

Coronary calcium score

Atherosclerosis

■ Repeated inflammation and repair

- ◆ Clinical end points
 - ☞ Related to arterial luminal stenosis
- ◆ Subclinical disease
 - ☞ Arterial wall disease
 - ☞ Progress without symptoms for decades

■ Visualization

- ◆ Luminogram
 - ☞ Detection of protruding lesion
 - ☞ Intervention
- ◆ Component of vessel wall
 - ☞ Detection of protruding and non-protruding lesion
 - ☞ Tissue characterization

Atherosclerosis imaging

- Intimal/medial thickness by carotid US
 - ◆ ∞ risk of future stroke
- Coronary artery calcium by EBT/MD CT
 - ◆ ∞ risk of future cardiac event
- MRI
 - ◆ Characterization of plaques
 - ◆ Blood flow quantification

How to do coronary artery calcium score (CACs) study ?

EKG gating in EBT/MD CT

■ Prospective EKG triggering

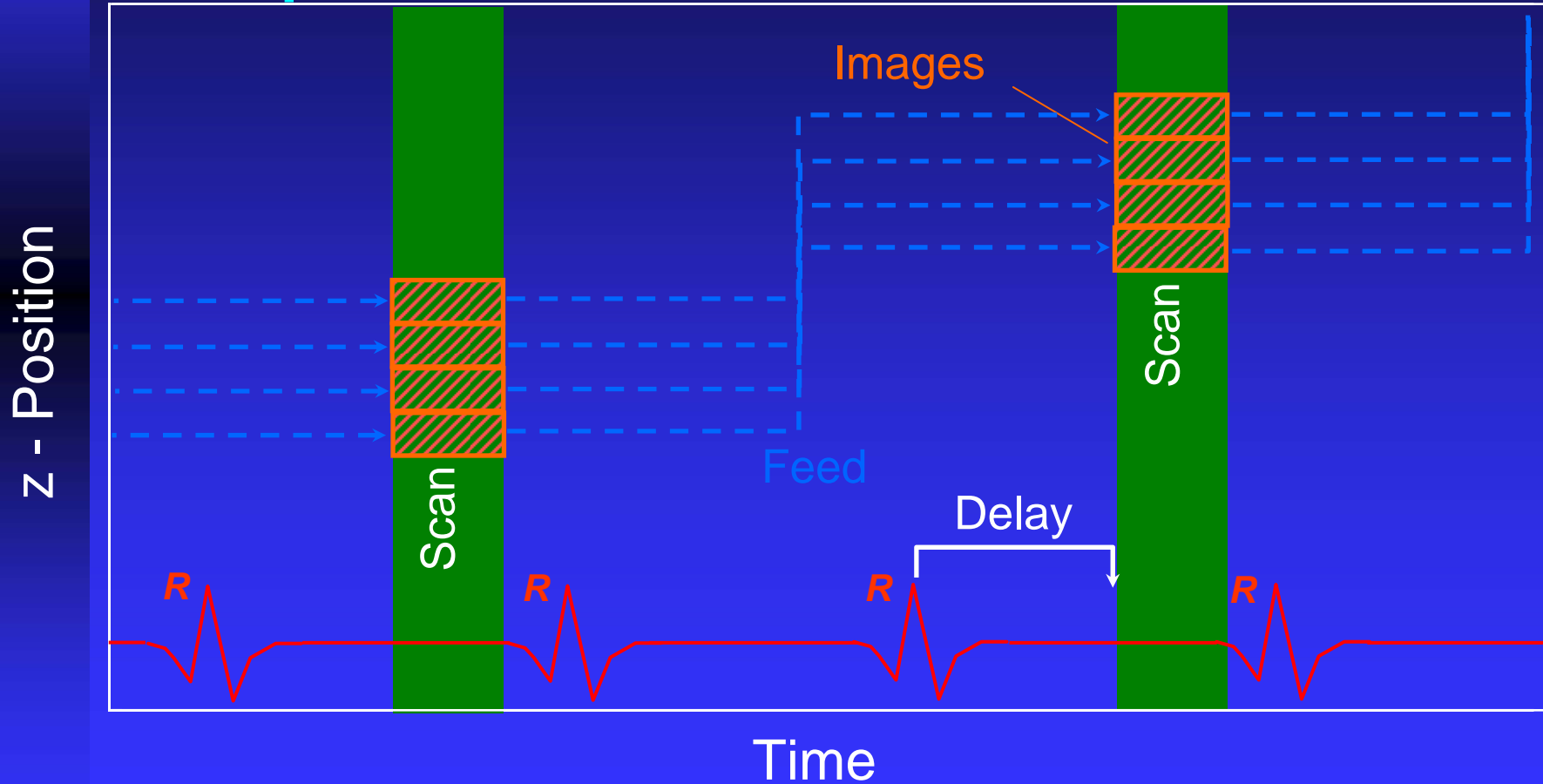
- ◆ Sequential multislice acquisition
- ◆ Identical reconstruction time for all 3 vessels

■ Retrospective EKG gating

- ◆ Continuous Spiral Acquisition & Parallel ECG Recording
- ◆ Retrospective phase selection for image reconstruction
 - ☞ LAD 60-70% of RR interval
 - ☞ LCX 50% of RR interval
 - ☞ RCA 40% of RR interval

