Acute Coronary Syndromes, Myocardial Infarction and Remodelling of the Heart

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Objectives

- To understand the pathogenesis of acute coronary syndromes, myocardial infarction and LV remodelling and their natural history

- To use this knowledge to develop the rationale for the clinical assessment, diagnosis and treatment of ACS and LV remodelling

Overview

- Basic science
  - Plaque
  - Myocardium
- Clinical
  - Classification
  - Diagnosis
  - Clinical Risk Stratification
  - Treatment

Definition

- Myocardial cell death arising from interrupted blood flow to the heart
  - Coronary plaque rupture
  - Coronary plaque erosion
  - Coronary dissection

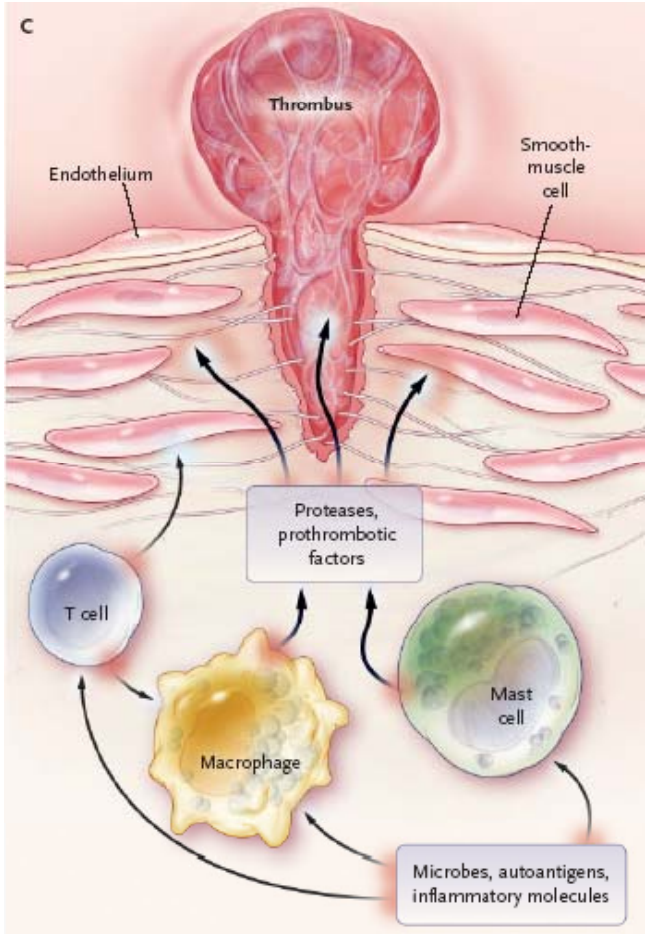
- Mechanisms of myocardial cell death
  - Oncosis
  - Apoptosis

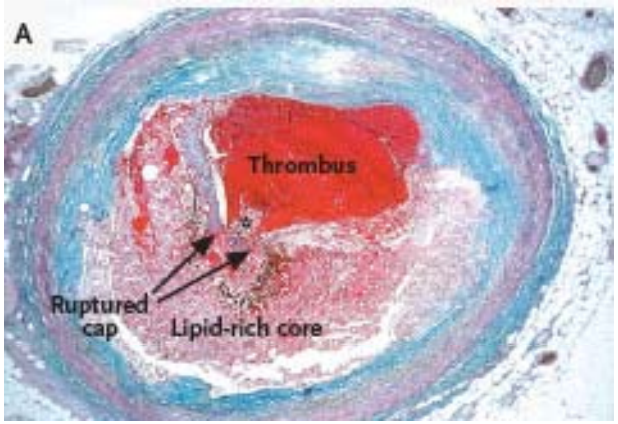
Acute MI

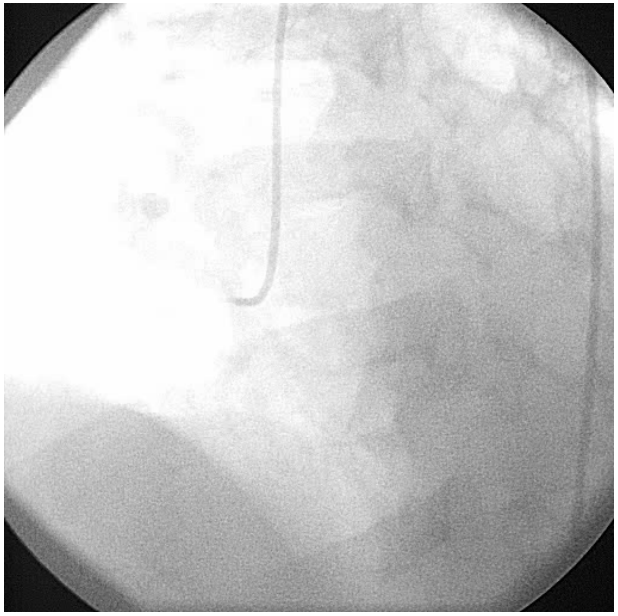
Key Elements for Acute MI

- Vulnerable plaque (inflammation)
- Trigger
- Thrombosis

Acute Coronary Syndromes







- **Inflammation**
  - Systemic
    - T2D, Lipids
  - Local
- **Plaque**
  - Rupture
  - Erosion
- **Thrombosis**

Hansson N Engl J Med 2005

Where does Plaque Rupture Occur?

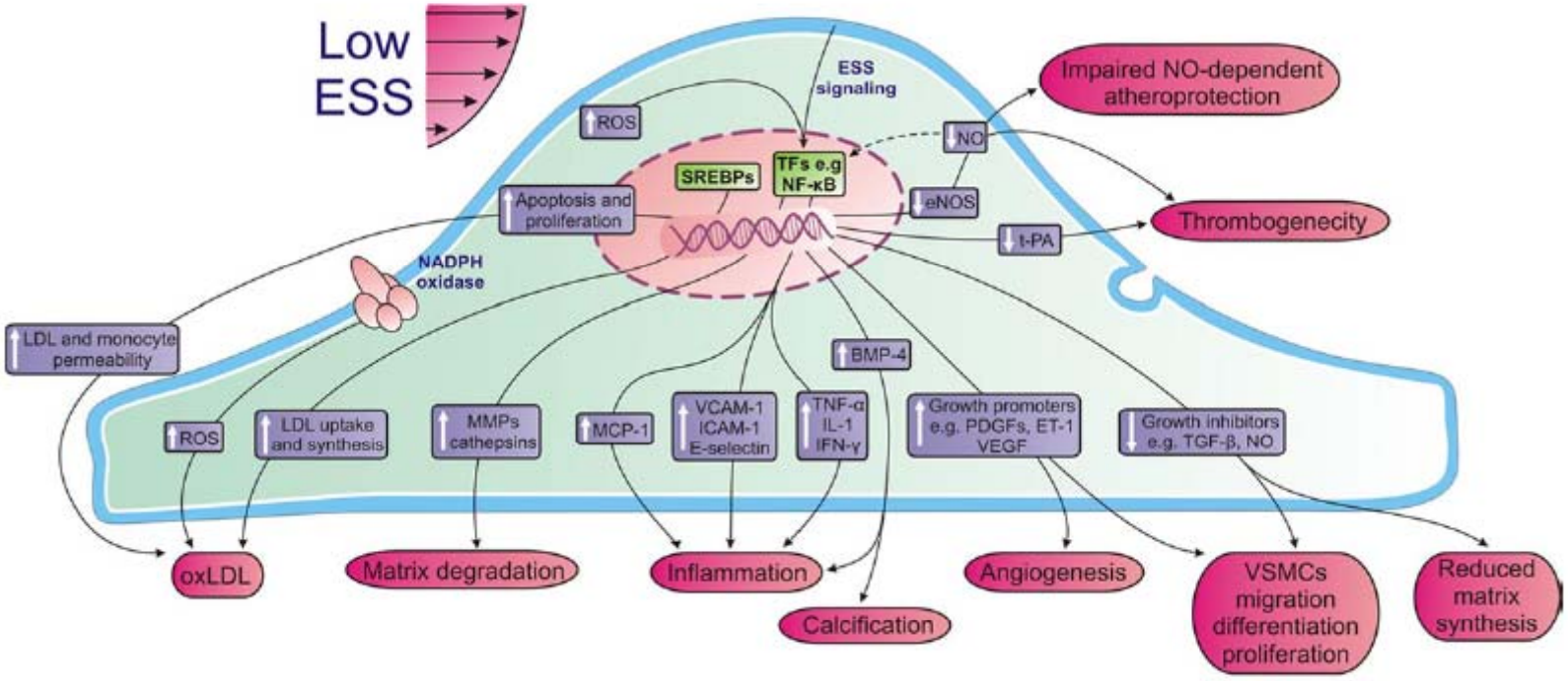
Low ESS

- Sidebranches
- Outer waist of bifurcations
- Inner curvature of arteries

Pathological Features

- Large plaque burden, necrotic core
- Thin fibrous cap (MMP's, cathepsins)
- Macrophages
- Reduced VSMC
- Intraplaque haemorrhage

Downstream Effects of Low Shear Stress



Wentzel et al. *Cardiovasc Res* 2012

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When do MI's Happen?

Observation

- Morning, within 1st hour of waking
- Monday's
- Winter, cold weather
- Emotional stress
- Vigorous exercise

Potential mechanism

- Increased sympathetic activity → plaque disruption
  - ↑ BP, HR, CBF
- Thrombosis
  - ↑ platelet reactivity
  - hypercoagulability
  - ↓fibrinolysis
- Vasoconstriction

“Man lives with atherosclerosis but dies from thrombosis”

Didischem 1957

ACS

THROMBOSIS

20-30 %
PLAQUE EROSION

70-80 %
PLAQUE RUPTURE

Acute MI – Thrombosis

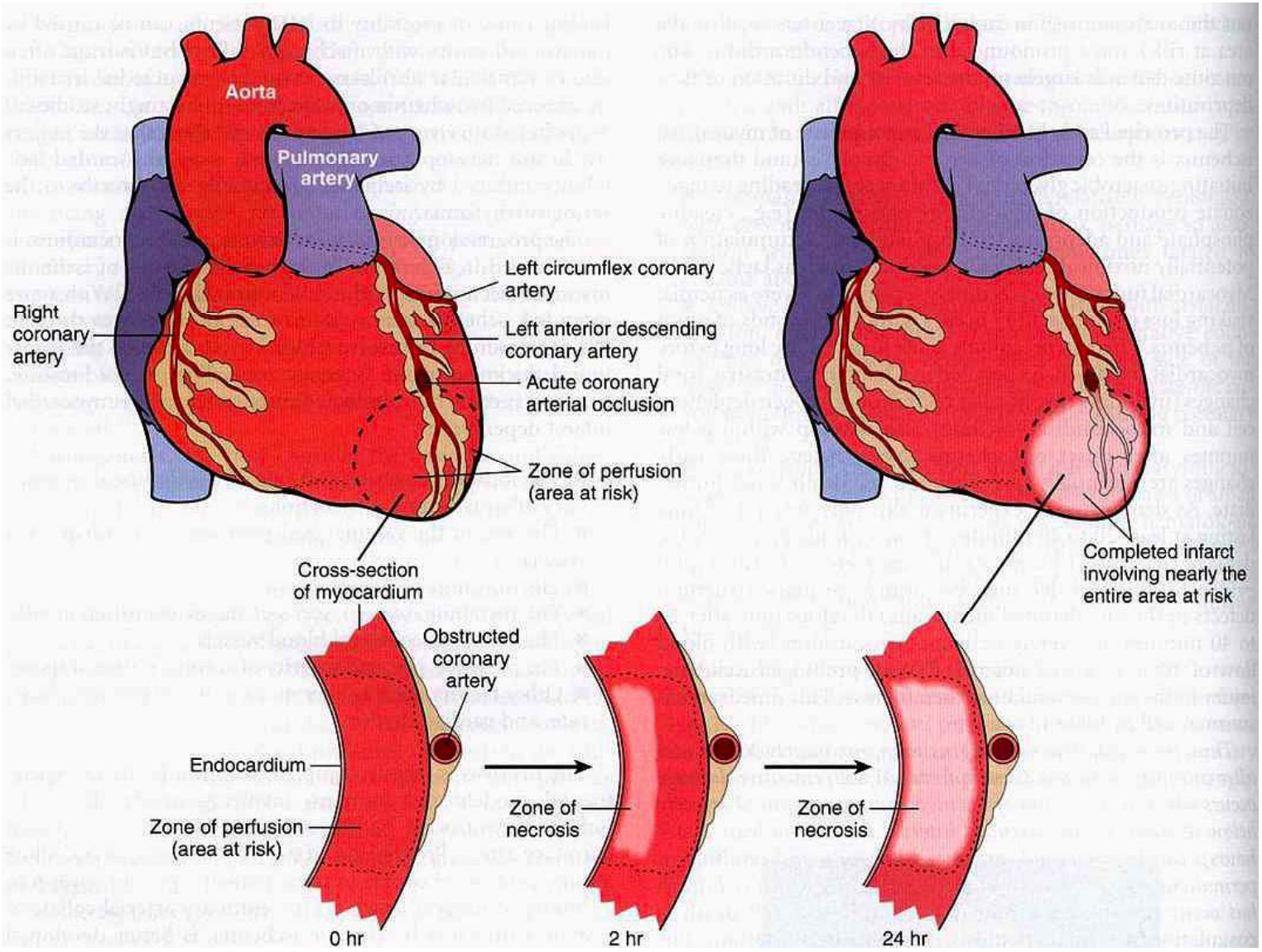
- Pro-coagulant state
  - Increased platelet reactivity
  - Increased circulating tissue factor
  - Reduced fibrinolysis
- Endothelial dysfunction
- Altered flow

