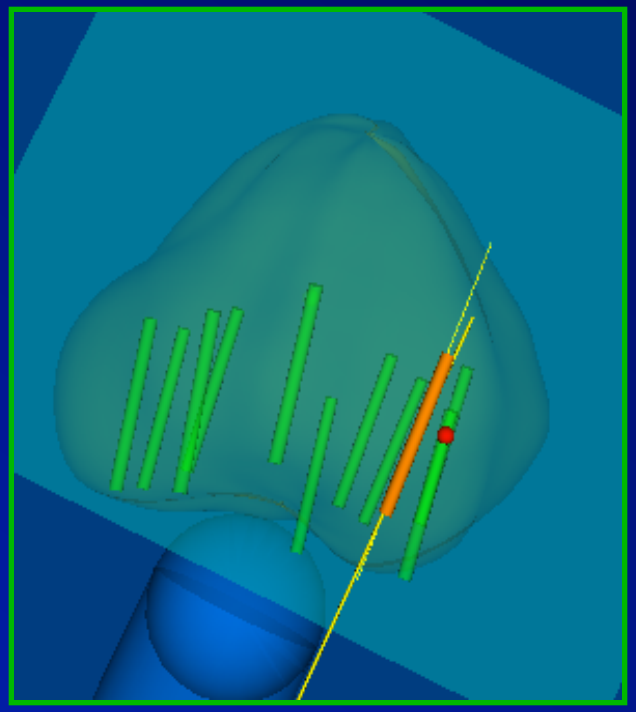
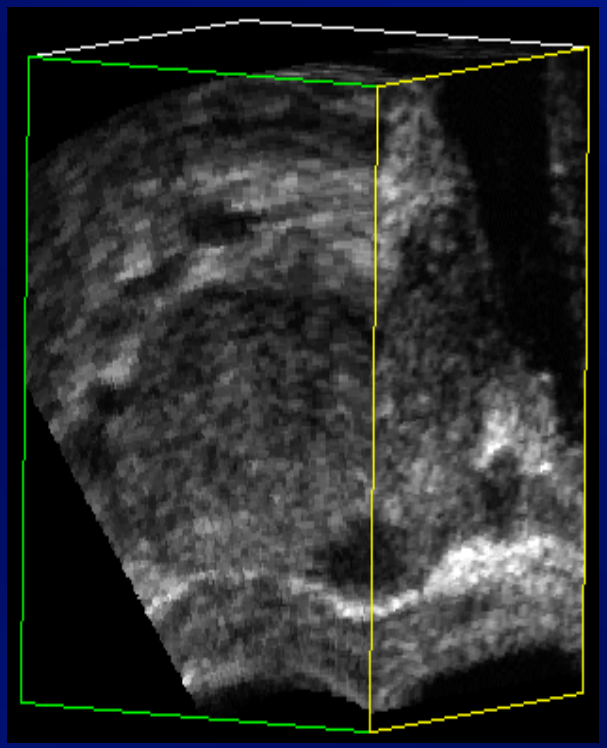
USE OF 3D ULTRASOUND IN DIAGNOSIS, TREATMENT AND RESEARCH



A. FENSTER, PhD

Robarts Research Institute
University of Western Ont.
London, Ontario, Canada



Disclosure

Mechanical 3D US guided biopsy and therapy technology has been licensed to Eigen (California, USA)

3D carotid ultrasound technology has been licensed to Enable Imaging Technologies for sale in China only

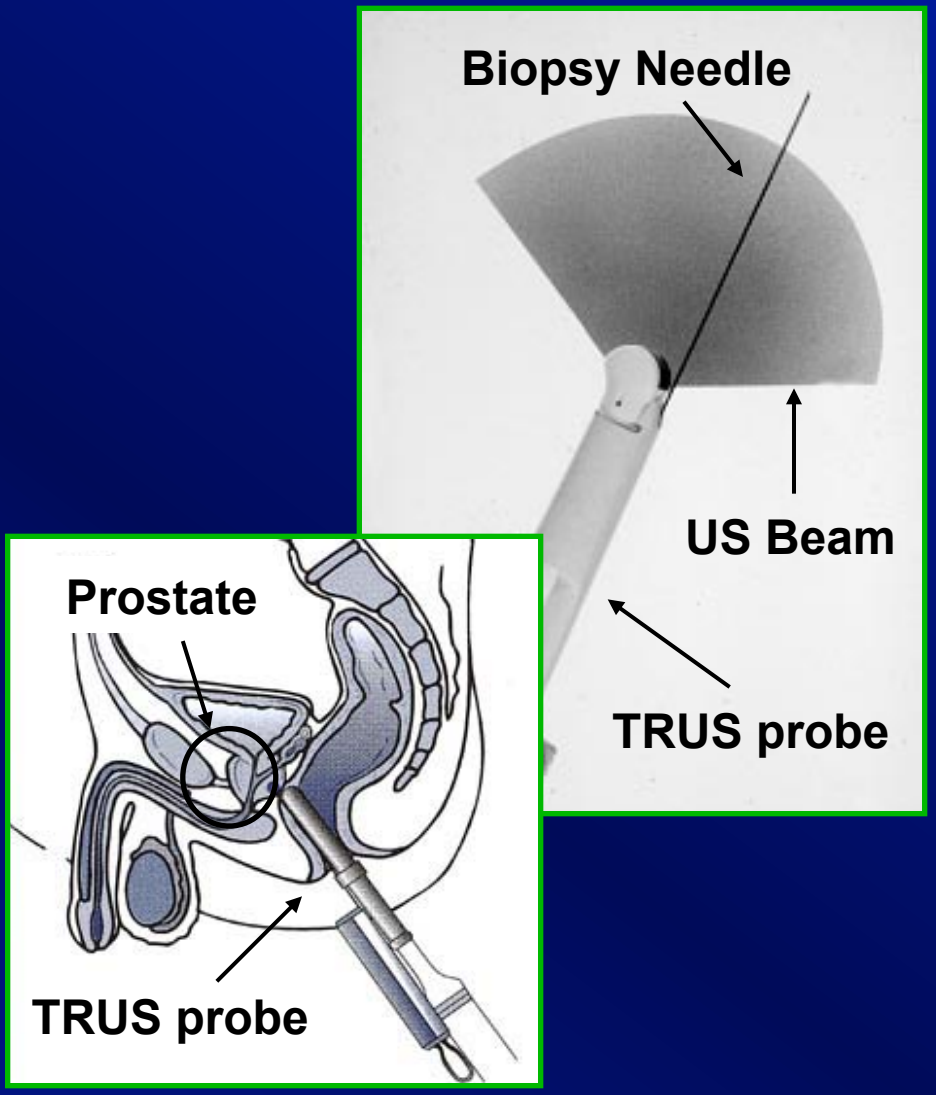
3D ULTRASOUND-GUIDED PROSTATE BIOPSY

Bax J, Cool DW, Gardi L, Knight K, Smith D, Montreuil J, Sherebrin S, Romagnoli C, Fenster A. Mechanically assisted 3D ultrasound guided prostate biopsy system. Med Phys. 35(12): 5397-5410, Nov 2008.

Prostate Cancer Diagnosis

Diagnostic Tests

- Digital rectal exam (DRE)
- Prostate Specific Antigen (PSA)
- **Gold Standard** → Needle biopsy using 2D transrectal US



Prostate Cancer Diagnosis

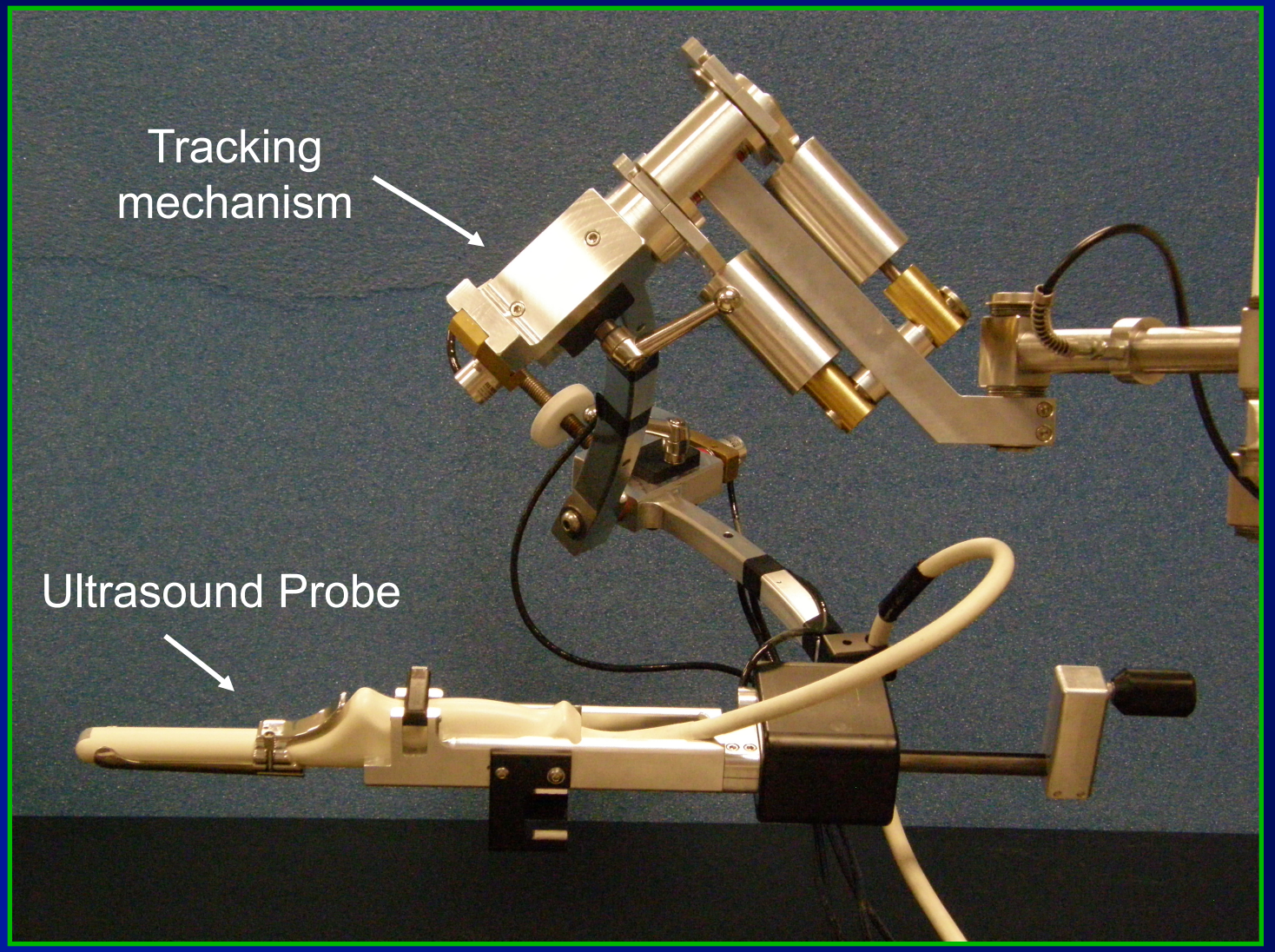
Biopsy Limitations

- Confined to 2D
- Few anatomical reference points to guide needle
- Pathology rarely visible → High rebiopsy rate ~34%
- Cannot easily use other modalities for guidance

GOAL: 3D US Guided Biopsy

- Combine 3D US with real-time guidance to form a 3D prostate biopsy system, with:
  - Prostate biopsy planning,
  - Recording of biopsy locations in 3D,
  - Targeting lesions identified from other modalities.

