

# Carotid Plaque Characterization and Intima-Media Thickness

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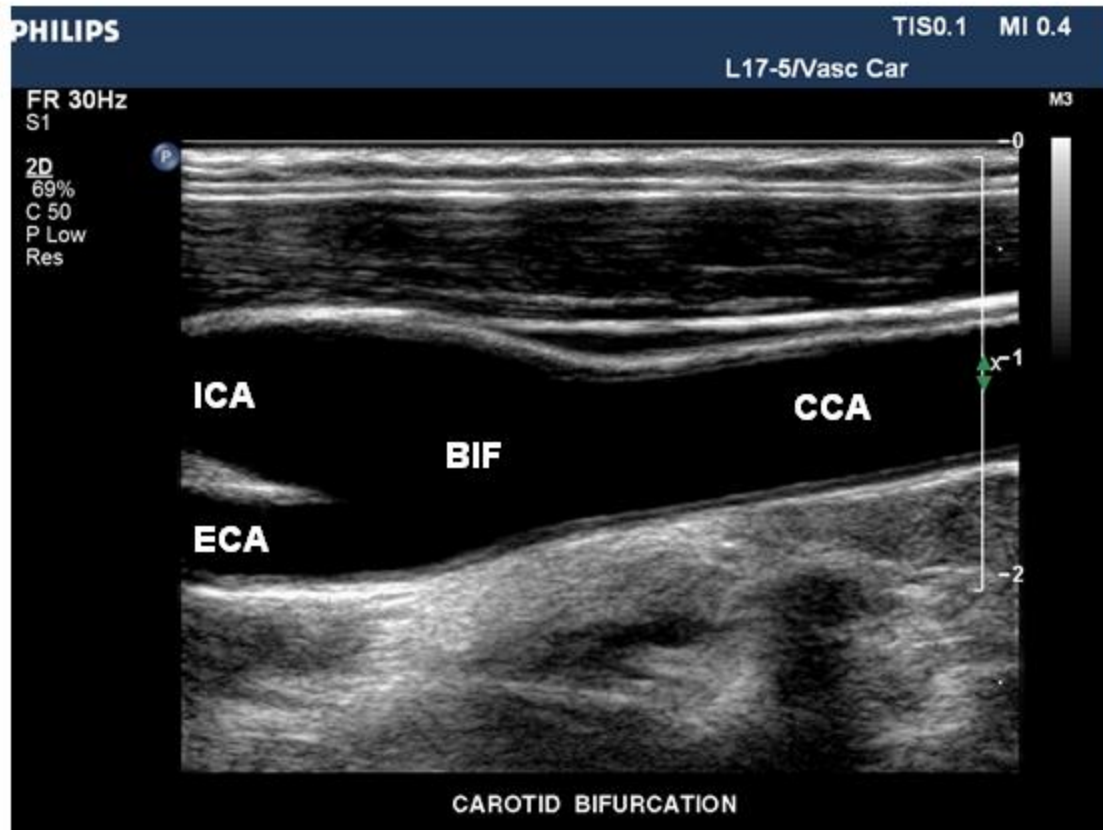
# CEA Specimen: ICA Plaque



# Carotid Plaque Characterization

- Most Rx decisions made based on Doppler/hemodynamic effect (% stenosis)
- Plaque features can influence decision
- Plaque characterization takes time and attention to detail
- Understanding of principles and adjustments

# Carotid B-Mode Imaging



# Carotid Plaque Characterization

- B-mode imaging gives 2-D gray scale image of vessel, wall, plaque, & soft tissue
- Location, size, course of vessels
- Information on plaque features: location, thickness, surface (smooth, irregular, ulcer), texture (homogeneous/heterogeneous), echodensity, and any movement

# B-Mode Imaging

- Provides ultrasonic picture of tissues, vessels, plaque (not true anatomic image)
- Best to use ultrasonic terms to describe
- Transducer frequency and focusing determine resolution
- Higher frequency, higher resolution
- Higher frequency, greater attenuation, less working depth

# Carotid Plaque Characterization

- Definition of plaque varies
- Absolute thickness
- Protrusion relative to adjacent wall thickness
- Features: Location, thickness, surface, cap thickness, texture, echodensity, motion

# Carotid Plaque Criteria

## WFBMC

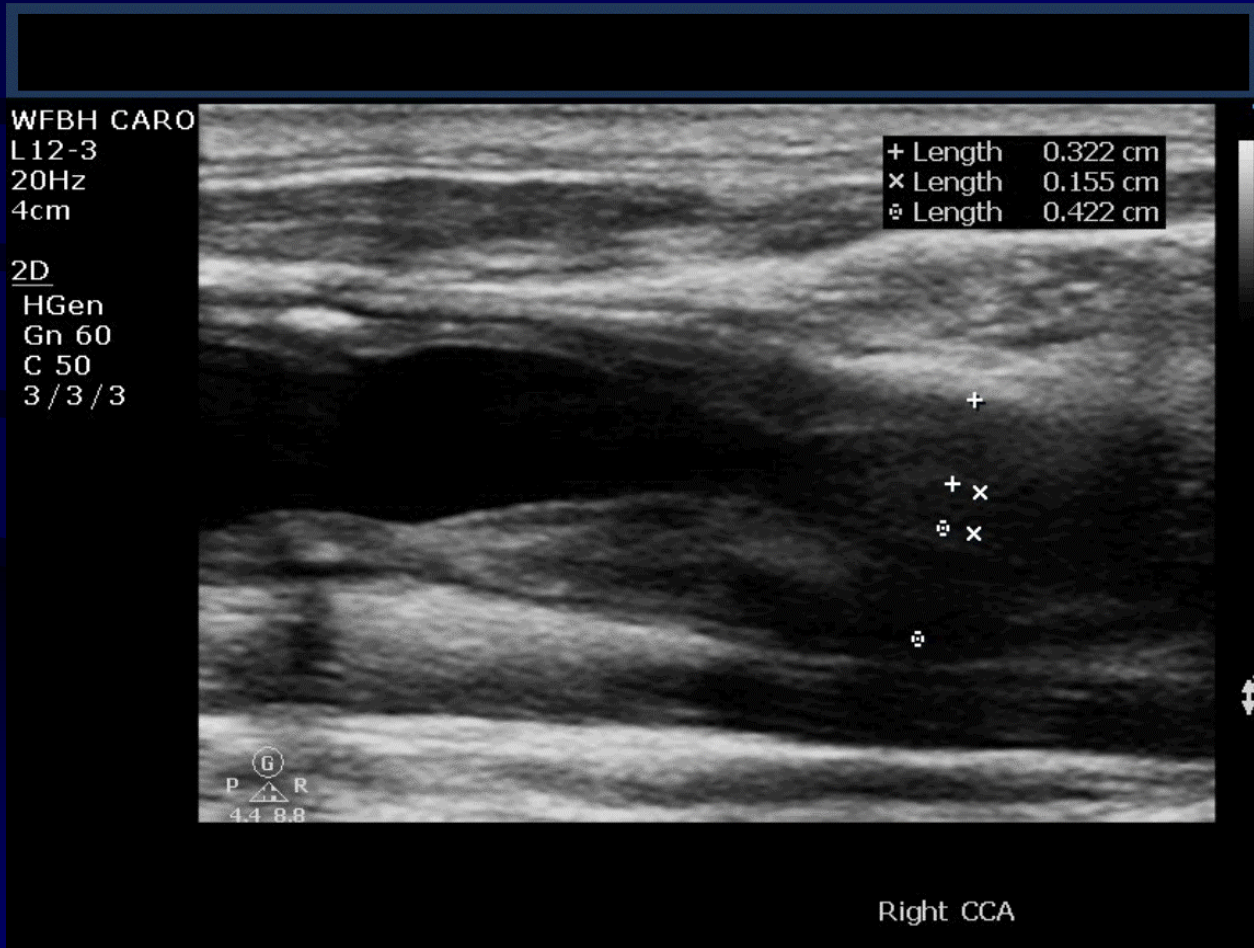
<u>Plaque Category</u>	<u>Measurement</u>
Normal	< 1.1 mm
Minimal / Mild	1.1 – 2.0 mm
Moderate	2.1 – 4.0 mm
Large / Severe	> 4.0 mm



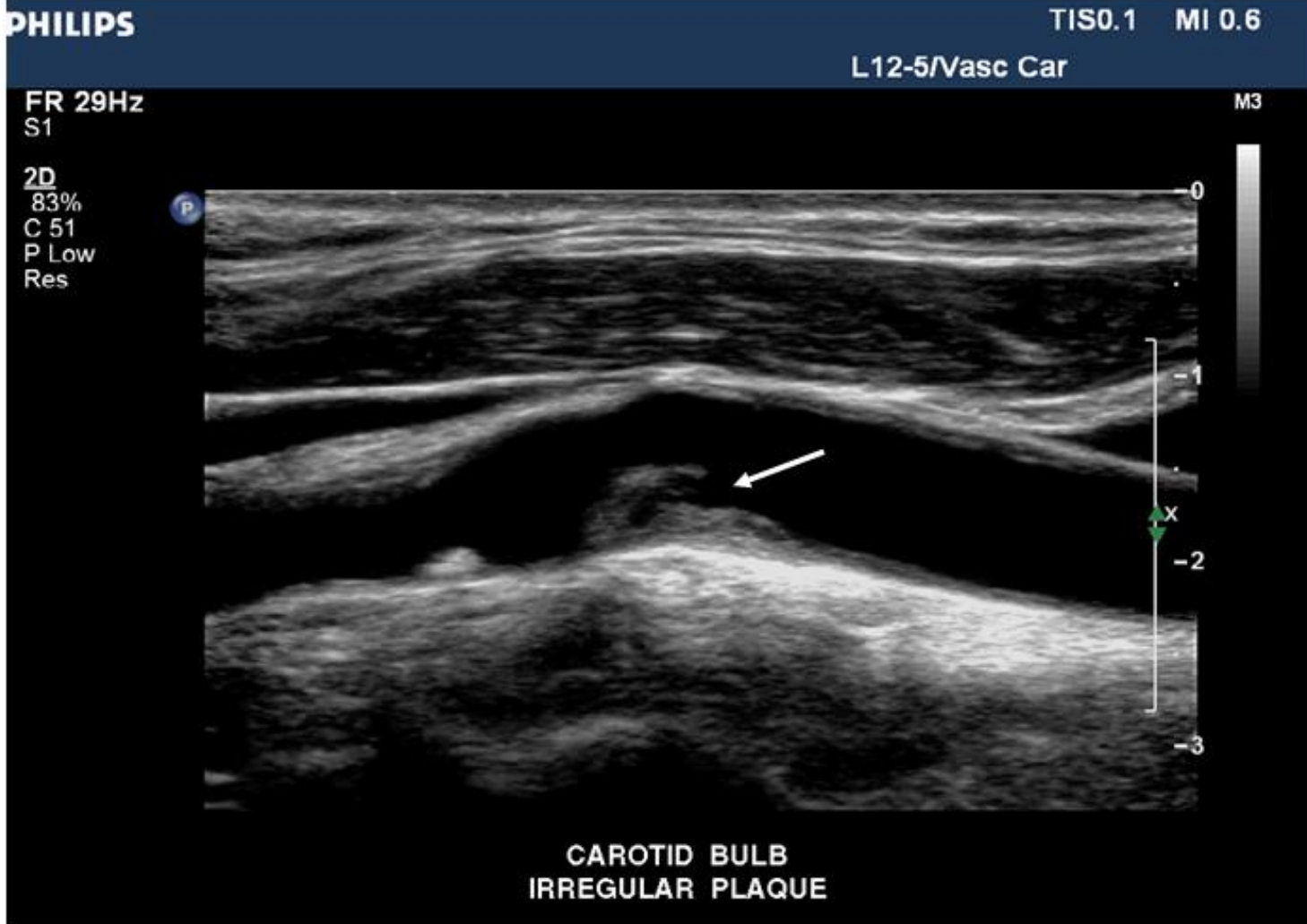
# Plaque Features

<u>Plaque Features</u>	<u>Descriptors / Parameters</u>
Location	Specific vessel segment Distribution
Surface Features	Smooth, Irregular, Crater/Ulcer/Niche
Texture / Composition	Homogeneous, Heterogeneous /mixed, Possible intraplaque hemorrhage
Echodensity	Hypechoic, Echogenic, Hyperechoic/dense, +/- shadowing
Plaque Motion	Radial (normal), longitudinal

