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2014 ESC/EACTS Guidelines on myocardial revascularization: web addenda

The Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS)

Developed with the special contribution of the European Association of Percutaneous Cardiovascular Interventions (EAPCI)

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Web appendix

The web appendix to the 2014 ESC/EACTS Guidelines on myocardial revascularization contains additional material which should be used for further clarification when reading the main document. The numbering of the sections in this web document corresponds to the section numbering in the main document.

3. Scores and risk stratification

Table 1 provides a summary of studies comparing the logistic EuroSCORE, EuroSCORE II, and STS score as risk model to predict outcomes after coronary revascularization.

5. Strategies for diagnosis: functional testing and imaging

5.1 Detection of coronary artery disease

Multidetector computed tomography (MDCT) provides a non-invasive means of directly imaging the coronary arteries.

Multidetector computed tomography coronary artery calcium score and angiography

Coronary artery calcium scores have been used to risk-stratify asymptomatic populations, but have no established role in individual decision-making in symptomatic patients. In detecting coronary artery disease (CAD), MDCT coronary angiography has generally shown high negative predictive values (NPVs)[9] while positive predictive values were only moderate. In the four published multi-centre trials on patients with stable angina, three were consistent with the results of prior meta-analyses,[10,11] but one showed only moderate NPV (83–89%).[12] Only about half of the stenoses classified as significant by MDCT are associated with ischaemia,[13] indicating that MDCT angiography cannot accurately predict the haemodynamic significance of coronary stenosis. MDCT can be also used to characterize coronary plaques but its impact on therapy decisions is currently unclear. Thus, MDCT angiography is reliable for ruling out significant CAD in patients with low-to-moderate probability of CAD and has prognostic value.[14]

In the setting of suspected ACS, MDCT coronary angiography has the potential to exclude the presence of significant CAD among low-risk patients without electrocardiographic ischaemic changes and with negative serum troponin. Several studies have reported high NPVs and/or benign clinical outcome in the presence of a normal MDCT scan in such patients.[15–17] Accordingly, MDCT coronary angiography can be considered to exclude ACS when there is a low-to-intermediate likelihood of CAD and when troponin and electrocardiogram (ECG) are negative or inconclusive.[18] Multidetector computed tomography coronary angiography has no role in the routine management of high-risk non-ST-segment elevation acute coronary syndrome (NSTE-ACS) and ST-segment elevation myocardial infarction (STEMI) patients.[19]

Table 1 Studies comparing the logistic EuroSCORE, EuroSCORE II, and STS score as risk model to predict outcomes after coronary revascularization

Author	No of patients	Inclusion	Design	Coronary procedures	Discrimination (c-statistic)			Calibration [goodness-of-fit (Hosmer-Lemershow)]		
					Log ES	ES II	STS	Log ES	ES II	STS
Biancari[1]	1027	2006–2011	Retrospective, single-centre	(i)CABG	0.838	0.852	-	-	-	-
Kirmani[2]	14 432	2001–2010	Retrospective, single-centre	66% (i)CABG, 12% CABG+valve	-	0.818	0.805	-	<0.001	<0.001
Kunt[3]	428	2004–2012	Retrospective, single-centre	(i)CABG	0.70	0.72	0.62	-	<0.01	0.10
Spiliopoulos[4]	216	1999–2005	Retrospective, single-centre	CABG+AVR	0.75	0.77	-	-	-	-
Wang[5]	818	2010–2012	Retrospective, single-centre	(i)CABG	0.675	0.642	0.641	0.061 ($\chi 2$ = 13.5)	0.15 ($\chi 2$ = 12.0)	0.243 ($\chi 2$ = 10.3)
Chalmers[6]	2913	2006–2010	Retrospective, single-centre	(i)CABG	0.77	0.79	-	0.41	0.052	-
Chalmers[6]	517	2006–2010	Retrospective, single-centre	CABG+AVR	0.67	0.74	-	0.38	0.38	-
Carnero-Alcázar[7]	1231	2005-2010	Retrospective, single-centre	(i)CABG	0.884	0.90	-	0.01 ($\chi 2$ = 20.1)	0.001 ($\chi 2$ = 26.6)	-
Carnero-Alcázar[7]	301	2005–2010	Retrospective, single-centre	CABG+valve	0.779	0.827	-	0.029 ($\chi 2$ = 17.3)	0.334 ($\chi 2$ = 9.1)	-
Osnabrugge[8]	16 096	2003–2012	Retrospective, multicenter	(i)CABG	-	0.77	0.81	-	STS score better in figure, no formal test	
Osnabrugge[8]	1627	2003–2012	Retrospective, multicenter	CABG+AVR	-	0.74	0.76	-	-	-