Kopp et al. Radiol 2001;221:683

Prospective ECG-Triggering & Sequential multi-slices



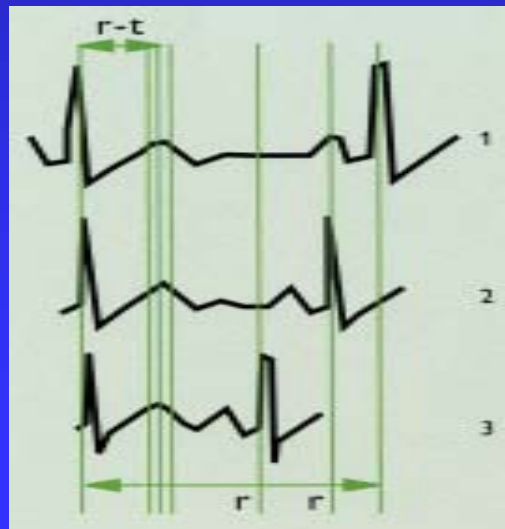
EBT vs. MD-CT

■ Temporal resolution

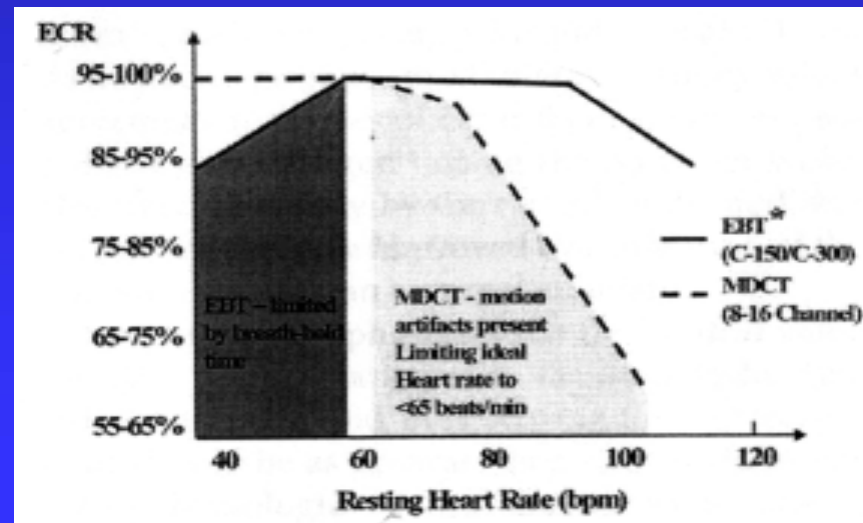
- ◆ EBT; 33, 50, 100 msec

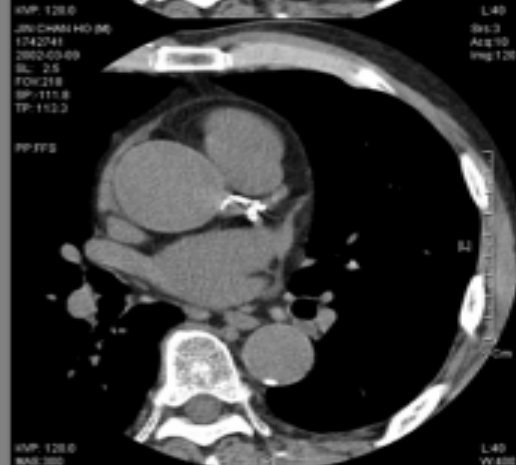
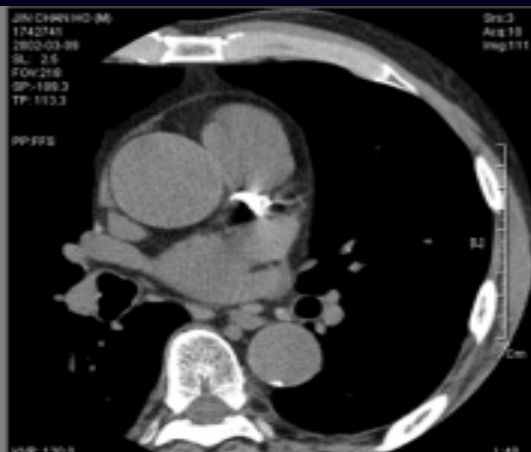
MD CT; gantry rotation time $\times (360+40)/2 \approx 200$ msec

- ◆ EBT; HR 55-110 vs. MD CT; HR <65



Length of diastolic phase vs. HR





Measurement of CAC score

■ Agatston method

- ◆ $>130\text{HU}$
- ◆ area ≥ 2 contiguous pixels
- ◆ density factor (130-199=1; 200-299=2; 300-399=3; $>400=4$)

Agatston et al. JACC '90;34:777

■ Calcium volume method

- ◆ Linear interpolation to isotropic volume
- ◆ All voxels (mm^3) $>130\text{HU}$ *Callister et al. Radiol 1998*

