# Novità emergenti dalla valutazione ultrasonica dei grossi vasi arteriosi nel paziente iperteso


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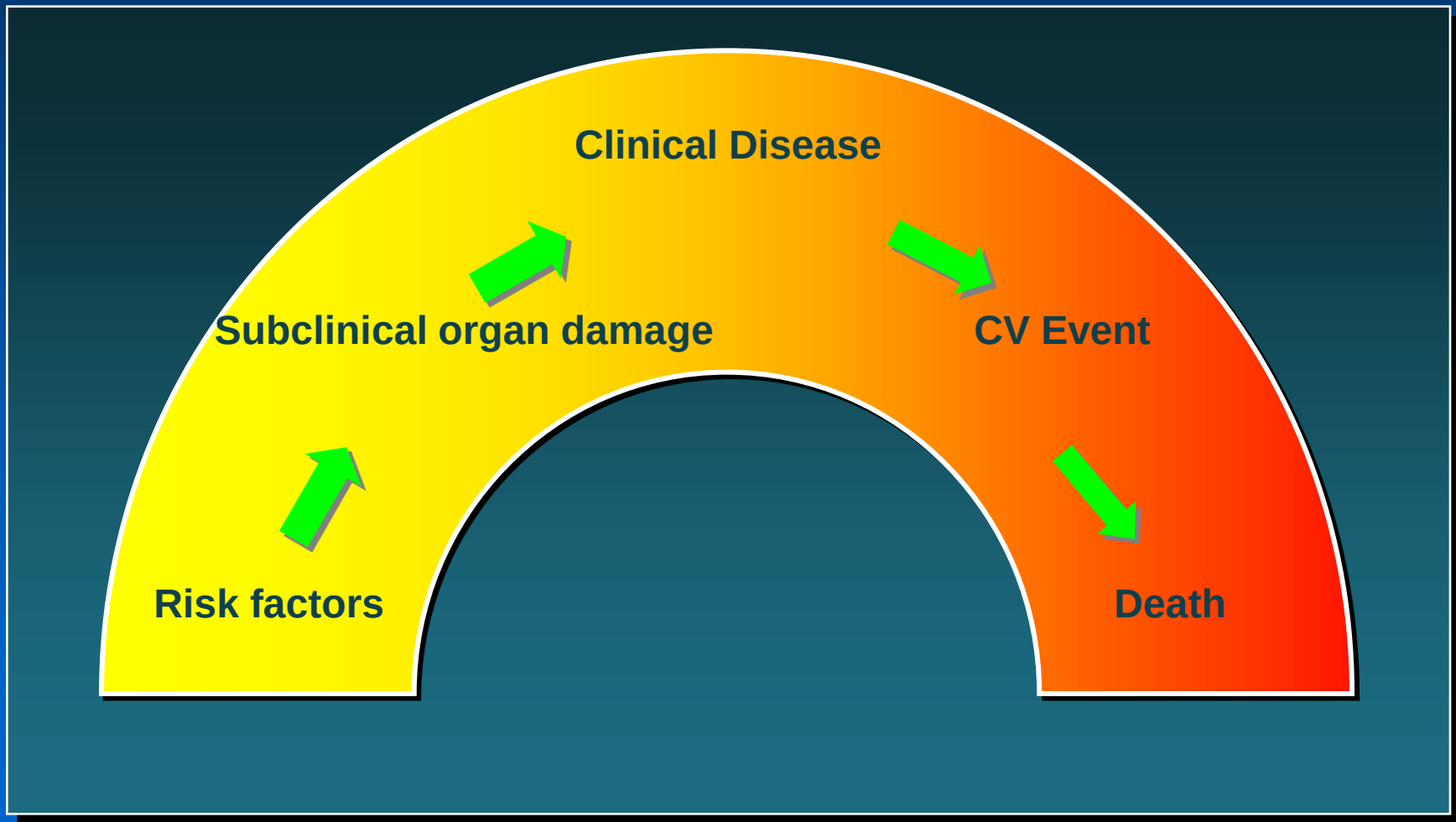
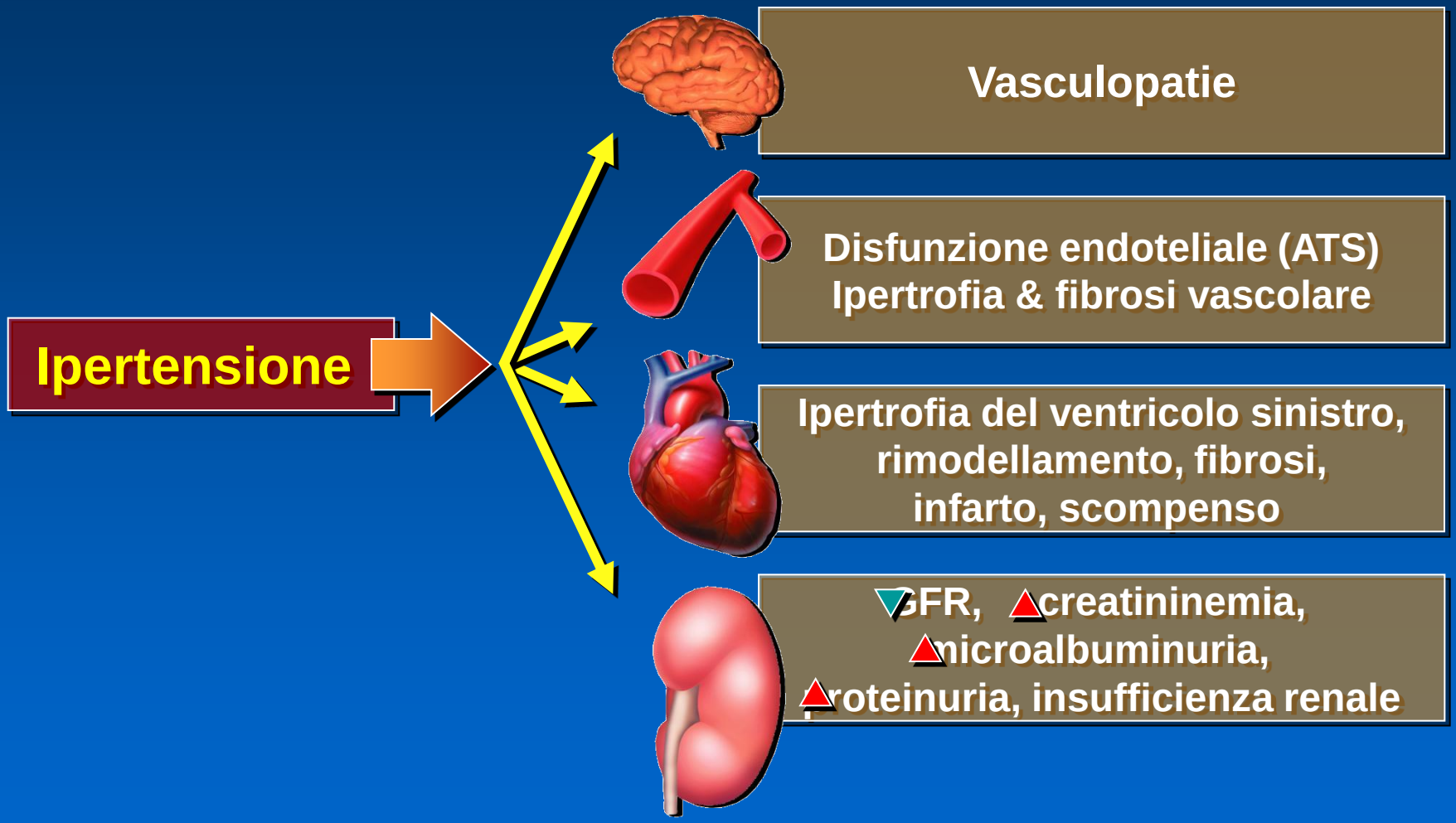
# The Cardiovascular Continuum



# Danno d'organo ed eventi clinici nell'ipertensione

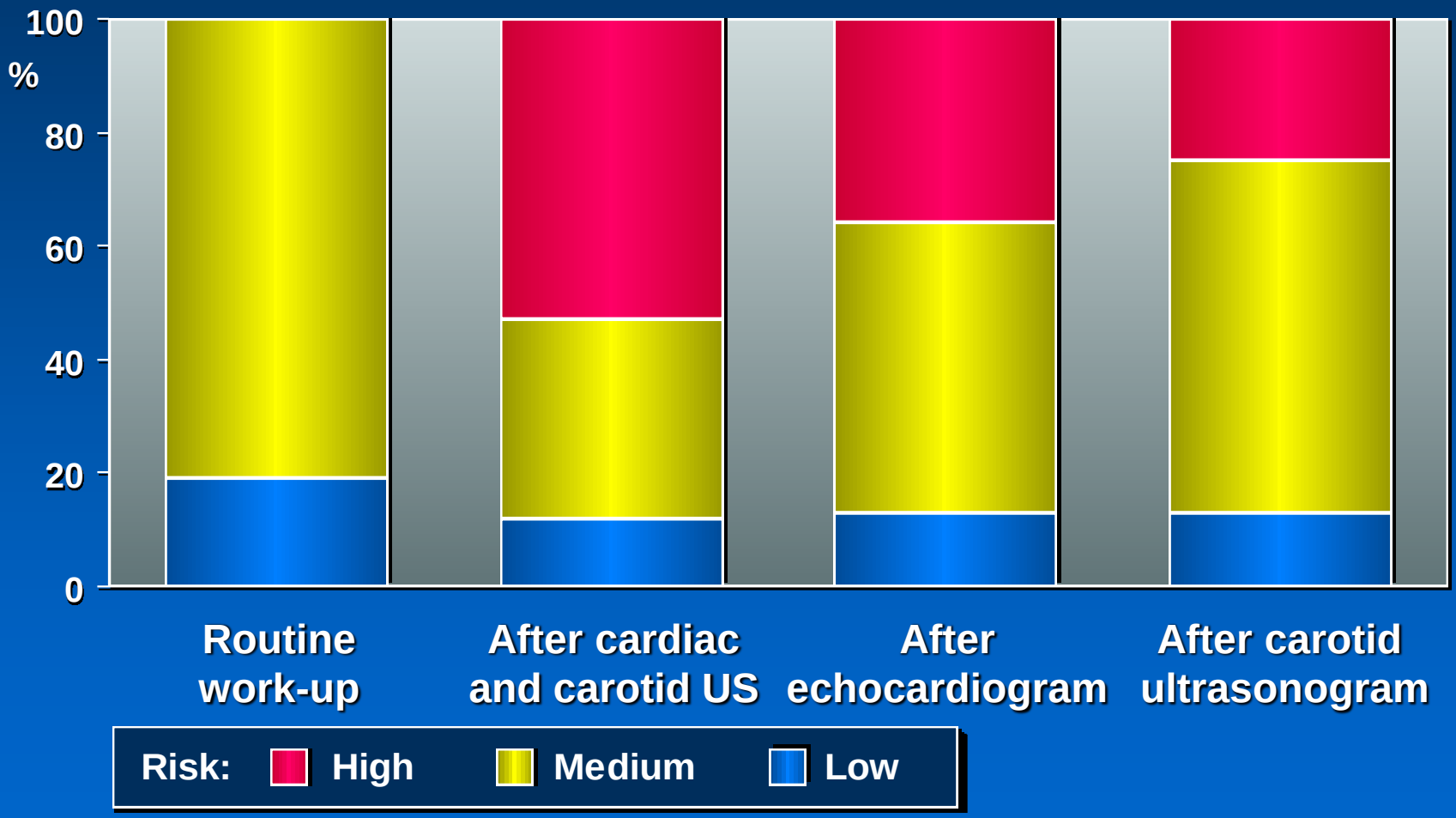


# ESH/ESC Guidelines and Search for Subclinical Organ Damage (OD)

| | Routine | Recommended |
|---|---|---|
| 2007 GLs | SCr<br>eGFR<br>Urinary protein excretion<br>EKG † | Echocardio #<br>Carotid ultrasonography °<br>Ankle/Brachial ratio<br>PWV * |

† LVH / MI / ischemia / arrhythmias etc
* Arterial stiffness
° Thickening / plaques
# LVH / concentric LVH / LA enlargement / diastolic dysfunction / systolic dysfunction etc

# Stratification of 1074 Patients by Global Level of Cardiovascular Risk after the Routine Work-Up and After Assessment of Target-Organ Damage by Echocardiography and Carotid Ultrasonography




*APROS Study, J Hypertens 2002*

# Ispessimento/placche carotidee, rigidità arteriosa e rischio CV

- L'incidenza a 10 anni degli eventi CV maggiori è stata superiore al 20% quando l'eco (carotide comune più biforcazione) dimostrava ispessimenti nei quintili più alti, verso un rischio inferiore al 10% per i quintili più bassi.

- Nello studio Copenhagen Country un aumento della Pulse Wave Velocity >12 m/s si è associato ad un aumento del 50% nel rischio di eventi Cv.

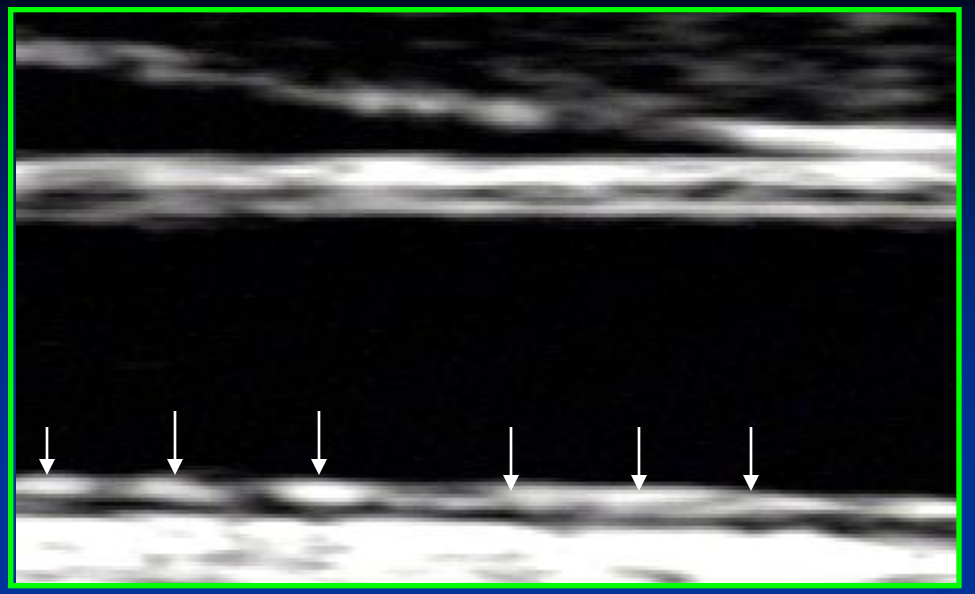
Circulation 2009; 120:1084–1090.
N Engl J Med 1999; 340:14–22.

*ESH Task Force, J Hypertens 2009*

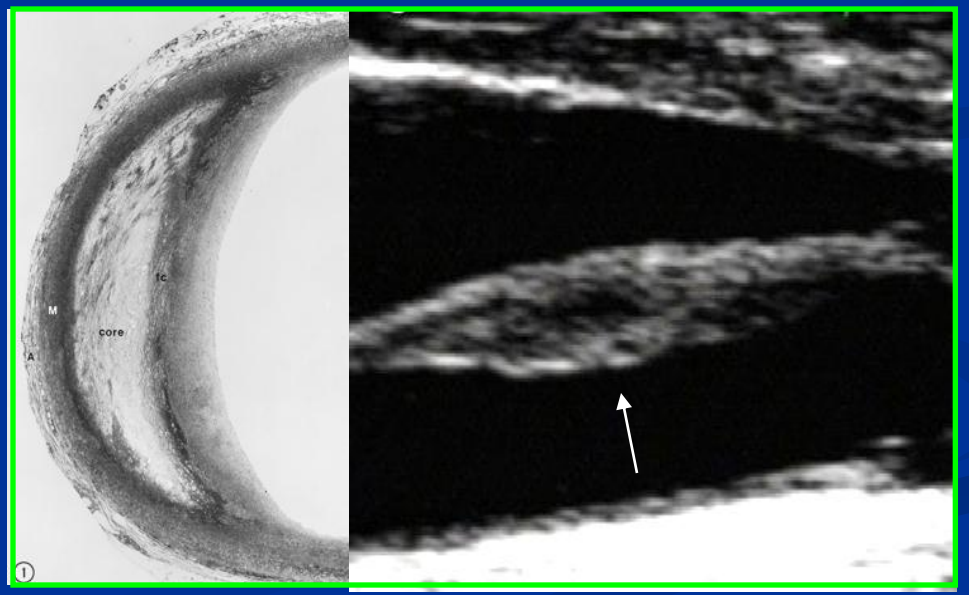
# IMT : what is it ?

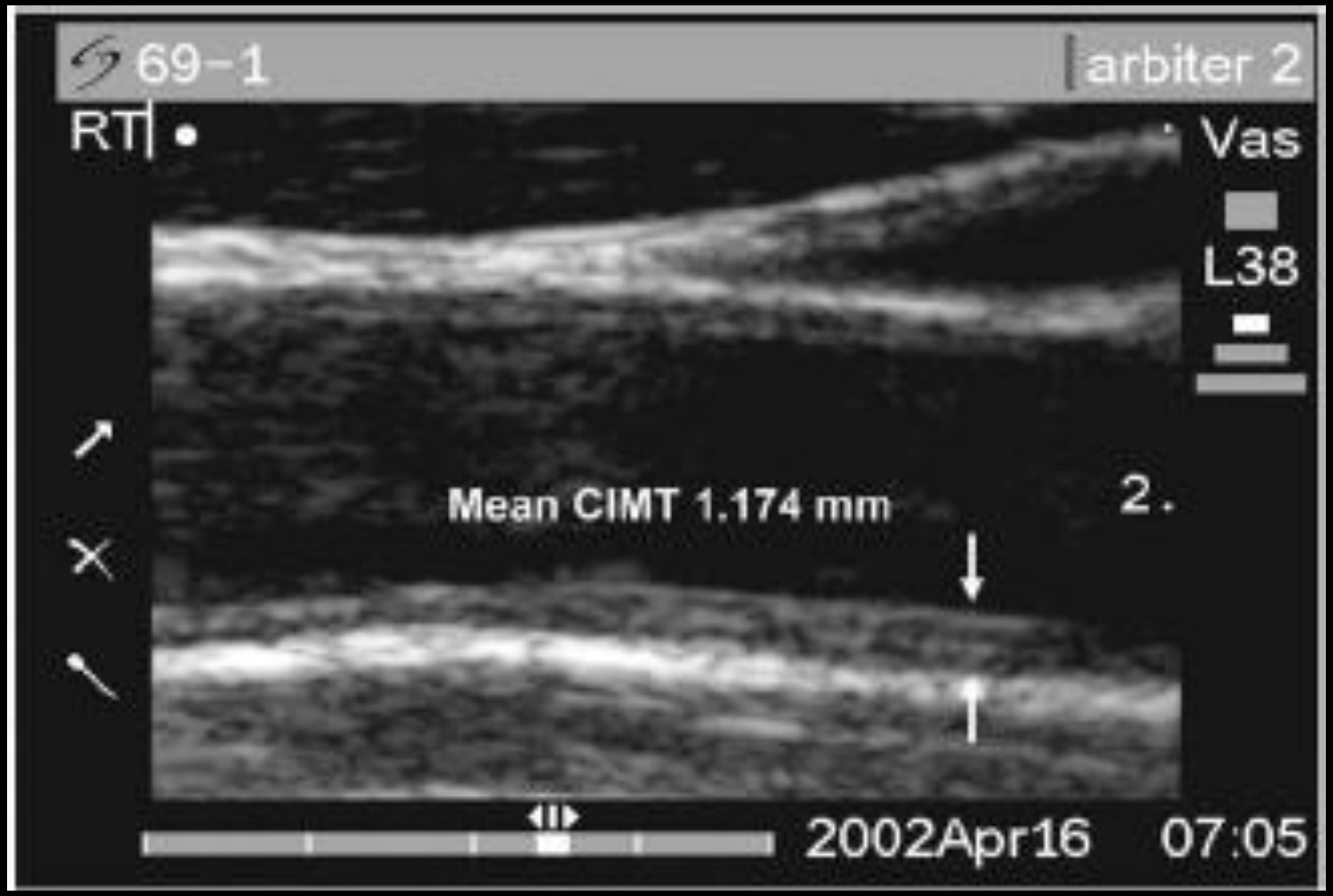
- It is an early marker of atherosclerosis

# IMT



# Placca



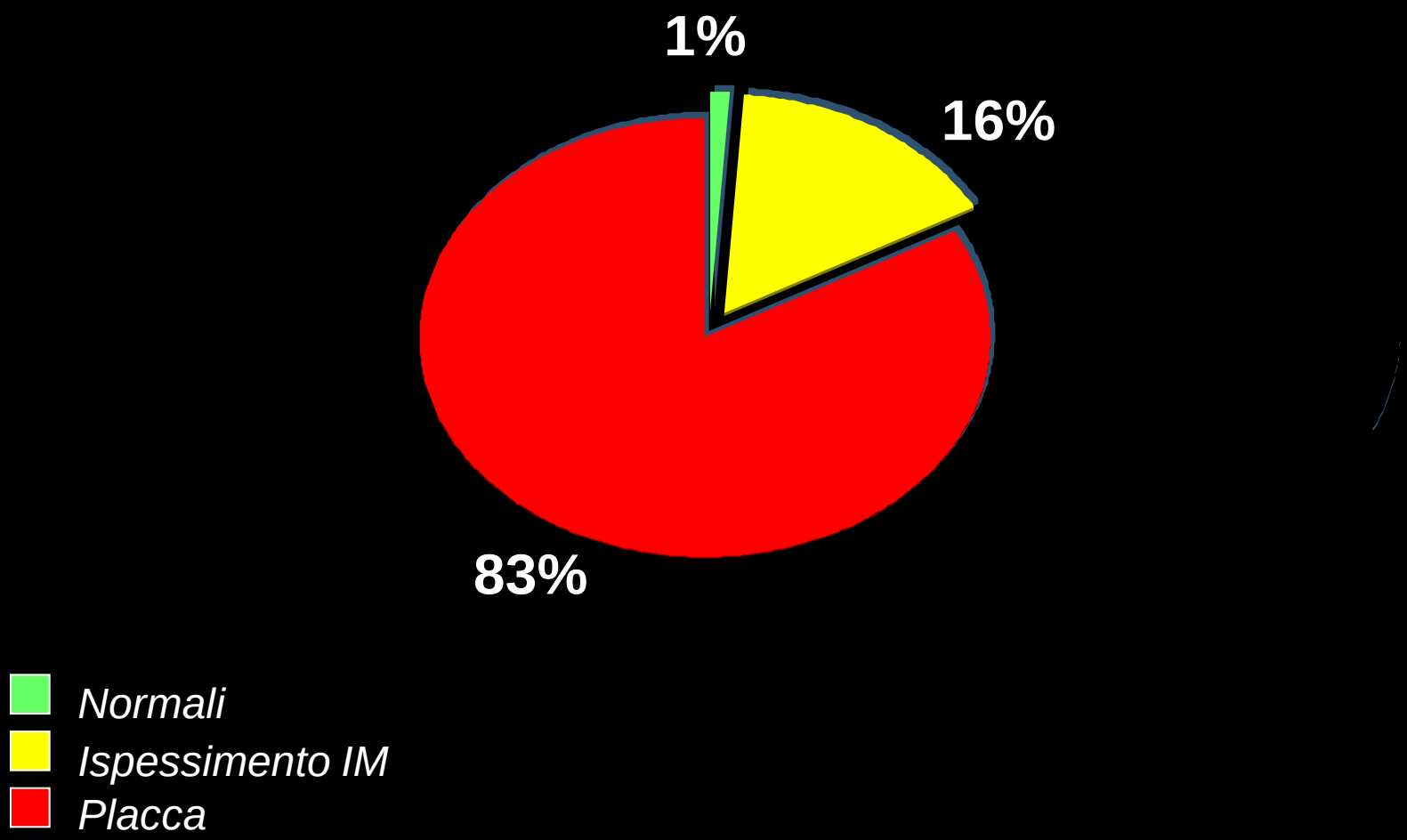

69-1
arbiter 2
RT
Vas
L38
Mean CIMT 1.174 mm
2.
2002Apr16
07:05

# IMT: Associated factors

- Age and sex
- Hypertension
- Lipids
- Diabetes
- Genetics
- Haemostatic parameters
- Cigarette smoking / Alcohol
- Obesity / Physical inactivity
- Others

# Prevalenza delle lesioni aterosclerotiche nei pazienti ipertesi negli studi ELSA

**ELSA**



# IMT : what is it ?

- It is an early marker of atherosclerosis
- It is an independent predictor of vascular disease

American Heart Association.