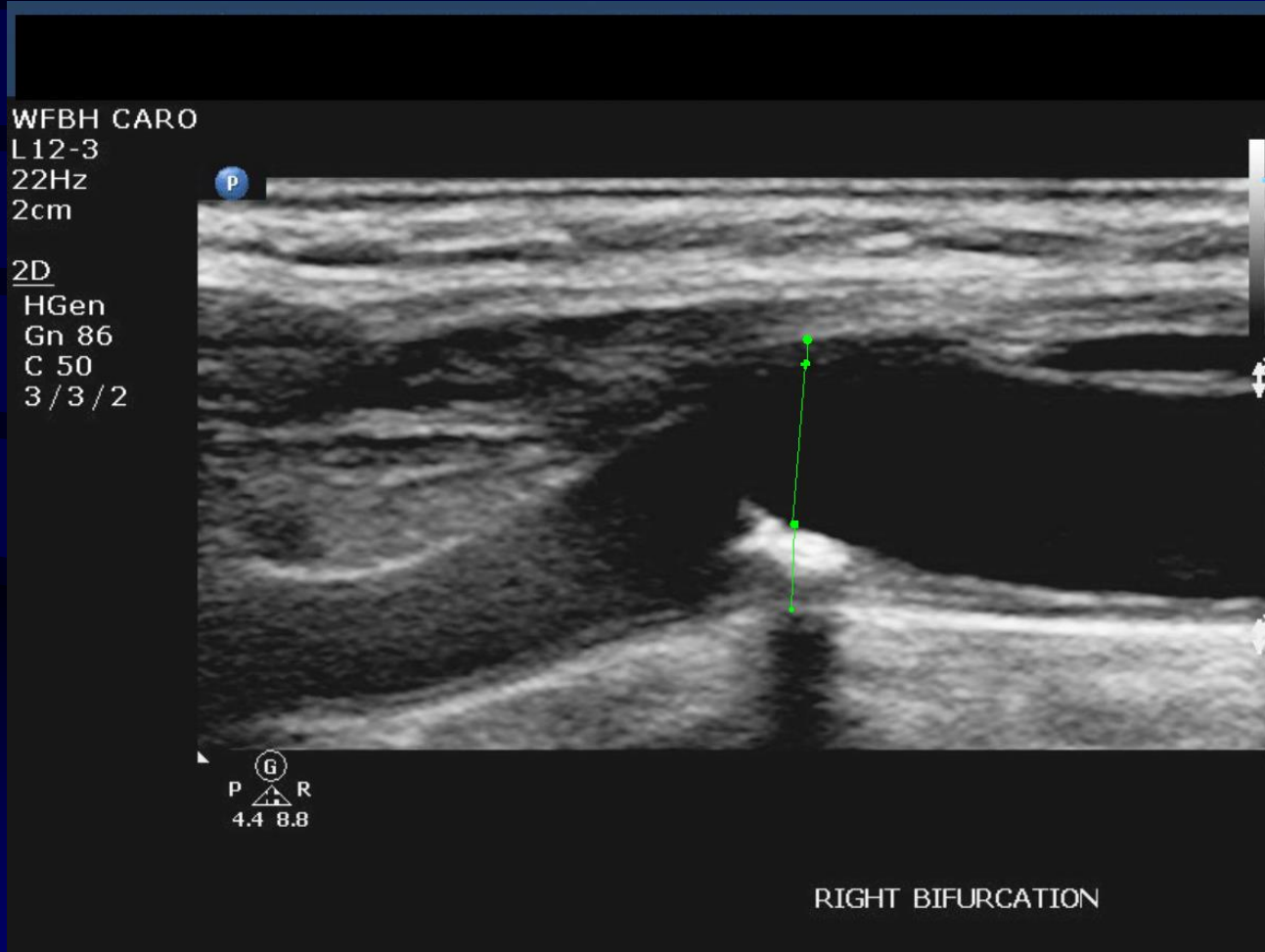
# Plaque Features: Smooth and Homogeneous