■ Calcium mass method

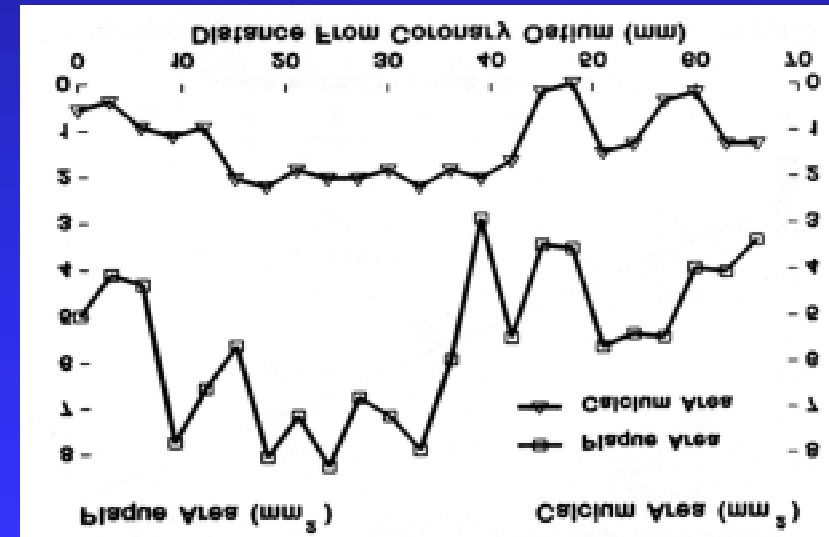
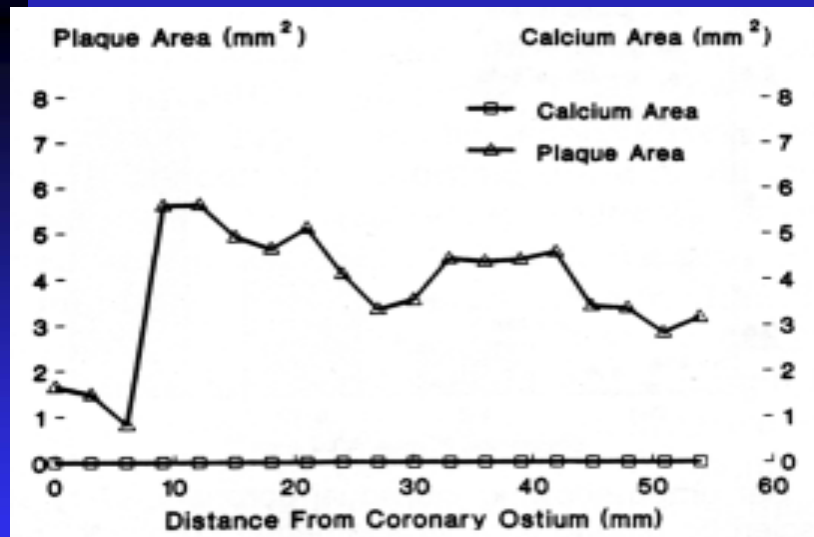
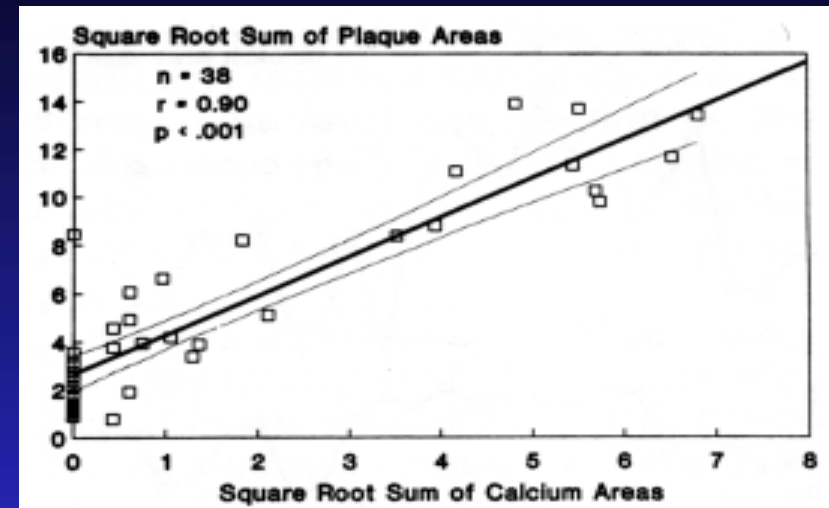
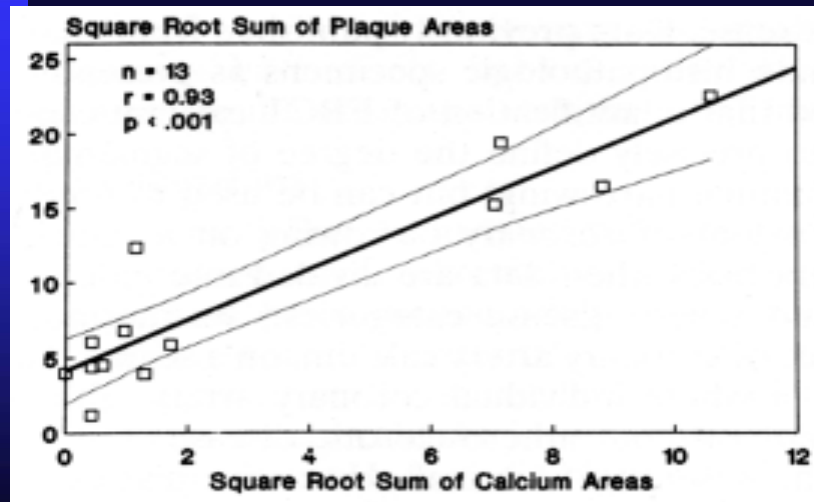
- ◆ Pixel volume X attenuation value X ratio = total mineral content Ca equivalent (mg) *Hong et al. Radiol 2002*

Coronary artery calcium (CAC): Pathogenic significance & correlation

- Pathognomonic of intimal atherosclerosis
 - ◆ No Monckeberg's calcific medial sclerosis in CA
- Ca in ashed specimen \propto CAC ($r=.97$)
- Histologic plaque area \propto CAC in each heart ($r=.96-.87$) and each artery ($r=.90-.70$)
- CAC \propto total atherosclerotic plaque burden**
- Poor correlation with CAC and a site-by-site luminal stenosis ($r=.07$)

*Mautner et al. Radiol 94;192:619,
Rumberger et al. Circul '95;92:2157
Sangiorgi et al. JACC '98;31:126*