Fighting Heart Disease and Stroke

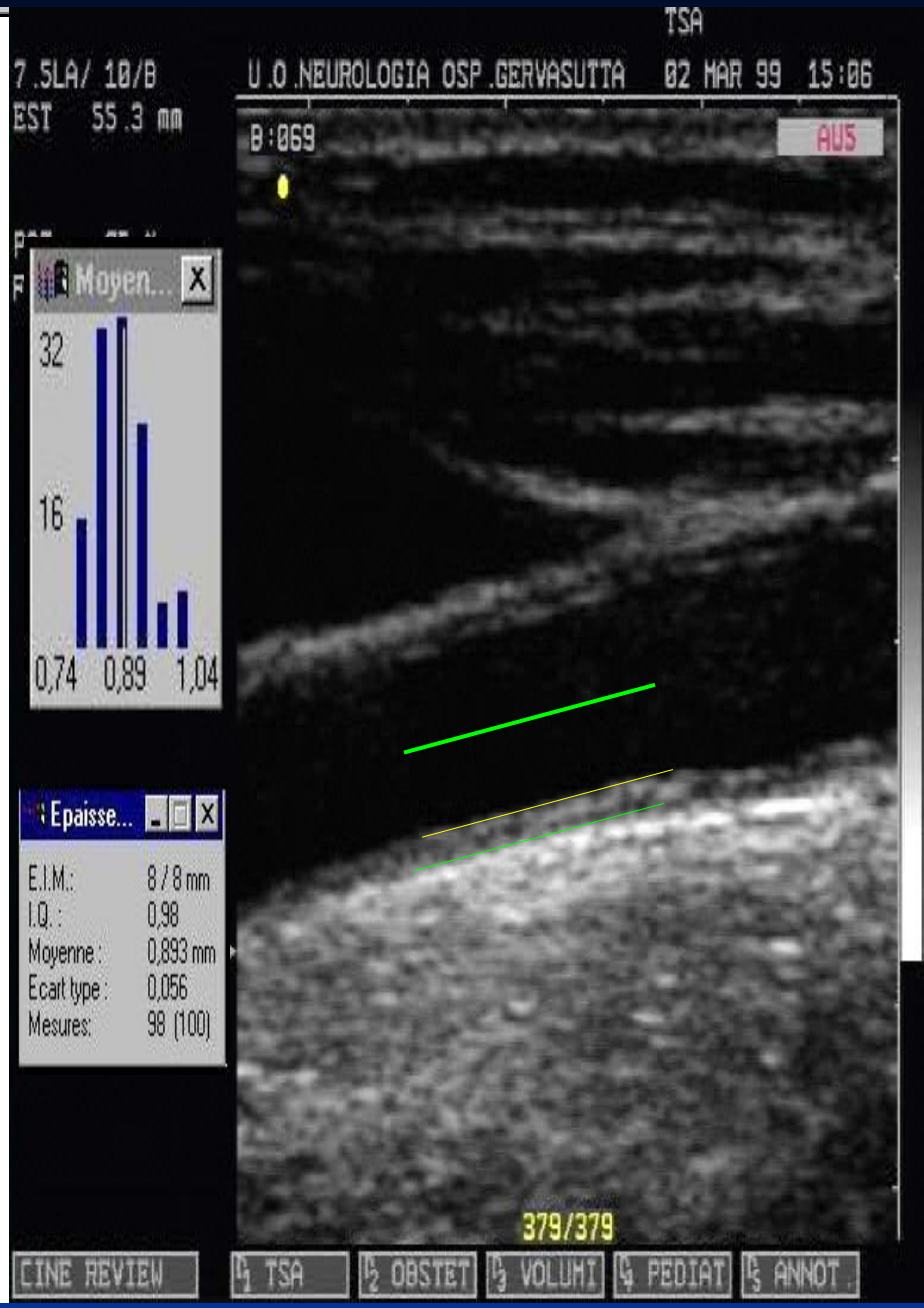
## RISK ASSESSMENT

The following risk assessment tool uses information from the Framingham Heart Study. This tool is designed for adults who do not have heart disease or diabetes.

To find your risk score, enter your information in the calculator below.

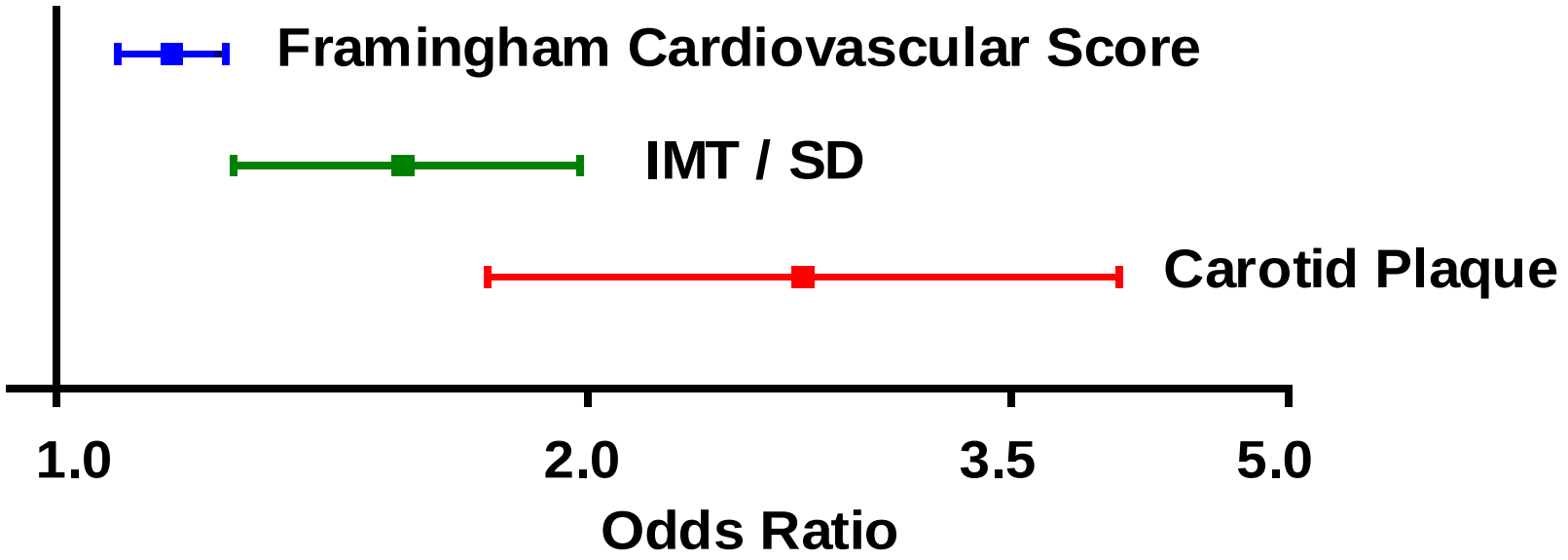
**Click on any link below for each category's definition and instructions.**

| | |
|---|---|
| Gender: | ○ Male ○ Female |
| Age: | [ ] Years (between 20 and 99) |
| Total Cholesterol: | [ ] mg/dL (between 130 and 320) |
| HDL Cholesterol: | [ ] mg/dL (between 20 and 100) |
| Systolic Blood Pressure: | [ ] mm Hg (between 90 and 200) |
| Are you currently on any medication to treat high blood pressure?: | ○ Yes ○ No |
| Current Smoker: | ○ Yes ○ No |

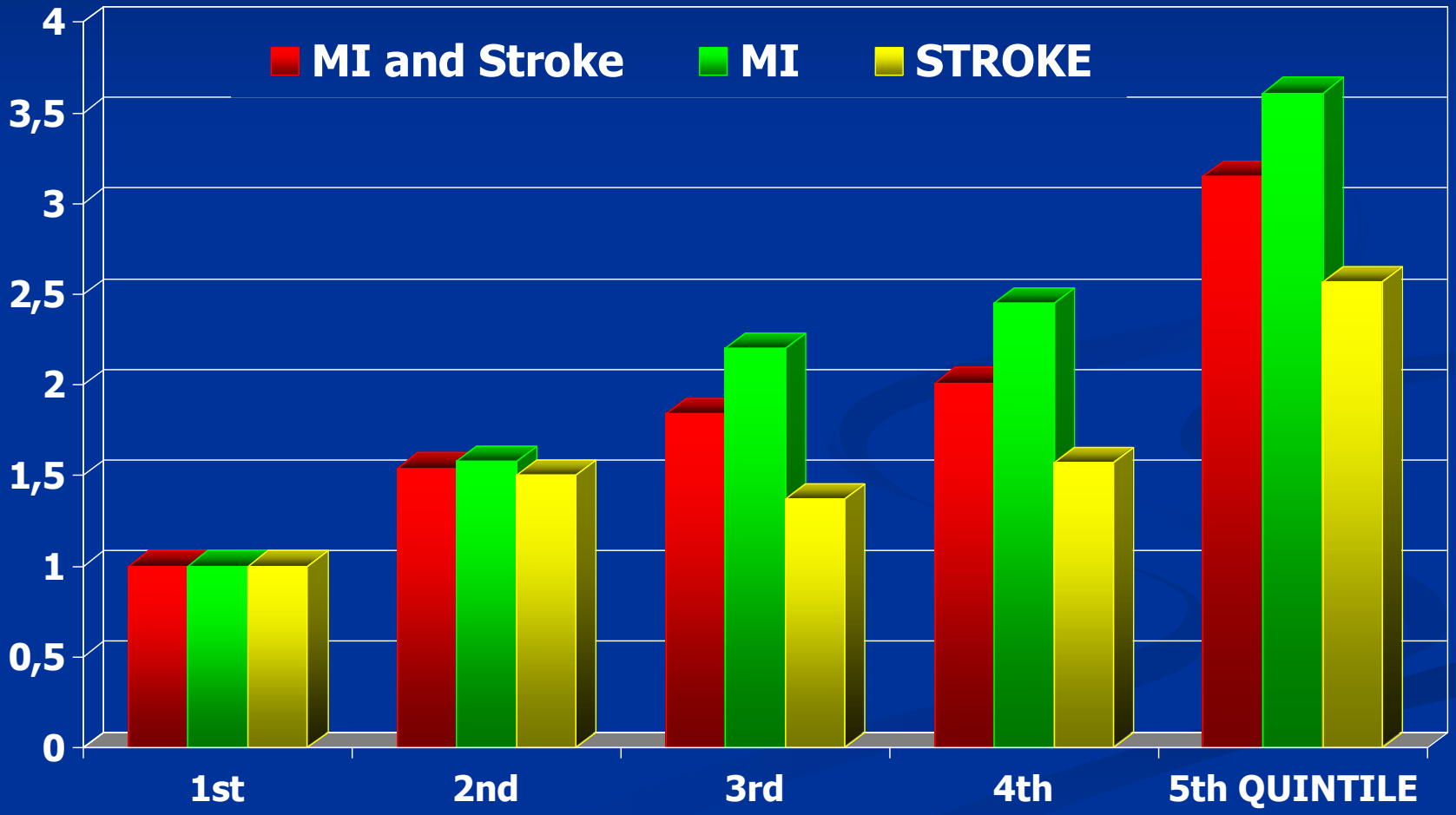


# PARC Study : Correlation of Framingham Score with CCAIMT

## Risk of Brain Infarction in all subjects
## Multivariate Analysis : FS, IMT, Plaque

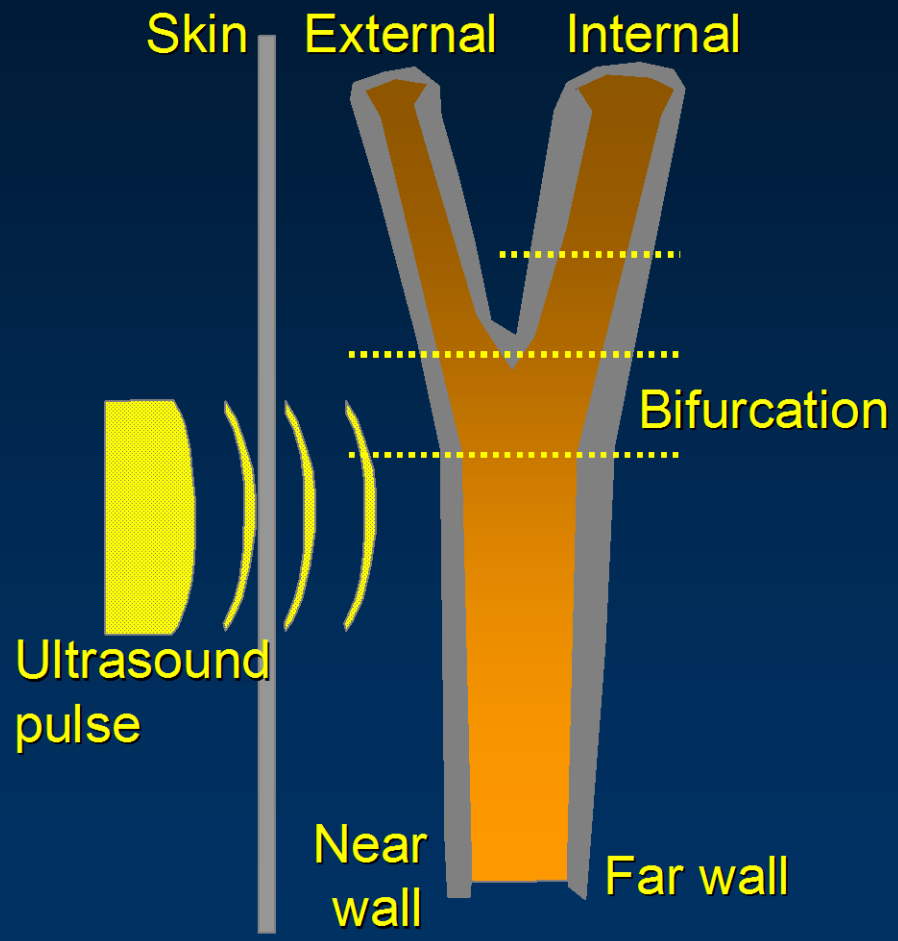


# Relative Risk of Stroke, MI, combined as a function of the maximal CCA and ICA IMT (adjusted for age, sex and other risk factors)



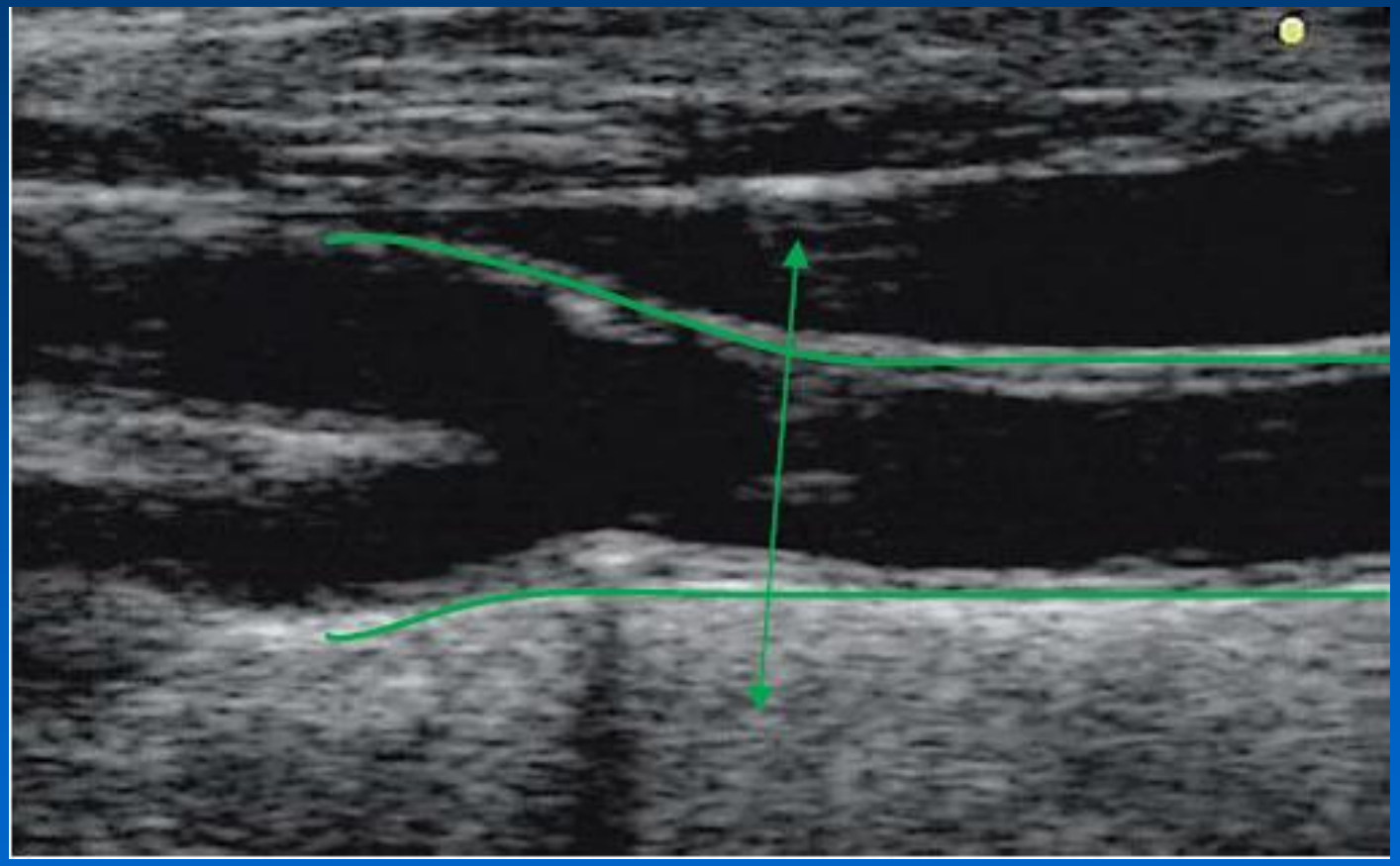

(O'Leary, NEJM 99)

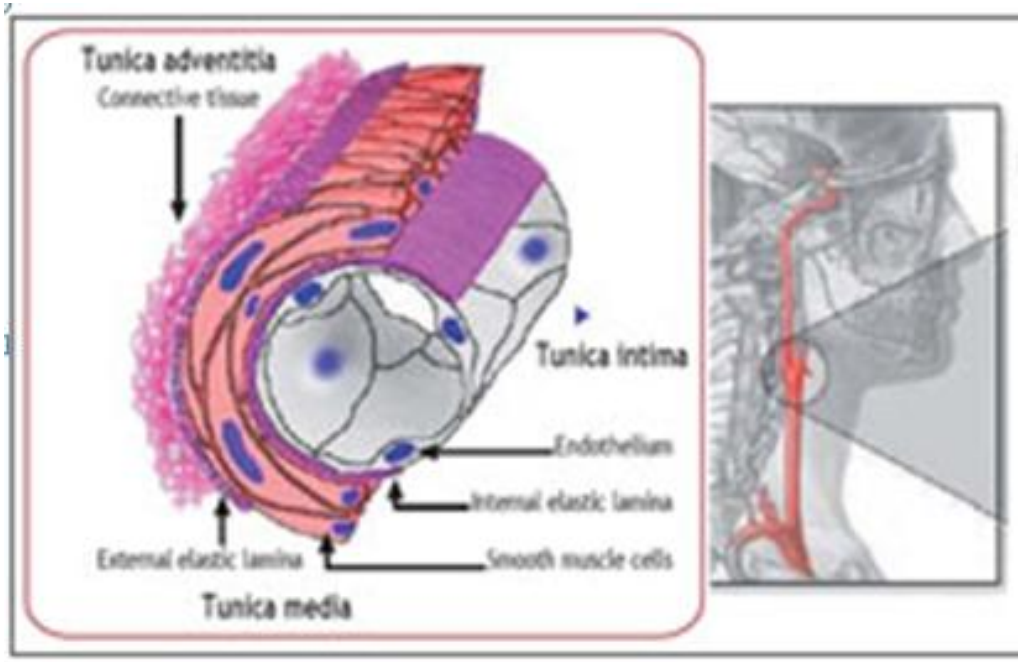
# B-Mode Ultrasound

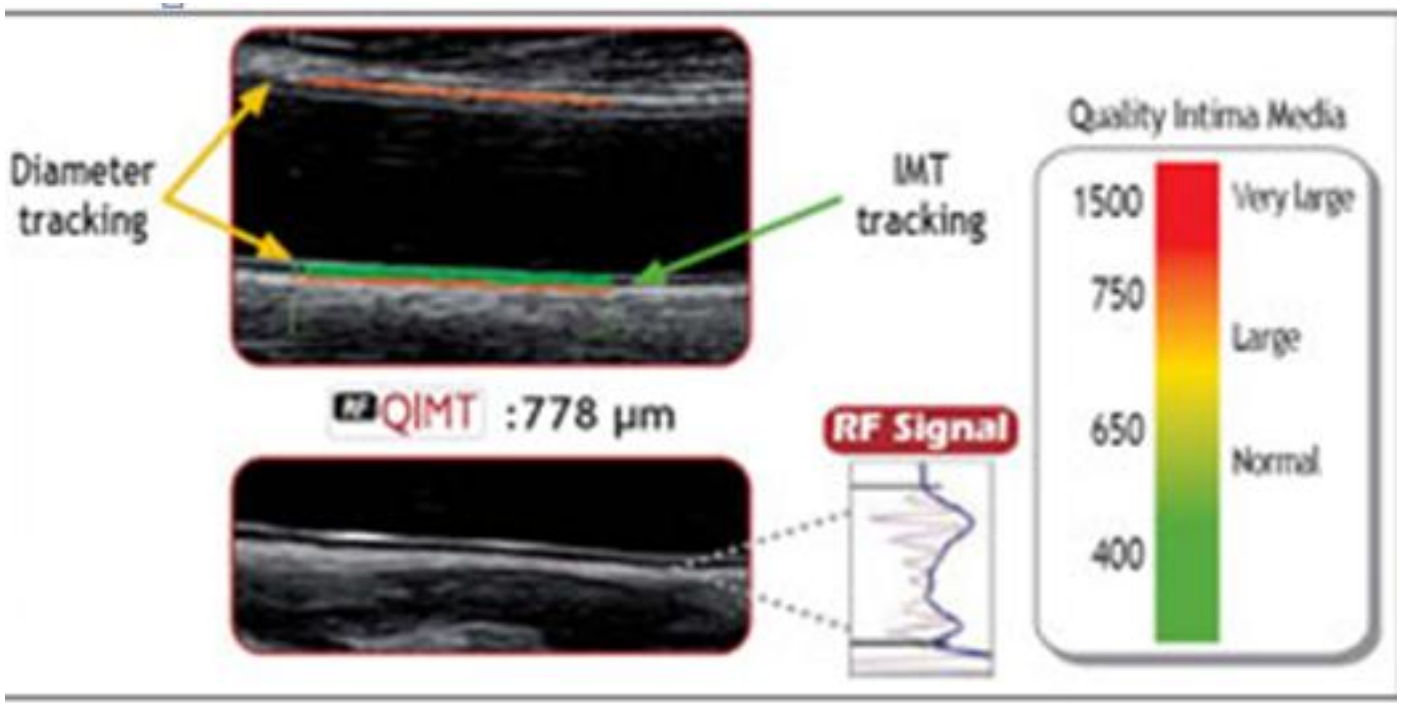



Kanters et al. *Stroke.* 1997;28:665-671.