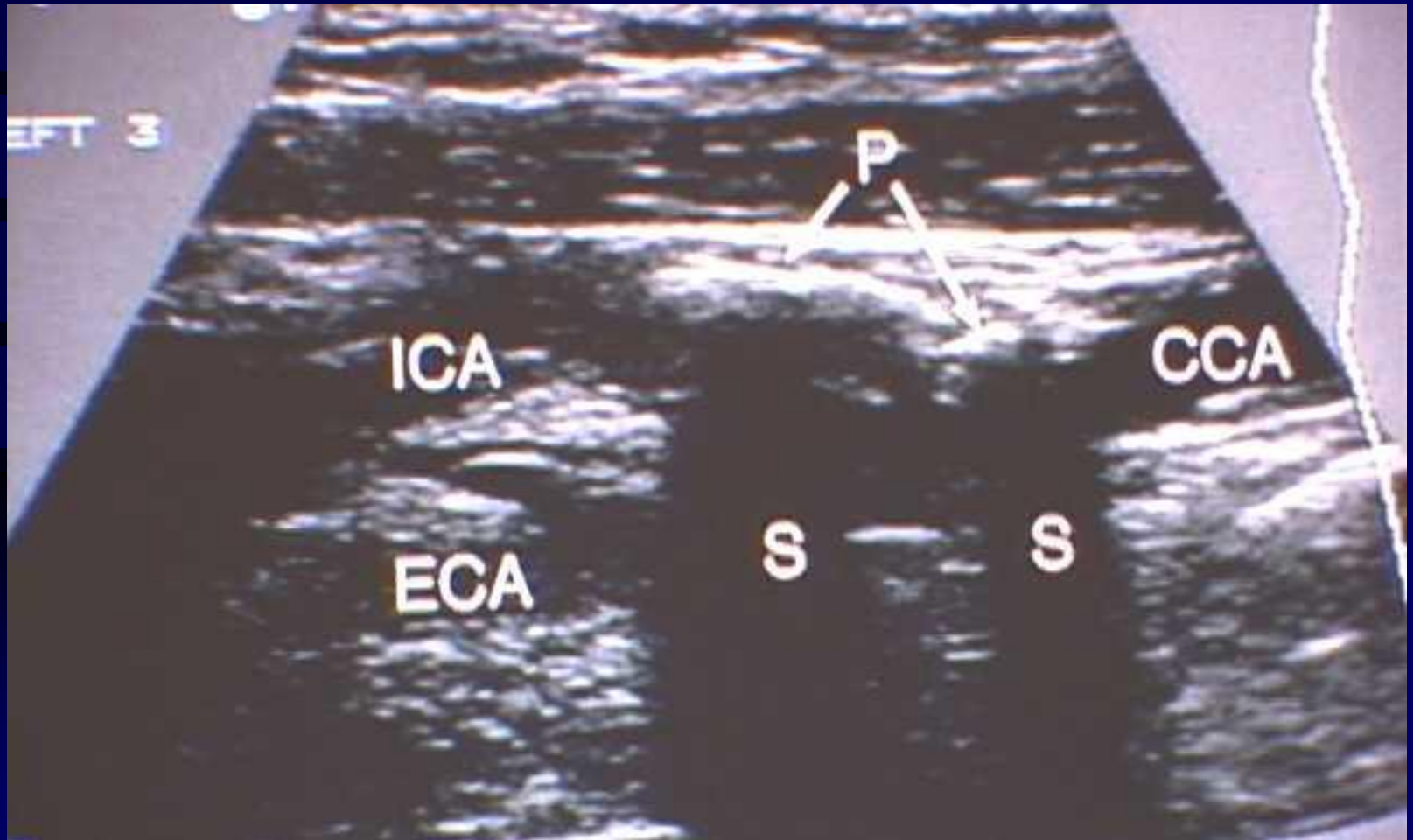
# Irregular Plaque



# Calcification/Shadowing



# Plaque Features: Calcification/Shadowing





WFU/BMC #4 062 85 30

CVIQPAUL

PHILIPS  
22 Jan 02  
10:45:27

A XDIST .146 CM

Large hypoechoic ICA plaque

LEFT

CCA

ICA

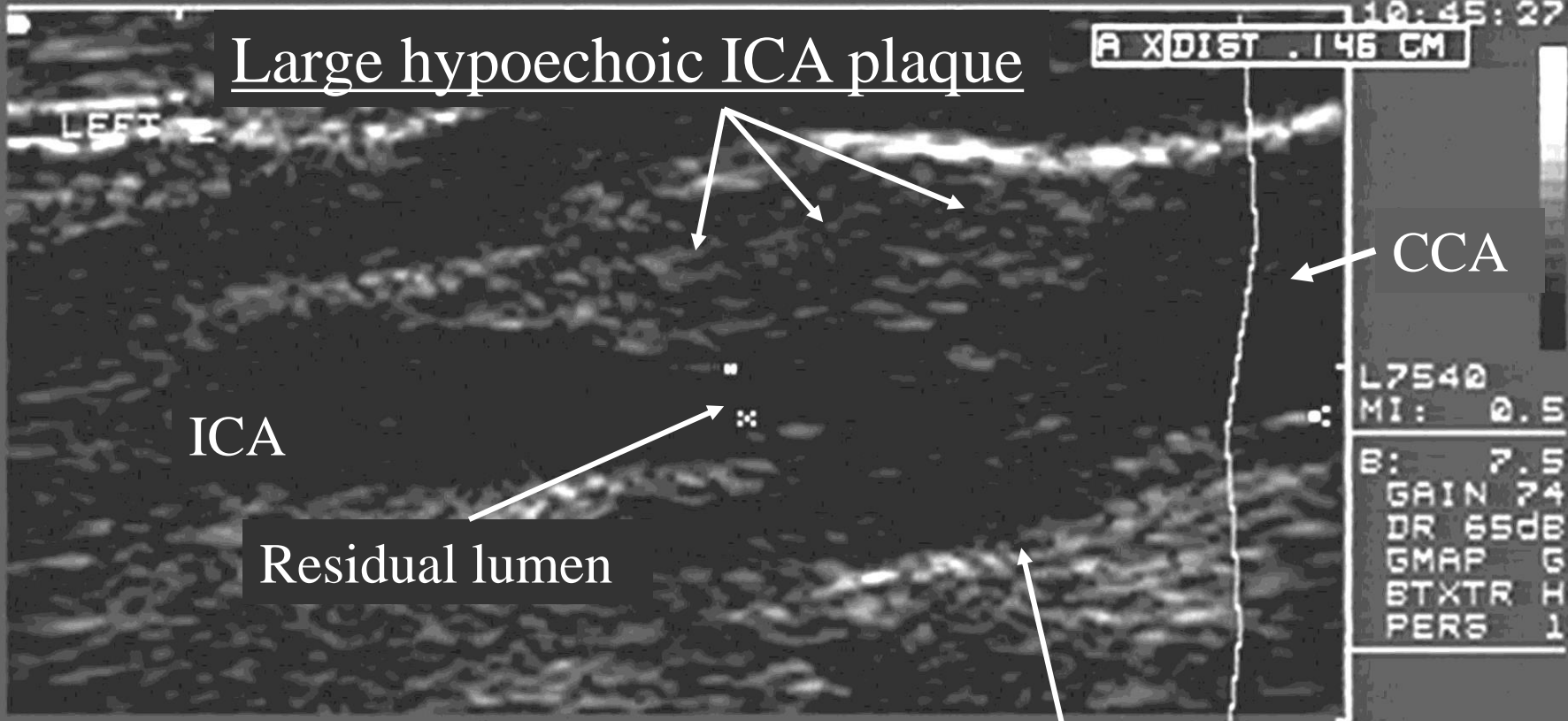
Residual lumen

BIF

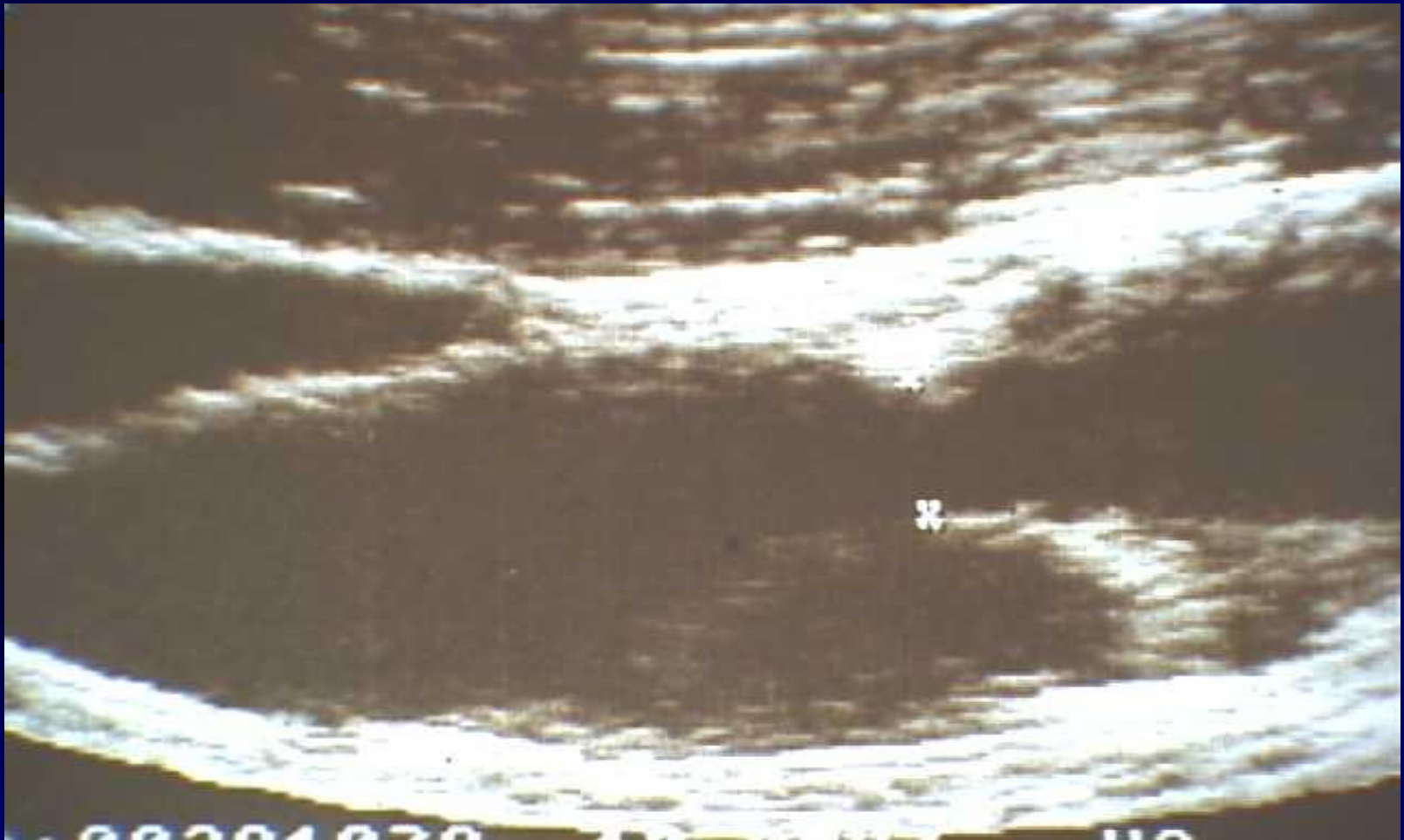
L7540
MI: 0.5
B: 7.5
GAIN 74
DR 65dB
GMAP 6
BTXTR H
PERG 1

4cm

7:02:07.10



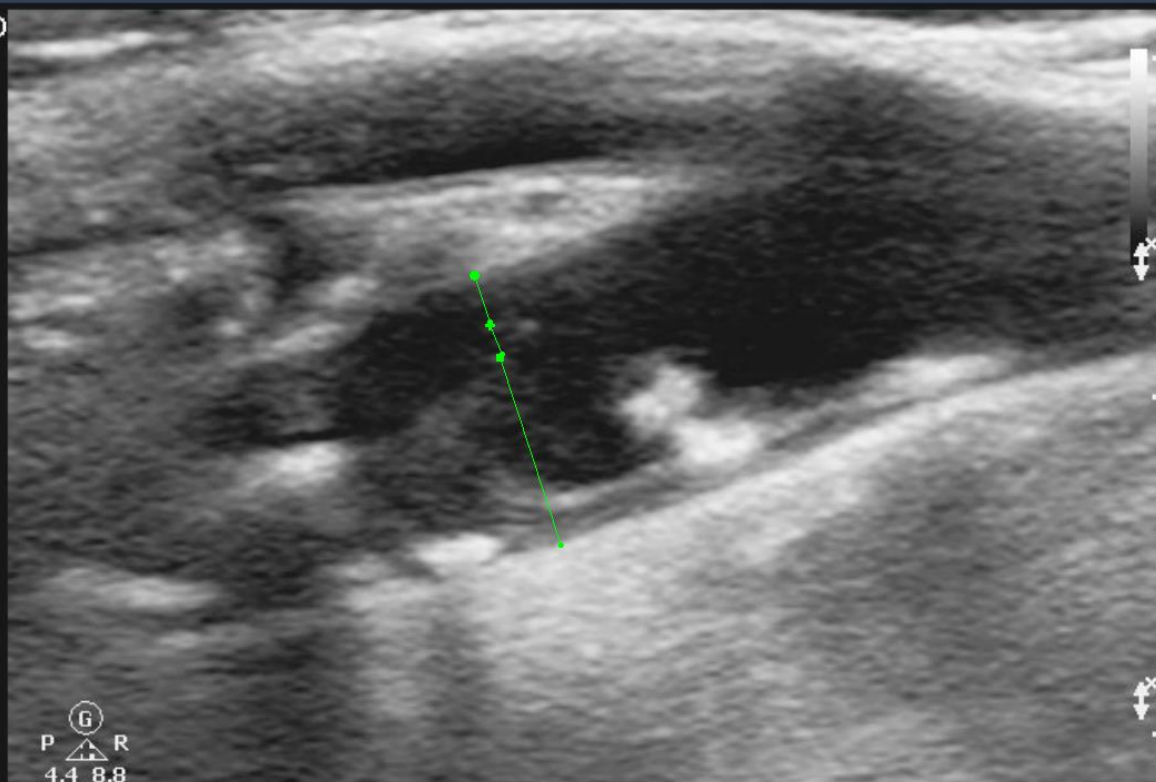
# Plaque Features: Hypoechoic region/? IPH