Histopathologic correlation



CAC score 0 ≠ Absence of atherosclerosis

Calcified plaque = 20% of total plaque burden

Coronary calcium

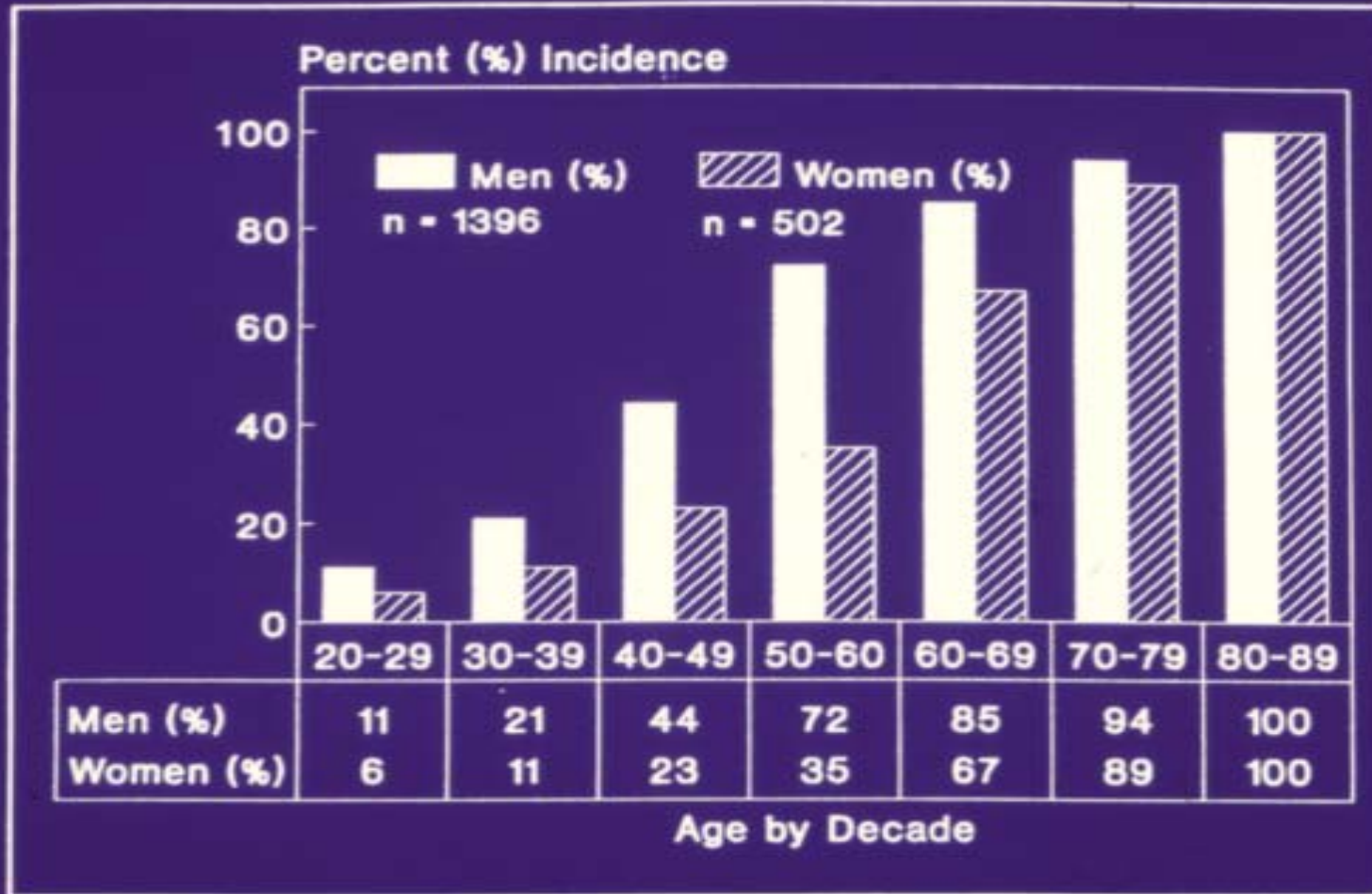
- Calcium is associated with coronary **atherosclerotic disease activity**.
 - ◆ CA seen in all degrees of atherosclerosis
 - ☞ From stage III (microscopic calcification) to VI
 - ◆ All subtypes of plaque coexist together by IVUS
 - ◆ Similar CA in stable and ruptured plaque
 - ◆ CA in IRA > non-IRA
 - ◆ >1000 had >50% AMI or death over 3yrs

Baumgart et al. JACC 97;30:57, Mascola et al. Am J Card 2002, Schmermund et al. Am J Card 2002, Wayhs et al. JACC 2002

CACS in general population

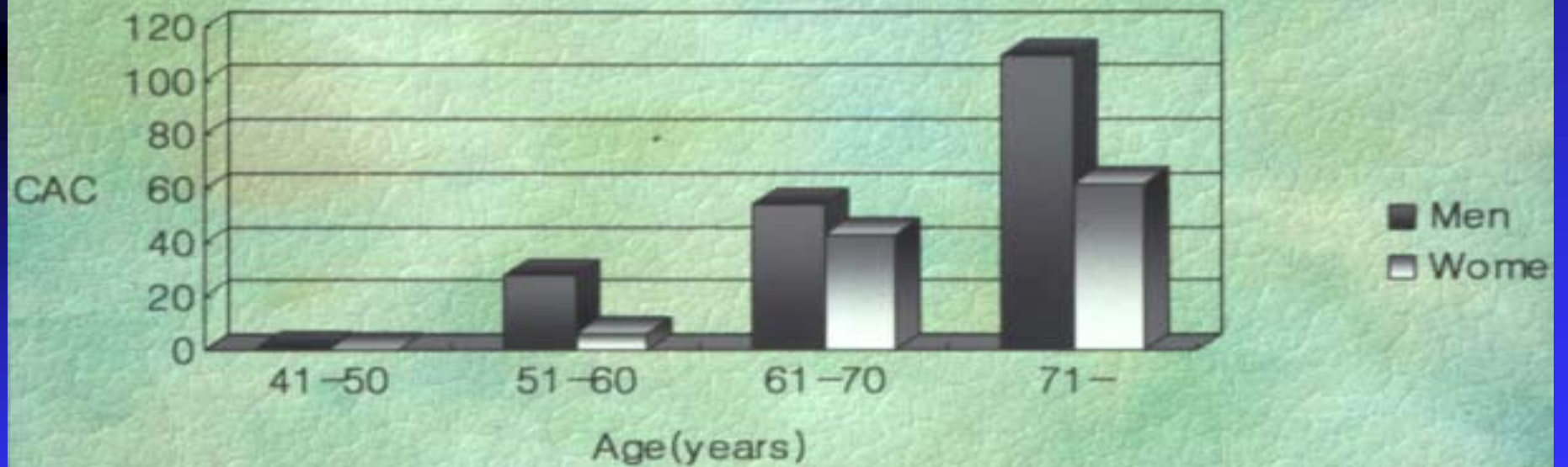
- Age
- Gender
- Risk factors for atherosclerosis
 - ◆ DM
 - ◆ hypertension
 - ◆ hypercholesterolemia (HDL <45mg/ml, LDL > 100mg/ml)
 - ◆ smoking (>10 cigarettes/day)
 - ◆ precocious family history (M<55, F<65)
 - ◆ obesity