Ischaemic Cell Death

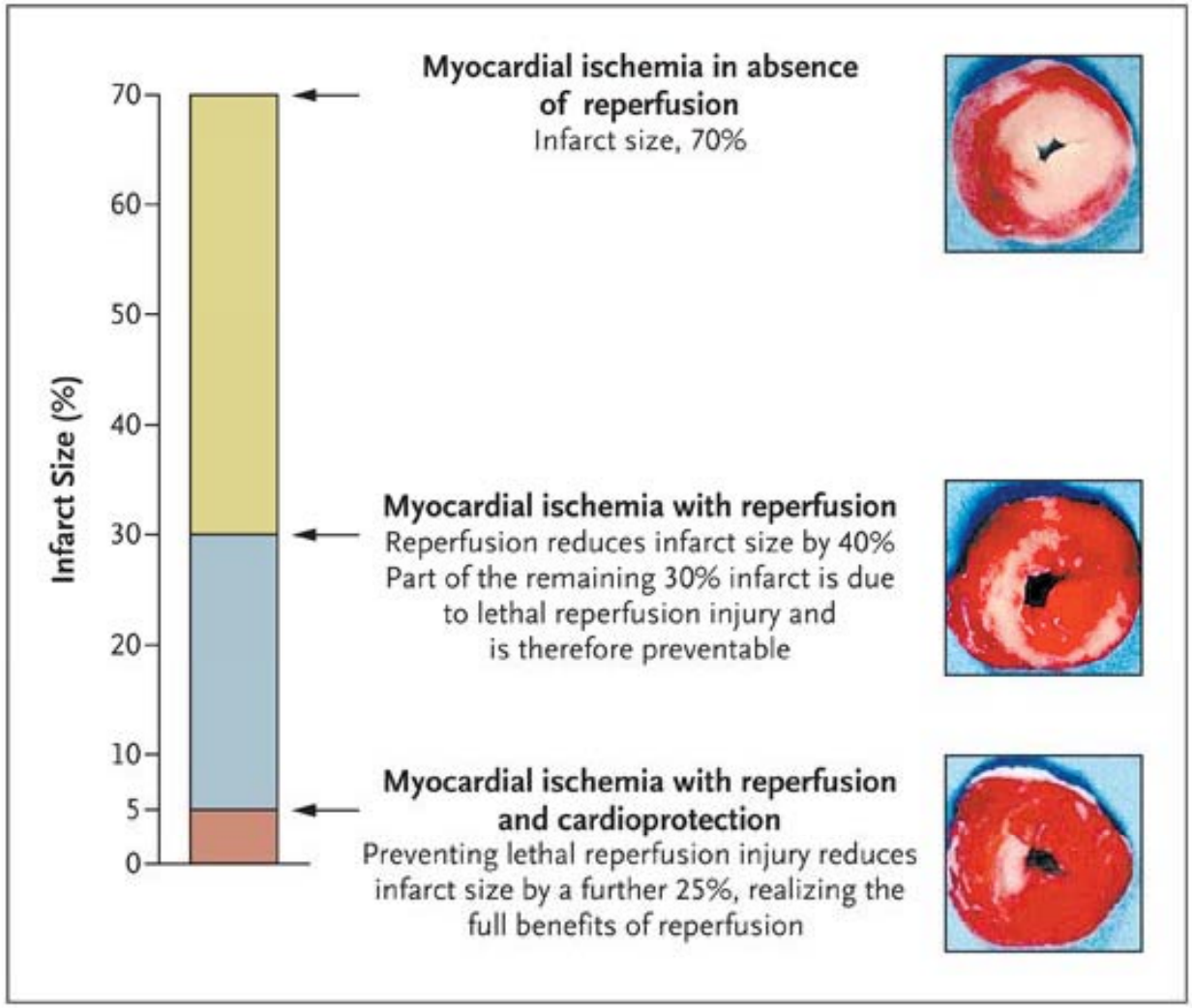
Oncosis	Apoptosis
o Cell swelling + death	o Cell shrinkage + death
o Depletion of high energy phosphates	o Depletion of high energy phosphates
o Accumulation of intracellular water, Na^+ ($\rightarrow \uparrow Ca^{++}$), H^+, Cl^-,	o Run down of mitochondrial electron transport chain
o Cytoplasmic, organellar, cellular swelling	o Cytochrome c release
o Plasma membrane blebbing	o Caspase activation
o Cell rupture	o Cell shrinkage and fragmentation

Coagulative necrosis
Activation of innate immune system
(TLR's, complement, RAGE, High Mobility Group Box 1 -> NFkB activation
Neutrophil (IL1) then monocyte/macrophage influx

Development of Infarction



Reperfusion Injury



Yellon & Hausenloy NEJM 2007

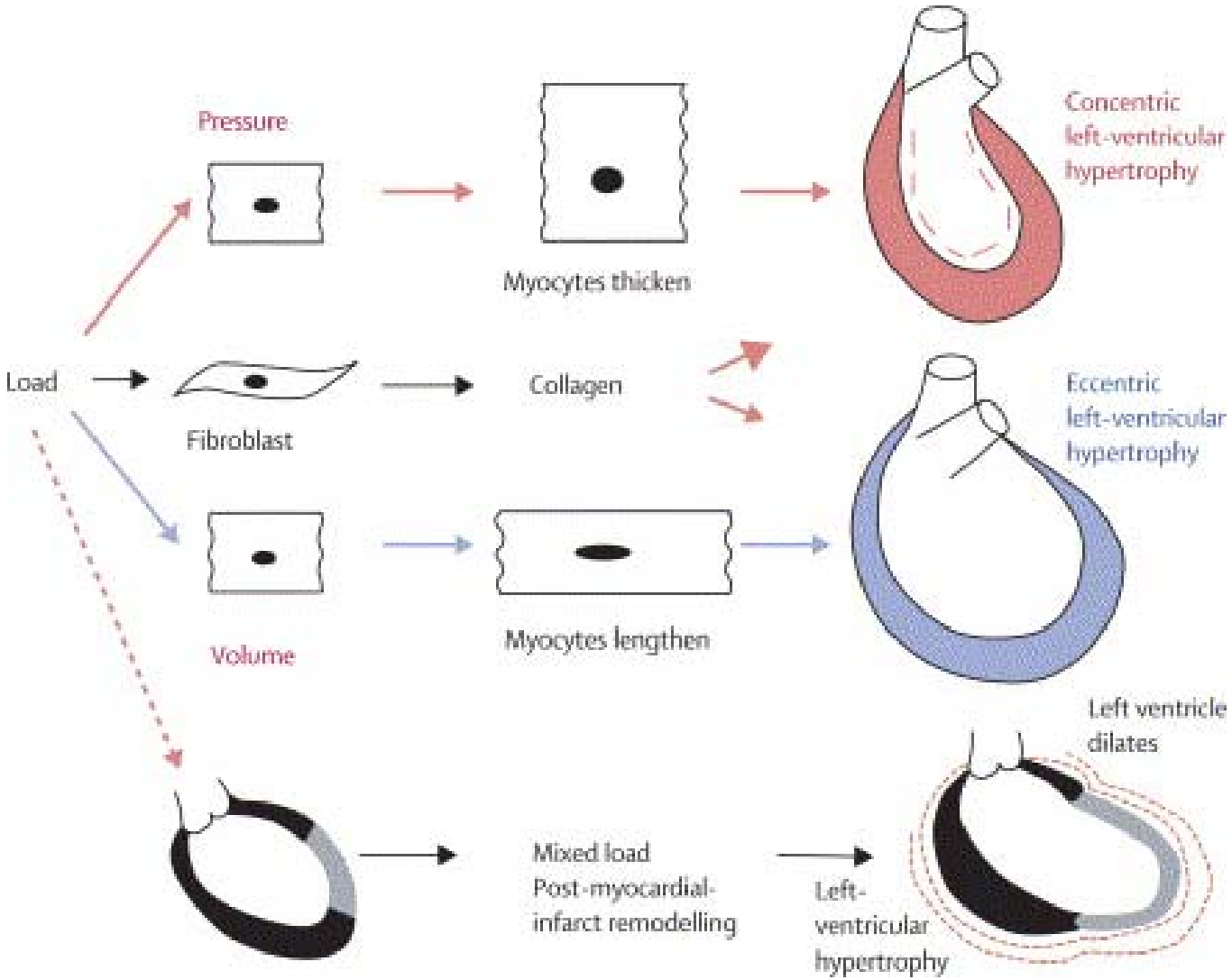
Reperfusion Injury - Mechanisms

- Oxygen paradox: free radicals
- Calcium paradox
- pH paradox
- Inflammation: “no-reflow” (neutrophils)
- mPTP opening: uncouples oxidative phophorylation