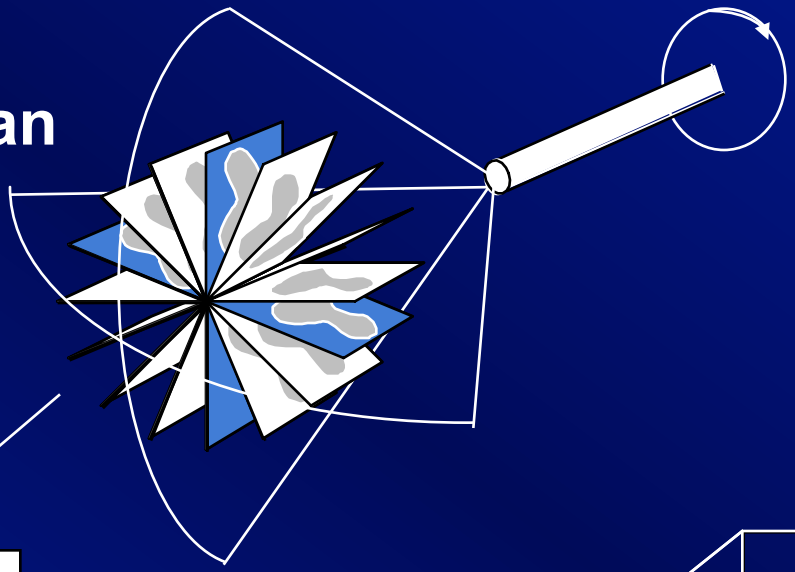
Mechanical Guidance System - ROBARTS

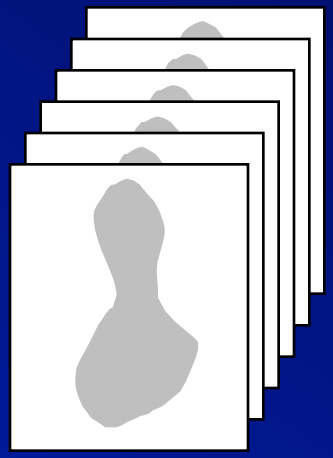


3D US Biopsy Guidance System - EIGEN

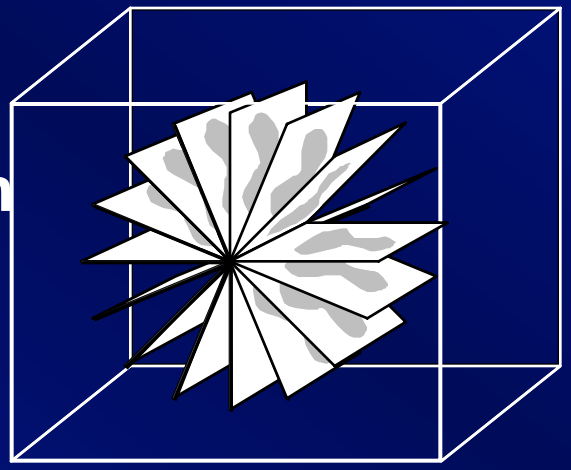
Rotational 3D Scanning

3D Motorized
or manual Scan





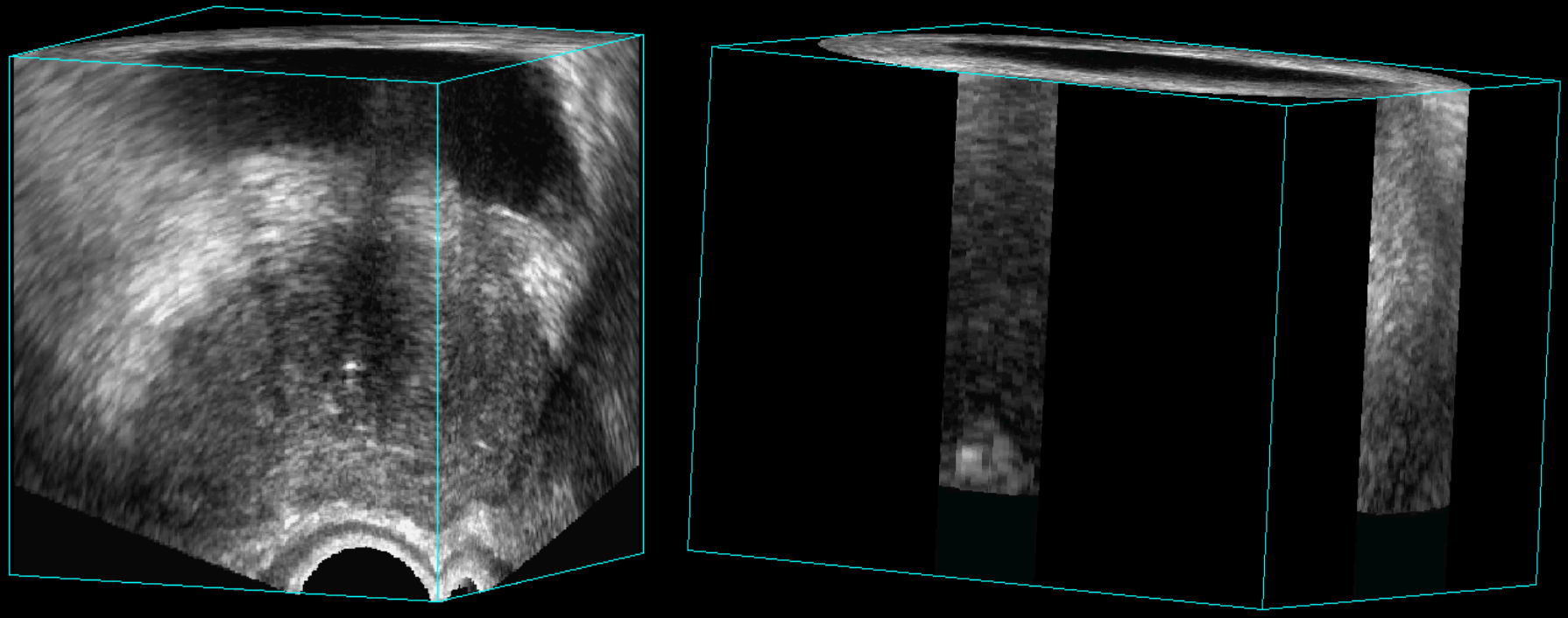
3-D Reconstruction



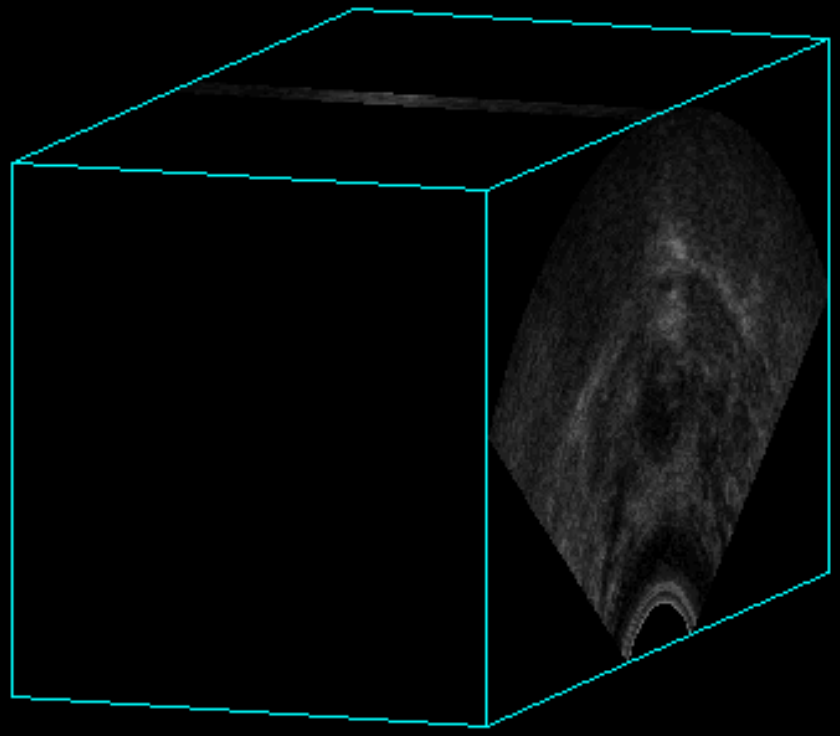
Digitize 2D Images

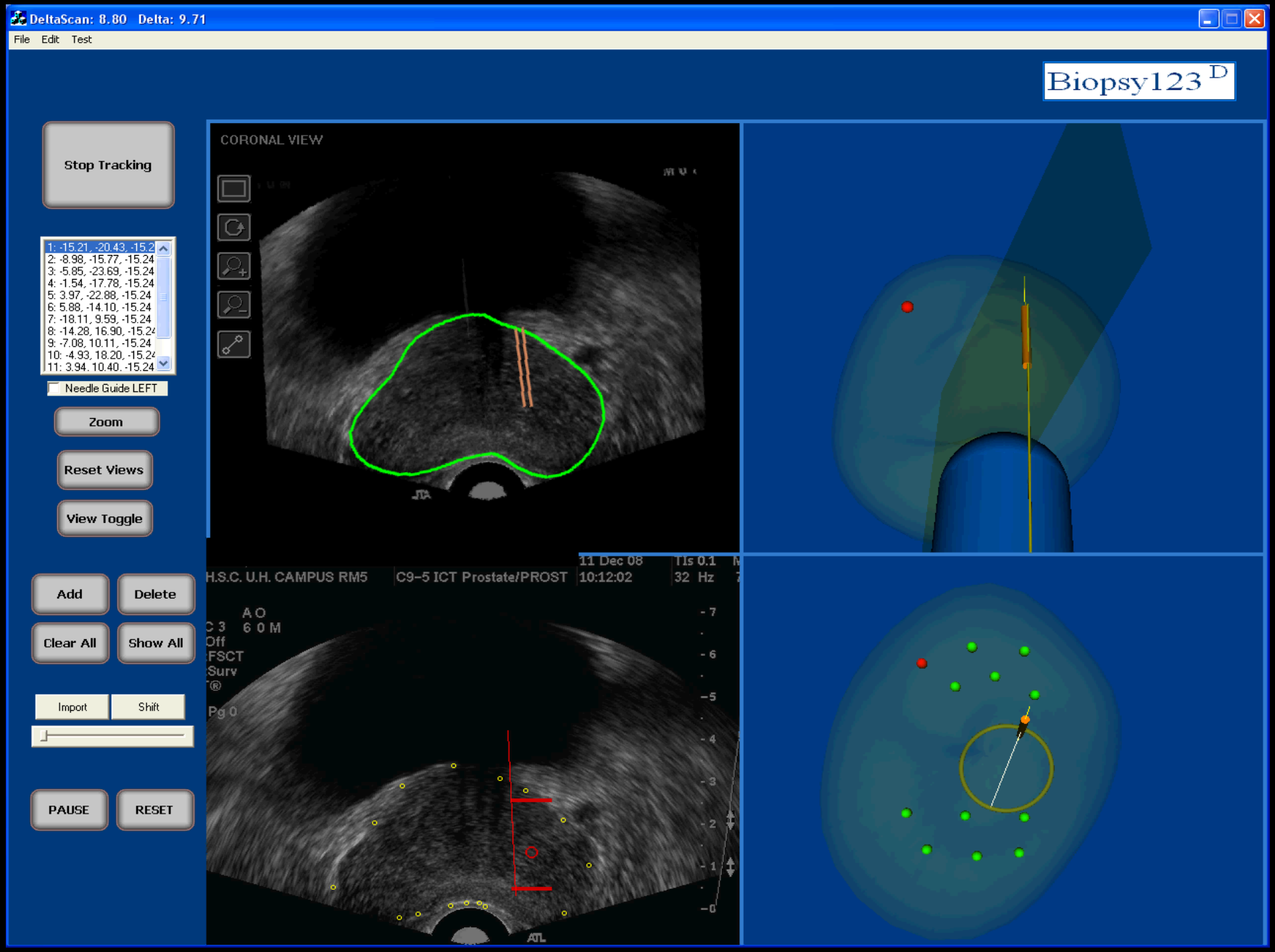
3-D Volume Image

3D Prostate Ultrasound

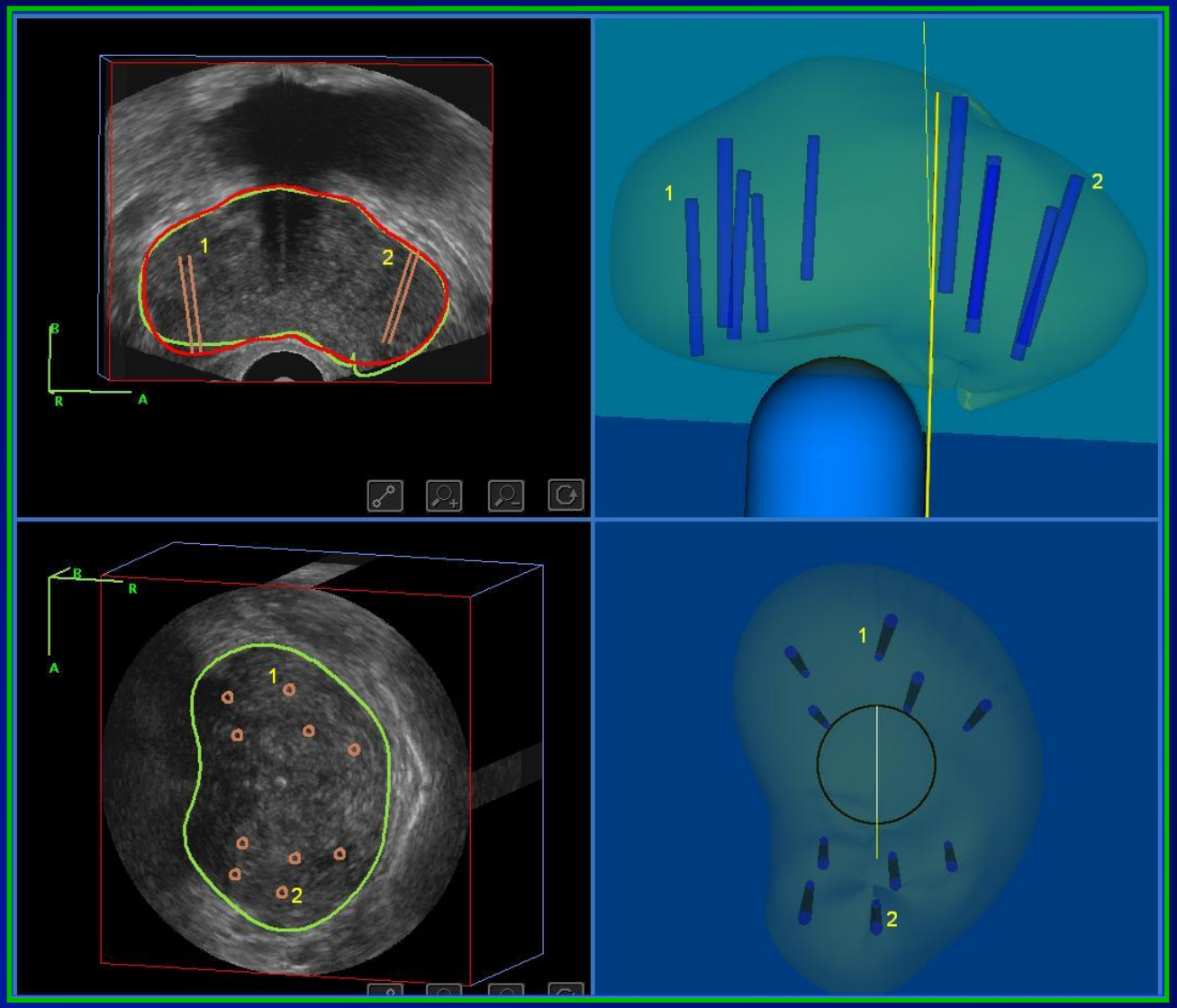


3D Prostate Segmentation




DeltaScan: 8.80 Delta: 9.71
File Edit Test
Biopsy123 D
Stop Tracking
1: -15.21, -20.43, -15.2
2: -8.98, -15.77, -15.24
3: -5.85, -23.69, -15.24
4: -1.54, -17.78, -15.24
5: 3.97, -22.88, -15.24
6: 5.88, -14.10, -15.24
7: -18.11, 9.59, -15.24
8: -14.28, 16.90, -15.24
9: -7.08, 10.11, -15.24
10: -4.93, 18.20, -15.24
11: 3.94, 10.40, -15.24
Needle Guide LEFT
Zoom
Reset Views
View Toggle
Add
Delete
Clear All
Show All
Import
Shift
PAUSE
RESET
CORONAL VIEW
H.S.C. U.H. CAMPUS RM5
C9-5 ICT Prostate/PROST
11 Dec 08
10:12:02

