2018 ESC / EACTS Guidelines on myocardial revascularisation

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

In collaboration with the European Association for Percutaneous Cardiovascular Interventions (EAPCI)

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**Abbreviations and acronyms**

**ABC**  age, biomarkers, clinical history

**ABSORB II**  A Bioresorbable Everolimus-Eluting Scaffold Versus a Metallic Everolimus-Eluting Stent II

**AIDA**  Amsterdam Investigator-Initiated Absorb Strategy All-Comers

**ACCOAST**  Comparison of Prasugrel at the Time of Percutaneous Coronary Intervention or as Pretreatment at the Time of Diagnosis in Patients with Non-ST Elevation Myocardial Infarction

**ACS**  acute coronary syndrome

**ACUITY**  Acute Catheterization and Urgent Intervention Triage strategy

**ADAPT-DES**  Assessment of Dual Antiplatelet Therapy With Drug-Eluting Stents

**ADP**  adenosine diphosphate

**AF**  atrial fibrillation

**AKI**  acute kidney injury

**ALPHEUS trial**  Assessment of Loading With the P2Y12 Inhibitor Ticagrelor or Clopidogrel to Halt Ischemic Events in Patients Undergoing Elective Coronary Stenting

**AMI**  acute myocardial infarction

**ANTARCTIC**  Platelet function monitoring to adjust antiplatelet therapy in elderly patients stented for an acute coronary syndrome

**ARCTIC**  Assessment by a Double Randomization of a Conventional Antiplatelet Strategy versus a Monitoring-guided Strategy for Drug-Eluting Stent Implantation and of Treatment Interruption versus Continuation One Year after Stenting

**ART**  Arterial Revascularisation Trial

**AS**  aortic stenosis

**ASA**  acetylsalicylic acid

**ASE**  American Society of Echocardigraphy

**ATLANTIC**  Administration of Ticagrelor in the Cath Lab or in the Ambulance for New ST-Elevation Myocardial Infarction to Open the Coronary Artery

**ATLAS-ACS 2–TIMI 51**  Anti-Xa Therapy to Lower cardiovascular events in Addition to Standard therapy in subjects with Acute Coronary Syndrome–Thrombolysis In Myocardial Infarction 51

**ATOLL**  Acute STEMI Treated with primary PCI and intravenous enoxaparin Or UFH to Lower ischaemic and bleeding events at short- and Long-term follow-up

**AVR**  aortic valve replacement

**AWESOME**  Angina With Extremely Serious Operative Mortality Evaluation

**BARC**  Bleeding Academic Research Consortium

**BARI-2D**  Bypass Angioplasty Revascularisation Investigation 2 Diabetes

**BES**  biolimus-eluting stent

**BEST**  Randomised Comparison of Coronary Artery Bypass Surgery and Everolimus-Eluting Stent Implantation in the Treatment of Patients with Multivessel Coronary Artery Disease

**b.i.d.**  bis in die (twice daily)
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<tr>
<td>BIMA</td>
<td>bilateral internal mammary artery</td>
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<tr>
<td>BMS</td>
<td>bare-metal stent</td>
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<tr>
<td>BRAVE</td>
<td>Bavarian Reperfusion Alternatives Evaluation</td>
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<tr>
<td>BRS</td>
<td>bioresorbable scaffolds</td>
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<tr>
<td>BVS</td>
<td>bioresorbable vascular scaffold</td>
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<tr>
<td>CABG</td>
<td>coronary artery bypass grafting</td>
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<td>CAD</td>
<td>coronary artery disease</td>
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<tr>
<td>CARDia</td>
<td>Coronary Artery Revascularisation in Diabetes</td>
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<tr>
<td>CAS</td>
<td>carotid artery stenting</td>
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<tr>
<td>CCS</td>
<td>Canadian Cardiovascular Society</td>
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<tr>
<td>CEA</td>
<td>carotid endarterectomy</td>
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<tr>
<td>CHA2DS2-VASc</td>
<td>Cardiac failure, Hypertension, Age ≥75 [Doubled], Diabetes, Stroke [Doubled] – Vascular disease, Age 65–74 and Sex category [Female])</td>
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<td>CHAMPION</td>
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<td>CHF</td>
<td>congestive heart failure</td>
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<tr>
<td>CI</td>
<td>confidence interval</td>
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<tr>
<td>CIN</td>
<td>contrast-induced nephropathy</td>
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<tr>
<td>CK-MB</td>
<td>creatine kinase-MB fraction</td>
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<tr>
<td>CKD</td>
<td>chronic kidney disease</td>
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<tr>
<td>CMR</td>
<td>cardiac magnetic resonance</td>
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<td>COMPASS trial</td>
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<td>COURAGE</td>
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<tr>
<td>CPG</td>
<td>ESC Committee for Practice Guidelines</td>
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<tr>
<td>CT</td>
<td>computed tomography</td>
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<tr>
<td>cTn</td>
<td>cardiac troponin</td>
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<td>CTO</td>
<td>chronic total occlusion</td>
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<td>CTSN</td>
<td>Cardiothoracic Surgical Trial Network</td>
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<td>cerebrovascular accident</td>
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<td>CYP2C19</td>
<td>cytochrome P2C19</td>
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<tr>
<td>DANAMI3-PRIMULTI</td>
<td>The Third DANish Study of Optimal Acute Treatment of Patients with ST-segment</td>
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Elevation Myocardial Infarction: PRImary PCI in MULTIvessel Disease

DAPT  dual antiplatelet therapy
DCB  drug-coated balloon
DEFINE-FLAIR  Define Functional Lesion Assessment of Intermediate Stenosis to Guide Revascularisation DES drug-eluting stent
DES  drug-eluting stents
DK  double kiss
DUS  duplex ultrasound
EACTS  European Association for Cardio-Thoracic Surgery
EAPCI  European Association for Percutaneous Cardiovascular Interventions
EBC TWO  European Bifurcation Coronary TWO
ECG  electrocardiogram
ECLS  extracorporeal life support
ECMO  extracorporeal membrane oxygenation
EES  everolimus-eluting stent
EF  ejection fraction
EMS  emergency medical service
EROA  effective orifice area
ESC  European Society of Cardiology
ESRD  end-stage renal disease
EuroSCORE  European System for Cardiac Operative Risk Evaluation
EUROMAX  European Ambulance Acute Coronary Syndrome Angiography
EXCEL  Evaluation of XIENCE Versus Coronary Artery Bypass Surgery for Effectiveness of Left Main Revascularisation
FAME-2  Fractional Flow Reserve versus Angiography for Multivessel Evaluation 2
FDG-PET  fluorodeoxyglucose positron emission tomography
FFR  fractional flow reserve
FITT-STEMI  Feedback Intervention and Treatment Times in ST-Elevation Myocardial Infarction
FMC  First medical contact
FREEDOM  Future Revascularisation Evaluation in Patients with Diabetes Mellitus
GFR  glomerular filtration rate
GLOBAL LEADERS  Long-term ticagrelor monotherapy versus standard dual antiplatelet therapy followed by aspirin monotherapy in patients undergoing biolimus-eluting stent implantation
GP IIb/IIIa  glycoprotein IIb/IIIa
GRACE  Global Registry of Acute Coronary Events
GRAVITAS  Gauging Responsiveness with A VerifyNow assay-Impact on Thrombosis And Safety
HAS-BLED  Hypertension, Abnormal renal/liver function, Stroke, Bleeding history or predisposition, Labile INR, Elderly, Drugs/alcohol
HEAT-PPCI  How Effective are Antithrombotic Therapies in primary PCI
HF  heart failure
HFrEF  heart failure with reduced ejection fraction
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>HORIZONS</td>
<td>Harmonizing Outcomes with Revascularisation and Stents in Acute Myocardial Infarction</td>
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<tr>
<td>HPR</td>
<td>high platelet reactivity</td>
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<tr>
<td>HR</td>
<td>hazard ratio</td>
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<tr>
<td>i.v.</td>
<td>intravenous</td>
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<td>IABP</td>
<td>intra-aortic balloon pump</td>
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<tr>
<td>ICD</td>
<td>implantable cardioverter defibrillator</td>
</tr>
<tr>
<td>iFR</td>
<td>instantaneous wave-free ratio</td>
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<tr>
<td>IMA</td>
<td>internal mammary artery</td>
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<tr>
<td>INR</td>
<td>international normalized ratio</td>
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<tr>
<td>IRA</td>
<td>infarct-related artery</td>
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<td>IRIS-MAIN</td>
<td>Interventional Research Incorporation Society-Left MAIN Revascularisation</td>
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<td>IRR</td>
<td>incident rate ratio</td>
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<td>ISAR-CABG</td>
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<td>ISAR-REACT</td>
<td>Intracoronary Stenting and Antithrombotic Regimen Rapid Early Action for Coronary Treatment</td>
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<tr>
<td>ISCHEMIA</td>
<td>International Study of Comparative Health Effectiveness With Medical and Invasive Approaches</td>
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<tr>
<td>IVUS</td>
<td>intravascular ultrasound imaging</td>
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<tr>
<td>LAA</td>
<td>left atrial appendage</td>
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<tr>
<td>LAD</td>
<td>left anterior descending</td>
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<tr>
<td>LBBB</td>
<td>left bundle branch block</td>
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<tr>
<td>LEAD</td>
<td>lower extremity artery disease</td>
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<tr>
<td>LGE-CMR</td>
<td>late-gadolinium-enhancement cardiac magnetic resonance imaging</td>
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<tr>
<td>LIMA</td>
<td>left internal mammary artery</td>
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<tr>
<td>LM/LMS</td>
<td>left main/left main stem</td>
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<tr>
<td>LMWH</td>
<td>low-molecular-weight heparin</td>
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<tr>
<td>LPR</td>
<td>low platelet reactivity</td>
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<tr>
<td>LV</td>
<td>left ventricle/left ventricular</td>
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<tr>
<td>LVAD</td>
<td>left ventricular assist device</td>
</tr>
<tr>
<td>LVEF</td>
<td>left ventricular ejection fraction</td>
</tr>
<tr>
<td>LVESV</td>
<td>left ventricular end-systolic volume</td>
</tr>
<tr>
<td>MACCE</td>
<td>major adverse cardiac and cerebrovascular events</td>
</tr>
<tr>
<td>MACE</td>
<td>major adverse cardiac events</td>
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<tr>
<td>MADIT II</td>
<td>Multicenter Automatic Defibrillator Implantation Trial II</td>
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<tr>
<td>MATRIX</td>
<td>Minimizing Adverse Haemorrhagic Events by Transradial Access Site and Systemic Implementation of AngioX</td>
</tr>
<tr>
<td>MCS</td>
<td>mechanical circulatory support</td>
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<tr>
<td>MI</td>
<td>myocardial infarction</td>
</tr>
<tr>
<td>MINOCA</td>
<td>myocardial infarction with non-obstructive coronary arteries</td>
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</tbody>
</table>
MLA  minimal luminal area
MR  mitral regurgitation
MSCT  multi-slice computed tomography
MT  medical therapy
MVD  multivessel coronary artery disease
MVO  microvascular obstruction
NAC  N-acetylcysteine
NCDR  National Cardiovascular Database Registry
NNT  number needed to treat
NOAC  non-vitamin K antagonist oral anticoagulant
NOBLE  Nordic-Baltic-British Left Main Revascularisation Study
NSTE-ACS  non-ST-segment elevation acute coronary syndrome
NSTEMI  non-ST-segment elevation myocardial infarction
NVAF  non-valvular atrial fibrillation
NYHA  New York Heart Association
OAC  oral anticoagulation
OASIS-5  Optimal Antiplatelet Strategy for Interventions-5
OCT  optical coherence tomography
ONCAB  on-pump CABG
OPCAB  off-pump CABG
OR  odds ratio
ORBITA  Objective Randomised Blinded Investigation with optimal medical Therapy of Angioplasty in stable angina
PARR-2  PET and Recovery following Revascularisation
p.o.  per os (orally)
PCI  percutaneous coronary intervention
PES  paclitaxel-eluting stent
PET  positron emission tomography
PF  platelet function
PIONEER  Prevention of bleeding in patients with AF undergoing PCI
PLATO  Study of Platelet Inhibition and Patient Outcomes
pLVAD  percutaneous left ventricular assist devices
PPI  proton pump inhibitor
PRAGUE-18  Comparison of Prasugrel and Ticagrelor in the Treatment of Acute Myocardial Infarction
PRAMI  Preventive Angioplasty in Acute Myocardial Infarction
PRECISE-DAPT  PREdicting bleeding Complications In patients undergoing Stent implantation and subsEquent Dual Anti Platelet Therapy
PRECOMBAT  Premier of Randomised Comparison of Bypass Surgery versus Angioplasty Using Sirolimus-Eluting Stent in Patients with Left Main Coronary Artery Disease
PROCAT  Parisian Region Out of Hospital Cardiac Arrest
"q.d." quaque die (once daily)
RBBB Right bundle branch block
RCT randomised controlled trial
RE-DUAL trial Randomised Evaluation of Dual Antithrombotic Therapy with Dabigatran versus Triple Therapy with Warfarin in Patients with Nonvalvular Atrial Fibrillation Undergoing Percutaneous Coronary Intervention
REPLACE 2 The Randomised Evaluation in PCI Linking Angiomax to Reduced Clinical Events 2
RIVAL Radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes
RR relative risk
RRR relative risk reduction
SASSICAIA Comparison of Loading Strategies With Antiplatelet Drugs in Patients Undergoing Elective Coronary Intervention
SAVR surgical aortic valve replacement
s.c. subcutaneous
SCAD stable coronary artery disease
SCD-HEFT Sudden Cardiac Death in Heart Failure Trial
SES sirolimus-eluting stent
SHOCK Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock
SMART-DATE Smart Angioplasty Research Team-safety of 6-month duration of Dual Antiplatelet Therapy after percutaneous coronary intervention in patients with acute coronary syndromes
SITA single internal thoracic artery
SPECT single photon emission computed tomography
SR sinus rhythm
STEEPLE Safety and Efficacy of Intravenous Enoxaparin in Elective Percutaneous Coronary Intervention Randomised Evaluation
STEMI ST-segment elevation myocardial infarction
STICH Surgical Treatment for Ischemic Heart Failure
STS Society of Thoracic Surgeons
SVG saphenous vein graft
SVR surgical ventricular reconstruction
SWEDHEART Swedish Web-system for Enhancement and Development of Evidence-based care in Heart disease Evaluated According to Recommended Therapies
SYNTAX Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery
TAP T and protrusion
TAVI transcatheter aortic valve implantation
TIA transient ischaemic attack
TIMACS Timing of Intervention in Acute Coronary Syndromes Trial
1. Preamble

Clinical practice guidelines summarize and evaluate all available evidence at the time of the writing process on a particular issue with the aim of assisting physicians in selecting the best management strategies for an individual patient with a given condition, taking into account the impact on outcome as well as the risk–benefit ratio of particular diagnostic or therapeutic means. Clinical practice guidelines are no substitutes for textbooks, but complement them, and cover the European Society of Cardiology (ESC) Core Curriculum topics. As such they should help physicians to make decisions in their daily practice. However, final decisions should be individualised by responsible physicians and the patient.

A great number of clinical practice guidelines have been issued in recent years both by the ESC as well as by other societies and organizations. Because of the impact on clinical practice, quality criteria for the development of guidelines have been established in order to make all decisions transparent to the user. The recommendations for formulating and issuing ESC and joint society guidelines can be found on the ESC website (http://www.escardio.org/guidelines-surveys/esc-guidelines/about/Pages/rules-writing.aspx). These Guidelines represent the official position of the ESC and the European Association for Cardio-Thoracic Surgery (EACTS) on this given topic and will be
Members of this Task Force were selected by the ESC and EACTS to represent professionals involved with the medical care of patients with this pathology. Selected experts in the field undertook a comprehensive review of the published evidence for diagnosis, management (including treatment) and/or prevention of a given condition according to the ESC Committee for Practice Guidelines (CPG) and EACTS policy. A critical evaluation of diagnostic and therapeutic procedures was performed including assessment of the risk–benefit ratio. Estimates of expected health outcomes for larger populations were included, where data exist. The level of evidence and the strength of recommendation of particular treatment options were weighed and graded according to predefined scales, as outlined in Tables 1 and 2.

The experts of the writing and reviewing panels completed declarations of interest forms on what might be perceived as real or potential sources of conflicts of interest. These forms were compiled into one file and can be found on the ESC and EACTS websites (http://www.escardio.org/guidelines and http://www.eacts.org). Any changes in declarations of interest that arise during the writing period must be notified to the ESC and EACTS and updated. The Task Force received its entire financial support from the ESC and EACTS without any involvement from the healthcare industry.

The CPG-ESC and EACTS supervised and coordinated the preparation of these new Guidelines produced by the joint Task Force. These entities are also responsible for the endorsement process of these Guidelines. The ESC/EACTS Guidelines underwent extensive review by a wide panel of relevant external experts. After appropriate revisions it was approved by all the experts involved in the Task Force. The finalized document was approved by the ESC CPG and EACTS for joint publication in the European Heart Journal and the European Journal of Cardio-Thoracic Surgery.

The task of developing clinical practice guidelines covers not only the integration of the most recent research, but also the creation of educational tools and implementation programmes for the recommendations. To implement the guidelines, condensed pocket guidelines, summary slides, booklets with essential messages, and an electronic version for digital applications (smartphones, etc.) are produced. These versions are abridged and,
thus, if needed, one should always refer to the full text version, which is freely available on the ESC and EACTS websites. The National Societies of the ESC are encouraged to endorse, translate, and implement the ESC Guidelines. Implementation programmes are needed because it has been shown that the outcome of disease may be favourably influenced by the thorough application of clinical recommendations.

Surveys and registries are needed to verify that real-life daily practice is in keeping with what is recommended in the guidelines, thus completing the loop between clinical research, writing of guidelines, and implementing them in clinical practice.

The guidelines do not, however, override the individual responsibility of health care professionals to make appropriate decisions in the circumstances of the individual patients, in consultation with that patient, and where appropriate and necessary the patient’s guardian or carer. It is also the health professional's responsibility to verify the rules and regulations applicable to drugs and devices at the time of prescription.

Table 1 Classes of recommendations

<table>
<thead>
<tr>
<th>Classes of recommendations</th>
<th>Definition</th>
<th>Suggested wording to use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>Evidence and/or general agreement that a given treatment or procedure is beneficial, useful, effective.</td>
<td>Is recommended/is indicated</td>
</tr>
<tr>
<td>Class II</td>
<td>Conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of the given treatment or procedure.</td>
<td></td>
</tr>
<tr>
<td>Class IIa</td>
<td>Weight of evidence/opinion is in favour of usefulness/efficacy.</td>
<td>Should be considered</td>
</tr>
<tr>
<td>Class IIb</td>
<td>Usefulness/efficacy is less well established by evidence/opinion.</td>
<td>May be considered</td>
</tr>
<tr>
<td>Class III</td>
<td>Evidence or general agreement that the given treatment or procedure is not useful/effective; and in some cases may be harmful.</td>
<td>Is not recommended</td>
</tr>
</tbody>
</table>

Table 2 Levels of evidence
<table>
<thead>
<tr>
<th>Level of Evidence A</th>
<th>Data derived from multiple randomized clinical trials or meta-analyses.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of Evidence B</td>
<td>Data derived from a single randomized clinical trial or large non-randomized studies.</td>
</tr>
<tr>
<td>Level of Evidence C</td>
<td>Consensus of opinion of the experts and/or small studies, retrospective studies, registries.</td>
</tr>
</tbody>
</table>
2. Introduction
With this guideline, it is now the third time that ESC and EACTS have brought together cardiologists and cardiac surgeons in a joint task force to review the ever-increasing body of evidence with the mission to draft balanced, patient-centred, practice guidelines on myocardial revascularisation. A summary of the key changes in comparison with the previous guideline is provided in Figure 1 and Figure 2.

