Imaging in CAD

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4 major imaging techniques:

- Echocardiography
- Magnetic resonance imaging
- Multi-slice CT
- Nuclear imaging (PET and SPECT)

Can provide all anatomical and functional information, but use should be clinically driven.
Diagnosis is important

But the imaging results need to have impact on choice of therapy
From atherosclerosis to heart failure: Where may imaging help?

- Asymptomatic patients at elevated risk for atherosclerosis/CVD: screening / early detection

  - Symptomatic patients: detection of coronary artery disease

  - Ischemic heart failure: extensive evaluation
Patient example

Woman 48 years old

Outpatient clinics:

No symptoms

Risk factors for CAD:
*Family history of CAD
Asymptomatic individual, low risk

The question is:

Risk stratification
Blood: biomarkers

Early detection of CVD

Large arteries: Global: atherosclerosis

Coronary arteries: Focal: lesion characteristics
Cardiovascular event-free survival, according to CRP and LDL

Ridker et al. NEJM 2002
Blood: biomarkers

Early detection of CVD

Large arteries:
Global: atherosclerosis

Coronary arteries:
Focal: lesion characteristics
Carotid Intima Media Thickness (CIMT)

Tissue between luminal edge of the artery and the boundary between media and adventitia

I = Intima
M = Media
A = Adventitia
Assessment of CIMT

Semi-automatic B-mode ultrasound measurements

Left and right common carotid artery, directly proximal to the bifurcation

Mean CIMT measurements at four angles

Calculation of the average of 8 mean CIMT per patient
CIMT in the general population

- Increases with age and cardiovascular risk factors
- Correlates with presence of cardiovascular disease
- Independent predictor of cardiovascular events

O’Leary et al. NEJM 1999
Cumulative event free rate (stroke or MI) according to IMT quintiles

Blood: biomarkers

Early detection of CVD

Large arteries: Global: atherosclerosis

Coronary arteries: Focal: lesion characteristics
Coronary calcifications provide a marker for atherosclerotic disease burden.
Calcium scoring (EBCT/MSCT)

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<th>Calcified Plaque Burden</th>
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<td>Minimal plaque burden</td>
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<td>Mild plaque burden</td>
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<td>&gt;1,000</td>
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Calcium score vs risk stratification

- All-cause mortality
- 25,253 asymptomatic individuals
Calcium Scoring (EBCT/MSCT)

- Presence of coronary calcifications associated with increased risk of coronary events
- Marker for CAD in general, rather than marker for specific site
- Unable to identify localized vulnerable plaque
- Population risk marker rather than individual specific
Screening for CVD

- What (blood, large vessels, coronary arteries) do we screen?
- Will it improve outcome?
- When do we screen?
- Do we need to screen periodically?
- What are the therapeutic consequences?
From atherosclerosis to heart failure: Where may imaging help?

• Asymptomatic patients at elevated risk for atherosclerosis/CVD: screening / early detection

☞ Symposiumtomatic patients: detection of coronary artery disease

• Ischemic Heart failure: extensive evaluation
Patient example

Man 47 years old

Outpatient clinics:

Dyspnea or atypical chest pain at exercise

Risk factors for CAD:

*Dyslipidemia
Non-invasive assessment of CAD: Which Patients?

Pre-test (Clinical) Probability of CAD (%)

Post-test Probability of CAD (%)

45 y/o M, asymptomatic, no risk factors
45 y/o M, asymptomatic, multiple risk factors
45 y/o M, typical angina

(+) test
(-) test

Patterson et al. JACC 1989
Non-invasive assessment of CAD: Which Patients?

Post-test Probability of CAD (%)

Pre-test (Clinical) Probability of CAD (%)
Symptomatic patient, low-intermed risk

The question is:

Atherosclerosis? (medical therapy needed and follow-up or discharge?)

夫妻 We order a non-invasive anatomical test to detect /exclude atherosclerosis
MRI – angiography (1.5T)

Leiden, NL
Aarhus, DK
Munich, GER
Boston, USA

Berlin, GER
Leeds, UK
Kurashiki, JP
St. Louis, USA

NEJM 2002
MRI - angiography

Stronger magnets: 3T coronary imaging

Yang et al. JACC 2009
CT angiography - raw data
curved MPR

RCA

LAD

LCX
Patient-based detection (n=1286)

- Sensitivity: 99%
- Specificity: 89%
- PPV: 93%
- NPV: 100%

- ≥ 50% stenosis
- versus CAG
- Not assessable: 4% (0-14%)
320-CT

Coverage of the heart in 1 rotation

16 cm
Patient example

Man 47 years old

Outpatient clinics:

Dyspnea or atypical chest pain at exercise

Risk factors for CAD:

*Dyslipidemia
Non-invasive angiography - MSCT

LAD: normal, intramural course mid

LCx: normal
320-CT – rule out CAD

57 yr old woman, 2x TIA
Analysis cardiac source of embolism
320-CT – rule out CAD

Smoking 39 pack years

Severe dyslipidemia (cholesterol 7.8 mmol/L)

MSCT angiography to exclude (?) CAD

No significant stenosis
Prognosis MSCT
13,966 pts, mean F-up 22.5 months

Mortality

- Normal CT: 0.65%
- Non-obstr CAD: 1.99%
- Non-high risk CAD: 2.90%
- High risk CAD: 4.95%

Chow et al. Circ 2011
Patient example

Man 58 years old

Outpatient clinics:

chest pain at rest, sometimes stress

Risk factors for CAD:
*Hypercholesterolemia
*Hypertension
*Smoking
Non-invasive assessment of CAD: Which Patients?