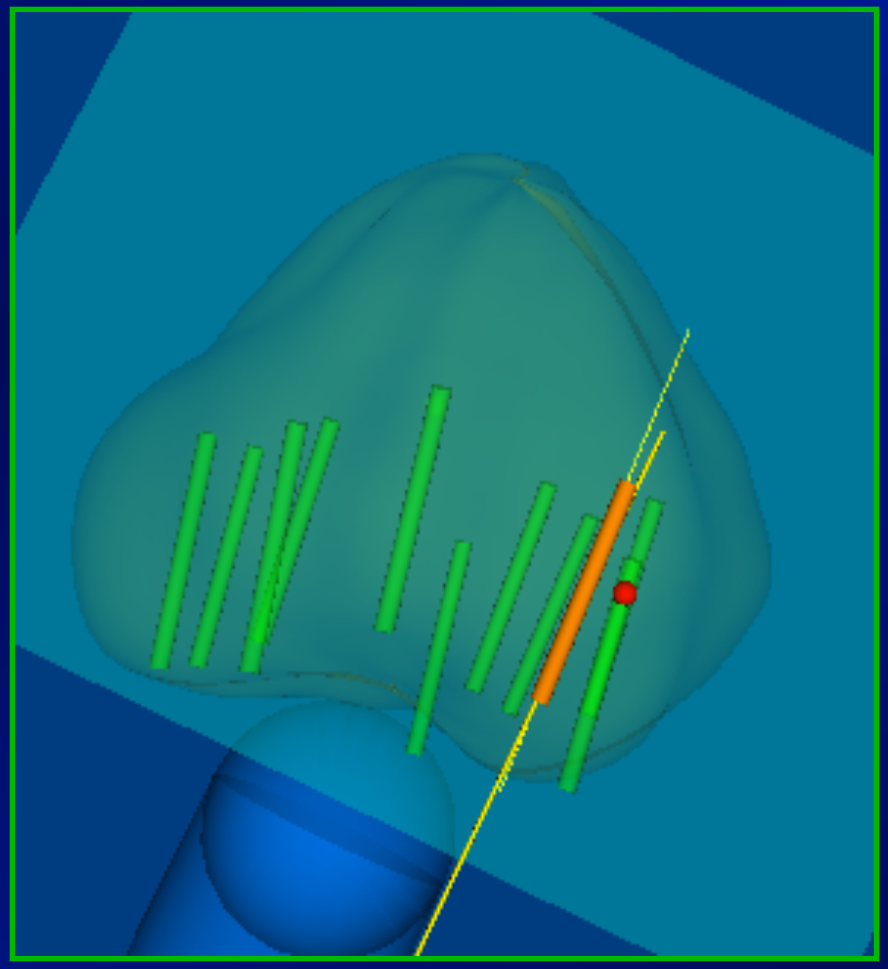
Record of Core Locations



RESULTS: Biopsy of test phantom

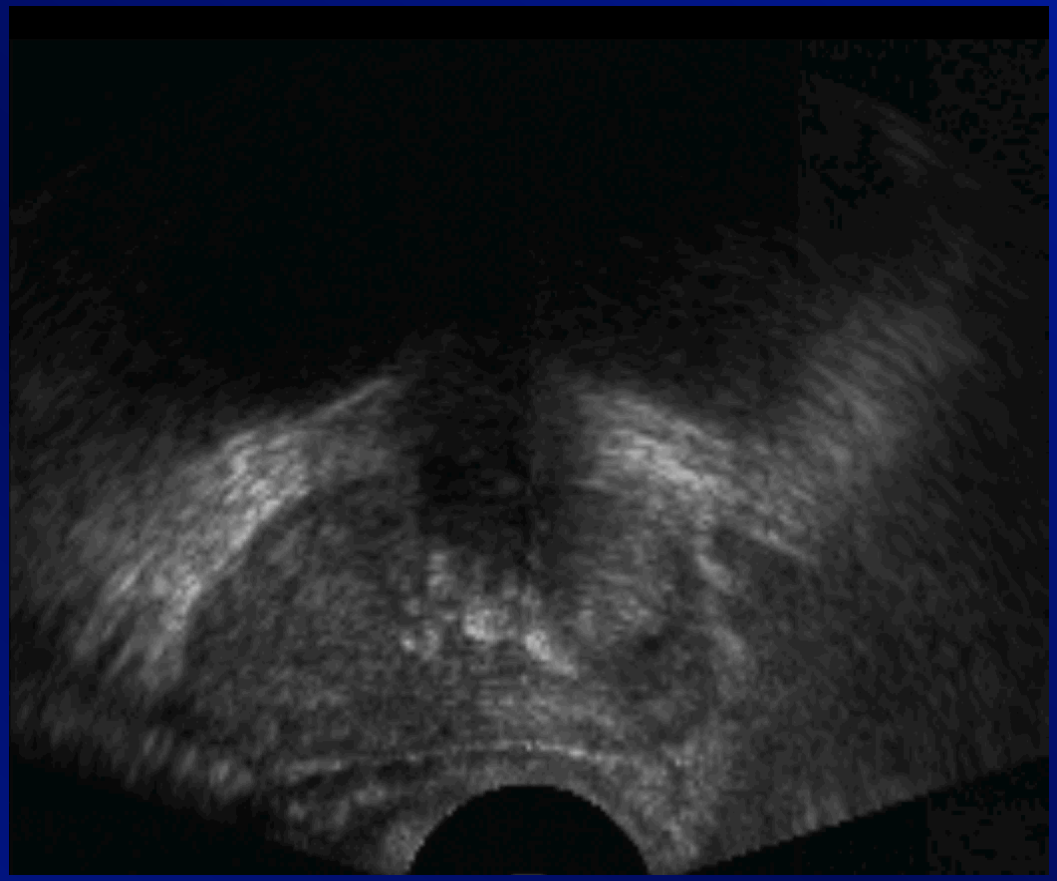
Navigation Error: n=30

	Targeting (mm)	Recording (mm)
Mechanical Tracking	2.1 ± 1.3	1.5 ± 0.9



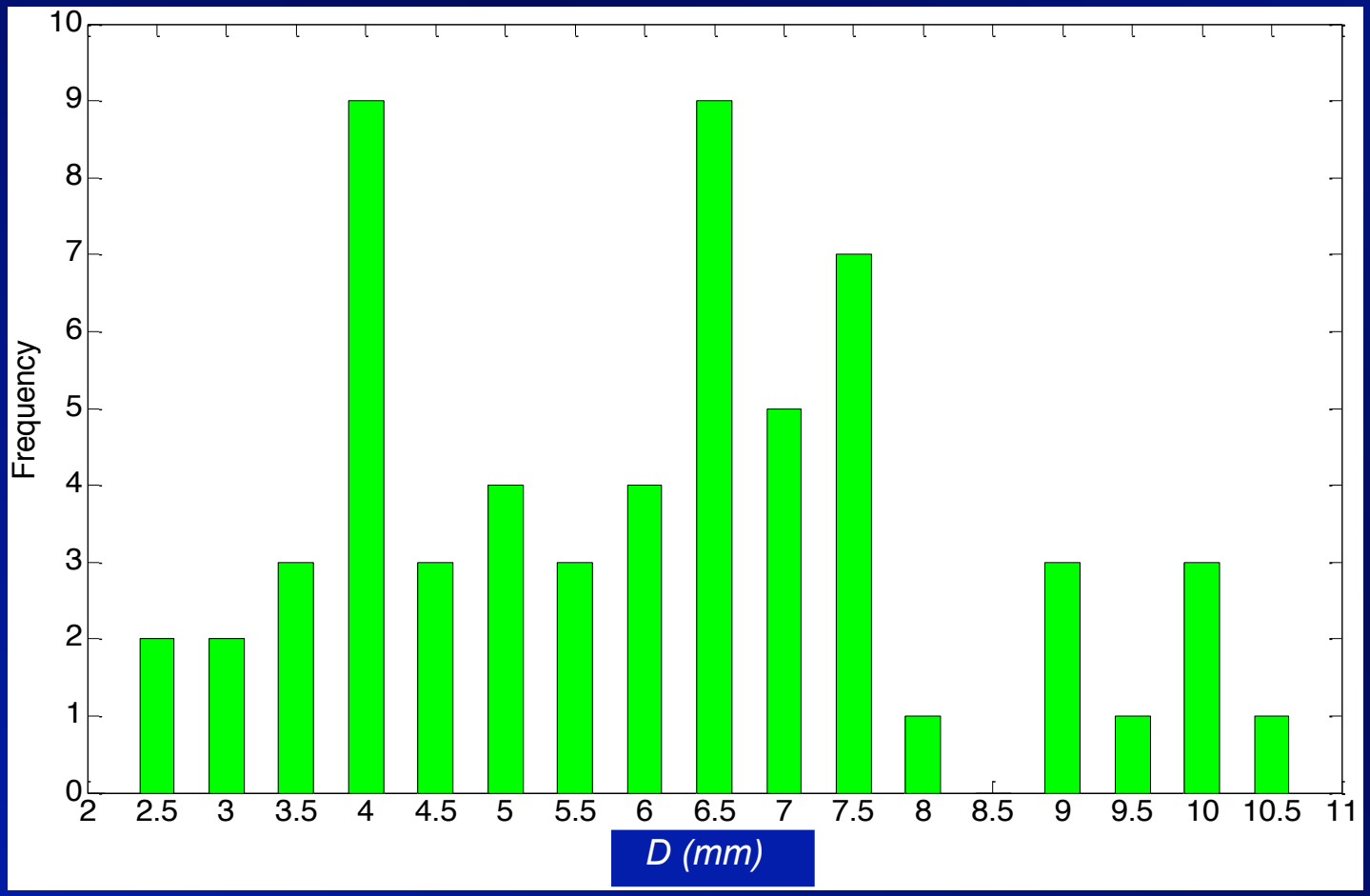
Intra-procedure: Prostate motion & deformation

- Intra-procedure prostate motion and/or deformation
- Biopsy plan no longer accurate if prostate moves/ deforms



Pre-registration

- *Mean distance (D) between corresponding fiducials ~ 6.11 mm*

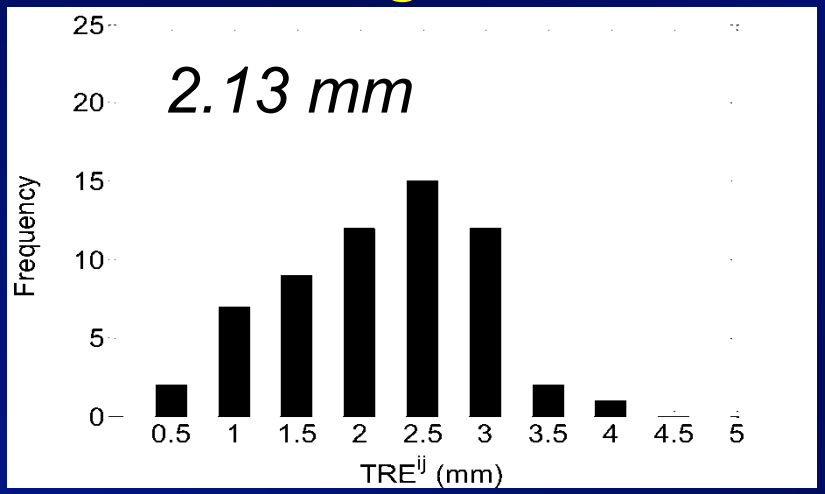


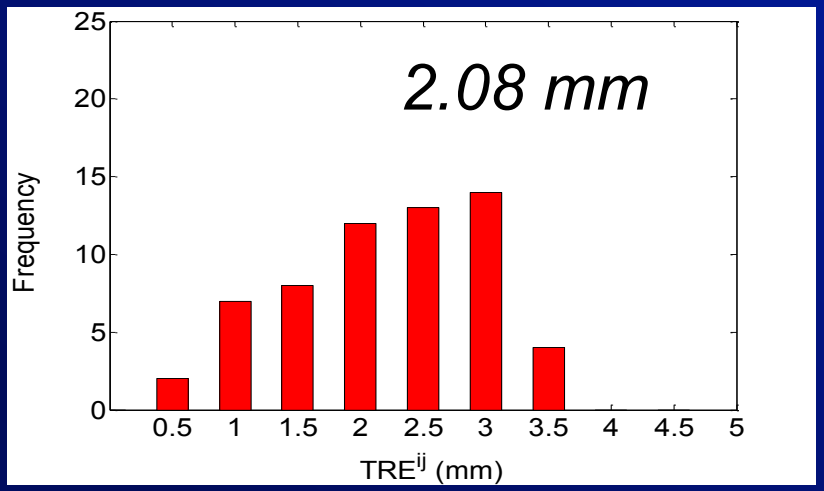
Desired accuracy 2.5 mm

Registration: Surface-based vs. Image-based TRE

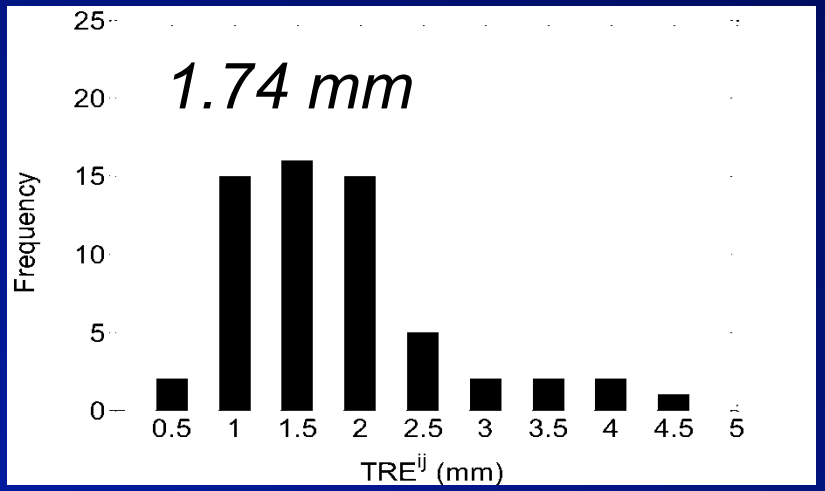
Rigid *Non-Rigid*

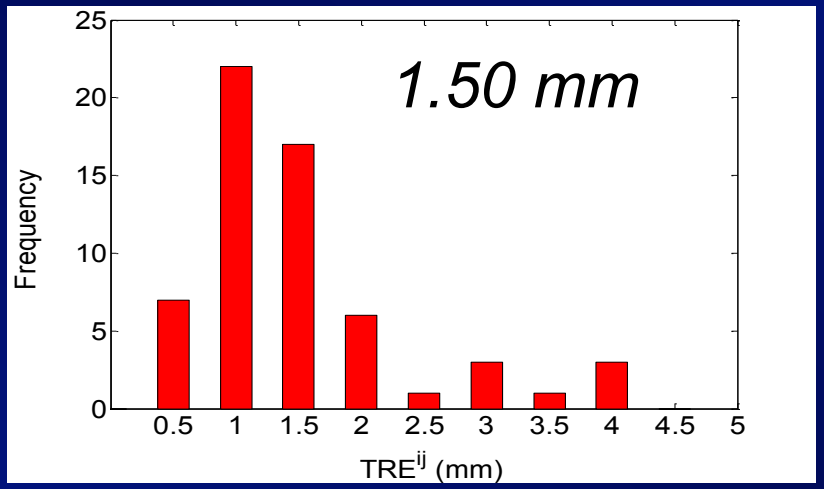
SB





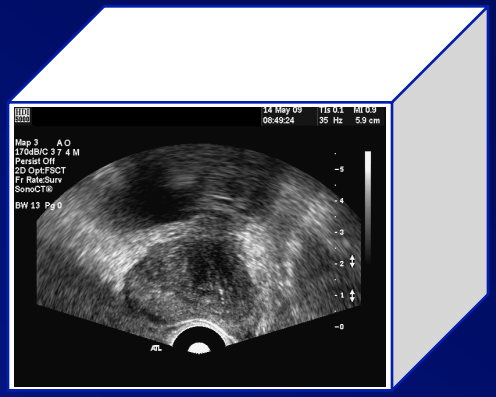
IB





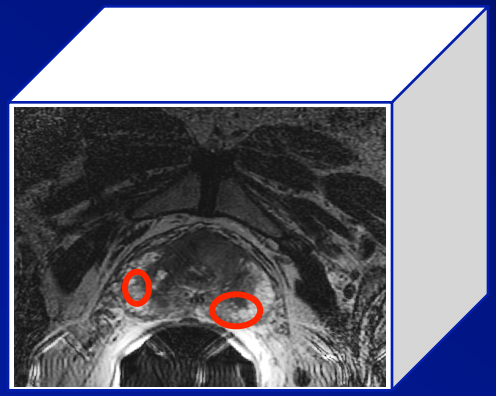
NON-RIGID 3D REGISTRATION OF 3D US to 3D MR IMAGES