There is considerable overlap of the current document with other guidelines, specifically with those on “Stable Coronary Artery Disease”, “Non-ST-Elevation Myocardial Infarction”, “ST-Elevation Myocardial Infarction”, “Heart Failure” and the “Focused Update on Dual Antiplatelet Therapy”. Unless supported by new evidence, we followed the recommendations of these guidelines where pertinent to our guideline and refer to the respective chapters in the previous documents for detailed discussion. We reserve more in-depth discussion for the topics that are specific to issues pertaining to myocardial revascularisation that are not covered in other guidelines. To keep the current document concise and reader-friendly, we also moved some of the detailed descriptions of study results to the web addenda. Moreover, details of references that were published prior to 2015 are listed in the web appendix.
**What is new in the 2018 version?**

**Figure 1**

<table>
<thead>
<tr>
<th>NEW RECOMMENDATIONS</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation of the Syntax Score, if left main or multivessel revascularization is</td>
<td>I</td>
</tr>
<tr>
<td>considered</td>
<td></td>
</tr>
<tr>
<td>Radial access as standard approach for coronary angiography and PCI</td>
<td>I</td>
</tr>
<tr>
<td>DES for any PCI</td>
<td>I</td>
</tr>
<tr>
<td>Systematic re-evaluation of patients after myocardial revascularisation</td>
<td>I</td>
</tr>
<tr>
<td>Revascularisation strategy according to principles for SCAD in stabilised NSTE-ACS</td>
<td>I</td>
</tr>
<tr>
<td>patients</td>
<td></td>
</tr>
<tr>
<td>Myocardial revascularisation in patients with CAD, heart failure, and LVEF ≤35%</td>
<td>I</td>
</tr>
<tr>
<td>CABG preferred</td>
<td></td>
</tr>
<tr>
<td>Pre- and post-hydration with isotonic saline should be considered if the</td>
<td>I</td>
</tr>
<tr>
<td>expected contrast volume is &gt; 100 mL</td>
<td></td>
</tr>
<tr>
<td>Competence of revascularization prioritized, when considering CABG vs PCI</td>
<td>IIa</td>
</tr>
<tr>
<td>NOAC preferred over VKA in patients with non-valvar AF requiring</td>
<td>IIb</td>
</tr>
<tr>
<td>anticoagulation and antiplatelet treatment</td>
<td></td>
</tr>
<tr>
<td>No-touch vein technique, if open vein harvesting for CABG</td>
<td>III</td>
</tr>
<tr>
<td>Non-emergency high-risk PCI procedures performed at centres without access to</td>
<td></td>
</tr>
<tr>
<td>circulatory support</td>
<td></td>
</tr>
<tr>
<td>Annual operator volume of at least 25</td>
<td></td>
</tr>
<tr>
<td>left main PCI cases per year</td>
<td></td>
</tr>
<tr>
<td>De-escalation of P2Y12 inhibitor guided by platelet function testing in ACS patients</td>
<td></td>
</tr>
<tr>
<td>Routine revascularisation of non-IRA lesions in myocardial infarction with</td>
<td></td>
</tr>
<tr>
<td>cardiogenic shock</td>
<td></td>
</tr>
<tr>
<td>Non-invasive imaging surveillance in high-risk patients 6 months after</td>
<td></td>
</tr>
<tr>
<td>revascularization</td>
<td></td>
</tr>
<tr>
<td>Double-kissing crush technique preferred over provisional T-stenting in true left</td>
<td></td>
</tr>
<tr>
<td>main bifurcations</td>
<td></td>
</tr>
<tr>
<td>Epi-aortic ultrasound scanning prior to aortic manipulation</td>
<td></td>
</tr>
<tr>
<td>Cangrelor in P2Y12-inhibitor naive patients undergoing PCI</td>
<td></td>
</tr>
<tr>
<td>GP IIb/III inhibitors for PCI in P2Y12-inhibitor naive patients with ACS</td>
<td></td>
</tr>
<tr>
<td>undergoing PCI</td>
<td></td>
</tr>
<tr>
<td>Hybrid procedures in specific patient subsets at experienced centres</td>
<td></td>
</tr>
<tr>
<td>Dabigatran 150-mg dose preferred over 110-mg dose when combined with single</td>
<td></td>
</tr>
<tr>
<td>antiplatelet therapy after PCI</td>
<td></td>
</tr>
<tr>
<td>Current generation BRS for clinical use</td>
<td></td>
</tr>
</tbody>
</table>

The figure does not show changes compared with the 2014 version of the Myocardial Revascularisation guidelines that were due to updates for consistency with other ESC guidelines published since 2014.

ACS = acute coronary syndromes; AF = atrial fibrillation; BRS = bioresorbable scaffolds; CABG = coronary artery bypass grafting; CAD = coronary artery disease; CT = computed tomography; DAPT = dual antiplatelet therapy; DES = drug-eluting stents; GP = glycoprotein; IRA = infarct-related artery; LVEF = left ventricular ejection fraction; NOAC = non-vitamin K oral anticoagulants; NSTE = non-ST-elevation; PCI = percutaneous coronary interventions; SCAD = stable coronary artery disease; STEMI = ST-elevation myocardial infarction; VKA = vitamin K antagonists.
**Figure 2**

**Changes in Class of Recommendation**

<table>
<thead>
<tr>
<th><strong>Upgrades</strong></th>
<th><strong>Downgrades</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>For PCI of bifurcation lesions, stent implantation in the main vessel only, followed by provisional balloon angioplasty with or without stenting of the side branch.</td>
<td>Distal protection devices for PCI of SVG lesions</td>
</tr>
<tr>
<td>Immediate coronary angiography and revascularization, if appropriate, in survivors of out of hospital cardiac arrest.</td>
<td>LV aneurysmectomy during CABG in patients with chronic heart failure and LVEF ≤ 35%</td>
</tr>
<tr>
<td>Assess all patients for the risk of contrast-induced nephropathy.</td>
<td>Bivalirudin as an alternative to UFH in NSTE-ACS</td>
</tr>
<tr>
<td>OCT for stent optimization.</td>
<td>PCI for MVD with diabetes and SYNTAX score &lt; 23</td>
</tr>
<tr>
<td></td>
<td>Mitral valve surgery in patients with moderate mitral regurgitation undergoing CABG</td>
</tr>
<tr>
<td></td>
<td>Bivalirudin for PCI in STEMI</td>
</tr>
<tr>
<td></td>
<td>Platelet function testing to guide antiplatelet therapy interruption in patients undergoing cardiac surgery</td>
</tr>
<tr>
<td></td>
<td>EuroSCORE II to assess in-hospital mortality after CABG</td>
</tr>
</tbody>
</table>

The figure does not show changes compared with the 2014 version of the Myocardial Revascularisation guidelines that were due to updates for consistency with other ESC guidelines published since 2014.

ACS = acute coronary syndromes; CABG = coronary artery bypass grafting; LVEF = left ventricular ventricular ejection fraction; MVD = multivessel disease; NSTE = non-ST-elevation; OCT = optical coherence tomography; PCI = percutaneous coronary interventions; STEMI = ST-elevation myocardial infarction, SVG = saphenous vein grafts; UFH = unfractionated heparin
3. Diagnostic tools to guide myocardial revascularisation

The use of diagnostic imaging and functional testing modalities to detect patients with coronary artery disease (CAD) is discussed in detail in clinical practice guidelines for patients with stable coronary artery disease. Further diagnostic assessment of patients with obstructive CAD is critical in order to identify patients and select specific lesions likely to benefit from myocardial revascularisation in additional to optimal medical therapy.

3.1 Non-invasive diagnostic tools

3.1.1 Assessment of myocardial ischaemia

Non-invasive diagnostic assessment of patients with CAD being considered for myocardial revascularisation comprises assessment of ischaemia and evaluation of viability in patients with regional wall motion abnormalities or reduced ejection fraction.

Functional testing to assess ischaemia is critical to the assessment of stable patients with CAD. Documentation of ischaemia using functional testing before elective invasive procedures for CAD is the preferred approach. It may also have a role in the assessment of some patients presenting with acute coronary syndrome. Because of the low sensitivity of exercise electrocardiogram (ECG) testing in the assessment of patients with symptoms of angina, non-invasive imaging is recommended as the first line test. Detection of a large area of myocardial ischaemia by functional imaging is associated with impaired prognosis of patients and identifies patients who should undergo revascularisation (see chapter 5 of this document).

In patients undergoing coronary computed tomography (CT), both CT-derived fractional flow reserve (CT-FFR) and CT perfusion represent possible approaches to evaluate lesion-specific ischemia. Although the evidence for both is limited at present, there is considerably more data from clinical investigations of CT-FFR. A number of trials have shown that correlation between CT-derived FFR and invasive FFR is high. The non-randomised PLATFORM study showed that in patients referred for invasive angiography due to chest pain (predominantly atypical angina) and intermediate pre-test probability of CAD, assessment with CT and CT-derived FFR reduced the number of patients with subsequently normal invasive coronary angiograms compared with standard care. Currently, clinical trial data with CT-derived FFR is insufficient to make a recommendation for use in clinical practice.
3.1.2 Assessment of myocardial viability in patients with heart failure and CAD

In patients with regional wall motion abnormalities or ventricular dysfunction, heart failure can be caused by stunned or hibernating myocardium and may be reversed by revascularisation. Assessment of myocardial viability may be done in order to select patients more likely to benefit from myocardial revascularisation and can be achieved with several imaging modalities: myocardial contrast echocardiography, SPECT, and late gadolinium enhancement CMR (LGE-CMR) all assess cellular integrity; positron emission tomography (PET) assesses cellular metabolism; and dobutamine techniques assess contractile reserve.\textsuperscript{1, 5} Assessment of ischaemia provides incremental benefit over viability in mild to moderate CAD, but with extensive CAD, viability assessment is sufficient.\textsuperscript{6} Patients with advanced heart failure (HF) and viable myocardium should first undergo revascularisation with coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI) before being considered for mechanical circulatory support (MCS) or heart transplantation.\textsuperscript{7, 8}

The PARR-2 trial (PET and Recovery following Revascularisation) included patients with severe left ventricular dysfunction being considered for revascularisation or heart failure/transplantation work-ups and randomised to management assisted by fluorodeoxyglucose positron emission tomography (FDG PET) or standard care.\textsuperscript{6} The primary outcome of cardiac death, myocardial infarction (MI), or recurrent hospital stay for cardiac cause at 1 year was not improved in the group managed by FDG-PET (relative risk 0.82, 95% confidence interval [CI] 0.59 to 1.14; \( p = 0.16 \)), though the rate of compliance with the treatment recommended by FDG-PET was variable.

The viability substudy of the STICH trial (Surgical Treatment for Ischemic Heart Failure) found viable myocardium in 487/601 patients (81%) and none in 114 (19%).\textsuperscript{9} There was a significant association between myocardial viability and outcome by univariate analysis but not on multivariable analysis. The lack of correlation between myocardial viability and benefit from revascularisation indicates that this strategy should not be the only test in selecting the optimal therapy.

### Recommendations for noninvasive imaging in patients with CAD and HF

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class(^a)</th>
<th>Level(^b)</th>
</tr>
</thead>
<tbody>
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<td></td>
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</table>
Non-invasive stress imaging (CMR, stress echocardiography, SPECT, PET) may be considered for the assessment of myocardial ischaemia and viability in patients with HF and CAD (considered suitable for coronary revascularisation) before the decision on revascularisation.

CAD = coronary artery disease; CMR = cardiac magnetic resonance; HF = heart failure; PET = positron emission tomography; SPECT = single photon emission computed tomography

\[ {\text{Class of recommendation.}} \]

\[ {\text{Level of evidence.}} \]

### 3.2 Invasive diagnostic tools

#### 3.2.1 Pressure-derived fractional flow reserve

##### 3.2.1.1 Use of FFR in patients with intermediate grade coronary stenosis including left main stenosis

Coronary pressure-derived FFR is the current standard of care for the functional assessment of lesion severity in patients with intermediate grade stenosis (typically around 40-80% stenosis) without evidence of ischaemia in non-invasive testing, or in those with multivessel disease.

Multiple studies have shown that PCI can be safely deferred if FFR > 0.75.\(^{12-15}\) The DEFER trial enrolled 325 patients scheduled for PCI of an intermediate stenosis.\(^{15}\) If FFR was \( \geq 0.75 \), patients were randomly assigned to deferral (Defer group; \( n = 91 \)) or performance (Perform group; \( n = 90 \)) of PCI. The composite rate of cardiac death and acute myocardial infarction in the Defer and Perform groups was 3.3% vs. 7.9% (\( p = 0.21 \)).

Most contemporary studies however use an FFR cut off of 0.80. A recent large-scale observational study supports the use of FFR > 0.80 rather than 0.75 as a cut off.\(^{16}\) Indeed, the two largest studies in this field, DEFINE-FLAIR (Define Functional Lesion Assessment of Intermediate Stenosis to Guide Revascularisation DES drug-eluting stent)\(^{17}\) and iFR-SWEDEHEART (Swedish Web-system for Enhancement and Development of Evidence-based care in Heart disease Evaluated According to Recommended Therapies)\(^{18}\) used the 0.80 cut-off for lesion selection by FFR resulting in favourable event rates at 1 year. Thus, 0.80 is the accepted FFR threshold for defining haemodynamically relevant lesions.
Haemodynamic relevance, as defined by FFR ≤ 0.80, correlates poorly with diameter stenosis by visual assessment. In the FAME trial, only 35% of the 50% to 70% stenoses were haemodynamically relevant and of the 71% to 90% stenoses 20% were not. Only an estimated diameter stenosis > 90% predicted haemodynamic relevance with high accuracy (96% correct classification). A number of studies have shown that utilization of an FFR-based assessment strategy at the time of angiography results in reclassification of the revascularisation strategy (PCI, bypass surgery or medical therapy) in a high proportion of patients with intermediate grade lesions (>40% of patients are reclassified).19-21 22 In addition, separate and pooled analysis of the patients included in those studies have shown that the end results of “FFR-based reclassification” in patients investigated at time of diagnostic angiography is overall neutral on the number of patients indicated to revascularisation.23

A patient-level and study-level meta-analysis of 9,173 lesions demonstrated that with lesions with FFR < 0.75 revascularisation reduced the 1-year risk of major adverse cardiac events (MACE) including a reduction in the composite risk of death and myocardial infarction. 24 Thus, the FFR threshold of 0.75 is used to define more severe ischaemia that is of prognostic relevance.

The presence of intermediate grade left main stem disease is not infrequent and angiographic evaluation may be challenging. Assessment using pressure-derived FFR is more challenging in comparison with non-left main stem stenosis due to requirement for disengagement of the guiding catheter and inability to administer intracoronary adenosine. Some observational data exist to support the use of FFR in order to decide if revascularisation should be deferred or performed.25 In the largest study including 230 patients with intermediate grade left main stem stenosis, only 23% showed FFR <0.80. Treatment was deferred in patients with an FFR ≥0.80 and bypass surgery was done in patients with an FFR <0.80.26 Clinical outcomes at 5 years were similar in both groups. It is important however to consider the potential influence of any untreated downstream disease in the left anterior descending or left circumflex arteries, which may be associated with an increased risk of a false negative FFR.27

The value of FFR to evaluate intermediate stenosis and guide selection of lesions for
revascularisation at the time of bypass surgery has been shown in an observational study. Of 627 patients with intermediate stenosis evaluated, 429 had bypass without FFR, 198 had bypass with FFR: In the latter group the proportion of patients with three-vessel disease was re-classified from 94 to 86%. Outcomes were similar in both groups at 3 years (hazard ratio [HR] for death/MI/target vessel revascularisation [TVR] = 1.03 (0.67–1.69) though the group with FFR guidance was associated with a lower number of graft anastomoses and a lower rate of on-pump surgery compared with angiography-guided coronary artery bypass graft surgery.

**3.2.1.2 Use of FFR to identify lesion-requiring revascularisation in patients with multivessel CAD undergoing PCI**

FFR may also be useful to select lesions requiring revascularisation in patients with multivessel CAD. The FAME trial (Fractional Flow Reserve versus Angiography for Multivessel Evaluation) showed that in patients with multivessel disease randomised to an FFR-guided PCI strategy (using a cut-off ≤ 0.80 to indicate requirement for PCI) outcomes at 12 months in terms of death, non-fatal MI and repeat revascularisation were superior compared with angiography-guided PCI and utilized less resources. In addition, the 2-year composite risk of death or myocardial infarction was significantly lower with the FFR-guided PCI strategy. Long-term follow-up at 5 years showed broadly consistent findings although differences between groups in relation to the primary endpoint were no longer significant. This suggests that FFR-guided PCI should be the preferred management strategy in these patients.

**3.2.1.3 FFR-guided management versus medical therapy in patients with CAD**

In patients with stable CAD and at least one stenosis with FFR ≤ 0.80, the FAME-2 trial showed that PCI using drug-eluting stent (DES) implantation improved the primary endpoint of death, non-fatal MI, or urgent revascularisation within 2 years compared with medical treatment alone, which was driven by a lower need for urgent revascularisation. The advantage of FFR-guided PCI over medical therapy alone was maintained at 3 years.

**3.2.2 Other pressure-derived indexes**

FFR evaluation requires maximal and stable hyperaemia—usually obtained by
administration of intravenous (i.v.) adenosine. Recently there has been renewed interest in resting indices derived from resting gradients alone (Distal coronary to aortic pressure \([P_d/P_a]\) or instantaneous wave-free ratio [iFR]). Two recent large-scale randomised trials showed broadly comparable results between FFR-guided and iFR-guided revascularisation strategies in patients with intermediate grade stenosis.\(^{17, 18}\) Revascularisation was indicated in both trials if FFR was 0.80 or lower or if iFR was 0.89 or lower. In the DEFINE-FLAIR trial the primary end point of major adverse cardiac events (MACE) at 1 year occurred in 6.8% in patients randomised to iFR-guided revascularisation vs. 7.0% in patients randomised to FFR-guided revascularisation (\(P <0.001\) for non-inferiority; HR 0.95, 95% CI 0.68 to 1.33; \(P =0.78\)).\(^{17}\) In the iFR-SWEDEHEART trial, the primary endpoint of death from any cause, non-fatal MI, or unplanned revascularisation was 6.7% in the iFR group and 6.1% in the FFR group (\(P =0.007\) for non-inferiority; HR 1.12, 95% CI 0.79 to 1.58; \(P =0.53\)).\(^{18}\) In iFR-SWEDEHEART 17.5% had acute coronary syndrome at the time of presentation. There was no interaction with outcomes. Both trials are limited by having a follow-up duration of only 1 year.

The SYNTAX II study (Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery), a single arm, prospective study in patients with multivessel disease incorporating a management strategy including iFR assessment of stenosis severity in addition to intravascular ultrasound (IVUS) guided stent implantation, and guideline-directed medical therapy showed encouraging outcomes compared with a historical cohort enrolled in the SYNTAX trial.\(^{34}\)

Randomised trials comparing iFR-guided revascularisation with angiography-guided revascularisation or medical therapy are not available. iFR has not been extensively validated for patients with left main stem stenosis.

There is no adequate randomised controlled trial (RCT) data to support the use of whole cardiac cycle Pd/Pa for guidance of revascularisation decisions.

### 3.2.3 Use of FFR and pressure-derived indexes in patients with severe aortic stenosis

In patients with intermediate coronary stenosis and concomitant severe aortic stenosis, although some observational studies exist (see chapter 11 of this document) there is no
adequate RCT data to support the use of FFR or iFR for guidance of revascularisation decisions.

3.2.4 Use of intravascular imaging for diagnostic assessment of stenosis

IVUS is an ultrasound-based modality of intravascular imaging with an axial resolution of ca. 150 µm. IVUS imaging allows a real-time, tomographic assessment of vessel size, lumen area, and plaque composition and volume. In comparison with optical coherence tomography (OCT) it has more limited spatial resolution but better penetration depth and potential advantage in terms of vessel sizing. OCT is a light-based modality of intravascular imaging with higher axial resolution compared with IVUS (15 vs. 150 µm). Disadvantages of OCT imaging are that it requires complete blood clearance from the lumen for imaging and that it has more limited penetration, which can limit assessment of complete plaque burden and may impair accurate vessel sizing.

Potential clinical uses of intravascular imaging for diagnostic assessment in patients being considered for myocardial revascularisation are evaluation of stenosis severity in lesions with intermediate grade stenosis, evaluation of lesion morphology in lesions ambiguous with angiographic assessment, and characterization of plaque composition. The majority of existing clinical trial data relate to the use of intravascular imaging-guidance during PCI and are discussed in chapter 16 of this document. Use of intravascular imaging to evaluate patients with stent failure is discussed in chapter 13 of this document.

Regarding the assessment of intermediate-grade stenosis, a number of studies have evaluated the optimal cut-off of minimal lumen area for identifying haemodynamically relevant lesions. One prospective registry showed overall moderate correlation of minimal lumen area with FFR values, with cut-off values for detecting haemodynamically-relevant stenosis (< 2.4 mm², < 2.7 mm², < 3.6 mm²) dependent on vessel size (reference vessel diameters < 3.0 mm, 3.0–3.5 mm, > 3.5 mm, respectively). Generally, haemodynamic assessment with FFR should be preferred for this indication.