# Mannheim Carotid Intima-Media Thickness Consensus (2004–2006)

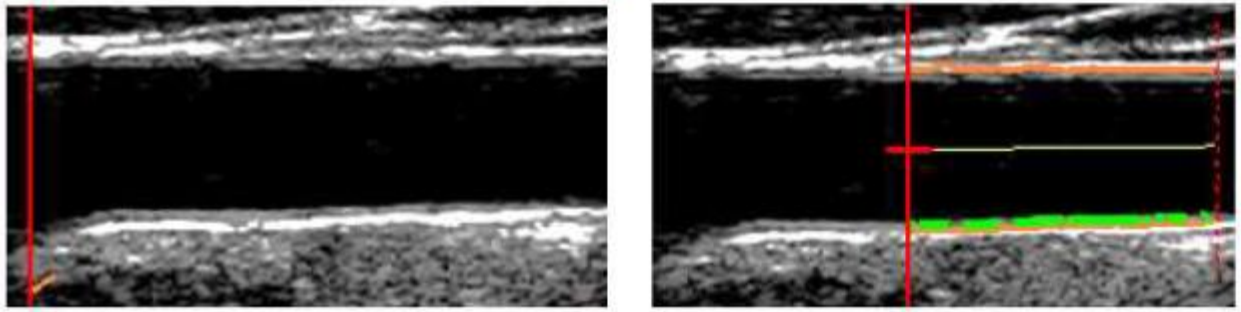



Tunica adventitia
Connective tissue
Tunica intima
Endothelium
Internal elastic lamina
External elastic lamina
Smooth muscle cells
Tunica media


Diameter tracking
IMT tracking
QIMT :778 µm
RF Signal
Quality Intima Media
1500
750
650
400
Very Large
Large
Normal

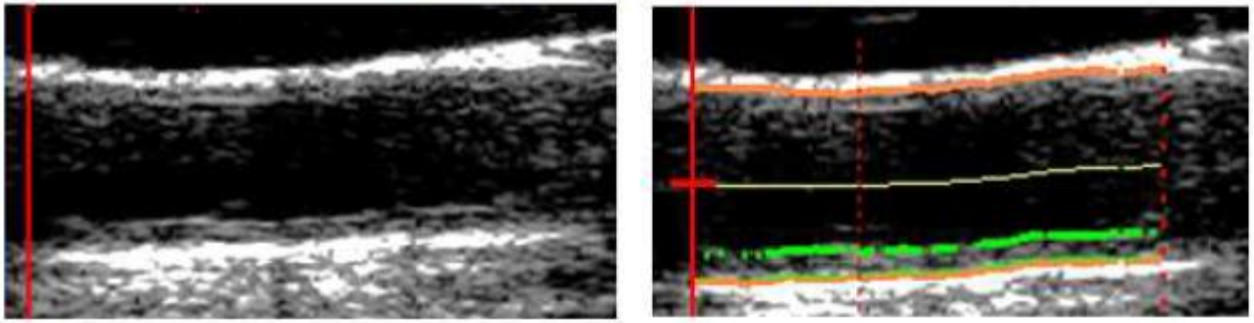
## Quality intima media thickeness ($^{RF}$QIMT)

### Healthy vessel



Diameter : 5.93 mm
IMT : 324 μm

### Diseased vessel



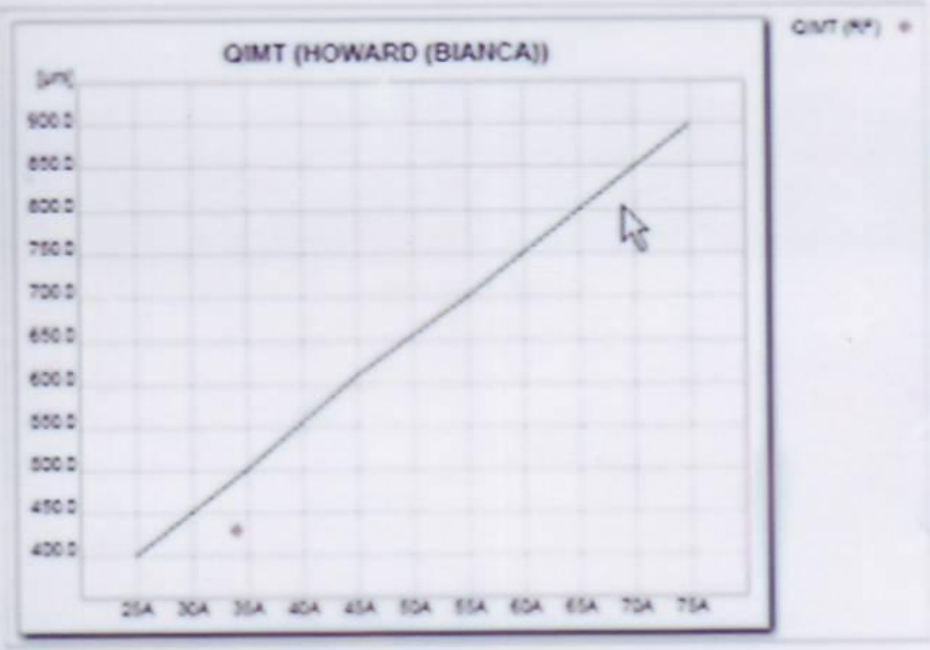
Diameter : 6.61 mm
IMT : 976 μm


11 OTT 2011 11:40:44
B RIS-A G 40%
P 37mm XV OFF
PRC 12/1/1 PRS 9
PST 0 C 3
3 11
TSA LA332
QIMT D
µm mm
1>> 585 7.67
2>> 596 7.60
3>> 659 7.58
4>> 665 7.66
5>> 632 7.75
6>>> 650 7.44
MED 641 7.63
DS 10 0.11
LA 13.86
10
0
1
2
3

31 DIC 2010 11:47:42

31 DIC 2010 11:45

| | | | |
|---|---|---|---|
| SESSO | M | | |
| IDENTIFICATIVO | | DATA ESAME | 31 DIC 2010 |
| NUMERO DI ACCESSO | | MEDICO CURANTE | |
| OPERATORE | | DIAGNOSI DI AMMISSIONE | |
| MEDICO ESECUTORE | | DATA REPORT | 31 DIC 2010 |




| QIMT S | | |
|---|---|---|
| QIMT S : | 429 | µm |
| **QIMT (RF)** | | |
| QIMT (RF) : | 429 | µm |
| DS : | 6 | µm |
| DIAMETRO : | 6.9 | mm |
| DS : | 0.25 | mm |
| LARGHEZZA : | 14.6 | mm |
| TABELLA QIMT: | HOWARD (BIANCA) | |
| QIMT PRESUNTO: | 490 | µm |

# WHY PULSE WAVE VELOCITY?

- **Clinical assessment of large arteries requires a simple, practical method.**

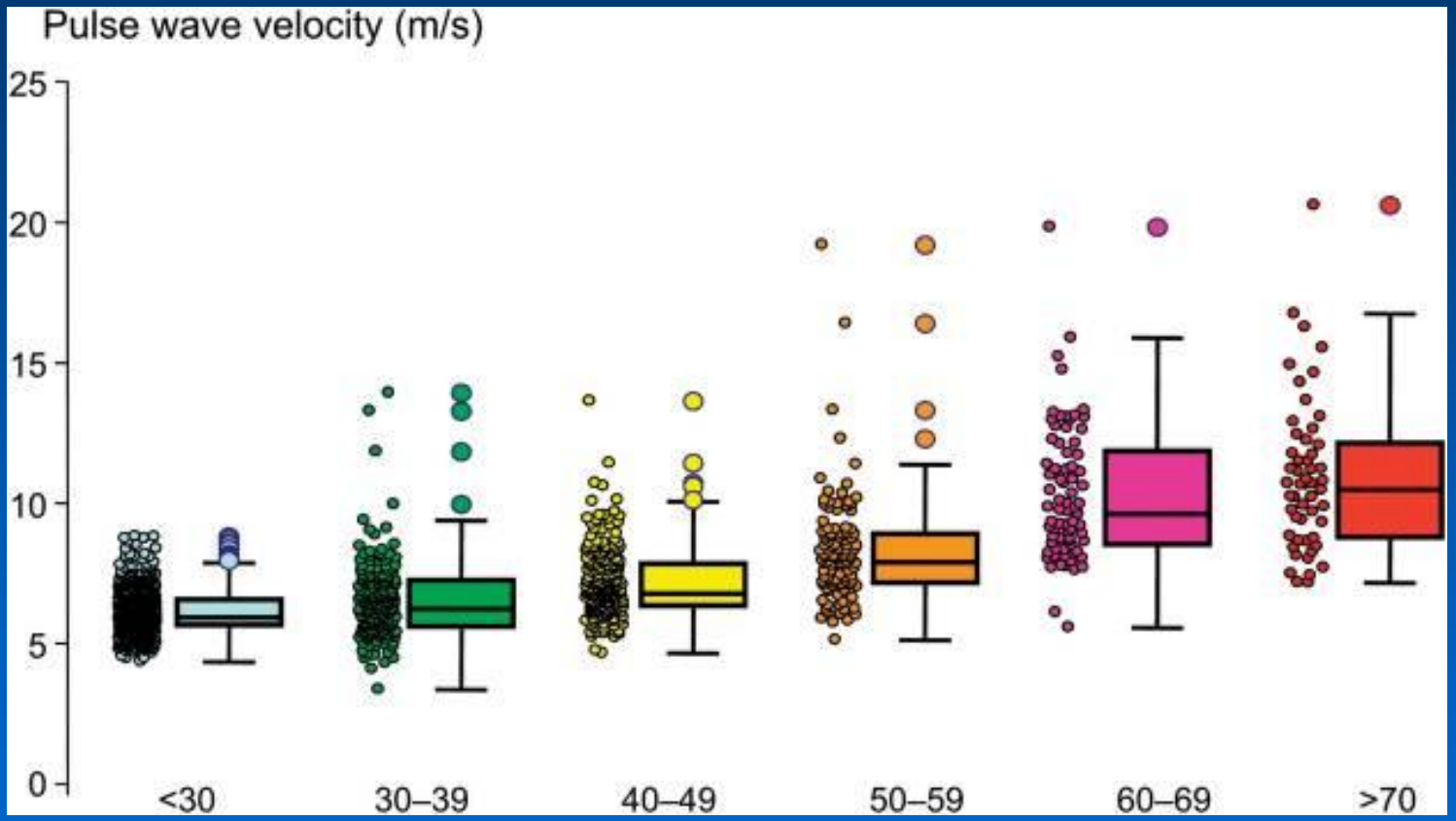
***Pulse wave velocity = Index of arterial stiffness***

- **Arterial stiffness will**
  - Play a potential **etiologic** role in cardiovascular disease.
  - Help to **recognize arterial changes**.
  - Constitute an "early **risk marker**" .
  - Be useful in assessing the **arterial effects** of drugs.

*«A man is as old as his arteries»*

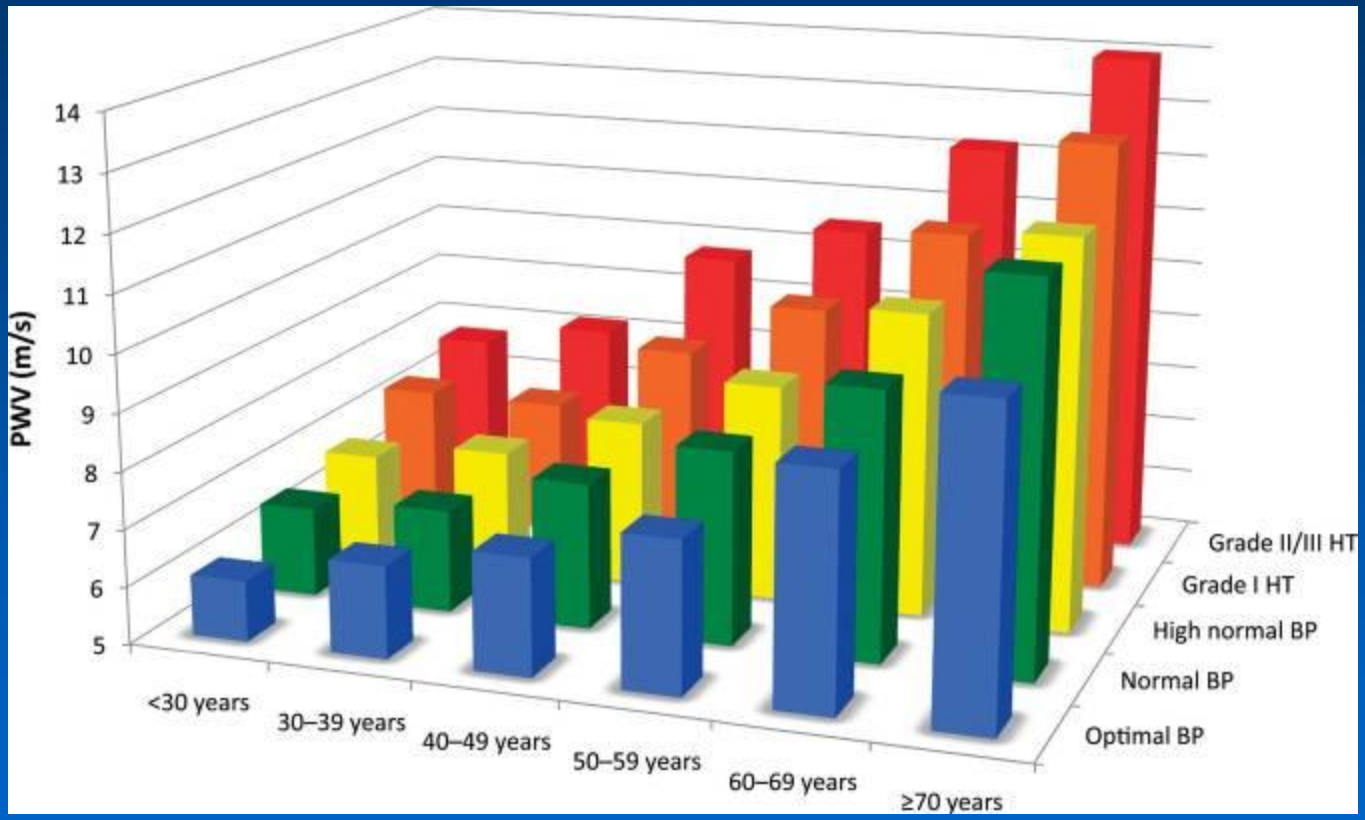
Thomas Sydenham (1624-1689)

# Normal values for pulse wave velocity: average according to age (1455 subjects)



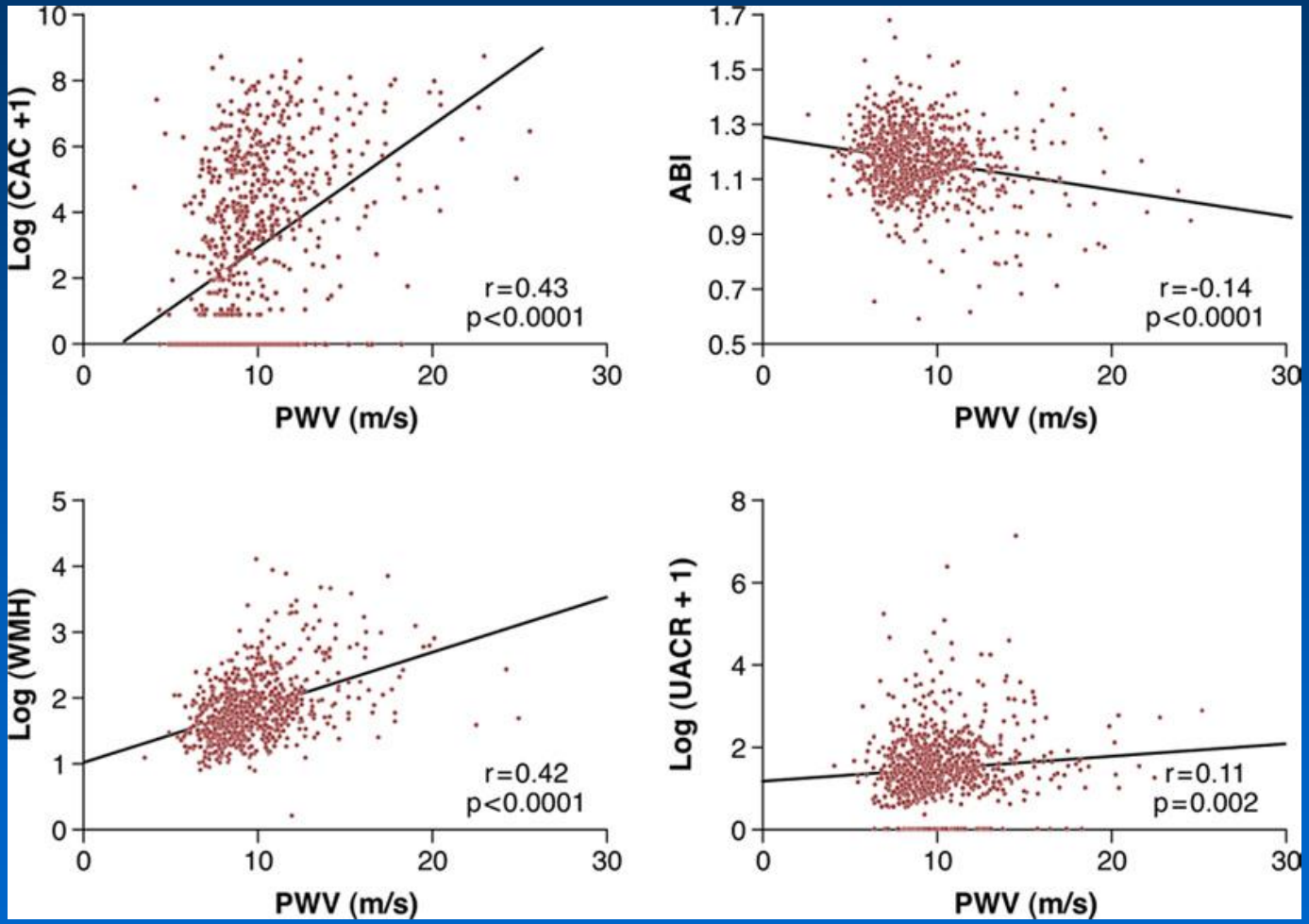

Boutourye P, Eur Heart J. 2010 October; 31(19): 2338–2350.

# Pulse wave velocity is related to age and blood pressure (BP) categories (11 092 subjects)




Boutourye P, Eur Heart J. 2010 October; 31(19): 2338–2350.