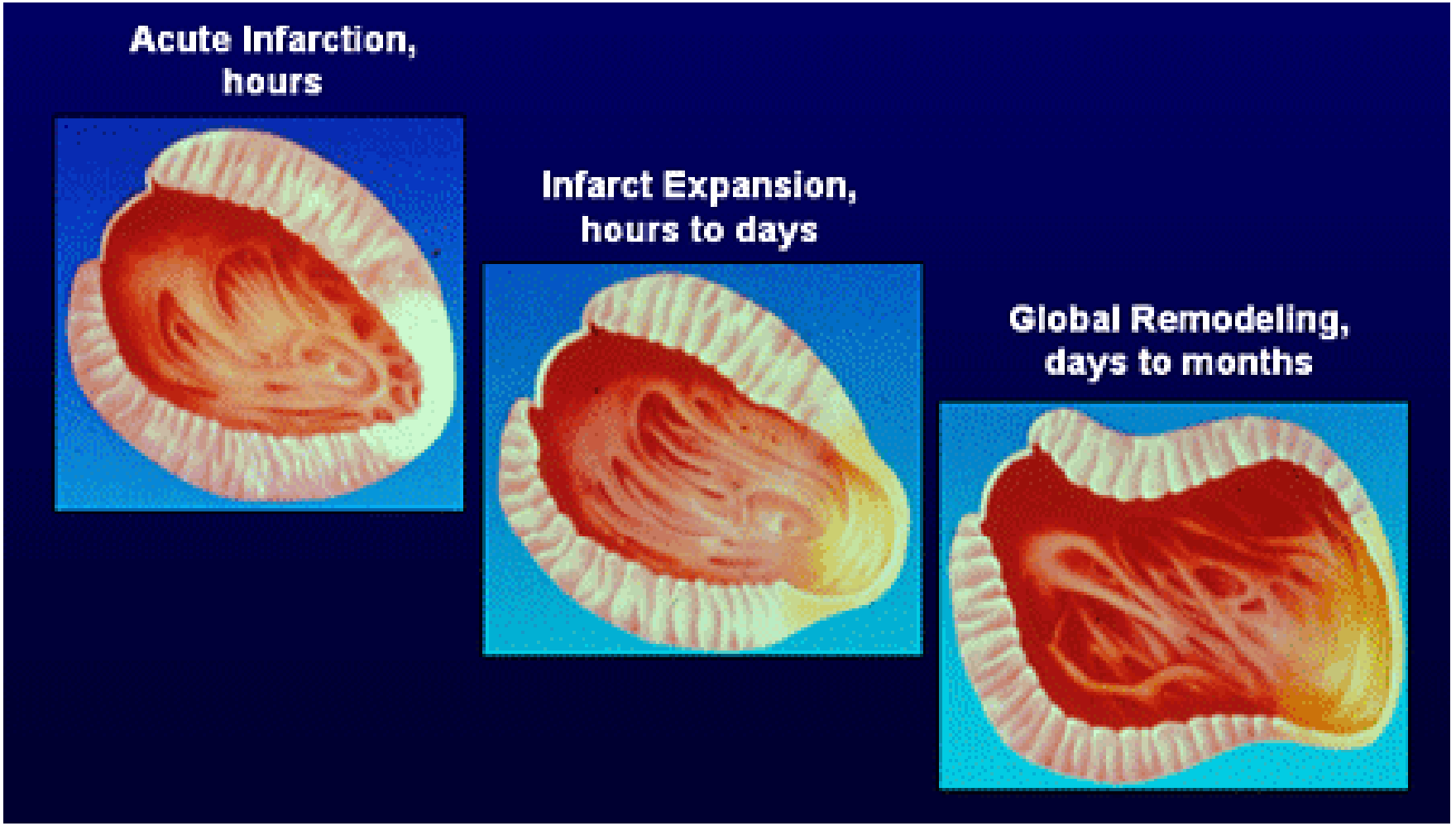
LV Myocardium - Constituents

- 4-5 x10^9 Cardiac myocytes
- Fibroblasts
- Extracellular matrix (Type I and III collagen)
- Capillary microcirculation

LV Remodelling



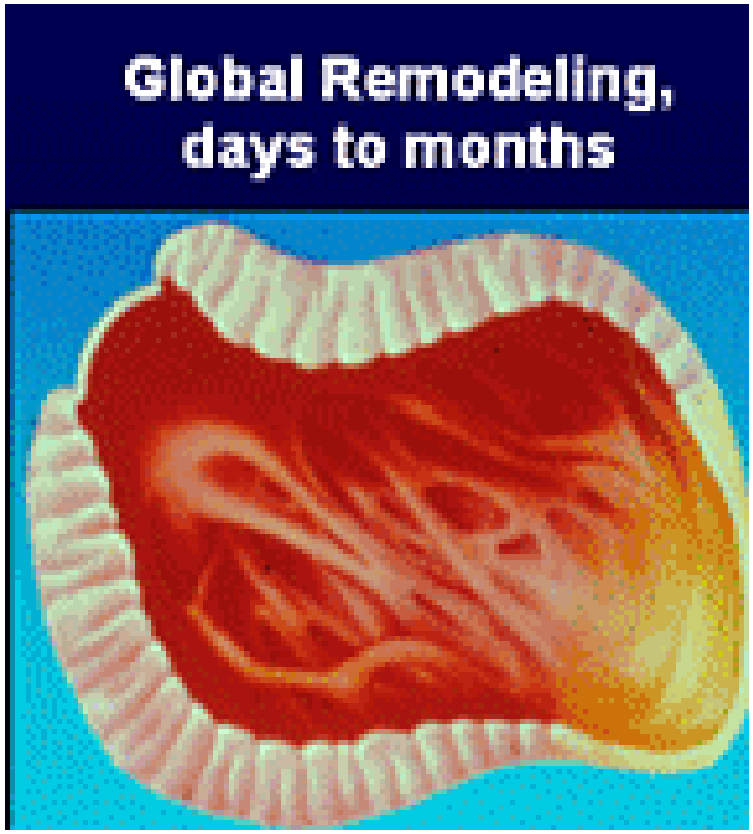
Post-MI LV Remodelling



Early LV Remodelling

- Degradation ECM (serine proteases, MMPs)
- Wall thinning, LV dilatation (myocyte slippage)
- Increased systolic and diastolic wall stress → LVH
- Increased stretch and contractile function in border and remote myocardium

Late LV Remodelling



- LV adopts more spherical shape
- Myocyte hypertrophy
- Altered electromechanical coupling
- Myocardial fibrosis
- Apoptosis
- Inflammation
- LV dilatation
  - Reduce wall tension
  - Maintain CO

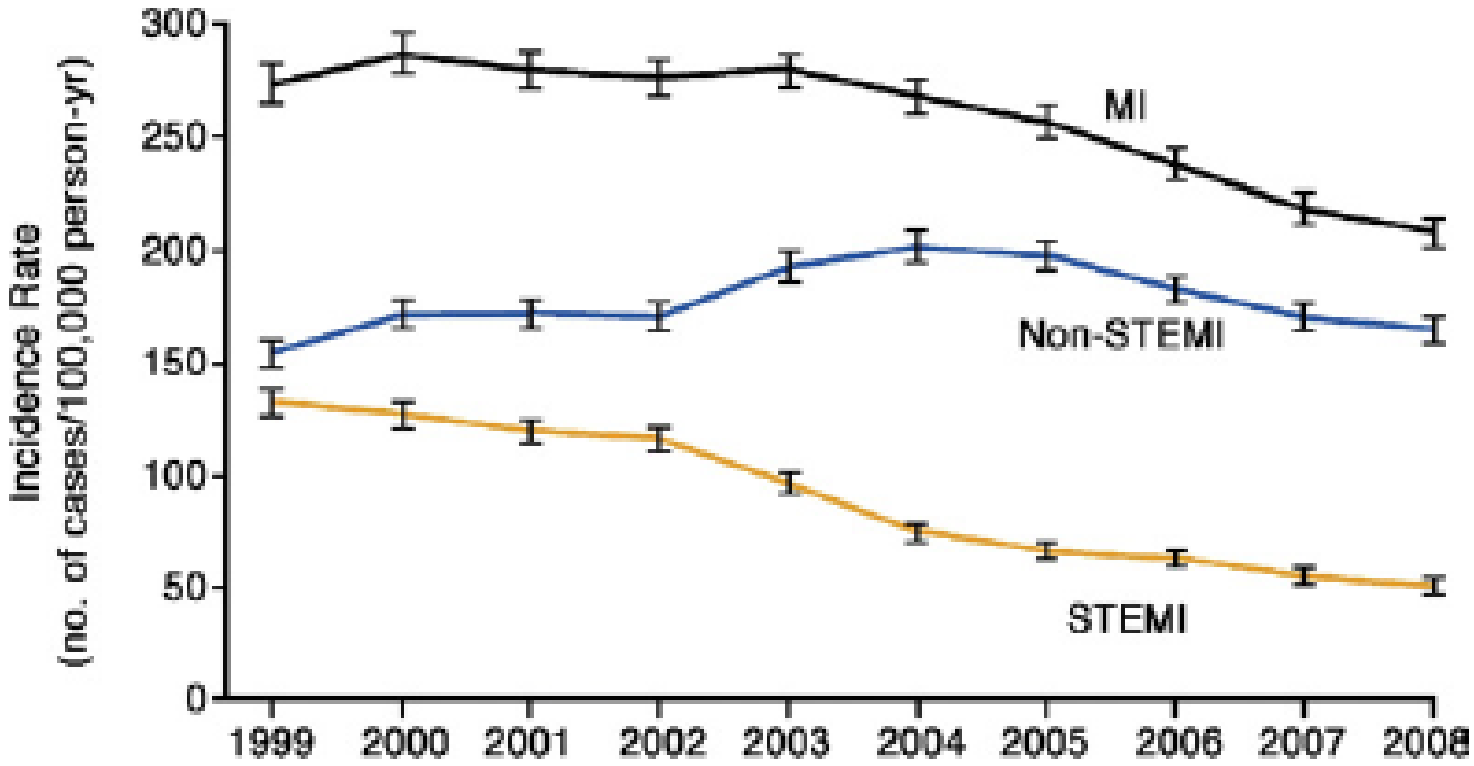
Consequences of Adverse LV Remodelling

- Increased systolic wall tension/stress
- Increased MVO2
- Reduced myocyte shortening
- Increased diastolic wall tension/stress
- Reduced subendocardial perfusion
- Dysynchronous depolarization/contraction
- Mitral regurgitation
- Ventricular arrhythmias
- Ventricular fibrillation

UK MI Statistics (2009-10)

- ~99,000 hospital admissions per year
- ~33,000 deaths per year (~6% of all deaths in UK)
- £3.6 billion per year

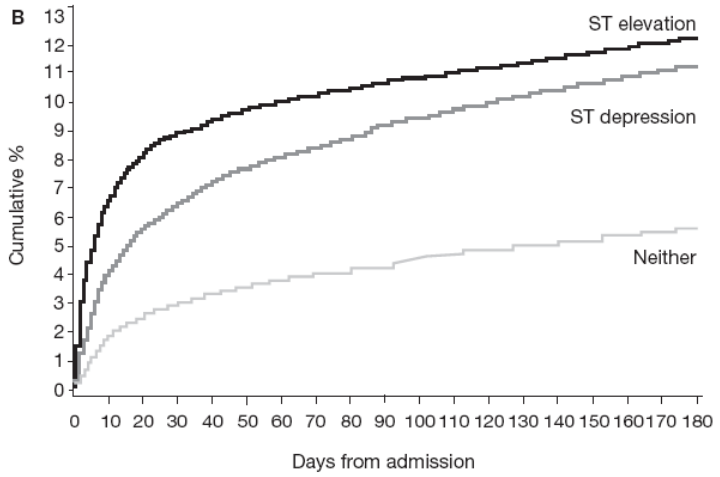
Population Trends in Incidence of AMI

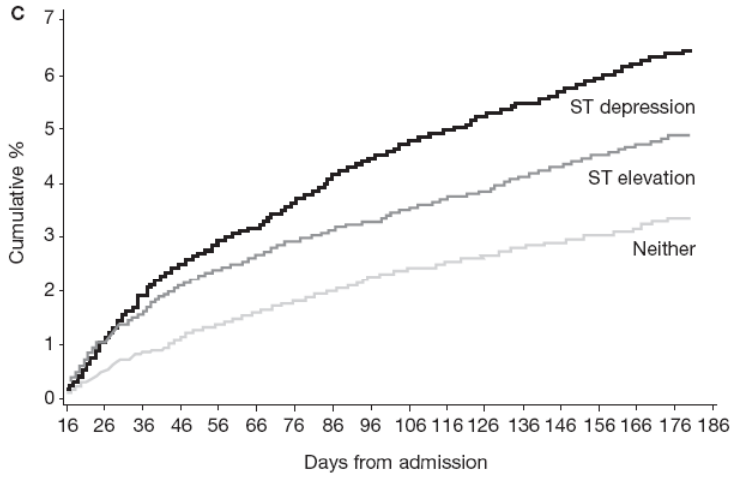


Yeh et al. NEJM 2010;362:2155

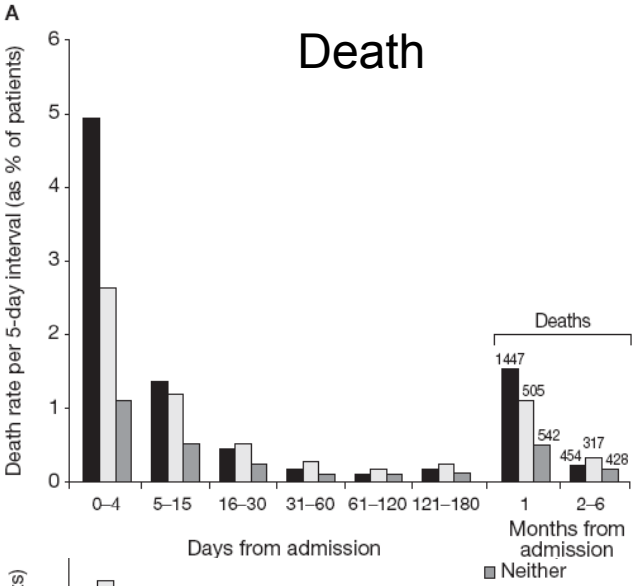
Adverse Events after ACS (GRACE)