The presence of intermediate grade left main stem disease is not infrequent and angiographic assessment may be challenging. Assessment using IVUS-evaluation of intermediate grade left main stem disease in patients being considered for bypass surgery or PCI is supported by data from a number of observational studies. In a multicentre,
A prospective study, revascularisation was mainly deferred if the minimal luminal area (MLA) was ≥6 mm² and performed if the MLA was <6 mm². After two-year follow-up, cardiac death-free survival was similar in both groups (98 percent and 95 percent, respectively). Another study suggested that deferral of intervention in 131 patients with an MLA ≥7.5 mm² showed favourable clinical outcomes. In Asian patients with generally smaller heart size, minimum studies have suggested that an IVUS MLA of 4.5–4.8 mm² may be the most appropriate.

**Recommendations on functional testing and intravascular imaging for lesion assessment**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>When evidence of ischaemia is not available, FFR or iFR are recommended to assess the haemodynamic relevance of intermediate-grade stenosis</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>FFR-guided PCI should be considered in patients with multivessel disease undergoing PCI</td>
<td>Ila</td>
<td>B</td>
</tr>
<tr>
<td>IVUS should be considered to assess severity of unprotected left main lesions</td>
<td>Ila</td>
<td>B</td>
</tr>
</tbody>
</table>

FFR = fractional flow reserve; iFR = instantaneous wave-free ratio; IVUS = intravascular ultrasound.

aClass of recommendation.
bLevel of evidence.

**3.3 Gaps in evidence**

Further studies investigating the role of novel combined non-invasive anatomical and functional imaging are needed, such as Randomised clinical trials with CT-FFR in patients with suspected and known CAD, as well as further clinical investigation of perfusion CT.

Randomised trials comparing iFR-based management of patients with intermediate grade stenosis compared with medical therapy are missing. Further study of whole cardiac cycle Pd/Pa for guidance of revascularisation in the setting of randomised clinical trials is also required.
Further studies including randomised trials are needed to assess the value of functional versus anatomical guidance for CABG.

4. Process for decision making and patient information

4.1 Patient information and informed consent

Informed consent requires transparency, especially if there is debate over various treatment options. Active patient participation in the decision-making process should be encouraged. Patient information needs to be unbiased, evidence-based, up-to-date, reliable, accessible, relevant, and consistent with legal requirements. Use of terminology that the patient understands is essential. Short-term procedure-related and long-term risks and benefits—such as survival, relief of angina, quality of life, potential need for late reintervention, the need for prevention measures and uncertainties associated with different treatment strategies—should be thoroughly discussed. Although current recommendations are mostly based on the ability of treatments to reduce adverse events including mortality, there is a growing interest in patient-reported outcome measures (PROM).\textsuperscript{40, 41} Patients are not only interested to know how recommended treatment impacts on prognosis but also on their life quality in the way they perceive it. A written evidence-based patient information document should be provided, potentially with decision aids.

Patients must have the time to reflect on the trade-offs imposed by the outcome estimates. In order to seek a second opinion or to discuss the findings and consequences with referring physicians, enough time should be allowed—up to several days, as required—between diagnostic catheterization and intervention. These recommendations pertain to patients in stable condition, for whom various treatment options exist and who can make a decision without the constraints of an urgent or emergent situation (Table 3). The patient’s right to decline the treatment option recommended by the Heart Team has to be respected. Patient refusal of a recommended treatment should be acknowledged in a written document after the patient has received the necessary information by the Heart Team members. In this case, the
patient may be offered an alternative treatment option by the Heart Team.

The patient has the right to obtain information on the level of expertise of the operator, the workload of the centre, whether all treatment options—including surgery—are available on-site and local results in the performance of percutaneous and surgical myocardial revascularisation procedures. Patients considered for revascularisation should also be clearly informed of the continuing need for medical therapy, as well as lifestyle modification and other secondary prevention strategies (see Chapter 19).

4.2 Multidisciplinary decision-making (Heart Team)

The Heart Team—comprising clinical or non-invasive cardiologists, cardiac surgeons, interventional cardiologists, and other specialists if deemed necessary—should provide a balanced, multidisciplinary decision-making process. Additional input may be needed from other specialties involved in the care of the patient. The Heart Team should meet on a regular basis to analyse and interpret the available diagnostic evidence, determine the need for myocardial revascularisation and assess the relative short- and long-term safety and effectiveness of the percutaneous and surgical options. Ad hoc meetings of the Heart Team should facilitate and support efficient clinical workflows.

The need for an interdisciplinary approach is underlined by reports on (i) underuse of revascularisation procedures in 18–40% of patients with CAD, and (ii) inappropriate use of revascularisation strategies with a lack of case discussions. The marked variability in PCI-to-CABG ratios between European countries (ranging from 2.4 to 7.6 in 2013, for example) has raised concerns regarding the appropriate selection of revascularisation strategies. Rates for the inappropriate use of PCI (10–15%) and for CABG (1–2%) are reported. Multidisciplinary decision-making in a Heart Team can minimize specialty bias and prevent self-referral from interfering with optimal patient care.

Several reports from different centres have established that the treatment
recommendations made in multidisciplinary Heart Team discussions are reproducible and implemented in the vast majority of cases (93–95%).

Interdisciplinary institutional protocols should be developed for common case scenarios, to avoid the need for the systematic case-by-case review of all diagnostic angiograms. However, complex cases—defined by the protocols—should be discussed individually. In these cases, revascularisation should not be performed at the time of diagnostic angiography, to allow sufficient time to assess all available information, and clearly explain and discuss the findings with the patient. The rationale for a decision and consensus on the optimal revascularisation treatment should be documented in the patient’s chart. For institutions without an on-site cardiac surgery unit, Heart Team discussion, and protocols defining when multidisciplinary discussion is needed, should be done in collaboration with an external cardiac surgery unit.

4.3 Timing of revascularisation

Patients in need for myocardial revascularisation may be at increased risk for adverse events during the waiting period. A recent meta-analysis of observational studies calculated that a waiting period of 3 months for surgical myocardial revascularisation may be associated with the risk of one death among 80 patients. Table 3 shows the preferred timing of revascularisation depending on the clinical presentation and extent and localization of CAD.

Chapters 7 and 8 show additional and more specific information in this regard for patients with acute coronary syndromes (ACS).

Ad hoc PCI is defined as a therapeutic intervention performed within the same procedure as the diagnostic coronary angiography. Ad hoc PCI is convenient, often cost-effective and safe, and is associated with fewer access site complications and lower radiation exposure. In the USA, however, up to 30% of patients undergoing ad hoc PCI are potential candidates for CABG. This number may be lower in Europe. Although it is not advisable for ad hoc PCI to represent the default approach for complex SCAD, it may be justified if a full diagnostic work-up, including functional testing, is available and the patient is adequately informed on both percutaneous and surgical myocardial
revascularisation options (see Chapter 4.1) Institutional protocols developed by the Heart Team in accordance with current guidelines should define specific anatomical criteria and clinical subsets that may be—or should not be—treated *ad hoc*. Stable patients with complex CAD, as reflected by a high SYNTAX score should, in general, be discussed by the Heart Team and not be treated *ad hoc*. 
<table>
<thead>
<tr>
<th>Table 3 Multidisciplinary decision pathways, patient informed consent, and timing of revascularisation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multidisciplinary decision making</strong></td>
</tr>
<tr>
<td>Shock</td>
</tr>
<tr>
<td>STEMI</td>
</tr>
<tr>
<td>NSTE-ACS</td>
</tr>
<tr>
<td><strong>Informed consent</strong></td>
</tr>
<tr>
<td>Witnessed verbal informed consent or family consent if possible without delay</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Time to revascularisation</strong></td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
ACS = acute coronary syndromes; NSTE-ACS = non-ST-segment elevation acute coronary syndrome; PCI = percutaneous coronary intervention; SCAD = stable coronary artery disease; STEMI = ST-segment elevation myocardial infarction.

This may not apply to countries that are not legally required to ask for written informed consent. ESC and EACTS advocate documentation of patient consent for all revascularisation procedures.

Severe symptoms (CCS class 3), anatomy (left main disease or equivalent, three-vessel disease or proximal left anterior descending artery), or depressed ventricular function.
### Recommendations for decision-making and patient information in the elective setting

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Level&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that patients undergoing coronary angiography are informed about benefits and risks as well as potential therapeutic consequences ahead of the procedure.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>It is recommended that patients are adequately informed about short- and long-term benefits and risks of the revascularisation procedure with the local experience and allowed enough time for informed decision making.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>It is recommended that institutional protocols are developed by the Heart Team to implement the appropriate revascularisation strategy in accordance with current guidelines.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>In PCI centres without on-site surgery, it is recommended that institutional protocols are established with partner institutions providing cardiac surgery.</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass grafting; PCI = percutaneous coronary intervention.

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence.

<sup>c</sup>See chapter 3
5. Revascularisation for stable coronary artery disease

5.1 Rationale for revascularisation

The indications for revascularisation in patients with stable CAD who receive guideline-recommended medical treatment are persistence of symptoms despite medical treatment and/or improvement of prognosis.\(^1\)

Several studies have shown that myocardial revascularisation by PCI or CABG more effectively relieves angina, reduces the use of anti-anginal drugs, and improves exercise capacity and quality of life compared with a strategy of medical therapy alone during short- and long-term follow-up (Supplementary Table 1).\(^32, 33, 57-62\) Recently, the Objective Randomised Blinded Investigation with optimal medical Therapy of Angioplasty in stable angina (ORBITA) trial for the first time randomly compared PCI with placebo (sham-procedure) in patients with stable CAD due to single vessel CAD (diameter stenosis >70%) and preserved left ventricular (LV) function in the presence of moderate symptoms of angina (CCS II in 59% of patients, duration 9 months).\(^63\) After 6 weeks of medication optimization (mean number of anti-anginal drugs of 3) and baseline cardiopulmonary exercise testing, 200 patients were randomised (105 PCI, 95 placebo). Following a 6-week post-randomisation period, the primary endpoint of increment in exercise time was not significantly different, but estimates were imprecise (PCI minus placebo 16.6 sec, 95% CI -8.9-42.0, p=0.20). The dobutamine stress echocardiography peak stress wall motion score index improved with PCI (-0.09, 95% CI -0.15 to -0.04, p=0.001). ORBITA raises the issue whether the symptom relief of PCI in the specific setting of stable single vessel CAD may be related at least in part to a placebo effect. Limitations of the study, as acknowledged by the investigators and outlined elsewhere, include the short observation period (6 weeks), the inclusion of patients with mild symptoms pre-randomisation (CCS Class 0-1 in 25% of patients), the group imbalance in ostial and proximal lesions (37% vs 57%, p=0.005), loss to follow-up after randomisation, and the insufficient power to detect a true difference.\(^64\) This precludes definite conclusions at this stage. Nevertheless, the ORBITA study underlines the value of optimal medical therapy in the management of stable CAD.
Three-year follow-up of FAME-2 indicates yearly and sustained improvement of angina (10.2% vs 28.5% at 1 month, 5.2% vs 9.7% at 3 years) in favour of FFR-guided PCI despite considerable cross-over in the medical therapy arm. Among patients with multivessel disease, assessment of frequency of angina and quality of life measures in SYNTAX, FREEDOM, and EXCEL consistently show early and sustained improvement for both PCI and CABG during long-term follow-up.  

5.2 Evidence basis for revascularisation

The indications for revascularisation in patients with stable angina or silent ischaemia are summarized in the recommendation table.

Indications for revascularisation in patients with stable angina or silent ischemia

<table>
<thead>
<tr>
<th>Extent of CAD (anatomical and/or functional)</th>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>For prognosis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left main disease with stenosis &gt; 50%c 68-71</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Proximal LAD stenosis &gt; 50%c, 68, 70, 72</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Two-vessel or three-vessel disease with stenosis &gt; 50%c with impaired LV function (LVEF ≤ 35%) 61, 62, 68, 70, 73-83</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Large area of ischaemia detected by functional testing (&gt; 10% LV) or abnormal invasive FFRd 595959595959595959595959824, 84-90</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Single remaining patent coronary artery with stenosis &gt; 50%c</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td><strong>For symptoms</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haemodynamically significant coronary stenosis c in the presence of limiting angina or angina equivalent, with insufficient response to optimized medical</td>
<td>I</td>
<td>A</td>
</tr>
</tbody>
</table>
therapy\textsuperscript{e} \cite{24, 63, 68, 91-97}

CAD = coronary artery disease; FFR = fractional flow reserve; iFR = instantaneous wave-free ratio; LAD = left anterior descending coronary artery; LV = left ventricular; LVEF = left ventricular ejection fraction.

\textsuperscript{a}Class of recommendation.

\textsuperscript{b}Level of evidence.

\textsuperscript{c}With documented ischaemia or haemodynamically relevant lesion defined by FFR ≤ 0.80 or iFR ≤ 0.89 (see section 3.2.1.1) or >90% stenosis in a major coronary vessel.

\textsuperscript{d}Based on FFR < 0.75 indicating a prognostically relevant lesion (see section 3.2.1.1)

\textsuperscript{e} in consideration of patient compliance and wishes in relation to intensity of antianginal therapy
5.2.1 Revascularisation with the use of percutaneous coronary intervention

Several meta-analyses comparing a strategy of PCI with initial medical therapy among patients with SCAD found no or only modest benefits in terms of survival or MI for an invasive strategy taking into account that up to 40% of patients crossed-over after to revascularisation during longer term follow-up.\textsuperscript{91, 98, 99} A network meta-analysis of 100 trials with 93,553 patients and 262,090 patient-years of follow-up comparing a strategy of initial medical therapy with revascularisation reported improved survival using PCI with new generation DES (everolimus: 0.75, 0.59 to 0.96; zotarolimus: 0.65, 0.42 to 1.00) compared with initial medical treatment.\textsuperscript{100}

In the FAME-2 trial (Fractional Flow Reserve versus Angiography for Multivessel Evaluation)\textsuperscript{32} patients with SCAD and at least one functionally significant stenosis (invasive fractional flow reserve (FFR) ≤ 0.80) were randomly assigned to medical therapy or medical therapy plus FFR-guided PCI using new generation DES. The 3-year report of FAME-2 reported a lower incidence of the primary composite endpoint death, myocardial infarction (MI), and urgent revascularisation (10.1% vs. 22.0%; \( P < 0.001 \)) driven by a lower incidence of urgent revascularisation in the PCI group (4.3% vs. 17.2%; \( P < 0.001 \)) and without significant differences in the rates of death and MI.\textsuperscript{33} At 2 years of follow-up, the rate of death or MI was lower in the PCI than the medical therapy group (4.6% vs. 8.0%; HR 0.56, 95% CI 0.32 to 0.97, \( P = 0.04 \)) in a landmark analysis between 8 days and 2 years of follow-up, whereas event rates were higher during days 0–7 due to peri-procedural MI. (For overview of studies see Supplementary Table 2) \textsuperscript{97}

5.2.2 Revascularisation with the use of coronary artery bypass grafting

The superiority of CABG over a strategy of initial medical therapy was established in a meta-analysis of seven RCTs\textsuperscript{68} more than two decades ago, demonstrating a survival benefit of CABG in patients with SCAD and LM or three-vessel SCAD, particularly when the proximal LAD coronary artery was involved and has been corroborated in more recent studies.\textsuperscript{100, 101} A network meta-analysis of 100 trials with 93,553 patients comparing a strategy of initial medical therapy with revascularisation reported improved survival (RR 0.80, 95%CI 0.63-0.99) and a reduced risk of myocardial infarction (RR 0.79, 95%CI 0.83-0.99) among patients undergoing CABG compared with initial medical treatment.\textsuperscript{100}
In the STICH trial, 1212 patients with CAD and a left ventricular ejection fraction (LVEF) ≤ 35% were randomised to initial medical therapy or CABG. The extended 10-year follow-up of STICH reported a significant reduction in all-cause (59% vs. 66%; HR 0.84, 95% CI 0.73 to 0.97; \( P = 0.02 \)) and cardiovascular mortality (41% vs. 49%; HR 0.79, 95% CI 0.66 to 0.93; \( P = 0.006 \)). \(^{81}\) (For overview of studies see Supplementary Table 2)

### 5.3 Percutaneous coronary intervention vs. coronary artery bypass grafting

The recommendation for the type of revascularisation (CABG or PCI) in patients with SCAD with suitable coronary anatomy for both procedures and low predicted surgical mortality are summarized in the recommendation table. The Heart Team should take into consideration the individual cardiac and extracardiac characteristics, in addition to patient preference, in the overall decision-making process (Figure 3). A summary of trials comparing outcomes of patients treated with angioplasty versus CABG and BMS versus CABG is shown in Supplementary Table 3 and of studies comparing DES and CABG Table 6.

#### 5.3.1 Criteria for decision making

Predicted surgical mortality, anatomical complexity of CAD, and the anticipated completeness of revascularisation are important criteria for decision making with respect to the type of revascularisation (CABG or PCI). Whether conservative therapy, PCI, or CABG is preferred should depend on the risk-benefit ratios of these treatment strategies, weighting the risks of periprocedural complications (e.g., cerebrovascular events, blood transfusions, renal failure, new onset arrhythmias, wound infections) against improvements in health-related quality of life, as well as long-term freedom from death, myocardial infarction or repeat revascularisation.

#### 5.3.1.1 Predicted surgical mortality

To assess the predicted surgical mortality, the European System for Cardiac Operative Risk Evaluation (EuroSCORE II) \((\text{www.euroscore.org/calc.html})\) and the Society of Thoracic Surgeons (STS) score \((\text{http://riskcalc.sts.org})\) were both developed based on clinical variables to estimate the operative in-hospital or 30-day mortality risk. \(^{102-104}\) (Supplementary Table 4) Both scores have demonstrated their
value in specific cohorts of patients undergoing CABG. Calibration of the STS score is updated on a regular basis. It has been suggested that the STS score outperforms the EuroSCORE II when compared directly in a cohort of CABG patients, although other studies have found a comparable performance of both models.

There are no established cut-offs for low predicted surgical mortality based on EuroSCORE II or STS score. Thus, individualised treatment decisions are needed. These decisions should respect the range of predicted surgical risks in the major RCTs which inform the choice of revascularisation modality (Table 4). In these studies, the predicted surgical risk was assessed by the logistic EuroSCORE. Compared with the more recent EuroSCORE II, the logistic EuroSCORE has similar discrimination, but poorer calibration and, thus, overestimates surgical mortality by roughly two-fold.

Despite the usefulness of these scores, there is not a single risk model that provides perfect risk assessment because the scores are limited by (i) the specific definitions used or the methodology applied, (ii) absence of important variables such as frailty, (iii) practicability of calculation, (iv) failure to reflect all relevant mortality and morbidity endpoints, and (v) limited external validation. Decision-making should not be solely dependent on risk scores. These scores should be used as a guide within the multidisciplinary Heart Team discussion.