AVR = aortic valve replacement; CABG = coronary artery bypass graft; (i)CABG = (isolated) coronary artery bypass grafting; ES = EuroSCORE; TS = Society of Thoracic Surgeons.

The interpretation of MDCT requires special expertise and its uncontrolled use may lead to inferior diagnostic outcome. Multidetector computed tomography typically overestimates the severity of atherosclerotic obstructions; the findings need to be put into clinical context and decisions for patient management often require further functional testing.

Invasive coronary imaging

In clinical practice, many patients with intermediate or high pre-test CAD probability undergo diagnostic coronary angiography without prior functional testing. Invasive coronary angiography has been regarded as the reference standard for the detection and assessment of the severity of CAD. It has better temporal and spatial resolution than MDCT; however, as an invasive procedure, it has higher procedure-related rate of adverse events than non-invasive imaging tests. It provides information about luminal narrowing and, without functional information, even experienced interventional cardiologists cannot accurately predict the significance of many intermediate stenoses on the basis of visual assessment or quantitative coronary angiography.[20] Intravascular ultrasound (IVUS) and optical coherence tomography (OCT) are techniques that allow more accurate assessment of the luminal narrowing and characterization of plaques. However, their value in clinical routine is not yet established.

5.2 Detection of ischaemia

The tests for detection of ischaemia are based on either reduction of perfusion or induction of ischaemic wall motion abnormalities during exercise or pharmacological stress. The best-established stress imaging techniques are echocardiography and perfusion scintigraphy. Both may be used in combination with exercise stress or pharmacological stress. Newer stress imaging techniques also include stress magnetic resonance imaging (MRI), positron emission tomography (PET) imaging, and combined approaches. The term 'hybrid imaging' refers to imaging systems in which two modalities [MDCT and PET, MDCT and single photon emission computed tomography (SPECT)] are combined in the same scanner, allowing both studies to be performed in a single imaging session.

Stress imaging techniques have several advantages over conventional exercise ECG testing, including superior diagnostic performance, the ability to quantify and localize areas of ischaemia, and the ability to provide diagnostic information in the presence of resting ECG abnormalities or when the patient is unable to exercise.[21] For these reasons, stress imaging techniques are preferred in patients with previous myocardial infarction, percutaneous coronary intervention (PCI), or coronary artery bypass grafting (CABG). In patients with angiographically confirmed intermediate coronary lesions, evidence of ischaemia is predictive of future events.

Stress echocardiography

Stress echocardiography is an established diagnostic test and is more accurate than exercise ECG in the detection of ischaemia.[21]

The most frequently used method is a physical exercise test, typically using a bicycle ergometer, but pharmacological stressors—such as dobutamine and, less frequently, dipyridamole—can also be used. The technique requires adequate training and experience, since it is more user-dependent than other imaging techniques. Pooled sensitivity and specificity of exercise echocardiography are reported as 80–85% and 84–86%, respectively,[21] and the method has shown also to provide significant prognostic value.[22–24]

Recent technical improvements involve the use of contrast agents to facilitate identification of regional wall motion abnormalities and to image myocardial perfusion. These agents improve the interpretability of the images, but the technique of perfusion imaging is not yet established.