# Correlations of PWV With Coronary, Lower Extremity, Cerebral, and Renal Arteriosclerosis

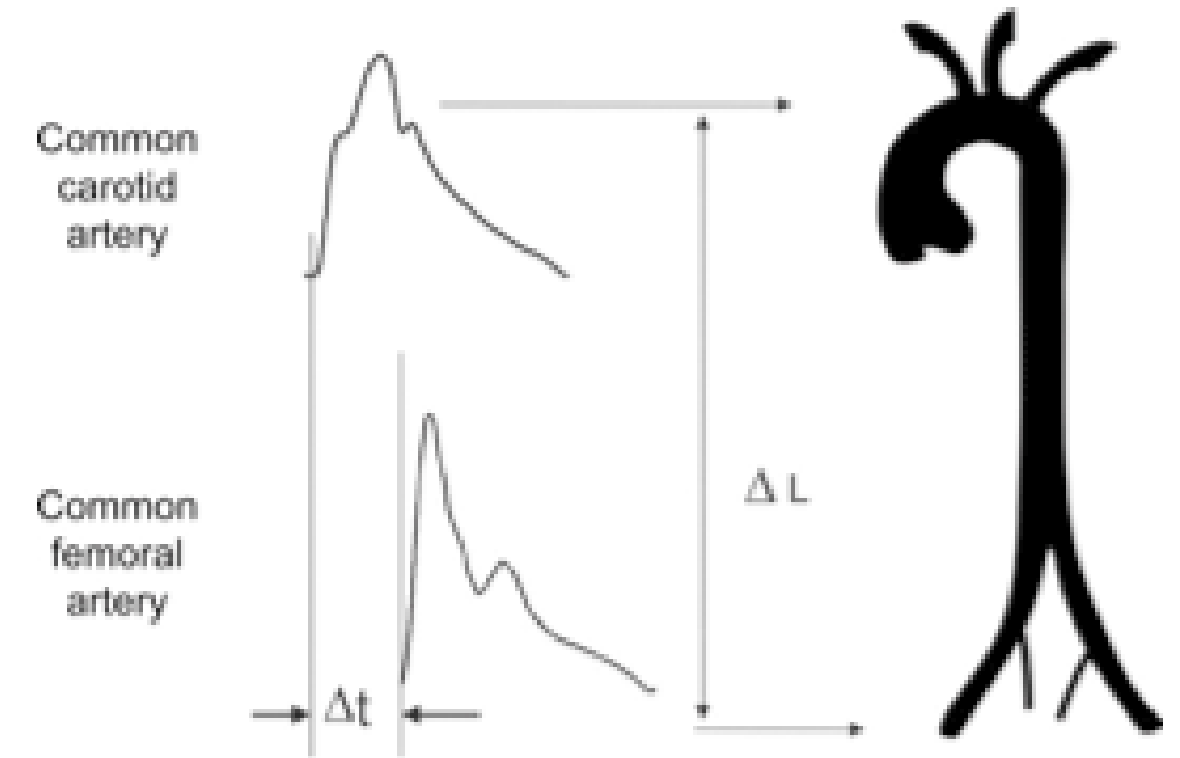



CoutinhoJ et al, JACC: CARDIOVASCULARIMAGING, VOL.4, NO.7, 2011

# PULSE WAVE VELOCITY

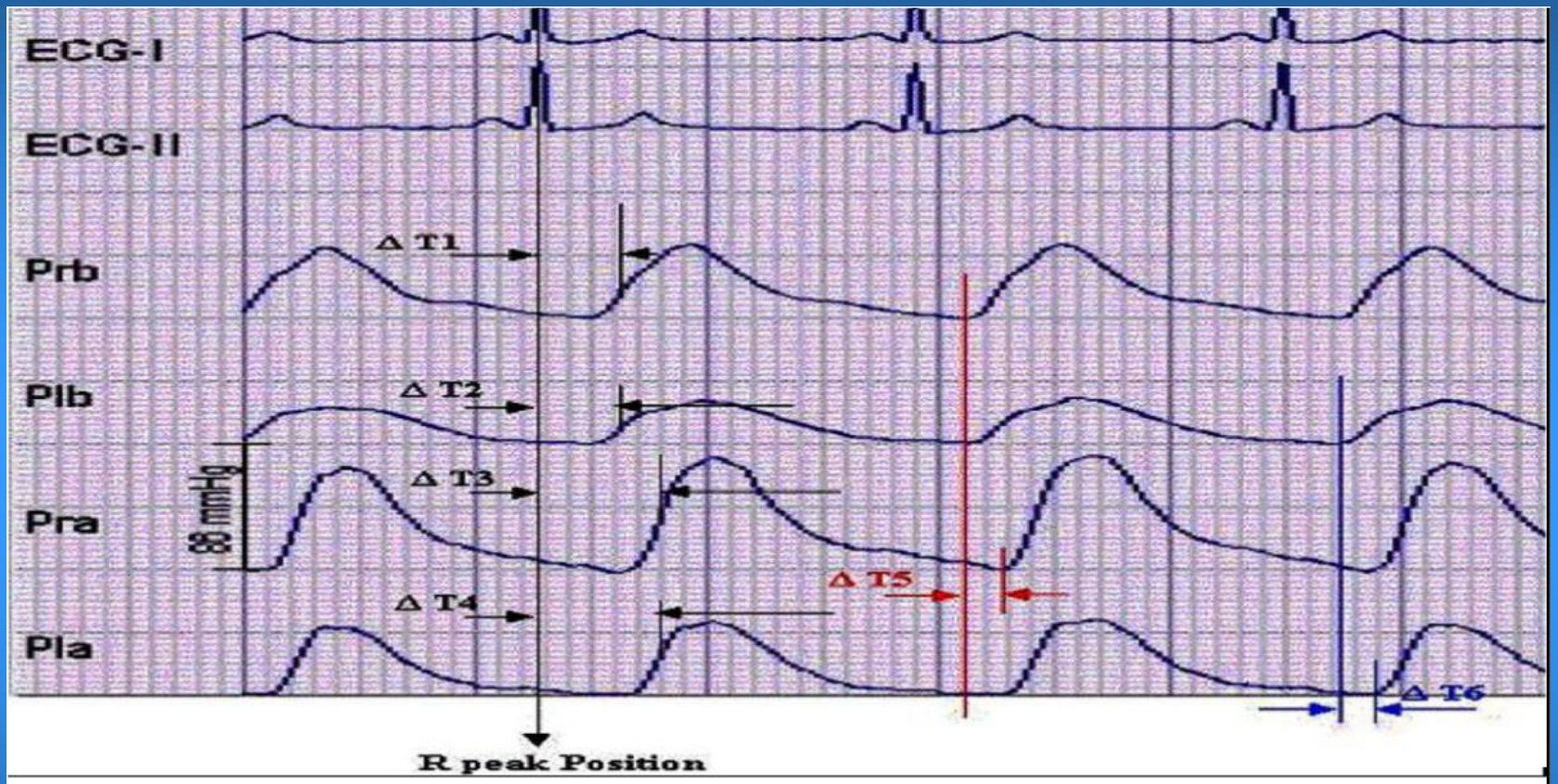
- **A simple method to assess arterial stiffness and distensibility.**
- **A long-established and widely used technique.**
- **Non-invasive, accurate and reproducible.**

# The Pulse Wave Velocity




Measurement of carotid-femoral PWV with the foot to foot method.

# The Pulse Wave Velocity




$$\text{Right hb PWV} = \frac{\text{Heart to Right Brachial Cuff Distance}}{\Delta T1}$$

$$\text{Left hb PWV} = \frac{\text{Heart to Left Brachial Cuff Distance}}{\Delta T2}$$

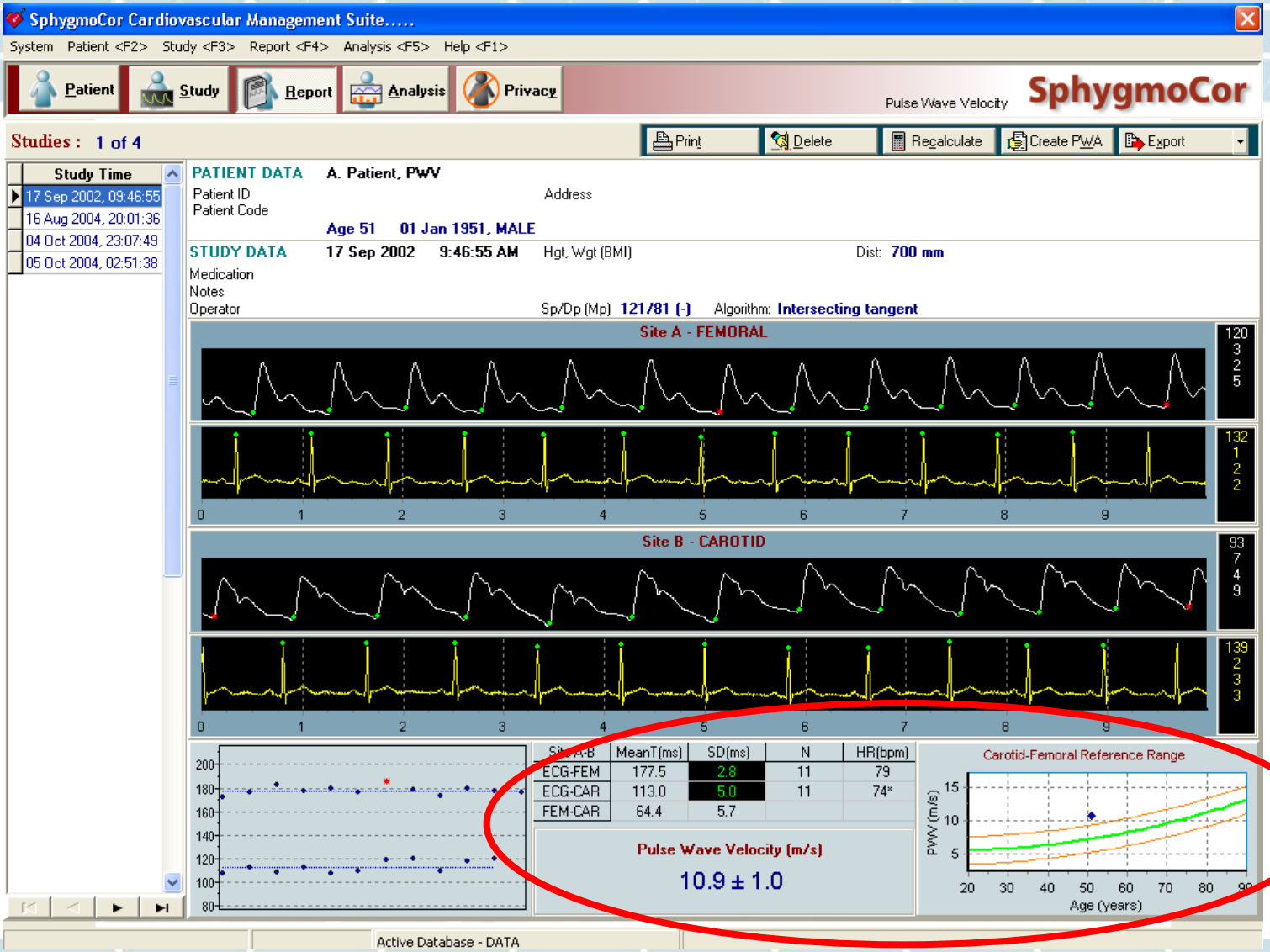
$$\text{Right ha PWV} = \frac{\text{Heart to Right Ankle Cuff Distance}}{\Delta T3}$$

$$\text{Left ha PWV} = \frac{\text{Heart to Left Ankle Cuff Distance}}{\Delta T4}$$

$$\text{Right ba PWV} = \frac{\text{Right Ankle to Right Brachial Cuff Distance}}{\Delta T5}$$

$$\text{Left ba PWV} = \frac{\text{Left Ankle to Left Brachial Cuff Distance}}{\Delta T6}$$

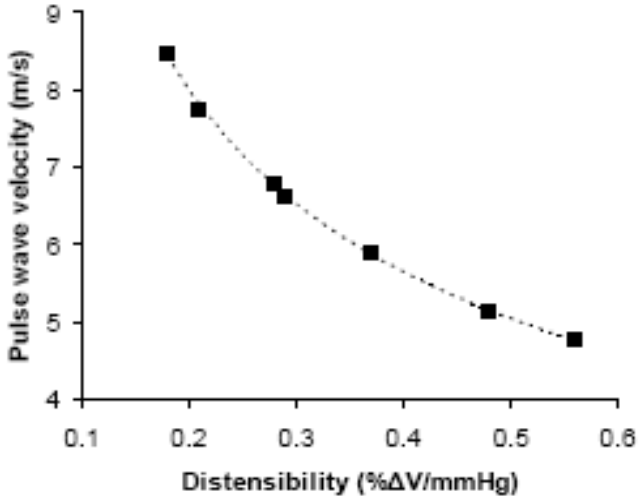
# Version 8.0 Pulse Wave Velocity Screen



# Pulse wave velocity

- PWV is inversely proportional to square root of arterial compliance

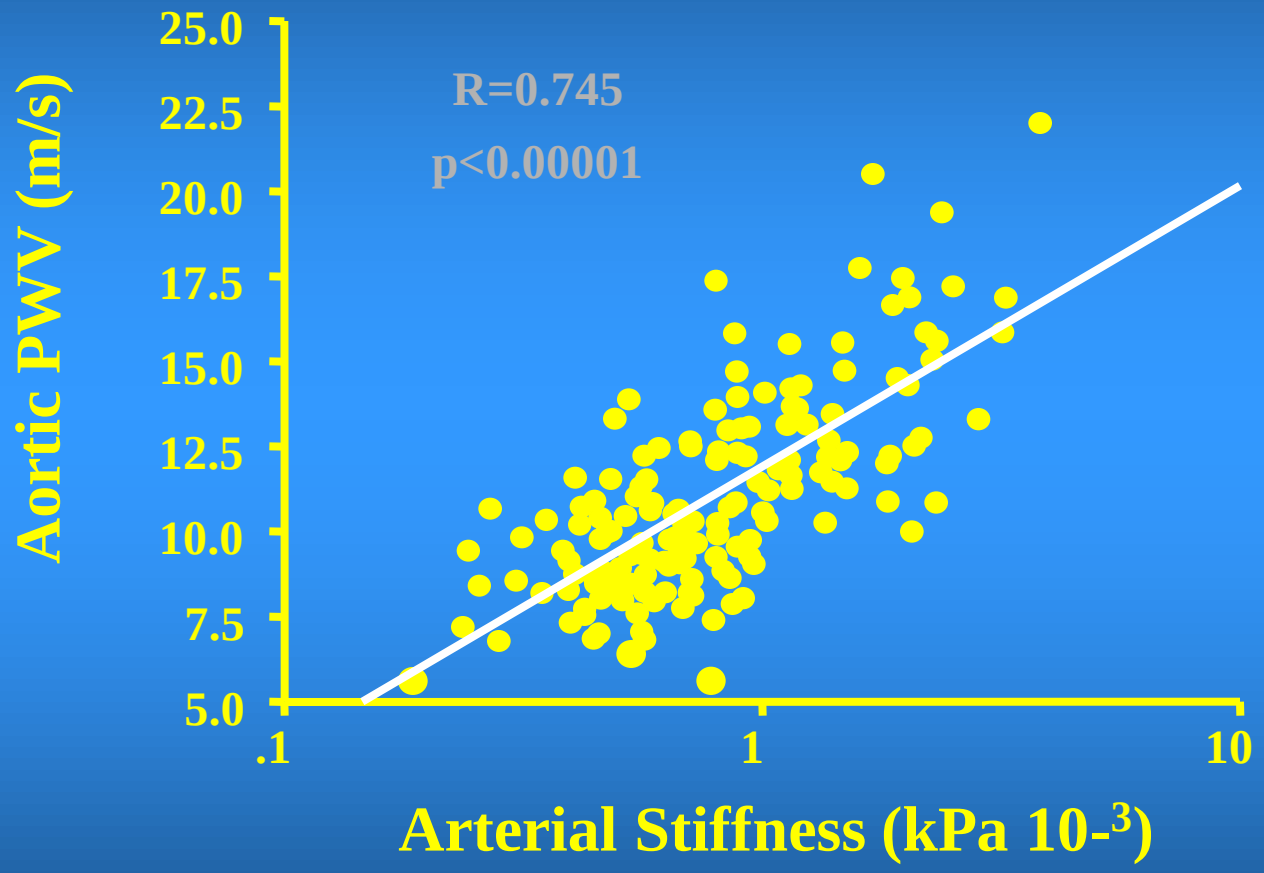
$$pwv \propto \sqrt{\frac{\Delta p \cdot v_0}{\Delta v}}$$




Bramwell & Hill, 1922

Hemingway *et al*, 1928

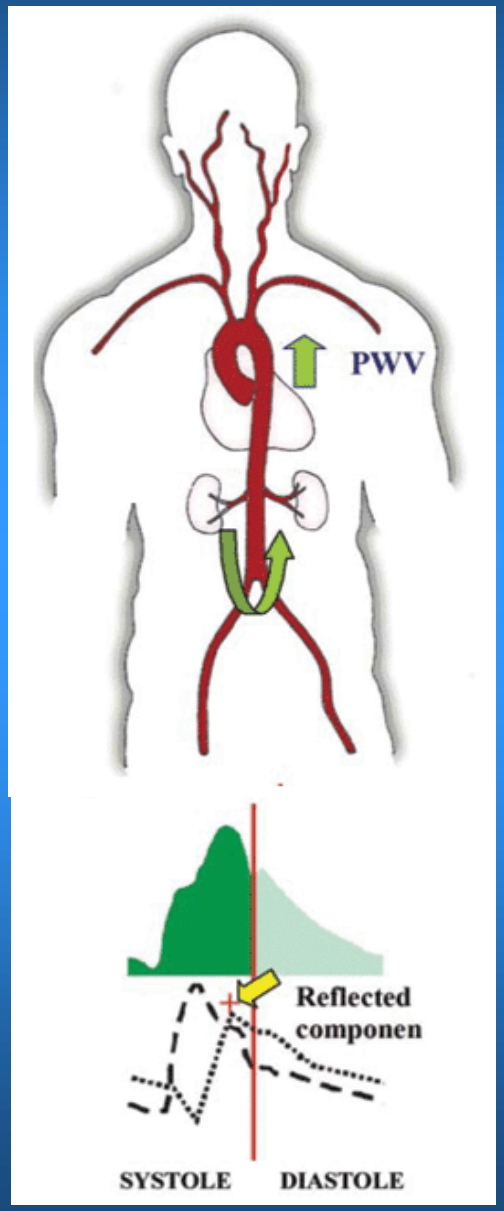
# Relationship between arterial stiffness and Aortic Pulse Wave Velocity (PWV)



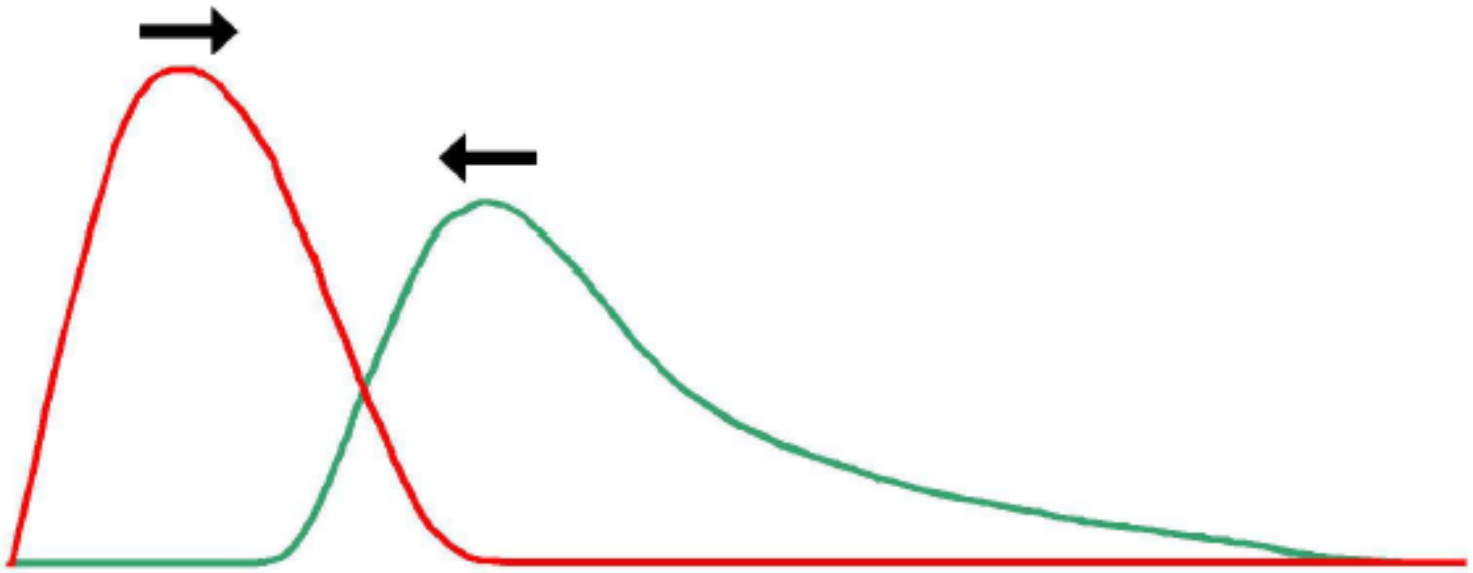

London et al adapted from Kidney Int 1996

# The wave reflection

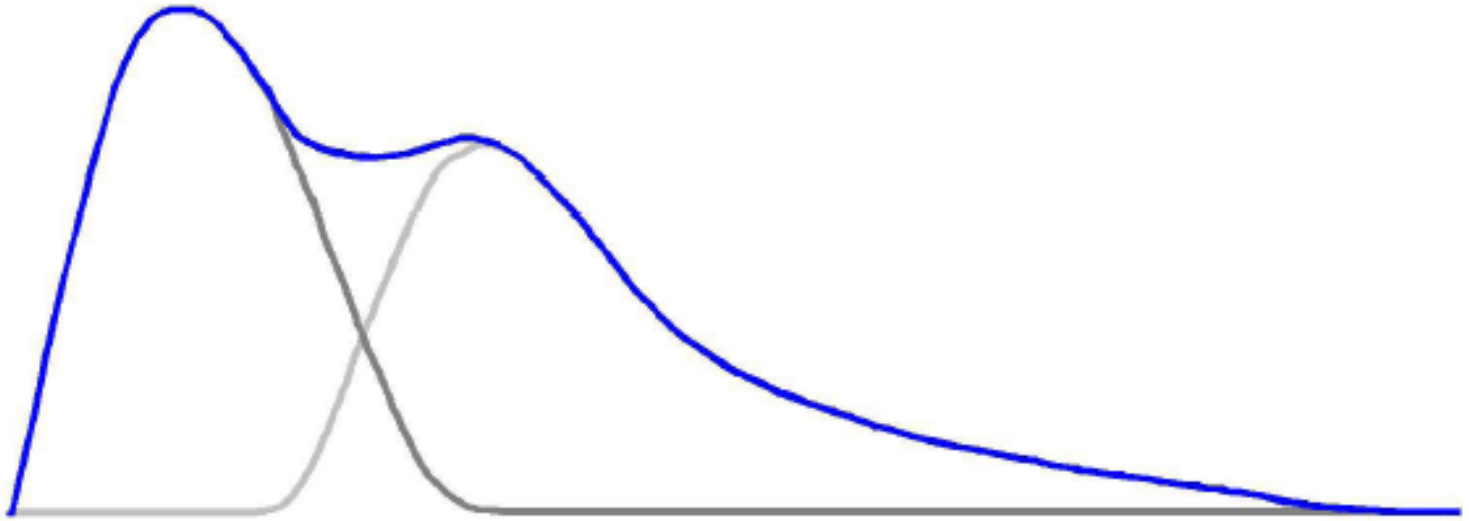
# The wave reflection



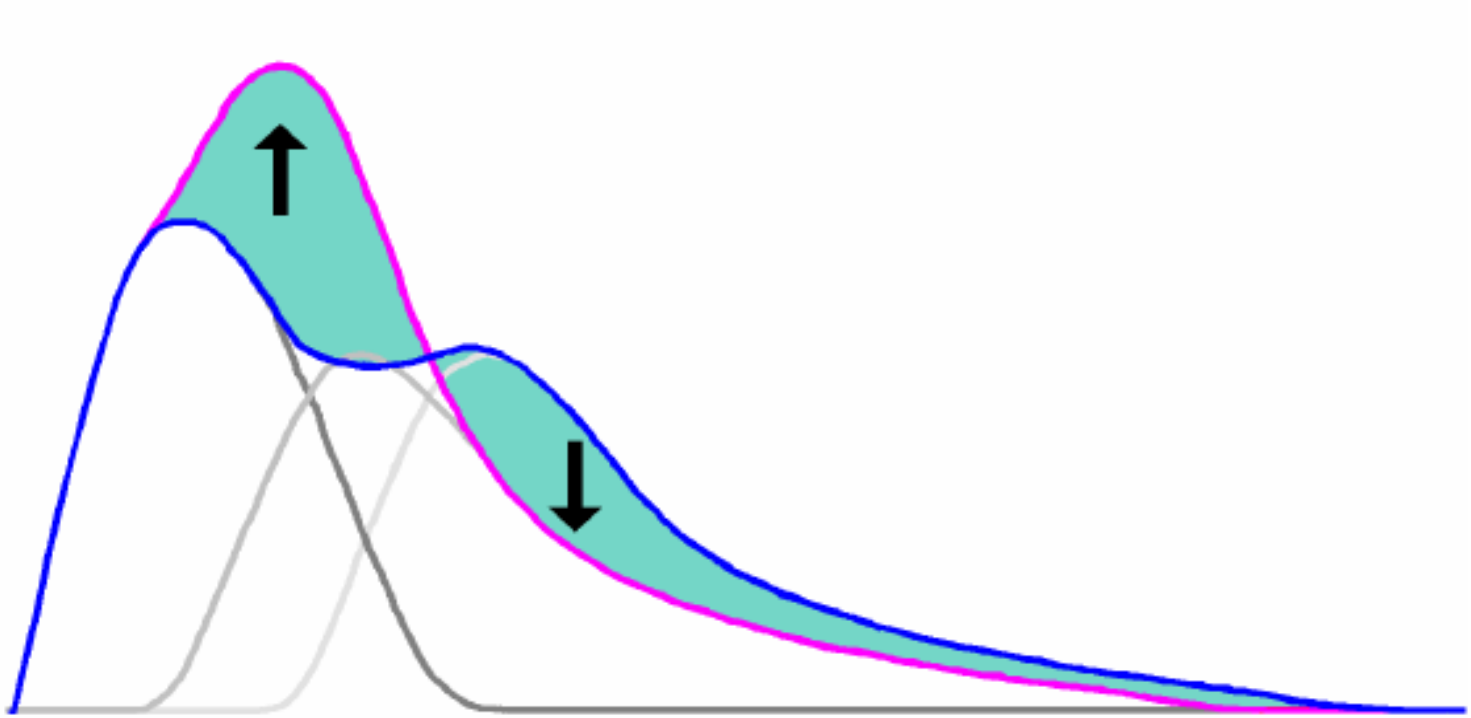
# The reflected wave augments the incident wave...



