Updates on Coronary Angiography

Rotational Angiography, 3-D Modeling, and Beyond…

Imaging and Physiology Summit 2009

November 21, 2009

Seoul, Korea

John D. Carroll, MD
Professor of Medicine
University of Colorado

Disclosure

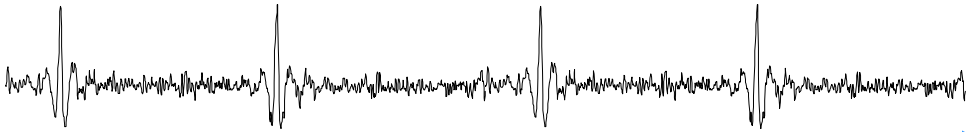
- Co-Inventor of 3-D Vascular Modeling and Analysis Software
  - Assigned to the University of Chicago and University of Colorado
- Philips Healthcare: Research grant, consultant, speaker

Catheter-Based Coronary Angiography 2010

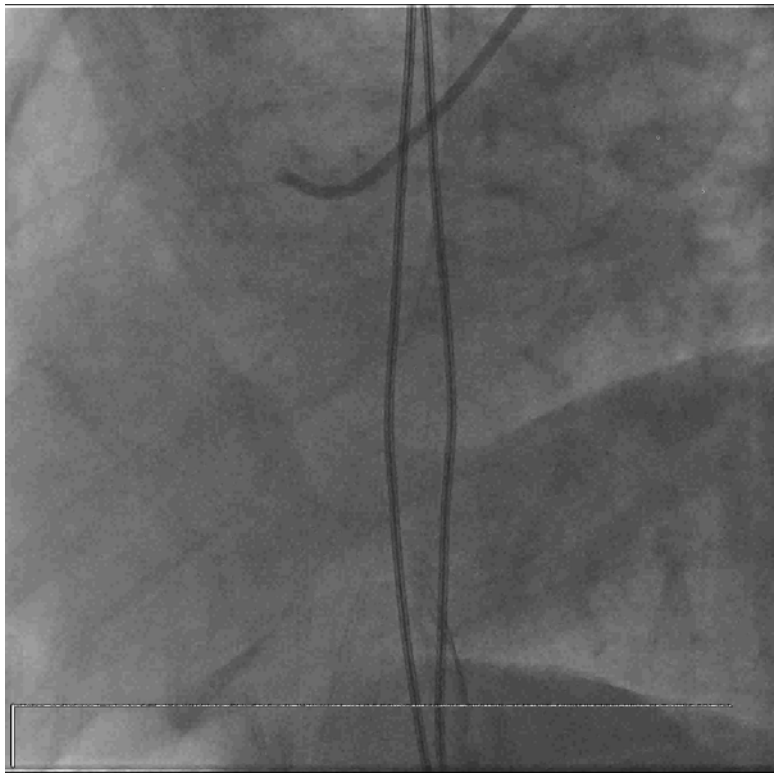
- Diagnosis
- PCI Planning
- PCI Execution
- PCI Assessment

3D Rotational Coronary Angiography:

Simple and Complex Arcs for Acquisition

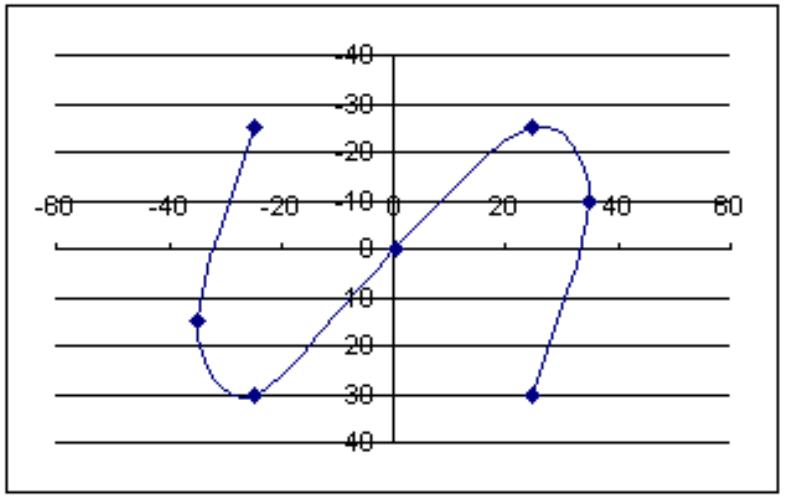


- 200-260 projections
- 180 deg. angular coverage
- 30 fps
- 55-80 bps → 6-10 beats/acq.
- Breath hold
- Simultaneous ECG acquisition
- Calibrated



Rotational Trajectories

1. Simple arc
   - 60 degree RAO to 60 degree LAO with cranial and caudal tilts
2. Complete 180 degree
   - Arms up
   – 7 second acquisitions
3. Dual axis
   – One LCA and One RCA
   – 4 to 7 second acquisitions

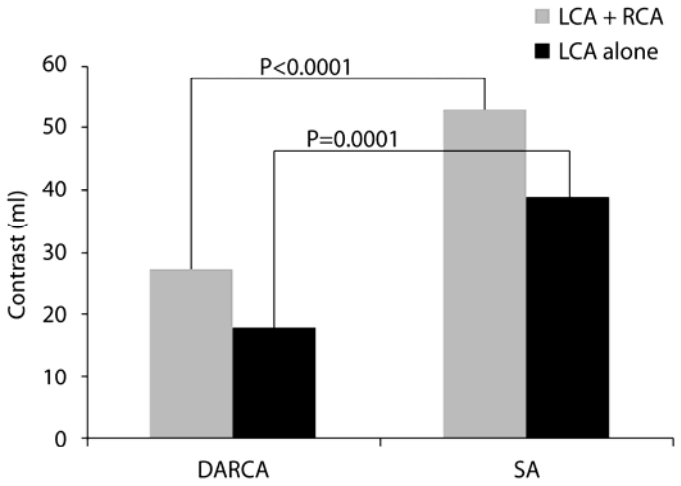


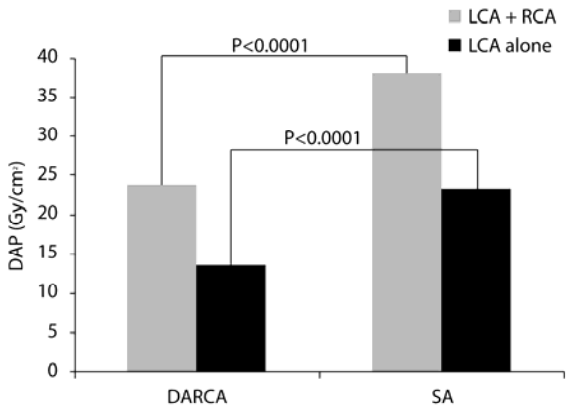
Dual Axis Rotational Angiography
Only One Injection of Left Coronary Artery