Post-test Probability of CAD (%)

Pre-test (Clinical) Probability of CAD (%)
The patient has high likelihood to have atherosclerosis

The question is: does he have ischemia? (is intervention needed?)

👉 We order a non-invasive ischemia test
The ischemic cascade

Systolic wall motion imaging

Perfusion imaging

angina

ECG changes

systolic dysfunction

diastolic dysfunction

hypoperfusion

Time from onset of ischemia

Schinkel et al. EHJ 2003
Ischemia as an expression of a flow-limiting stenosis

- Assessment of perfusion abnormalities (stress-inducible)
- Assessment of systolic wall motion abnormalities (stress-inducible)
Nuclear perfusion imaging, SPECT

STRESS

REST

SA

VLA

HLA

POLAR MAP TO QUANTIFY EXTENT AND SEVERITY OF ISCHEMIA
Nuclear perfusion imaging with ECG gating

-Permits assessment of LVEF, LV volumes and regional function
-At rest and stress
Stress echo to assess flow-limiting stenosis: wall motion
Addition on intravenous contrast to improve border opacification
Stress MRI to assess flow-limiting stenosis: wall motion
MRI – perfusion imaging
Comparison of imaging techniques for diagnosis of CAD

• In low-intermediate likelihood:
  • atherosclerosis imaging (non-invasive angiography)
  • MSCT preferred over MRI

• In intermediate-high likelihood:
  • ischemia imaging
  • all modern techniques can assess perfusion and systolic function
From atherosclerosis to heart failure: Where may imaging help?

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Patient example

Male, 62 yrs
- 1987: Infero-postero-lateral infarct
- 1988: Repeat inferior infarct
- 1994: Antero-septal infarct
- 1996: CABG: LIMA-graft LAD, venous graft MO-LCX and RDP/RCA
- 2000: Non-sustained ventricular tachycardia

Co-morbidities
- Diabetes II
- COPD
- chronic renal failure (creatinine 300 micromol/l)
Patient example

Male, 62 yrs

- Reduced exercise capacity
- NYHA III
- Dizziness / Hypotension

- Weight 53 kg, length 1.64 m
- RR 90/65 mmHg
- Holosystolic murmur 3/6 apex
Severe heart failure patient

To determine therapy, the information below is needed:

- LV function and LV size?
- CAD: ischemia/viability?
- Severe MR?
- ICD needed?
LV function and size?

Adapted from White et al. NEJM 1986
LV function and size?
LV function and size?
Towards 3D imaging?
We need:

- Highest resolution images in every patient
- Assessment of LVEF but also
  - LV dimensions: LVESD, LVEDD
  - LV volumes: LVESV, LVEDV

- Exact quantification – prognosis but also for justification of ICD therapy
Advanced LV function assessment

Longitudinal strain
From regional to global LV strain
Global strain maps: HF, infarction, and normal

GLPSS Avg: -7.3 ± 3%

GLPSS Avg: -13.8 ± 3.3%

GLPSS Avg: -19.1 ± 3.1%

P<0.001
Is there viability?

to predict prognosis post-surgery
N= 20 studies, 2362 pts
All retrospective analyses

Viable +

Viable -
Is there viability?

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Infarct imaging with delayed enhancement MRI
Viability assessment - Future?
Severe MR affects prognosis
Severe MR?

TTE  TEE
Is quantification of MR severity needed?

Lancellotti et al. Circ 2003
MRI: 3D Flow Quantification in All Valves

3D volume scan w 3-dir velocity encoded MRI
MRI: 3D Flow Quantification mitral valve

MV flow

\[ V_{\text{forward}} = 116 \text{ ml} \]
\[ V_{\text{back}} = 32 \text{ ml} \]
\[ V_{\text{eff}} = 84 \text{ ml} \]

Regurg. Fraction = 27%
Severe MR – other techniques?

3D TTE
Importance of MV anatomy
Is surgical repair feasible?

3D TEE
ICD needed?

- Patients with:
  - previous infarction
  - LVEF <30%

- Benefit from ICD:

- MADIT II: improved survival
ICD shocks in primary prevention

N=720 pts, MADIT II
Follow-up 21 months

ICD needed?

Moss et al. Circ 2004
What is the pathophysiological substrate for SCD in CAD?

Epicardium

Endocardium

Scar

Courtesy W Stevenson
MRI to assess arrhythmogenic substrate:

- Late-gadolinium enhancement: scar area and peri-infarct zone
Value of border zone to predict VTs

HR (95% CI): 1.47 (1.04 to 2.08)
P = 0.003
Severe heart failure patient

Complex information is needed to determine therapy

Can be provided by multi-modality imaging
Conclusions

• Virtually all anatomical and functional information can be obtained by (a combination) of the available imaging techniques

• The choice of techniques should be guided by the information needed

• Implementation of pre-defined care tracks may promote systematic use of the different techniques