Perfusion scintigraphy

SPECT perfusion is an established diagnostic test. It provides a more sensitive and specific prediction of the presence of CAD than exercise ECG. The reported sensitivity and specificity of exercise scintigraphy ranges from 85–90%, compared with the 70–75% of invasive angiography.[21]

Newer SPECT techniques with ECG gating improve the diagnostic accuracy in various patient populations, including women, diabetics, and elderly patients[25]; a recent meta-analysis detected a sensitivity of 85% and a specificity of 85%, and the method has been shown to provide significant prognostic value.[26] Adding information from a simultaneously performed calcium score using MDCT may further increase the accuracy.[27]

Cardiovascular magnetic resonance imaging

Cardiac MRI stress testing with pharmacological stressors can be used to detect wall motion abnormalities induced by dobutamine infusion, or perfusion abnormalities induced by adenosine. Cardiac MRI has only recently been applied in clinical practice, therefore fewer data have been published than for other established non-invasive imaging techniques.[21]

A recent meta-analysis showed that stress-induced wall motion abnormalities from MRI had a sensitivity of 83% and a specificity of 86% in patient-based analysis, and perfusion imaging demonstrated 91% sensitivity and 81% specificity.[28] When evaluated prospectively in two multi-centre trials, the sensitivities have been 85% and 67% and specificities 67% and 61%.[29,30] Cardiac MRI has significant prognostic value.[31,32]

Multidetector computed tomography perfusion and multidetector computed tomography-derived fractional flow reserve

MDCT can be used for perfusion imaging, but data obtained in clinical settings are still limited. The fractional flow reserve (FFR) derived from anatomical MDCT images has also been put forward as a functional measure, but more evidence is needed before the clinical value of the method is understood.[33]

Positron emission tomography

Studies with myocardial perfusion PET have reported excellent diagnostic capabilities in the detection of CAD. The comparisons of PET perfusion imaging have also favoured PET over SPECT.[34]

Two meta-analyses with PET demonstrated 90–93% sensitivity and 81–88% specificity for CAD detection,[26,35] superior to myocardial perfusion SPECT. Myocardial blood flow, expressed in absolute units (mL/g/min), measured by PET further improves diagnostic accuracy, especially in patients with multi-vessel disease, and can be used to monitor the effects of various therapies. The method also has significant prognostic value.[36,37]

Hybrid/combined imaging

The combination of anatomical and functional imaging has become appealing because the spatial correlation of structural and functional information contained in the fused images facilitates comprehensive interpretation of coronary lesions and their pathophysiological relevance. This combination can be obtained either with image co-registration or with devices that have two modalities in combination (MDCT and SPECT; MDCT and PET).

Numerous single-centre studies have demonstrated that integrated coronary artery calcium or MDCT and perfusion imaging provide independent information for diagnosis, assessment of the severity of CAD and prognosis, and also have significant impact on clinical decision-making.[38–43] No large, multi-centre studies are currently available. Hybrid imaging has also been shown to have prognostic value.[44,45]

6. Revascularization for stable coronary artery disease

6.1 Rationale for revascularization

6.1.1 Impact on symptoms, quality of life, and anti-angina drugs

Angina is associated with impaired quality of life, reduced physical endurance, mental depression, and recurrent hospitalizations and office visits.[46] Revascularization by PCI or CABG more effectively relieves angina, reduces the use of anti-angina drugs, and improves exercise capacity and quality of life than with a strategy of medical therapy alone (*Table 2*).[47–53]

The Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation (COURAGE) study showed an incremental benefit from PCI over medical therapy in terms of freedom from angina, angina frequency and stability, measures of physical limitation, treatment satisfaction and quality of life for 6–24 months, the benefit being attenuated after 36 months.[54] The benefit from PCI was greatest among patients with severe and frequent angina. The findings have to be interpreted in the light of the considerable cross-over from medical therapy to subsequent revascularization and the fact that 25% of patients had missing follow-up health status assessments. Freedom from angina at one year was relatively low, with 66% in the PCI group of COURAGE compared with 81% in the PCI group of Fractional Flow Reserve Versus Angiography for Multi-vessel Evaluation (FAME-2),[50] a difference that may be explained by the near-exclusive use of DES, reducing the rate of re-stenosis, in the FAME-2 trial.