**Table 4. Logistic EuroSCOREs in major randomised trials comparing PCI with CABG**

<table>
<thead>
<tr>
<th>Trial</th>
<th>EuroSCORE PCI</th>
<th>EuroSCORE CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYNTAX</td>
<td>3.8 ± 2.6</td>
<td>3.8 ± 2.7</td>
</tr>
<tr>
<td>BEST</td>
<td>2.9 ± 2.0</td>
<td>3.0 ± 2.1</td>
</tr>
<tr>
<td>FREEDOM</td>
<td>2.7 ± 2.4</td>
<td>2.8 ± 2.5</td>
</tr>
<tr>
<td>PRECOMBAT</td>
<td>2.7 ± 1.8</td>
<td>2.8 ± 1.9</td>
</tr>
<tr>
<td>EXCEL</td>
<td>not reported</td>
<td>not reported</td>
</tr>
</tbody>
</table>

Numbers are mean ± standard deviation or median [interquartile range]

**5.3.1.2 Anatomical complexity of CAD**
The SYNTAX score (http://www.syntaxscore.com) was prospectively developed for the SYNTAX trial to grade the anatomical complexity of coronary lesions in patients with LM or three-vessel disease (Table 5, Supplementary Table 4).\textsuperscript{110} In the cohort of the SYNTAX trial and subsequently in external validation cohorts, the SYNTAX score was found to be an independent predictor of long-term major adverse cardiac and cerebrovascular events (MACCE) and of death in patients treated with PCI but not CABG.\textsuperscript{111-114}

**Table 5. Guide to calculate the SYNTAX score**

<table>
<thead>
<tr>
<th>Steps</th>
<th>Variable assessed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Dominance</td>
<td>The weight of individual coronary segments varies according to coronary artery dominance (right or left). Co-dominance does not exist as an option in the SYNTAX score.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Coronary segment</td>
<td>The diseased coronary segment directly affects the score as each coronary segment is assigned a weight depending on its location, ranging from 0.5 (ie, posterolateral branch) to 6 (ie, left main in case of left dominance).</td>
</tr>
<tr>
<td>Step 3</td>
<td>Diameter stenosis</td>
<td>The score of each diseased coronary segment is multiplied by x2 in case of a stenosis 50-99% and by x5 in case of total occlusion.</td>
</tr>
</tbody>
</table>

In case of total occlusion, additional points will be added as follows:
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Trifurcation lesion</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Bifurcation lesion</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Aorto-ostial lesion</td>
</tr>
<tr>
<td>7</td>
<td>Severe tortuosity</td>
</tr>
<tr>
<td>8</td>
<td>Lesion length</td>
</tr>
<tr>
<td>9</td>
<td>Calcification</td>
</tr>
<tr>
<td>10</td>
<td>Thrombus</td>
</tr>
<tr>
<td>11</td>
<td>Diffuse disease/small vessels</td>
</tr>
</tbody>
</table>

In the SYNTAX trial, tertiles of SYNTAX score with low, intermediate and high anatomical complexity stratified patients into those similar outcomes with both, PCI and CABG, and those who derived significant benefit from CABG.\(^\text{116-118}\) In subsequent RCTs, the interaction of the strata of SYNTAX score with the effect of the randomised treatment was less pronounced and did not reach statistical significance.\(^\text{119-121}\) However, in a recent collaborative individual patient pooled analysis of randomised trials including 11,518 patients the test for trend across ordered tertiles of SYNTAX score of the SYNTAX study was positive at \(p=0.0011\), confirming the strata of SYNTAX score as an effect modifier to be considered.\(^\text{122}\) There is concern about bias and inter-individual variability in calculating the SYNTAX score.\(^\text{123}\) This should be minimized by adequate training.
To combine clinical and anatomical risk estimation, the SYNTAX II score was retrospectively derived from the SYNTAX cohort and subsequently externally validated. Nevertheless, compared with SYNTAX score its value in assigning patients to PCI or CABG is less well investigated. The fact that the SYNTAX II score failed to predict the outcome of the EXCEL trial (Evaluation of XIENCE Versus Coronary Artery Bypass Surgery for Effectiveness of Left Main Revascularisation) raises additional concern.

5.3.1.3 Completeness of revascularisation
The aim of myocardial revascularisation is to minimise residual ischaemia. In support of this concept, the nuclear substudy of the COURAGE trial (Clinical Outcomes Utilizing Revascularisation and Aggressive Drug Evaluation) demonstrated an incremental benefit in reducing the risk of death and MI by reducing residual stress-induced ischaemia from > 10% of the myocardium to ≤ 5%.

In the SYNTAX trial, anatomical complete revascularisation was defined as PCI or bypass of all epicardial vessels with a diameter exceeding ≥ 1.5 mm and a luminal reduction of ≥ 50% in at least one angiographic view. A meta-analysis of 89,883 patients enrolled in RCTs and observational studies revealed a lower long-term mortality (relative risk (RR): 0.71, 95% CI 0.65 to 0.77; p < 0.001), myocardial infarction (RR: 0.78, 95% CI: 0.68 to 0.90; p = 0.001), and repeat myocardial revascularisation (RR: 0.74, 95% CI: 0.65 to 0.83; p < 0.001) by complete revascularisation (based on anatomical definition in 87% of the patients) as compared with incomplete revascularisation. The benefit of complete revascularisation was independent of the treatment modality. A more recent meta-analysis suggested enhanced benefit of when performed with state-of-the-art techniques in high-risk patients. Likewise, in a post-hoc analysis of the SYNTAX trial, anatomical incomplete revascularisation was associated with inferior long-term outcomes after both CABG and PCI. A residual SYNTAX score > 8 after PCI was associated with significant increases in the 5-year risk of death and of the composite of death, MI and stroke, and any residual SYNTAX score > 0 was associated with the risk of repeat intervention. In an observational study from the New York State registry that compared CABG with PCI using new generation DES (Everolimus-
eluting stent (EES)) in 9223 pairs of propensity matched patients with multivessel CAD, the significantly higher risk of MI associated with PCI as compared to CABG was not seen among matched pairs of patients in which the PCI group had complete revascularisation \((P = 0.02 \text{ for interaction})\).\(^{131}\) Consistent findings were obtained in a pooled analysis of 3,212 patients of the SYNTAX, BEST and PRECOMBAT trials.\(^{132}\) A mean SYNTAX score of 27 and a LVEF of 59%. In a propensity matched analysis mortality and the composite risk of death, MI and stroke were significantly lower after PCI with complete versus incomplete revascularisation. After PCI with complete revascularisation the risk of death or of the composite of death, MI or stroke was not significantly different from that after CABG with complete revascularisation (adjusted HR [95%-CI] 1.16 [0.83 to 1.63], \(p=0.39\) and 1.14 [0.87 to 1.48], \(p=0.35\); respectively), whereas these risks were significantly elevated after PCI with incomplete revascularisation.

Functional complete revascularisation is achieved, when all lesions causing resting or stress-induced ischaemia are bypassed or treated by PCI. Given the limitations of non-invasive imaging techniques (see Chapter 3), these lesions are best identified by FFR or iFR during diagnostic angiography. For PCI, the FAME study demonstrated that the more restrictive selection of target lesions by functional guidance conferred superior long-term outcomes than anatomically guided lesion selection (see Chapter 3).\(^{133}\) Vice versa, leaving functionally relevant lesions untreated resulted in a high rate of re-interventions in FAME-2.\(^{33}\) Based on the data of FAME and FAME II complete revascularisation based on the functional definition is the preferred strategy for PCI.

The role of functional guidance for CABG is less clear.\(^{28,134}\) One of the potential benefits of CABG is protection against disease progression in proximal segments, which may be diminished by restricting the bypass targets to functionally relevant lesions. This has to be weighed against the risk of bypass closure, when native vessel flow is high. Thus, for ambiguous lesions functional testing may also help guide the surgical revascularisation strategy.
## Recommendations on criteria for the choice between CABG and PCI

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Level&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assessment of surgical risk</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is recommended to calculate the STS score to assess in-hospital or 30-day mortality, and in-hospital morbidity after CABG. ¹⁰⁶, ¹⁰⁸, ¹³⁵</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>It may be considered to calculate the EuroSCORE II to assess in-hospital mortality after CABG ¹⁰⁶ ¹⁰²</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td><strong>Assessment of CAD complexity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In patients with LM or multivessel disease it is recommended to calculate the SYNTAX score to assess the anatomical complexity of CAD and the long-term risk of mortality and morbidity after PCI. ¹¹⁶, ¹²²</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>When considering the decision between CABG and PCI, completeness of revascularisation should be prioritized ¹²⁸</td>
<td>IIa</td>
<td>B</td>
</tr>
</tbody>
</table>

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence.

<sup>c</sup>Level of evidence refers to prediction of outcomes
### Table 6 Randomised clinical trials comparing PCI with DES versus surgical revascularisation trials

<table>
<thead>
<tr>
<th>Stent type and Year of publication</th>
<th>Study</th>
<th>N</th>
<th>Age (y)</th>
<th>Women (%)</th>
<th>Diabetes (%)</th>
<th>MV disease (%)</th>
<th>EF (%)</th>
<th>Baseline characteristics</th>
<th>Primary endpoint&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Secondary endpoints&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Definition</td>
<td>Y</td>
</tr>
<tr>
<td>DES</td>
<td>PES</td>
<td>2009</td>
<td>SYNTAX</td>
<td>1800</td>
<td>65</td>
<td>22</td>
<td>25</td>
<td>MV 61</td>
<td>Death, MI, stroke, or repeat revasc</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>SES</td>
<td>2011</td>
<td>Boudriot</td>
<td>201</td>
<td>68</td>
<td>25</td>
<td>36</td>
<td>LM 100</td>
<td>Death, MI, or repeat revasc</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>SES</td>
<td>2011</td>
<td>PRECOMBAT</td>
<td>600</td>
<td>62</td>
<td>24</td>
<td>32</td>
<td>LM 100</td>
<td>Death, MI, stroke, or TVR</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>EES</td>
<td>2015</td>
<td>BEST</td>
<td>880</td>
<td>64</td>
<td>29</td>
<td>41</td>
<td>MV 100</td>
<td>Death, MI or TVR</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>BES</td>
<td>2016</td>
<td>NOBLE</td>
<td>1201</td>
<td>66</td>
<td>22</td>
<td>15</td>
<td>LM 100</td>
<td>Death, MI or TVR</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>EES</td>
<td>2016</td>
<td>EXCEL</td>
<td>1905</td>
<td>66</td>
<td>24</td>
<td>30</td>
<td>LM 100</td>
<td>Death, MI or stroke</td>
<td>3</td>
</tr>
</tbody>
</table>

BES = biolimus-eluting stents; DES = drug-eluting stents; EES = everolimus-eluting stent; EF = left ventricular ejection fraction; LM = left main coronary artery disease; MI = myocardial infarction; MV = multivessel coronary artery disease; PES = paclitaxel-eluting stents; SES = sirolimus-eluting stents; TVR = target vessel revascularisation; Y = years.

*P <0.05.

<sup>a</sup>Non-inferiority met.

<sup>b</sup>Non-procedural MI (exclusion of peri-procedural MI).
Results are reported as PCI vs. CABG
Age and ejection fraction are reported as means.
Recommendation for the type of revascularisation in patients with stable coronary artery disease in the absence of diabetes with suitable coronary anatomy for both procedures and low predicted surgical mortality*

<table>
<thead>
<tr>
<th>Recommendations according to extent of CAD</th>
<th>CABG</th>
<th>PCI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class</td>
<td>Level</td>
</tr>
<tr>
<td>One-vessel CAD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without proximal LAD stenosis</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>With proximal LAD stenosis 68, 101, 139-143 144</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Two-vessel CAD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without proximal LAD stenosis</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>With proximal LAD stenosis 68, 70, 73</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Left main CAD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left main disease with low SYNTAX score 0-22 69, 116, 117, 122, 145-148</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Left main disease with intermediate SYNTAX score 23-32 69, 116, 117, 122, 145-148</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Left main disease with high SYNTAX score ≥33 116, 117, 122, 146-148</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Three-vessel CAD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three-vessel disease with low SYNTAX score 0-22 116, 118, 131, 136, 149, 150 119, 122</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Three-vessel disease with intermediate and high SYNTAX score &gt; 22c 116, 118, 119, 122, 131, 136, 149, 150</td>
<td>I</td>
<td>A</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass grafting; CAD = coronary artery disease; LAD = left anterior descending coronary artery; PCI = percutaneous coronary intervention; SCAD = stable coronary artery disease; SYNTAX = Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery.

Syntax score calculation [http://www.syntaxscore.com](http://www.syntaxscore.com)

*aClass of recommendation  
*bLevel of evidence
PCI should be considered, if the heart team is concerned about the surgical risk or if the patient refuses CABG after adequate counselling by the heart team including a cardiac surgeon.

*eg. absence of previous cardiac surgery, severe morbidities, frailty, immobility, precluding CABG (also see Table 4)
Figure 3 – Aspects to be considered by the Heart Team for the decision making between percutaneous coronary intervention and coronary artery bypass grafting among patients with stable multivessel and/or left main coronary artery disease [Pictograms to be redrawn by medical artist]

<table>
<thead>
<tr>
<th>Favours PCI</th>
<th>Favours CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinical Characteristics</strong></td>
<td><strong>Clinical Characteristics</strong></td>
</tr>
<tr>
<td>Presence of severe co-morbidity (not adequately reflected by scores)</td>
<td>Diabetes</td>
</tr>
<tr>
<td>Advanced age/frailty/ reduced life expectancy</td>
<td>Reduced LV function (EF≤35%)</td>
</tr>
<tr>
<td>Restricted mobility and conditions that affect the rehabilitation process</td>
<td>Contraindication to DAPT</td>
</tr>
<tr>
<td><strong>Anatomical and technical aspects</strong></td>
<td><strong>Anatomical and technical aspects</strong></td>
</tr>
<tr>
<td>MVD with SYNTAX score 0-22</td>
<td>MVD with SYNTAX score ≥23</td>
</tr>
<tr>
<td>Anatomy likely resulting in incomplete revascularisation with CABG due to poor quality or missing conduits</td>
<td>Anatomy likely resulting in incomplete revascularisation with PCI</td>
</tr>
<tr>
<td>Severe chest deformation or scoliosis</td>
<td>Severely calcified coronary artery lesions limiting lesion expansion</td>
</tr>
<tr>
<td>Sequelae of chest radiation</td>
<td>Need for concomitant interventions</td>
</tr>
<tr>
<td>Porcelain aorta*</td>
<td>Ascending aortic pathology with indication for surgery</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass grafting; DAPT = dual antiplatelet therapy; LV= left ventricular; EF = ejection fraction; MVD = multivessel coronary artery disease; PCI = percutaneous coronary intervention; SYNTAX = Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery.
*consider no-touch off-pump CABG in case of porcelain aorta
5.3.2 Isolated proximal left anterior descending coronary artery disease
Comparing CABG and PCI among patients with isolated proximal LAD disease, available evidence suggests similar outcomes in terms of death, MI and stroke but a higher risk of repeat revascularisation with PCI.

5.3.3 Left main coronary artery disease
Available evidence from RCTs and meta-analyses comparing CABG with PCI using DES among patients with LM disease suggests equivalent results for the safety composite of death, MI and stroke up to 5 years of follow-up. A significant interaction with time is notable providing early benefit for PCI in terms of MI and periprocedural stroke, which is subsequently offset by a higher risk of spontaneous MI during long-term follow-up. The need for repeat revascularisation is higher with PCI than with CABG.

The EXCEL trial compared CABG with PCI using new generation DES (EES) among 1905 patients with significant LM disease. At 3 years of follow-up, the primary endpoint of death, stroke or MI occurred with similar frequency in the CABG and PCI group (14.7% vs. 15.4%; HR 1.00, 95% CI 0.79 to 1.26; P =0.98). The preplanned landmark analysis from 30 days to 3 years showed a significant difference for the primary endpoint in favour of surgery (7.9% vs. 11.5%; P =0.02).

The NOBLE (Nordic-Baltic-British Left Main Revascularisation Study) trial compared CABG with PCI using new generation DES (biolimus-eluting stent, BES) among 1201 patients with significant LM disease (mean SYNTAX score of 23). At a median follow-up of 3.1 years, the primary endpoint of death, non-procedural MI, stroke and repeat revascularisation occurred more frequently in the PCI than the CABG group (29% vs. 19%; HR 1.48, 95% CI 1.11 to 1.96; P =0.007).

A recent collaborative individual patient pooled analysis of randomised trials including 11,518 patients reviewed currently available evidence from randomised trials comparing CABG with PCI for left main or multivessel disease. Primary outcome was all-cause mortality. In the overall cohort, CABG was associated with a significant survival benefit during a mean follow-up of 3.8±1.4 years (5 year all-cause mortality 11.5% after PCI vs 8.9% after CABG; HR 1.28, 95% CI 1.09–1.49; p=0.0019). There
was a linear trend for hazard ratios of death increasing with increasing SYNTAX tertiles (p for trend=0.00114). Among 4478 patients with LM disease, however, those randomly assigned to CABG or PCI with a mean follow-up of 3.4±1.4 years reported similar risks for the primary outcome all-cause mortality (PCI: 10.7% vs CABG 10.5%, HR=1.07, 95% CI 0.87.-1.33, P=0.52) at 5 years. There were no significant differences in mortality between PCI and CABG in subgroup analyses according to SYNTAX score. Nevertheless, in patients with high SYNTAX score a trend towards better survival with CABG was noted. The proportion of patients with high SYNTAX score was limited in view of the inclusion criteria of the respective studies.

Current evidence indicates that PCI is an appropriate alternative to CABG in LM disease and low-to-intermediate anatomical complexity. Among patients with LM disease and low anatomical complexity, there is evidence that the outcomes with respect to major clinical endpoints are similar for PCI and CABG, resulting in a class I recommendation. Among patients with LM disease and high anatomical complexity, the number of patients studied in RCTs is low due to exclusion criteria and the risk estimates and confidence intervals are imprecise, but suggest a trend towards better survival with CABG. Therefore, PCI in this setting cannot be endorsed as reflected by a class III recommendation. For PCI in LM with intermediate anatomical complexity, the previous class IIa recommendation was maintained in view of the incomplete 5-year follow-up of the two largest RCTs in this setting.

5.3.4 Multivessel coronary artery disease
The observation of a survival advantage of CABG over PCI has been consistent among patients with severe three-vessel CAD (intermediate to high SYNTAX score) and has been attributed at least in part to the placement of bypass grafts to the mid coronary vessels providing prophylaxis against the development of new proximal disease.

The BEST (Randomised Comparison of Coronary Artery Bypass Surgery and Everolimus-Eluting Stent Implantation in the Treatment of Patients with Multivessel Coronary Artery Disease) trial comparing CABG with PCI using new generation DES (EES) among patients with multivessel CAD (77% three-vessel CAD, 23% two-vessel disease, mean SYNTAX score 24) prematurely stopped enrolment after inclusion of
880 patients due to slow recruitment. At a median follow-up of 4.6 years, PCI was associated with a higher incidence of the primary endpoint (death, MI, and TVR) (15.3% vs. 10.6%; HR 1.47, 95% CI 1.01 to 2.13; \( P = 0.04 \)) than CABG. The risk of death, MI and stroke was not statistically different between the two treatment groups (11.9% vs. 9.5%; HR 1.26, 95% CI 0.84 to 1.89; \( P = 0.26 \)), whereas repeat revascularisation of any vessel (11.0% vs. 5.4%; HR 2.1, 95% CI 1.28 to 3.41; \( P = 0.003 \)) but not target lesion revascularisation (5.7% vs. 3.8%; HR 1.51, 95% CI 0.82 to 2.80; \( P = 0.19 \)) was more frequent in the PCI group. CABG resulted in more complete revascularisation (71.5% vs. 50.9%; \( P < 0.001 \)) and a lower incidence of revascularisation for new lesions (5.5% vs. 2.3%; HR 2.47, 95% CI 1.18 to 5.17; \( P = 0.01 \)).

Consistent with findings in the overall cohort (see section 5.3.3), the collaborative individual patient pooled analysis found that in 7040 patients with multivessel disease those assigned to CABG had a significantly lower 5-year all-cause mortality than those assigned to PCI (PCI: 11.5% vs CABG 8.9%, HR=1.28, 95% CI 1.09-1.49, \( P = 0.0019 \)). Outcomes for the endpoint all-cause mortality were modified by two variables: diabetes and disease complexity as assessed by the SYNTAX score. As compared to patients without diabetes (8.7% vs 8.0%, HR=1.08, 95% CI 0.86-1.36, \( P = 0.49 \)), mortality was higher after PCI than CABG in patients with diabetes (15.5% vs. 10.0%, HR=1.48, 95% CI 1.19-1.84, \( P = 0.0004 \), \( P \) for interaction =0.045). There was a gradient of risk with a stepwise increase in mortality for PCI according to SYNTAX score tertile (SYNTAX score 0-22; 10.5% vs 8.4%, HR=1.11, 95% CI 0.77-1.62, \( P = 0.57 \); SYNTAX score 23-32; 14.0% vs 9.5%; HR=1.50, 95% CI 1.09-2.08; \( P = 0.0129 \); SYNTAX score >23: 19.2% vs 11.2%; HR=1.70, 95% CI 1.13-2.55; \( P = 0.0094 \)).

