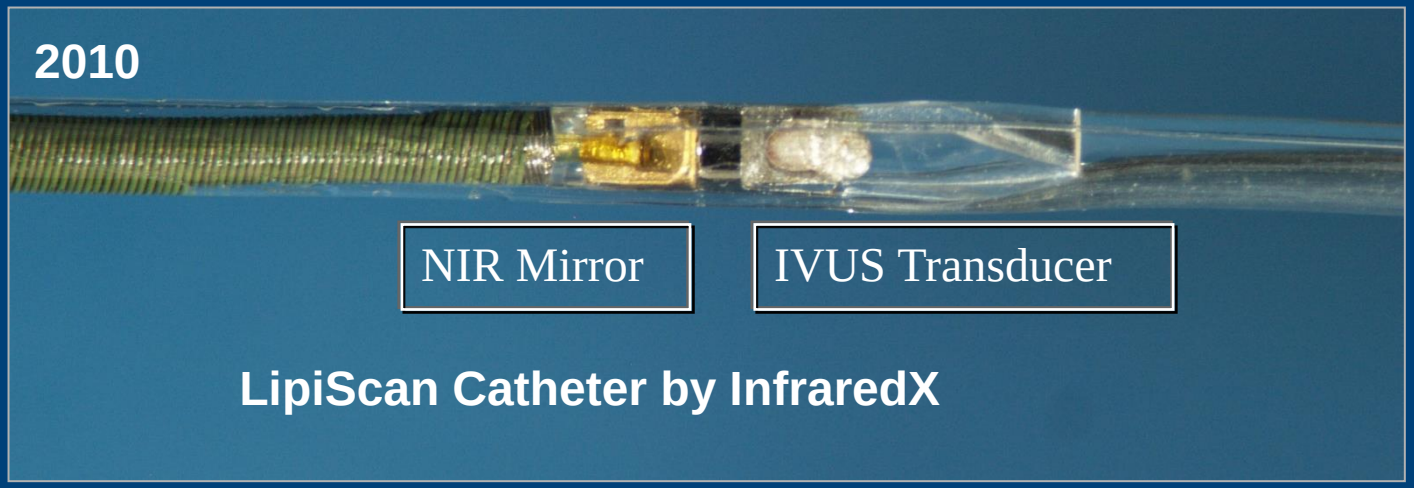
Nir-Infrared Spectroscopy (NIRS)
Combination with Ultrasound

- **Catheter: 3.2Fr, 6Fr compatible, 0.014” guidewire**
- **NIRS: Same as LipiScan™,** cleared by FDA Apr ‘08
- **Ultrasound: 40MHz, 16 fps**
- **Pullback speed: 0.5mm/sec**
- **Single catheter & pullback, thru blood**

  → simultaneous, co-registered NIR & IVUS data



LipiScan Catheter by InfraredX

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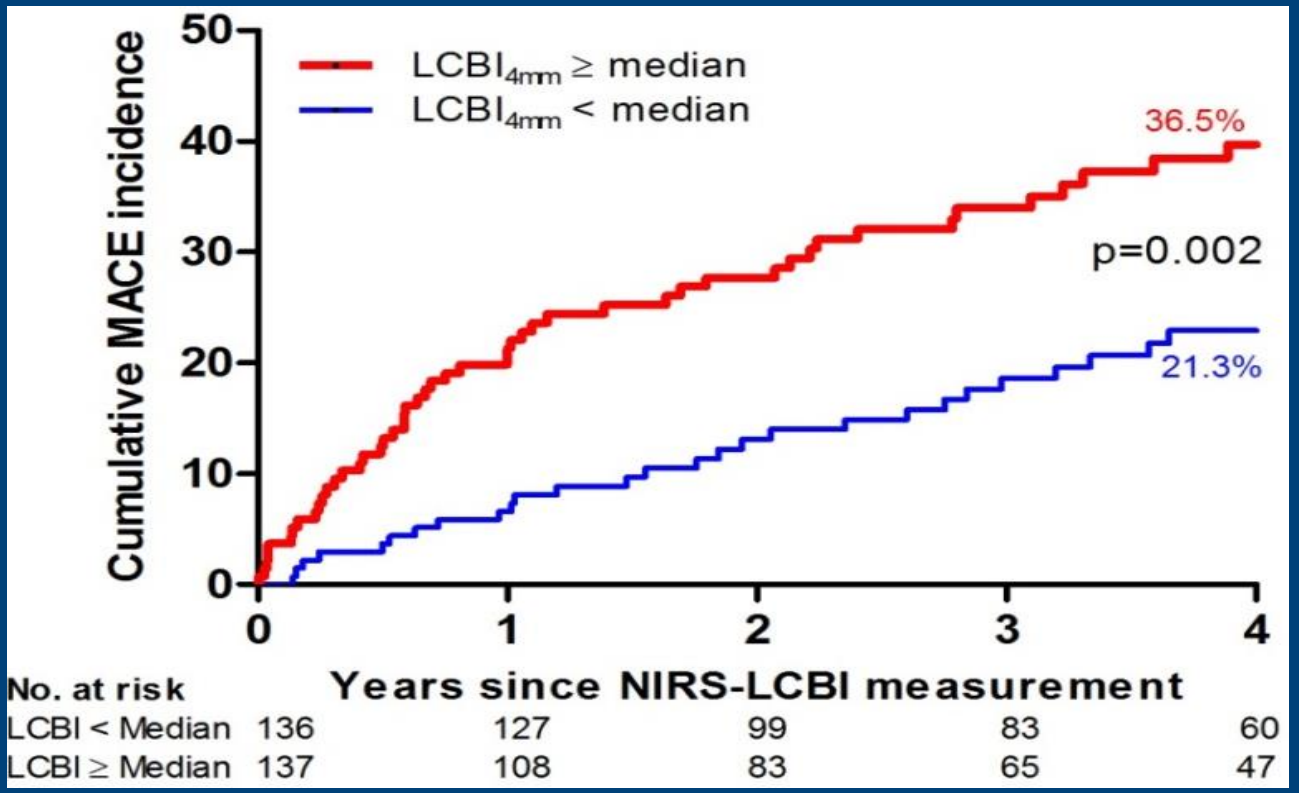
Nir-Infrared Spectroscopy (NIRS)