A meta-analysis of 14 RCTs enrolling 7818 patients reported a benefit on angina relief of PCI over medical treatment (OR 1.69; 95% CI 1.24–2.30).[55] The benefit of PCI appeared less pronounced in more recent RCTs, potentially resulting from greater use of evidence-based medical treatment. Notably, only the longest available follow-up information was used in this study—which is a limitation, in view of the diminishing *observed* benefit during earlier time points as a consequence of the ongoing cross-over from medical treatment to revascularization. A more recent meta-analysis of 12

Table 2 Revascularization versus medical therapy: angina, exercise time, and number of medications at early and late follow-up

Study	Angina		Exercise time		Number of medications	
	Early	Late	Early	Late	Early	Late
ACME[57]	64% vs. 46%* free of angina at 6 months	62% vs. 47%* free of angina at 3 years	11.2 min vs. 9.5* min exercise time duration at 6 months	10.0 min vs. 8.5* min exercise time duration at 3 years	30% vs. 50% on ß-blocker*, 35% vs. 71% on CCB*, and 24% vs. 50% on nitrate* at 6 months	28% vs. 39% on ß-blocker, 47% vs. 72% on CCB*, and 24% vs. 52% on nitrate* at 3 years
RITA-2[47,58]	19.4% vs. 35.9%* at 3 months	15.0% vs. 21.4%* at 5 years	37 s in favor of PCI* at 3 months	25 s in favor of PCI* at 3 years	37% vs. 57% on ≥2 drugs at 3 months	31% vs. 45% on ≥2 drugs at 5 years
AVERT[59]	Improvement in angina 54% vs. 41%* at 1.5 years	-	-	-	61% vs. 60% on ß-blocker, 44% vs. 49% on CCB, and 50% vs. 60% on nitrate at 1.5 years	-
TIME[60]	Significant improvement in angina class at 6 months	No differences in angina class at 1 year	-	-	Significant reduction of number of drugs at 6 months	Significant reduction of number of drugs at 1 year
MASS II[53,61]	21% (PCI) vs. 12% (CABG) vs. 54% (MT) free of angina* at 1 year	41% (PCI) vs. 36% (CABG) vs. 57% (MT) free of angina* at 10 years	-	-	-	-
SWISSI II[51]	-	-	Max workload at bicycle ergometry 169 W vs. 148 W* at 4 years	Max workload at bicycle ergometry 173 W vs. 136 W* at 10 years	49% vs. 86% on ß-blocker*, 21% vs. 51% on CCB*, and 12% vs. 47% on nitrate* at 4 years	39% vs. 84% on ß-blocker*, 17% vs. 32% on CCB, and 4% vs. 45% on nitrate* at 10 years
COURAGE[54]	56% vs. 47%* free of angina at 6 months	59% vs. 56% free of angina at 3 years	-	-	85% vs. 89% on ß-blocker, 40% vs. 49% on CCB*, and 53% vs. 67% on nitrate* at 1 year	85% vs. 86% on ß-blocker, 42% vs. 52% on CCB*, and 40% vs. 57% on nitrate* at 5 years

*$P < 0.05$
CCB = calcium-channel blocker; PCI = percutaneous coronary intervention; CABG = coronary artery bypass grafting; MT = medical therapy; W = watts.

RCTs enrolling 7182 patients confirmed a benefit of PCI over medical treatment in terms of freedom from angina (RR 1.20; 95% CI 1.06–1.37) at all follow-up points, but no beneficial effect on death, myocardial infarction or repeat revascularization.[56]