Coronary Calcium Score in American

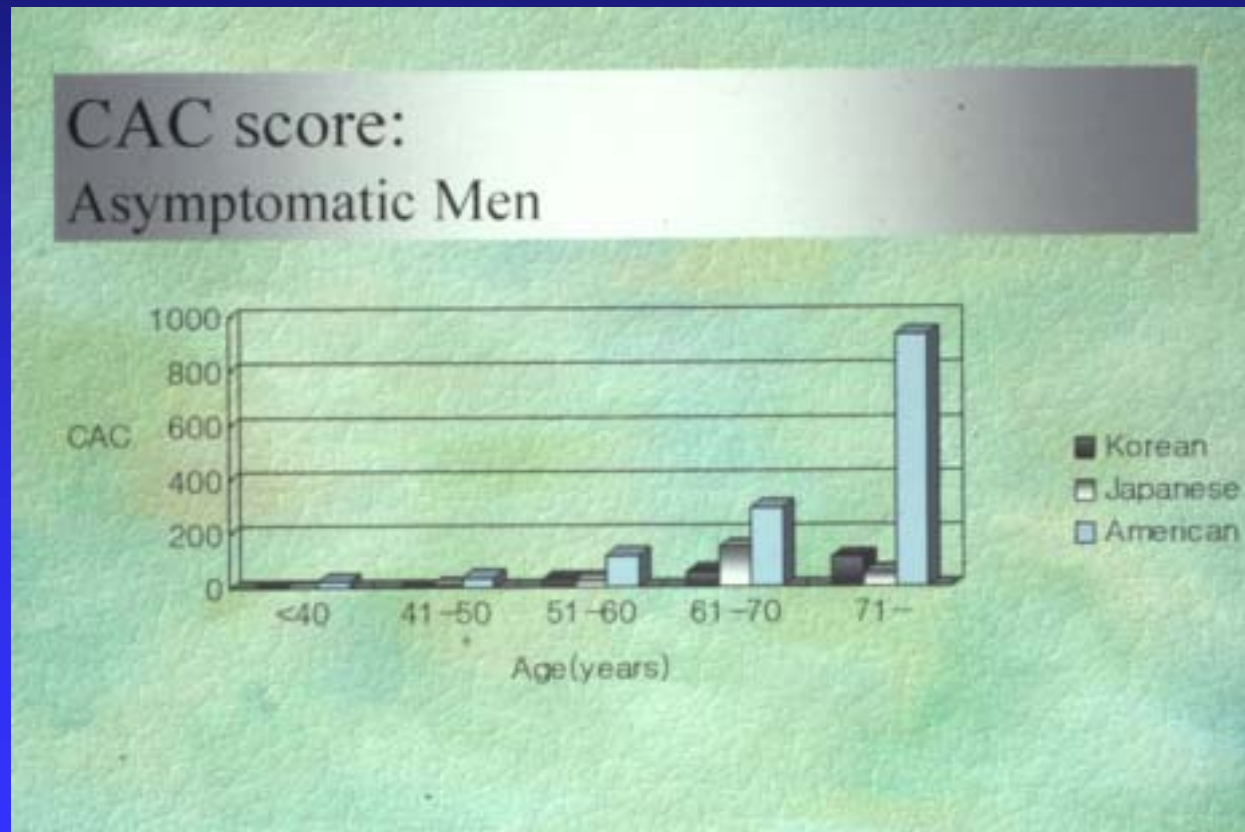


Prevalence of CAC mimic the incidence of CV atherosclerotic disease in men and women.