NIRS derived Lipid Core Burden Index (LCBI) predicts major adverse cardiovascular events in pts with coronary artery disease during long-term follow-up



MACE major adverse cardiovascular event
NIRS Near Infrared Spectroscopy
LCBI Lipid Core Burden Index

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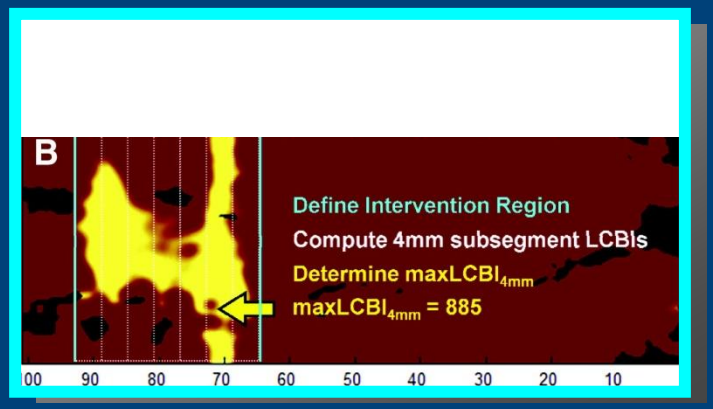
Schuurman et al. EHJ 2017

Nir-Infrared Spectroscopy (NIRS)

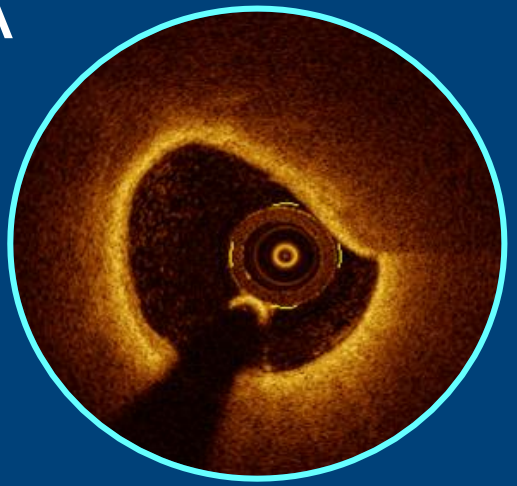
Culprit TCFA have a higher risk for periprocedural MI and worse outcome

RR 12 (3.3-48)
Max. LCBI≥500



Goldstein J at el. Circ Cardiovasc Interv 2011.

OR 10 (3.7-29)
TCFA



Lee et al. Circ Cardiovasc Interv 2011.

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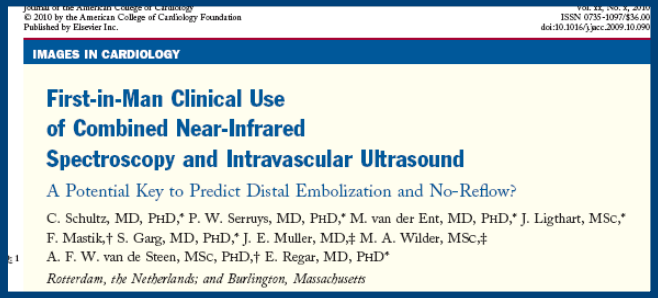
Nir-Infrared Spectroscopy (NIRS)

Combination with Ultrasound: Clinical Observations

Culprit TCFA have a higher risk for periprocedural MI and worse outcome



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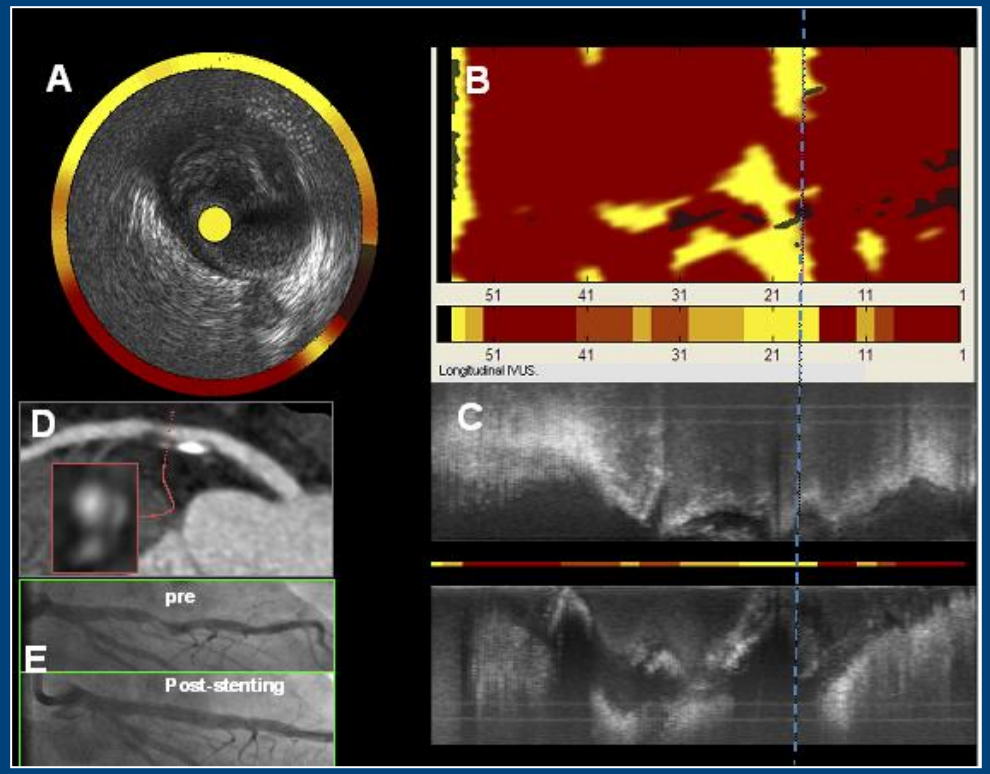
IMAGES IN CARDIOLOGY

First-in-Man Clinical Use of Combined Near-Infrared Spectroscopy and Intravascular Ultrasound

A Potential Key to Predict Distal Embolization and No-Reflow?