Death

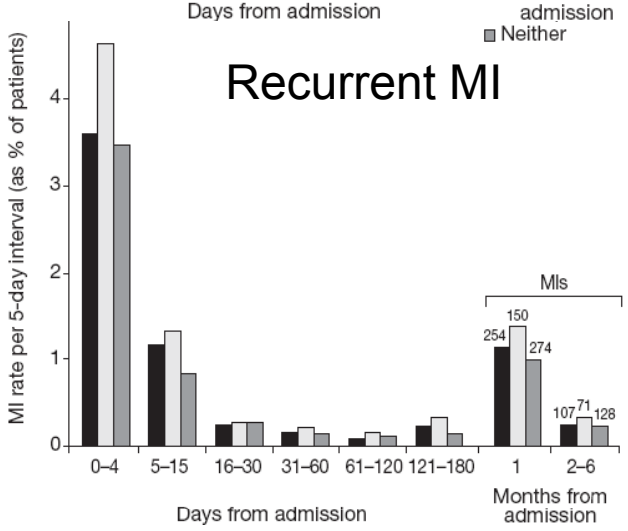




Death



Recurrent MI



Fox et al. Nat Clin Pract Cardiovasc Med 2008;5:580

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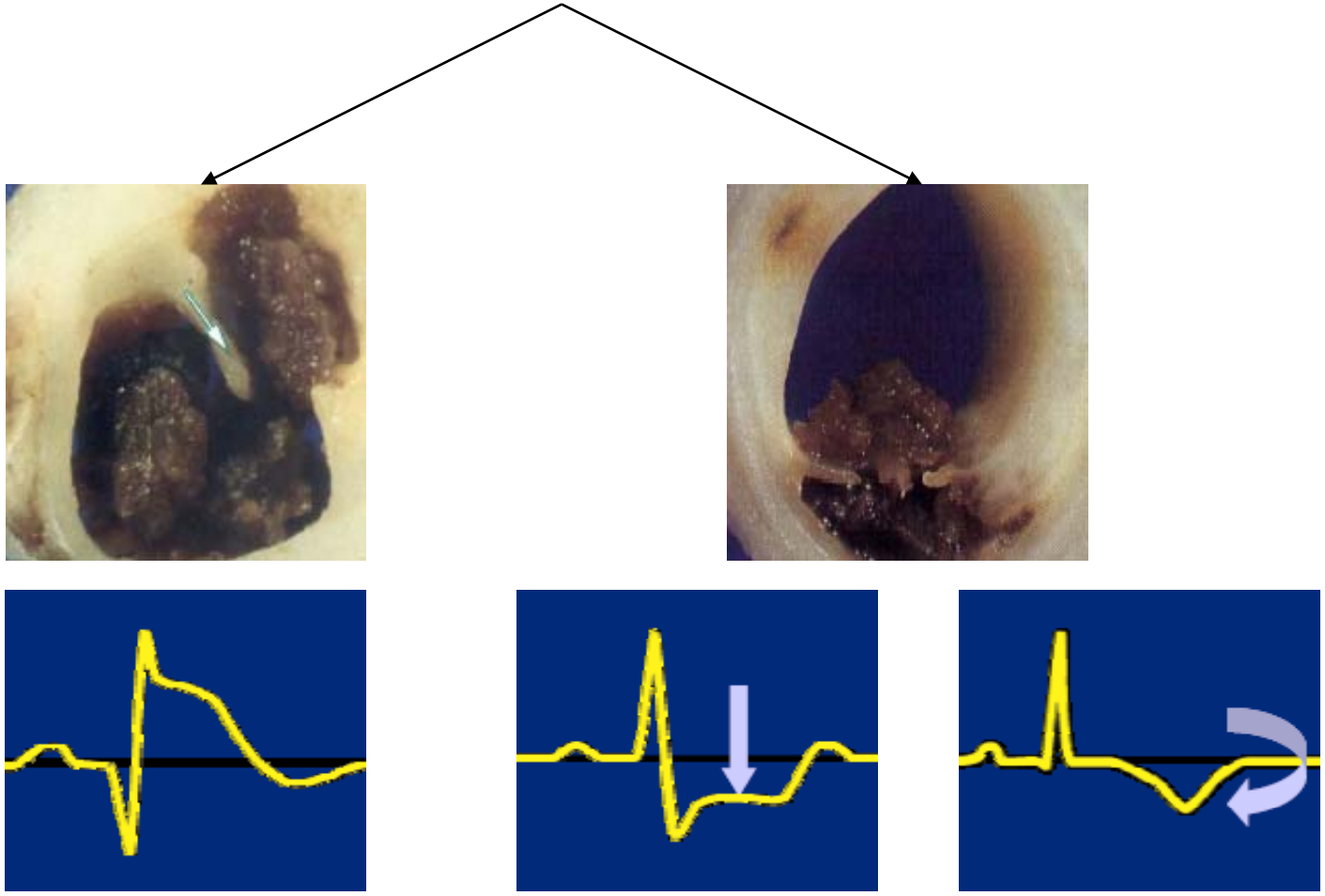
Clinical Management of MI

- Diagnosis
- Risk Stratification
- Immediate treatment
- Long term treatment

What do you need to diagnose MI?

- Symptoms
- ECG changes
- Biomarker evidence of myocardial necrosis

Acute Coronary Syndromes



ST elevation

ST depression

T wave inversion

or normal ECG

ESC NSTE-ACS Guidelines 2007

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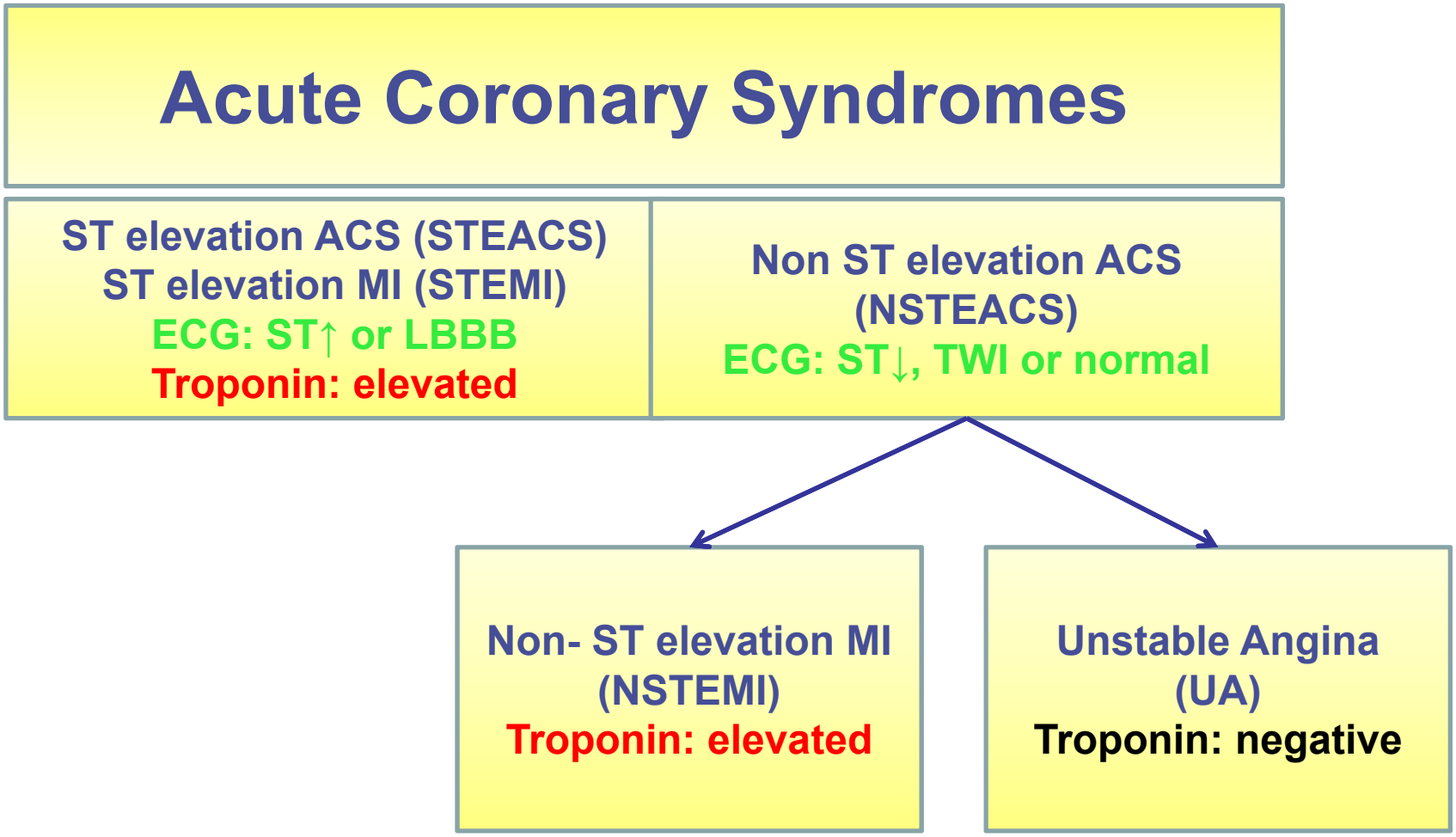
Clinical Terminology