An individual patient data pooled analysis of SYNTAX and BEST comparing CABG with PCI using DES among 1,275 patients with multivessel disease in the absence of diabetes (89% three-vessel CAD, mean SYNTAX score 26) reported a lower risk of death (6.0% vs 9.3%, HR 0.65, 95% CI 0.43-0.98, \( P = 0.04 \)) and myocardial infarction 3.3% vs 8.3%, HR 0.40, 95% CI 0.24-0.65, \( P < 0.001 \)) in the CABG group at a median follow-up of 61 months. The risk of death was not significantly different among patients with low (0-22) Syntax score (6.0% vs 7.5%, \( P = 0.66 \)), whereas the
benefit of CABG over PCI was greater in patients with intermediate to high (>22) Syntax Score (7.1% vs 11.6%, P=0.02). Another individual patient data pooled analysis of SYNTAX and BEST comparing CABG with PCI using DES among 1,166 patients with multivessel disease involving the proximal LAD (88% three-vessel CAD, mean Syntax score 28) reported a higher risk of the composite of death, myocardial infarction and stroke (16.3% vs 11.5%, HR 1.43, 95% CI 1.05-1.96, P=0.02), cardiac death, myocardial infarction and repeat revascularisation in the PCI group at 5 years of follow-up. Of note, outcomes were not significantly different for CABG and PCI for all endpoints except myocardial infarction among the subgroup of patients with low Syntax score (0-22).

Available evidence suggests that in multivessel CAD without diabetes and low anatomical complexity PCI and CABG achieve similar long-term outcomes with respect to survival and the composite of death, MI and stroke, justifying a class I recommendation for PCI. In patients with multivessel CAD and intermediate-to-high anatomical complexity the two large trials using DES, SYNTAX and BEST, found a significantly higher mortality and a higher incidence of death, MI and stroke with PCI in the absence of diabetes. Consistent results were also obtained for patients with multivessel CAD in the recent individual patient-level meta-analysis. Thus, the previous class III recommendation for PCI in multivessel CAD and intermediate-to-high complexity was maintained.

5.4 Gaps in evidence
It remains to be determined whether revascularisation by PCI improves prognosis in patients with SCAD. The ISCHEMIA (International Study of Comparative Health Effectiveness With Medical and Invasive Approaches) study (NCT01471522) is currently recruiting 5000 patients with SCAD and evidence of moderate to severe ischaemia detected by non-invasive imaging, who are randomised before coronary angiography to medical therapy or an invasive strategy to detect differences in the primary endpoint of death or MI. Current techniques rely on coronary angiography and detection of ischaemia-producing lesions. However, future adverse events are related at least in part to non-flow limiting, vulnerable plaques. Identification of vulnerable plaques and appropriate treatment strategies require further development. Along the same lines, completeness and timing of revascularisation is not well
defined and neither is the role of residual ischaemia and lesions. Very long-term, extended follow-up (10 years) of trials comparing PCI and CABG particularly in the setting of LM disease will provide further insights into the relative merits of both revascularisation techniques.

6. Revascularisation in non-ST-elevation acute coronary syndrome

Myocardial revascularisation in patients with non-ST-segment elevation acute coronary syndrome (NSTE-ACS) is addressed by a prior guideline that is endorsed by the current task force. In the present guideline, we discuss new evidence where previous recommendations require an update.

6.1 Early invasive vs. conservative strategy

An invasive strategy has become the standard of care for high-risk patients. This approach allows prompt diagnosis of the underlying CAD, identification of the culprit lesion, guidance for antithrombotic management, and the assessment of the suitability of coronary anatomy for PCI or CABG. Numerous factors interplay in the decision-making process including clinical presentation, comorbidities, risk stratification (Figure 4), high-risk features specific for a revascularisation modality such as frailty, cognitive status, estimated life expectancy and functional and anatomical severity of CAD.

Up to 40% of NSTE-ACS patients with obstructive CAD present with multiple complex plaques and 25% with an acute occluded coronary artery, so that identification of the culprit lesion may be challenging. Correlation with ECG or echo changes and the use of OCT in the 25% of NSTE-ACS patients with angiographically normal epicardial coronary arteries may be helpful for identifying the culprit lesion or rule-out other mechanisms such as dissection or haematomas (myocardial infarction with non-obstructive coronary arteries [MINOCA]).

A routine invasive strategy in NSTE-ACS has been shown to improve clinical outcomes, a benefit was mainly confined to biomarker-positive patients and patients with other high-risk features as defined in Figure 4. Of importance, the use of radial approach, new-generation DES as well as more effective P2Y12 inhibitors were not available or broadly implemented in these trials and led to a magnified benefit in frail ACS populations.
6.2 Timing of angiography and intervention
The current recommendations on timing of angiography and intervention as defined in Figure 4 are based on evidence discussed in detail by the prior guideline on NSTE-ACS. Specifically, a reduction in recurrent or refractory ischaemia and length of hospital stay was found with early intervention. More recently, an updated collaborative meta-analysis on individual published and unpublished data (n=5324 patients with a median follow-up of 180 days) suggested that early intervention might also be associated with decreased mortality. This meta-analysis showed a statistical trend towards decreased mortality with an early invasive strategy as compared with a delayed invasive strategy in unselected patients with NSTE-ACS (HR 0.81, 95% CI 0.64–1.03; p=0.0879). The survival benefit of the early invasive strategy appeared more pronounced in high risk subsets, including elevated cardiac biomarkers at baseline (HR 0.761, 95% CI 0.581–0.996), diabetes (HR 0.67, 95% CI 0.45–0.99), a GRACE risk score more than 140 (HR 0.70, 95% CI 0.52–0.95), and age 75 years older (HR 0.65, 95% CI 0.46–0.93), although tests for interaction were inconclusive.

6.3 Type of revascularisation
6.3.1 Percutaneous coronary intervention
6.3.1.1 Technical aspects
Implantation of new generation DES is the standard treatment strategy even when dual antiplatelet therapy (DAPT) cannot be sustained beyond one month post intervention and the radial approach has also become the standard of care. DAPT is recommended for 12 months irrespective of stent type, while in patients at high ischaemic risk not experiencing bleeding events, DAPT may be extended (see Chapter 17). There is no evidence for any additional benefit of thrombectomy in patients undergoing PCI in the setting of NSTE-ACS. While FFR is considered the invasive gold standard for the functional assessment of lesion severity in stable CAD, it has been shown to be feasible, reliable, safe and effective in NSTE-ACS patients with multivessel disease although its prognostic value is unclear yet.

6.3.1.2 Revascularisation strategies and outcomes
Complete revascularisation of significant lesions should be attempted in multivessel
disease NSTE-ACS patients, given that it was mandated in trials testing early vs. late
intervention\textsuperscript{164, 175, 176} and that the prognosis of patients with incomplete
revascularisation is known to be worse.\textsuperscript{128, 177} In addition, it seems that complete one
stage revascularisation is associated with better clinical outcome than multistage
PCI.\textsuperscript{178} Periprocedural complications of PCI defined as MI or myocardial injury as well
as the long-term ischaemic risk remains higher in NSTE-ACS than in stable
patients\textsuperscript{179, 180} For ACS patients who underwent PCI, revascularisation procedures
represent the most frequent, most costly and earliest cause for rehospitalization.\textsuperscript{181, 182} As in STEMI, routine treatment of non-culprit lesions during the primary
intervention by PCI is harmful in NSTE-ACS with cardiogenic shock, as shown by the
recently published Culprit Lesion Only PCI versus Multivessel PCI in Cardiogenic
Shock (CULPRIT-SHOCK) trial (see section 7.3).\textsuperscript{183}

6.3.2 Coronary artery bypass grafting
Approximately 5% up to 10% of NSTE-ACS patients require CABG\textsuperscript{184} and represent
a challenging subgroup given their high-risk characteristics compared with patients
undergoing elective CABG.\textsuperscript{185} In the absence of randomised data, optimal timing for
non-emergent CABG in NSTE-ACS patients should be determined individually. The
risk of ischaemic events possibly related to suboptimal antiplatelet therapy while
awaiting surgery is less than 0.1% while perioperative bleeding complications
associated with platelet inhibitors is higher than 10%.\textsuperscript{186} In patients with ongoing
ischaemia or haemodynamic instability and with an indication for CABG, emergency
surgery should be performed and not postponed as a consequence of antiplatelet
treatment exposure.

6.3.3 Percutaneous coronary intervention vs. coronary artery bypass grafting
There is no randomised comparison of PCI vs. CABG in the specific setting of NSTE-ACS. Currently available evidence indirectly suggests that the criteria applied in
patients with stable CAD to guide the choice of revascularisation modality should be
applied to stabilized patients with NSTE-ACS.\textsuperscript{100, 116, 149, 187} A recent individual-
patients data analysis from BEST, PRECOMBAT and SYNTAX compared the
outcome of CABG with that of PCI in 1246 patients with stabilised NSTE-ACS and
multivessel or left main disease.\textsuperscript{187} The 5-year incidence of the primary outcome, the
composite of death, MI or stroke, was significantly lower with CABG than with PCI (13.4% vs 18%, \( p = 0.036 \)). The findings of this meta-analysis were consistent with the main findings of the studies included, thus supporting the concept that the principles of SCAD should apply to stabilised patients with NSTE-ACS as well. For complex cases, Heart Team discussion and use of the SYNTAX score are recommended,\(^{188}\) in particular given its ability to predict death, MI and revascularisation in multivessel disease NSTE-ACS patients undergoing PCI where recent evidence suggests a greater benefit of CABG versus PCI.\(^{189}\)

**Recommendations for invasive evaluation and revascularisation in non-ST-elevation acute coronary syndrome**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class(^a)</th>
<th>Level(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urgent</strong> coronary angiography (&lt; 2 hours) is recommended in patients at very high ischaemic risk (Figure 3).(^{190})</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td><strong>An early</strong> invasive strategy (&lt; 24 hours) is recommended in patients with at least one high-risk criterion (Figure 3). (^{157, 167, 169})</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>An invasive strategy (&lt; 72 hours after first presentation) is indicated in patients with at least one intermediate-risk criterion (Figure 3) or recurrent symptoms. (^{163, 164})</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>It is recommended to base the revascularisation strategy (ad hoc culprit-lesion PCI/multivessel PCI/CABG) on the <strong>clinical status</strong> and comorbidities as well as the <strong>disease severity</strong>, i.e. distribution and angiographic lesion characteristics (e.g. SYNTAX score), according to the principles for SCAD*.(^{187})</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>In cardiogenic shock, routine revascularisation of non-IRA lesions is not recommended during primary PCI.(^{183})</td>
<td>III</td>
<td>B</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass grafting; PCI = percutaneous coronary intervention; SCAD = stable coronary artery disease; SYNTAX = SYNergy between percutaneous coronary intervention with TAXus.

\(^a\)Class of recommendation

\(^b\)Level of evidence

*may apply to stabilised NSTE-ACS patients
6.4 Gaps in evidence
In the setting of NSTE-ACS, there are no dedicated prospective studies on the revascularisation strategy with multivessel disease. Thus, current recommendations on choice of lesions to be treated and treatment modality (PCI or CABG) are based on an analogy to findings obtained in stable CAD or STEMI. Likewise, the prognosis role of FFR and iFR in guiding myocardial revascularisation needs additional clarification.

7. Revascularisation in ST-segment elevation myocardial infarction
Myocardial revascularisation in patients with STEMI is addressed by the 2017 ESC guidelines on STEMI. After reviewing the subsequent literature, the current task force endorses most recommendations of this guideline.¹⁹¹

7.1 Time delays
Delays in the timely implementation of reperfusion therapy are key issues in the management of STEMI. Detailed recommendations on time lines, logistics and prehospital management have been provided in the recent ESC STEMI guidelines (Figure 5).¹⁹¹
A recent analysis of 12,675 STEMI patients of the Feedback Intervention and Treatment Times in ST-Elevation Myocardial Infarction (FITT-STEMI) trial emphasizes the strong impact of time delays on mortality, particularly in STEMI patients with cardiogenic shock or out-of-hospital cardiac arrest.\(^{192}\) In shock without out-of-hospital cardiac arrest, every 10-min treatment delay between 60 and 180 min from the first medical contact resulted in 3.3 additional deaths per 100 PCI-treated patients and in 1.3 additional deaths after out-of-hospital cardiac arrest without cardiogenic shock. In stable STEMI patients time delays were substantially less relevant (0.3 additional deaths per 100 PCI-treated patients for every 10-min delay between 60 to 180 min from the first medical contact). Thus, the high-risk STEMI patients with cardiogenic shock or out-of-hospital cardiac arrest are those whose benefit most from expediting all steps of the care pathway.

### 7.2 Selection of reperfusion strategy

Primary PCI, defined as percutaneous catheter intervention in the setting of STEMI without previous fibrinolysis, is the preferred reperfusion strategy. It has replaced fibrinolysis in patients with STEMI, provided it can be performed in a timely manner in high-volume PCI centres with experienced operators and 24-hour, 7-day catheterization laboratory activation.\(^{191, 193, 194}\) In settings where primary PCI cannot be performed in a timely fashion, fibrinolysis should be administered as soon as possible. If FMC is out of hospital lysis should be implemented pre-hospital (e.g. in the ambulance). (Figure 5).\(^{195-199}\) It should be followed by transfer to PCI-capable centres for routine coronary angiography in all patients, and should be performed without delay for rescue PCI in the case of unsuccessful fibrinolysis or within 2 to 24 hours after the bolus administration.\(^{191}\) Emergency CABG may be indicated in selected STEMI patients unsuitable for PCI.

**Figure 5** Modes of patient’s medical contact, components of ischaemia time and
flowchart for reperfusion strategy selection.

EMS = Emergency Medical System; FMC = First Medical Contact; PCI = Percutaneous Coronary Intervention; STEMI = ST-segment elevation myocardial infarction. The recommended mode of patient presentation is by alerting the EMS (call national emergency number: 112 or similar number according to region). When STEMI diagnosis is made in the out-of-hospital setting (via EMS) or in a non-PCI centre, the choice of reperfusion strategy is based on the estimated time from STEMI diagnosis to PCI-mediated reperfusion (wire crossing). System delay for patients alerting the EMS starts at the time of phone alert, although FMC occurs when EMS arrives to the scene. ¹ denotes minutes. ⁴Patients receiving fibrinolysis should be transferred to a PCI centre immediately after administration of the lytic bolus.

7.3 Primary percutaneous coronary intervention
Key points for optimizing and guiding primary PCI are summarized below. The infarct-related artery (IRA) should be systematically treated during the initial intervention. Patients with extensive CAD in vessels remote from the IRA have an
adverse prognosis following primary PCI.\textsuperscript{200} Staged PCI in patients with multivessel disease and no haemodynamic compromise is an independent predictor of survival, and more frequent ischaemic events have been reported in direct vs. staged revascularisation of STEMI patients with multivessel disease.\textsuperscript{201-203}

Four major randomised trials (Preventive Angioplasty in Acute Myocardial Infarction [PRAMI]\textsuperscript{204}, Complete Versus Lesion-Only Primary PCI trial [CvLPRIT],\textsuperscript{205} complete revascularisation versus treatment of the culprit lesion only in patients with STEMI and multivessel disease [DANAMI-3−PRIMULTI],\textsuperscript{206} and Compare-Acute\textsuperscript{207}) have consistently shown a benefit of complete revascularisation (performed immediately or staged) as compared to IRA-only PCI in patients with STEMI and multivessel disease (for details see web addenda). A recent meta-analysis of 10 trials has shown that complete revascularisation was associated with a lower risk of MACE (RR 0.57, 95% CI 0.42 to 0.77), due to a lower risk of urgent revascularisation (RR 0.44, 95% CI 0.30 to 0.66), with no significant difference in mortality (RR 0.76, 95% CI 0.52 to 1.12) or MI (RR 0.54, 95% CI 0.23 to 1.27).\textsuperscript{208} This meta-analysis did not include Compare-Acute. Yet, similar to earlier studies the benefit of complete revascularisation over culprit-only revascularisation seen in Compare-Acute was driven by a lower need for unplanned re-intervention, whereas the incidences of death and recurrent MI were similar between the two strategies.\textsuperscript{207}

Most of the studies support the concept of full revascularisation either during the initial hospital stay for STEMI or a staged admission,\textsuperscript{208} but it remains to be determined how clinicians can identify lesions that should be revascularised beyond the culprit lesion and whether complete revascularisation should be performed in single- or multi-stage procedures. Moreover, there is lack of evidence on optimal timing of staged procedures. In most of the studies, staged procedures were performed during the initial hospital stay. At present, one-stage multivessel PCI during STEMI without cardiogenic shock should be considered in patients in the presence of multiple, critical stenoses or highly unstable lesions (angiographic signs of possible thrombus or lesion disruption), and if there is persistent ischaemia after PCI on the supposed culprit lesion.

In patients with multivessel disease and acute myocardial infarction with cardiogenic
shock, the recently published CULPRIT-SHOCK trial showed that a strategy with PCI of culprit lesion only with possible staged revascularisation determined a lower 30-day risk of the composite of all-cause mortality or severe renal failure as compared to immediate multivessel PCI.\textsuperscript{183} This was driven by a significant risk reduction in 30-day all-cause mortality by the culprit only strategy as compared with immediate multivessel PCI (43.3\% vs. 51.6\%; HR 0.84, 95\% CI 0.72-0.98; P=0.03). These findings need to be interpreted in light of a low 12.5\% (43 out of 344 patients) crossover rate from culprit only to immediate multivessel PCI based on physician’s judgment. Based on these findings, culprit only PCI is recommended as the default strategy in patients with acute myocardial infarction with cardiogenic shock. A more detailed discussion of the revascularisation strategy in MI with cardiogenic shock is found in the web addenda.

In patients with STEMI, DES, in particular new generation DES, have demonstrated better efficacy as compared to bare-metal stent (BMS) and should be used as the default strategy in STEMI patients, even when DAPT cannot be sustained beyond 1 month.\textsuperscript{170, 171, 209-211} (see Chapter 16.1.2). As discussed in Chapter 16.4, the radial access is preferred over the femoral access.

Delaying stenting in primary PCI has been investigated as an option to reduce microvascular obstruction (MVO) and preserve microcirculatory function in two small trials with conflicting results.\textsuperscript{212, 213} More recently, in the larger Deferred versus conventional stent implantation in patients with STEMI (DANAMI 3-DEFER) trial in 1215 STEMI patients, there was no effect on the primary clinical outcome (composite of death, non-fatal MI, or ischaemia driven revascularisation of non-IRA lesions) over a median follow-up of 42 months.\textsuperscript{214} Routine deferred stenting was associated with a higher risk of TVR.

Thrombus aspiration has been proposed as an adjunct during primary PCI, to further improve epicardial and myocardial reperfusion by the prevention of distal embolization of thrombotic material and plaque debris.\textsuperscript{215} Two landmark randomised controlled trials adequately powered to detect superiority of routine manual thrombus aspiration vs. conventional PCI showed no benefit on clinical outcomes of the routine aspiration strategy overall or in any subgroup of patients indicating high thrombotic risk.\textsuperscript{216-219} A
safety concern emerged in the Trial of Routine Aspiration Thrombectomy with PCI versus PCI Alone in Patients with STEMI (TOTAL) with an increase in the risk of stroke.\textsuperscript{218, 220} Taken together, these results suggest that the routine use of thrombus aspiration is not indicated. In the high thrombus burden subgroup, the trend towards reduced cardiovascular death and increased stroke/transient ischaemic attack (TIA) provides a rationale for future trials of improved thrombus aspiration technologies in this high-risk subgroup (although statistical tests did not support significant subgroup interaction).\textsuperscript{221}

7.4 Percutaneous coronary intervention after thrombolysis and in patients with late diagnosis
The benefits of early, routine PCI after thrombolysis were seen in the absence of an increased risk of adverse events (stroke or major bleeding). Based on data from the four most recent trials, all of which had a median delay between start of thrombolysis and angiography of 2–6 hours, a time-frame of 2–24 hours after successful lysis is recommended.\textsuperscript{199, 222-224} In cases of failed fibrinolysis, or if there is evidence of re-occlusion or re-infarction with recurrence of ST segment elevation, the patient should undergo immediate coronary angiography and rescue PCI.\textsuperscript{225} Patients presenting between 12 and 48 hours after onset of symptoms, even if pain-free and with stable haemodynamics, may still benefit from early coronary angiography and possibly PCI.\textsuperscript{226, 227} In patients presenting days after the acute event with a completed MI, only those with recurrent angina or documented residual ischaemia—and proven viability on non-invasive imaging in a large myocardial territory—may be considered for revascularisation when the infarct artery is occluded. Routine late PCI of an occluded IRA after MI in stable patients has no incremental benefit over medical therapy.\textsuperscript{228}

7.5 Gaps in evidence
Patients undergoing primary PCI benefit from full revascularisation but the optimal timing of treatment of the non-culprit lesion is not known. More studies evaluating the use the non-culprit lesions by FFR or IFR at the time of acute PCI and studies investigating whether intravascular imaging guidance of primary PCI can improve outcomes of STEMI patients are needed. Future trials of improved thrombus aspiration technologies may address role of this strategy in patients with high-risk features, such large thrombus burden.\textsuperscript{221}
### Primary percutaneous coronary intervention for myocardial reperfusion in ST-elevation myocardial infarction: indications and logistics

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Level&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indication</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reperfusion therapy is indicated in all patients with time from symptom onset &lt; 12 hours duration and persistent ST-segment elevation&lt;sup&gt;193, 194, 229&lt;/sup&gt;.</td>
<td>I</td>
<td>A</td>
</tr>
</tbody>
</table>
| In the absence of ST-segment elevation, a primary PCI strategy is indicated in patients with suspected ongoing ischaemic symptoms suggestive of MI and at least one of the following criteria present:  
  - haemodynamic instability or cardiogenic shock  
  - recurrent or ongoing chest pain refractory to medical treatment  
  - life-threatening arrhythmias or cardiac arrest  
  - mechanical complications of MI  
  - acute heart failure  
  - recurrent dynamic ST-segment or T-wave changes, particularly with intermittent ST-segment elevation | I                  | C                 |
| A primary PCI strategy is recommended over fibrinolysis within indicated timeframes<sup>230, 231</sup>. | I                  | A                 |
| In patients with time from symptom onset >12 h, a primary PCI strategy is indicated in the presence of ongoing symptoms or signs suggestive of ischaemia, haemodynamic instability, or life-threatening arrhythmias. | I                  | C                 |
| A routine primary PCI strategy should be considered in patients presenting late (12–48 h) after symptom onset<sup>226, 227, 232</sup>. | IIa                | B                 |
| **Logistics**                                                                 |                    |                   |
| It is recommended that the prehospital management of | I                  | B                 |
STEMI patients be based on regional networks designed to deliver reperfusion therapy timely and effectively, and to offer primary PCI to as many patients as possible.\(^\text{233, 234}\)

It is recommended that all EMSs, emergency departments, coronary care units, and catheterization laboratories have a written updated STEMI management protocol, preferably shared within geographic networks.