C. Schultz, MD, PhD,* P. W. Serruys, MD, PhD,* M. van der Ent, MD, PhD,* J. Ligthart, MSc,* F. Mastik,† S. Garg, MD, PhD,* J. E. Muller, MD,‡ M. A. Wilder, MSc,‡ A. F. W. van de Steen, MSc, PhD,† E. Regar, MD, PhD*

Rotterdam, the Netherlands; and Burlington, Massachusetts



Schultz et al; JACC 2010

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Nir-Infrared Spectroscopy (NIRS)
Combination with Ultrasound: Clinical Observations

PROSPECTIVE CLINICAL TRIALS

- LIPID RICH PLAQUE STUDY
- PROSPECT II STUDY

Multi-Modality Intracoronary Plaque Imaging

Photoaccoustics

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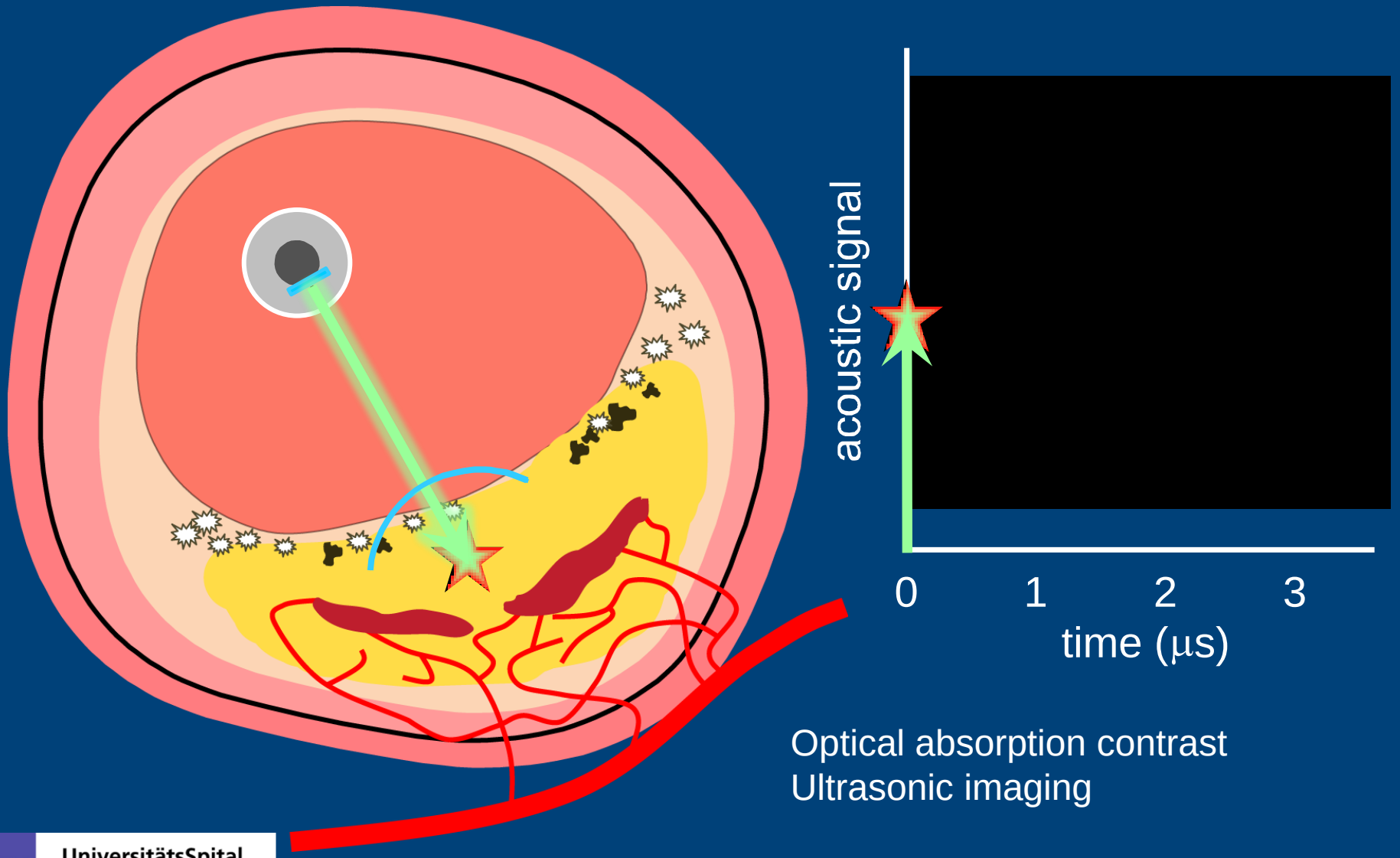
Multi-Modality Intracoronary Plaque Imaging