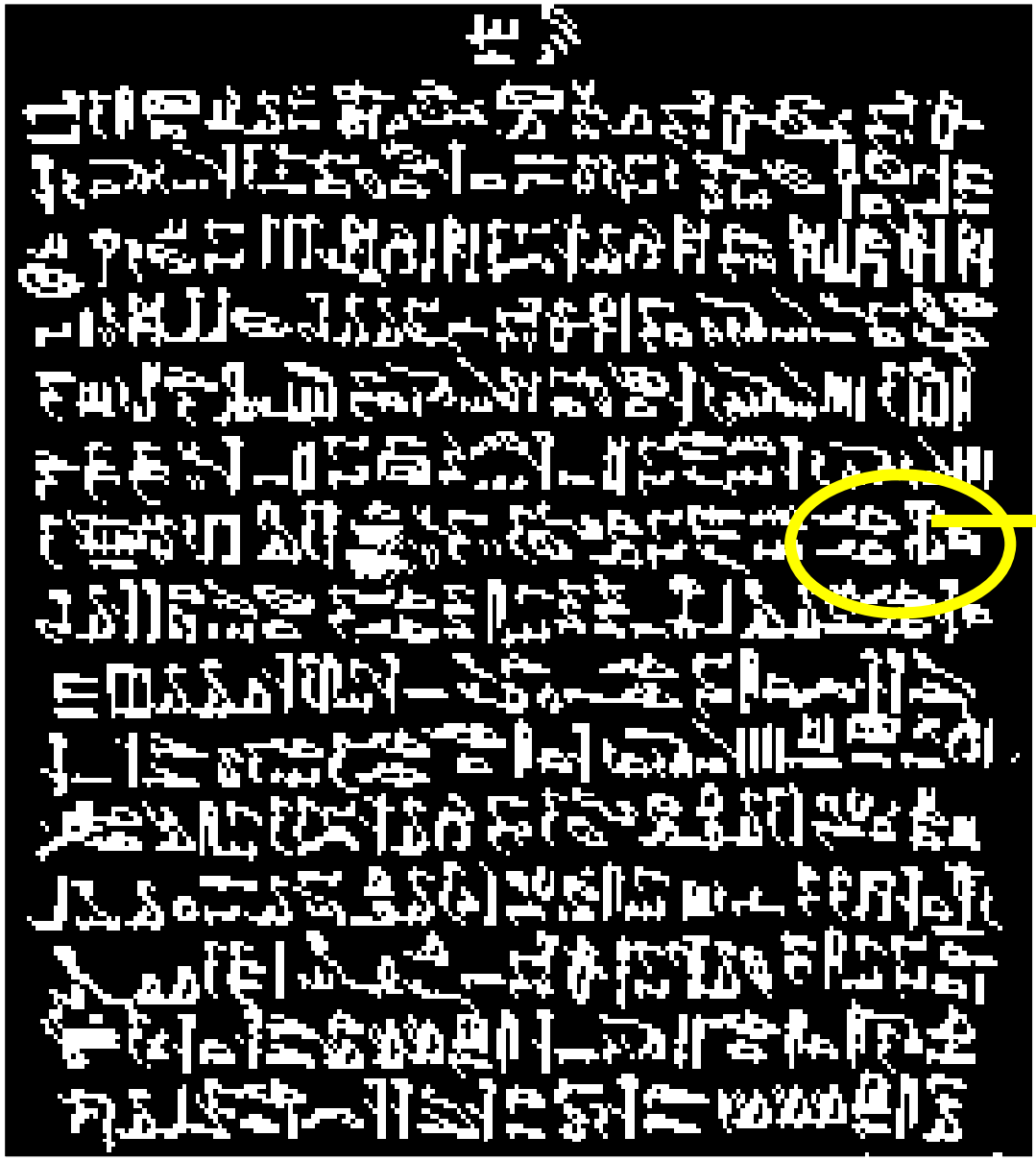


Management Goals

- Make the correct diagnosis
- Assess risk
  - Death, re-MI, heart failure
  - Complications of treatment (bleeding)
- Rapidly administer appropriate treatment
- Reduce risk of major adverse events
  - Death, MI, heart failure, re-hospitalisation

Clinical Assessment

- History
- Physical examination
- Investigations
- Differential diagnosis
- Management plan



…a man with severe chest pain going down the arms: Death is near …

The Ebers Papyrus 2600 B.C.

with kind permission from J.C. Kaski

Symptoms

- Chest discomfort
  - Central, band like, constricting
  - Radiating to neck, jaw, arms
- Dyspnoea
- Nausea, vomiting
- Sweating
- Preceding crescendo angina
- Time of onset of persistent symptoms

Risk Factors

- Increased age
- Cigarette smoking
- Diabetes mellitus
- Dyslipidaemia
- Hypertension
- Obesity
- Family history

Past Cardiac History

- Previous MI or angina
- CABG
- PCI
- Coronary angiogram
- Obtain dates/locations, if possible

Co-morbidities

- Recent TIA/stroke
- Chronic kidney disease
- Anaemia
- Pregnancy
- Recent bleeding, trauma, surgery
- Chronic lung disease
- Chronic liver disease

Physical Examination

- Airway, Breathing, Circulation
- Signs of shock
  - Cool, clammy, ashen, SBP<80 mm Hg, HR >100
- Signs of cardiac failure
  - ↑ HR, ↑ RR, ↑JVP, basal creps, gallop, ↓O_2 sats
- Murmur (MR, VSD, AS, AR, pericardial rub)
- Peripheral pulses, BP both arms – clinical exclusion of dissection
- Exclude acute neurological event

Investigations

- Serial 12 lead ECG's
- Biomarkers
  - Troponin (I or T)
- Metabolic
  - Glucose
  - Lipids
  - Renal function
  - Liver function
- Haematology
  - FBC
  - Coagulation screen
  - Group + Save
- CXR
- Echocardiogram

Differential Diagnosis

Common

- Pulmonary embolism
- Pneumonia
- Viral pleuritis
- Gastro-oesophageal reflux
- Costochondritis
- Anxiety/panic disorder

Uncommon

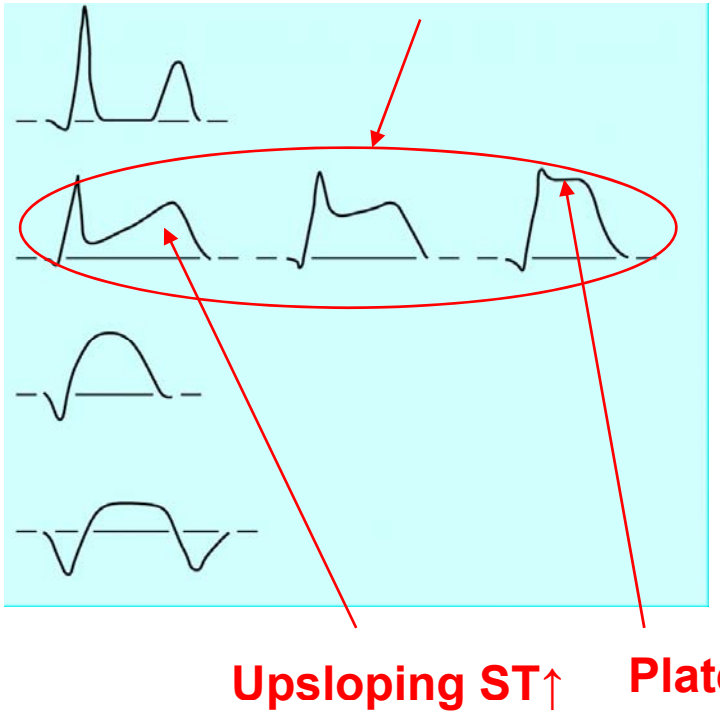
- Pericarditis
- Cardiac tamponade
- Aortic dissection
- Aortic stenosis
- Mitral valve prolapse
- Pneumothorax
- Pulmonary hypertension
- Peptic ulcer disease
- Oesophageal spasm
- Acute cholecystitis
- Pancreatitis
- Herpes zoster
- Gastritis

What can you get from the ECG?

- Diagnosis
  - Is there ST elevation or LBBB?
  - Is there ST depression?
  - Is there T wave inversion?
- Prognosis
  - Establish location
  - Estimate infarct size
- Complications
  - Arrhythmia

Evolution of ECG in acute STEMI

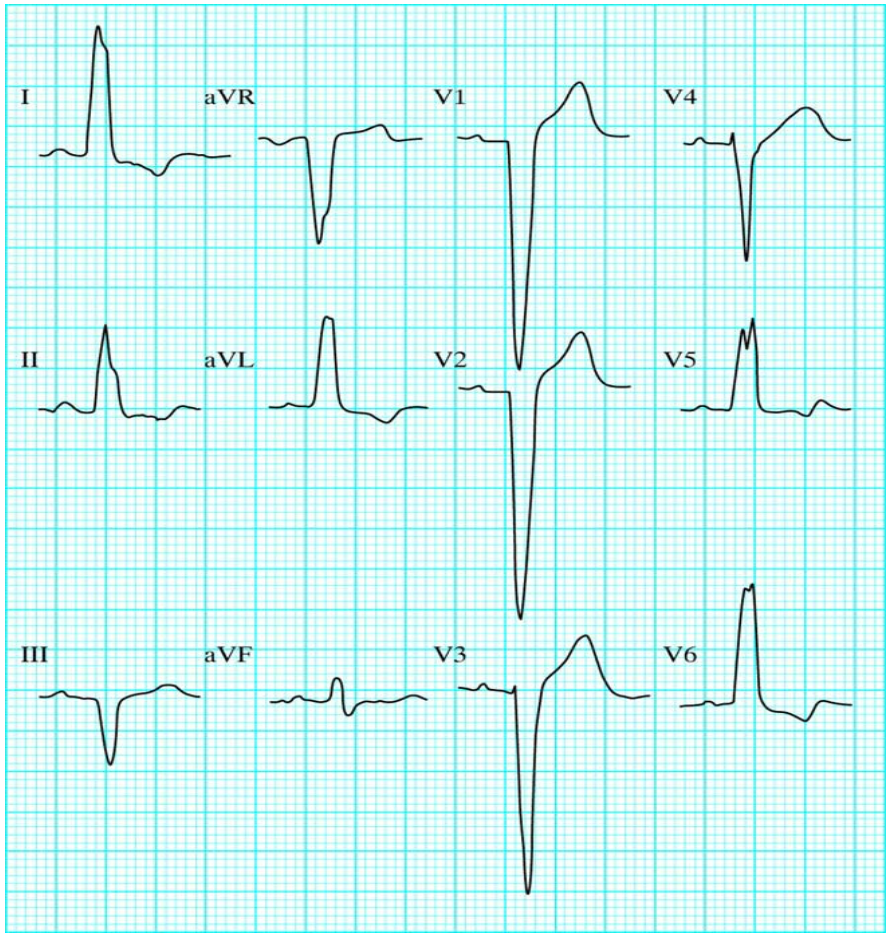
- Hyperacute T wave
- ST elevation
- Q waves + Loss of R wave
- T wave inversion



Morris F, Brady WJ. *BMJ* 2002;324:831-4

LBBB

- QRS >120msec
- QS or RS in V1
- notched broad R wave V5/V6
- no Q in I, V5, V6



Morris F, Brady WJ. *BMJ* 2002;324:831-4

Differential Diagnosis of ST Elevation

- Acute pericarditis
- Acute myocarditis
- Hyperkalaemia
- Brugada syndrome
- ARVD
- Massive PE
- Acute aortic dissection
- Prinzmetal's angina
- LV aneurysm
- Subarachnoid haemorrhage
- post-DC shock
- Early repolarization/High "take-off"/normal variant

Wang et al. NEJM 2003;349:2128-35

Acute STEMI – ECG Criteria

- ST↑
  - >2mm in 2 contiguous leads V1-V3 or
  - >1 mm in at least 2 contiguous other leads
- LBBB (if no previous ECGs available, then LBBB should be presumed to be new)