It is recommended that primary PCI-capable centres deliver a 24-hour/7-day service and ensure for primary PCI to be performed as fast as possible.\(^\text{235-237}\)

It is recommended that patients transferred to a PCI-capable centre for primary PCI bypass the emergency department and CCU/ICCU and are transferred directly to the catheterization laboratory.\(^\text{238-240}\)

CCU = coronary care unit; ECG = electrocardiogram; EMS = emergency medical service; ICCU = intensive coronary care unit; LBBB = left bundle branch block; RBBB = right bundle branch block, PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction.

\(^a\)Class of recommendation.

\(^b\)Level of evidence.

### Primary percutaneous coronary intervention for myocardial reperfusion in ST-elevation myocardial infarction: procedural aspects (strategy and technique)

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class(^a)</th>
<th>Level(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Routine revascularisation of non-IRA lesions should be considered in patients with multivessel disease before hospital discharge.(^\text{204, 205 206, 207})</td>
<td>IIa</td>
<td>A</td>
</tr>
<tr>
<td>CABG should be considered in patients with ongoing ischaemia and large areas of jeopardised myocardium if PCI of the IRA cannot be performed.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>In cardiogenic shock, routine revascularisation of non-IRA lesions is not recommended during primary PCI.(^\text{183})</td>
<td>III</td>
<td>B</td>
</tr>
</tbody>
</table>
Routine use of thrombus aspiration is not recommended \textsuperscript{216-219, 221} III A

CABG = coronary artery bypass grafting; IRA = infarct-related artery; PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction.

\textsuperscript{a}Class of recommendation.

\textsuperscript{b}Level of evidence.

8. Myocardial revascularisation in patients with heart failure

8.1 Chronic Heart Failure

8.1.1 Recommendations for myocardial revascularisation in patients with chronic heart failure

When compared to medical therapy alone, coronary revascularisation is superior in improving survival in patients with heart failure (HF) of ischaemic origin and is recommended in clinical practice. \textsuperscript{81, 241} However, the optimal revascularisation strategy is not defined. The choice between CABG and PCI should be made by the Heart Team after careful evaluation of the patient's clinical status and coronary anatomy, expected completeness of revascularisation (see section 5.3.1.3), myocardial viability, coexisting valvular disease and co-morbidities. Considerations relating to the need for viability testing prior to revascularisation are discussed in chapter 3 of this document.

Randomised clinical trial data comparing revascularisation with medical therapy exists only for CABG in the setting of the Surgical Treatment for Ischemic Heart Failure (STICH) trial\textsuperscript{81}. One analysis from this trial showed that CABG can be performed with acceptable 30-day mortality rates (5.1\%) in patients with left ventricular dysfunction (LVEF\leq 35\%).\textsuperscript{242} Extended follow-up in the STICH Extension Study (STICHES) support a significant survival benefit of CABG combined with medical therapy versus medical therapy alone in a 10-year observation.\textsuperscript{81}

There are currently no dedicated randomised clinical trials comparing PCI vs. medical therapy in patients with HFrEF (Heart Failure with Reduced Ejection Fraction). In addition, CABG vs. PCI randomised trials have excluded patients with severe HF. In one prospective registry including 4616 patients with multivessel disease and severe HFrEF, propensity-score matched comparison revealed similar survival (mean follow-
up 2.9 years) with PCI (using EES) versus CABG.\textsuperscript{243} PCI was associated with a higher risk of MI, particularly in patients with incomplete revascularisation, and repeat revascularisation. CABG was associated with higher risk of stroke. The conclusion of the study was that multivessel PCI can be a valuable option in HF patients, if complete revascularisation is possible. A systematic review of studies comparing revascularisation with medical therapy in patients with an ejection fraction $\leq 40\%$ showed that there was a significant mortality reduction with CABG (hazard ratio, 0.66; 95\% confidence interval, 0.61-0.72; $P<0.001$) and PCI (hazard ratio, 0.73; 95\% confidence interval, 0.62-0.85; $P<0.001$) versus medical therapy, though these finding are limited by the predominantly observational nature of the included studies and missing information on completeness of revascularisation.\textsuperscript{241}

A recent observational study investigated outcomes with PCI or CABG for multi-vessel CAD and LV dysfunction in 1738 propensity-matched patients with diabetes mellitus.\textsuperscript{244} Similar to the findings in absence of LV dysfunction, CABG as compared with PCI was associated with a significantly lower risk of MACE, which included a significant reduction in mortality. Event curves separated early during the first year and continued to separate out to 12 years.

In older patients without diabetes in whom complete revascularisation can be achieved PCI should be considered whereas in younger patients with more extensive CAD or those with diabetes CABG is preferred. In patients with diabetes and LV moderate or severe dysfunction (EF<50\%) CABG is associated with better long term survival and reduced incidence of MACCE.\textsuperscript{243, 244}

### 8.1.2 Ventricular reconstruction and aneurysm resection

The aim of surgical ventricular reconstruction (SVR) is to restore physiological volume, and achieve an elliptical shape of the LV, by scar resection and LV wall reconstruction on a mannequin of predefined size. The aim of ventricular aneurysmectomy is to remove fibrous scar in cases of severe dilatation, thrombus formation or as a source of life-threatening ventricular arrhythmias.

The STICH trial revealed no difference in the primary outcome (total mortality or cardiac hospitalization) between patients randomly allocated to CABG versus combined CABG and SVR.\textsuperscript{245} Subgroup analyses of patients with a less dilated LV
and better LV ejection fraction showed benefit from SVR. In the STICH trial, a postoperative LV end-systolic volume index of 70 mL/m² or lower, after CABG plus SVR, resulted in improved survival compared with CABG alone. In experienced centres, SVR may be done at the time of CABG if HF symptoms are more predominant than angina and if myocardial scar and moderate LV remodeling are present.

Recommendations on revascularisations in patients with chronic heart failure and systolic left ventricular dysfunction (ejection fraction ≤ 35%)

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>In patients with severe LV systolic dysfunction and coronary artery disease suitable for intervention, myocardial revascularisation is recommended</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>CABG is recommended as first revascularisation strategy choice in patients with multivessel disease and acceptable surgical risk.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>In patients with 1 or 2 vessel disease, PCI should be considered as an alternative to CABG when complete revascularisation can be achieved</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>In patients with 3 vessel disease PCI should be considered based on the evaluation by the Heart Team of the patient’s coronary anatomy, expected completeness of revascularisation, diabetes status, and co-morbidities.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>Left ventricular aneurysmectomy during CABG should be considered in patients with NYHA class III/IV, large LV aneurysm, large thrombus formation or if the aneurysm is the origin of arrhythmias.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>Surgical ventricular restoration during CABG may be considered in selected patients treated in centres with expertise</td>
<td>IIb</td>
<td>B</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass grafting; LAD = left anterior descending; LV = left ventricular; LVESV = left ventricular end-systolic volume; PCI = percutaneous coronary intervention.

aClass of recommendation.
8.2 Acute Heart Failure and Cardiogenic Shock

Acute myocardial ischaemia in the setting of AMI is the antecedent event for the majority of patients with cardiogenic shock undergoing percutaneous revascularisation. Mechanical complications, such as papillary muscle rupture with severe mitral valve regurgitation, ventricular septal defect, or free wall rupture, are additional precipitating causes.

8.2.1 Revascularisation

The SHOCK trial (Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock) demonstrated that in patients with cardiogenic shock complicating acute myocardial infarction, emergency revascularisation with PCI or CABG improved long-term survival when compared with initial intensive medical therapy. All-cause mortality at 6 months was lower in the group assigned to revascularisation than in the medically treated patients (50.3% vs. 63.1%, respectively; RR 0.80, 95% CI 0.65 to 0.98; P=0.03).

The revascularisation strategy for patients with cardiogenic shock and multivessel disease is addressed in chapter 7 of this document.

A sub-analysis of the SHOCK trial comparing patients treated with CABG or PCI showed similar survival rates between the two subgroups. There were more patients with diabetes (48.9% versus 26.9%; P=0.02), 3-vessel disease (80.4% versus 60.3%; P=0.03), and left main coronary disease (41.3% versus 13.0%; P=0.001) in the CABG group. The findings of this non-randomised comparison suggest that CABG should be considered in patients with cardiogenic shock who have suitable anatomy, particularly if successful PCI is not feasible.

8.2.2 Mechanical circulatory support
Short-term MCS devices currently available are the intra-aortic balloon pump (IABP), veno-arterial extracorporeal membrane oxygenation (ECMO) and percutaneous left ventricular assist devices (pLVAD). Short-term MCS may be considered in refractory cardiogenic shock depending on patient age, comorbidities, neurological function, and prospects for long-term survival and quality of life.

8.2.2.1 Intraaortic Balloon Pump
IABP is a low cost device that is easy to insert and remove. It moderately increases cardiac output and coronary and cerebral perfusion while decreasing ventricular workload. In patients with cardiogenic shock complicating acute MI, the IABP-SHOCK II randomised trial (600 patients) showed that the use of IABP did not reduce 30-day mortality and that there was no evidence of long-term benefit.\textsuperscript{253, 254} A recent Cochrane review of seven trials (790 patients) showed that IABP may have a beneficial effect on some haemodynamic parameters but did not result in survival benefits.\textsuperscript{255} Thus, the routine use of IABP in patients in cardiogenic shock with cardiogenic shock complicating acute MI is not recommended.

8.2.2.2 Extracorporeal Membrane Oxygenation
Veno-arterial ECMO (VA-ECMO), also known as extracorporeal life support (ECLS), in its current form is a modified form of cardiopulmonary bypass. It decompresses the venous system, increases coronary, cerebral and peripheral perfusion, and also provides supplementary blood oxygenation. When performed percutaneously, it does not allow for left ventricular decompression, and leads to increasing LV afterload.
In patients with cardiac arrest, evidence from observational trials supports better survival in patients treated with VA-ECMO compared with those without.\textsuperscript{256} When compared with IABP, VA-ECMO provides superior circulatory support.\textsuperscript{257, 258} Moreover, a meta-analysis of observational studies suggested that in patients with cardiogenic shock post ACS, VA-ECMO showed a 33% higher 30-day survival compared with IABP (95% CI, 14–52%; p < 0.001; NNT 13).\textsuperscript{256} However, the low number of patients included in the analysed studies and the non-random treatment allocation are important limitations.

### 8.2.2.3 Percutaneous Left Ventricular Assist Devices

The majority of clinical experience with currently available pLVADs is limited to two types of devices: 1) transaortic microaxial pump (Impella) which directly unloads left ventricle providing 2.5-5l/min blood flow and 2) a transseptal centrifugal assist device (TandemHeart) which unloads the LV via a cannula introduced into left atrium through transseptal puncture.

A recent meta-analysis on MCS in cardiogenic shock included four randomised trials investigating the efficacy and safety of pLVADs vs IABP and demonstrated similar short-term mortality despite initial beneficial effects on arterial blood pressure and peripheral perfusion, measured by serum lactate levels.\textsuperscript{259} In all trials, higher rate of bleeding from vascular access sites and a significantly higher incidence of limb ischaemia following pLVAD was noted. Similar outcomes were noted in a RCT in high-risk PCI in patients with impaired LV function. The 30-day incidence of major adverse events was not different for patients with pLVAD versus IABP.\textsuperscript{260}

In summary, the evidence for pLVAD is insufficient to provide a recommendation on clinical use in cardiogenic shock.

### 8.2.2.4 Surgically implanted LVAD

There is limited data with surgically-implanted left ventricular assist device (LVAD) therapy in patients with AMI and cardiogenic shock. One multicentre registry showed that despite being more critically ill prior to implantation, patients with acute MI managed with LVAD had outcomes similar to other LVAD populations.\textsuperscript{261}
A suggested algorithm for the management of patients with cardiogenic shock is shown in Figure 6.

Figure 6. Algorithm for management of patients with cardiogenic shock

Patient with cardiogenic shock

- Medical therapy
- Inotropic support
- Ventilatory support
- Reperfusion
- Revascularization
- Repair of mechanical complications

Patient unstable

- Short-term mechanical circulatory support

Patient stable

- Weaning

Recovery of cardiac function

- Weaning

No recovery of cardiac function

- Assess neurological / end organ function

Recovery of cardiac function

- Standard therapy

Irreversible neurological deficit

- Weaning

Favourable neurological function

- Mechanical circulatory support for destination therapy or as bridge to cardiac transplantation

8.3 Gaps in Evidence

There is no RCT comparing revascularisation with PCI vs CABG in patients with HF. There is limited evidence on the role of active MCS in patients with cardiogenic shock compared with standard therapy.
## Recommendations for management of patients with cardiogenic shock

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Level&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency coronary angiography is indicated in patients with acute heart failure or cardiogenic shock complicating ACS&lt;sup&gt;251, 262&lt;/sup&gt;.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Emergency PCI of the culprit lesion is indicated for patients with cardiogenic shock due to STEMI or NSTEMI-ACS independent of time delay of symptom onset. if coronary anatomy is amenable to PCI&lt;sup&gt;251&lt;/sup&gt;.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Emergency CABG is recommended for patients with cardiogenic shock if the coronary anatomy is not amenable to PCI&lt;sup&gt;251&lt;/sup&gt;.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>In case of haemodynamic instability, emergency surgical or catheter-based repair of mechanical complications of ACS is indicated as decided by the heart team.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>In selected patients with ACS and cardiogenic shock, short-term mechanical circulatory support may be considered, depending on patient age, comorbidities, neurological function and prospects for long-term survival and predicted quality of life.</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>Routine use of IABP in patients with cardiogenic shock due to ACS is not recommended&lt;sup&gt;253-255&lt;/sup&gt;.</td>
<td>III</td>
<td>B</td>
</tr>
</tbody>
</table>

ACS = acute coronary syndrome; CABG - coronary artery bypass grafting VA ECMO - veno-arterial extracorporeal membrane oxygenation. IABP = intra-aortic balloon pump; NSTEMI-ACS = non-ST-elevation acute coronary syndrome; PCI = percutaneous coronary intervention; STEMI = ST-elevation myocardial infarction.

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence

### 9. Revascularisation in patients with diabetes

Patients with diabetes mellitus have a higher prevalence of CAD which often manifests earlier in life and confers a substantially worse prognosis than for patients without diabetes.<sup>263</sup> Patients with diabetes who have suffered an MI have a worse prognosis, particularly those requiring treatment with insulin, and the presence of
diabetes amplifies the risk of any cardiovascular event.\textsuperscript{264} Diabetes mellitus is present in 25–30\% of patients admitted with ACS and in up to 40\% of patients undergoing CABG.\textsuperscript{265}

The anatomical pattern of CAD in patients with diabetes clearly influences their prognosis and response to revascularisation. Angiographic studies have demonstrated that patients with diabetes are more likely to have LM disease and multivessel coronary artery disease (MVD) with more diffuse disease involving smaller vessels.\textsuperscript{266} In addition, patients with diabetes have a greater atherosclerotic burden and an increased number of lipid-rich plaques which are prone to rupture,\textsuperscript{267, 268} and those with unstable angina have more fissured plaques and intracoronary thrombi.\textsuperscript{269} Patients with diabetes undergoing revascularisation, either with CABG or PCI, are at greater risk for kidney injury than patients without diabetes.

9.1 Evidence for myocardial revascularisation
In patients with diabetes, the indications for myocardial revascularisation are the same as those in patients without diabetes (see Chapters 5 to 7). A meta-analysis of nine RCTs with 9904 ACS patients did not show an interaction between diabetic status and the benefit from invasive management and revascularisation.\textsuperscript{270} Yet, absolute risk reductions were larger in the diabetic subsets as compared with non-diabetic subsets. Consistent with the findings in the absence of diabetes, the adverse impact of incomplete revascularisation in patients with diabetes was also demonstrated in the BARI-2D (Bypass Angioplasty Revascularisation Investigation 2 Diabetes) trial.\textsuperscript{271}

Data from randomised trials on revascularisation in patients with diabetes are summarized in Supplementary Table 5.

9.2 Type of myocardial revascularisation
The selection of the optimal myocardial revascularisation strategy for patients with diabetes and MVD requires particular consideration. The recommendations are provided in Chapter 5.

9.2.1. Randomised clinical trials
The Future Revascularisation Evaluation in Patients with Diabetes Mellitus (FREEDOM) trial compared elective revascularisation with CABG or PCI with first generation DES (94%) in 1900 patients with diabetes (6% of the screened population) with multivessel disease but without LM stenosis.\textsuperscript{149} The primary endpoint of any cause death, non-fatal MI, or stroke at 5 years occurred in 26.6% in the PCI group, as compared with 18.7% in the CABG group (absolute difference 7.9%, 95% CI 3.3% to 12.5%; \( P =0.005 \)). The incidence of death (16.3% in the PCI group vs. 10.9% in the CABG group; absolute difference 5.4%, 95% CI 1.5% to 9.2%; \( P =0.049 \)) and MI (13.9% in the PCI group vs. 6.0% in the CABG group; \( P <0.001 \)) were higher in the PCI group but the incidence of stroke was lower (2.4% vs. 5.2%; \( P =0.03 \)). Within the FREEDOM trial at 5 years, patients with diabetes treated with insulin had higher event rates, but there was no significant interaction of treatment and insulin requirement for the primary end point (\( P_{\text{interaction}} =0.40 \)) even after adjusting for SYNTAX score: the NNT with CABG vs. PCI to prevent 1 event was 12.7 for insulin treated patients and 13.2 in those not requiring insulin.\textsuperscript{272}

The Veterans Affairs Coronary Artery Revascularisation in Diabetes Study (VACARDS) compared CABG with PCI in patients with diabetes and extensive CAD in the USA.\textsuperscript{273} Only 198 patients with diabetes were randomised due to early termination of the study. The combined risk for death or non-fatal MI was 18.4% for the CABG arm and 25.3% for the PCI arm (HR 0.89, 95% CI 0.47 to 1.71, \( p<0.05 \)).\textsuperscript{273}

In the Coronary Artery Revascularisation in Diabetes (CARDia) trial, 510 patients with diabetes and multivessel or complex single-vessel CAD were randomly assigned to either CABG or PCI with use of either BMS or DES and routine use of abciximab.\textsuperscript{274} There were no differences between CABG and PCI for the primary endpoint of 1-year composite of death, MI, or stroke at 1 year but the trial was underpowered to detect these differences. However, repeat revascularisation was more likely to occur in patients treated with PCI (\( P <0.001 \)).\textsuperscript{274}

In the subset of 452 patients with diabetes and multivessel CAD who were enrolled in the SYNTAX trial, there were no differences in the composite safety end-point of all-cause death/stroke/MI at 5-year follow-up.\textsuperscript{275} However, the need for repeat revascularisation (HR 2.01, 95% CI 1.04 to 3.88; \( P <0.001 \)) was significantly more
frequent in patients with diabetes treated with PCI than in those who underwent CABG.  