Using 3D MRI fused to 3D TRUS

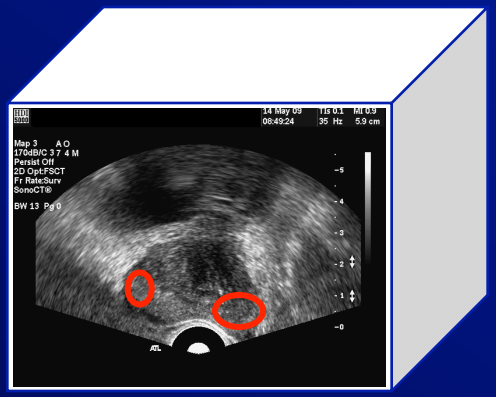


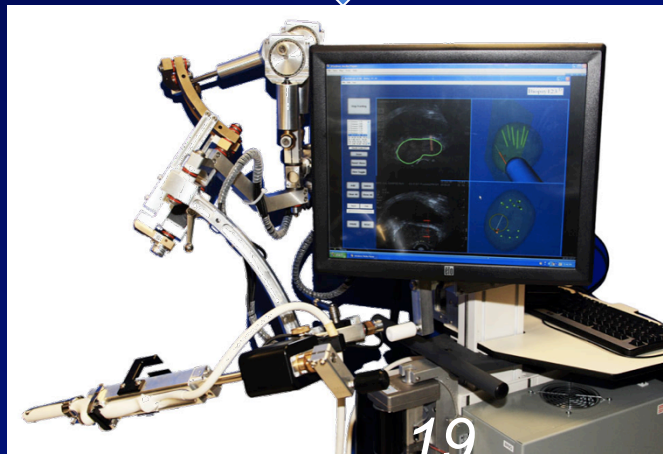
3D TRUS

3D
Non-rigid
Registration

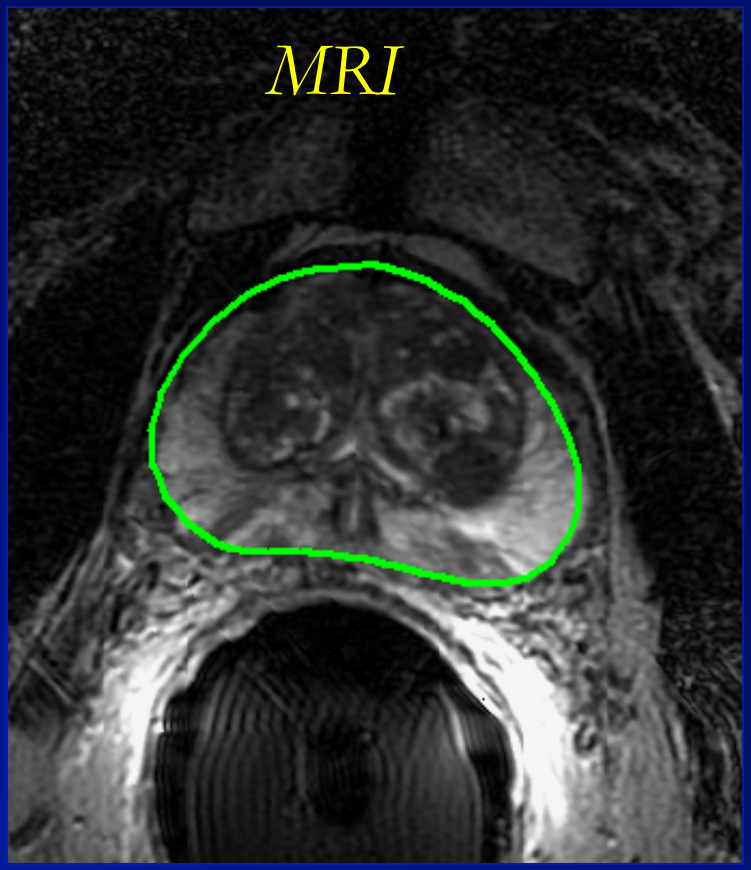


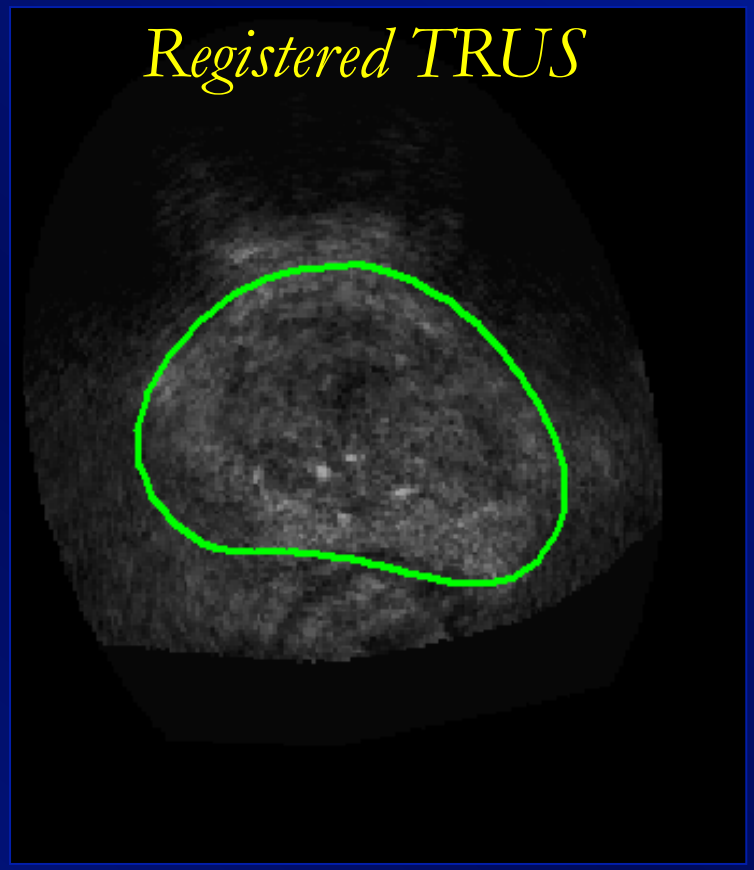
3D MRI





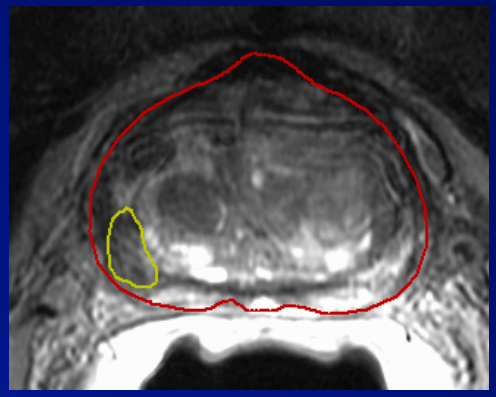
3D TRUS/MRI REGISTRATION

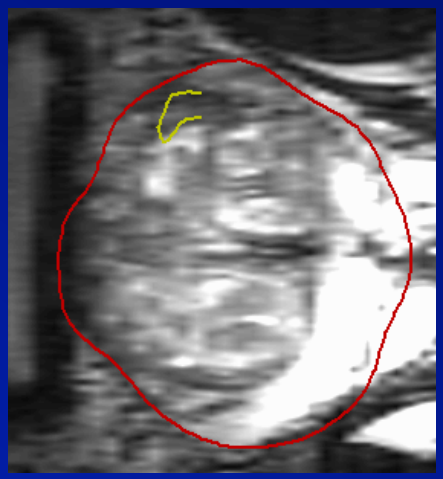


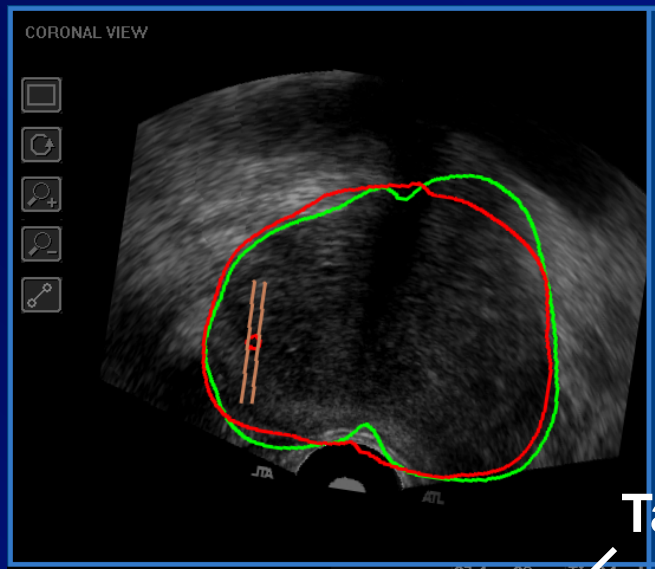


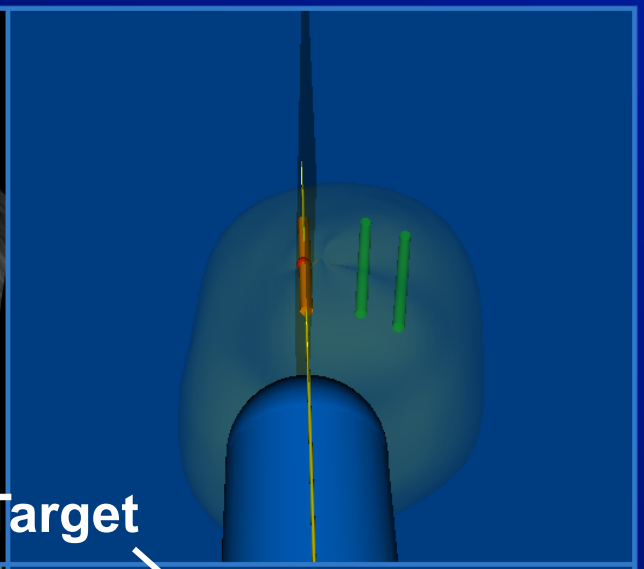
3D MR - US Guided Biopsy

Intra-Biopsy Guidance

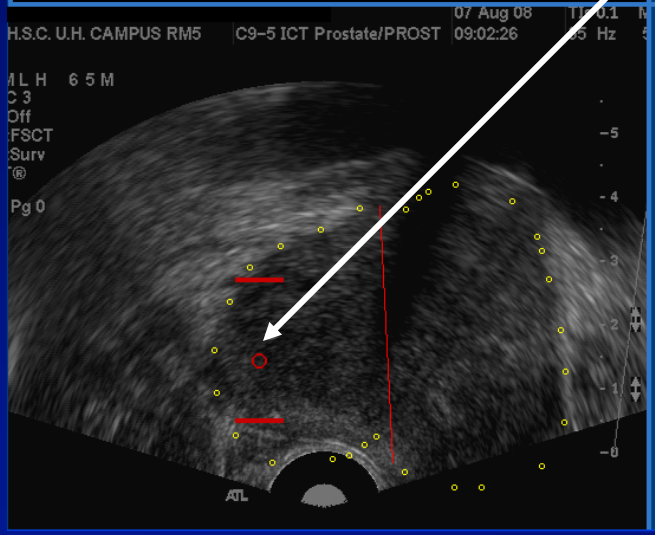


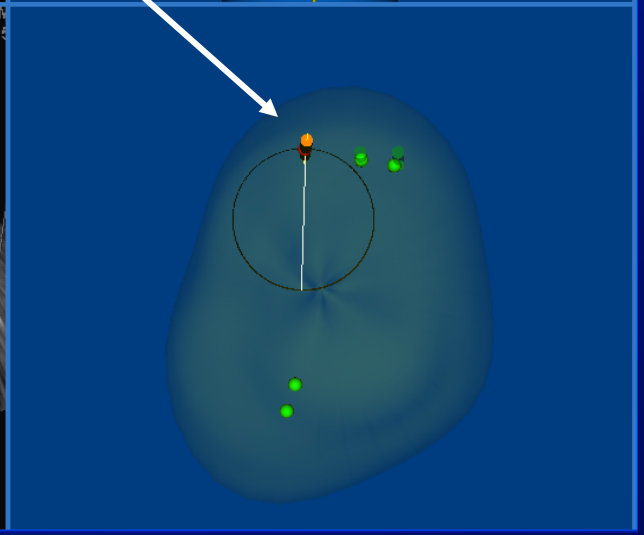


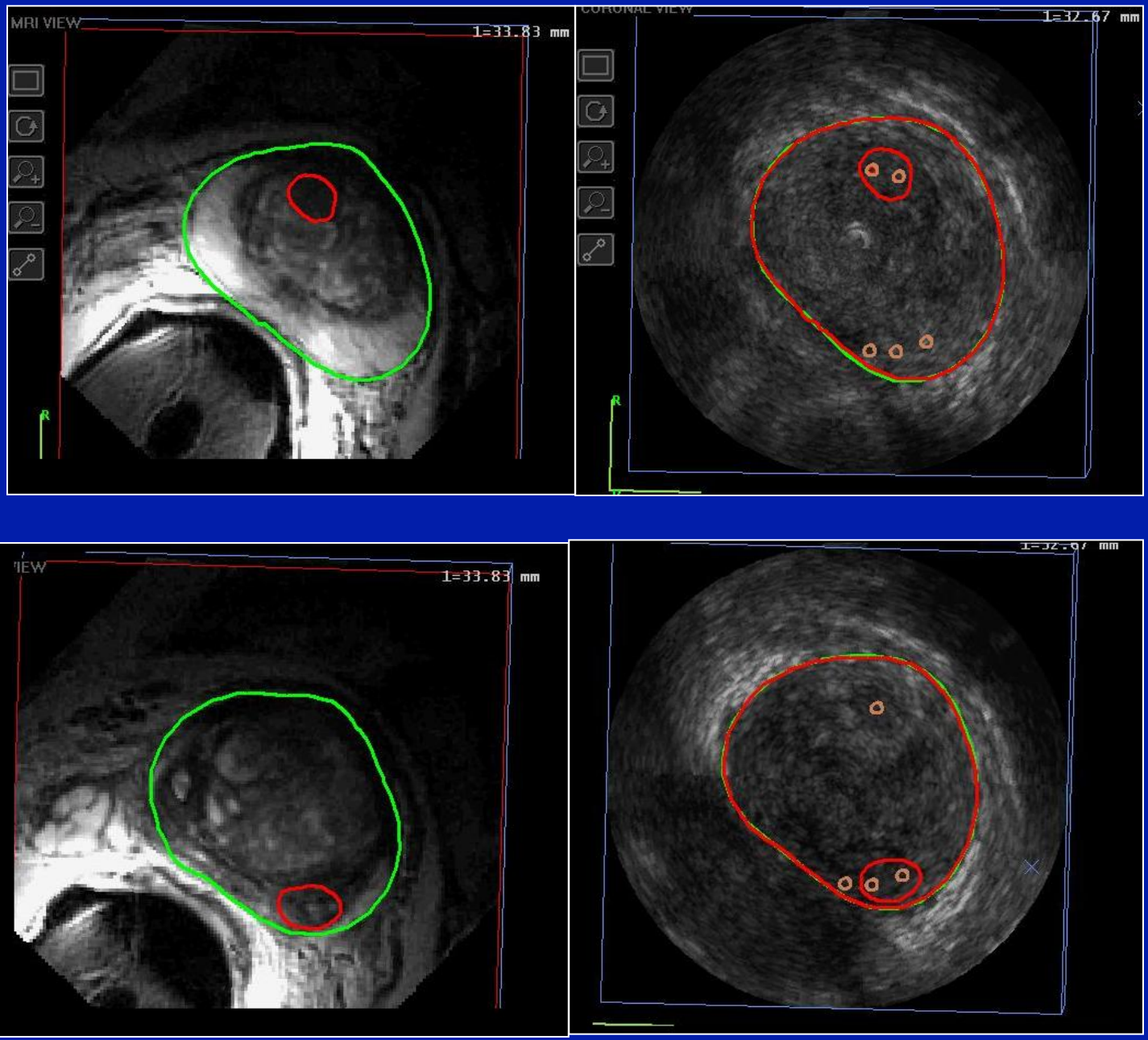




Target






MRI VIEW
1=33.83 mm
CORONAL VIEW
1=32.67 mm
1=33.83 mm

SUMMARY

We have developed a 3D ultrasound navigation system to allow:

- Recording of core locations in 3D
- Guide biopsy to desired location
  - To previous biopsy location
  - To location identified with MRI