Safety and Efficacy of Dual-Axis Rotational Coronary Angiography vs. Standard Coronary Angiography

Klein et al. Manuscript in preparation

- **Results:** As directly compared to SA, use of DARCA reduced contrast utilization (51%), radiation exposure (35%) and procedural time (18%). Both independent reviewers noted DARCA to be at least equivalent if not superior to SA with respect to the ability to screen for CAD.





Why Rotational Angiography?

- *Quality and Safety*
  - Raw projections images are comprehensive in image content
  - Less radiation and contrast
- *Workflow*
  - Improves efficiency
- *Analysis*
  - Projection images are calibrated for accurate QCA
  - *3-D and 4-D models and reconstructions can be created*

Initial Clinical Experience of Selective Coronary Angiography Using One Prolonged Injection and a 180° Rotational Trajectory

Joel A. Garcia,[1] MD, S.-Y. James Chen,[1] PhD, John C. Messenger,[1] MD, Ivan P. Casserly,[2] MB, BCH, Adam Hansgen,[1] BS, Onno Wink,[3] PhD, Babak Movassaghi,[4] PhD, Andrew J. Klein,[1] MD, and John D. Carroll,[1]* MD

Garcia et al. Catheterization and Cardiovascular Interventions 70:190–196 (2007)

Why Not?

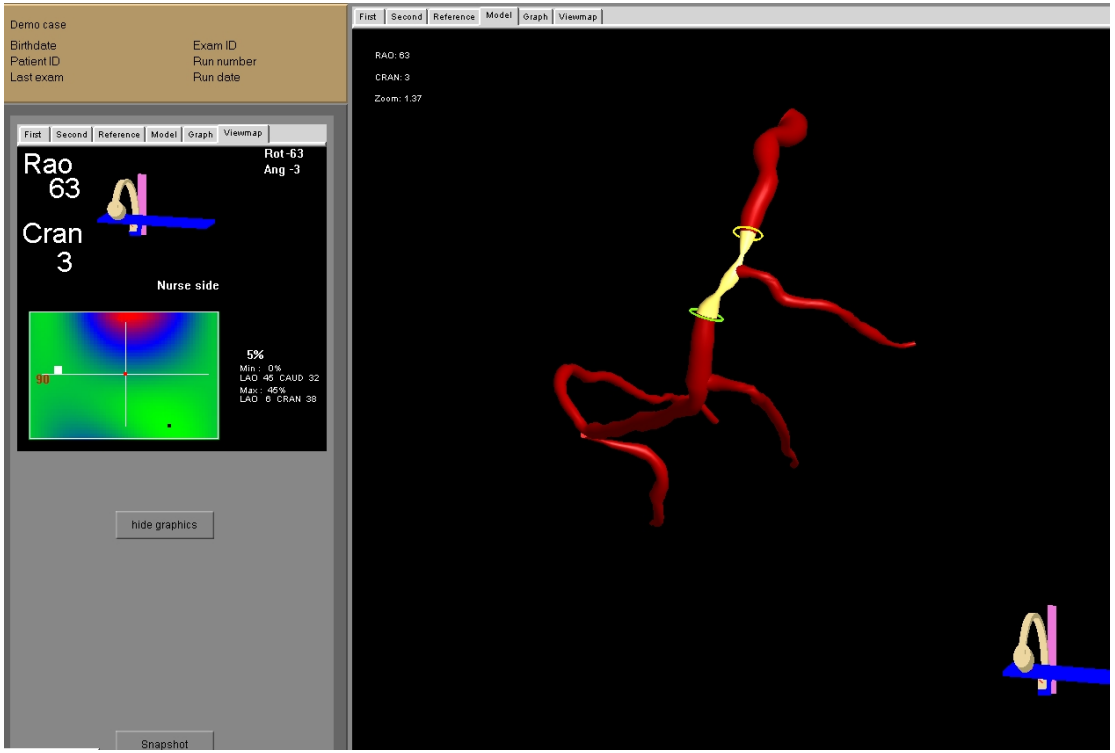
- X-ray system cannot perform RA.
- Do not know how to isocenter.
- Anti-collision software makes setting up for RA a pain. Staff not on board.
- Don’t believe 3-D helps.
- Cannot teach old dogs new tricks.

3-D Modeling

Using Two Views

- James Chen, PhD, Father of coronary 3-D modeling.
  - Modeling techniques generate binary (i.e. vessel vs. no vessel) 3D object representations, typically in the form of centerlines with diameter information
  - Advanced analysis: 4-D analysis of coronary motion, stent straightening, quantification of tortuosity, bifurcation angles, etc.

Commercial Coronary Modeling

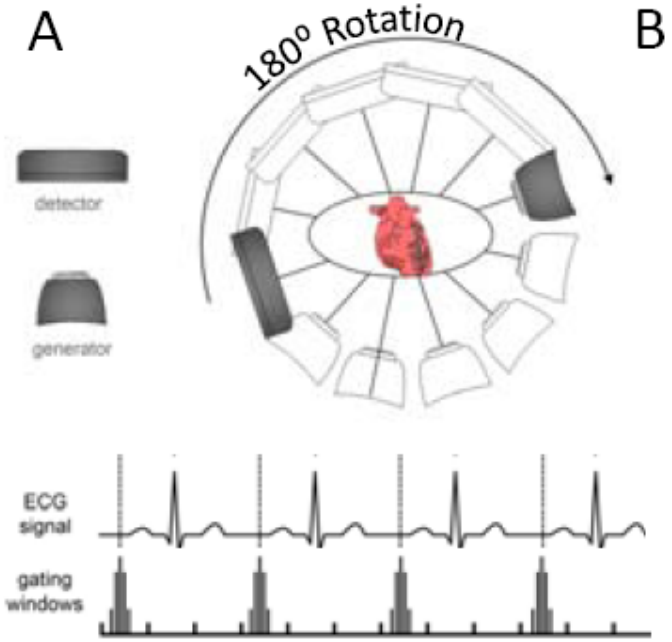


1. **CardiOp-B from Paieon Medical, Israel.**
2. **3D-CA from Philips HealthCare, The Netherlands.**
3. **Cardiovascular Angiography Analysis System for 3D Quantitative Coronary Analysis from Pie Medical Imaging, The Netherlands.**