Principle of intravascular photoacoustic imaging



Optical absorption contrast
Ultrasonic imaging

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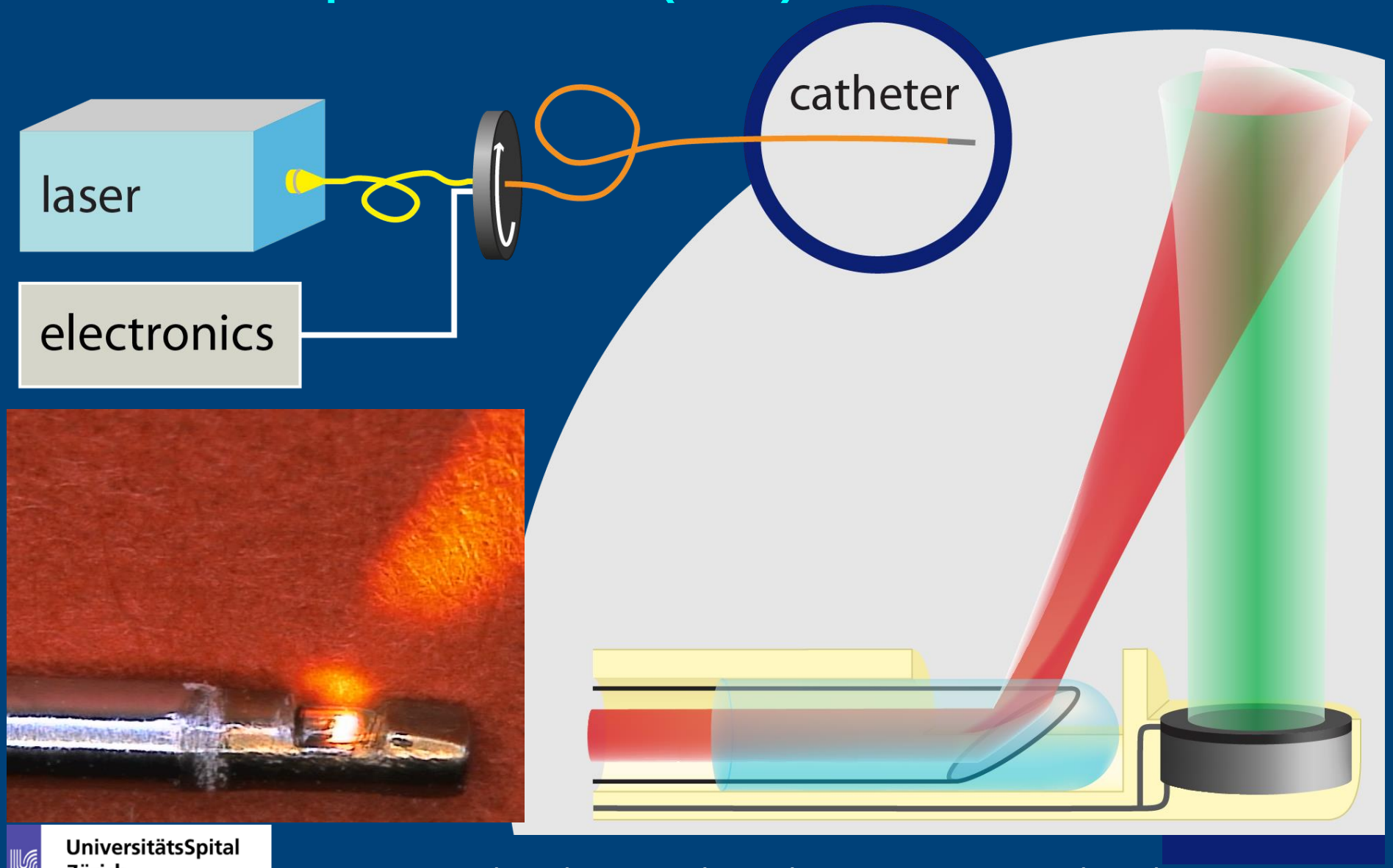
Jansen, Van der Steen, UMB 2014. 40(6): p. 1037-1048.

Multi-Modality Intracoronary Plaque Imaging

Intravascular photoacoustic (IVPA) catheter



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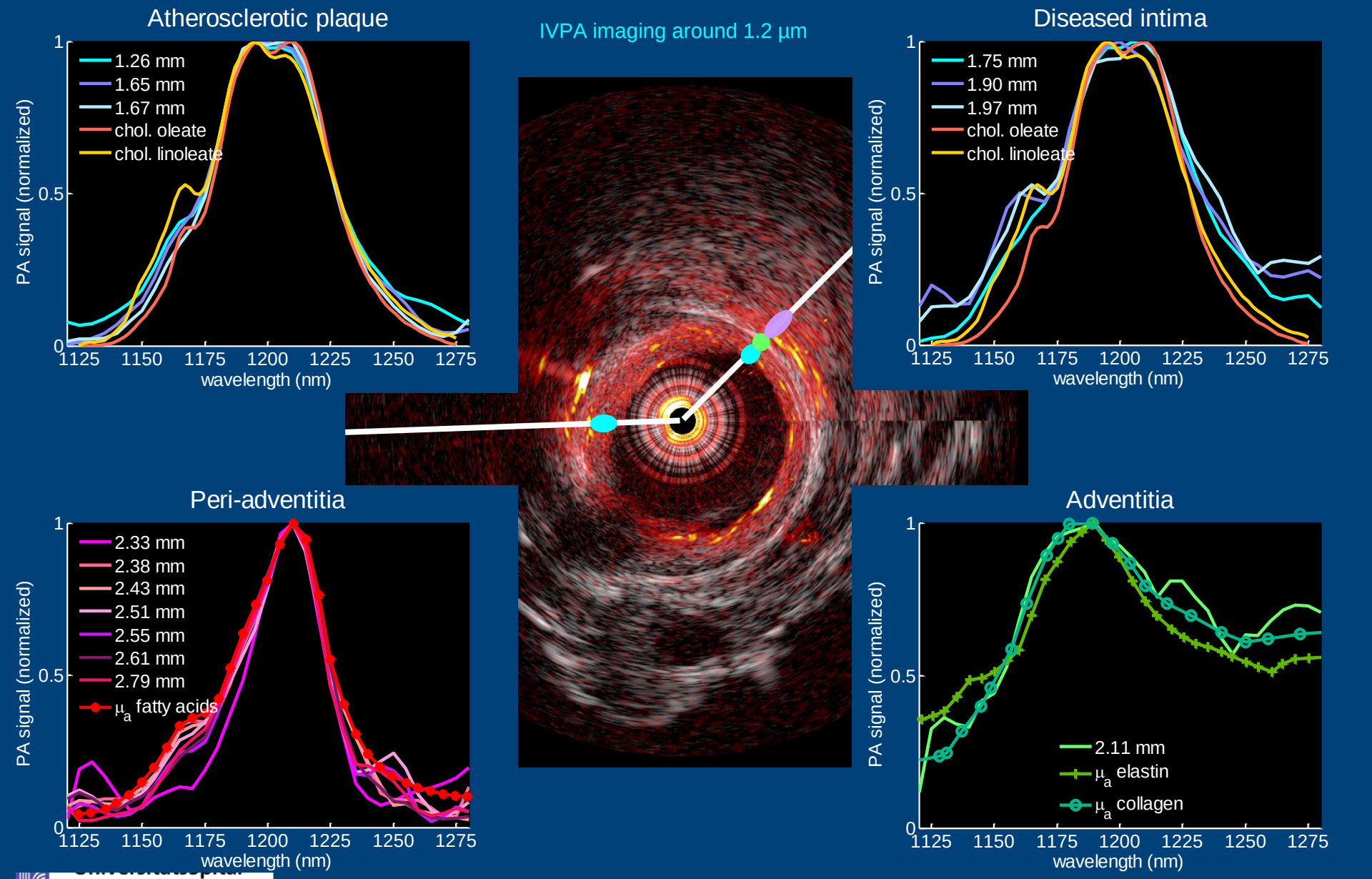
Jansen et al., Opt Lett **36**, 597-599 (2011); Wu et al., Appl Opt **53**, 8131-8139 (2014)