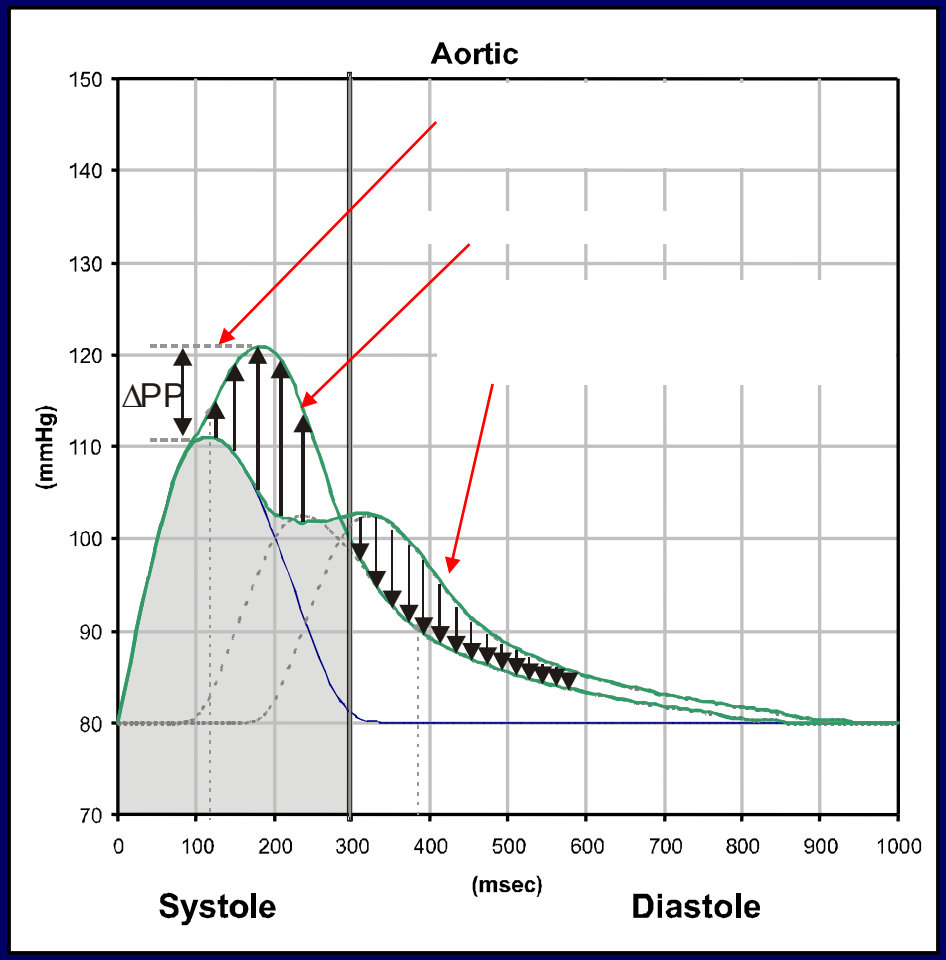
# …and determines the overall wave pressure and shape



# …increasing systolic pressure and changing the pulse contour

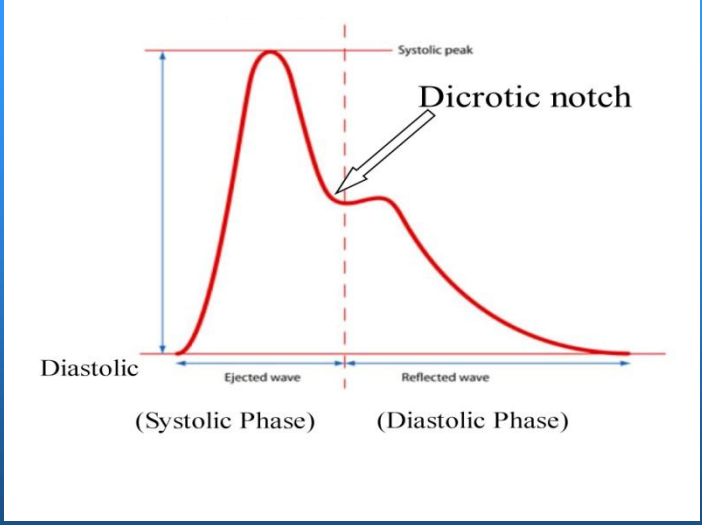


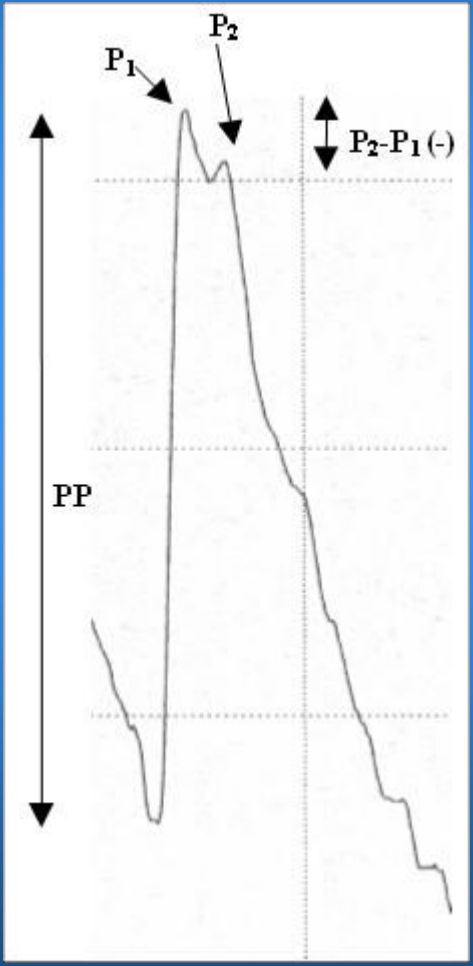
# The Impact of the Early Wave Reflection




- **This earlier return to the heart of the reflected pressure wave (due to stiffening of the arteries) changes the aortic root pressure waveform,** … with 3 key clinical implications
- **Central pulse pressure increases ...** increasing risk of stroke and renal failure
- **LV Load increases….** increasing LV mass**, and accelerating progress towards LV hypertrophy and heart failure**
- **Coronary artery perfusion pressure in diastole reduces….** increasing risk of myocardial ischemia

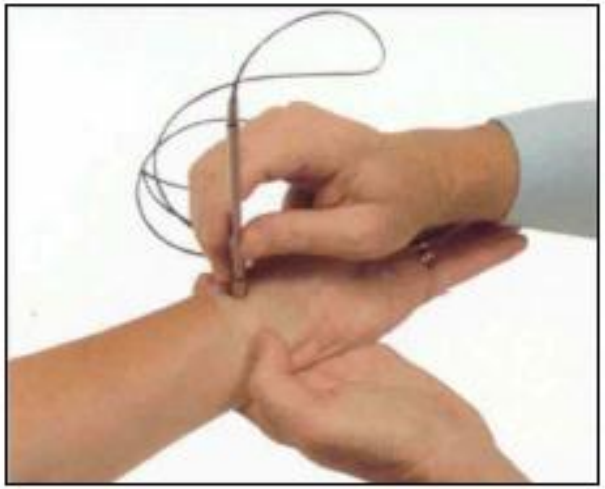
# The wave reflection contributes to arterial-ventricular coupling



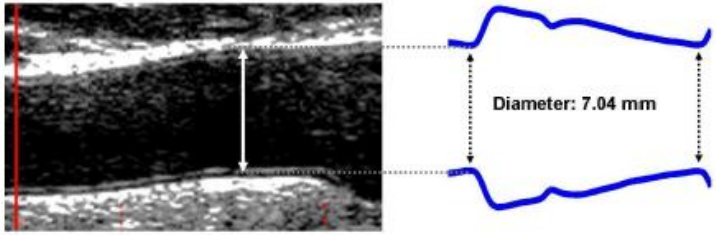



# Pulse wave analysis

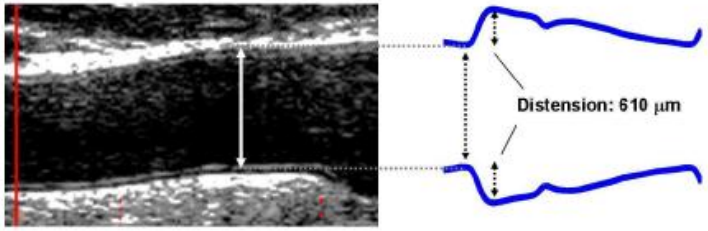
- Non-invasive
  - Applanation tonometry
  - Infra-red sensor – digit volume pulse, DVP

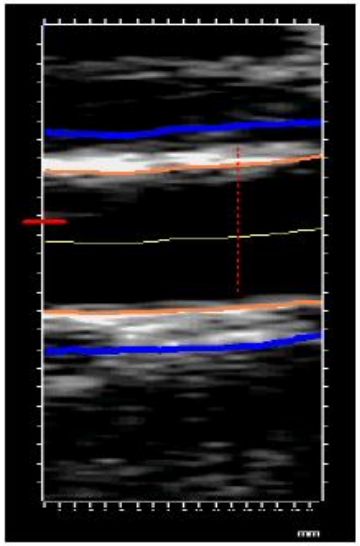


What is diameter?




What is distension?



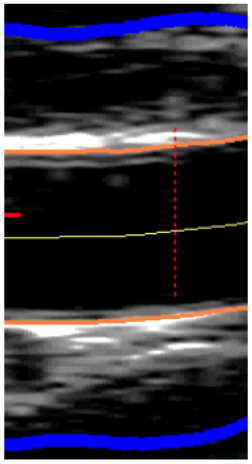



**Vessel parameters**

Diameter: 7.04 mm
Distension: 536 µm
Stiffness PWV: 5.7 m/s

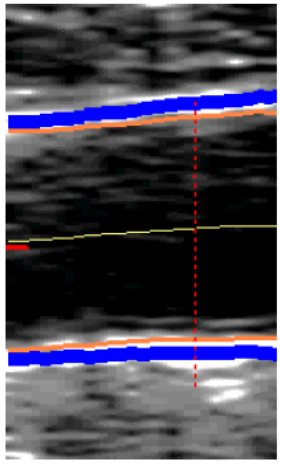
## Stiffness measurements

**Age: 24**



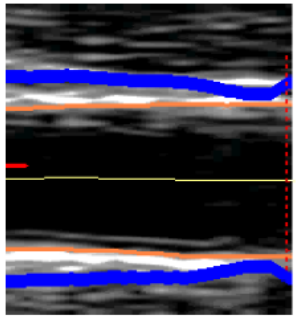
D: 7.0 mm
ΔD: 605 µm
PWV: **5.3 m/s**

**Age: 45**

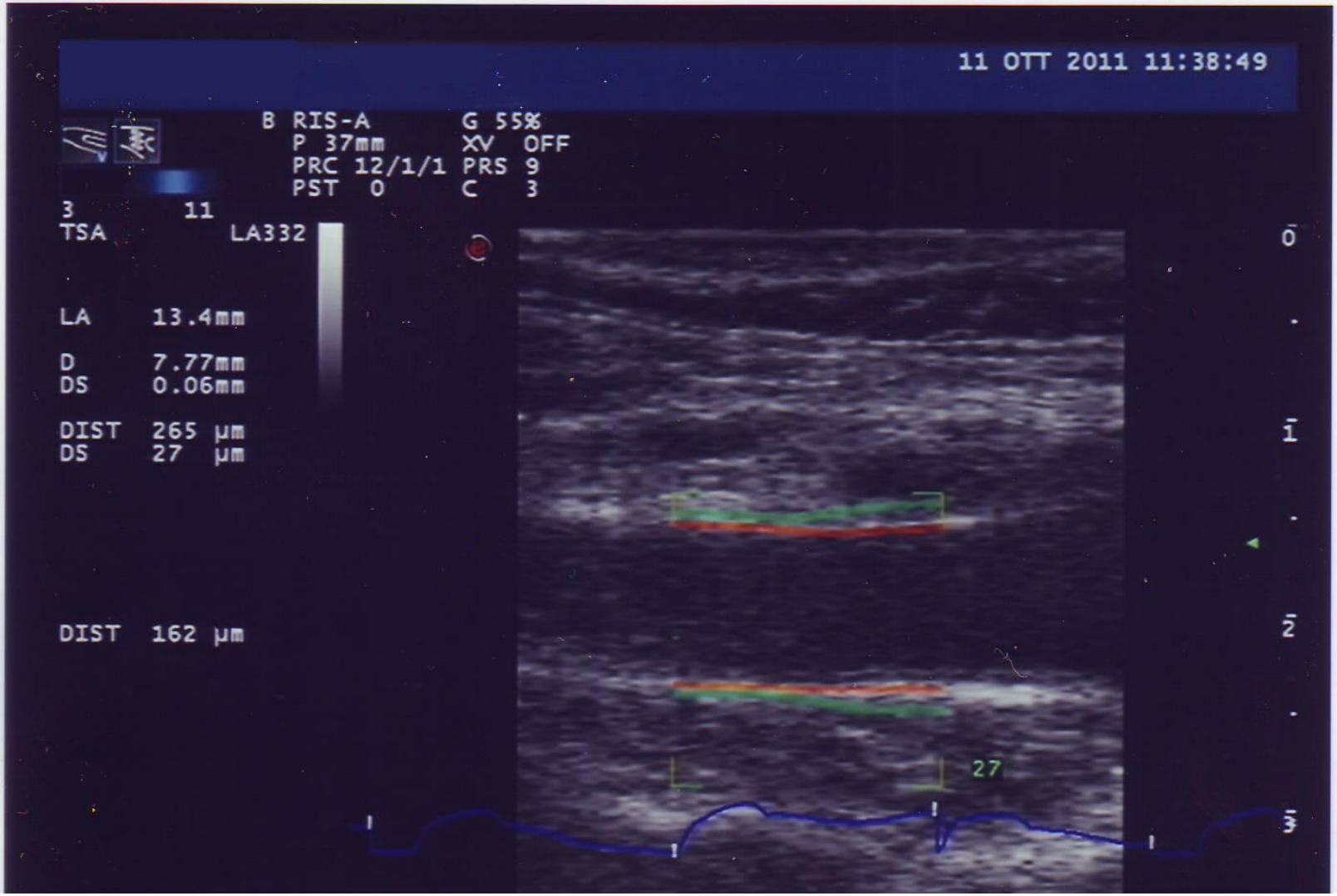


D: 7.5 mm
ΔD: 281 µm
PWV: **8.1 m/s**

**Patient**



D: 6.3 mm
ΔD: 124 µm
PWV: **11.3 m/s**


11 OTT 2011 11:38:49
B RIS-A G 55%
P 37mm XV OFF
PRC 12/1/1 PRS 9
PST 0 C 3
3 11
TSA LA332
LA 13.4mm
D 7.77mm
DS 0.06mm
DIST 265 µm
DS 27 µm
DIST 162 µm
27
0
1
2
3

31 DIC 2010 11:39:39

31 DIC 2010 11:35

QAS ACC D

1/1

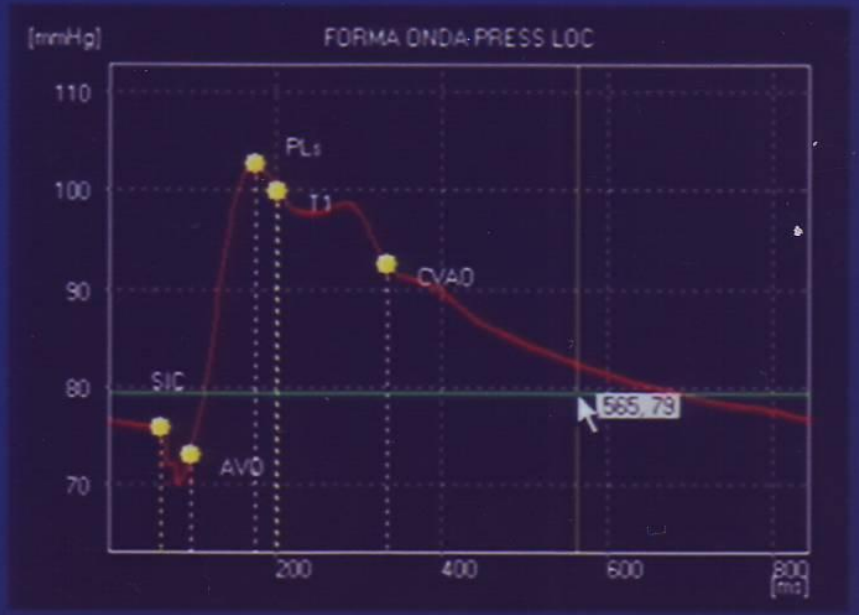
| PARAMETRO | VALORE | UNITA | MISURA 1 | MISURA 2 | MISURA 3 |
|---|---|---|---|---|---|
| DISTENSIONE | 365 | µm | 365 | | |
| DS | 46 | µm | 46 | | |
| DIAMETRO | 7.2 | mm | 7.2 | | |
| DS | 0.19 | mm | 0.19 | | |
| PR BR sis | 120.0 | mmHg | 120.0 | | |
| PR BR dia | 70.0 | mmHg | 70.0 | | |

**RIGIDITA**

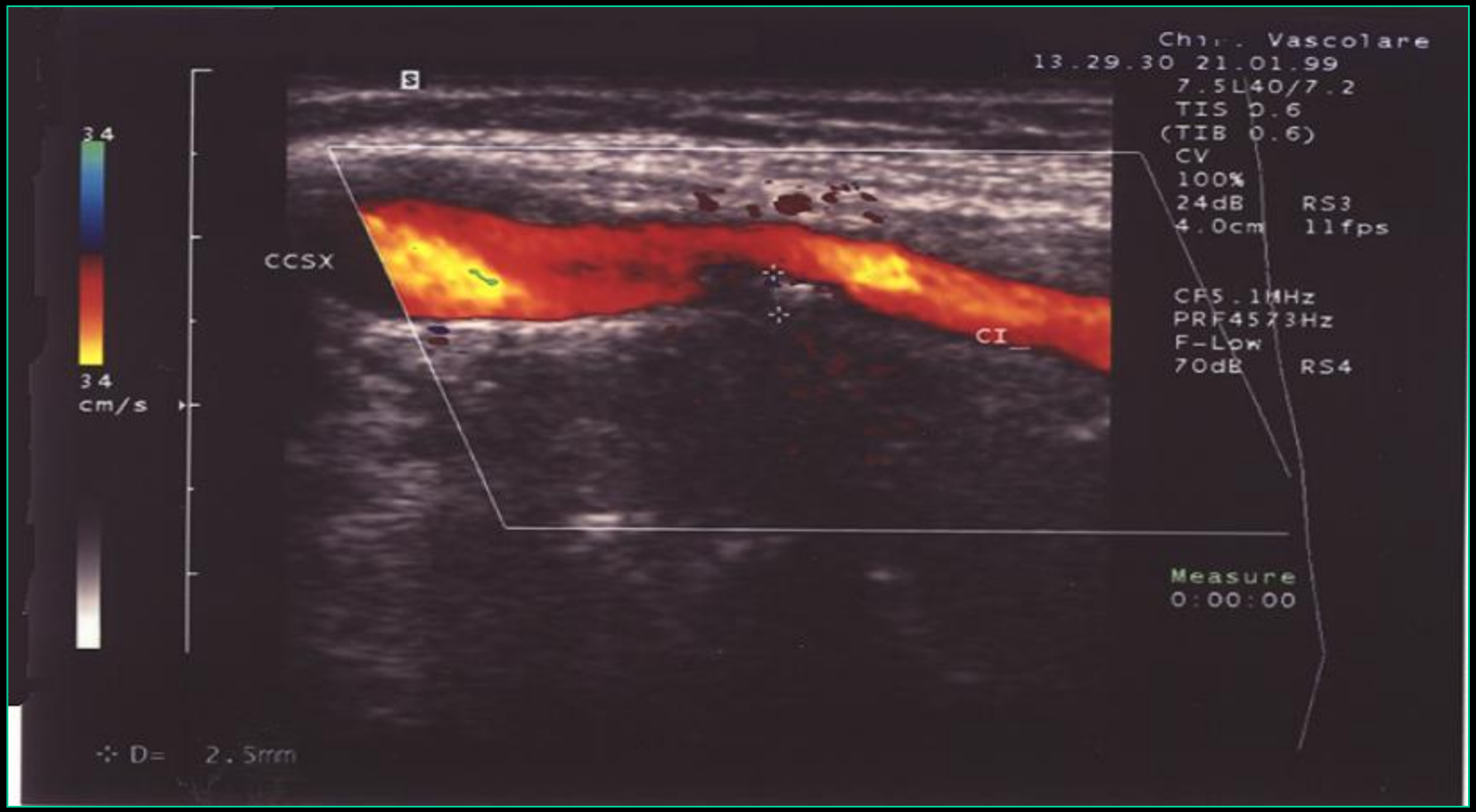
| | | |
|---|---|---|
| CD | 0.02 | 1/kPa |
| CC | 0.82 | mm²/kPa |
| α | 4.19 | |
| ß | 8.60 | |
| V PW | 6.82 | m/s |