Rotational Coronary Angiography and Automatic 3-D Reconstruction

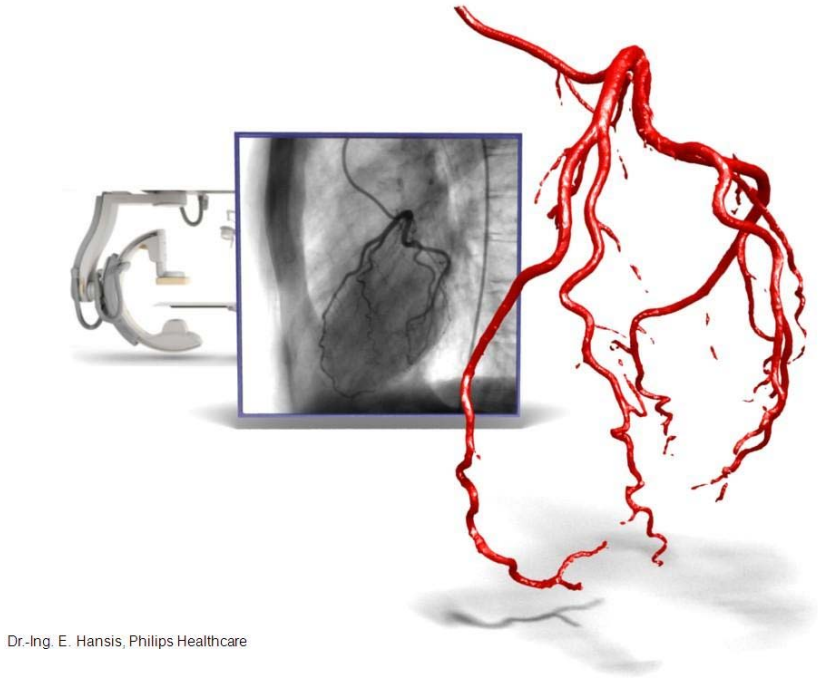
- Clinical Feasibility of a Fully Automated 3D Reconstruction of Rotational Coronary X-Ray Angiograms
  - Neubauer, Garcia, Messenger, Hansis, Kim, Klein,

  Schoonenberg, Carroll.
  - ***Accepted Circulation Intervention yesterday!***



Volumetric Coronary 3-D

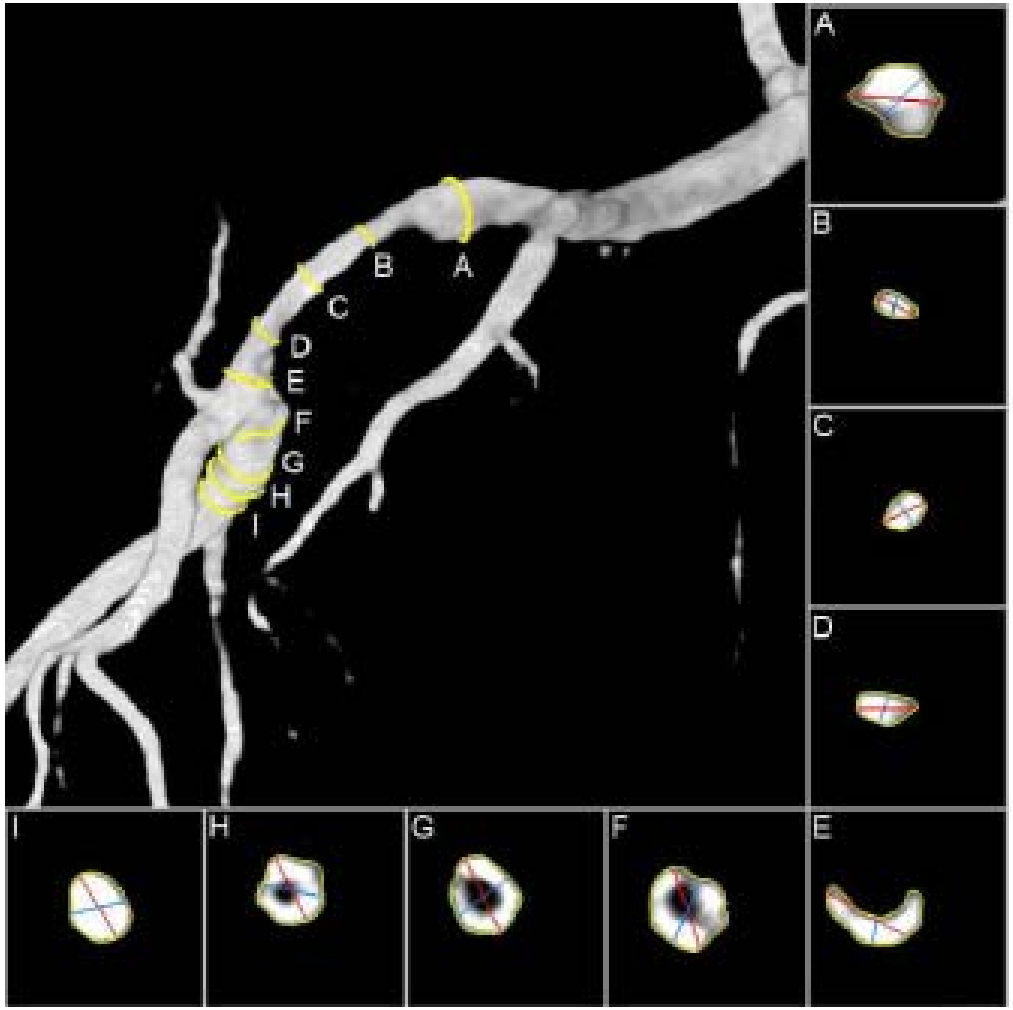
in-room *fully automated gated reconstruction in 3 minutes!!!*



Conclusions: Fully automated reconstruction of rotational coronary X-ray angiograms is feasible, produces 3D volumetric images that overcome some of the limitations of standard 2D angiography, and is ready for further implementation and study in the clinical environment.