- Clinical trials in progress

QUANTIFICATION OF CAROTID PLAQUE PROGRESSION and REGRESSION USING 3D US

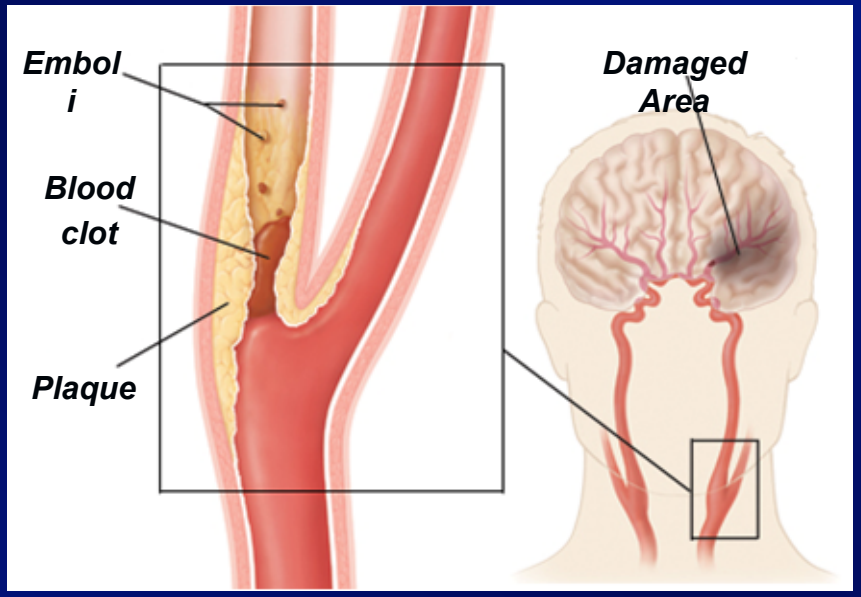
Landry A, Spence JD, Fenster A. Quantification of carotid plaque volume measurements using 3D ultrasound imaging.

Ultrasound Med Biol. 31(6): 751-762, May 2005.

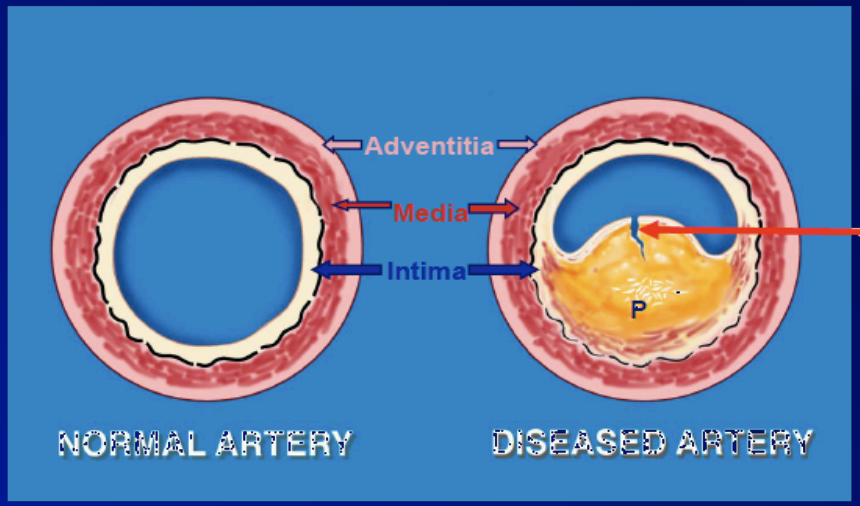
Landry A, Ainsworth C, Blake C, Spence JD, Fenster A. Manual planimetric measurement of carotid plaque volume using three-dimensional US imaging. Med Phys. 34(4): 1496-505, Apr 2007.

CAROTID ATHEROSCLEROSIS

Sagittal view



Transverse view



Ulcerated plaque

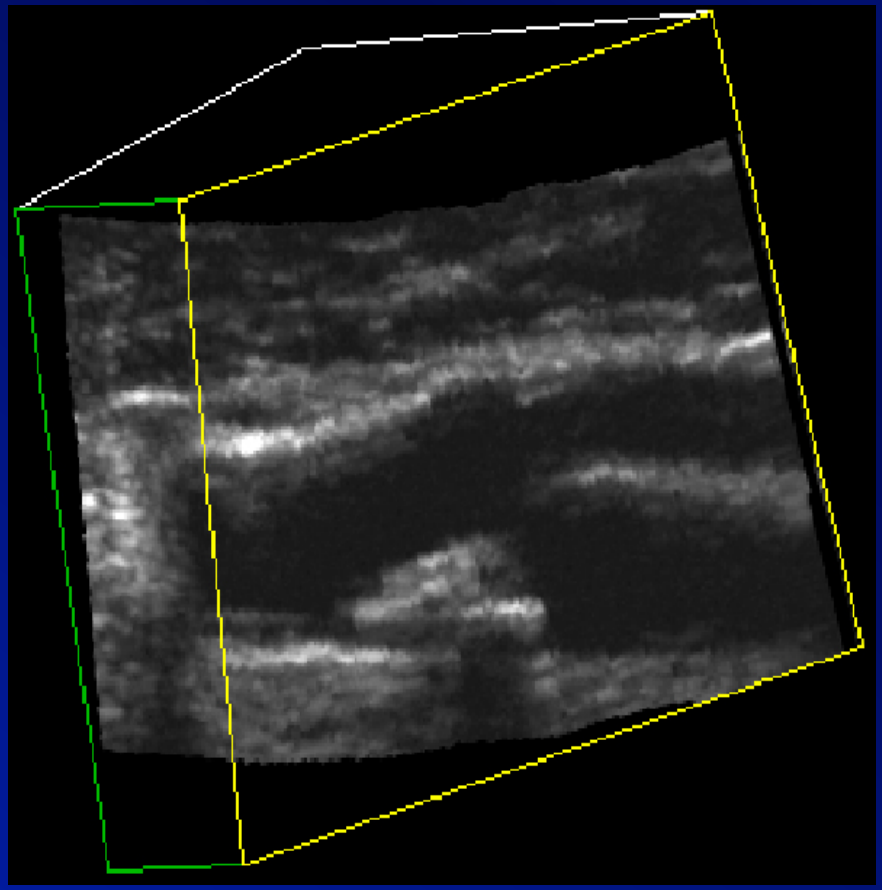
MONITORING CAROTID PLAQUE CHANGES

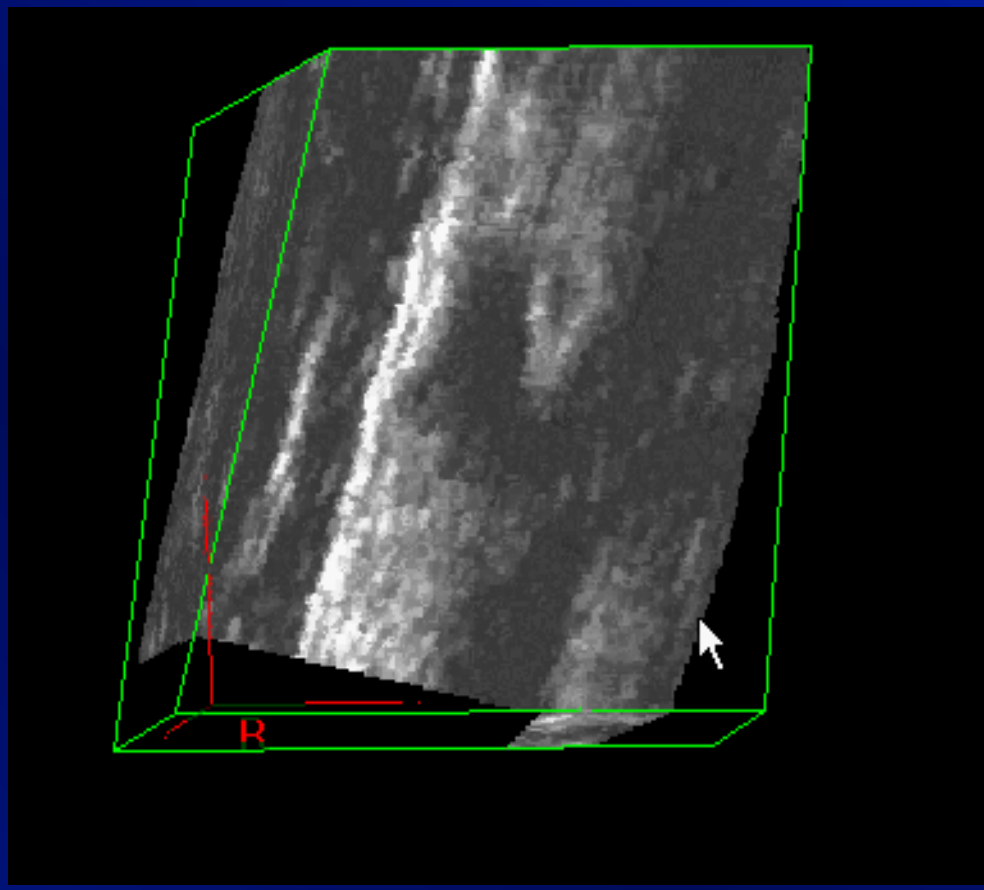
Developing S/W tools to quantify plaque morphology from 3D US images

- 3D distribution of plaque
- Plaque volume
- Surface characteristics
- Plaque “composition”