ECG – Localize Infarct Territory

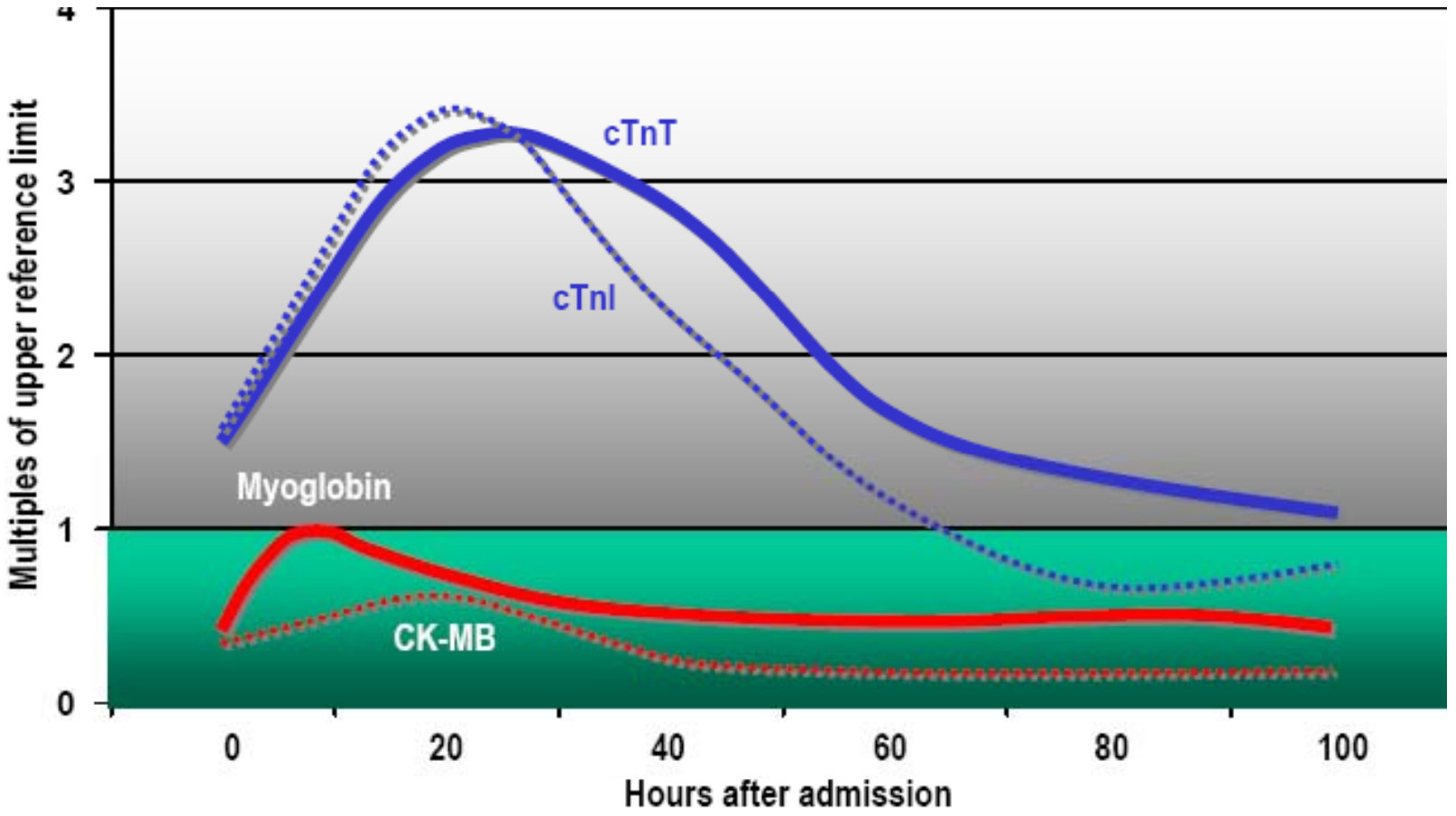
- Antero-septal: ST↑ V1-V4 or LBBB (LAD)
- Inferior: ST↑ II, III, aVF (RCA)
- Lateral: ST↑ I, aVL, V5, V6 (LCx)
- Posterior: ST↑ V7-V9; ST↓ V1-3; dominant R V1 (LCx)
- RV: ST↑ V4R-V6R (RCA)

ECG and Prognosis

- Prognosis worsens as the number of leads showing ST↑ increases
- Location and 30 d mortality (GISSI)
  - Anterior – 16.3%
  - Multi-site – 10.3%
  - Lateral – 9.7%
  - Inferior – 6.2%

Mauri et al. Am J Cardiol 1989;63:1291-5

Cardiac Enzyme Changes in ACS



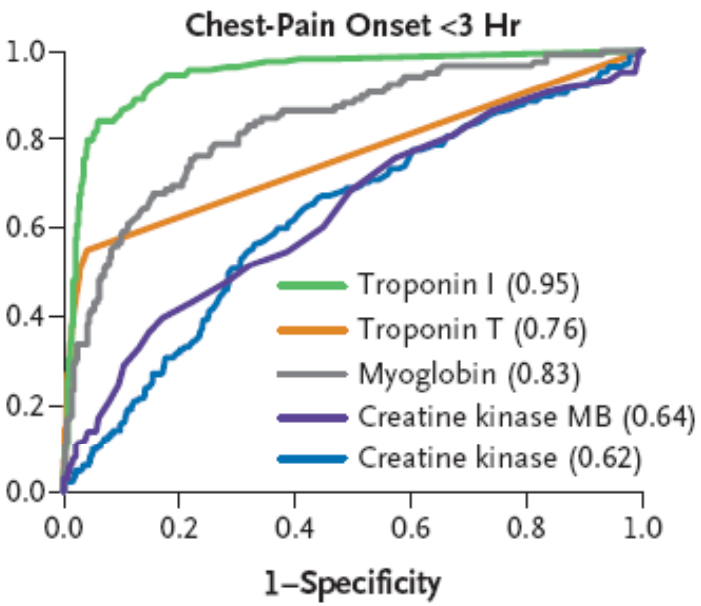
ESC NSTE-ACS Guidelines 2007

3rd Universal Definition Acute MI

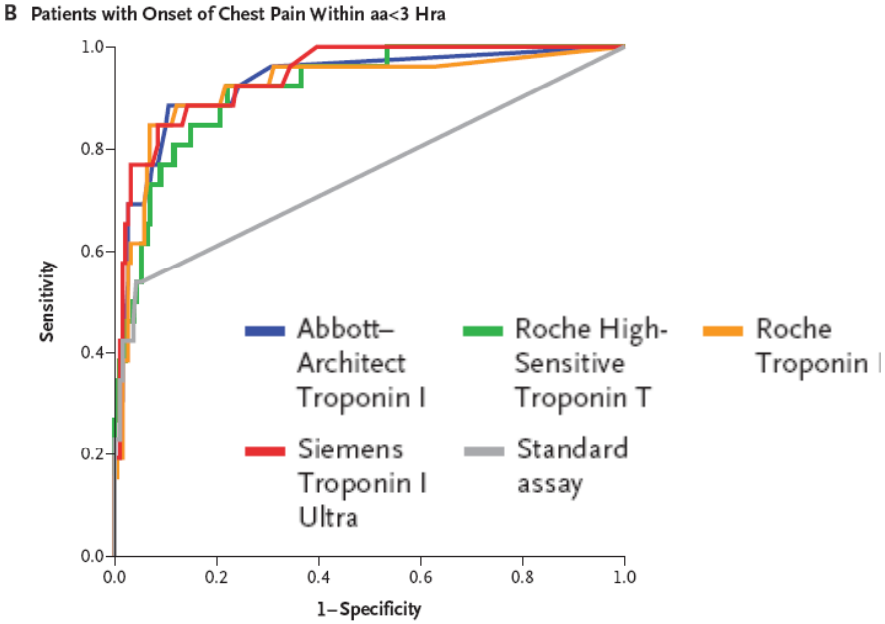
- Rise/fall in cardiac biomarker (ideally cTn) with at least one value >99th centile for a normal reference population + at least one of:
  - Symptoms of ischaemia
  - New/presumed new ST-T changes or new LBBB
  - Development of pathological Q waves
  - Imaging evidence of new loss of viable myocardium or new RWMA
  - Identification of intracoronary thrombus by angiography or autopsy

High Sensitivity Cardiac Troponin Assays

- >100-fold more sensitive
- MI defined as >99th centile of normal population
- Earlier diagnosis
- ↓specificity



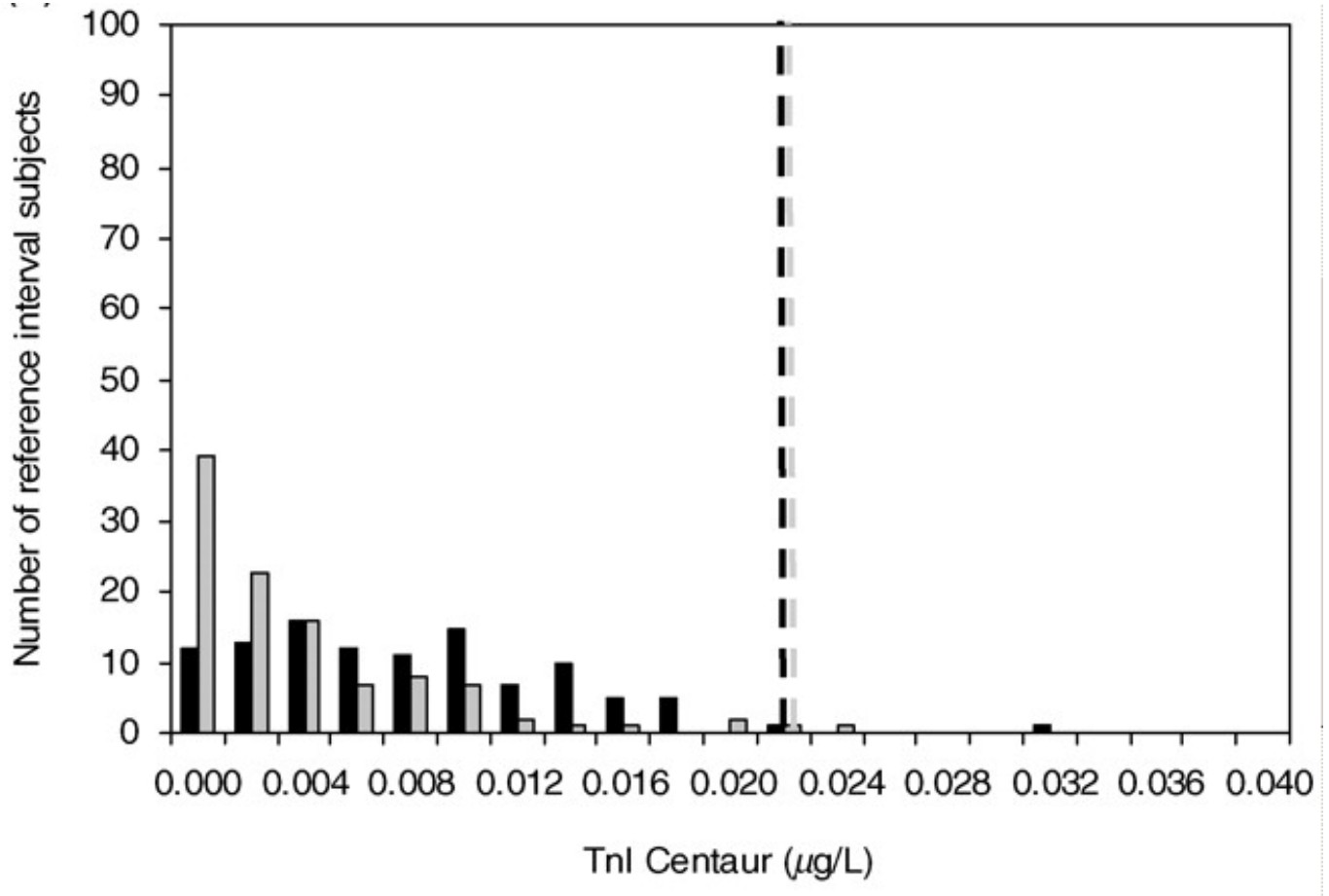
Keller et al NEJM 2009



Reichlin et al NEJM 2009

Definition of Troponin Elevation

>99th centile for normal reference population
Rise or fall
Precise assay
AND symptoms, ECG changes