# Complex Plaque ICA

WFBH CARO  
L12-3  
20Hz  
4cm

2D  
HGen  
Gn 88  
C 50  
3/3/2

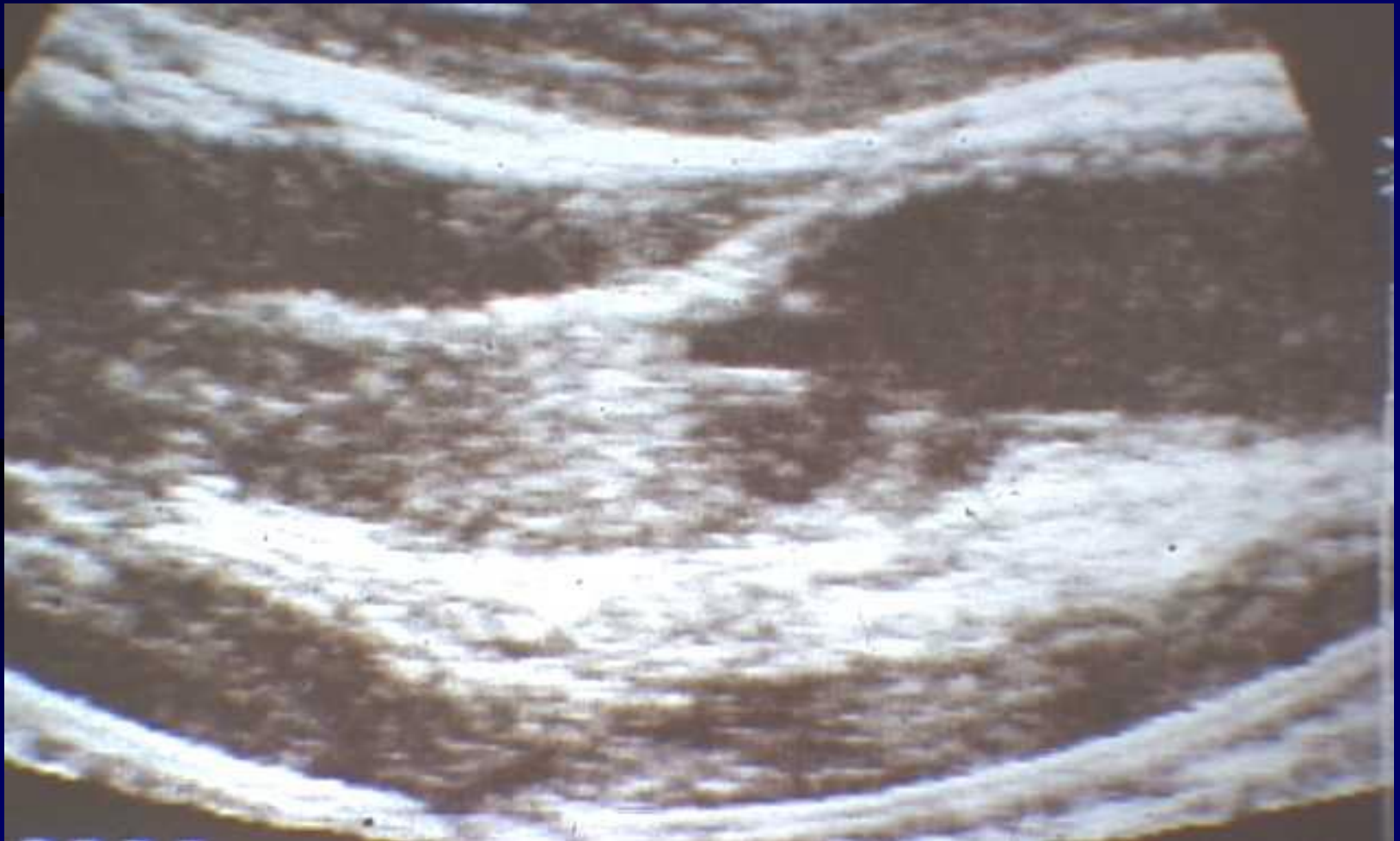


G  
P R  
4.4 8.8

LEFT ICA



# Thrombosis/Occlusion of ICA

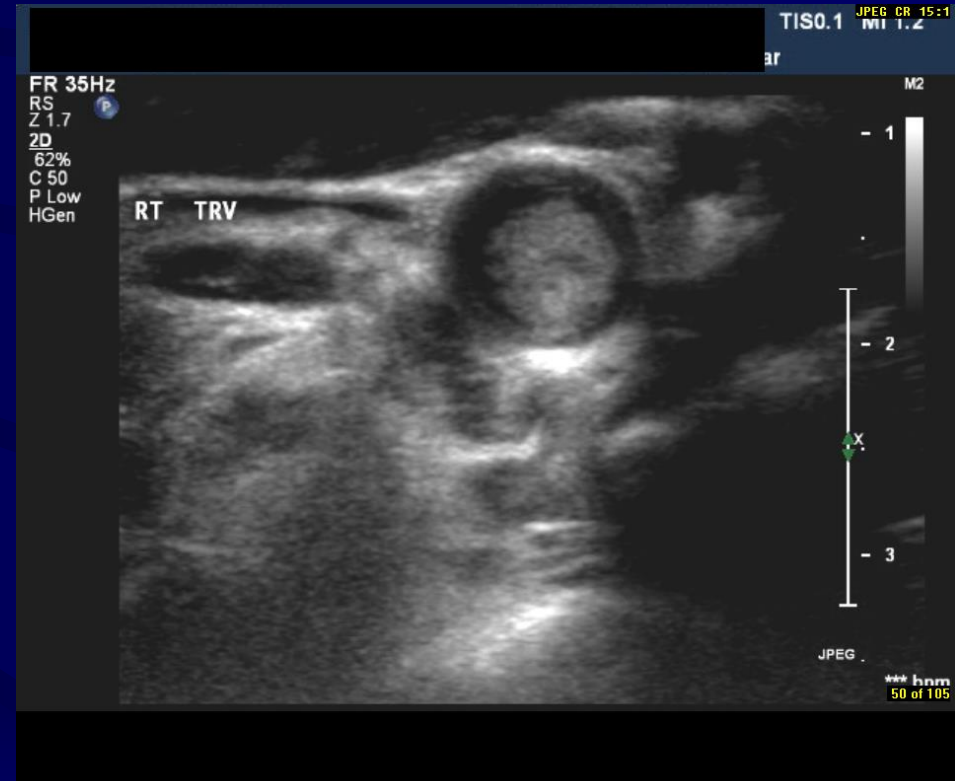


# CCA Thrombus in Acute Stroke

## Longitudinal



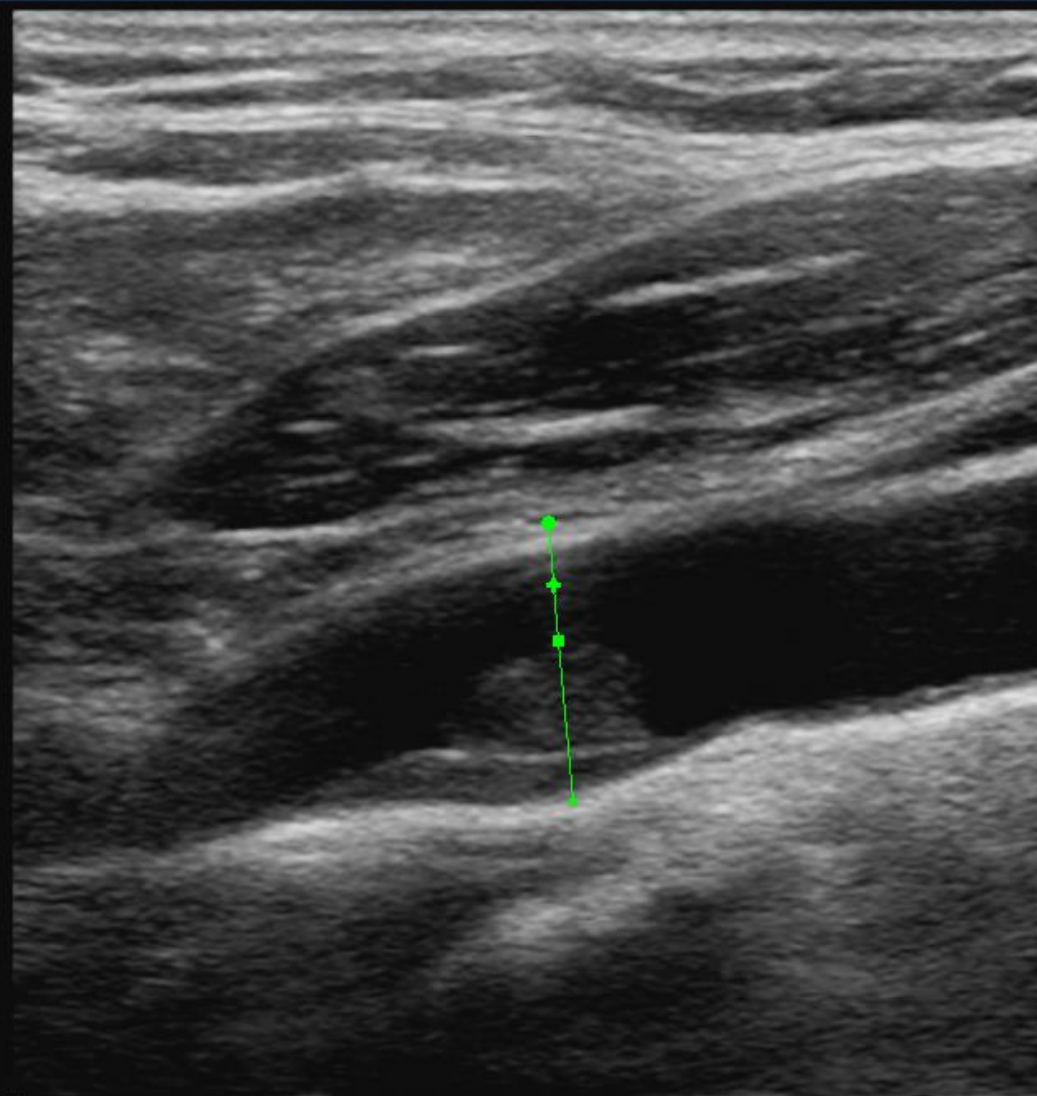
## Transverse



WFBH CARO  
L12-3  
20Hz  
4cm

P

2D  
HGen  
Gn 78  
C 50  
3 / 3 / 2



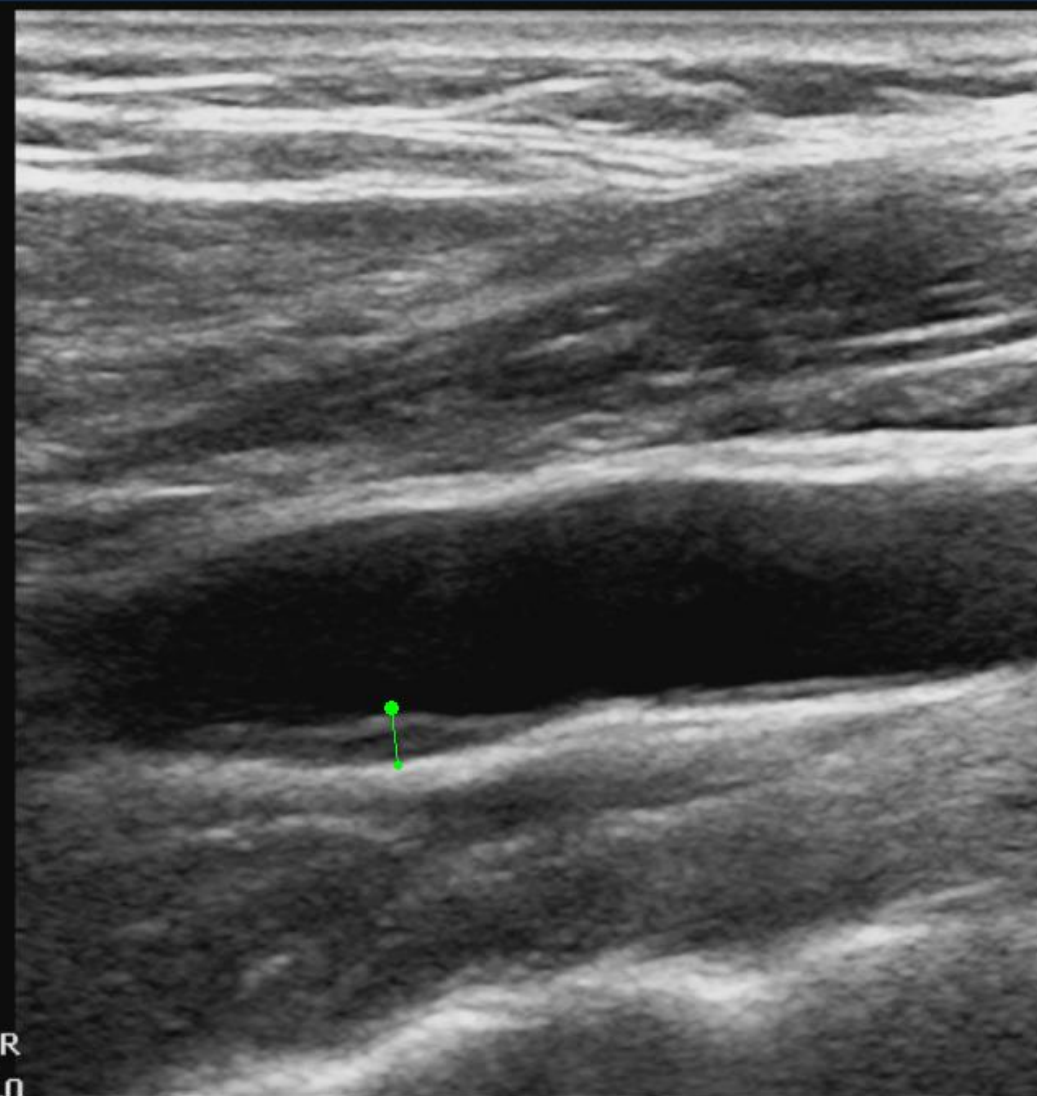
G  
P R  
4.4 8.8

RIGHT BIFURCATION

WFBH CARO  
L12-3  
29 Hz  
4.0cm

P

2D  
Gen  
Gn 88  
C 50  
3 / 3 / 3



G  
P R  
3.0 12.0



4.0cm

RIGHT ICA



# Plaque Characteristics

- Suffered from lack of standardized nomenclature and scheme
- Many suggested systems, but pathologic correlations mixed
- More emphasis on hemodynamics, color flow, technical challenges, and time

# Plaque Features

## Clinical Implications

- Lusby (%/location of hypoechoic regions predict risk)
- Johnson (depth of crater predicts risk)
- Leahy (heterogeneity predicts risk)
- NASCET (ulcer high risk in nonsurgical pt)
- Crater/ulcer less critical independent risk
- Role in stroke risk, esp in less % stenosis



# Plaque Features

## Lusby Criteria

### ULTRASOUND PLAQUE TYPES

Type I



Predominantly echolucent raised lesion, echogenic rim

Type II



Echogenic lesions with substantial areas of echolucency, especially near luminal surface (predominantly echolucent)

Type III



Dominantly echogenic lesions with small areas of echolucency deeply located

Type IV



Uniformly and densely echogenic

# Plaque Characteristics

- Unique capability of B-mode ultrasound
- Identifies burden and nature of any atherosclerosis
- Can contribute to understanding of risk, and impact management
- Takes more time and care, but well worth the effort