6.1.2 Impact on ischaemia

Ischaemia is of prognostic importance in patients with SCAD, particularly when occurring at low levels of exertion.[62,63] Revascularization more effectively relieves myocardial ischaemia than medical treatment alone. In the Swiss Interventional Study on Silent Ischaemia Type II (SWISSI II) trial, patients with silent ischaemia after recent myocardial infarction showed lower rates of ischaemia when randomized to PCI (12%) than with medical treatment (29%; $P = 0.03$) and also had improved LV function (LVEF 56% vs. 49%, respectively; $P < 0.001$).[51] In the prospectively defined myocardial perfusion substudy of COURAGE, in comparison to medical therapy alone, PCI achieved an absolute reduction in myocardial ischaemia (−2.7% vs. −0.5%, respectively; $P < 0.0001$), and a higher number of patients with a relevant reduction in ischaemia (33% vs. 19%, respectively; $P = 0.0004$), particularly among those with moderate-to-severe ischaemia (78% vs. 52%, respectively; $P = 0.007$).[64] In this study, the rate of death or myocardial infarction was lower among those with significant ischaemia reduction (>5%), particularly if baseline ischaemia was moderate to severe (significant reduction: 16.2% vs. no significant reduction: 32.4%; unadjusted $P < 0.001$; risk-adjusted $P = 0.09$).[64] An observational myocardial perfusion study of 13 969 patients, with a mean follow-up of 8.7 ± 3.3 years, showed a survival benefit of revascularization over medical treatment in patients with significant ischaemia (>10% of LV inducible ischaemia), whereas no such benefit was apparent in patients with only mild ischaemia or none at all.[63] The benefit of revascularization has also been shown to be directly related to the extent of ischaemic myocardium.[65] In a meta-analysis of five RCTs covering 5286 patients and site-reported ischaemia at baseline, at a median of 5 years follow-up there were no differences between PCI and medical treatment in terms of angina death, myocardial infarction or unplanned revascularization.[66] The extent, location, and severity of coronary artery obstruction, as assessed by coronary angiography or coronary CT angiography, are important prognostic factors in addition to ischaemia and left ventricular function.[67–69] Observational data from large-scale registries with long-term follow-up, provide evidence for a gradient of prognostic benefit from revascularization over medical treatment in patients with increasingly severe CAD, including obstructive left main, proximal LAD, and proximal two- and three-vessel CAD.[70–73]

8. Revascularization in ST-segment elevation myocardial infarction

8.1 ST-segment elevation myocardial infarction networks

The main features of STEMI networks are the following:

- Clear definition of geographical areas of responsibility.
- Shared protocols, based on risk stratification and transportation by trained paramedic staff in appropriately equipped ambulances or helicopters.
- Pre-hospital triage of STEMI patients to the appropriate institutions, by-passing non-PCI hospitals whenever primary PCI can be implemented within the recommended time limits.
- On arrival at the appropriate hospital, the patient should immediately be taken to the catheterization laboratory, by-passing the emergency department.
- Patients presenting to a non-PCI-capable hospital and awaiting transportation for primary or rescue PCI must be attended in an appropriately monitored and staffed area.
- If the diagnosis of STEMI has not been made by the ambulance crew and the ambulance arrives at a non-PCI-capable hospital, the ambulance should await the diagnosis and, if STEMI is confirmed, should continue to a PCI-capable hospital.

11. Revascularization in patients with chronic kidney disease

Renal dysfunction may occur in association with hypertension, diabetes, or renovascular disease. Cardiovascular disease is the main cause of mortality in patients with severe chronic kidney disease (CKD), particularly in combination with diabetes.[75] Cardiovascular mortality is much higher among patients with CKD than in the general population or compared with age-matched controls without CKD, and CAD is the main cause of death among diabetic patients after kidney transplantation—all reasons for which CKD is considered a CAD risk-equivalent.[76–78] The adverse association between CKD and cardiovascular outcome is apparent across the spectrum of CAD.[18,19,21,79,80] Despite the increased risk associated with CKD, affected patients receive fewer evidence-based medications and undergo fewer diagnostic coronary angiographies,[76] despite clinical indications that negatively impact on prognosis.[81]

11.2 Definition of chronic kidney disease

Estimation of glomerular renal function in patients undergoing revascularization requires calculation of the glomerular filtration rate (GFR) using a creatinine (or cystatin C)-based method such as the Cockcroft–Gault Modification of Diet in Renal Disease, or Chronic Kidney Disease Epidemiology Collaboration formulae. Normal GFR values are approximately 100–130 mL/min/1.73 m^2 in young men, and 90–120 mL/min/1.73 m^2 in young women, depending on age, sex, and body size. Chronic kidney disease is classified into five different stages, according to progressive GFR reduction and evidence of renal damage (*Table 3*). Patients with GFR $<$60 mL/min/1.73 m^2 are defined as having CKD in clinical practice, and the cut-off GFR value of 60 mL/min/1.73 m^2 correlates with major adverse cardiac event (MACE).