Non-ACS Causes of Troponin Elevation

Chronic or acute renal dysfunction	Cardiac contusion, ablation, pacing, cardioversion, or endomyocardial biopsy
Severe congestive **heart failure** – acute and chronic	Hypothyroidism
Hypertensive crisis	Apical ballooning syndrome (Tako-Tsubo cardiomyopathy)
Tachy- or bradyarrhythmias	Infiltrative diseases, e.g. amyloidosis, haemochromatosis, sarcoidosis, sclerodermia
Pulmonary embolism, severe pulmonary hypertension	Drug toxicity, e.g. adriamycin, 5-fluorouracil, herceptin, snake venoms
Inflammatory diseases, e.g. **myocarditis**	Burns, if affecting >30% of body surface area
Acute neurological disease, including **stroke**, or subarachnoid haemorrhage	Rhabdomyolysis
Aortic dissection, aortic valve disease or hypertrophic cardiomyopathy	Critically ill patients, especially with respiratory failure, or sepsis

High Risk Features

- Age >75y
- Cardiac arrest
- Cardiogenic shock
- Heart failure
- Diabetes mellitus, chronic kidney disease, ♀
- Murmur
  - MR, VSD
- ECG
  - LBBB > ST↑ > ST↓ > TWI > normal
  - Anterior > Posterior > Lateral > Inferior

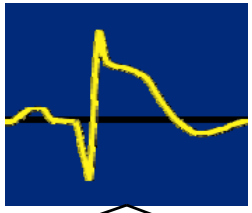
Management Goals

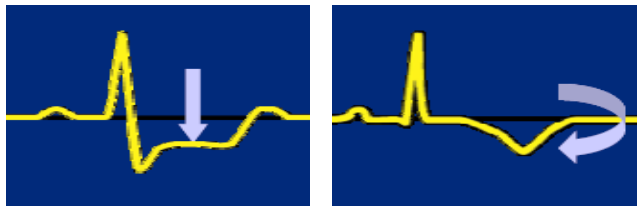
- Reduce MI size
- Stabilise plaques
- Manage thrombosis
- Manage LV remodelling

Reduce MI size

- Open the artery as quickly as possible
  - PPCI or fibrinolysis
  - Adenosine, nitroprusside, nicardipine, Gp IIb/IIIa antagonists (reduce no-reflow)
- Drugs
  - β blockers
  - *Cyclosporine*
  - *Sodium nitrite*
- Other
  - *Post-conditioning*
  - *Progenitor cells*

ACS





PPCI
Transfer <1h
DTB <60 min
Cardiogenic shock
CI to lysis

Lysis
Pre-hospital
Pain to Rx <2h
If transfer >2h:
Lytic+GpIIbIIIa

Fail to reperfuse → Rescue PCI

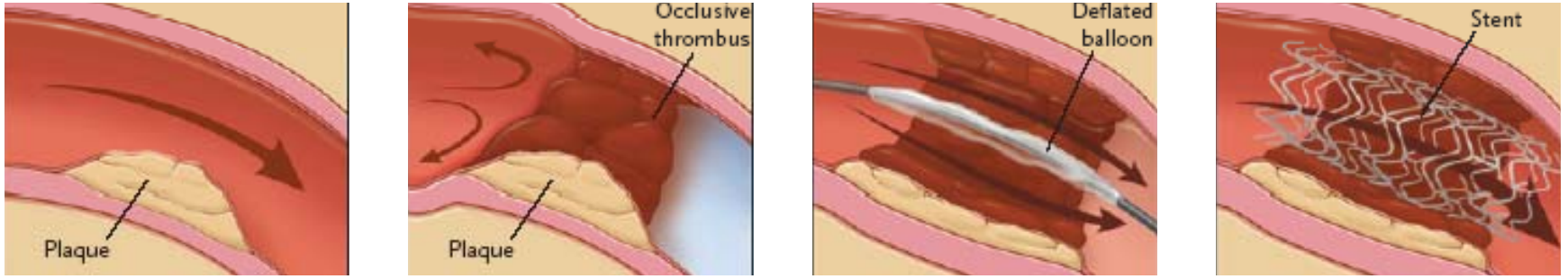
PCI within 24h

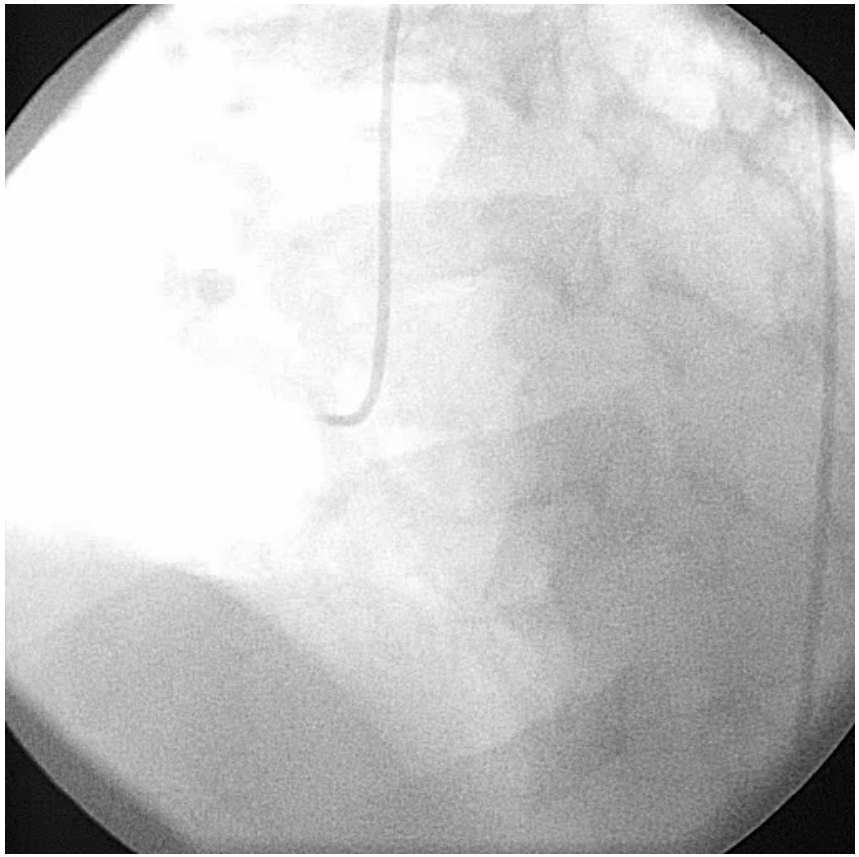
Medical Rx
Risk Stratification

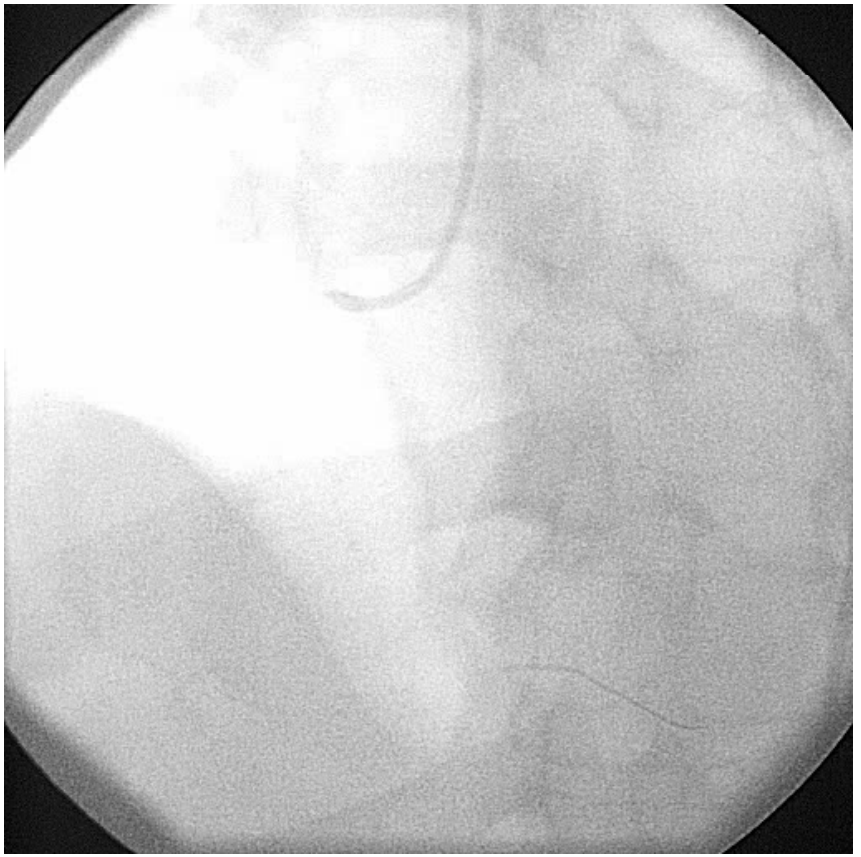
High/Intermediate Risk → Angiography ± Revasc. within 24h

Low Risk → Medical Rx ± Revasc.