# CCA Intima-Media Thickness



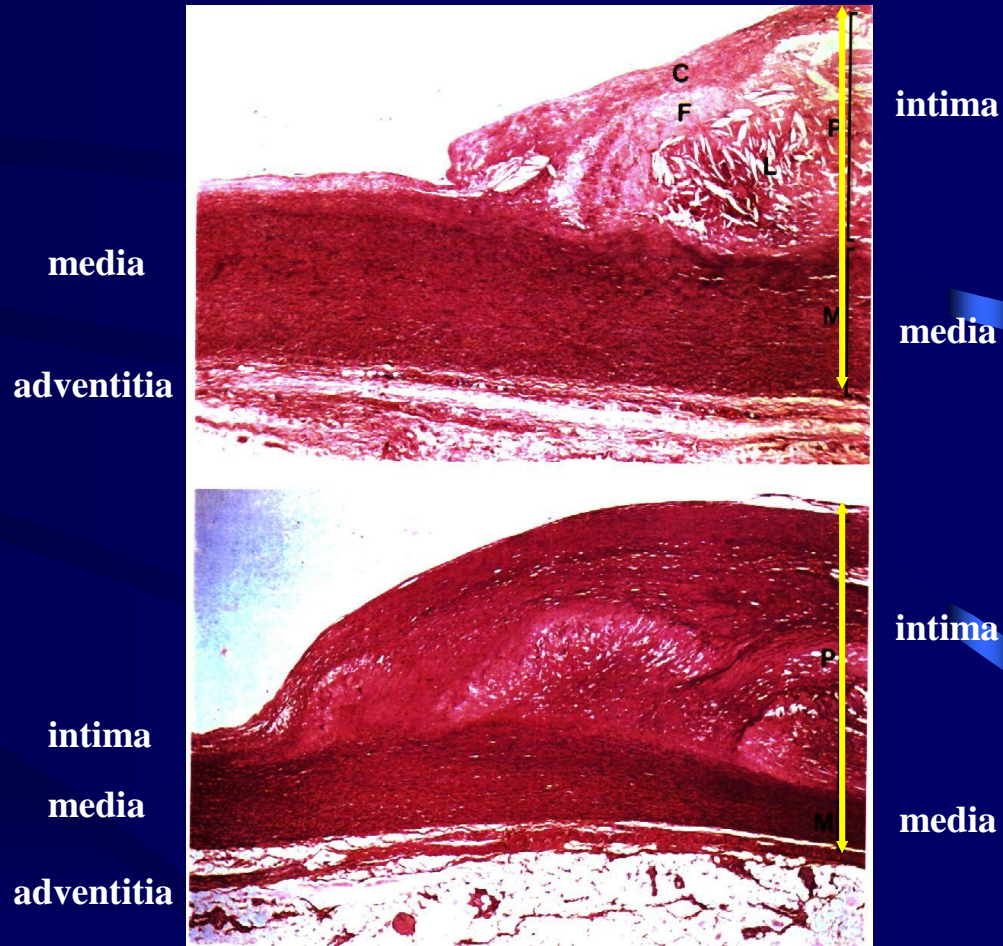
# Carotid IMT Definition

- IMT is an acronym often used to refer to the phrase “*intima-media thickness*” .
- IMT refers to the combined thickness of the intimal and medial layers of the arterial wall.
- Carotid IMT is measured from two-dimensional noninvasive B-mode ultrasound images.

# Carotid IMT Definition (Cont')

## Anatomic Basis for IMT

- **Histological slices show the intimal and medial layers of two atherosclerotic arteries with *B-mode Carotid IMT Definition* (different plaque characteristics).**
- **The maximum IMT of each wall is indicated by the vertical yellow line.**
- **This thickness includes that of both the media (M) and the plaque (P). The plaques affect both the intima and the media.**



# B-mode Appearance of Interfaces



Pulse duration

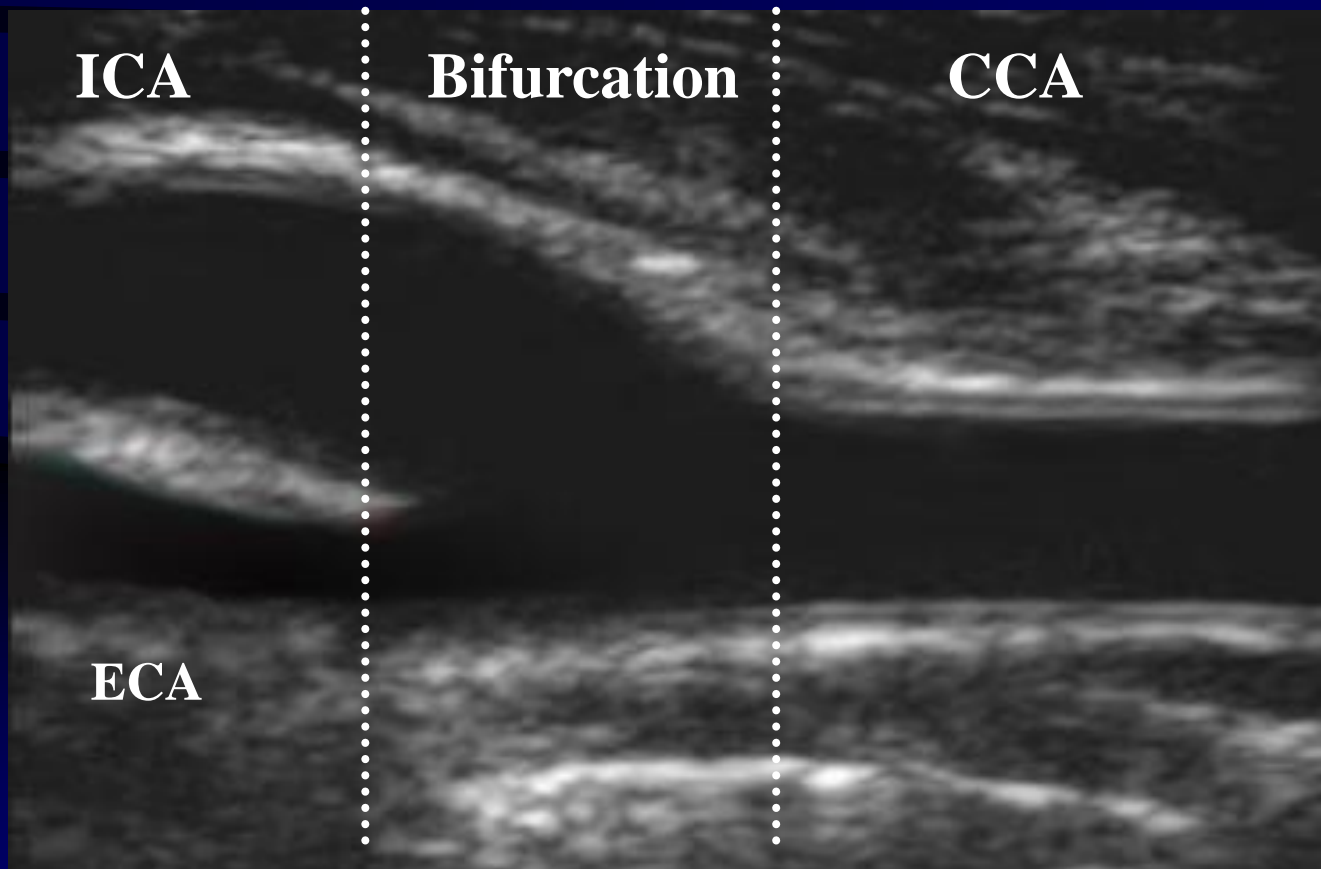
Pulse duration

# *Carotid IMT Protocols*



**Ultrasound Direction**

*Skin*



**ICA**

**Bifurcation**

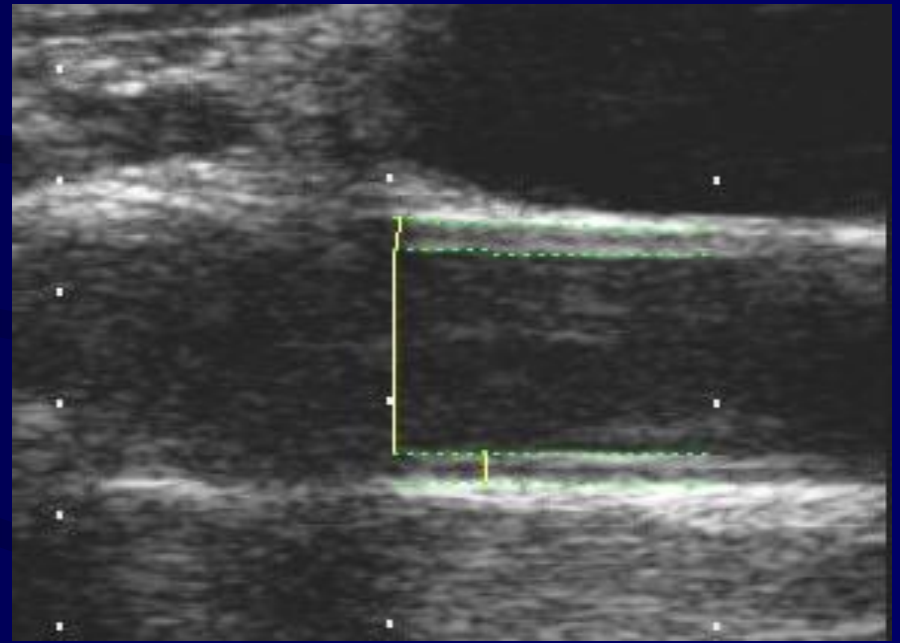
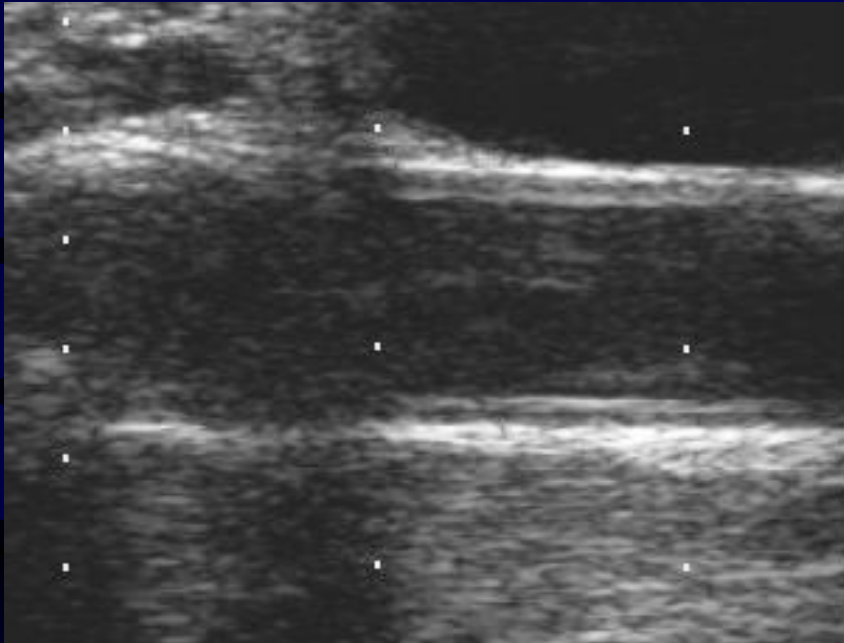
**CCA**