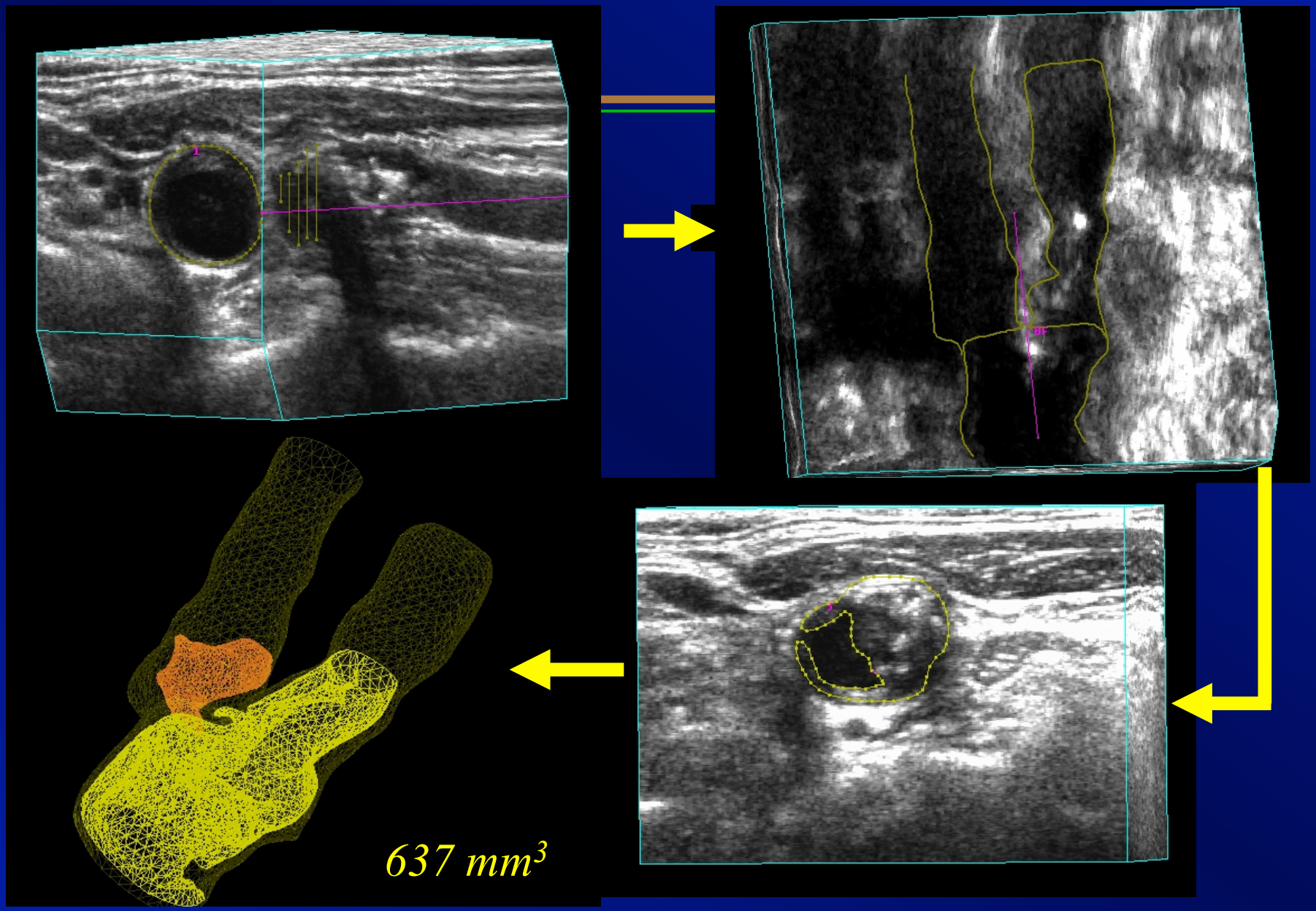
3D CAROTID ULTRASOUND

3D US: Carotid arteries

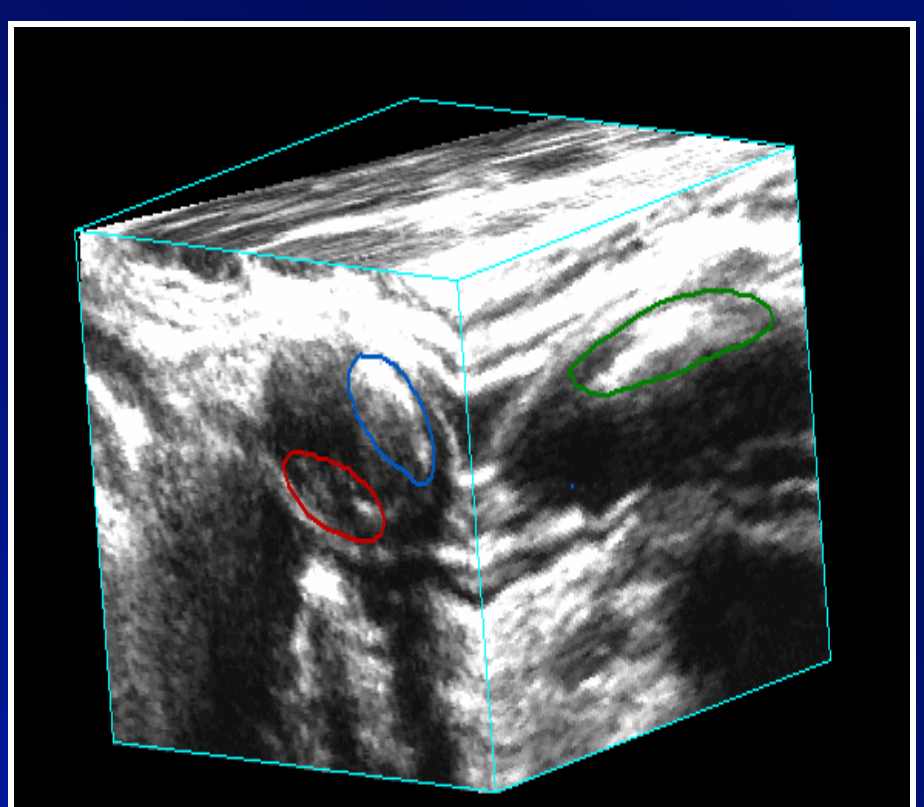


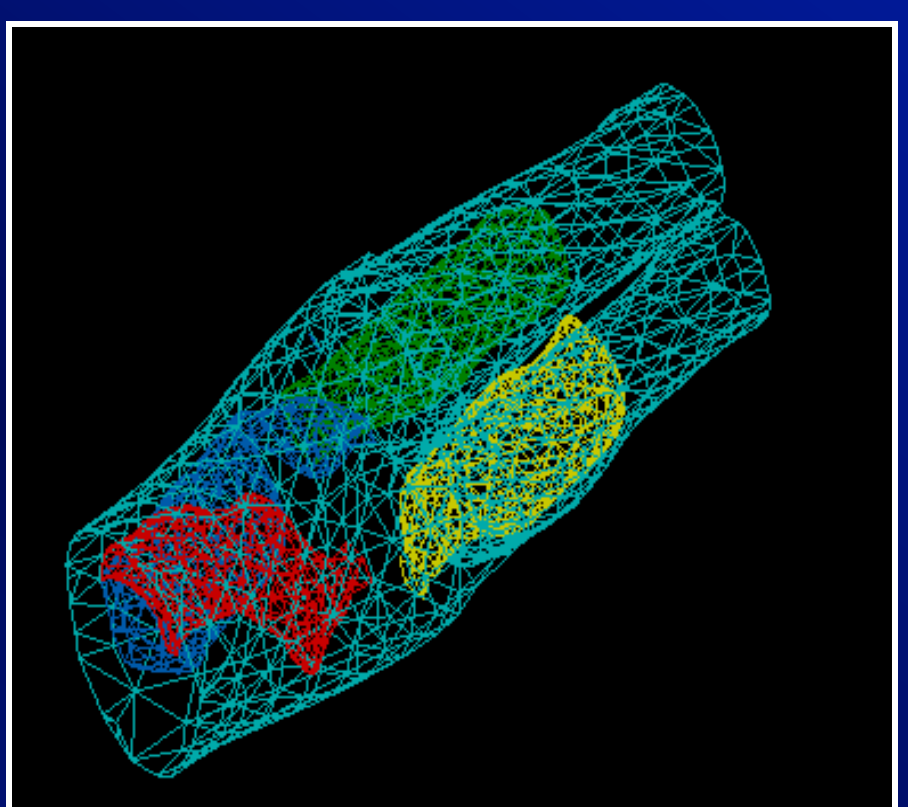


PROCEDURE: Plaque volume



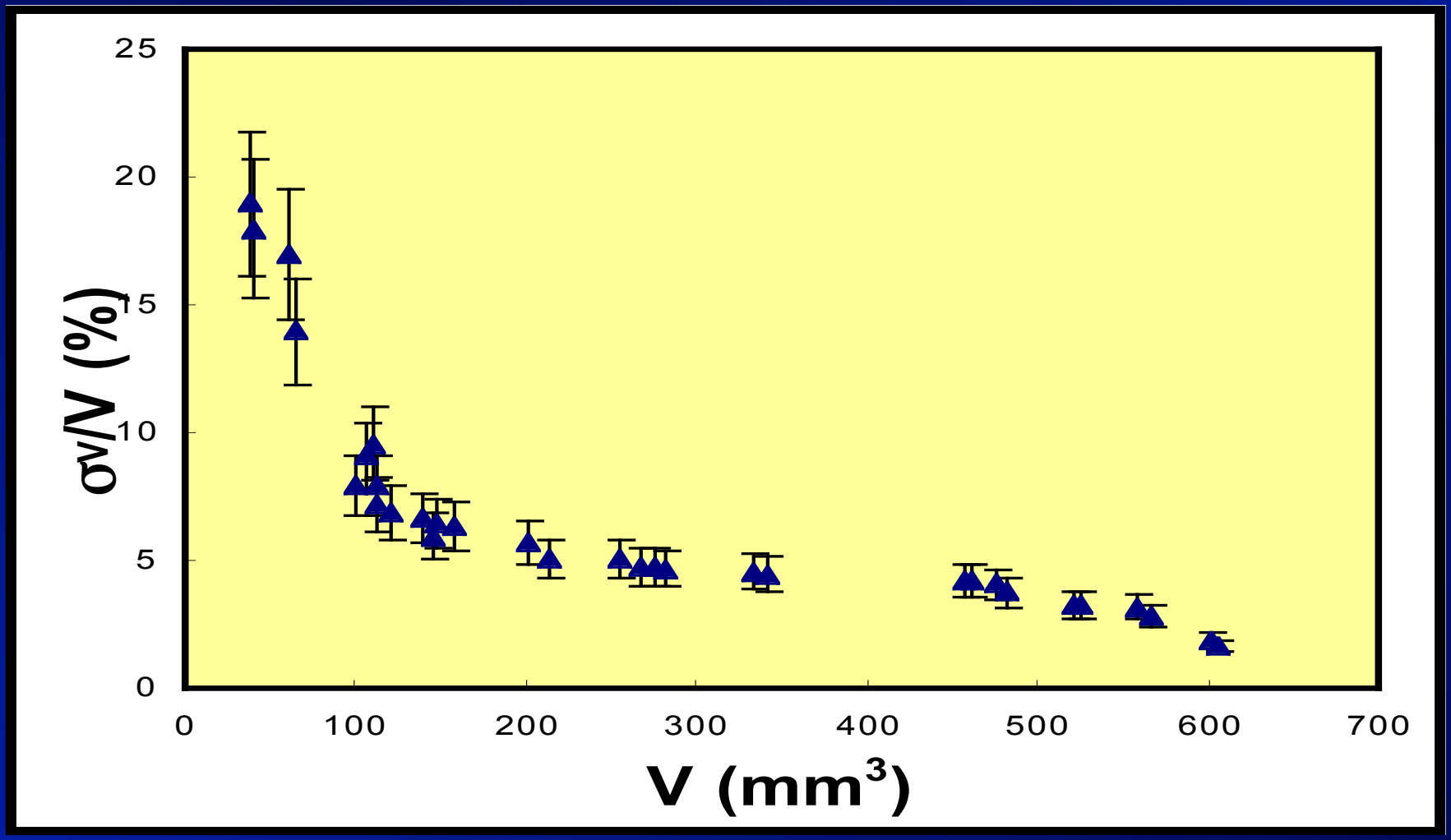
PLAQUE VOLUME: Variability





- *40 patients*
- *5 observers*
- *37.4 mm^3 to 604*
- *5 measurements/observer/plaqu*

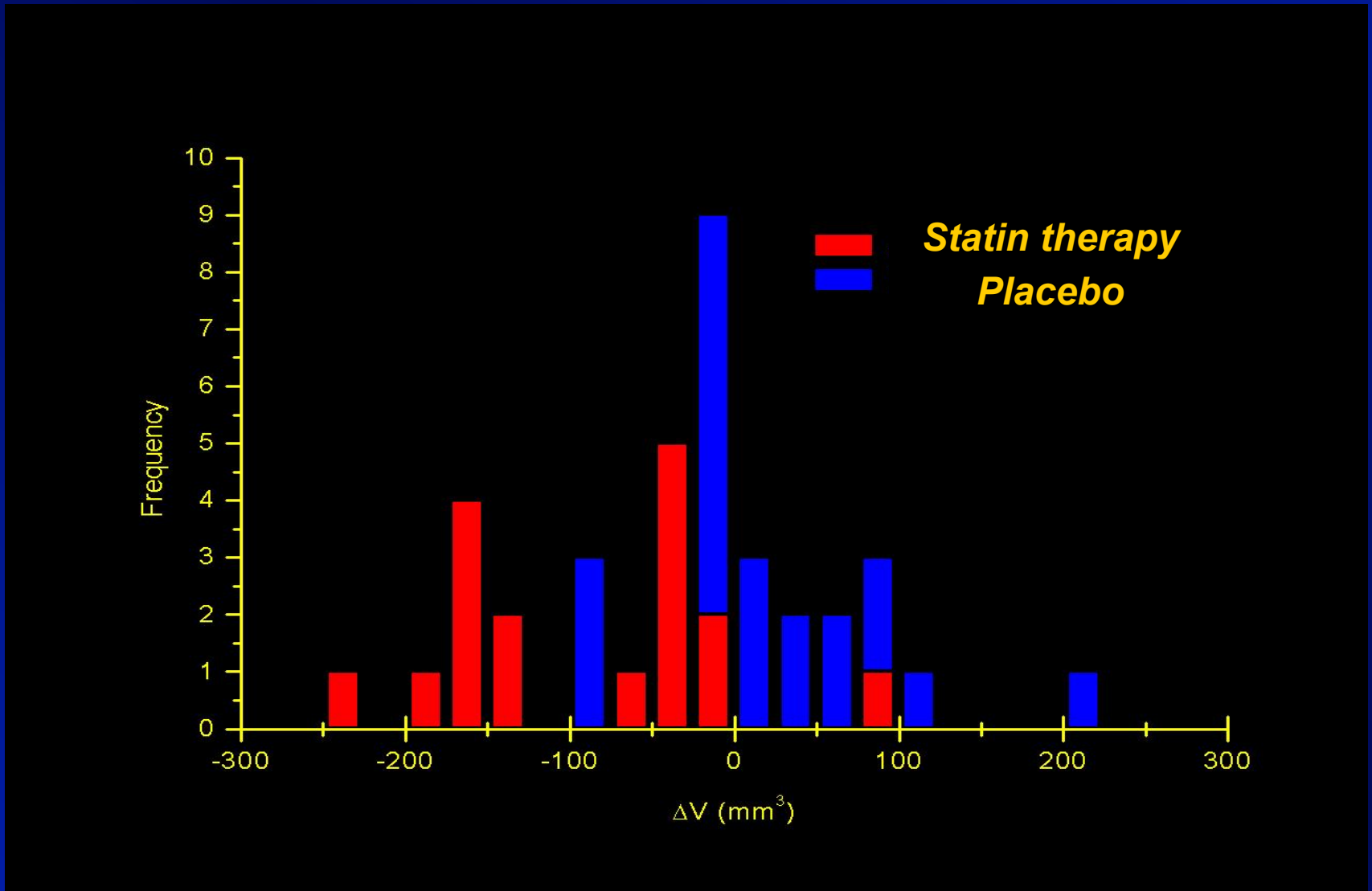
PLAQUE VOLUME: Variability



MONITORING PLAQUE REGRESSION & PROGRESSION

Ainsworth, Blake, Tamayo, Beletsky, Fenster, Spence. Stroke 36: 1904-1909, (2006)