**PRESSIONE LOCALE**

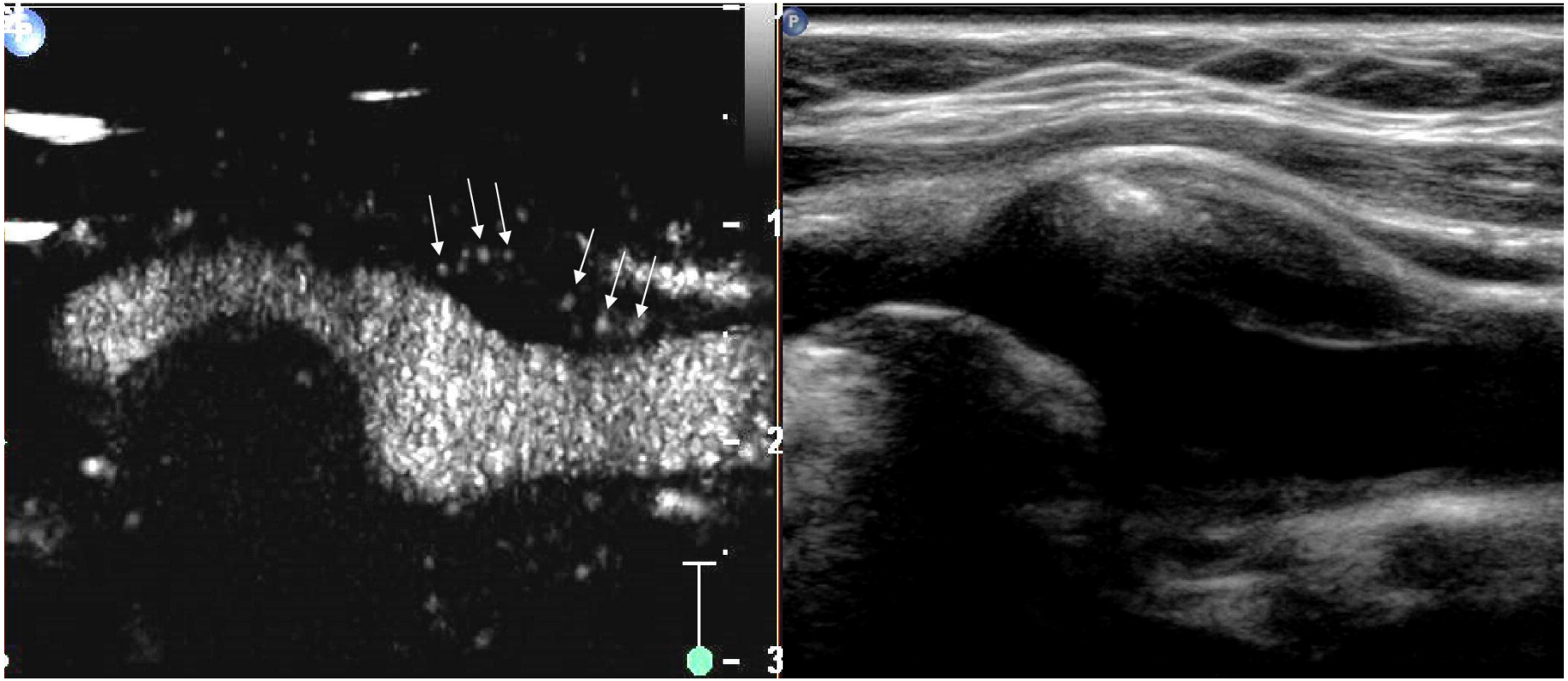
| | | |
|---|---|---|
| PR LOCsis | 103 | mmHg |
| PR LOCdia | 70 | mmHg |
| P(T1) | 100 | mmHg |
| AP | 3 | mmHg |
| AIx | -8.31 | % |
| ICP | 36 | ms |
| DE | 238 | ms |



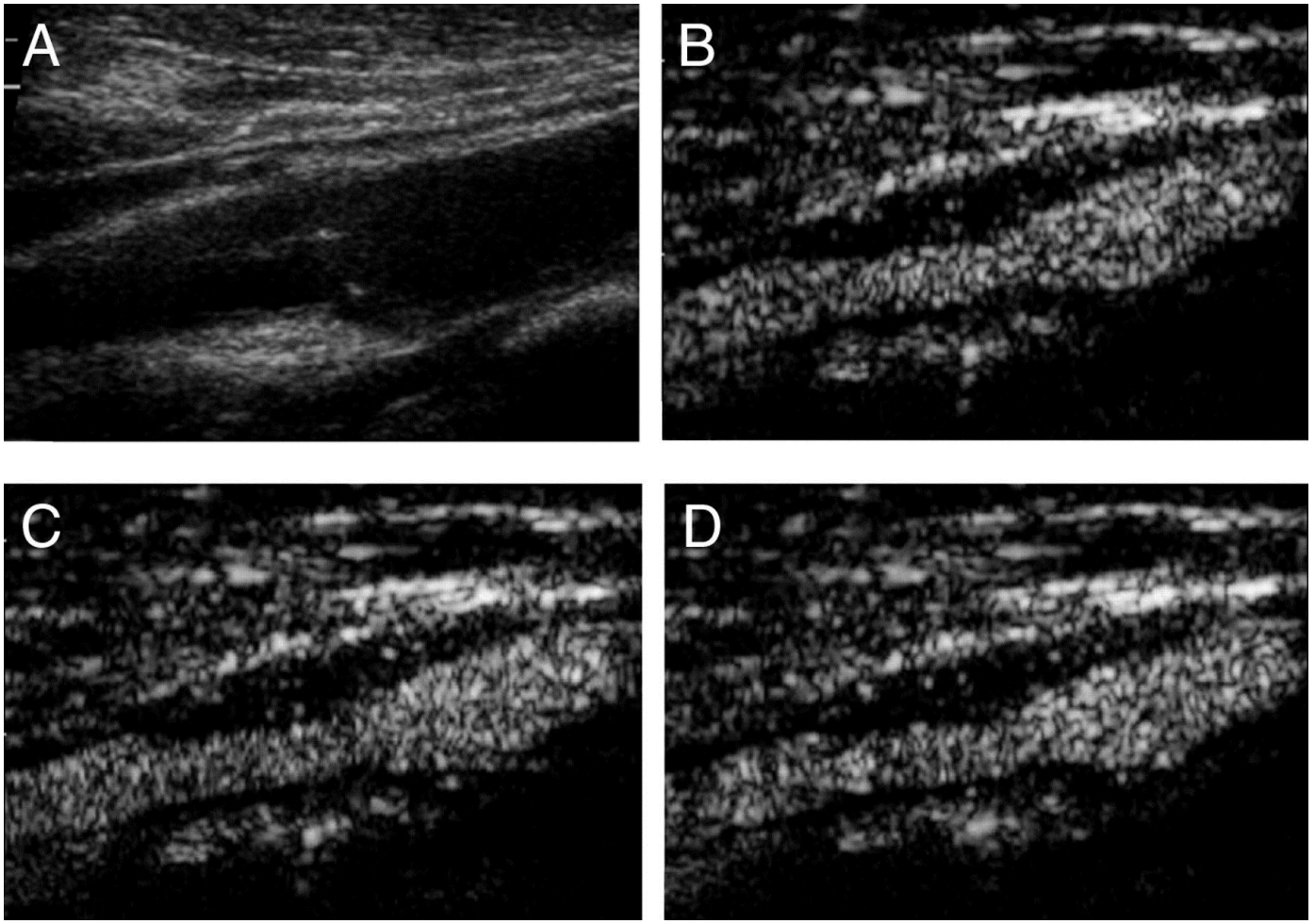
# Carotid plaque



# Contrast-enhanced ultrasound imaging of the vasa vasorum: from early atherosclerosis to the identification of unstable plaques

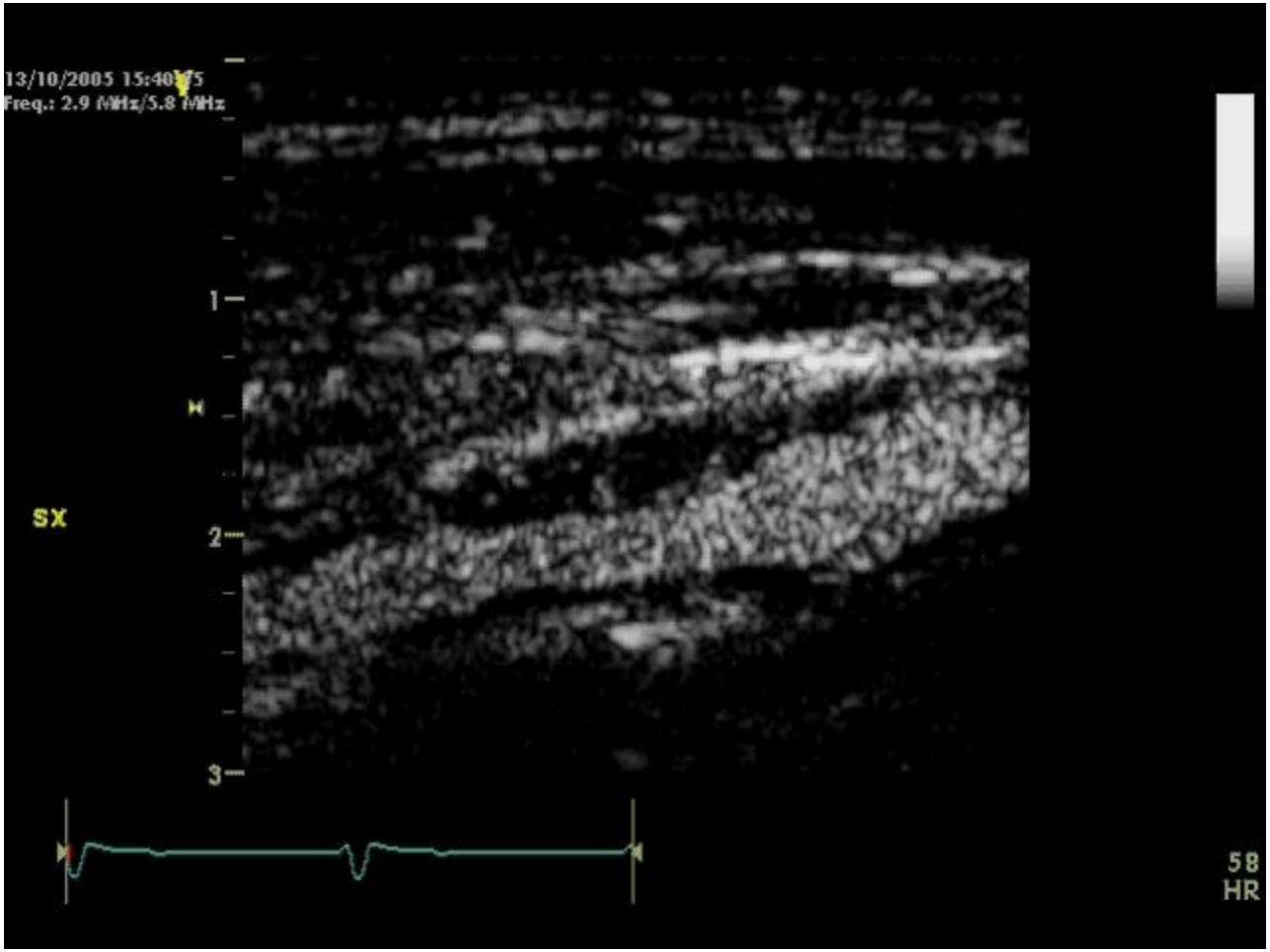


# Hypoechoic Carotid Plaque With Extensive (Grade 2) Contrast-Agent Enhancement



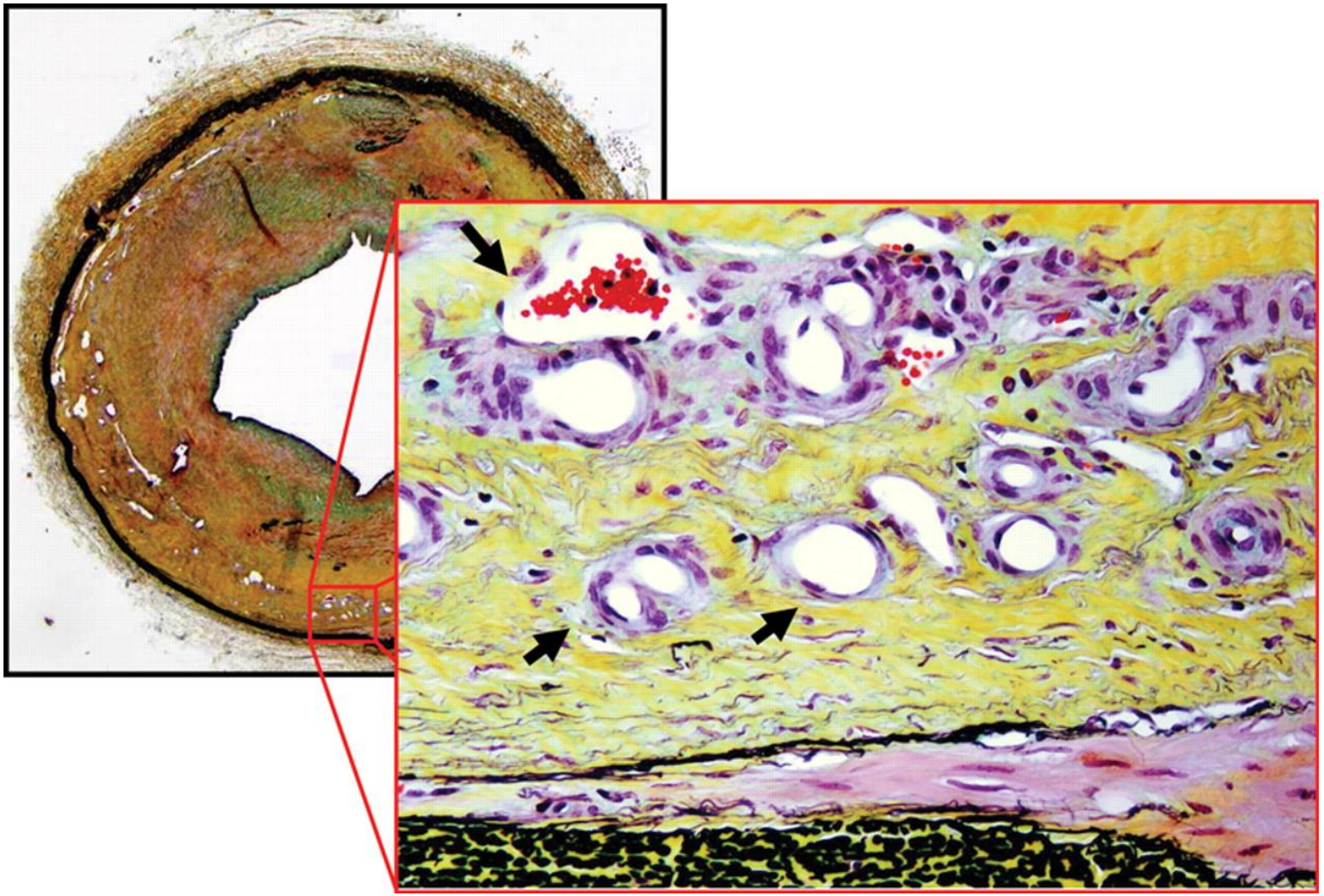

Coli, S. et al. J Am Coll Cardiol 2008;52:223-230

# Hypoechoic Carotid Plaque With Extensive (Grade 2) Contrast-Agent Enhancement




**Coli, S. et al. J Am Coll Cardiol 2008;52:223-230**

**Histology sample demonstrating neovascularization (vasa vasorum indicated by the black arrows) in the tunica media (Movat pentachrome staining), after 43 weeks follow-up.**