**ECA**

*Blood Flow Direction*

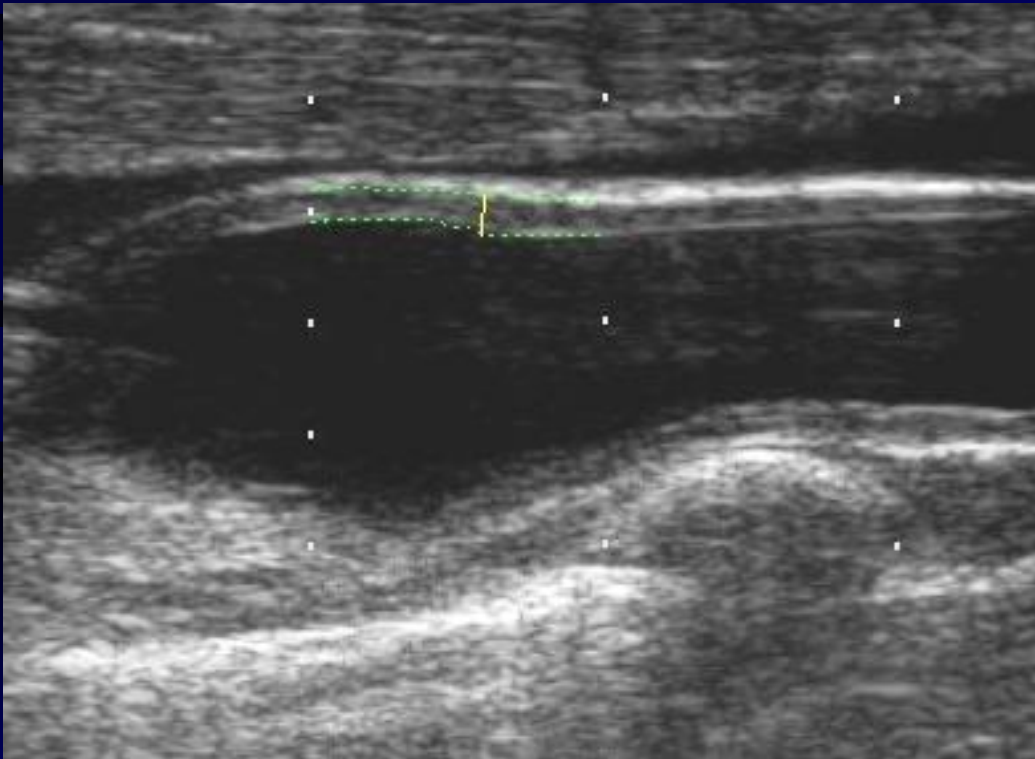


# *IMT Measurement by Automated Edge Detection IMT Software*



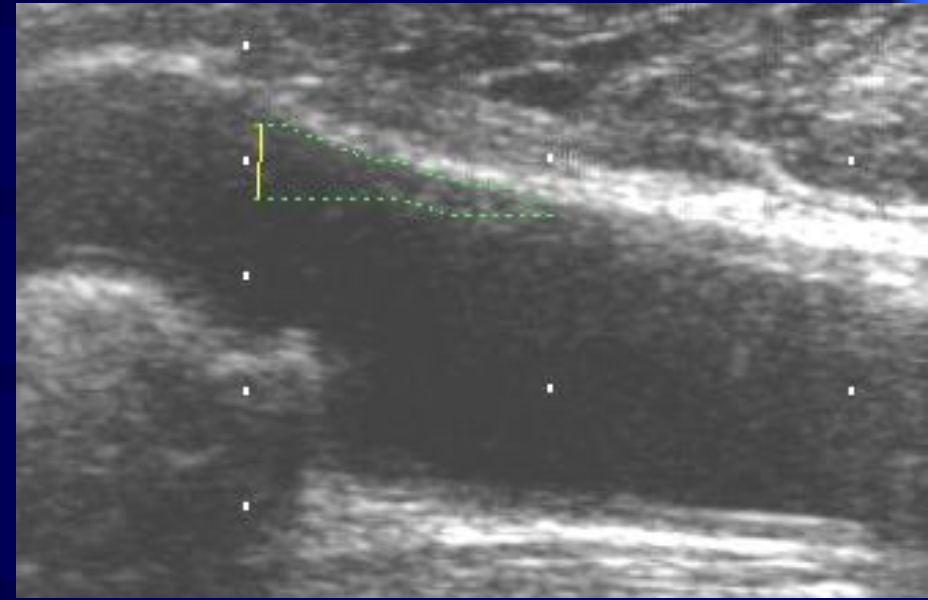
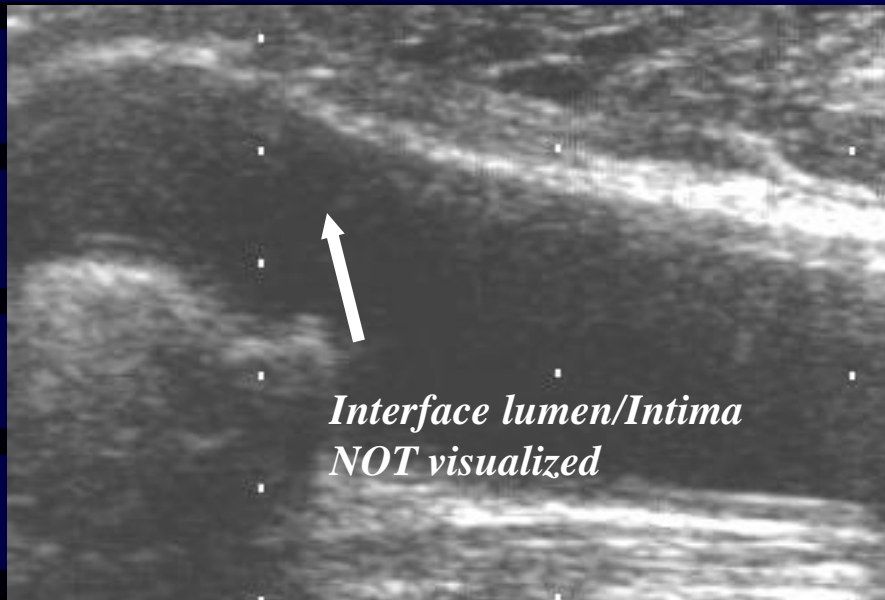
- 1. Sharp interfaces.**
- 2. Correct edge detection.**
- 3. Valid IMT measurement.**

# *IMT Measurement by Automated Edge Detection IMT Software (Cont')*



- **Sharp interfaces**
- **Artifact not present**
- **Correct edge detection**
- **Perpendicular to wall**
- **Valid IMT measurement**

# *IMT Measurement by Automated Edge Detection IMT Software (Cont')*



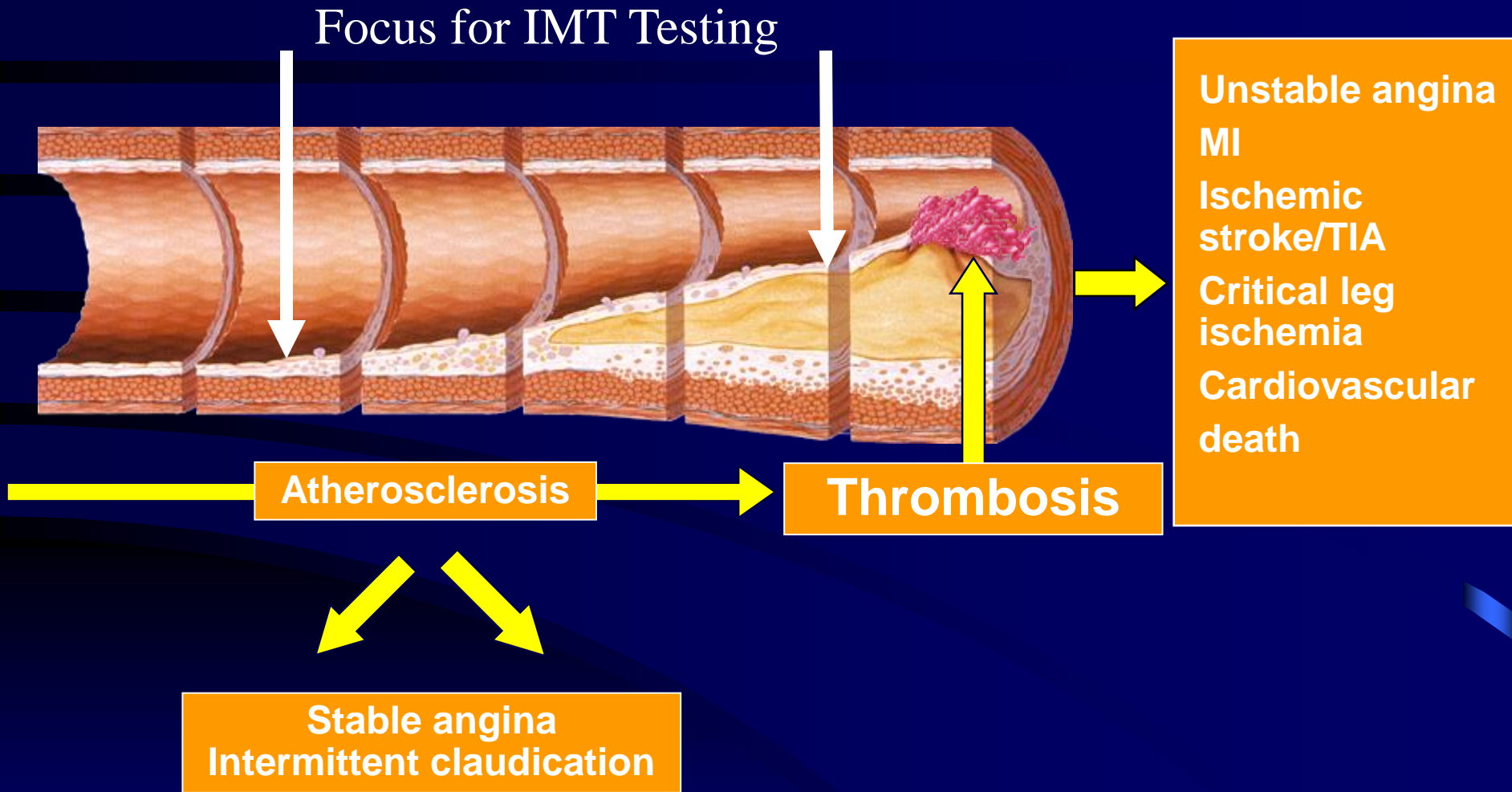
- 1. False edge detection.**
- 2. Measurement line oblique to wall.**
- 3. Invalid IMT measurement!**

**Operator editing is required for a valid IMT measurement!**



# Progression of Atherosclerosis

## Spectrum of Disease



# *Clinical Value of Carotid IMT*

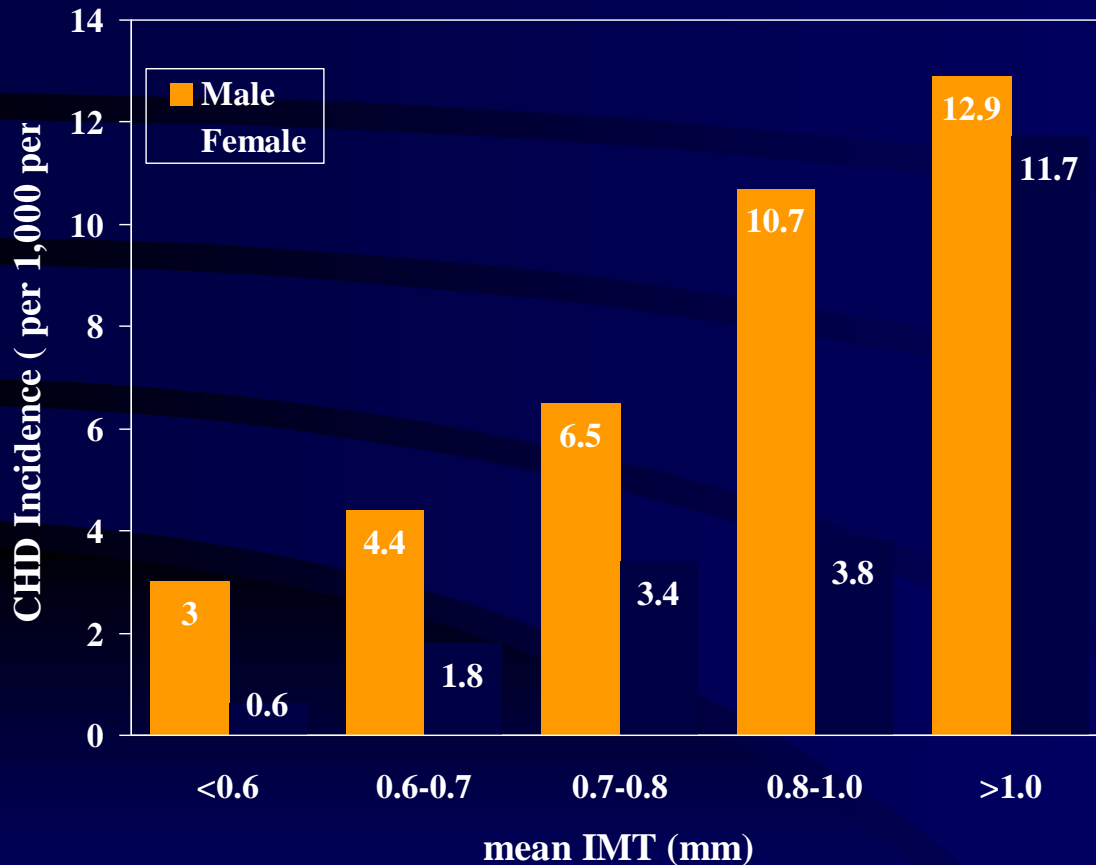
- **Prediction of risk for cardiovascular events using traditional risk factors, such as Framingham Risk Score (ATP-III risk assessment tool), is limited.**
- **Approximately 50% of cardiovascular events cannot be predicted from traditional risk factors (lipids, blood pressure, smoking, etc.).**