Kidney function is an independent predictor of the Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery (SYNTAX) score in patients with established CAD.[77] An inverse relationship between GFR and the long-term

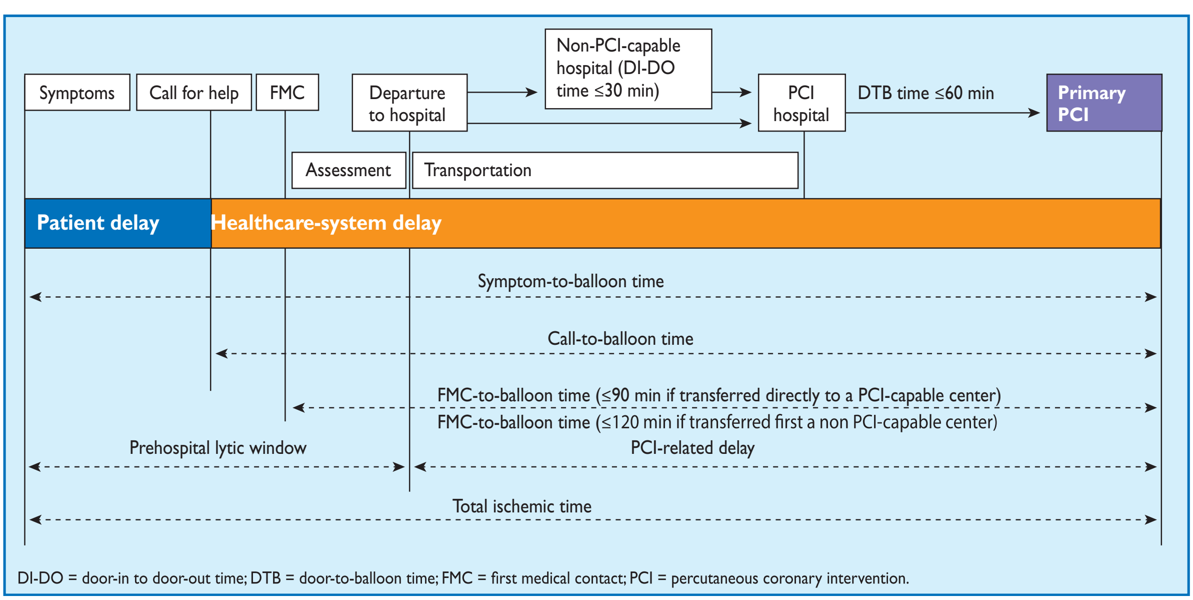

Figure 1 Timeline metrics in the management of ST-segment elevation myocardial infarction. Adapted from Gershlick et al.[74]

Table 3 National Kidney Foundation[86] – classification of chronic kidney disease (CKD) based on glomerular filtration rate (GFR)

GFR stage	GFR (mL/min/1.73 m²)	Description
G1	≥90	Normal or high
G2	60–89	Mildly decreased
G3a	45–59	Mildly to moderately decreased
G3b	30–44	Moderately to severely decreased
G4	15–29	Severely decreased
G5	<15	Kidney failure (add D if treated by dialysis)

CKD = chronic kidney disease; GFR = glomerular filtration rate.

risk of death or myocardial infarction, as well as of bleeding, has been observed in patients undergoing revascularization by CABG or PCI, which is highest among those with end-stage renal disease.[82–85]

17. Procedural aspects of percutaneous coronary intervention

17.2 Adjunctive invasive diagnostic tools

The diagnostic value of intracoronary diagnostic techniques is summarized in *Table 4*.

Table 4 Diagnostic value of intracoronary diagnostic techniques

IVUS to detect total plaque burden and disease progression / regression.
IVUS to assess transplant vasculopathy.
IVUS to assess severity of angiographically intermediate lesions.
IVUS for stent failure (in-stent restenosis, stent thrombosis).
Radiofrequency-IVUS-Virtual histology to detect high-risk coronary plaques.
OCT to detect features suggestive of TCFA, intracoronary thrombus, and cap rupture.
OCT to assess transplant vasculopathy.
OCT to assess stent healing (neointimal proliferation, strut coverage, strut apposition).
OCT for stent failure (in-stent restenosis, stent thrombosis).
FFR for assessment of side-branch lesion severity.