Volumetric Reconstruction

MIP Images and Ability to Present in Cross-Sectional Format



Schoonenberg, Garcia, and Carroll. CCI 2009.

IVUS validation study in progress

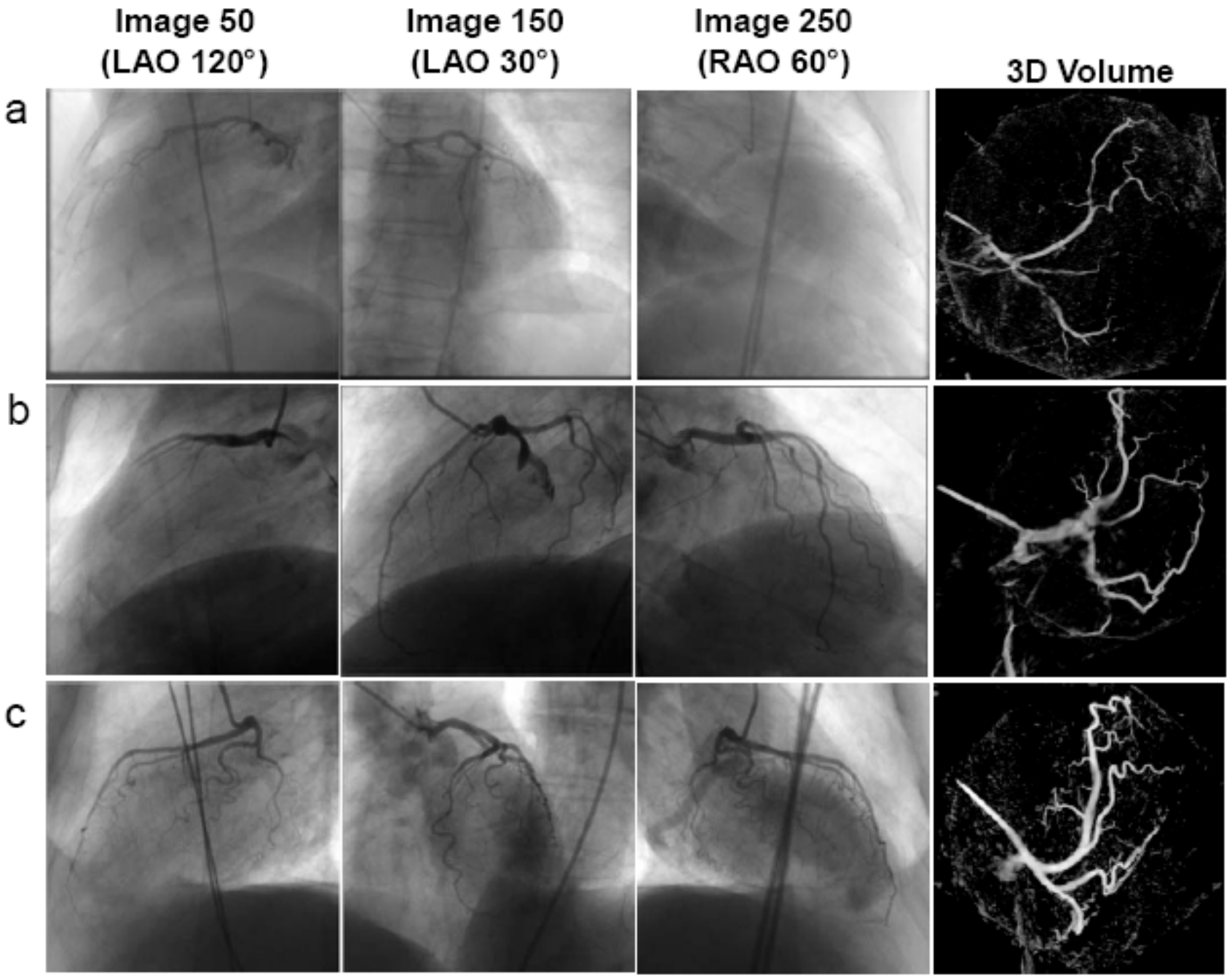
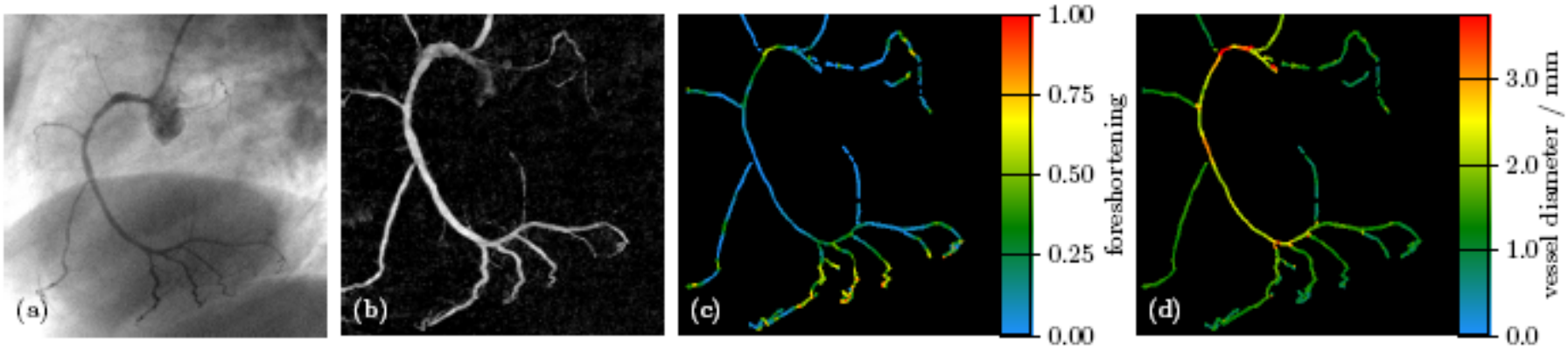