## *Clinical Value of Carotid IMT (Cont')*

- **Carotid IMT is an independent predictor of cardiovascular events in general populations after adjustment for traditional risk factors**
- **Observational studies have found that for an absolute carotid IMT difference of 0.1 mm, the future risk of MI increases by 10% to 15%, and the stroke risk increases by 13% to 18%**

# Absolute IMT and Risk of CHD

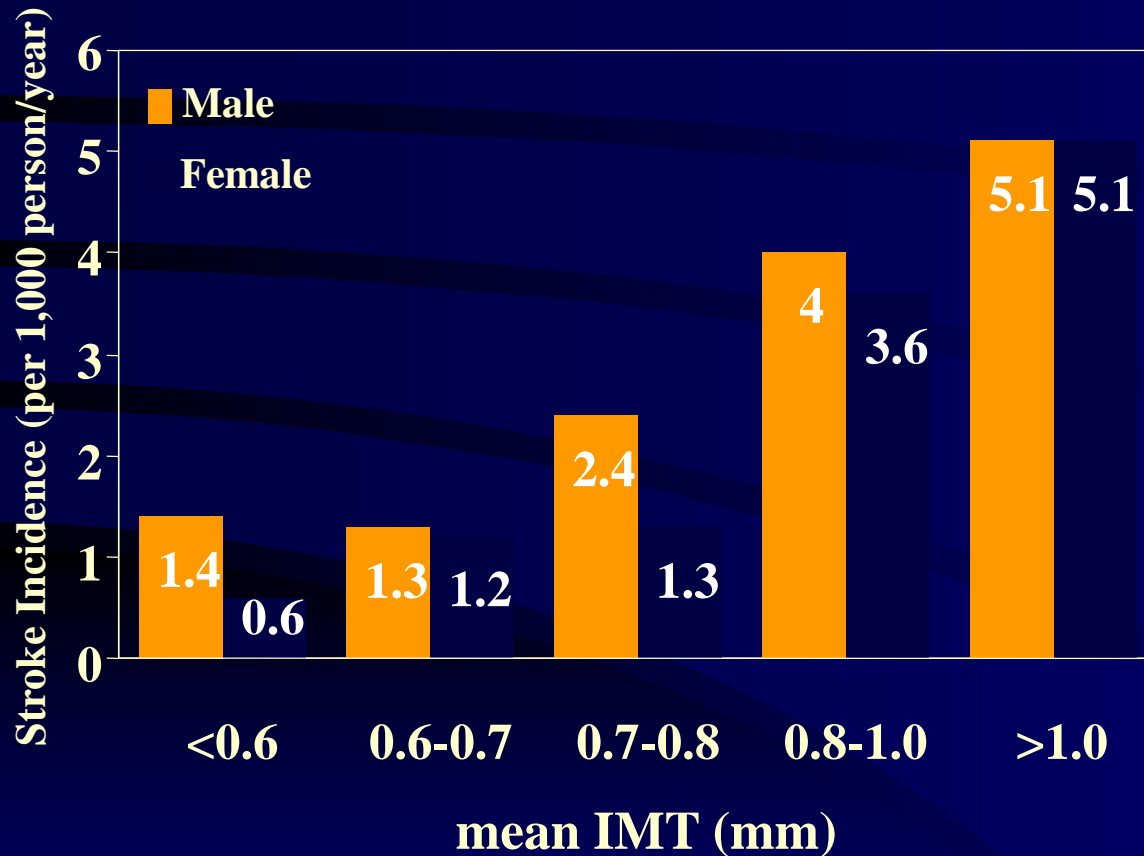
## Atherosclerosis Risk in Communities (ARIC)



- N=12,841
- Age: 45~64 years
- 'Healthy', No CVD symptom
- Follow-up: 4~7 years
- Adjusted for age, center and race

# *Absolute IMT and Risk of Stroke*

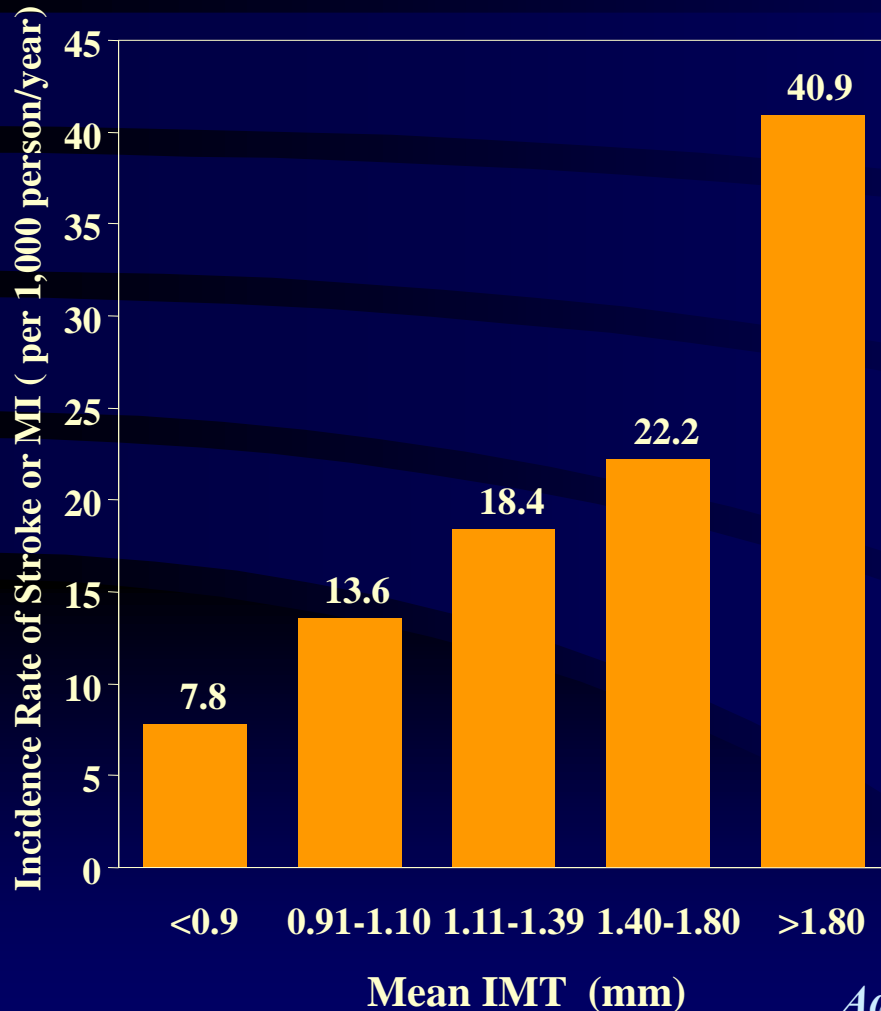
## Atherosclerosis Risk in Communities (ARIC)



- N=14,214
- Age: 45~64 years
- 'Healthy' without CVD symptom
- Followed-up: 6~9 years
- Adjusted for age, center and race

# *Absolute IMT and Risk of Stroke or MI*

## Cardiovascular Health Study (CHS)

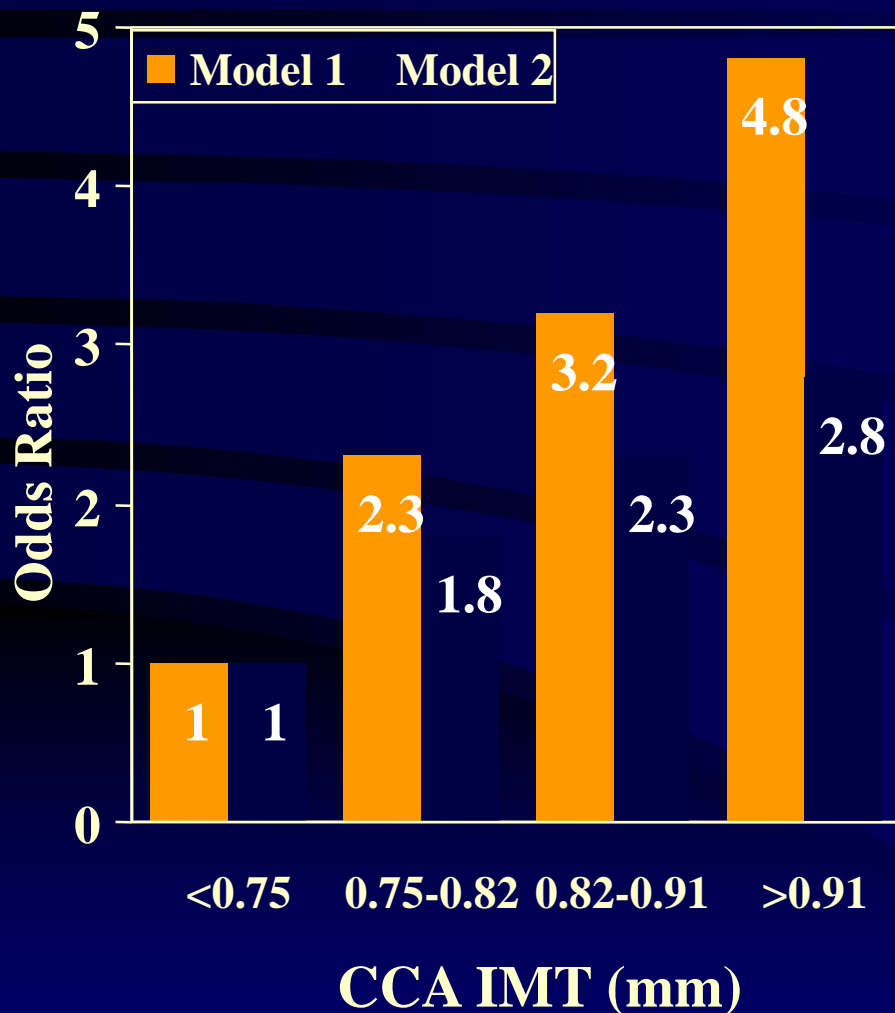


- **N=4,476**
- **Age:  $\geq 65$  years**
- **'Healthy', No CVD symptom**
- **Follow-Up: 7 years**
- **After controlling for age/sex, the odds ratio of MI or stroke was 4.5 for the highest IMT quintile as compared to the lowest quintile**
- **The possibility of stroke or MI incidence was 4% for the lowest IMT quintile, 26% for the highest quintile**
- **Compared to other risk factors, IMT was the strongest predictor of stroke or MI**