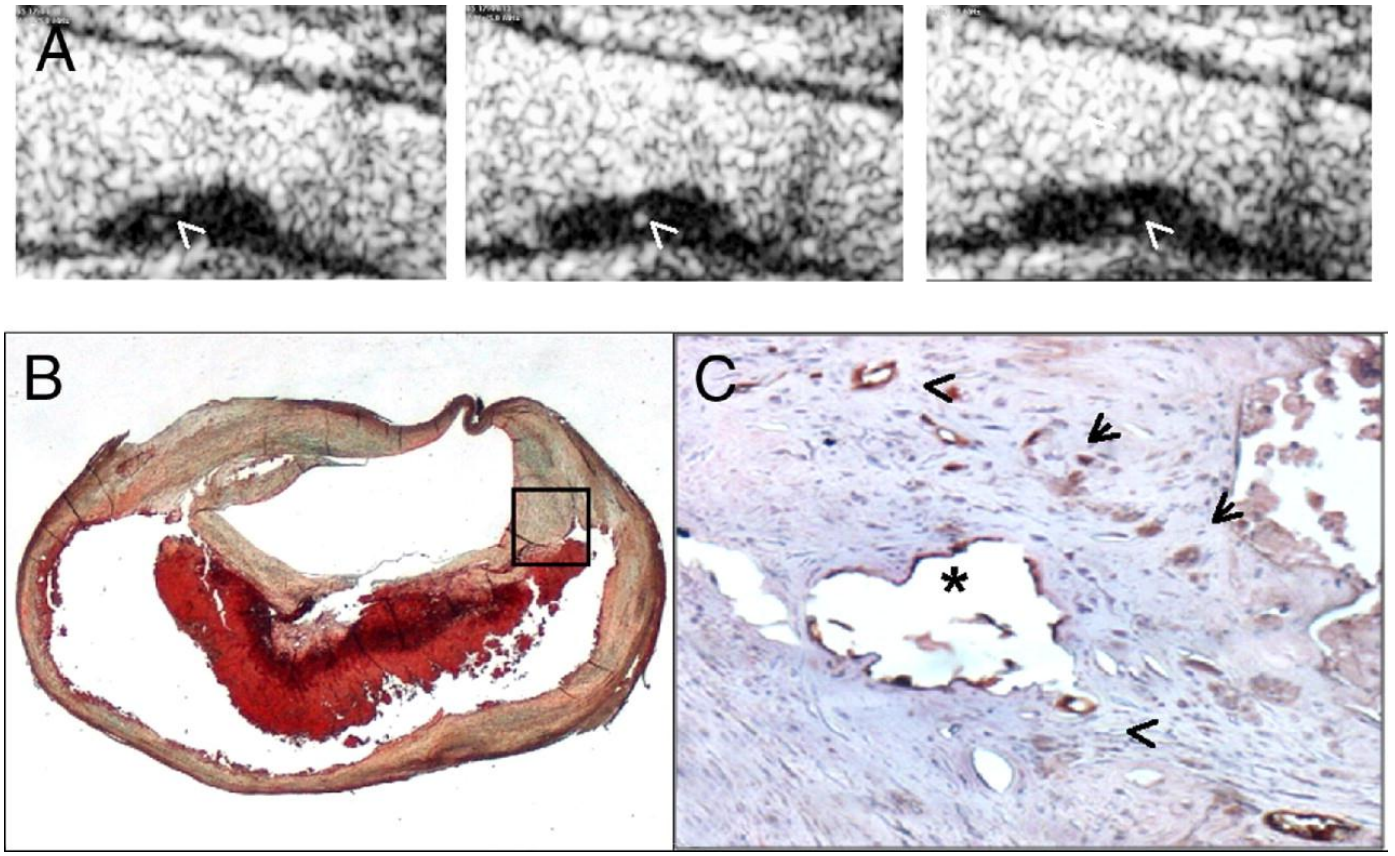


**Schinkel A F et al. Eur J Echocardiogr 2010;11:659-664**



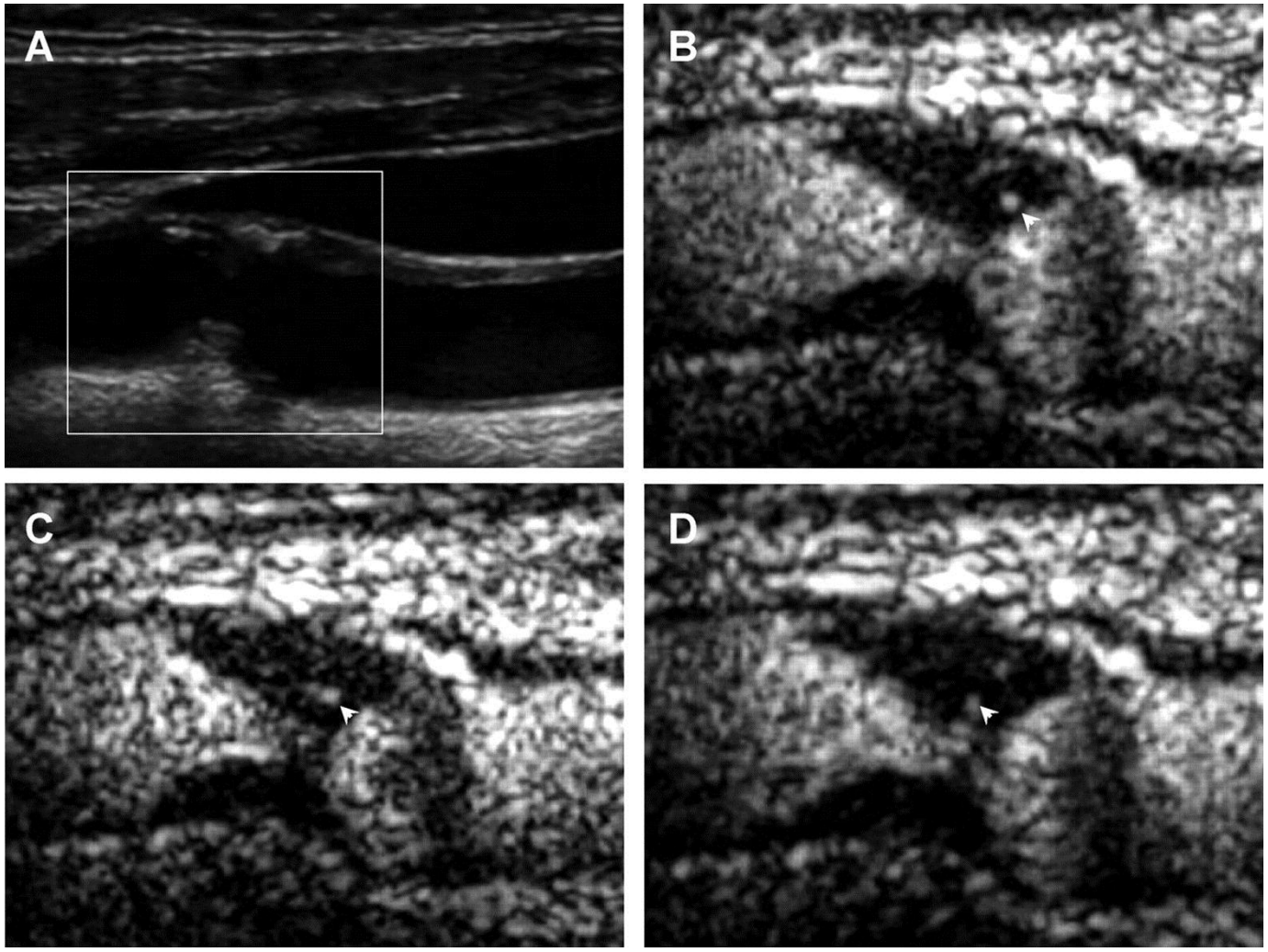
European Journal of Echocardiography

# Plaque With Grade 2 Contrast-Agent Enhancement Showing Abundant Neovascularization at Histology




Coli, S. et al. J Am Coll Cardiol 2008;52:223-230

**Figure 2. Carotid artery with intraplaque neovascularization grade 2 on contrast-enhanced ultrasound.**




**Staub D et al. Stroke 2010;41:41-47**

# Vasa Vasorum and Plaque Neovascularization on Contrast-Enhanced Carotid Ultrasound Imaging

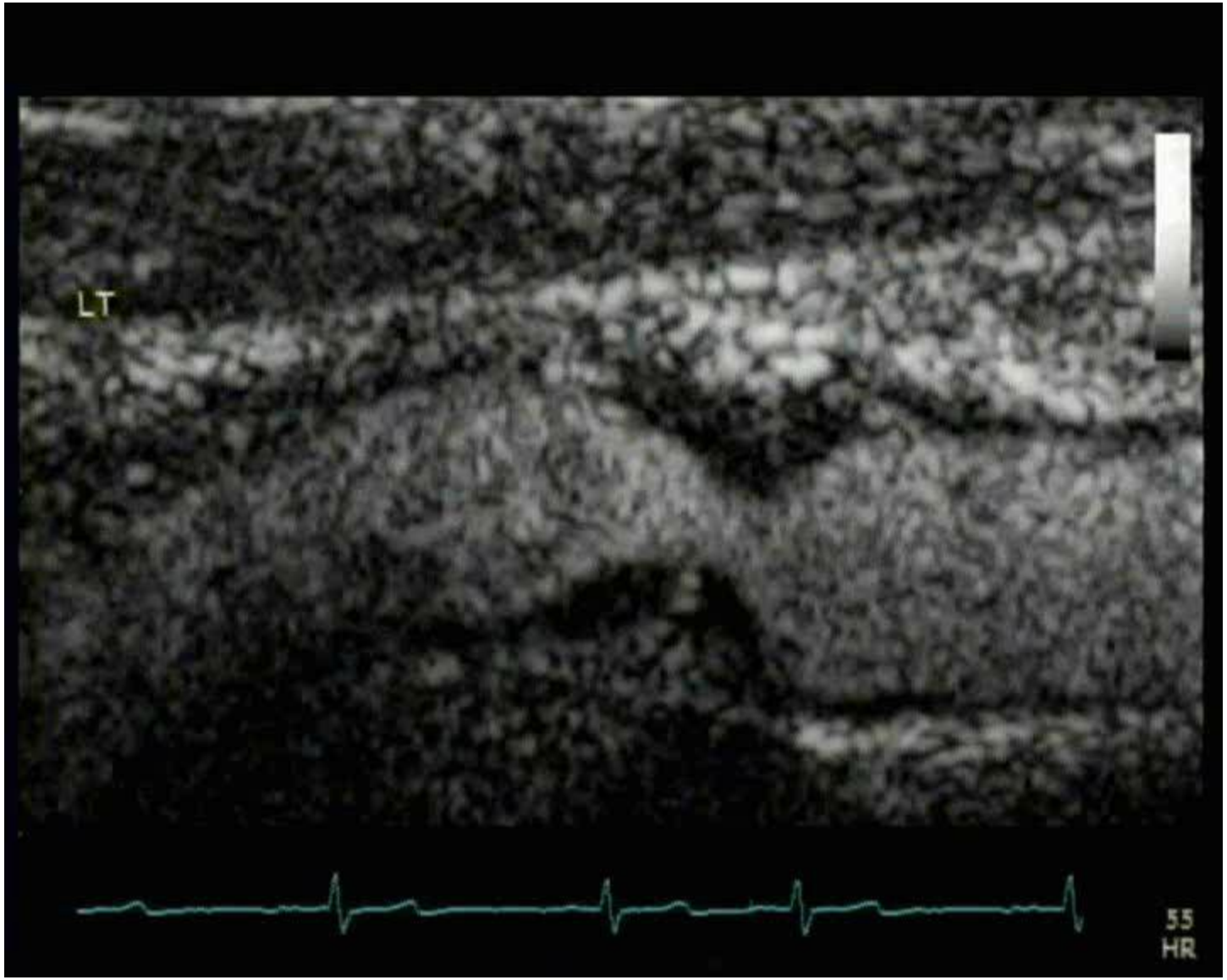
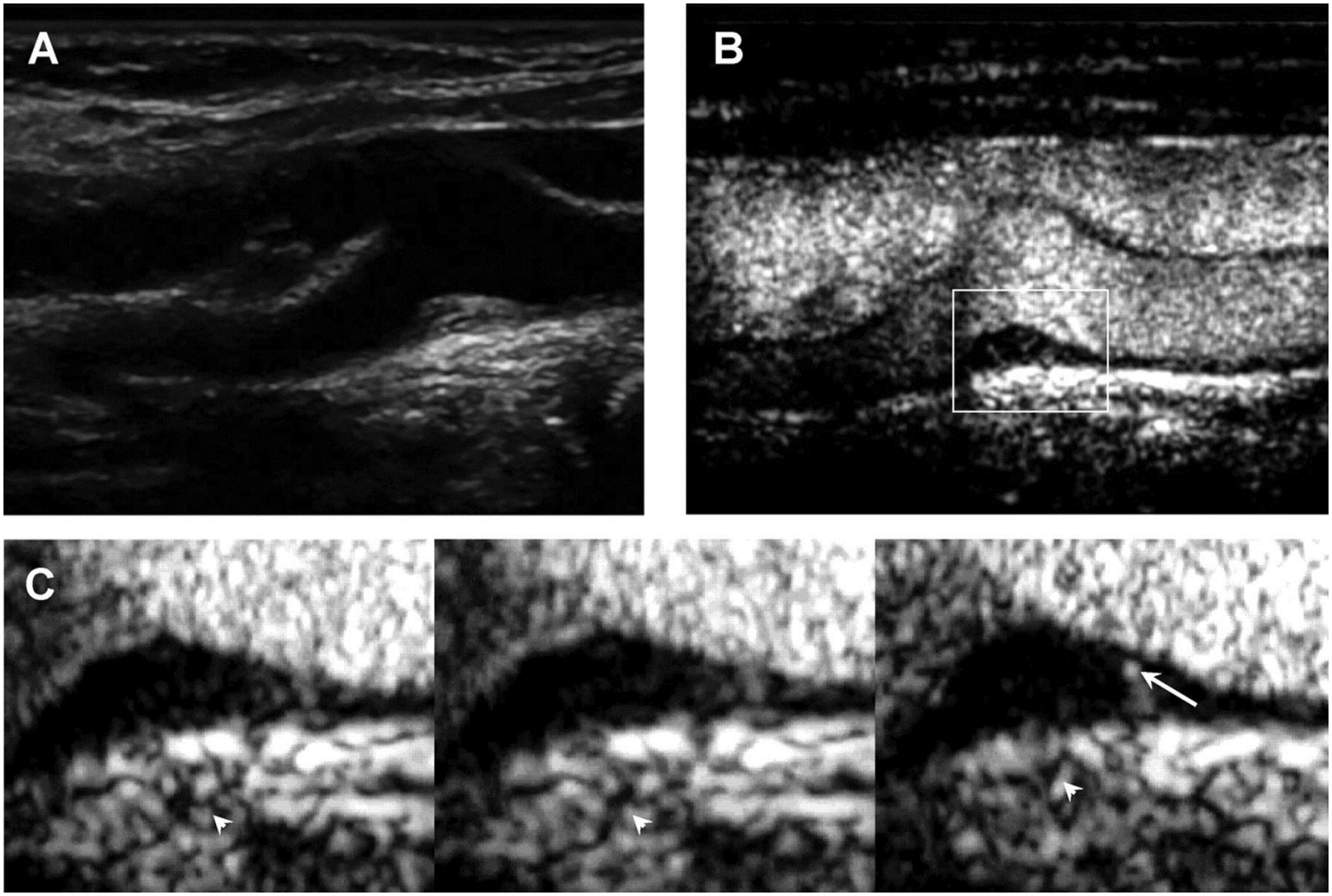
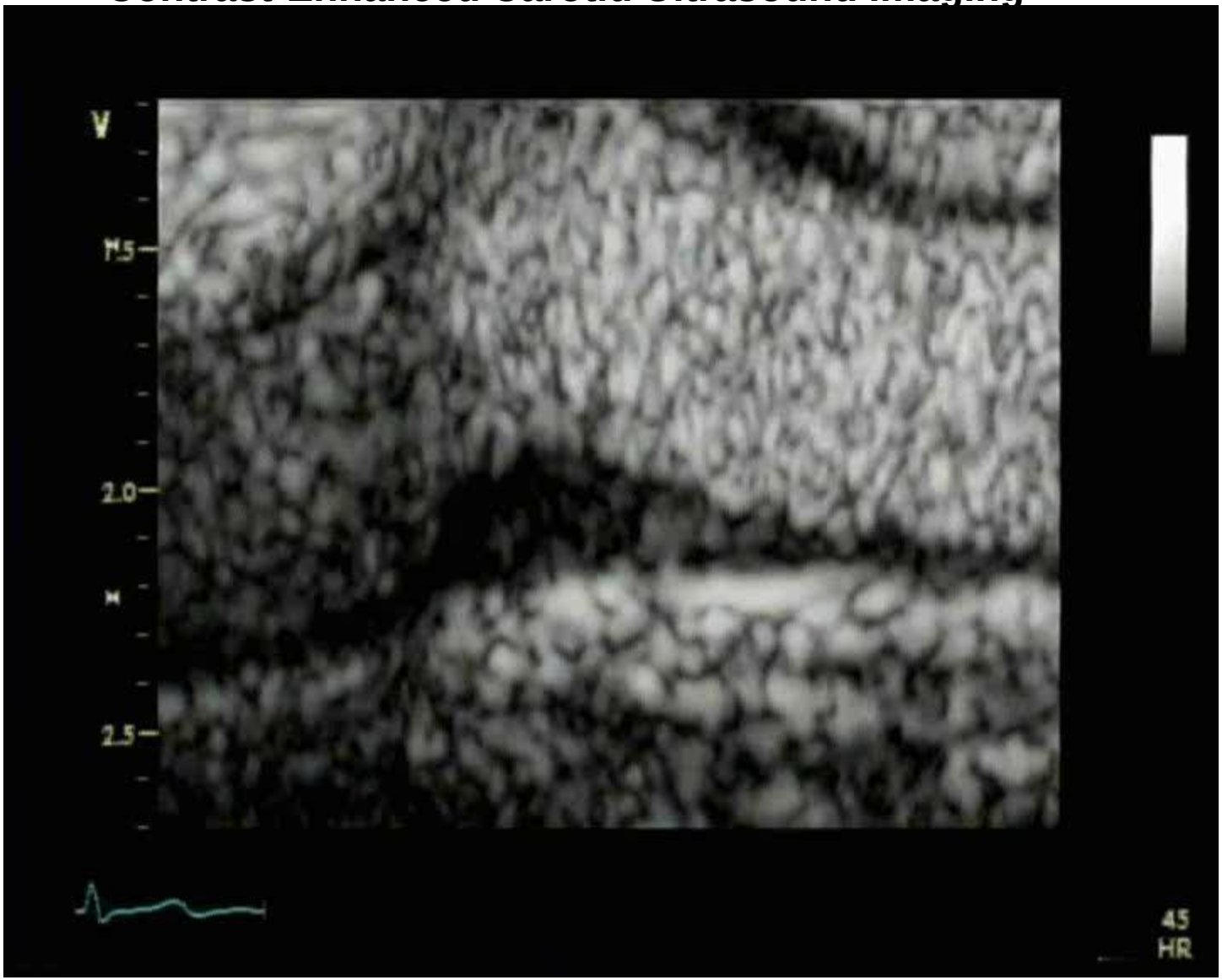


**Figure 1. Carotid artery with vasa vasorum grade 2 on contrast-enhanced ultrasound.**




**Staub D et al. Stroke 2010;41:41-47**

# Vasa Vasorum and Plaque Neovascularization on Contrast-Enhanced Carotid Ultrasound Imaging

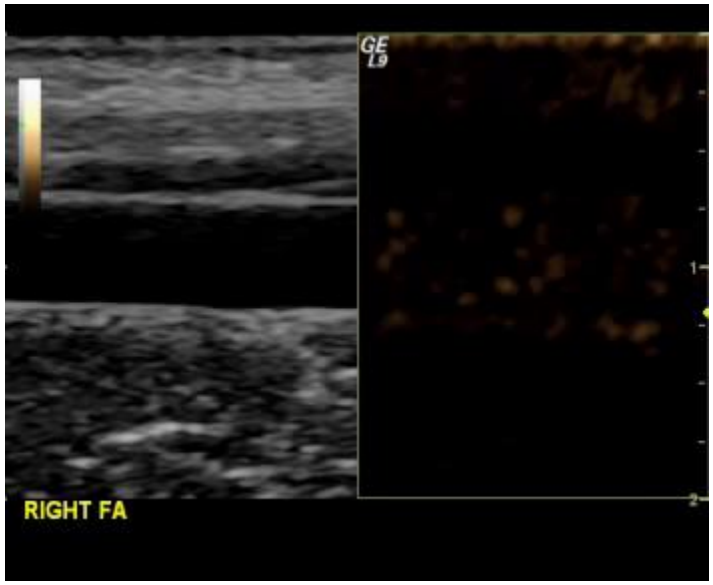


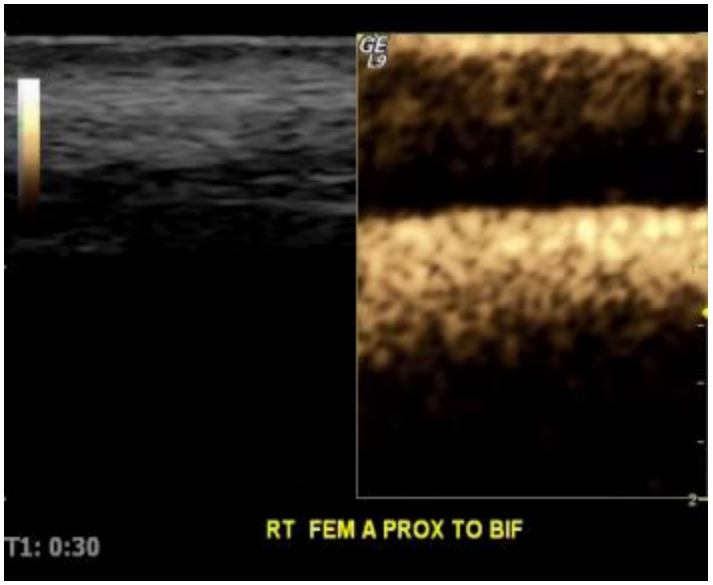
**CONCLUSIONI**

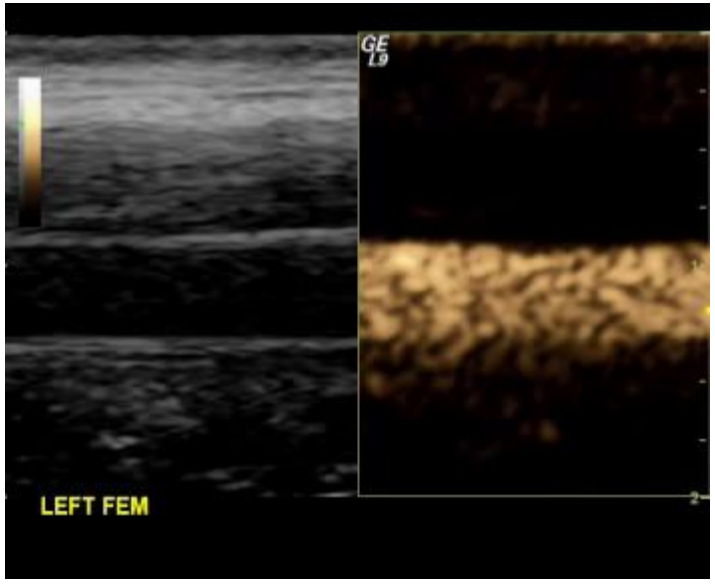
Con le nuove tecniche di indagine ultrasonica dei grossi vasi arteriosi (carotidi) nel paziente iperteso è possibile, con il sistema echotracking RF, determinare automaticamente l'entità degli IMT, dell' augmentation index (onda riflessa), il grado di distensibilità della parete arteriosa (stiffness) e la PWV, tutti elementi che entrano in gioco nel coupling arterio-ventricolare e contribuiscono, insieme al stroke volume ed alle resistenze periferiche, al determinismo della PA sistolica e diastolica centrale e locale.
Inoltre, lo studio della morfologia della placca con la tecnica ultrasonica a contrasto con microbolle, consente non solo una migliore definizione della superficie e del grado di stenosi, ma permette anche di visualizzare la eventuale neoangiogenesi dei *vasa vasorum*, espressione della attività flogistica-immunitaria del processo ATS, ritenuta responsabile delle complicanze di placca e pertanto marker precoce di vulnerabilità ed instabilità della placca.

# FINE

## Grazie per l'attenzione


GE
L9
RIGHT FA


GE
L9
T1: 0:30
RT FEM A PROX TO BIF


GE
L9
LEFT FEM

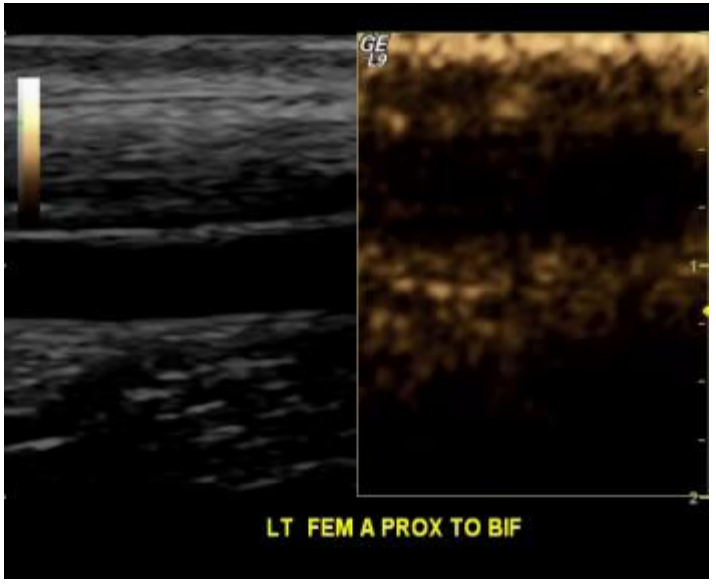
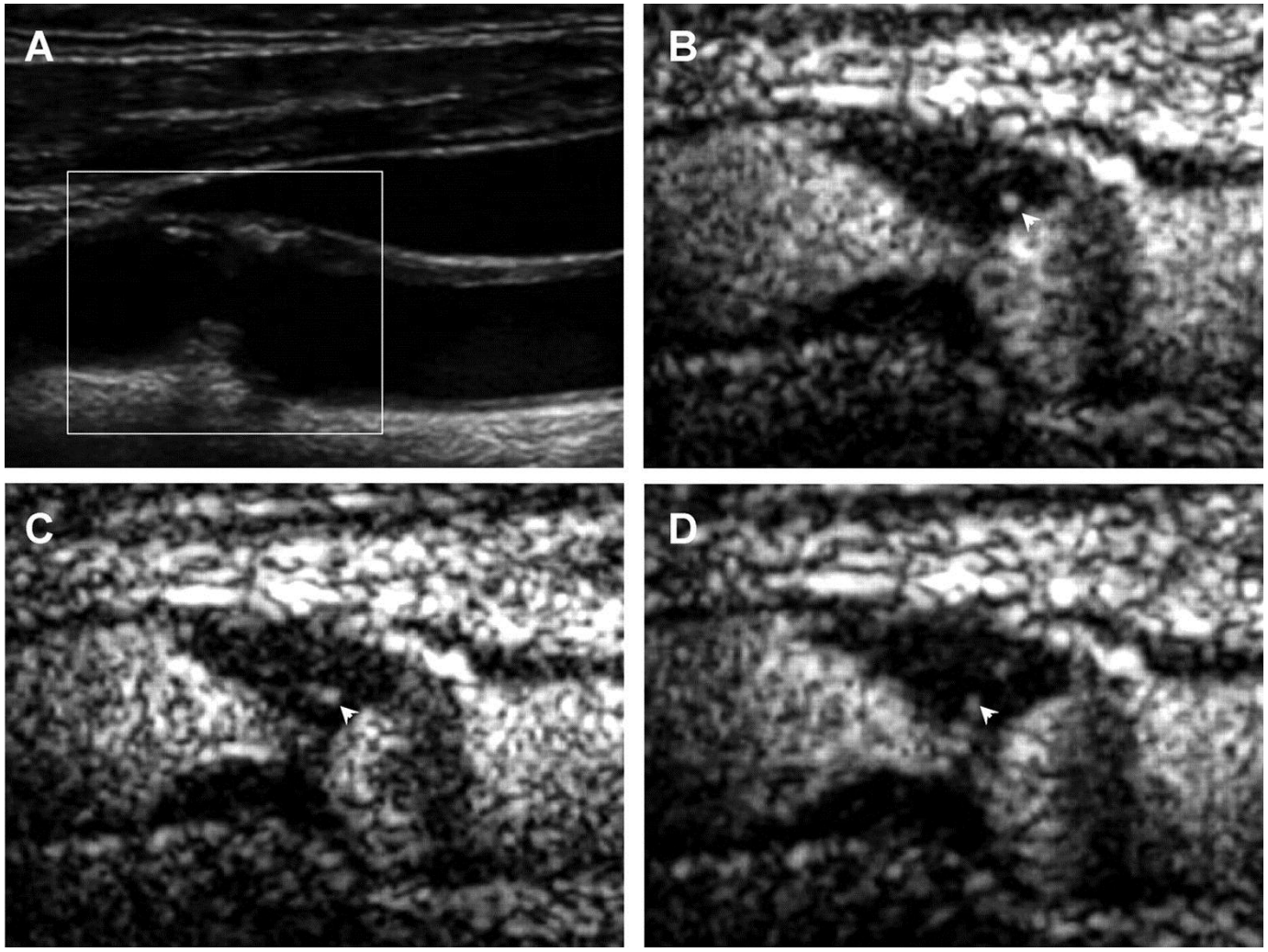
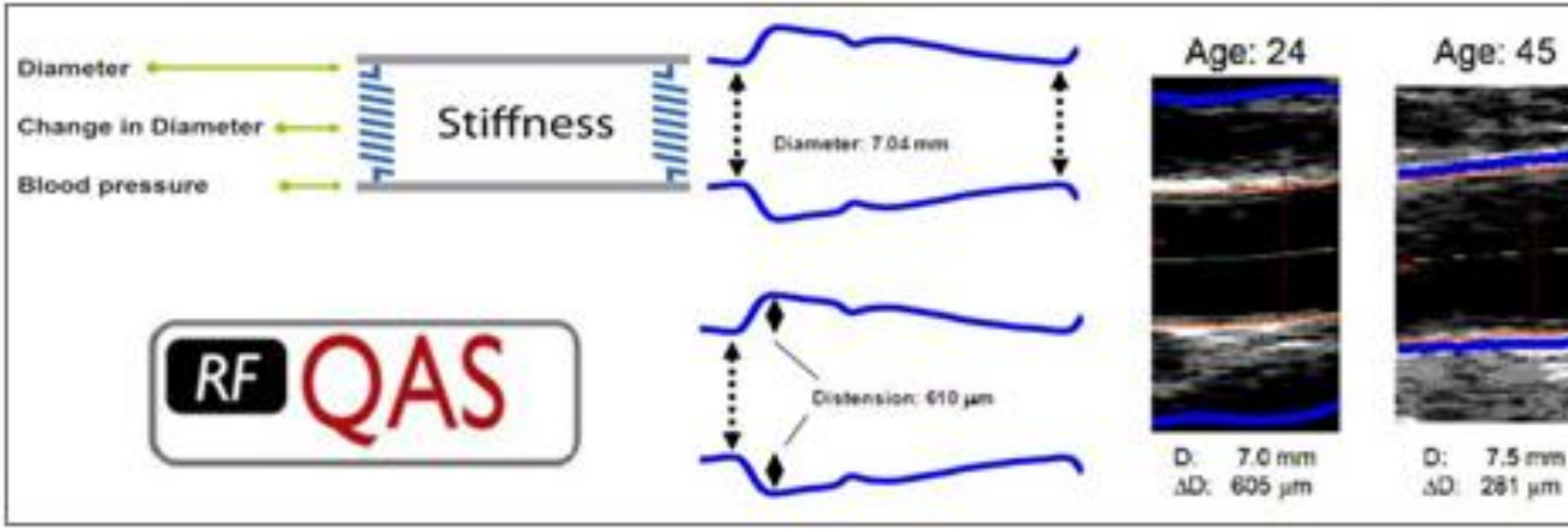
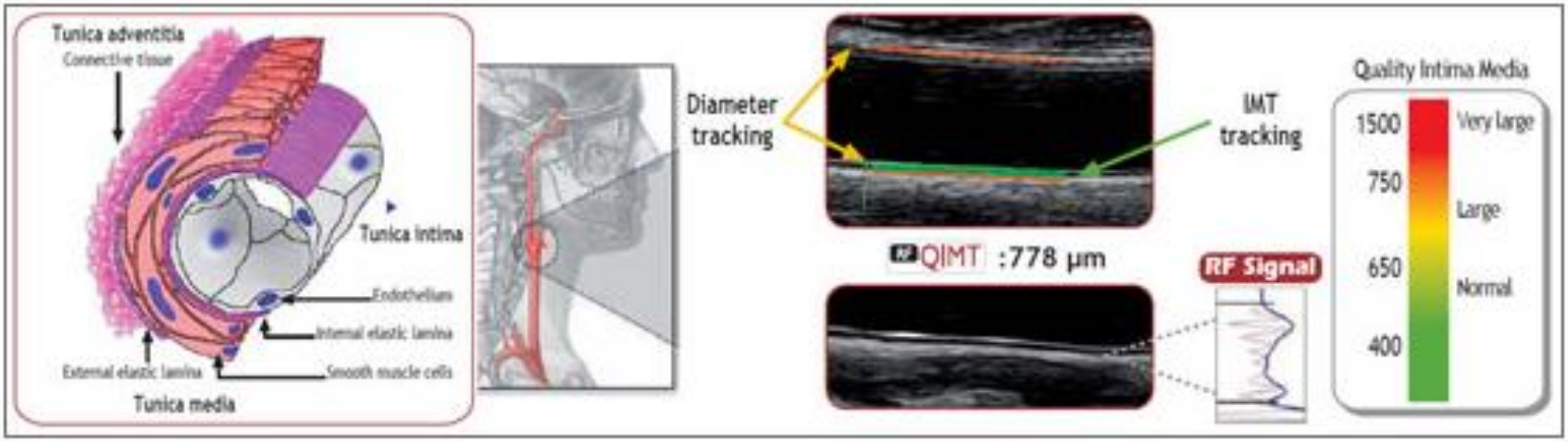