Image 50
(LAO 120°)
Image 150
(LAO 30°)
Image 250
(RAO 60°)
3D Volume
a
b
c

Imaging Science and Computer Graphics 2009

$$\chi_j^{(\nu+1)} = \chi_j^{(\nu)} + \alpha \left(\sum_{i=1}^{m} w_{\phi(i)} a_{ij} \frac{y_i - \sum_{j'=1}^{n} a_{ij'} H(\chi_{j'}^{(\nu)}) \chi_{j'}^{(\nu)}}{\max\left(C_{min}, \sum_{j'=1}^{n} a_{ij'} H(\chi_{j'}^{(\nu)}) \right)} \right) / \left(\sum_{i=1}^{m} w_{\phi(i)} a_{ij} \right)$$

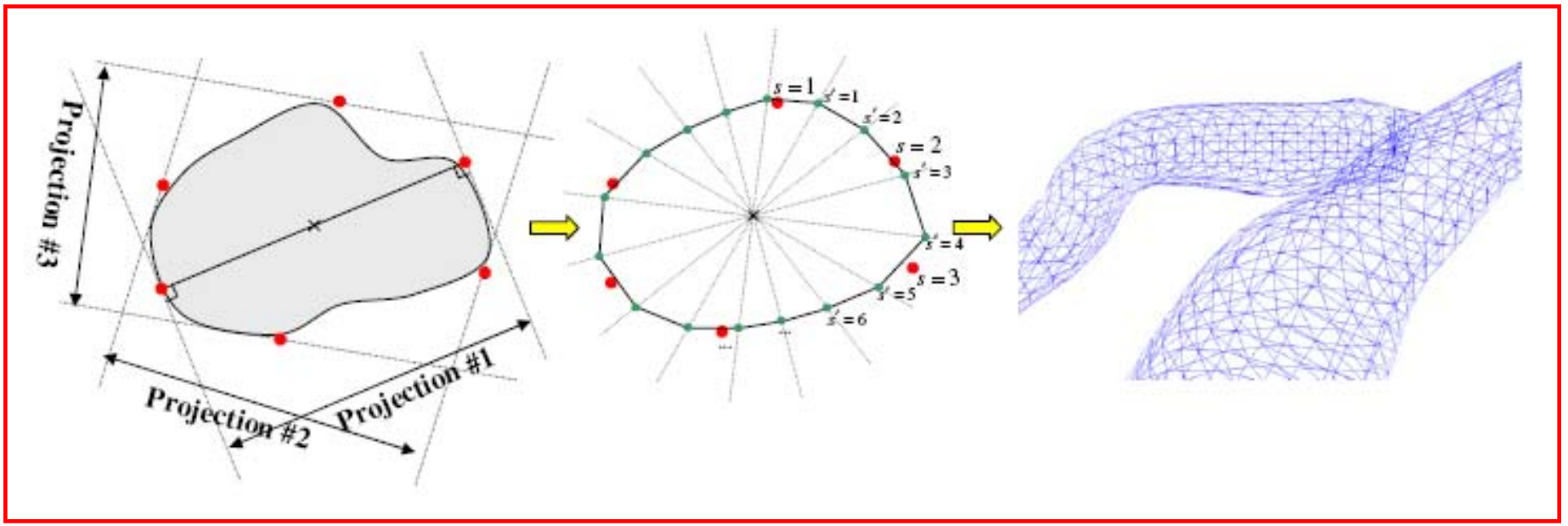


- Hansis E, Carroll JD, Schaefer D, Doessel O, Grass M. High-quality 3-D coronary artery imaging on an interventional C-arm X-ray system. Under revision at Medical Physics.

Clinical Uses for 3-D Coronary Reconstruction

1. 3-D coronary tree to simulate and plan optimal gantry position for PCI
   - Applying optimal view application
   - C-arm follow technology
2. 3-D lesion and vessel quantification
   - Lengths, bifurcation angles, curvature
   - Diameters, cross-section areas
   - Can we automate SYNTAX scoring?
3. 4-D Road mapping and navigation systems