FFR = fractional flow reserve; IVUS = intravascular ultrasound; OCT = optical coherence tomography; TCFA = thin-cap fibroatheroma.

20. Medical therapy, secondary prevention, and strategies for follow-up

20.1 Medical therapy to prevent adverse cardiovascular events

Medical therapies and secondary prevention after myocardial revascularization—to reduce the risk of adverse cardiovascular events—include:

- Statin therapy [low-density lipoprotein cholesterol (LDL-C) goal <70 mg/dL; <1.8 mmol/L].
- Statin therapy is the primary recommended therapy for lowering LDL-C. Fibrate or niacin therapy has not been shown to give better prognostic benefits than statin treatment.
- Antithrombotic therapy:
  - Low-dose aspirin (75–100 mg/day). In patients with aspirin intolerance, clopidogrel is recommended as an alternative.
  - In patients with SCAD undergoing PCI, clopidogrel is recommended in addition to aspirin. In patients with ACS, ticagrelor or prasugrel is recommended in addition to aspirin (see detailed information in the main document (section 18).
- ACE inhibition is recommended in patients with diabetes, hypertension, or LV dysfunction.
  - Only agents and doses with proven efficacy for secondary prevention should be employed.
- Antihypertensive therapy (blood pressure target <140/90 mmHg; in diabetic patients <140/85mmHg).
- Antidiabetic therapy (HbA_{1c} target of <7.0%).
- Beta-blocker and aldosterone receptor antagonists in patients with chronic heart failure or LV dysfunction (see below).

Owing to its well-established benefit, the level of risk factor control in patients with CAD in clinical practice needs to be further improved.[87] A recent analysis of four randomized trials has shown that, even in clinical trials, less than 25% of diabetic patients with CAD achieved pre-specified targets for four major modifiable cardiovascular risk factors.[87]

20.2 Medical therapy to improve symptoms and reduce ischaemia

In symptomatic patients, the frequency of episodes of angina and nitroglycerine consumption can be reduced by the use of beta-blockers, calcium antagonists, and long-acting nitrates or molsidomine. In patients with SCAD who remain symptomatic despite anti-anginal therapy with one or two of these treatments, ranolazine can be used to improve exercise tolerance and reduce the frequency of angina episodes. Nicorandil can be used to reduce angina pectoris in patients with SCAD. Nicorandil showed lower levels of cardiovascular events in one study, but the result was driven by the effects of nicorandil on 'hospital admission for cardiac chest pain', and the risk reduction regarding cardiac death or non-fatal myocardial infarction was non-significant. The sinus node inhibitor ivabradine can be used to improve exercise tolerance (e.g. time to limiting angina) in patients with SCAD and angina pectoris in sinus rhythm (heart rate >60/min).

20.3 Lifestyle changes and cardiac rehabilitation programmes

Patients require counselling to help adopt a healthy lifestyle (including smoking cessation, regular physical activity, and a healthy diet) and encourage adherence to their medication plan. The role of the interventional cardiologist and cardiac surgeon is to recommend lifestyle changes, medical therapy for secondary prevention and, when appropriate, cardiac rehabilitation to all revascularized patients.[88–90] Therapy should be initiated during hospitalization, when patients are highly motivated. Adherence to lifestyle and risk-factor modification requires individual behavioural education and can be implemented during exercise-based cardiac rehabilitation.[91]

Early mobilization and physical conditioning programmes should vary according to individual clinical status.[91,92] Adherence to the prescribed recommendations and the achievement of the planned goals should be evaluated during regular clinical evaluation (at 6-month intervals).