IVPA spectra of human atherosclerotic coronaries



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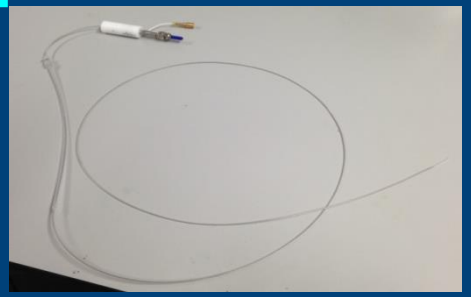
Jansen et al., J Biomed Opt **19**(2) 026006 (2014)

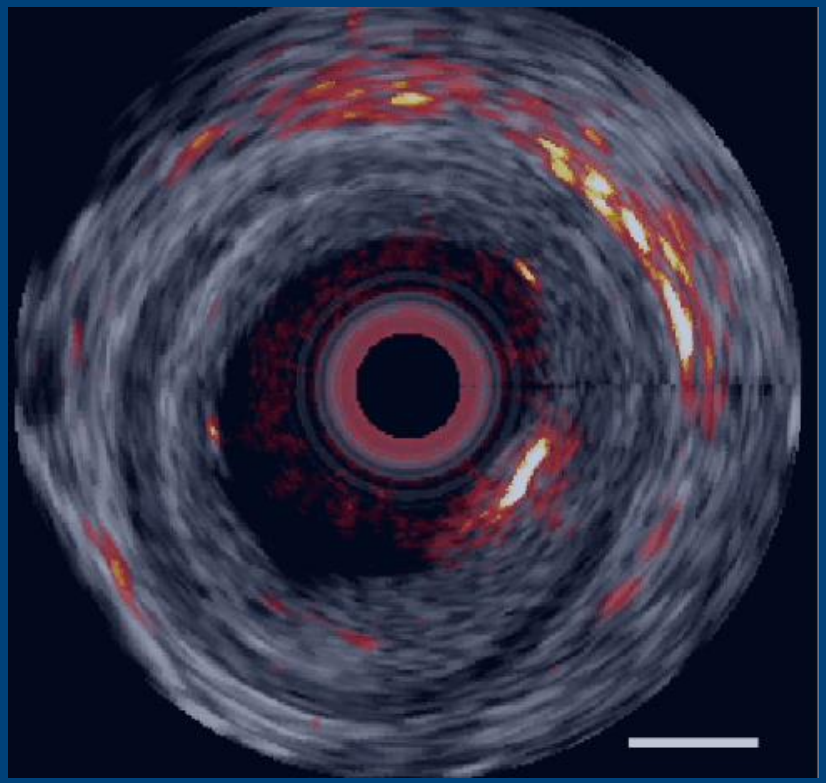
IVPA imaging

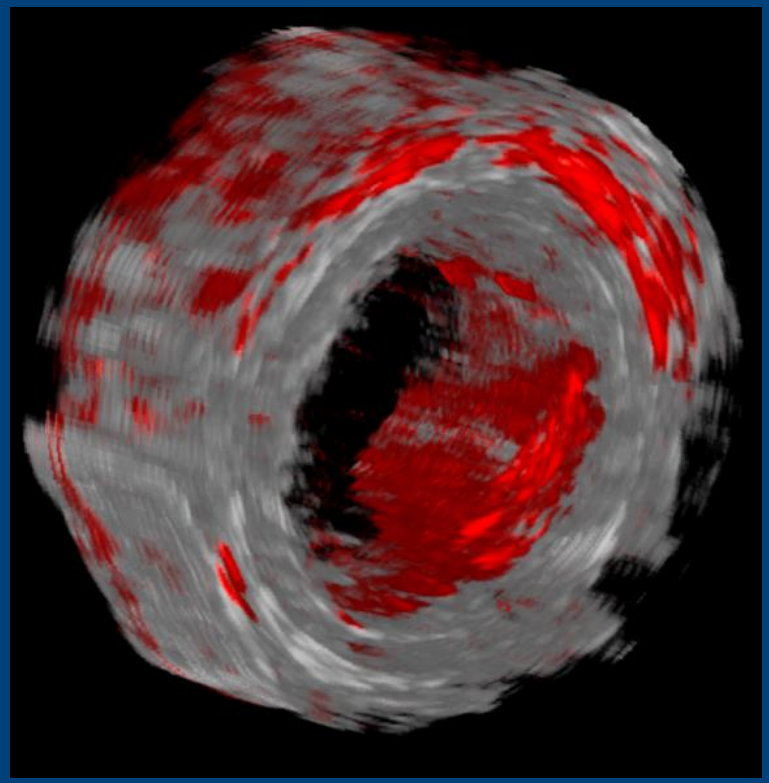
Next Steps



Further catheter minimuarization

IVPA pullback imaging at 20 fps





Human LAD; autopsy sample

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Multi-Modality Intracoronary Plaque Imaging
Hybrid OCT-IVUS

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Multi-Modality Intracoronary Plaque Imaging
Hybrid OCT-IVUS

Technical Progress

3F Catheter – IVUS and OCT are aligned co-linearly