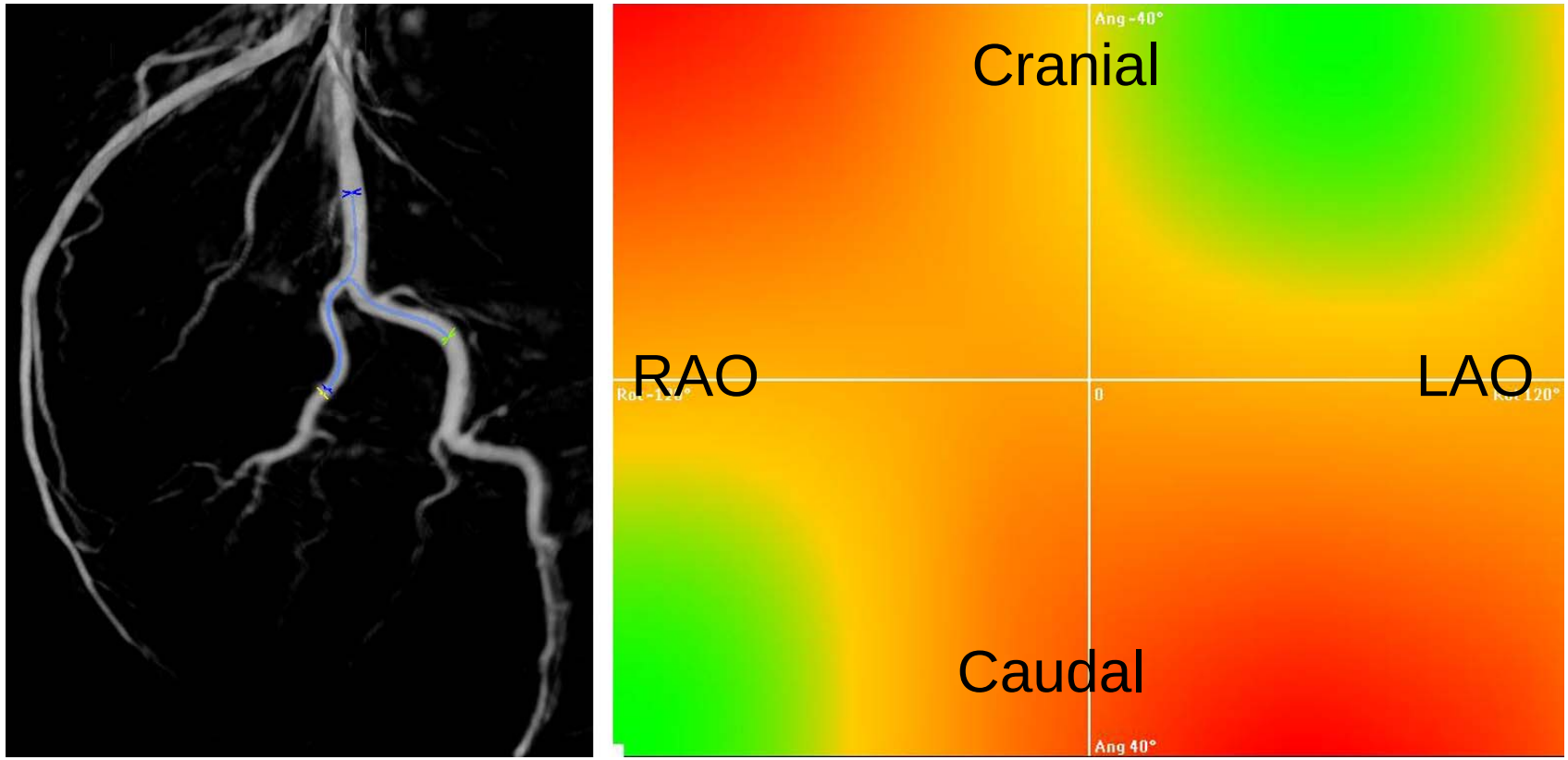
3-D Lesion Characterization



Jandt et al. Automatic generation of time resolved motion vector fields of coronary arteries and 4D surface extraction using rotational x-ray angiography.

Phys. Med. Biol. **54** (2009) 47–66

Computer assistance in optimizing PCI working view

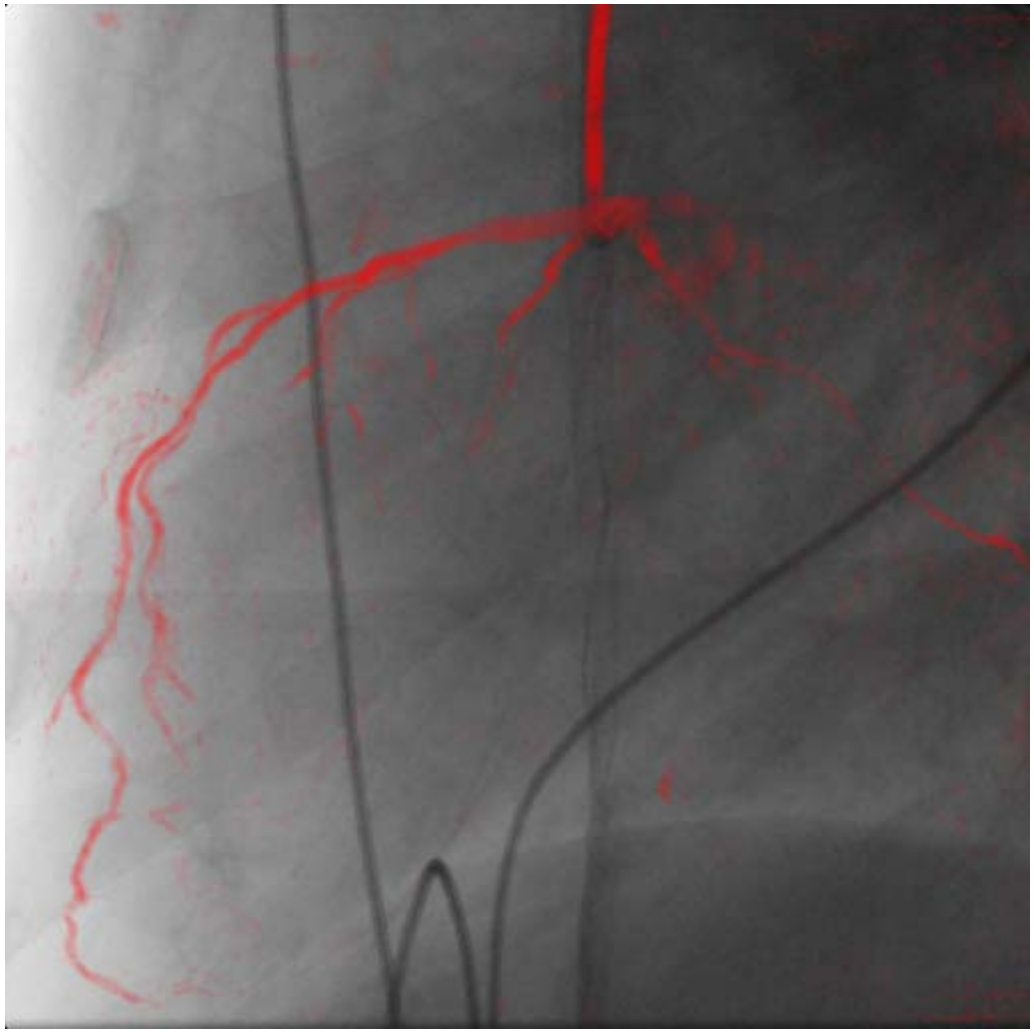


Color coded map of foreshortening on a bifurcation region based on 3-D angio data

The Future of Image Guidance for PCI

4-D Road-Mapping

- Original images acquired at University of Colorado Hospital with 180 degree rotation.
- Advanced Image Processing performed at Philips Research in Hamburg
  - Michael Grass, PhD and team