*Adapted from O'Leary DH, et al. N Engl J Med 1999;340*

# Absolute IMT and Risk for Stroke (Cont')

## The Rotterdam Study



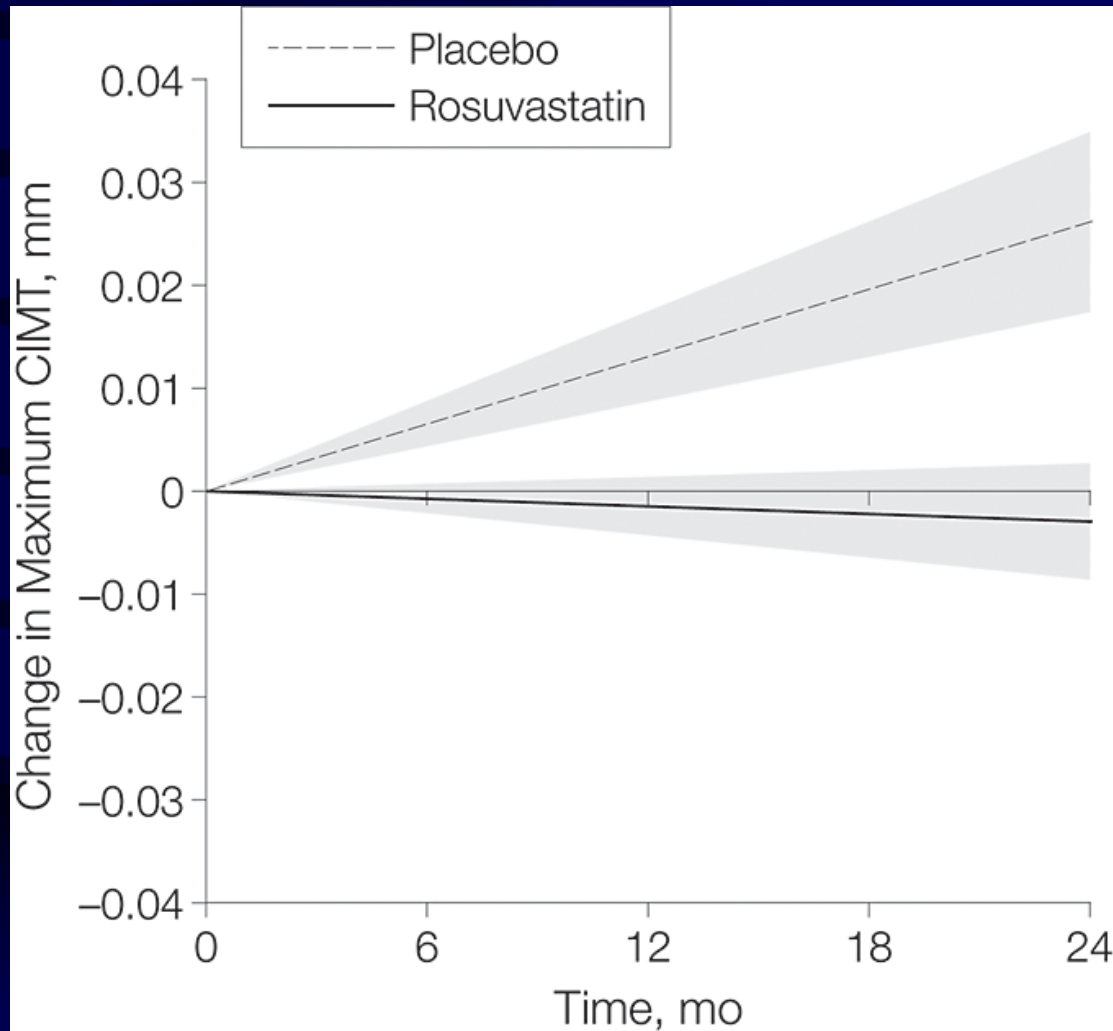
- N=1,683
- Age  $\geq$  55 years
- Model 1- adjusted for age/sex
- Model 2- adjusted for age/sex, stroke history, BMI, smoke, SBP, TPC, HDL-C, DM
- With every 0.15 mm increase in Baseline IMT, the 10 year absolute risk for stroke increased by 4.1%

# AstraZeneca Research

- METEOR International Study used CIMT to assess and measure change in the carotid artery of asymptomatic subjects with early atherosclerotic disease and at low CHD risk.
- First study to show positive benefit on atherosclerosis for people with early signs of diseased arteries.
- FDA approved expanded marketing of Crestor based on CIMT data in the METEOR Study (drug halted progression of disease)
- Data showed a 0.0014 mm/yr decrease in the mean maximum carotid intima-media thickness—a marker of atherosclerotic burden, of Crestor patients, compared to a progression of 0.0131 mm/yr for those on placebo.
- The Ward A Riley Ultrasound Center was the Core Reading Laboratory and Ultrasound Training and Quality Control/Quality Assurance Center for the United States as well as an IMT Scanning site for this important pharmaceutical trial.



# Change in Maximum Carotid Intima-Media Thickness (CIMT) for the Primary End Point



Crouse, J. R. et al. JAMA 2007;297:1344-1353.

# Carotid IMT

- Precise, computer assisted measurements of carotid wall thickness (IMT) are associated with risk factors
- IMT predicts cardiovascular risk
- Used as surrogate for atherosclerosis and clinical endpoints
- Assess IMT given age, race, gender to predict CV risk – translate to clinical realm
- Devil in the details for protocol and reading

# Ward A. Riley Ultrasound Center

## CIMT Screening Exam Report

Max CIMT: 4.401  
 Report Generated at 12:03  
 on 11JAN12

**Table 1. Far Wall IMT Measurements**

Arterial Site	Far Wall IMT		Far Wall Percentile <sup>1</sup>	
	Observed	80% Prediction Interval <sup>2</sup>	Observed	80% Prediction Interval <sup>2</sup>
Left Bifurcation	0.98 mm	(0.76,1.2)	92 %	(75,99)
Left Common	1.06 mm	(0.84,1.27)	99 %	(96,99)
Left Internal	0.69 mm	(0.52,0.86)	79 %	(41,92)
Right Bifurcation	2.04 mm	(1.36,2.71)	99 %	(98,99)
Right Common	0.84 mm	(0.73,0.95)	99 %	(89,99)
Right Internal	0.87 mm	(0.64,1.1)	87 %	(67,93)
Average	1.08 mm		93 %	

<sup>1</sup> Percentiles:

Percentiles are based on individuals of similar age, gender and ethnicity from the Atherosclerosis Risk in Communities (ARIC) Study (ref: Stroke 1993;24:1297-1304). Percentiles greater than 50 are associated with thicker IMT and greater risk. Percentiles less than 50 imply thinner IMT and lower risk.

<sup>2</sup> Prediction Intervals:

Prediction Intervals describe uncertainty in IMT measurements. If a large number of repeat examinations were performed, we would expect 4 of every 5 new measurements to fall within the interval shown for each arterial site.

Figure 1. Percentile Intervals (Star = Average Percentile)

**Risk Assessment:**

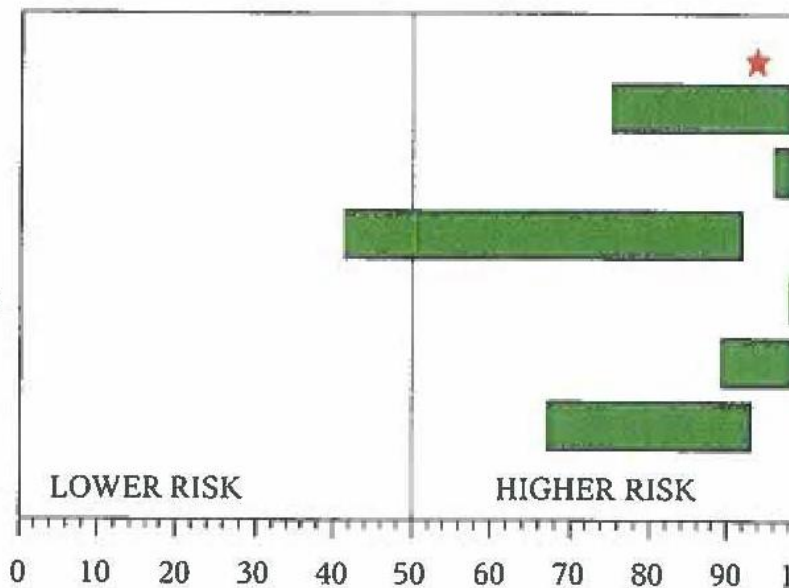
Your relative risk for CHD is 2.17, based on your average far wall percentile score and data from 4-7 years of follow-up in the ARIC Study (Am J Epi 1997;146:483-494). A relative risk of 2.17 means that you are 117% more likely to develop heart disease than other people of similar age, gender and ethnicity

Presence of plaque  $\geq 2$  mm suggests increased cardiovascular risk independent of IMT results

Plaque  $\geq 2$  mm identified?

No  Yes (see comment below)

- Left Bifurcation
- Left Common
- Left Internal
- Right Bifurcation
- Right Common
- Right Internal



**Physician Notes:**

*Large plaque was seen in the right BIF/ICA region (4.9 mm, far wall). No hemodynamically important stenosis was seen.*

Percentile

I have personally reviewed the CIMT results and agree with the interpretation.

Reviewing Physician:

*Charles H. Tegeler, M.D.*  
Charles H. Tegeler, M.D.

Date:

*1/18/12*



# Ward A. Riley Ultrasound Center

## CIMT Screening Exam Report

Max CIMT: 1.323  
 Report Generated at 11:28  
 on 03FEB12

**Table 1. Far Wall IMT Measurements**

Arterial Site	Far Wall IMT		Far Wall Percentile <sup>1</sup>	
	Observed	80% Prediction Interval <sup>2</sup>	Observed	80% Prediction Interval <sup>2</sup>
Left Bifurcation	0.71 mm	(0.56,0.87)	51 %	(21,76)
Left Common	0.53 mm	(0.45,0.6)	26 %	(8,49)
Left Internal	0.6 mm	(0.45,0.74)	57 %	(24,77)
Right Bifurcation	0.72 mm	(0.55,0.88)	49 %	(17,75)
Right Common	0.53 mm	(0.45,0.6)	25 %	(8,49)
Right Internal	0.5 mm	(0.37,0.63)	28 %	(6,53)
Average	0.6 mm		39 %	

<sup>1</sup> Percentiles:

Percentiles are based on individuals of similar age, gender and ethnicity from the Atherosclerosis Risk in Communities (ARIC) Study (ref: Stroke 1993;24:1297-1304). Percentiles greater than 50 are associated with thicker IMT and greater risk. Percentiles less than 50 imply thinner IMT and lower risk.

<sup>2</sup> Prediction Intervals:

Prediction Intervals describe uncertainty in IMT measurements. If a large number of repeat examinations were performed, we would expect 4 of every 5 new measurements to fall within the interval shown for each arterial site.

**Risk Assessment:**

Your relative risk for CHD is 0.86, based on your average far wall percentile score and data from 4-7 years of follow-up in the ARIC Study (Am J Epi 1997:146:483-494). A relative risk of 0.86 means that you are 14% less likely to develop heart disease than other people of similar age, gender and ethnicity

Presence of plaque  $\geq 2$  mm suggests increased cardiovascular risk independent of IMT results

Plaque  $\geq 2$  mm identified?

No    Yes (see comment below)

**Physician Notes:**

I have personally reviewed the CIMT results and agree with the interpretation.

Reviewing Physician: \_\_\_\_\_

*C. Tegeler*  
Charles H. Tegeler, M.D.

Date: \_\_\_\_\_

*2/8/12*

Figure 1. Percentile Intervals (Star = Average Percentile)