GE
L9
LT FEM A PROX TO BIF

**Figure 2. Carotid artery with intraplaque neovascularization grade 2 on contrast-enhanced ultrasound.**




**Staub D et al. Stroke 2010;41:41-47**


Diameter
Change in Diameter
Blood pressure
Stiffness
Diameter: 7.04 mm
Distension: 610 µm
RF QAS
Age: 24
Age: 45
D: 7.0 mm
ΔD: 605 µm
D: 7.5 mm
ΔD: 281 µm


Tunica adventitia
Connective tissue
Tunica intima
Endothelium
Internal elastic lamina
External elastic lamina
Smooth muscle cells
Tunica media
Diameter tracking
IMT tracking
QIMT :778 µm
RF Signal
Quality Intima Media
1500
750
650
400
Very large
Large
Normal

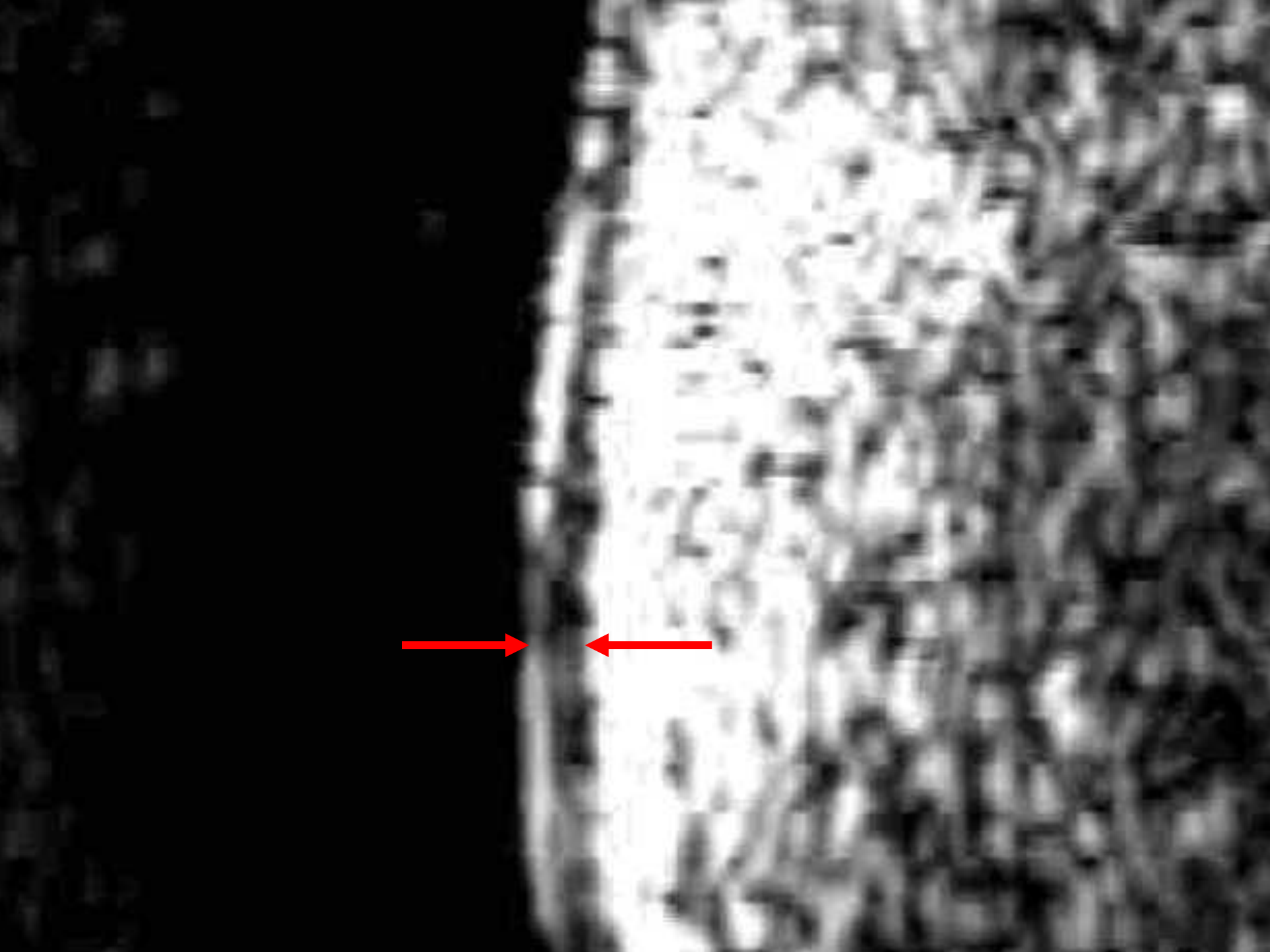
# Techniques

- Pressure/distension changes
- Pulse wave velocity
- Pulse wave analysis

# Pulse wave velocity

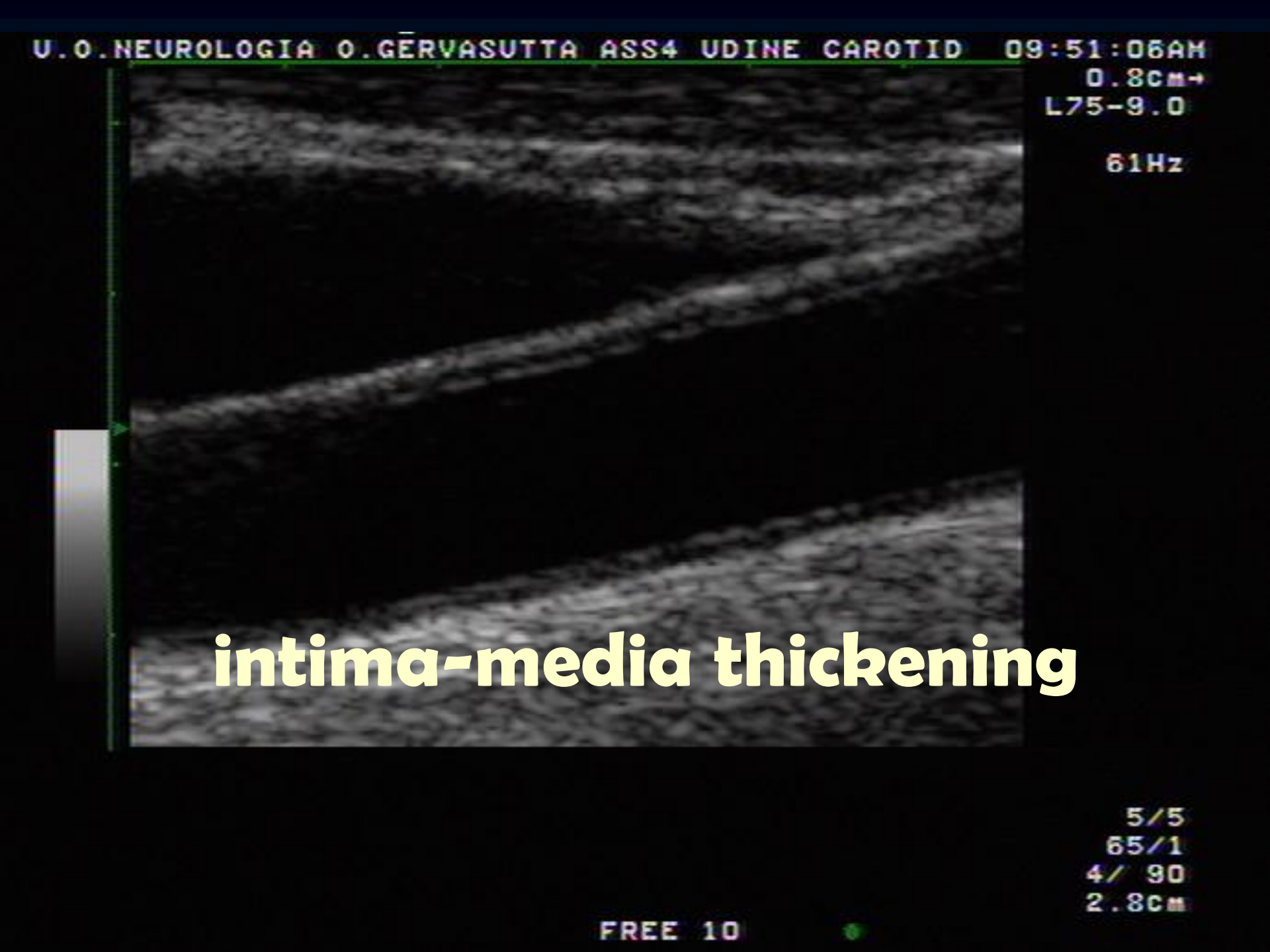
- Arrival of pulse wave can be detected by
  - Pressure transducers (e.g. tonometers)
  - Infra-red sensors
  - Doppler ultrasound (detects flow wave)
  - MRI

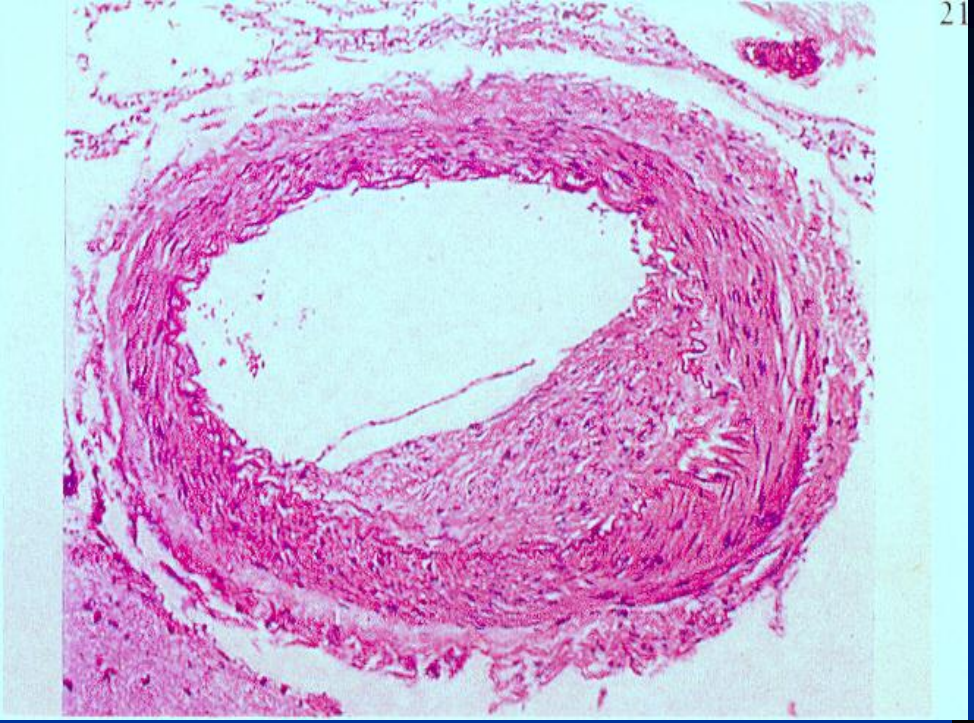
- Sequential arterial measurements can be made by synchronising waves with the ECG



# Risk Factor

- Strong and independent association
- Biological plausibilty
- Regression with treatment
- Reproducibility
- Standardization
- Low cost


U.O.NEUROLOGIA O.GERVASUTTA ASS4 UDINE CAROTID 09:51:06AM
0.8cm
L75-9.0
61Hz
intima-media thickening
5/5
65/1
4/ 90
2.8cm
FREE 10

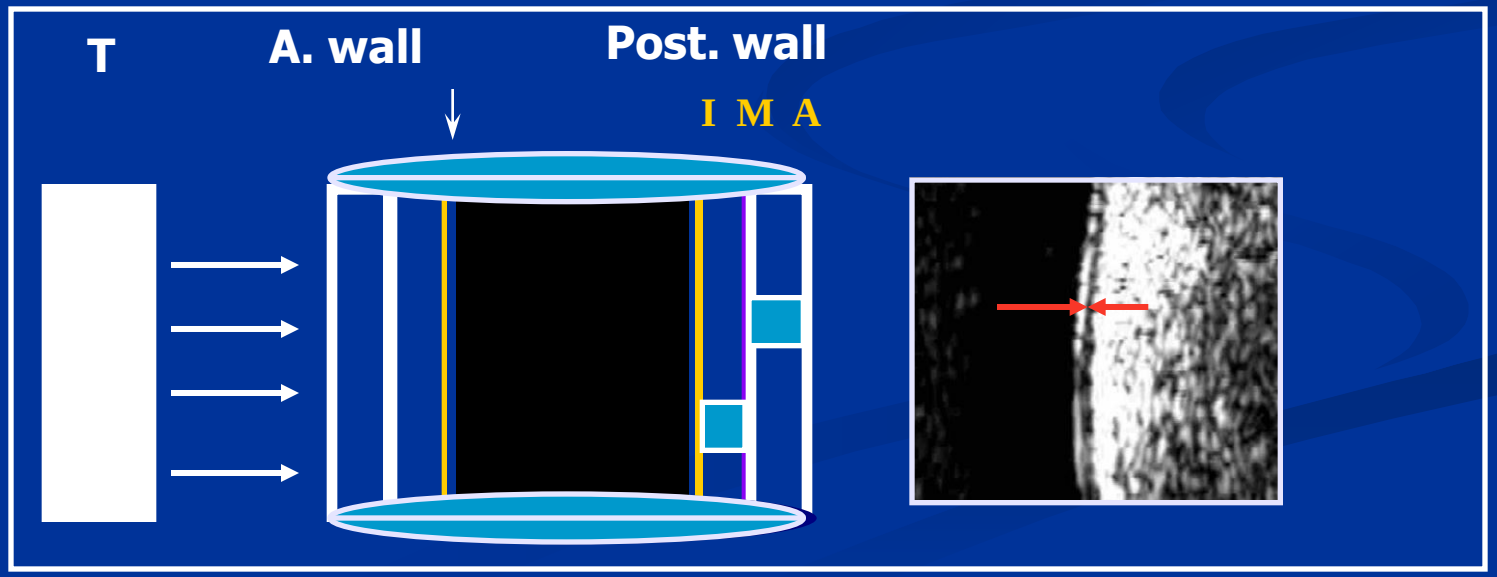



L75-9.0
61Hz
5/5
65/1
4/ 90
2.8cm
FREE 10

# CCA IMT

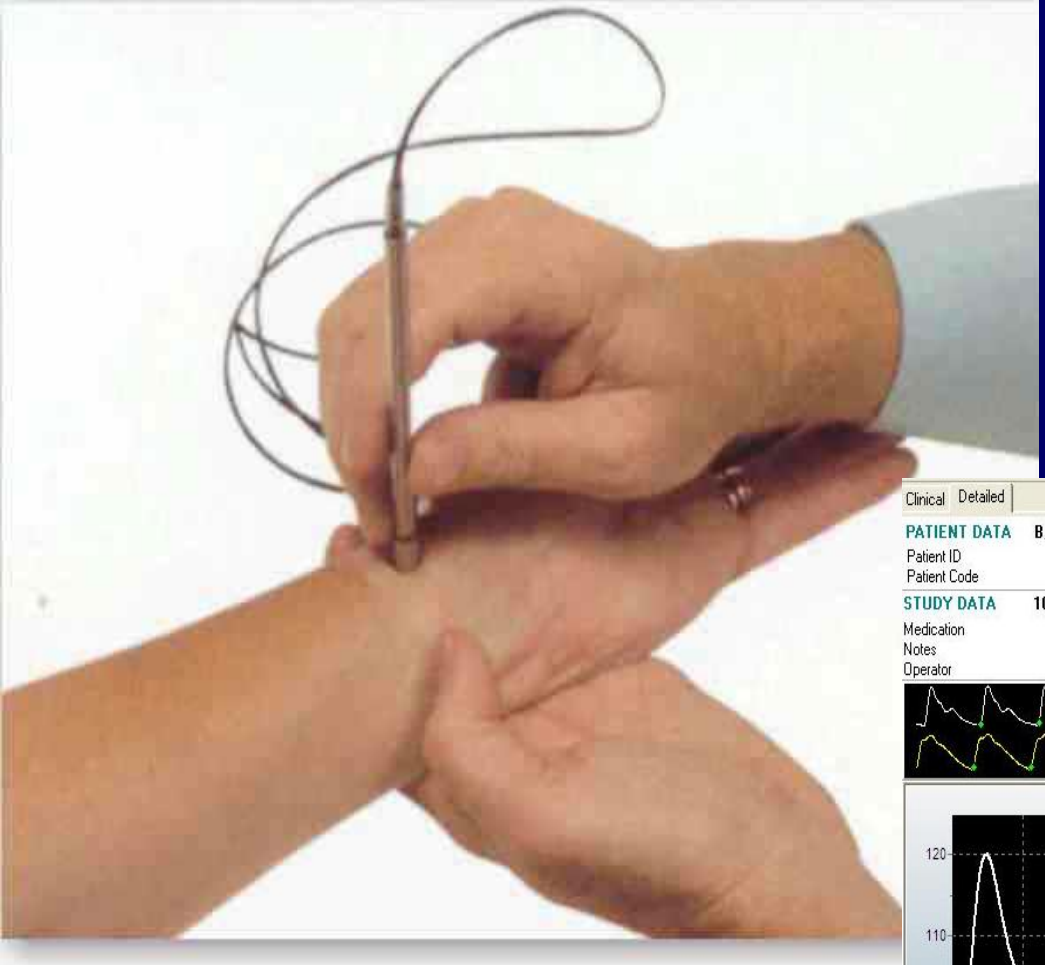
- **Validazione**

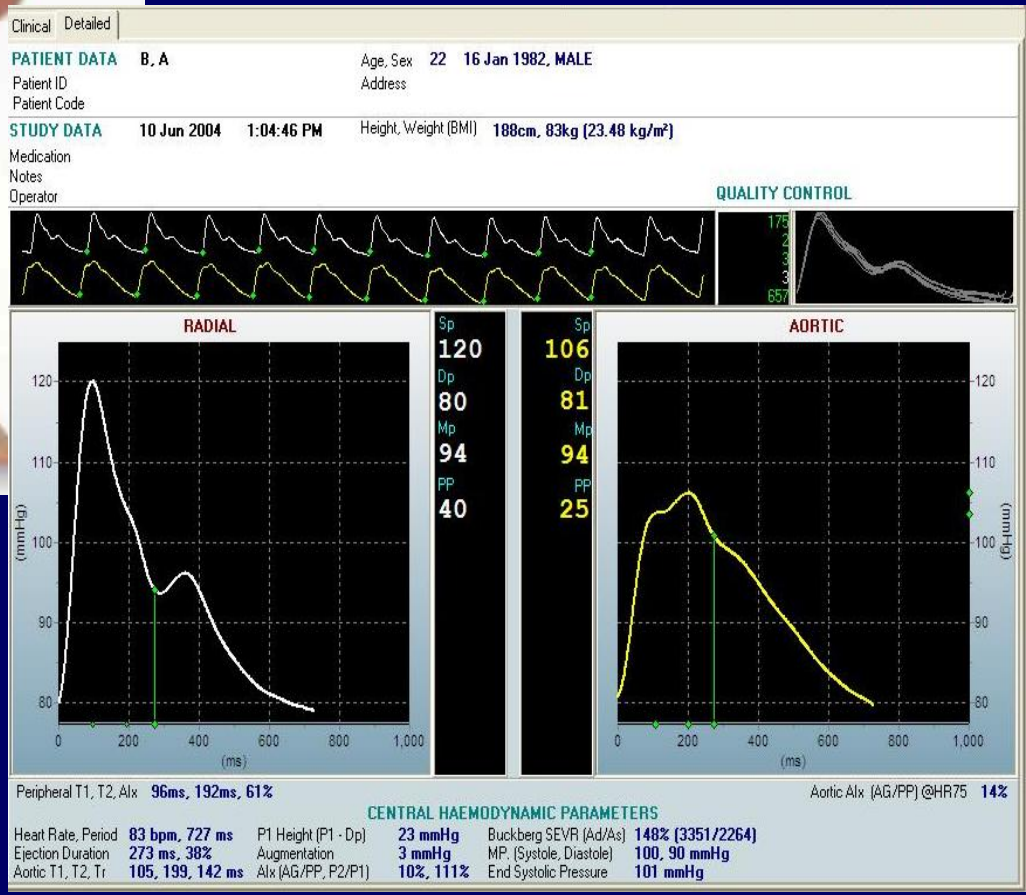
- **Correlazione:**
- **Struttura anatomica**
- **Pattern ecografico di due linee parallele iperecogene**




(Pignoli P., Circulation 1986)

# Sphygmocor






## Pulse Wave Velocity & Augmentation Index

- Uses Arterial tonometer (radial)

# FINE

## Grazie per l'attenzione