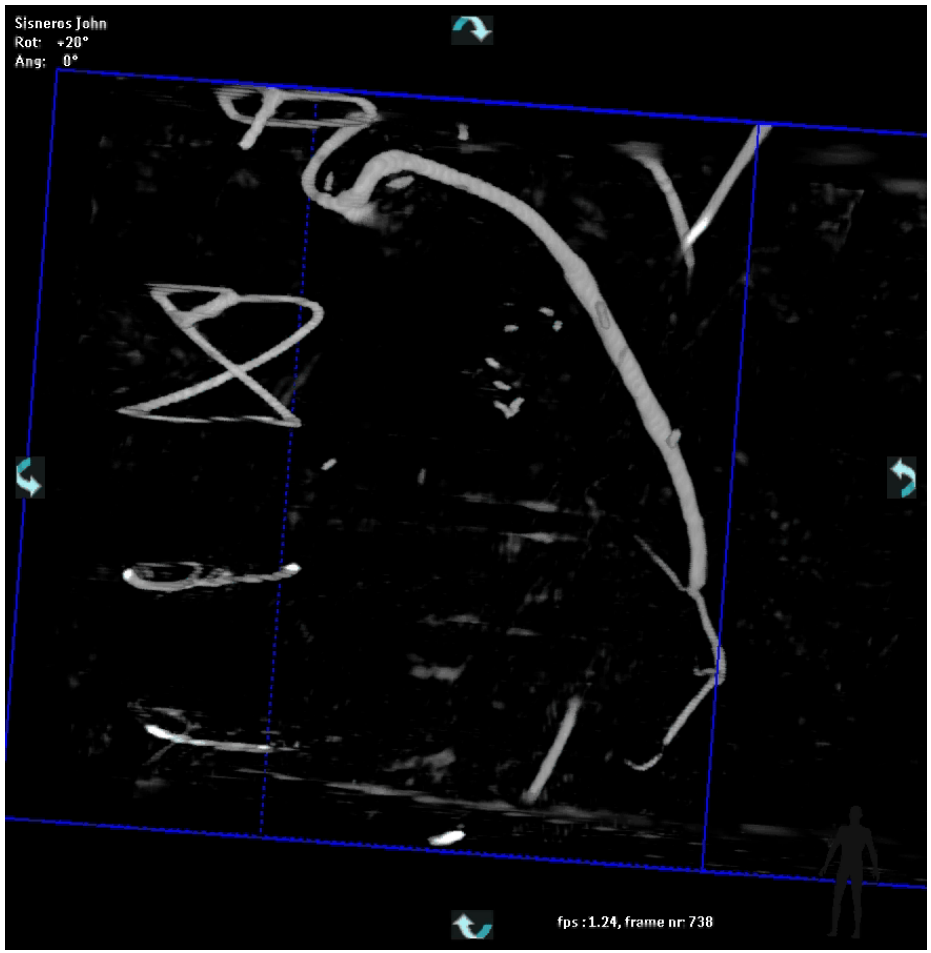


Immediate Post-PCI Assessment

- Check Your Result
- Stent Visualization

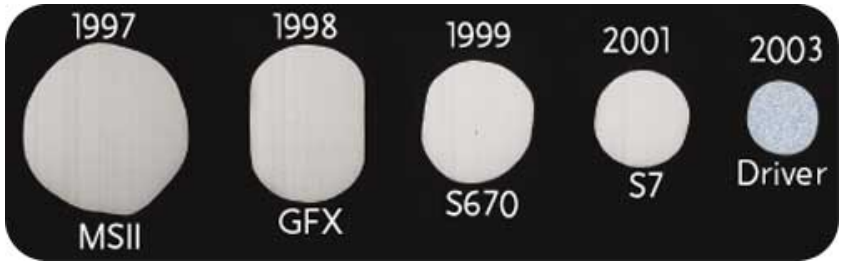
Clinical Value of 3-D in PCI

Inspection of PCI Results



1 cc per second contrast injection rate

The Challenges of Assessing Stents



1. Stent manufacturers have enhanced deliverability by reducing strut thickness and thus reducing opacity.
2. Coronary stents are small and move – an inherently difficult imaging target.
3. The obese patient makes visualization difficult and "turning up the juice" is not best for the patient.
4. Complex and "repeat" patients coming for additional PCI may involve placement of additional stents relative to previously placed stents.
   - Calcium may add to difficulty of seeing the stent

Assessment of Stent Visibility
Perception Studies

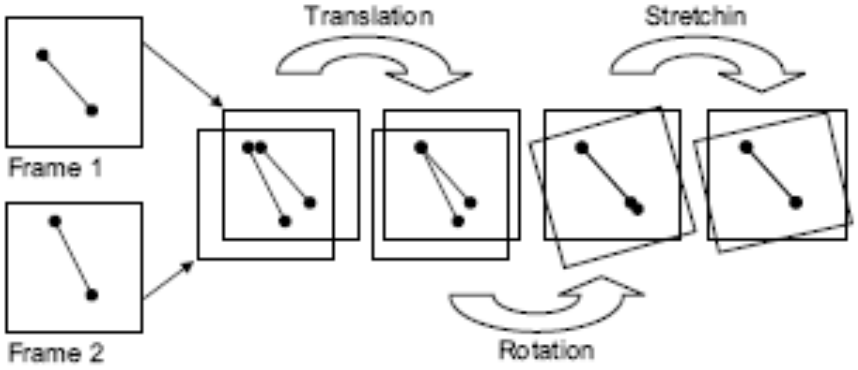
- Visibility of the stent
  - 1 = not visible
  - 2 = poorly visible
  - 3 = visible
  - 4 = well visible
  - 5 =crystal clear

RESULTS

Conventional images = 1.7±0.6

KoolenJJ, vanhetVeer M,HanekampC. StentBoost image enhancement: first clinical experience. Medicamundi 2005;49(2):4–8.

Motion Compensated Integration



- The strategy is to take a series of x-ray images, co-register the frames on the basis of stent location, and average the frames.
  - *Registration is based on delivery system markers*

- MCI enhances the visibility of stents through two mechanisms:
  - the integration of multiple image frames to reduce noise
  - removing motion enabling the observer to inspect a spatially static stent.