For functional evaluation and exercise training prescription, in most patients, symptom-limited exercise testing can be safely performed 7–14 days after primary PCI for STEMI. Sub-maximal exercise evaluations and 6-minute walk tests represent useful alternatives to symptom-limited stress testing, which should be considered as the first-choice approach.[92]

During physical training, exercise intensity should be set at 70–85% of the peak heart rate. In the case of symptomatic exercise-induced ischaemia, the level of exercise intensity can be set either at 70–85% of the ischaemic heart rate or just below the anginal threshold. In asymptomatic exercise-induced ischaemia, exercise to 70–85% of the heart rate at the onset of ischaemia (defined as ≥1 mm of ST depression) has been proposed.[92] Cardiac rehabilitation and secondary prevention programmes are implemented in or out of hospital, according to the clinical status and the local facilities. A structured in-hospital (residential) cardiac rehabilitation programme—either in a hospital or a dedicated centre—is suited to high-risk patients who may have persistent clinical, haemodynamic, or arrhythmic instability, or severe complications or comorbidities.

After uncomplicated PCI or CABG procedures, physical activity counselling can start the following day, and such patients can walk on the level and up the stairs within a few days. After a revascularization procedure in patients with significant myocardial damage, physical rehabilitation should start after clinical stabilization.

The following general criteria should be considered in planning an exercise testing modality for exercise prescription: safety (i.e. stability of clinical, haemodynamic, and rhythmic parameters), ischaemic and angina threshold (in the case of incomplete revascularization), degree of LV impairment, and associated factors (i.e. sedentary habits, orthopaedic limitations, occupational and recreational needs).

20.4 Strategies for follow-up

Although the need to detect re-stenosis has diminished in the DES era, recurrence of symptoms or ischaemia due to disease progression or re-stenosis deserves attention. Likewise, the durability of CABG results has increased with the use of arterial grafts, and ischaemia stems mainly from SVG attrition and/or progression of CAD in native vessels.

Follow-up strategies should focus primarily on the assessment of patients' functional status and symptoms, as well as on secondary prevention, but also on the detection of re-stenosis or graft occlusion. A baseline assessment of physical capacity is needed when entering a rehabilitation programme after revascularization.[93]

Physical examination, resting ECG, and routine laboratory testing should be performed within 7 days of PCI. Special attention should be given to healing of the puncture site, haemodynamics, and possible anaemia or contrast-induced nephropathy (CIN). For ACS patients, lipid-lowering therapy should be initiated or plasma lipids should be re-evaluated 4–6 weeks after an acute event to evaluate whether target levels have been achieved and to screen for liver dysfunction or symptoms of myalgia; the second plasma lipid control should be scheduled at 3 months.[263] Liver enzymes should be evaluated at the time of first statin treatment, 8–12 weeks after statin initiation, after dose increase, then annually or more frequently if indicated.

Stress testing

Previously published guidelines[94,95] and several authors advise against routine testing of asymptomatic patients. Others argue that all patients should undergo stress testing following revascularization, given the adverse outcome associated with silent ischaemia. Early stress testing (1–6 months after PCI)—to verify that culprit lesions have been successfully treated—may be recommended after incomplete or suboptimal revascularization, as well as in other specific patient subsets. Stress ECG should preferably be combined with functional imaging, because of the low sensitivity and specificity of stress ECG alone in this subset,[95] and its inability to localize ischaemia, and to assess improvement in regional wall motion of revascularized segments. Exercise is considered to be the most appropriate stressor but, in patients unable to exercise, pharmacological stressors—dipyridamole, dobutamine and adenosine—are recommended. The inability to perform an exercise stress test, by itself, indicates a worse prognosis. The choice between imaging modalities is based on criteria similar to those used before intervention (main document, section 5). With repeated testing, radiation burden should be considered as part of the test selection. Estimation of coronary flow using transthoracic Doppler echocardiography may be used to assess coronary flow in a non-invasive manner, but larger studies are needed to confirm the accuracy of this technique.

Imaging stent or graft patency

CT angiography can detect occluded and stenosed bypass grafts with very high diagnostic accuracy.[9,96] However, clinical assessment should not be restricted to graft patency, and should include evaluation of the native coronary arteries. This will often be difficult because of advanced CAD and pronounced coronary calcification. Furthermore, anatomical imaging by CT angiography does not assess ischaemia, which remains essential for therapeutic decisions. CT angiography can detect in-stent re-stenosis, depending on stent type and diameter, yet the aforementioned limitations are equally applicable. Patients who have undergone PCI of unprotected left main artery may be scheduled for routine control CT or invasive angiography within 3–12 months.

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