Patients with diabetes had a higher rate of repeat revascularisation after PCI when compared with CABG in the low (≤ 22) (38.5% vs. 18.5% respectively, \( P = 0.014 \)) and intermediate (23–33) (27% vs. 13.4% respectively, \( P = 0.049 \)) SYNTAX score tertiles. Further analyses according to treatment with either oral hypoglycaemic agents or insulin showed that the MACCE rate was significantly greater after PCI in both the oral hypoglycaemic agent group (PCI 40.4% vs. CABG 26.4%, \( P = 0.022 \)) and the insulin dependent group (PCI 56.2% vs. CABG 32.6%, \( P = 0.002 \)). A higher incidence of cardiac death was noted in the insulin-dependent patients treated with PCI (PCI 18.8% vs. CABG 7.1%, \( P = 0.023 \)).

In the SYNTAX trial, diabetes was not an independent predictor of outcomes once the SYNTAX score was entered into the multivariable model. Consequently the SYNTAX 2 score does not include diabetes as one of the eight variables that impacts on preferential selection of revascularisation modality. Conflicting data were seen in a patient-level pooled analysis of 6081 patients treated with stents (75% newer generation DES), stratified according to diabetes status and SYNTAX score. After Cox regression adjustment, that SYNTAX score and diabetes were both associated with MACE (HR 1.25, 95% CI 1.03 to 1.53; \( P = 0.026 \)) and TVR and similar death and MI rates.

In the BEST trial, patients with diabetes treated with PCI had a higher rate of the primary endpoint of death, MI, or TVR compared with CABG (EES: \( n = 177 \); CABG: \( n = 186 \)), (19.2% vs. 9.1%, \( P = 0.007 \)) (see Chapter 5).

### 9.2.2 Meta-analysis of CABG vs PCI in patients with diabetes

A meta-analysis—restricted to four RCTs covering 3052 patients, compared PCI with use of early-generation DES vs. CABG in patients with diabetes and multivessel CAD. It suggested a higher risk of death and MI with revascularisation by early-generation DES (RR 1.51, 95% CI 1.09 to 2.10; \( P < 0.01 \)) but a lower risk of stroke (2.3% vs. 3.8%; RR 0.59, 95% CI 0.39 to 0.90; \( P < 0.01 \)). A sensitivity analysis revealed that this superiority of CABG over early-generation DES for the endpoint...
MACCE was most pronounced among patients with a high SYNTAX score. A network meta-analysis had suggested that the survival benefit of CABG over PCI in patients with diabetes might be lost when using EES, though this was not confirmed in a subsequent meta-analysis which also included the direct comparison between EES and CABG in the subset of BEST.

In a collaborative individual patient-data pooled analysis of 11,518 patients with multivessel or LM disease randomised to CABG or PCI with stents, all-cause death was significantly different after CABG (9.2%) and PCI (11.2%) (P=0.0038), which was evident in patients with diabetes (10.7% versus 15.7%, respectively; P=0.0001) but not in patients without diabetes (8.4% versus 8.7%, respectively; P=0.81) (P for interaction = 0.0077). Similar results were found in the subgroup of 7040 patients with multivessel disease (P for interaction 0.0453), while the interaction with diabetes was not significant in the 4478 patients with LM disease (P for interaction 0.13).

A recent population based analysis has confirmed the benefit of CABG compared to PCI in patients with diabetes when patients present with an ACS. Consequently overall current evidence continues to favour CABG as the revascularisation modality of choice for patients with diabetes and multivessel disease. When patients present with co-morbidity that increases surgical risk, the choice of revascularisation method is best decided by multidisciplinary individualised risk assessment.

9.3 Revascularisation with the use of percutaneous coronary intervention
For reasons discussed above, PCI in patients with diabetes is often more complex than PCI in the absence of diabetes. Nevertheless, irrespective of diabetic status, the same principles apply as discussed in Chapter 16. Placement of new generation DES is the default strategy.

9.4 Antithrombotic pharmacotherapy
In the current context of use of oral P2Y₁₂ inhibitors, there is no indication that antithrombotic pharmacotherapy should differ between diabetic and patients without diabetes undergoing revascularisation. For detailed discussion refer to Chapter 17.

9.5 Metformin
There is a theoretical risk of the risk of lactic acidosis and deteriorating renal function in patients treated with metformin who are exposed to iodinated contrast media. Consequently, it is generally recommended that in elective cases metformin should be withheld before angiography or PCI for 48 hours, as the plasma half-life of metformin is 6.2 hours, and reintroduced 48 hours later. However, clinical experience suggests that the actual risk of lactate acidosis is very small and checking renal function after angiography in patients on metformin and withholding the drug when renal function deteriorates appears to be an acceptable alternative. In patients with renal failure, metformin should be stopped before the procedure. Accurate recognition of metformin-associated lactic acidosis based on arterial pH < 7.35, blood lactate > 5 mmol/L (45 mg/dL), and detectable plasma metformin concentration should prompt initiation of haemodialysis.

### Recommendations for revascularisation in patients with diabetes

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>In patients with stable multivessel CAD and an acceptable surgical risk, CABG is recommended over PCI.</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>In patients with stable multivessel CAD and SYNTAX Score ≤ 22, PCI may be considered as alternative to CABG.</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>It is recommended to check renal function if patients have taken metformin immediately before angiography and withhold metformin if renal function deteriorates</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>

*aClass of recommendation.

*bLevel of evidence.

### 9.6 Gaps in evidence

Following successful revascularisation, the rate of events during follow-up remains high in patients with diabetes, independent of the mode of revascularisation. Future research should be focused on identifying new disease modifying therapies to influence the progression of vascular disease in this high-risk cohort.

### 10 Revascularisation in patients with chronic kidney disease

#### 10.1 Evidence-base for revascularisation and recommendations
Myocardial revascularisation in patients with chronic kidney disease (CKD), specifically National Kidney Foundation stages 3 or higher, is addressed by the 2014 ESC/EACTS guidelines on myocardial revascularisation. After reviewing the subsequent literature, the current task force does not find evidence to support any major update. A recent post-hoc analysis of the SYNTAX trial on patients with chronic kidney disease confirms the principles for allocating patients to PCI or CABG,\(^{281}\) as discussed in Chapter 5 of this document.

**10.2 Prevention of contrast-induced nephropathy**

The risk of contrast-induced nephropathy (CIN) depends on patient related factors, such as CKD, diabetes mellitus, congestive HF, haemodynamic instability, reduced plasma volume, female sex, advanced age, anaemia and periprocedural bleeding, as well as on the type and volume of contrast administered.\(^{282-288}\) When the ratio of total contrast volume (in ml) to glomerular filtration rate (GFR, in ml/min) exceeds 3.7, the risk of CIN increases significantly.\(^{287,288}\)

Adequate hydration remains the mainstay of CIN prevention.\(^{289-294}\) High-dose statins as indicated for secondary prevention irrespective of the risk of CIN are also beneficial.\(^{293}\) All other strategies for prevention of CIN do not have sufficient evidence to justify a recommendation in favour or against.\(^{293,294}\) For more detailed discussion refer to the web addenda.

**10.3 Gaps in evidence**

Thus far, patients with CKD have been excluded from randomised trials on myocardial revascularisation, hence current data are based on observational studies only. A randomised trial on optimal long-term revascularisation strategies in patients with moderate to severe stress induced ischaemia and severe CKD is currently ongoing (ISCHEMIA-CKD https://clinicaltrials.gov/ct2/show/NCT01985360). Moreover, additional randomised evidence on optimal strategies for CIN prevention is needed.

**Recommendations for prevention of contrast-induced nephropathy**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Dose</th>
<th>Class(^a)</th>
<th>Level(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients undergoing coronary angiography or MSCT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is recommended to assess all patients for the risk of contrast-induced nephropathy.</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Adequate hydration is recommended.</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

**Patients with moderate or severe CKD (National Kidney Foundation stages 3b and 4)**

| Use of low-osmolar or iso-osmolar contrast media is recommended. | I | A |
| It is recommended to minimize volume of contrast media. | total contrast volume/GFR < 3.7\textsuperscript{c}. | I | B |
| In statin-naïve patients, pretreatment with high-dose statins should be considered. | Rosuvastatin 40/20mg or atorvastatin 80 mg | Ila | A |
| Pre- and post-hydration with isotonic saline should be considered if the expected contrast volume is > 100 mL. | 1 mL/kg/h 12 hours before and continued for 24 hours after the procedure (0.5 mL/kg/h if LV EF ≤ 35% or NYHA > 2). | Ila | C |
| As an alternative to the pre- and post-hydration regimen tailored hydration regimens\textsuperscript{d} may be considered. | | IIb | B |

**Patients with severe CKD (National Kidney Foundation stage 4)**

| Prophylactic haemofiltration 6 hours before complex PCI may be considered. | Fluid replacement rate 1000 mL/h without negative loss and saline hydration continued for 24 hours after the procedure. | IIb | B |
| Haemodialysis is not recommended as a preventive measure. | | III | B |

CIN = contrast-induced nephropathy; CKD = chronic kidney disease; EF = ejection fraction; GFR = glomerular filtration rate; i.v. = intravenous; LV = left ventricular; MSCT = multi-slice computed tomography; NYHA = New York Heart Association; PCI = percutaneous coronary angiography.

\textsuperscript{a}Class of recommendation.

\textsuperscript{b}Level of evidence.

\textsuperscript{c} Example: 370 ml of contrast medium in a patient with a GFR of 100 ml/min will yield a ratio of 3.7.

\textsuperscript{d} Options are: infusion of normal saline adjusted to central venous pressure\textsuperscript{295}; furosemide with matched infusion of normal saline \textsuperscript{296, 297} (for details see web addenda)
11. Revascularisation in patients requiring valve interventions

11.1 Primary indication for valve interventions

Myocardial revascularisation in patients undergoing primary valve interventions either by surgery or transcatheter routes is addressed by the 2014 ESC/EACTS guidelines on myocardial revascularisation. After reviewing the subsequent literature, the current task force endorses the recommendations of the 2014 guidelines and does not find evidence to support any major update. These recommendations are included in the table below for ease of reference. Of note, available evidence on invasive functional assessment of CAD (with FFR or iFR) in patients with severe aortic stenosis (AS) is limited to few small-scale observational studies. These studies support the feasibility of FFR and iFR in this setting.\textsuperscript{302-304} Notwithstanding, available evidence is insufficient to support the use of invasive functional assessment of coronary lesions in patients with AS, particularly in consideration of the altered hemodynamic condition related to the presence of AS. Therefore, the Task Force is in consensus to maintain indications for myocardial revascularisation based on angiographic assessment of CAD, consistent with 2014 ESC/EACTS guidelines on myocardial revascularisation and 2017 ESC/EACTS guidelines for the management of valvular heart disease.\textsuperscript{305}

11.2 Primary indication for myocardial revascularisation

11.2.1 Aortic Valve Disease

The recommendations for patients undergoing CABG for the clinically leading problem of CAD, who also have coexisting severe aortic stenosis or regurgitation, remain unchanged from 2014 and support replacement of the aortic valve.\textsuperscript{305} However, in the current era of rapid developments in transcatheter valve implantation technologies, decision regarding replacement of the aortic valve for moderate stenosis/regurgitation should be carefully considered on a case-by-case basis in discussion with the Heart Team. The patient’s age, type of prosthesis, pathogenesis of aortic stenosis/regurgitation, aortic annular size, predicted size of implanted valve, transcatheter aortic valve implantation (TAVI) access routes and technical feasibility of a TAVI procedure in the future in case of disease progression should all be taken into account.\textsuperscript{306}
11.2.2 Mitral Valve Disease

Patients with concomitant severe primary mitral regurgitation should undergo mitral valve repair at the time of CABG in keeping with guidance for surgical repair of primary MR. There is also consensus based on expert opinion on surgical repair of severe secondary MR at the time of CABG. Considerable controversy exists, however, about the treatment of moderate secondary or ischaemic MR in patients undergoing CABG. Until the publication of 2-year outcomes of the Cardiothoracic Surgical Trials Network (CTSN) randomised trial on treatment of “moderate” ischaemic MR, the literature in this field was limited to small single centre randomised trials, observational studies and case series and failed to provide clear direction. The CTSN trial showed that addition of surgical mitral valve repair to CABG made no significant difference to survival, overall reduction in adverse events or LV reverse remodelling at 2 years. Increased length of intensive care and hospital stay and perioperative morbidity, including neurological complications and supraventricular arrhythmias, were reported in the CTSN and other randomised trials in this group of patients. Because the CTSN trial used a very broad definition of moderate MR, including an EROA ≤0.2 cm² plus additional criteria, no firm conclusions can be drawn concerning patients with an EROA >0.2 cm². Observational data suggest that in secondary MR, an EROA of >0.2 cm² and regurgitant volume of >30 ml indicates greater risk of cardiovascular events. In the absence of dedicated trials in this setting, the decision for combining mitral valve surgery with CABG in patients with an EROA of >0.2 cm² and regurgitant volume of >30 ml needs to be made on a case-by-case basis by the heart team. For a more detailed discussion of this issue, please refer to the web addenda.

11.3 Gaps in evidence

In patients with concomitant valvular and coronary disease, the possibility of future transcatheter therapy for the aortic and mitral valves has made a significant impact on decision making for patients with predominantly coronary disease with moderate valve lesions. There is, however, little evidence currently on this topic. Also, the need and timing of PCI in patients undergoing TAVI is an area with limited evidence. The long-term outcomes of patients with concomitant surgical repair of ischaemic MR are also awaited.
Recommendations for combined valvular and coronary interventions

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class(^a)</th>
<th>Level(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary valve intervention and coronary revascularisation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CABG is recommended in patients with a primary indication for aortic/mitral valve surgery and coronary artery diameter stenosis &gt; 70%.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>CABG should be considered in patients with a primary indication for aortic/mitral valve surgery and coronary artery diameter stenosis 50–70%.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>PCI should be considered in patients with a primary indication to undergo TAVI and coronary artery diameter stenosis &gt; 70% in proximal segments.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>PCI should be considered in patients with a primary indication to undergo transcatheter mitral valve interventions and coronary artery diameter stenosis &gt; 70% in proximal segments.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td><strong>Primary myocardial revascularisation and valve intervention</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAVR is indicated in patients with severe AS undergoing CABG, or surgery of the ascending aorta or another valve.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Mitral valve surgery is indicated in patients with severe(^c) secondary MR undergoing CABG, and LVEF &gt; 30%.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Mitral valve surgery may be considered in symptomatic patients with severe(^c) secondary MR, LVEF &lt; 30% but with evidence of viability and option for surgical revascularisation.</td>
<td>IIa</td>
<td>C</td>
</tr>
</tbody>
</table>

AS = aortic stenosis; CABG = coronary artery bypass grafting; LVEF = left ventricular ejection fraction; MR = mitral regurgitation; PCI = percutaneous coronary intervention; SAVR = surgical aortic valve replacement; TAVI = transcatheter aortic valve implantation.

\(^a\)Class of recommendation

\(^b\)Level of evidence

\(^c\)Severe secondary MR was defined as an EROA > 0.40 cm\(^2\)

12. Associated peripheral artery diseases

12.1 Prevention of stroke associated with carotid artery disease and myocardial revascularisation
The early risk of stroke after myocardial revascularisation is higher after CABG as compared with PCI. After 30 days, stroke rates between revascularisation techniques were similar in a recent individual patient-data meta-analysis of 11 randomised trials.

Ischaemic stroke after CABG is multifactorial: thrombo-embolism from the aorta, its branches or the heart, atrial arrhythmias, inflammatory pro-thrombogenic milieu, lower levels of antiplatelet therapy peri-operatively and haemodynamic instability. However, the most consistent predictor of peri-operative stroke is previous stroke or TIA. There is no strong evidence that carotid artery stenosis is a significant cause of peri-operative stroke except for bilateral severe carotid bifurcation stenosis. Therefore, indications for pre-operative carotid bifurcation screening by duplex ultrasound are limited. Also, there is no evidence that prophylactic revascularisation of unilateral asymptomatic carotid stenoses in CABG candidates reduce the risk of perioperative stroke. It may be reasonable to restrict prophylactic carotid revascularisation to patients at highest risk of postoperative stroke, i.e. patients with severe bilateral lesions or a history of prior stroke/TIA. Hence, the indication for revascularisation and the choice between carotid endarterectomy or carotid artery stenting in these patients should be made by a multidisciplinary team including a neurologist.

The 2017 Guidelines on the diagnosis and treatment of peripheral arterial diseases in collaboration with the European Society of Vascular Surgery cover the screening for and management of carotid artery disease in patients scheduled for coronary artery bypass grafting including screening, indications, timing and type of carotid revascularisation. Its recommendations are reproduced here.

Particularly for patients at high risk for peri-operative stroke risk after CABG, such as elderly patients or patients with previous TIA/stroke, specific preventive measures have been suggested. CT scan screening of the ascending aorta/arch atheroma has been proposed to better assess the risk stratification and guide surgical strategy in elderly patients. It is recommended to restart acetylsalicylic acid 6 hours or at the latest 24 hours after surgery and add clopidogrel or ticagrelor in patients with ACS.
New onset atrial fibrillation (AF) is associated with a 2–3 times higher risk of stroke after CABG. Its management is discussed in Chapter 14.

12.2 Associated coronary and peripheral artery diseases

Seven to 16% of patients with CAD have lower extremity artery disease (LEAD), which is associated with a worse prognosis, even if it remains frequently asymptomatic, masked by cardiac symptoms. On the other hand, in patients with LEAD, CAD is present in up to 70% of patients. The choice between CABG and PCI is controversial and in the absence of solid data, it should follow a multidisciplinary approach. In patients undergoing CABG, the saphenous vein should be preserved or harvested guided by the results of clinical examination including ankle-brachial index. In addition, inter-arm blood pressure asymmetry should lead to investigation of subclavian artery stenosis. Further details are provided in the 2017 PAD guidelines.

Recommendations on the management of carotid stenosis in patients undergoing coronary artery bypass grafting

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>In patients scheduled for CABG it is recommended that the indication (and if so the method and timing) for carotid revascularisation be individualised after discussion within a multidisciplinary team, including a neurologist.</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>

In patients scheduled for CABG, with recent (< 6 months) history of TIA/stroke:

- Carotid revascularisation should be considered in patients with 50–99% carotid stenosis

<table>
<thead>
<tr>
<th>Classa</th>
<th>Levelb</th>
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<tbody>
<tr>
<td>IIa</td>
<td>B</td>
</tr>
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</table>

- Carotid revascularisation with CEA should be considered as first choice in patients with 50–99% carotid stenosis

<table>
<thead>
<tr>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIa</td>
<td>B</td>
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</table>

- Carotid revascularisation is not recommended in patients with carotid stenosis < 50%.

<table>
<thead>
<tr>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>C</td>
</tr>
<tr>
<td>In neurologically asymptomatic patients scheduled for CABG:</td>
<td></td>
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<tr>
<td>-------------------------------------------------------------</td>
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</tr>
<tr>
<td>- Routine prophylactic carotid revascularisation in patients with a 70−99% carotid stenosis is not recommended</td>
<td>III C</td>
</tr>
<tr>
<td>- Carotid revascularisation may be considered in patients with bilateral 70−99% carotid stenosis or 70−99% carotid stenosis and contralateral occlusion</td>
<td>IIb C</td>
</tr>
<tr>
<td>- Carotid revascularisation may be considered in patients with a 70−99% carotid stenosis, in the presence of one or more characteristics that may be associated with an increased risk of ipsilateral stroke,(^c) in order to reduce stroke risk beyond the perioperative period.</td>
<td>IIb C</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass grafting; CEA = carotid endarterectomy; TIA = transient ischaemic attack.

\(^a\)Class of recommendation.

\(^b\)Level of evidence.