STATIN THERAPY:Plaque volume: Baseline & 3 months



SEMI-AUTOMATED VWV SEGMENTATION

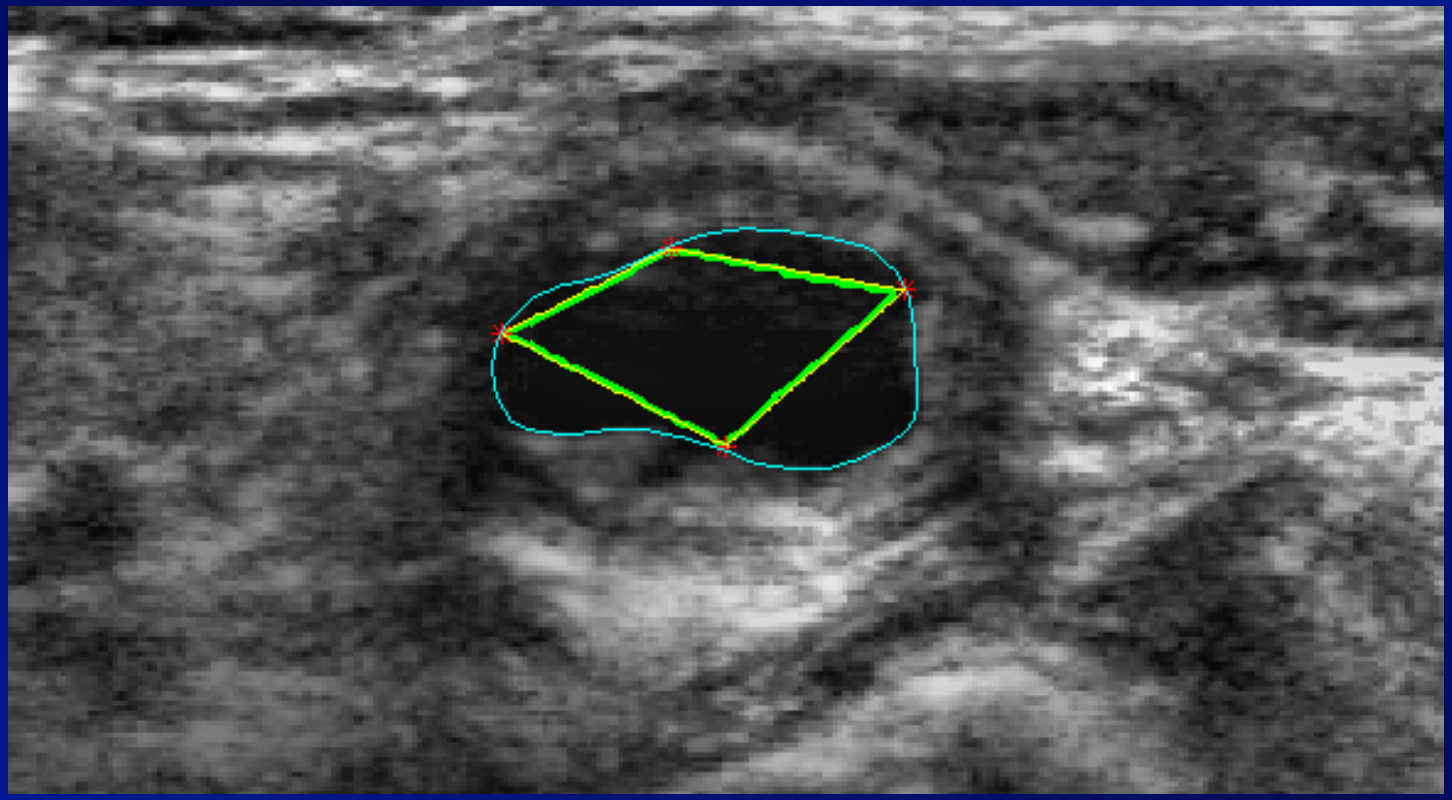
Ukwatta E, Awad J, Ward AD, Buchanan D, Samarabandu J, Parraga G, Fenster A. 3D US of carotid atherosclerosis: Semi-automated segmentation using a level set-based method. Med Phys. In Press: 2011.

GOAL

- To develop and validate a semi-automated algorithm for segmenting carotid arteries from 3D US
  - The media-adventitia boundary (MAB)
  - The lumen-intima boundary (LIB)
- To quantify vessel wall volume (VWV) for monitoring plaque progression and regression

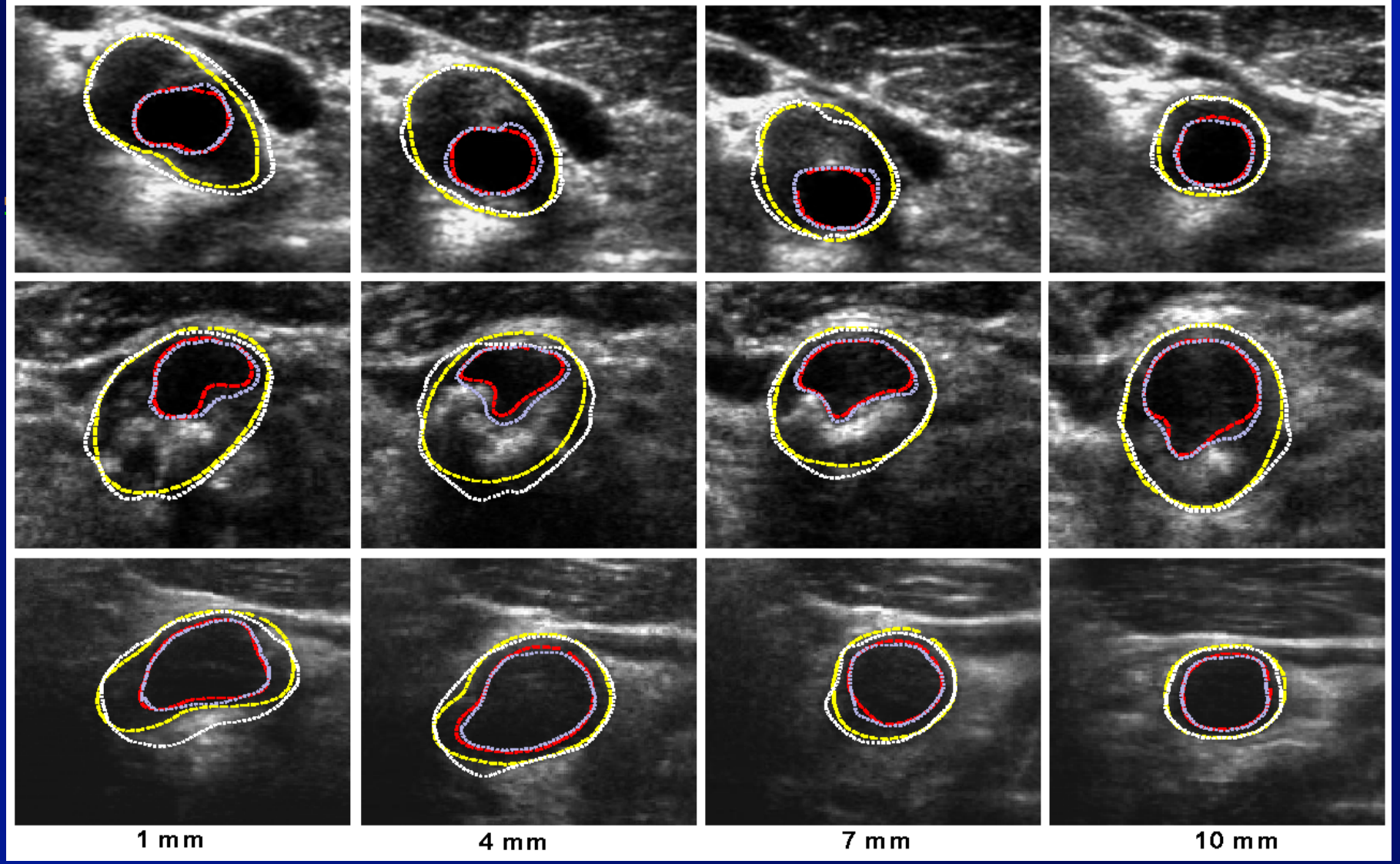
DEFORMABLE ACTIVE CONTOURS

Energy minimization approach to segmentation



Given: initial contour near desirable object

Goal: Evolve the contour to fit exact object boundary



Dashed inner contour - manual boundary for the LIB

Dotted inner contour - algorithm generated boundary for the LIB

Dashed outer contour - manual boundary for the MAB

Dotted outer contour - algorithm generated boundary for the MAB

Results: summary

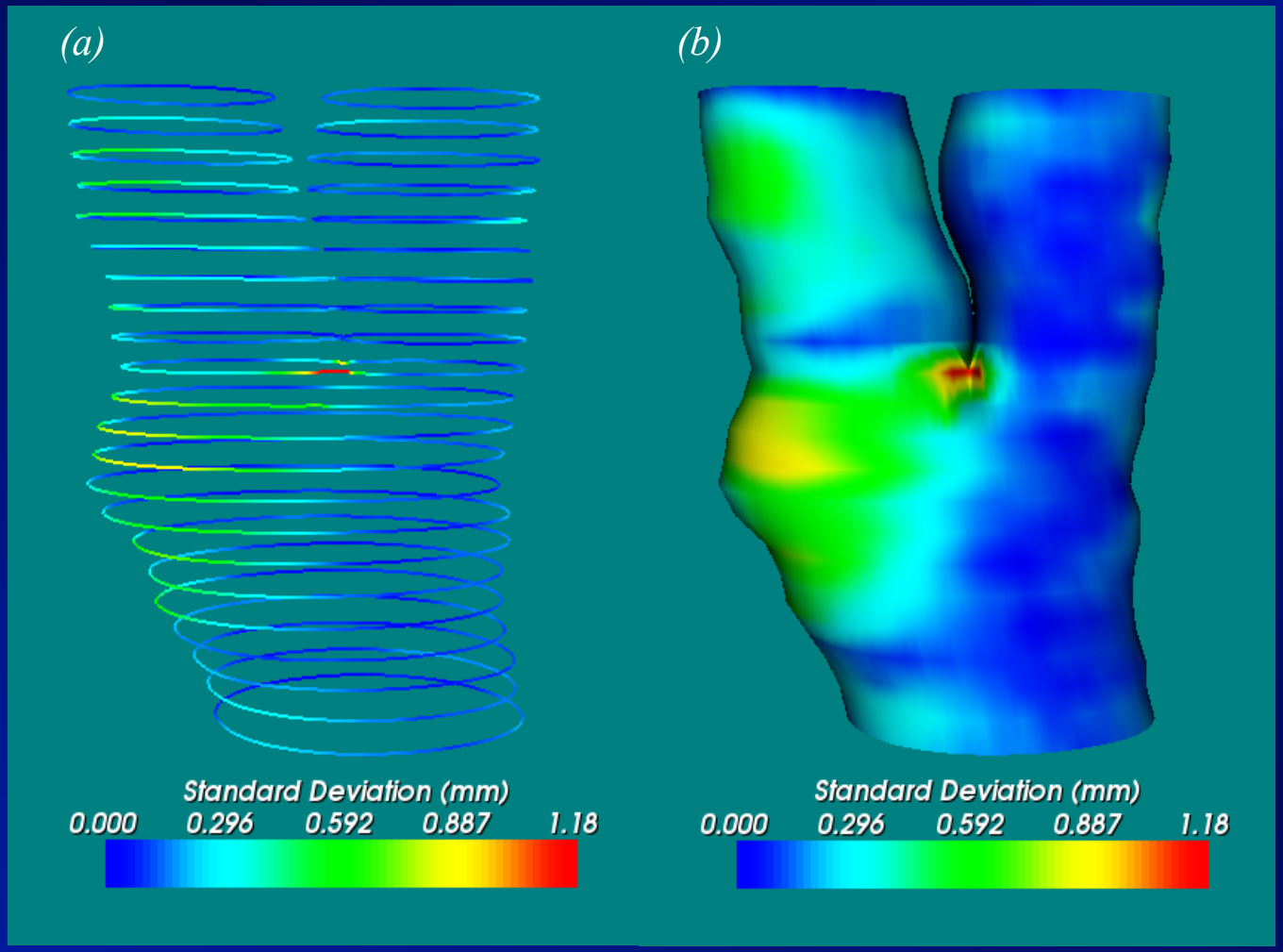
Metric	MAB Segmentation	LIB Segmentation
Volume error (%)	2.4 ± 1.9	5.6 ± 3.1
Dice coefficient (%)	95.3 ± 1.6	93.1 ± 3.1
MAD (mm)	0.2 ± 0.1	0.2 ± 0.1
MAXD (mm)	0.6 ± 0.3	0.7 ± 0.6