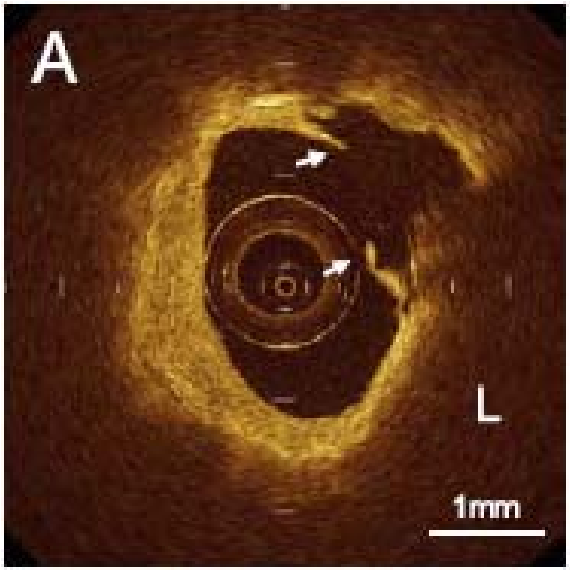
PPCI for STEMI

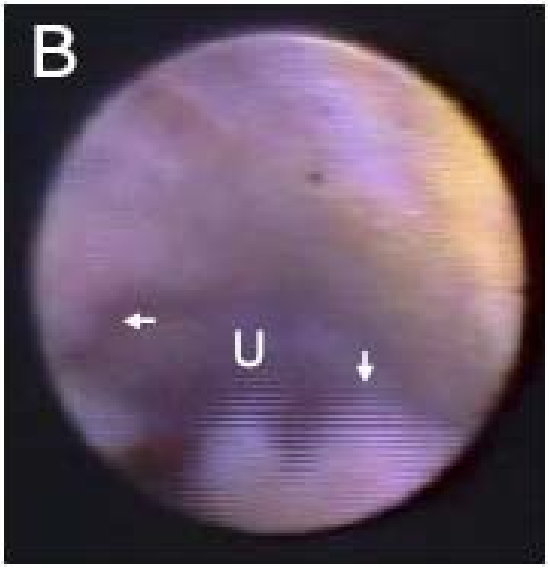


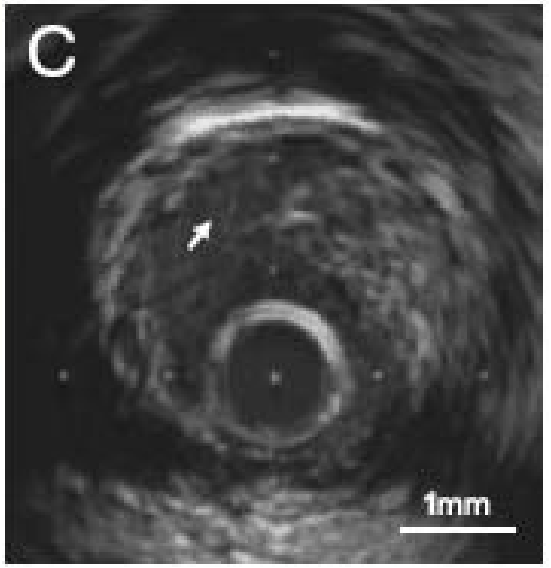




Plaque Rupture In Vivo





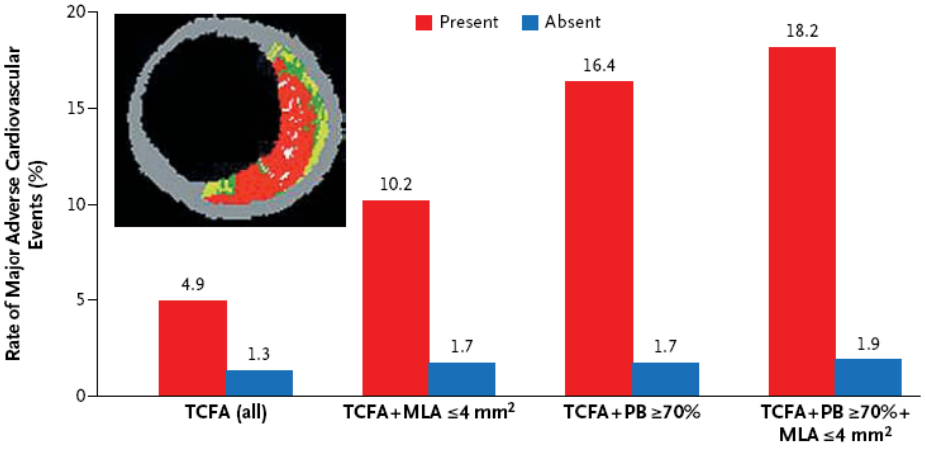


OCT **Angioscopy** **IVUS**

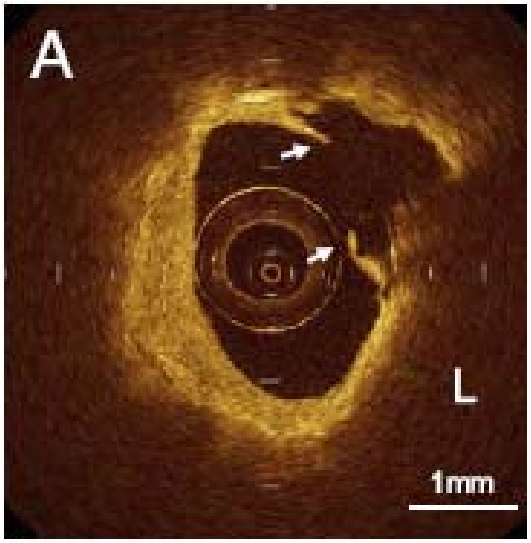
Kubo et al. JACC 2007

Novel Diagnostics in NSTEACS

- Plaque characterisation
- IVUS
- OCT



Lesion hazard ratio (95% CI)	3.90 (2.25–6.76)	6.55 (3.43–12.51)	10.83 (5.55–21.10)	11.05 (4.39–27.82)
P value	<0.001	<0.001	<0.001	<0.001
Prevalence (%)	46.7	15.9	10.1	4.2



Stone et al. NEJM 2011

STEACS Immediate Drug Treatment

PPCI

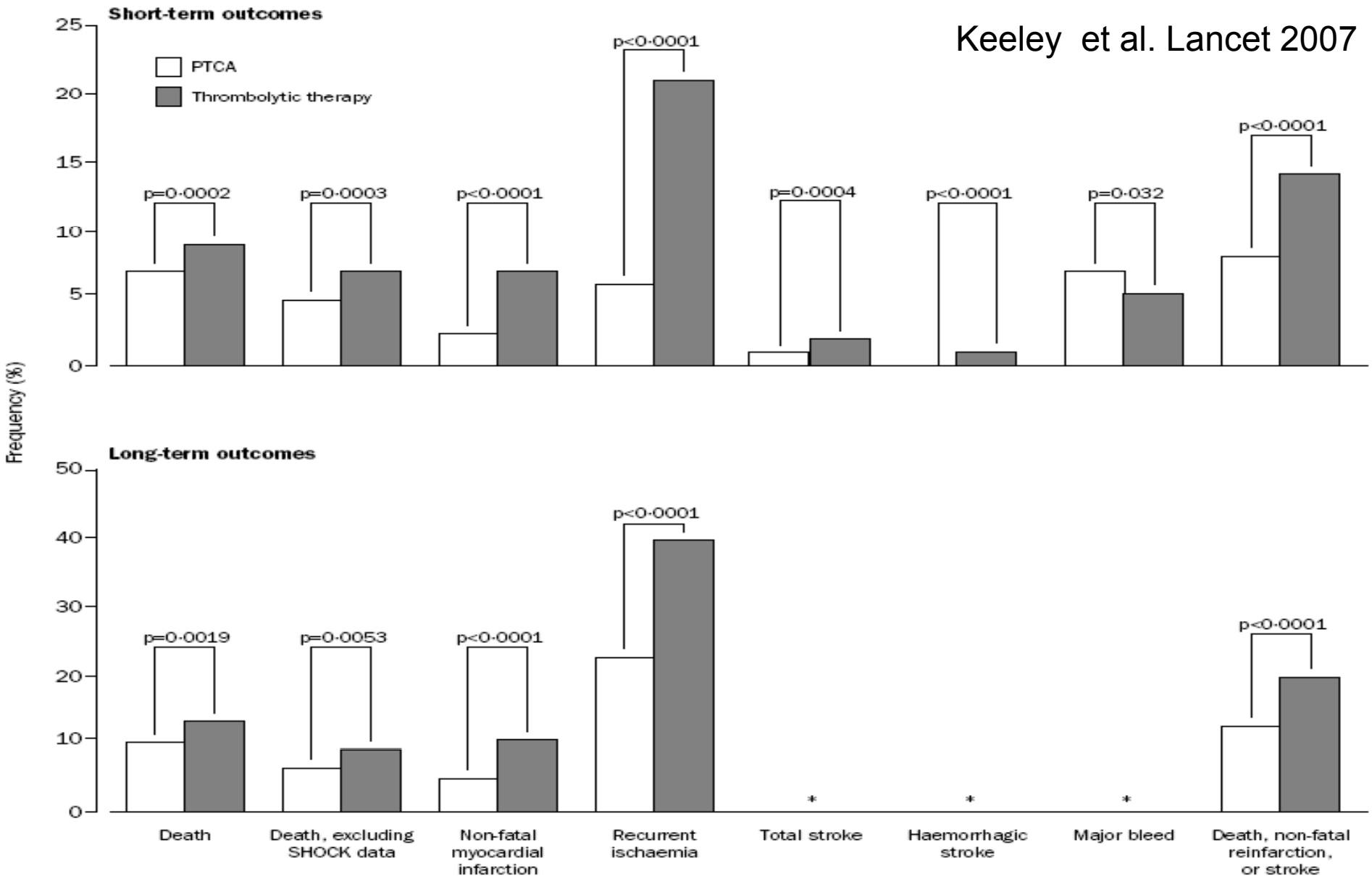
- Aspirin 300mg
- P2Y12 receptor antagonist
  - Clopidogrel 600mg *(CURRENT-OASIS7)*
  - Prasugrel 60mg *(TRITON-TIMI38, HR 0.81, NNT=46)*
  - Ticagrelor 180 mg *(PLATO, HR 0.84, NNT=54)*
- Antithrombin
  - UFH
  - Enoxaparin *(ATOLL)*
  - Bivalirudin *(HORIZONS-AMI)*

Lysis

- Fibrin specific
  - Tenecteplase
- Aspirin 300mg
- P2Y12 receptor antagonist
  - Clopidogrel 300mg *(CLARITY-TIMI28)*
- Antithrombin
  - UFH
  - Enoxaparin *(EXTRACT-TIMI25)*
  - Fondaparinux *(OASIS-6)*

PPCI v Fibrinolysis

Keeley et al. Lancet 2007



Manage Thrombotic Burden/Risk

Acute

- Thrombectomy
- Drugs
  - Oral: Aspirin, clopidogrel, prasugrel, ticagrelor
  - SC: LMWH, fondaparinux
  - IV: Bivalirudin, GpIIb/IIIa inhibitors, fibrinolytics, *Factor Xa inhibitors*

Recurrent

- Oral antiplatelet drugs
- Anticoagulants
  - *Direct thrombin inhibition*
  - *Factor Xa inhibitors*

Plaque Stabilisation

Mechanical

- Stent
- Biobasorbable vascular scaffolds

Drugs

- Statins (high dose)
- ACE inhibitors
- *LpPLA2 inhibitors?*
- *Ivabradine?*

Manage LV Remodelling

Non-Drug

- CRT-P/D
- Progenitor cells

Drugs

- β blockers
- ACE inhibitors
- Angiotensin receptor blockers
- Aldosterone receptor antagonists

QUESTIONS?

Imperial College London

Royal Brompton & Harefield NHS
NHS Foundation Trust

NHS
National Institute for Health Research

Clinical Diagnosis of ACS

Feature	High Likelihood Any of the following:	Intermediate Likelihood *Absence of high-likelihood features and presence of any of the following:*	Low Likelihood *Absence of high- or intermediate-likelihood features but may have:*
History	Chest or left arm pain or discomfort as chief symptom reproducing prior documented angina Known history of CAD, including MI	Chest or left arm pain or discomfort as chief symptom Age greater than 70 years Male sex Diabetes mellitus	Probable ischemic symptoms in absence of any of the intermediate likelihood characteristics Recent cocaine use
Examination	Transient MR murmur, hypotension, diaphoresis, pulmonary edema, or rales	Extracardiac vascular disease	Chest discomfort reproduced by palpation
ECG	New, or presumably new, transient ST-segment deviation (1 mm or greater) or T-wave inversion in multiple precordial leads	Fixed Q waves ST depression 0.5 to 1 mm or T-wave inversion greater than 1 mm	T-wave flattening or inversion less than 1 mm in leads with dominant R waves Normal ECG
Cardiac markers	Elevated cardiac TnI, TnT, or CK-MB	Normal	Normal

Clinical Risk Stratification

Feature	High Risk *At least 1 of the following features must be present:*	Intermediate Risk *No high-risk feature, but must have 1 of the following:*	Low Risk *No high- or intermediate-risk feature but may have any of the following features:*
History	Accelerating tempo of ischemic symptoms in preceding 48 h	Prior MI, peripheral or cerebrovascular disease, or CABG; prior aspirin use	
Character of pain	Prolonged ongoing (greater than 20 min) rest pain	Prolonged (greater than 20 min) rest angina, now resolved, with moderate or high likelihood of CAD Rest angina (greater than 20 min) or relieved with rest or sublingual NTG Nocturnal angina New-onset or progressive CCS class III or IV angina in the past 2 weeks without prolonged (greater than 20 min) rest pain but with intermediate or high likelihood of CAD (see Table 6)	Increased angina frequency, severity, or durationAngina provoked at a lower threshold New onset angina with onset 2 weeks to 2 months prior to presentation
Clinical findings	Pulmonary edema, most likely due to ischemia New or worsening MR murmur S_3 or new/worsening rales Hypotension, bradycardia, tachycardia Age greater than 75 years	Age greater than 70 years	
ECG	Angina at rest with transient ST-segment changes greater than 0.5 mm Bundle-branch block, new or presumed new Sustained ventricular tachycardia	T-wave changes Pathological Q waves or resting ST-depression less than 1 mm in multiple lead groups (anterior, inferior, lateral)	Normal or unchanged ECG
Cardiac markers	Elevated cardiac TnT, TnI, or CK-MB (e.g., TnT or TnI greater than 0.1 ng per ml)	Slightly elevated cardiac TnT, TnI, or CK-MB (e.g., TnT greater than 0.01 but less than 0.1 ng per ml)	Normal