- Same tissue at same time
- Inherently precise co-registration
- Facilitates identification and comparison of features in images
- Facilitates dual-modality measurements (EEL–IVUS, Lumen–OCT)
- Will enable novel methods of combining IVUS and OCT that are dependent on precise co-registration for composite images in future

Courtesy B. Courtney, Conavi Medical Inc

Multi-Modality Intracoronary Plaque Imaging
Hybrid OCT-IVUS

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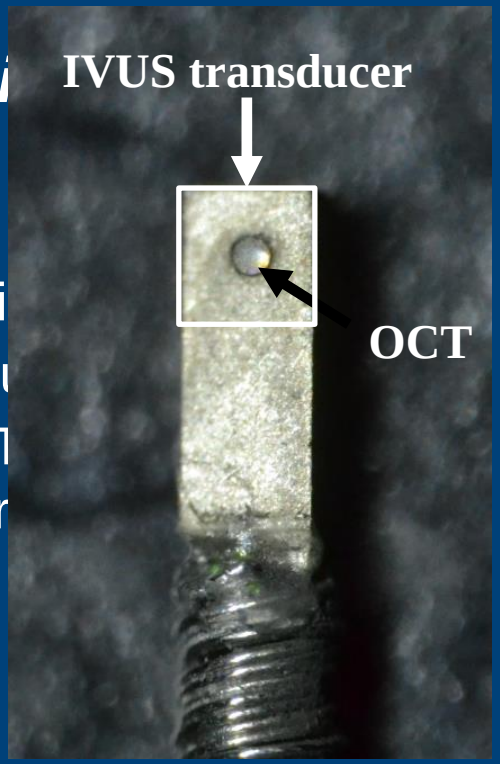
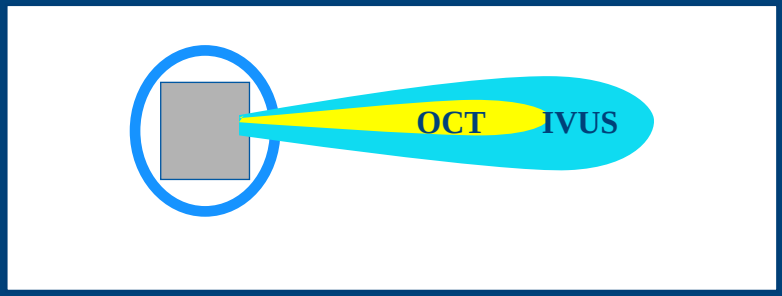


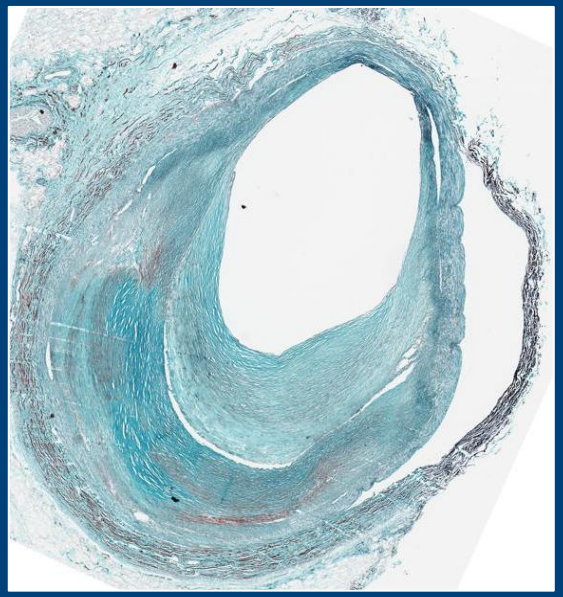


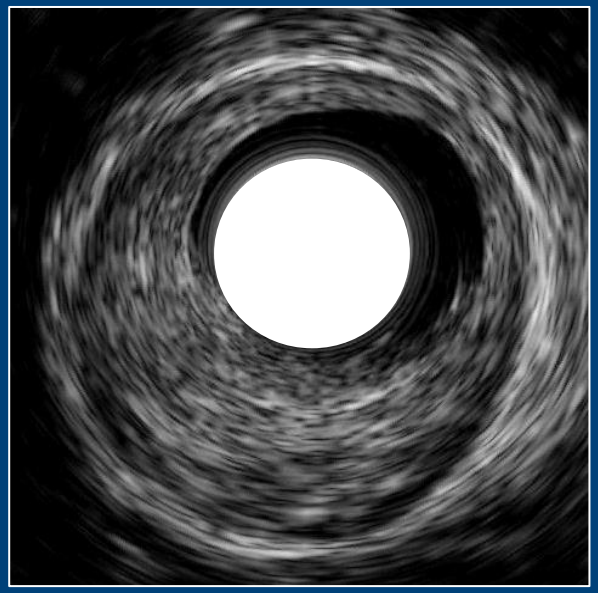
Investigational device, under development and not approved in any jurisdiction