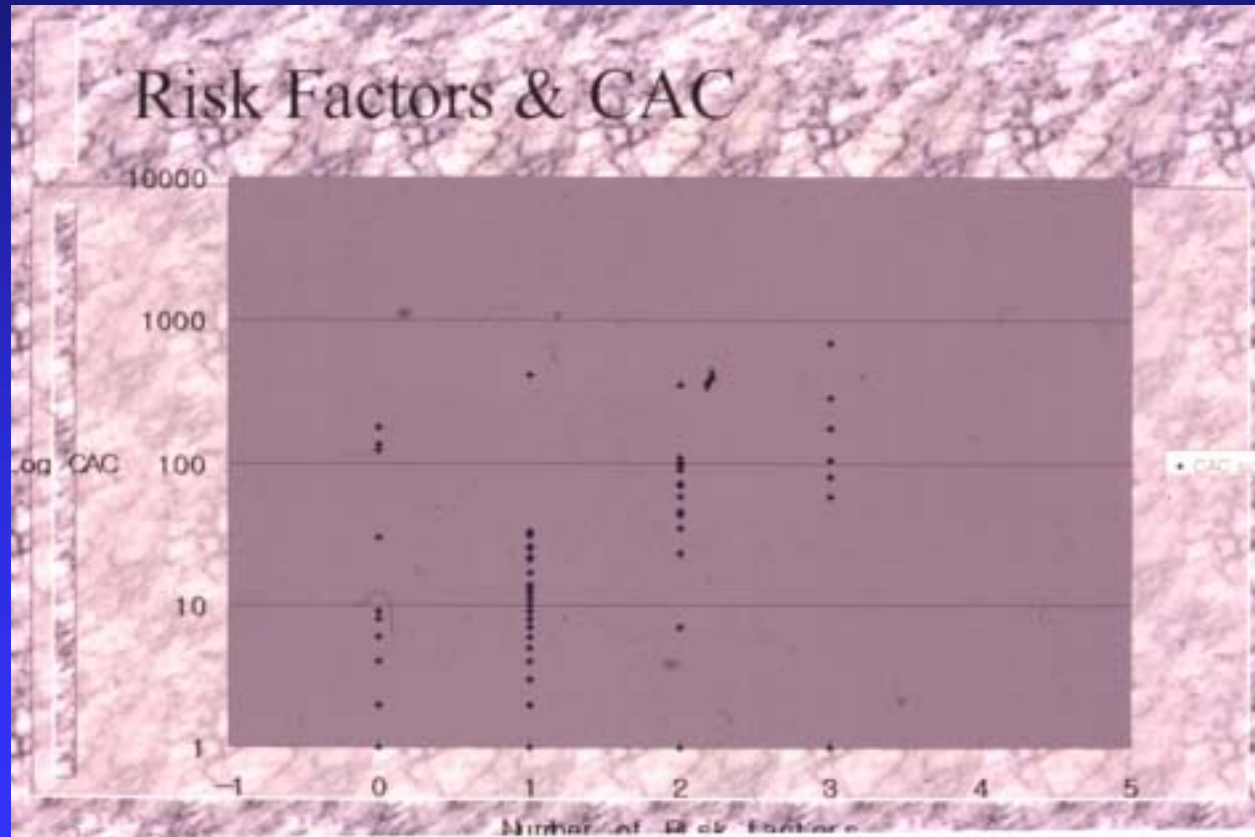
CAC score in Korean: Yonsei employees



CAC score among various ethnic group



CAC score in Korean





Clinical Application

Cardiac events in asymptomatics

	N	CACS cutoff	Risk ratio
Arad	1173	≥ 60	20.2
Detrano	1196	≥ 44	2.3
Raggi	632	Top quintile	15.4
Arad	5585	≥ 100	10.7
Kondos	5635	≥ 0	M;10.5, F;2.6

*Arad et al. Circul '96;93:1953, Detrano et al. Circul '99;99:2633
Raggi et al. Am Heart J '01;141:375, Arad et al. JACC '03;41:6
Kondos et al. Circul '03;107:2571*

Annual event rate of CAOD in asymptomatics

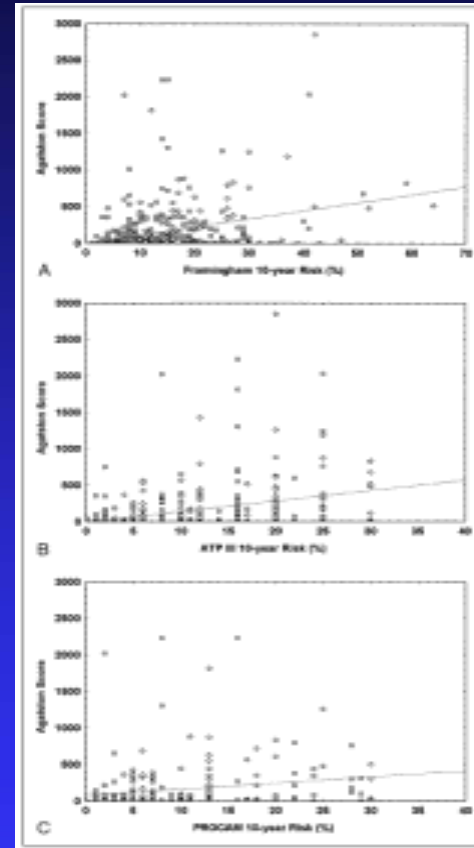
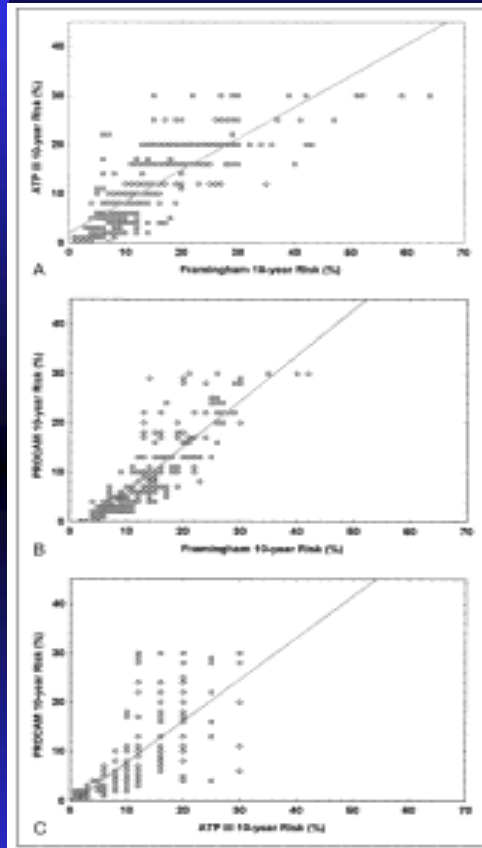
CACS	event/yr
0	0.11 - 0.31%
1 - 99	2.1%
100 - 400	4.1%
>400	4.8 - 13.9%
>1000	25%

Guerci et al. AJC '97;79:128, Raggi et al. Am Heart J '01;141:375, Georgiou et al. JACC '01;38:105, Wayhs et al. JACC '02;39:225

FRI, ATP III & PROCAM

RI vs. RI

RI vs. CACS



Achebach et al. Am J Cardiol 03;92:1471

FRI; Risk at one time point

CACS; Risk accumulated

Risk to be detected and measured

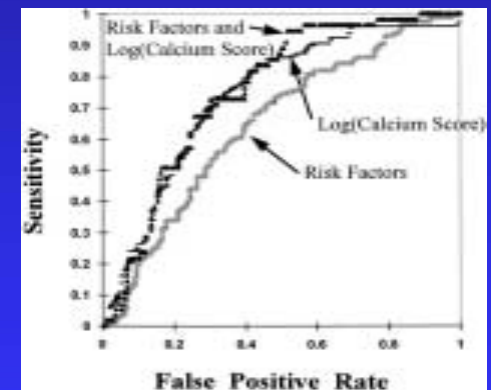
Risk factors for CACS & CAOD

- Identical for
 - ◆ Age, male gender, total/LDL cholesterol ratio, fibrinogen in large degree
 - ◆ Hypertension in lesser degree
- Only for angio, not CAC
 - ◆ Smoking