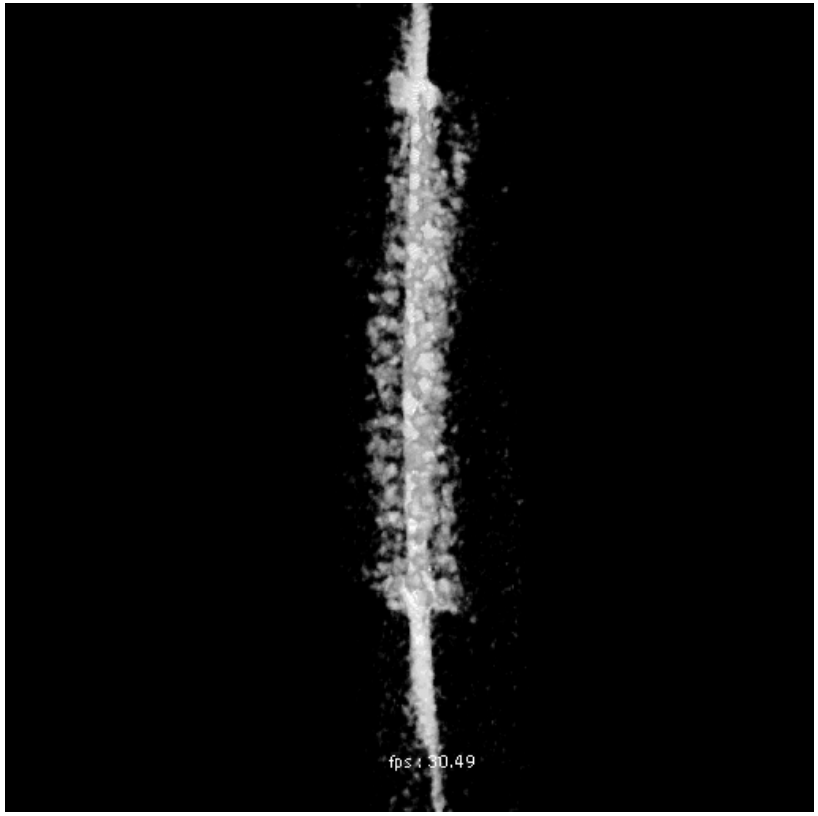
Stent Visualization

3-D Stent Boost

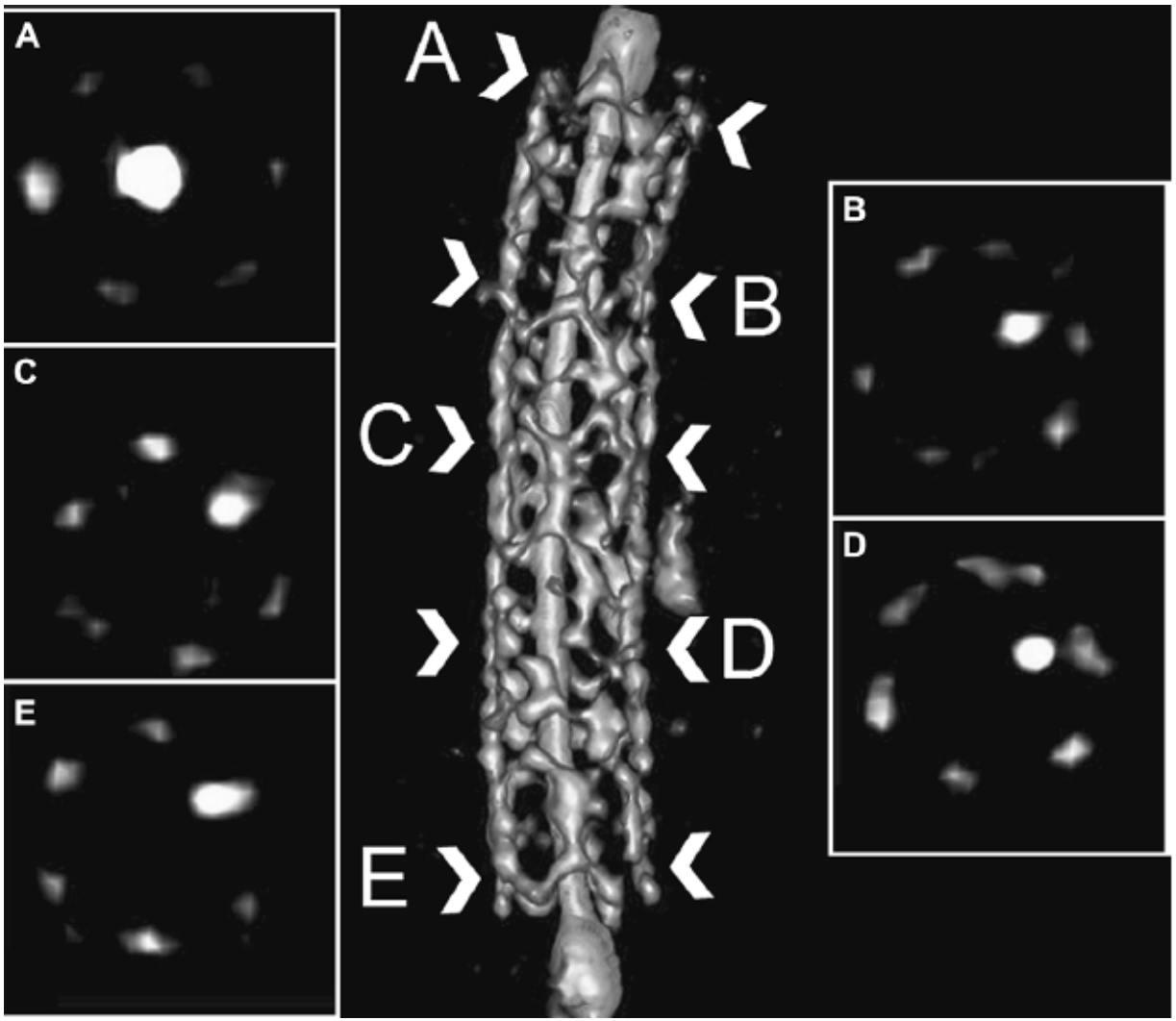
Improved visualization of a deployed stent by registration and integration utilizing motion compensation via markers

Works-In-Progress 2007-2010

- 3D Reconstruction of Coronary Stents in Vivo Based on Motion Compensated X-Ray Images
- Gert Schoonenberg, Philips Medical and University of Colorado Group



3-D Visualization and Stent Enhancement



Volume-rendered reconstructed Taxus Express 3.0 x 16-mm stent with five cross-sectional views (virtual pullback).

From Schoonenberg G, and Florent R.
in
“Advances in Coronary Angiography “
Editors Chen and Carroll. 2009
Cardiology Clinics

CONCLUSIONS

- Coronary angiography is undergoing a **major evolution** with rotational acquisition.
- The ability to visualize the human coronary arteries in a **3–D format**, in the cardiac cath lab, is a central new functionality of image processing.
- Rendering coronary arteries in 3-D and advanced analysis tools **will complement** the 2-D images of conventional angiography.
- Tools to facilitate PCI
  - 2-D and 3-D and 4-D road-mapping
  - Enhanced visualization and quantification of stents post-implantation
- X-ray coronary angiography is the perfect partner to fuse OCT and other catheter-based technologies.