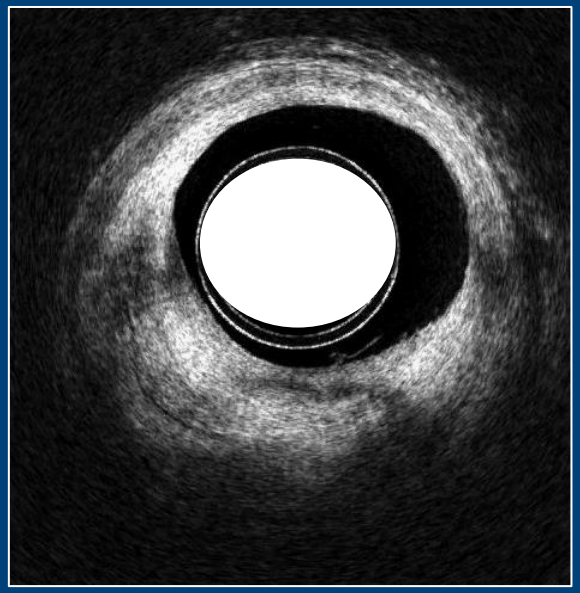
Courtesy B. Courtney, Conavi Medical Inc

Multi-Modality Intracoronary Plaque Imaging

Hybrid OCT-IVUS: In vitro







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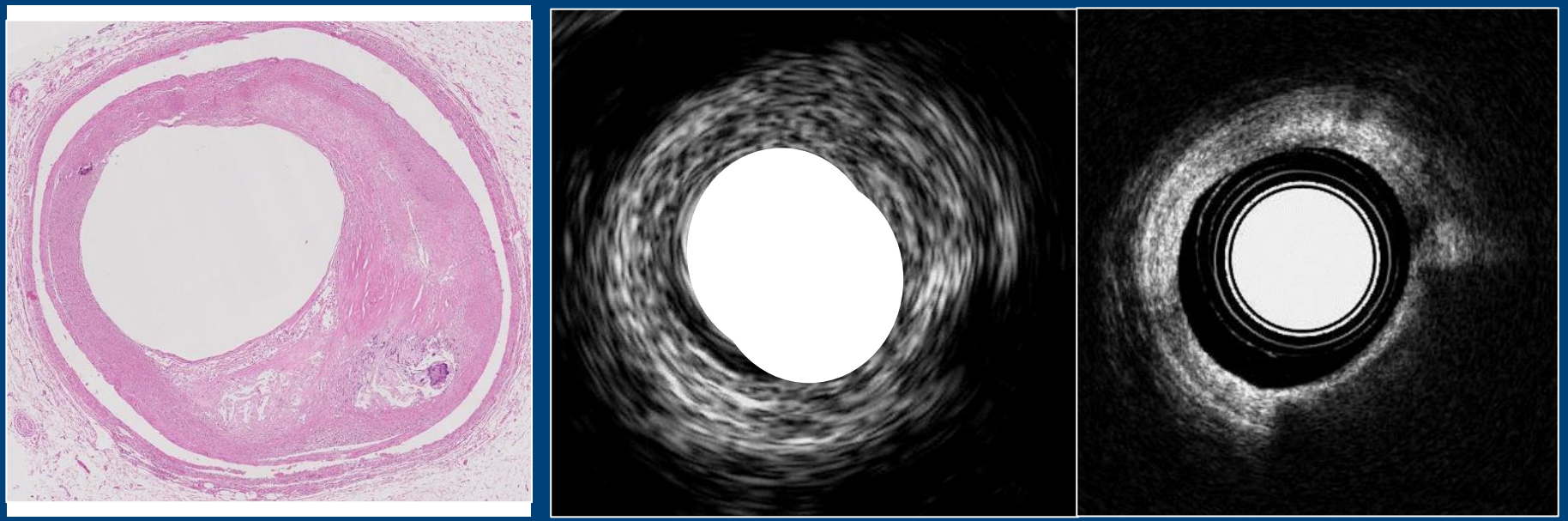
Multi-Modality Intracoronary Plaque Imaging