Schmermund et al. JACC '98;31:1267

Combine atherosclerotic imaging with risk factor assess

- AHA prevention V (1998) *Greenland et al. Circ 00;101;E16*
 - ◆ The test can be used as an adjunct to risk assessment based on through knowledgeable physician referral.
- ACC/AHA (2000) *O'Rourke et al. Circul '00;102:126,*
 - ◆ Concerns cost effectiveness
 - ◆ High NPV for short-term events
- NCEP ATPIII (2002) *Circ 02;106;3143*
 - ◆ Risk assessment at first
 - ◆ Selection of the group with cost effectiveness



Risk stratification in asymptomatics

Prevention of CAOD

■ Secondary prevention

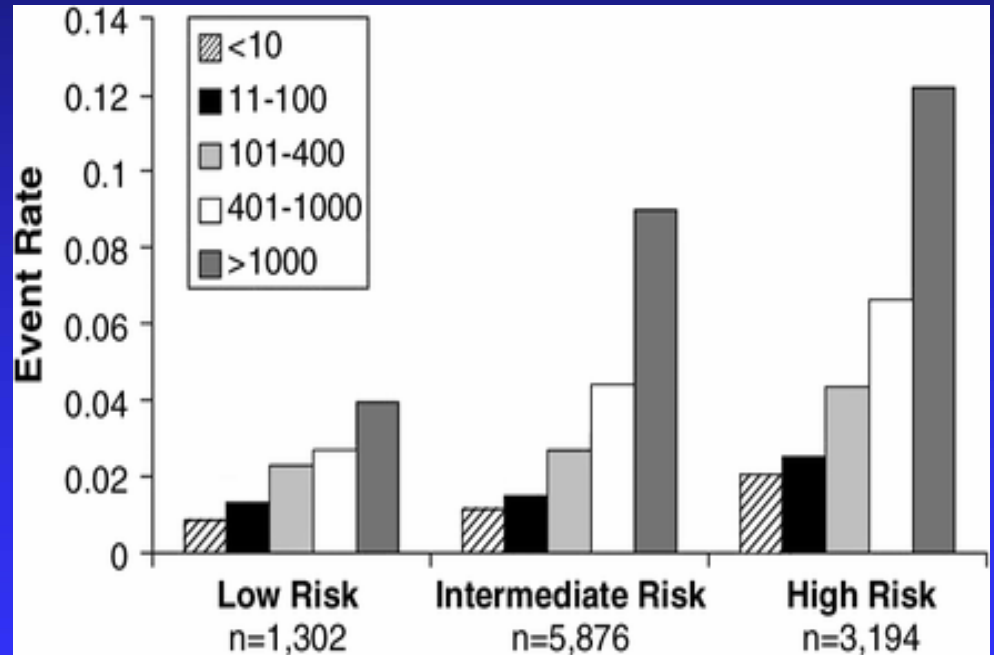
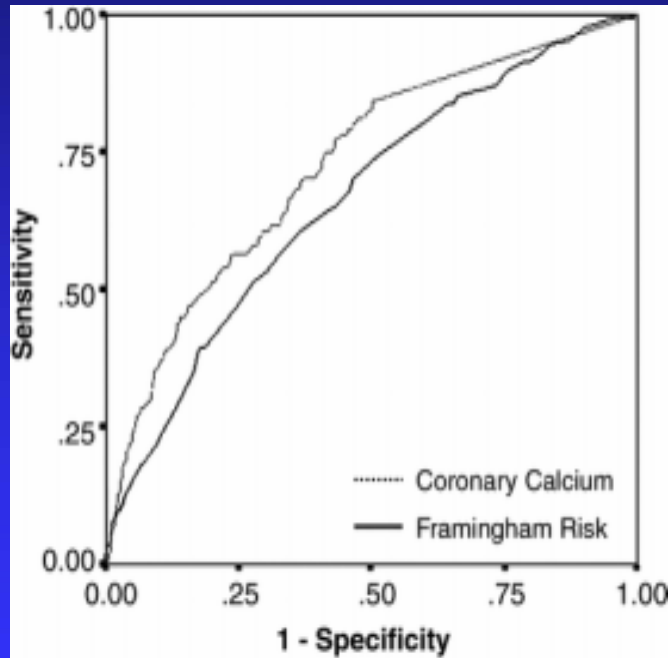
- ◆ aggressive Rx in pts with established CAOD

■ primary prevention

- ◆ Low risk; <6%/10yr, Retest in 5 yrs (35%)
- ◆ **Intermediate risk; 6-20%/10yr (40%)**
- ◆ High risk; >20%/10yr (25%)
 - ↳ Intensive Rx reserved for CAOD patients

AHA prevention V conference

Prognostic value of RFs and CAC



Shaw LJ et al. Radiol 2003;228;826

Annual rate of CHD in asymptomatics with intermediate risks

Authors	n	age	CACS	Rate/yr
Arad et al.	1173	53	>80 th %tile	1.8%
Detrano et al.	1196	67	>67 th %tile	2.3%
Raggi et al.	692	53	>75 th %tile	4.5%

Arad et al. JACC '00;36:1253, Detrano et al. '99;99:2633, Raggi et al. Circ '00;101:850

New NCEP ATP III guideline

- Measurement of coronary calcium is an option for advanced risk assessment in appropriately selected persons.
 - ◆ Asymptomatics with intermediate risks
 - ◆ Elderly
- In persons with multiple risk factors, high CACS (>75th percentile for age and sex) denotes advanced coronary atherosclerosis and provides a rationale for intensified LDL-lowering therapy.