** Voxel size: 0.1 × 0.1 × 0.15 mm^3*

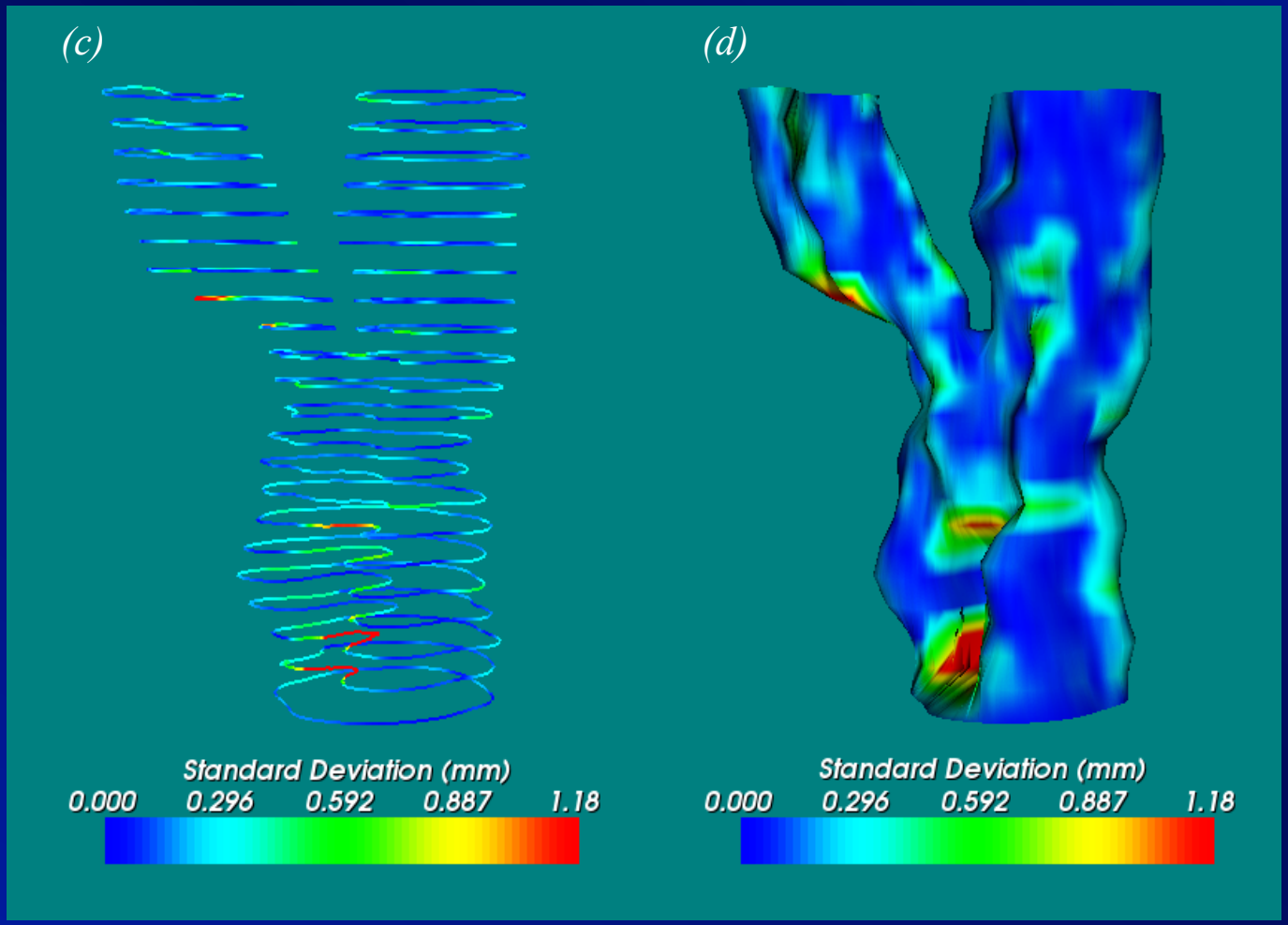
MONITORING LOCAL PLAQUE CHANGES

Chiu, Egger, Spence, Parraga, Fenster. Med. Phys. 35: 3691-3710, (2008)

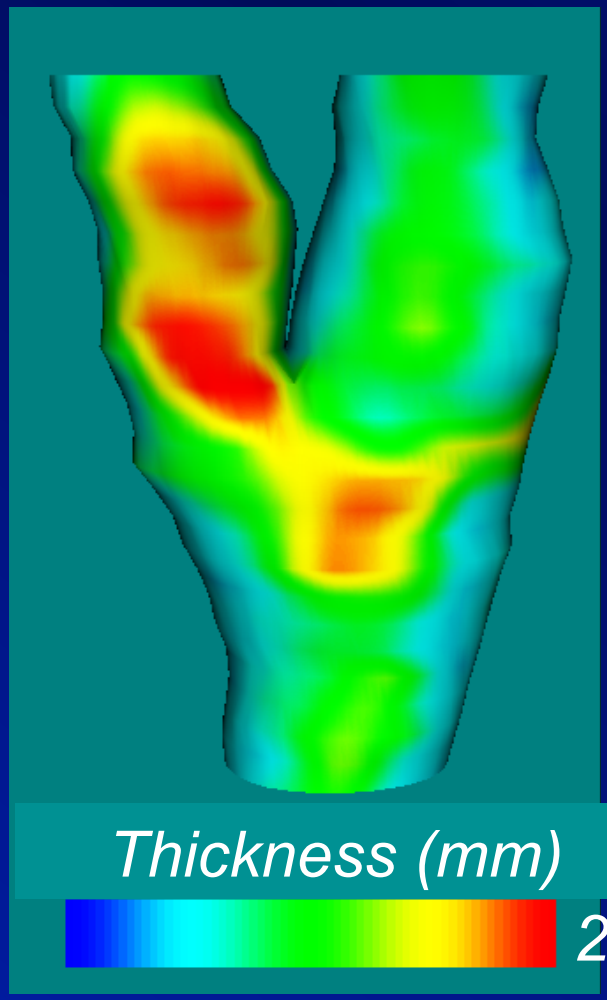
CAROTID WALL BOUNDARY



CAROTID LUMEN BOUNDARY

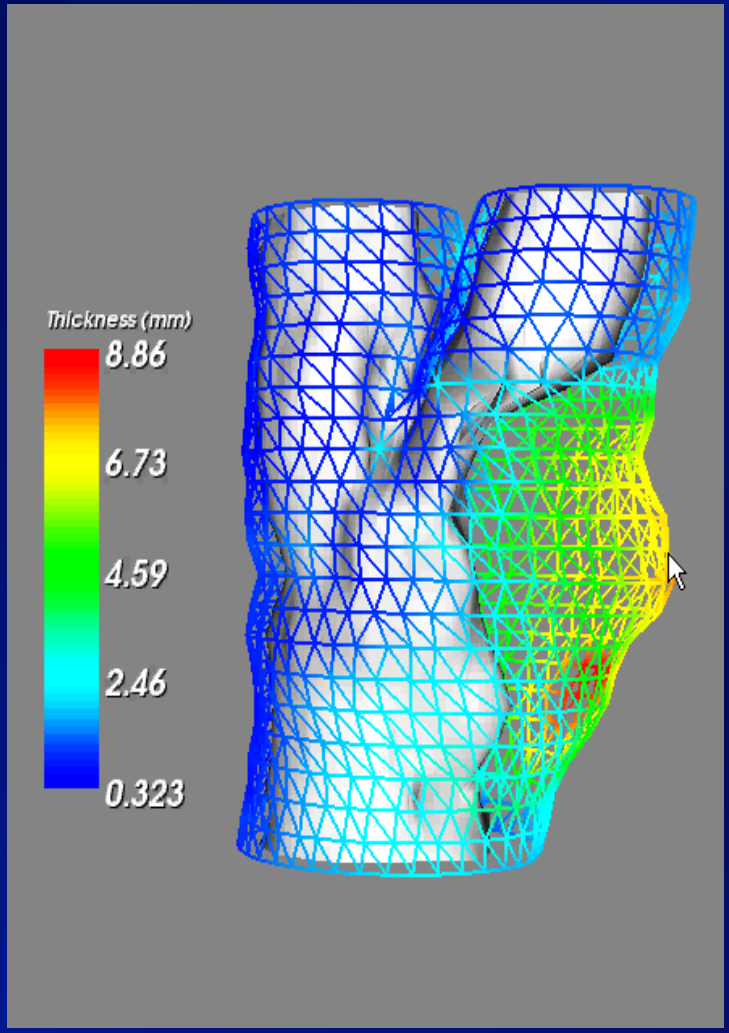


PLAQUE THICKNESS



- Plaque thickness: Distance between wall and lumen surface
- Display:
  - Mean vessel wall surface
  - colour-coded plaque thickness map superimposed on mean surface

BASELINE IMAGE

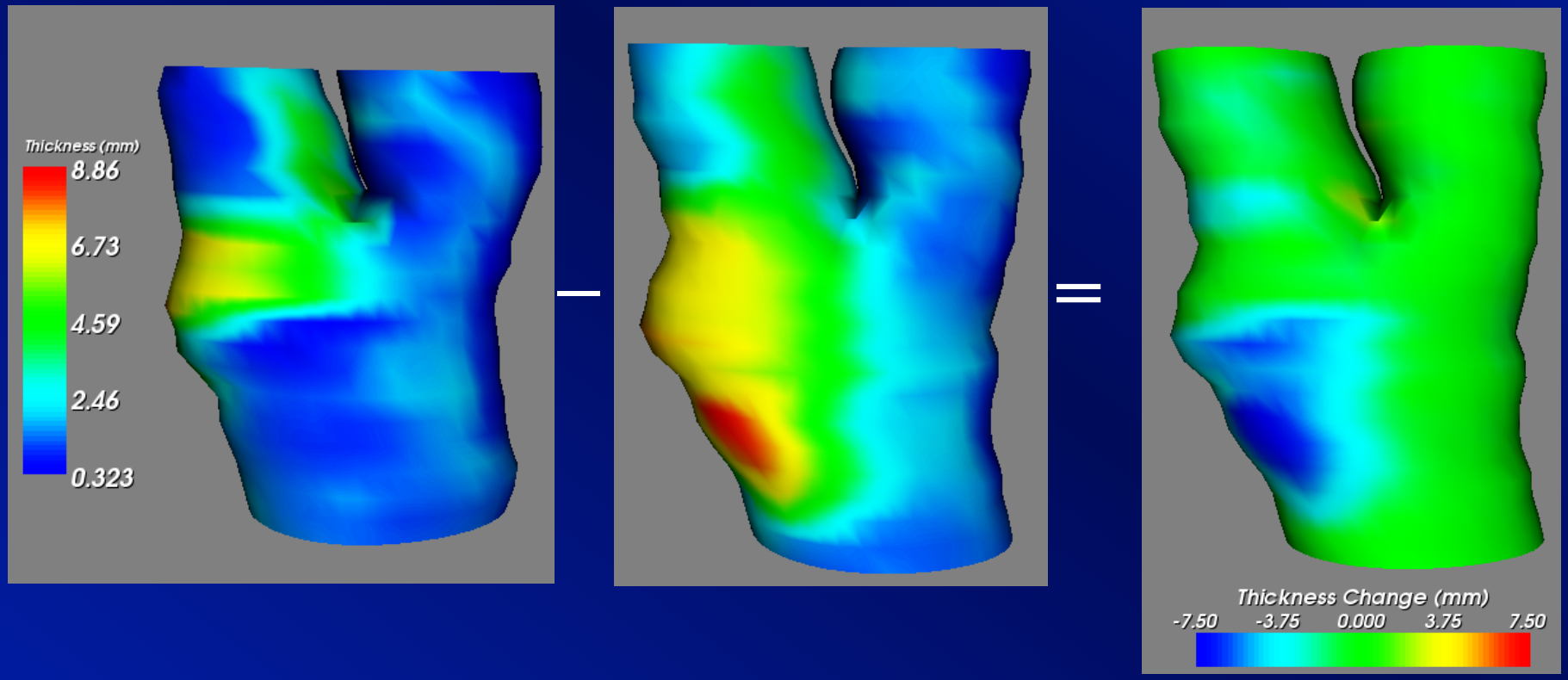


VWT Change: Subject 1

Time: 3 months

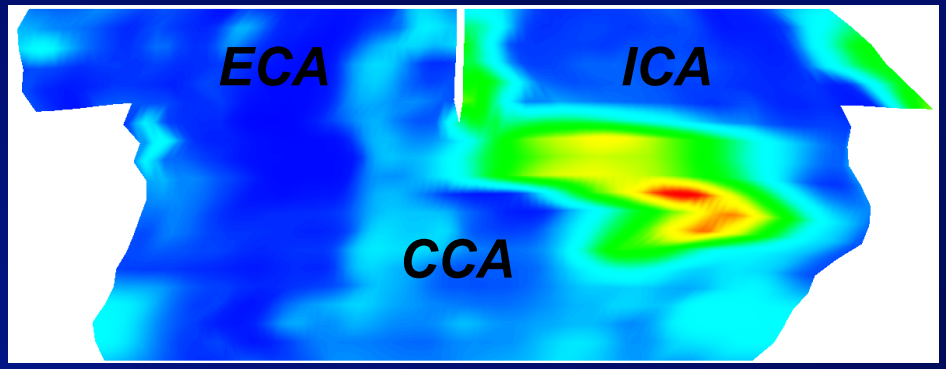
Time: 0

Difference



VWT Change: Flattened Map

Time: 3 months



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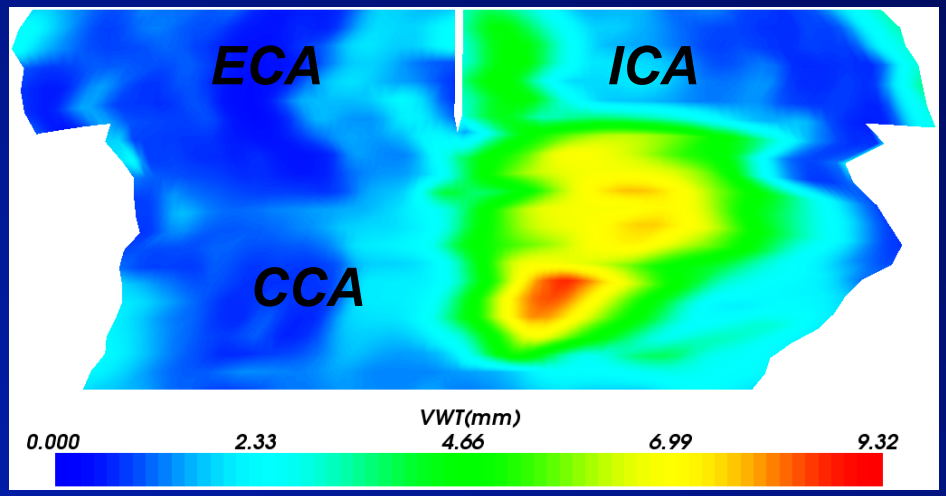
Time: 0



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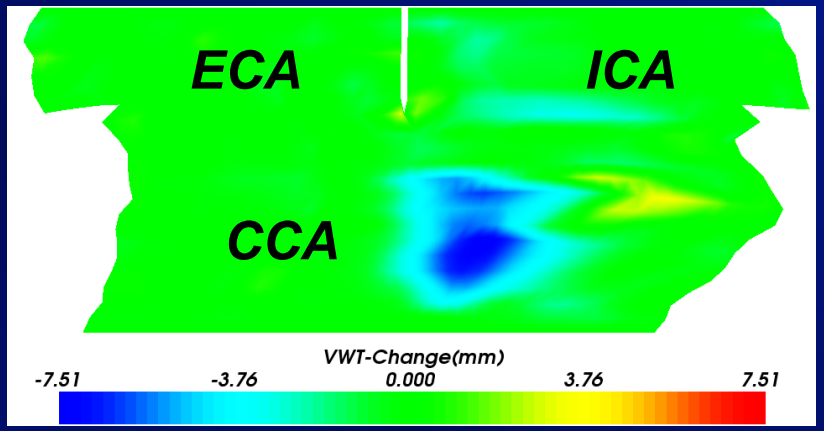
Subject 1

Change



3D CAROTID ULTRASOUND: Summary

- Technique and software for analysis and monitoring of carotid plaque:
  - Software for segmentation well characterized
  - Flattened map approach developed
  - Plaque progression/regression trials ongoing
  - New features ongoing (*e.g.* surface morphology)
  - Many collaborators and users

Thank You

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