Hybrid OCT-IVUS: In vitro



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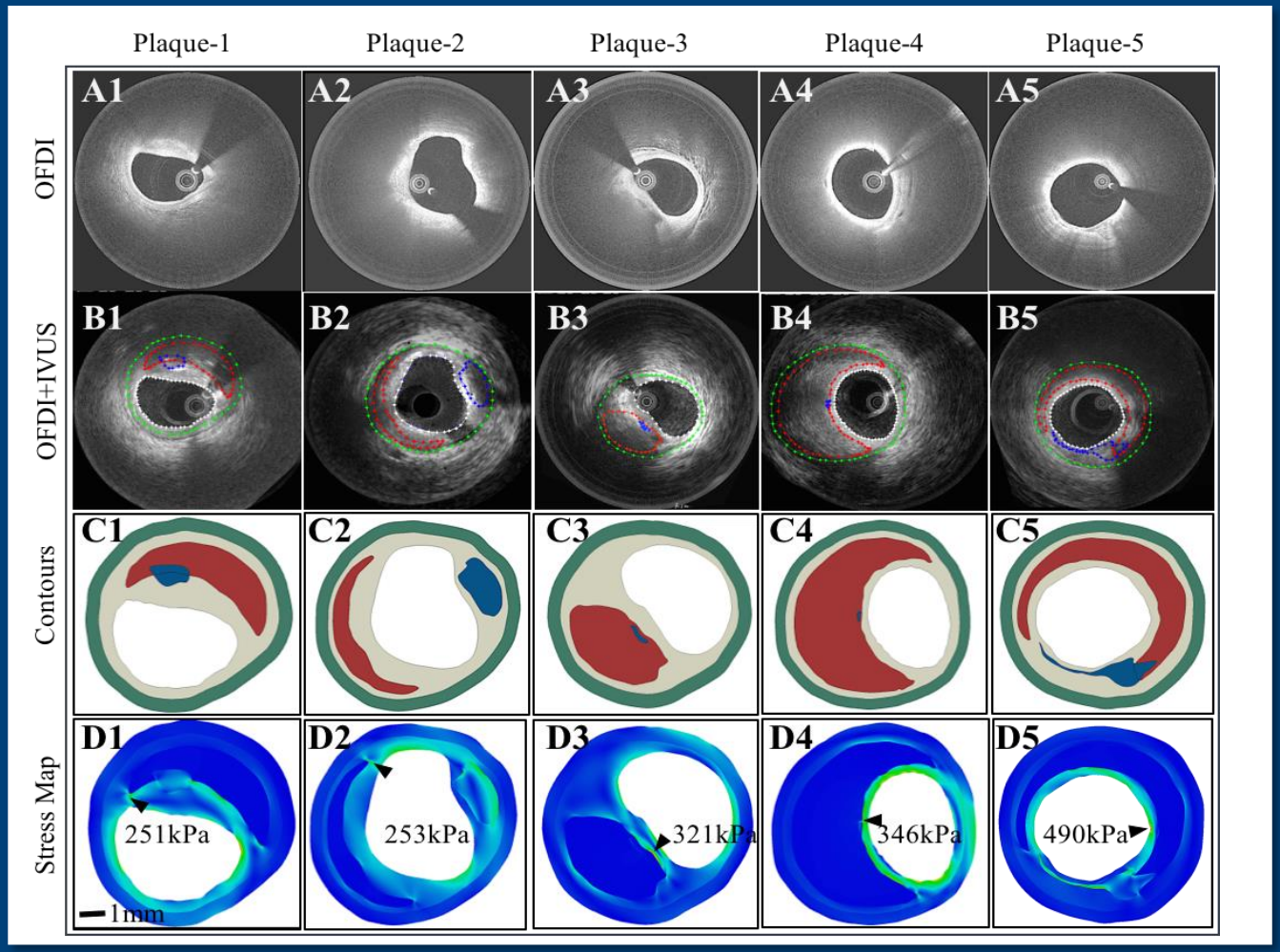
Multi-Modality Intracoronary Plaque Imaging
Direct Estimation of Peak Stress in Fibrous Cap

Overlay of OCT & IVUS

Multifarious coronary necrotic core plaque geometries in patients



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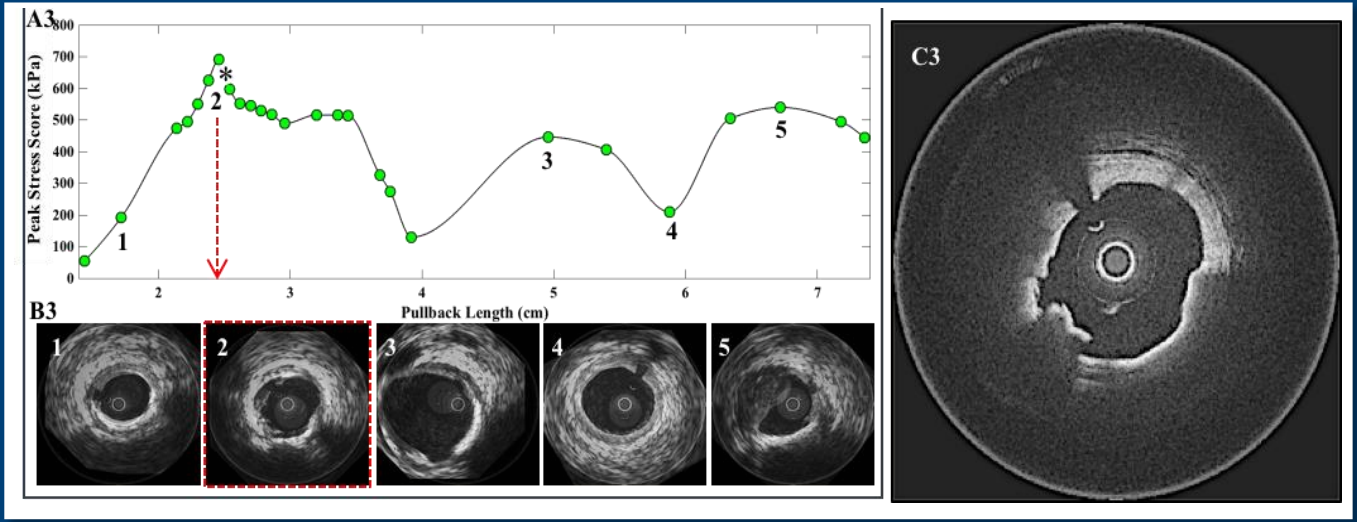
Doradla P et al. submitted

Multi-Modality Intracoronary Plaque Imaging
Direct Estimation of Peak Stress in Fibrous Cap

Novel Multifactorial Stress Equation:
Culprit rupture site is located adjacent to the location of the maximum PSS.

A) Peak stress score (PSS) along the pullback
B) Corresponding overlaid OFDI-IVUS cross section (maximum peak stress location, red arrow)
C) Culprit rupture site with thrombi corresponding to the locations of the asterisks



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Doradla P et al. submitted

Multi-Modality Intracoronary Plaque Imaging

There is increasing evidence that tissue composition plays a pivotal role with regards to clinical manifest cardiac events.

Multi-modality intracoronary imaging

- allows to combine the advantages of both, sound-based and light-based, imaging.
- provides the operator in the cathlab with information in *real-time* and in a *co-registered* manner.
- allows for user-independent, automated and quantitative analysis of tissue composition & properties.

Thank You For Your Attention!

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