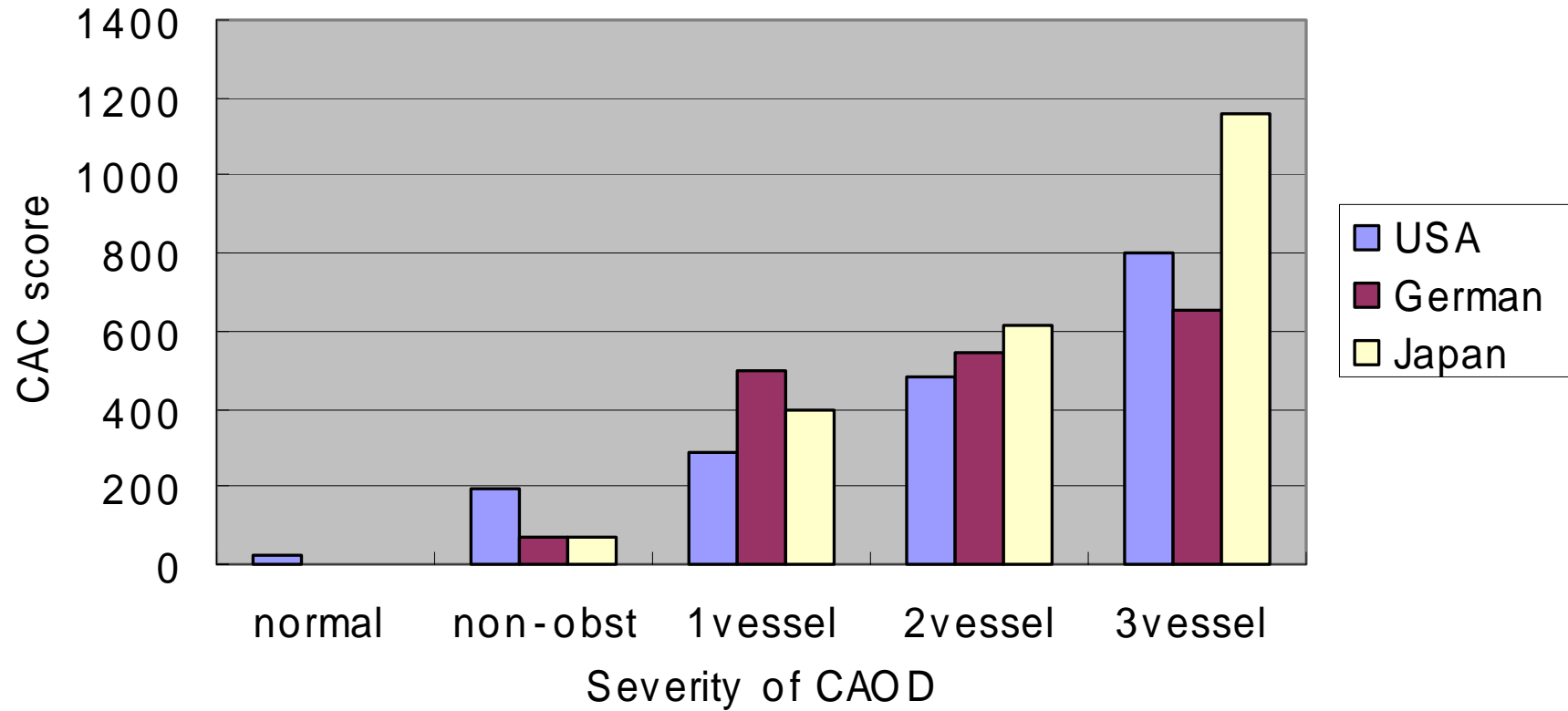
Executive sum of 3^d report of NECP. JAMA '01;285:2486

CACS;

Preventive cardiology

- More likely to have cardiac event
- Early prevention is better than delayed treatment.
- Selection of asymptomatic persons who should be on drugs for lifetime
 - ◆ Framingham risk index $>20\%/10\text{yr}$
 - ◆ intermediate FRI with CAC $> 75^{\text{th}}$ percentile
(>100 in women and $<60\text{yo}$ men and >400 in $>60\text{yo}$ men)
- Motivate life-style behavior changes
“Seeing is believing”

CAC score in CAOD



Detection of silent ischemia in asymptomatics with high risks

CACS	+ stress tests
1 - 100	<2%
100 - 400	6 - 18%
>400	14.6 - 48.3%

*He et al. Circul '00;101:244, Miranda et al. Circul '00;102:II-543,
Berman et al. JACC '04;44:923, Anand et al. J Nucl Cardiol '04;11:450*

CACS

- Indication in symptomatics

- ◆ Atypical chest pain
- ◆ Nonspecific + on TMT

- If CACS = 0

- ◆ NPV of EBT is very high ($\geq 99\%$) and score 0 can virtually exclude CAOD, making the test an effective filter before invasive angiography.

Conclusion;

Coronary calcium score study

- Pathognomonic of atherosclerosis
- Total atherosclerotic burden
 - ◆ Identify CAD in preclinical stage
- Preventive cardiology
 - ◆ ↑ risk assess
 - ◆ ↑ cost-effectiveness in primary prevention
 - ◆ modify natural history of atherosclerosis

Thank for your attention!

CACS in Korean

- Asymptomatic, middle-aged, /s prior CAOD
 - ◆ Total 445 (M 260, F 185)
 - ◆ Age 37-81 (mean 57.5 ± 8.0)
 - ◆ CACS in average 72.1 ± 234.9
 - ☞ Men 87.1 ± 270.2
 - ☞ Women 51.1 ± 172.2
 - ◆ Prevalence of CAC in average 45.4%
 - ☞ Men 51.5%
 - ☞ women 36.8%

CACS in Korean

Risk Factors	No.	%	MW(p)
Overweight (BMI >25Kg/m ²)	67	24.6	0.068
Smoking	64	22.1	0.118
Hypertension (>140/90mmHg)	62	21.4	0.001
Precocious family history	21	7.3	0.836
HDL (<35mg/dl)	21	7.3	0.049
DM (>140mg/dl fasting glucose)	8	3.1	0.998
Total cholesterol (> 240mg/dl)	6	2.5	0.483

MW; Mann-Whitney test