\(^c\)Contralateral TIA/stroke, ipsilateral silent infarction on cerebral imaging, intraplaque haemorrhage or lipid-rich necrotic core on magnetic resonance angiography, or any of the following ultrasound imaging findings: stenosis progression (>20%), spontaneous embolization on transcranial Doppler, impaired cerebral vascular reserve, large plaques, echolucent plaques, increased juxta-luminal hypoechogenic area 317

**Preoperative strategies to reduce the incidence of stroke in patients undergoing coronary artery bypass grafting**
<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Level&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>In patients undergoing CABG, carotid DUS is recommended in patients with recent (&lt; 6 months) history of stroke/TIA&lt;sup&gt;321, 322&lt;/sup&gt;</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>In patients with no recent (&lt; 6 months) history of TIA/stroke, carotid DUS may be considered before CABG in the following cases: age ≥ 70 years, multivessel coronary artery disease, concomitant LEAD, or carotid bruit&lt;sup&gt;321, 322&lt;/sup&gt;</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>Screening for carotid stenosis is not indicated in patients requiring urgent CABG with no recent stroke/TIA.</td>
<td>III</td>
<td>C</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass graft surgery; DUS = duplex ultrasound; LEAD = lower extremity artery disease; TIA = transient ischaemic attack.

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence.

### 13. Repeat revascularisation and hybrid procedures

#### 13.1 Early graft failure

Early graft failure after CABG is reported in up to 12% of grafts as evaluated by intraoperative angiography.<sup>323</sup> However, only a minority, around 3%, are clinically apparent. Graft failure can be due to conduit defects, anastomotic technical errors, poor native vessel run-off, or competitive flow with the native vessel. When clinically relevant, acute graft failure may result in MI with consequently increased mortality and major cardiac events. The suspicion of early graft failure should arise in the presence of ECG signs of ischaemia, ventricular arrhythmias, biomarker changes, new wall motion abnormalities, or haemodynamic instability.<sup>324, 325</sup> Owing to the low specificity of ECG changes and echocardiographic wall motion abnormalities during the postoperative course and the delay in appearance of biomarker changes, a careful assessment of all variables will influence the decision making for angiographic evaluation.

Perioperative angiography is recommended in cases of suspected severe myocardial ischaemia to detect its cause and aid decision making on the most appropriate treatment.<sup>323, 325, 326</sup> In symptomatic patients, early postoperative graft failure can be
identified as the cause of ischaemia in 40–80% of cases.\textsuperscript{324, 326-328} The optimal treatment strategy in patients with acute graft failure should be decided by \textit{ad hoc} consultation between the cardiovascular surgeon and the interventional cardiologist, on the basis of the patient’s clinical condition and extent of myocardium at risk. In the case of early postoperative graft failure, emergency \textit{ad hoc} PCI may limit the extent of infarction, if technically feasible. The target for PCI is the native vessel or the internal mammary artery (IMA) graft, while the acutely occluded saphenous vein graft (SVG) and any anastomotic site should be avoided, if possible, due to concerns regarding embolisation or perforation. Re-do surgery should be favoured if the anatomy is unsuitable for PCI, if several important grafts are occluded, or in the case of clear anastomotic errors. In asymptomatic patients, repeat revascularisation should be considered if the artery is of appropriate size and supplies a large territory of myocardium.

Further details on diagnosis and management of perioperative MI is provided in a recent ESC Position Paper.\textsuperscript{329}

\subsection*{13.2 Acute percutaneous coronary intervention failure}

The need for urgent surgery to manage PCI-related complications is uncommon (<1%) and only required in patients with major complications that cannot be adequately resolved by percutaneous techniques.\textsuperscript{330, 331} The need for emergency CABG is mainly confined to patients with a large, evolving MI due to iatrogenic vessel occlusion that cannot be salvaged percutaneously, or in patients with recurrent cardiac tamponade after pericardiocentesis following PCI-related vessel rupture.\textsuperscript{330, 332, 333}

\subsection*{13.3 Disease progression and late graft failure}

Ischaemia after CABG may be due to progression of disease in native vessels or \textit{de novo} disease of bypass grafts.\textsuperscript{334} Repeat revascularisation in these patients is indicated in the presence of significant symptoms despite medical treatment, and in asymptomatic patients with objective evidence of large myocardial ischaemia (> 10% of the LV).\textsuperscript{32, 87}

\textit{Re-do coronary artery bypass grafting or percutaneous coronary intervention}
PCI in patients with prior CABG has worse acute and long-term outcomes than in patients without prior CABG.\textsuperscript{335, 336} Likewise, redo CABG has a two- to four-fold increased mortality compared with first-time CABG and repeat CABG is generally performed infrequently.\textsuperscript{334, 337-339} There are limited data comparing the efficacy of PCI vs. redo CABG in patients with previous CABG. The proportion of patients undergoing PCI, redo CABG, or conservative treatment differs significantly between studies; in one study PCI was favoured in about 50\% of patients with only 22\% undergoing redo CABG, while another study favoured CABG in 67\% of patients.\textsuperscript{340, 341} In the Angina With Extremely Serious Operative Mortality Evaluation (AWESOME) RCT and registry, overall 3-year mortality was comparable between redo CABG and PCI.\textsuperscript{341, 342} A more recent study also found comparable rates of death and MI between redo CABG and PCI, although there were significantly more repeat revascularisations with PCI.\textsuperscript{341, 343}

In view of the higher risk of procedural mortality with redo CABG and the similar long-term outcome, PCI is the preferred revascularisation strategy in patients with amenable anatomy.\textsuperscript{340} PCI via the bypassed native artery should be the preferred approach. If PCI in the native vessel fails or is not an option, PCI in the diseased SVG should be considered. CABG should be considered for patients with extensively diseased or occluded bypass grafts and diffuse native vessel disease, especially in the absence of patent arterial grafts.\textsuperscript{340} The IMA is the conduit of choice for revascularisation during re-do CABG if not previously used, or can be salvaged and reused in specific cases.\textsuperscript{344, 345}

\textit{Percutaneous coronary intervention for saphenous vein graft lesions}

PCI in SVGs is associated with an increased risk of distal coronary embolisation, frequently resulting in periprocedural MI.\textsuperscript{346} PCI of \textit{de novo} SVG stenosis is considered a high-risk intervention because SVG atheroma is friable and more prone to distal embolisation. Several different approaches have been evaluated to prevent distal embolisation of particulate debris, including distal occlusion/aspiration, proximal occlusion, suction, filter devices or covered stents. Distal protection devices using filters have shown the most encouraging results. However, although a single Randomised trial supports the use of distal embolic protection during SVG PCI, observational studies including data from large-scale registries are conflicting.\textsuperscript{347-349}
Outcomes from studies with other devices used for SVG PCI is not sufficient to recommend use. 350-353

Based on data from a small number of randomised trials, implantation of DES in SVG lesions is associated with a lower risk of repeat revascularisation than with BMS at 1 year follow-up. 354-356 In the only trial powered for a clinical endpoint—the Is Drug-Eluting-Stenting Associated with Improved Results in Coronary Artery Bypass Grafts (ISAR-CABG) trial 354—the primary endpoint of death, MI and target lesion revascularisation was significantly reduced with DES vs. BMS. Longer-term follow-up of the two smaller trials is available; one suggested sustained superiority of DES over BMS, while the other suggested loss of efficacy advantage of the DES. 357, 358

13.4 Repeat percutaneous coronary intervention
Recurrence of symptoms or ischaemia after PCI is the result of restenosis, incomplete initial revascularisation, or disease progression. 334 Patients may require repeat PCI due to late and very late stent thrombosis.

Restenosis
Restenosis associated with angina or ischaemia should be treated by repeat revascularisation, and repeat PCI remains the strategy of choice for most of these patients. In this setting, the results from DES are superior to those obtained with balloon angioplasty, BMS implantation or brachytherapy. 359-363

For restenosis within BMS, drug-coated balloon (DCB) proved superior to plain balloon angioplasty 364-366 and comparable to first generation DES. 364, 365, 367-371 One trial showed inferior angiographic outcomes in comparison to new generation DES, 372 while a second trial showed comparable outcomes. 373 For restenosis within DES, DCB also proved superior to plain balloon angioplasty 366, 368, 370 and comparable to first generation DES. 370 In one study, DCB were inferior to new generation DES in terms of the primary angiographic outcome measure. 374 In a more recent study, including patients with any type of in-stent restenosis, outcomes between DCB and repeat stenting with new generation DES were comparable. 375 A single Randomised trial of patients undergoing DCB for restenosis within DES showed superior angiographic outcomes in patients who underwent lesion preparation with scoring
Network meta-analysis suggest that repeat stenting with new generation DES (with EES) and DCB are ranked first and second as the highest efficacy treatments.\textsuperscript{377, 378} The superior angiographic anti-restenotic efficacy of new generation DES should be weighed against a possible excess of long-term adverse events with repeat stenting during longer-term follow-up of these trials.\textsuperscript{379, 380} However, observations in relation to clinical events must be interpreted with caution as none of the trials were powered for clinical endpoints and the comparator stent in studies with long-term follow-up was an early generation DES.

The use of intracoronary imaging provides unique insights into the underlying mechanisms of in-stent restenosis (see Chapter 16.2). OCT is able to detect the presence of neoatherosclerosis in a significant number of these patients. Underexpanded stents should be aggressively tackled with high-pressure dilatations using non-compliant balloons. Optimising final results remains crucial during reinterventions for in-stent restenosis and, in this regard, the use of intracoronary imaging may be particularly helpful. Outcomes of patients with in-stent restenosis after DES are poorer than those in patients with BMS in-stent restenosis, independently of the therapeutic modality.\textsuperscript{381} In patients with recurrent episodes of diffuse in-stent restenosis in large vessels—and in those with associated multivessel disease, especially in the presence of other complex lesions such as chronic total occlusions—CABG should be considered before a new PCI attempt.

\textit{Disease progression}

Patients with symptomatic disease progression after PCI account for up to 50% of re-interventions.\textsuperscript{382, 383} They should be managed using criteria similar to those applied to patients without previous revascularisation.

\textit{Stent thrombosis}

Although stent thrombosis is very rare, particularly since the advent of new-generation DES, it may have devastating clinical consequences. Stent thrombosis usually presents as a large MI and patients should be treated according to the principles outlined in Chapter 8.\textsuperscript{384} Aggressive, high-pressure balloon dilation should
be used to correct underlying, stent-related, predisposing, mechanical problems.  

Liberal use of intracoronary imaging in order to detect and modify underlying mechanical factors is recommended (Figure 7) (see Chapter 16.2).

Although repeat stenting in patients with stent thrombosis may be avoided when satisfactory results are obtained with balloon dilation, a new stent may be required to overcome edge-related dissections and adjacent lesions or to optimise final results.

There is no evidence that the post-interventional management of patients with stent thrombosis should differ from that of patients with thrombosis of a de novo lesion resulting in STEMI.

**Figure 7 Intracoronary Imaging for the Assessment of Stent Failure**
Recommendations on repeat revascularisation

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Early postoperative ischaemia and graft failure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary angiography post-CABG is recommended for patients with:</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>• symptoms of ischaemia and/or abnormal biomarkers suggestive of perioperative myocardial infarction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ischaemic ECG changes indicating large area of risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• new significant wall motion abnormalities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• haemodynamic instability.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is recommended to decide for either emergency reoperation or PCI by <em>ad hoc</em> consultation in the Heart Team and based on feasibility of revascularisation, area at risk, comorbidities and clinical status.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td><strong>Disease progression and late graft failure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeat revascularisation is indicated in patients with large area of ischaemia or severe symptoms despite medical therapy[^32],[^334].</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>If considered safe, PCI should be considered as first choice over CABG</td>
<td>I[la]</td>
<td>C</td>
</tr>
<tr>
<td><strong>CABG</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMA is the conduit of choice for redo CABG in patients in whom the IMA was not used previously[^344].</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Redo CABG should be considered for patients without a patent IMA graft to the LAD[^340],[^341],[^344].</td>
<td>I[la]</td>
<td>B</td>
</tr>
<tr>
<td><strong>PCI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal protection devices should be considered for PCI of SVG lesions[^348],[^350],[^351]</td>
<td>I[la]</td>
<td>B</td>
</tr>
<tr>
<td>PCI of the bypassed native artery should be considered over PCI of the bypass graft.</td>
<td>I[la]</td>
<td>C</td>
</tr>
<tr>
<td><strong>Restenosis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DES are recommended for the treatment of in-stent restenosis of BMS or DES.[^372],[^374],[^377],[^378]</td>
<td>I</td>
<td>A</td>
</tr>
</tbody>
</table>
Drug-coated balloons are recommended for the treatment of in-stent restenosis of BMS or DES. 372, 374, 377, 378

In patients with recurrent episodes of diffuse in-stent restenosis, CABG should be considered by the Heart Team over a new PCI attempt.

IVUS and/or OCT should be considered to detect stent-related mechanical problems leading to restenosis.

BMS = bare-metal stent; CABG = coronary artery bypass grafting; DES = drug-eluting stent; ECG = electrocardiogram; IMA = internal mammary artery; LAD = left anterior descending artery; PCI = percutaneous coronary intervention; SVG = saphenous vein graft. OCT = optical coherence tomography. IVUS = intravascular ultrasound.

Class of recommendation
Level of evidence.

14. Arrhythmias

14.1 Ventricular arrhythmias

14.1.1 Revascularisation for prevention of sudden cardiac death in patients with stable coronary artery disease and reduced left ventricular function

Revascularisation plays an important role in reducing the frequency of ventricular arrhythmias in patients with normal or mildly reduced LV function388, 389 as well as the risk for sudden cardiac death in patients with CAD and LVEF ≤ 35%.390 An indirect evidence for a protective effect of revascularisation is demonstrated in the MADIT II (Multicenter Automatic Defibrillator Implantation Trial II) and SCD HEFT studies (Sudden Cardiac Death in Heart Failure Trial), where the efficacy of cardioverter defibrillator implantation (ICD) is reduced if revascularisation is performed prior to implantation.391, 392 Coronary artery bypass surgery in patients with reduced ejection fraction reduces cardiac and overall mortality for a follow-up of 10 years.78, 81 In view of the protective effect of revascularisation on ventricular arrhythmias, patients with ischaemic LV dysfunction (LVEF ≤ 35%), who are considered for primary preventive ICD implantation should be evaluated for ischaemia and/or for potential revascularisation targets.

14.1.2 Revascularisation for treatment of electrical storm

Electrical storm is a life-threatening syndrome related to incessant ventricular arrhythmias, which is most frequently observed in patients with ischaemic heart disease, advanced systolic HF, valve disease, corrected congenital heart disease,
and genetic disorders such as Brugada syndrome, early repolarization and long QT syndromes.\textsuperscript{393} Urgent coronary angiography and revascularisation should be part of the management of patients with electrical storm, as well as antiarrhythmic drug therapy and/or ablation of ventricular tachycardia.

14.1.3 Revascularisation after out-of-hospital cardiac arrest
Approximately 70\% of survivors of out-of-hospital cardiac arrest have CAD, with acute vessel occlusion observed in 50\%.\textsuperscript{394} Multiple non-randomised studies suggest that emergency coronary angiography and, if appropriate, PCI after out-of-hospital cardiac arrest yields a favourable survival rate of up to 60\% at 1 year, which is considerably higher than the 25\% overall survival rate in patients with aborted cardiac arrest.\textsuperscript{395, 396} More recent data suggest that almost one-quarter of patients, resuscitated from cardiac arrest but without ST-segment elevation, show a culprit lesion (either vessel occlusion or irregular lesion).\textsuperscript{397–400} Recent, large-scale, observational studies have showed an impact on mortality of early angiography after out-of-hospital cardiac arrest.\textsuperscript{401, 402} Thus, in survivors of out-of-hospital cardiac arrest, early coronary angiography and PCI, if appropriate, should be performed irrespective of the ECG pattern if no obvious non-cardiac cause of the arrhythmia is present.\textsuperscript{403}

14.2 Atrial arrhythmias
The management of atrial fibrillation in patients with ischaemic heart disease is addressed by the 2016 ESC Guidelines for the management of atrial fibrillation developed in collaboration with EACTS.\textsuperscript{404} After reviewing the subsequent literature, the current task force endorses the Recommendations of the 2016 guidelines and does not identify the need for any major update. Accordingly, the current recommendations tables are taken from this guideline. For a detailed discussion, we refer to the previous guideline.\textsuperscript{404}

14.2.1 Atrial fibrillation complicating percutaneous coronary intervention
New-onset AF in patients undergoing PCI occurs in 2–6\% of procedures and increases with age, pre-existing HF, AMI and arterial hypertension.\textsuperscript{405–408} Notably, new-onset AF (defined as change from sinus rhythm (SR) at admission to AF during/after PCI) typically occurs during the first 4 days after AMI and is associated
with impaired prognosis and a more than doubling the risk of death, CHF and stroke.\textsuperscript{403}

The use of oral anticoagulation (OAC) for stroke prevention in patients with AF occurring during or after PCI should follow the guidelines for antithrombotic treatment of AF that occurs outside the setting of PCI,\textsuperscript{404} although prospective studies are scarce. The combination and duration of anticoagulation and antiplatelet therapy should be assessed according to the clinical situation, as outlined in Chapter 17 as well as in the ESC Guidelines on Atrial Fibrillation\textsuperscript{404} and ESC Focused Update on Dual Antiplatelet Therapy.\textsuperscript{409}

14.2.2 Atrial fibrillation complicating coronary artery bypass grafting
Postoperative AF affects one-third of patients undergoing cardiac surgery.\textsuperscript{410-413} The main risk factor for postoperative AF is age, and it is associated with an increased immediate risk of stroke, increased morbidity and 30-day mortality.\textsuperscript{414-416} In the long-term, patients with an episode of postoperative AF have a two-fold increase in cardiovascular mortality and a substantially increased risk of future AF and ischaemic stroke compared to patients who remain in SR after surgery.\textsuperscript{415, 417-421}

Postoperative AF is a common complication, in which prophylactic treatment has a moderate effect. Preoperative anti-arrhythmic drug treatment may be initiated but will have to be weighed against side-effects. Beta-blockers decrease the incidence of postoperative AF after CABG.\textsuperscript{411, 422-428}

14.2.3 Post-operative atrial fibrillation and stroke risk
Patients with postoperative AF have an increased stroke risk postoperatively as well as during follow-up,\textsuperscript{418, 429} and warfarin medication at discharge has been associated with a reduced long-term mortality.\textsuperscript{430} There are to date no studies indicating that postoperative AF is less harmful than any other form of AF, and good quality data are needed. Anticoagulation treatment with warfarin or non-vitamin K antagonist oral anticoagulants (NOAC) for stroke prevention in patients with postoperative AF should therefore follow the guidelines for antithrombotic treatment of AF occurring outside the setting of CABG using the CHA\textsubscript{2}DS\textsubscript{2}-VASc Score. The duration and timing of OAC in postoperative AF patients should be assessed individually.
Whether surgical left atrial appendage (LAA) obliteration reduces stroke risk has been studied in smaller trials and registry studies, with conflicting results, \(^{431-433}\) and is currently under investigation in a large randomised trial.\(^{434}\) Removal or closure of the LAA should be considered as an adjunct to anticoagulation and not as an alternative until more data are available.

### Recommendations for prevention of ventricular arrhythmias by revascularisation

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class (^a)</th>
<th>Level (^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A primary PCI strategy is recommended in patients with resuscitated cardiac arrest and an ECG consistent with STEMI.(^{394, 396, 435, 436})</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Urgent angiography (and PCI if indicated) should be considered in patients with resuscitated cardiac arrest without diagnostic ST-segment elevation but with a high suspicion of ongoing myocardial ischaemia.</td>
<td>Ila</td>
<td>C</td>
</tr>
<tr>
<td>In patients with electrical storm urgent coronary angiography and revascularisation as required should be considered.</td>
<td>Ila</td>
<td>C</td>
</tr>
</tbody>
</table>

ECG = electrocardiogram; STEMI = ST-elevation myocardial infarction; PCI = percutaneous coronary intervention

\(^a\)Class of recommendation.

\(^b\)Level of evidence

### Recommendations for prevention and treatment of atrial fibrillation in the setting of myocardial revascularisation

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class (^a)</th>
<th>Level (^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peri-operative oral beta-blocker therapy is recommended for the prevention of postoperative AF after CABG surgery. (^{411, 437})</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td><strong>Restoration of sinus rhythm by electrical cardioversion or antiarrhythmic drugs is recommended in postoperative AF with haemodynamic instability.</strong></td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td><strong>Peri-operative amiodarone should be considered as prophylactic therapy to prevent AF after CABG surgery</strong></td>
<td>Ila</td>
<td>A</td>
</tr>
<tr>
<td><strong>Long-term anticoagulation should be considered in patients with AF after CABG or PCI at risk for stroke, considering individual stroke and bleeding risk</strong></td>
<td>Ila</td>
<td>B</td>
</tr>
<tr>
<td><strong>Asymptomatic postoperative AF should initially be managed with rate control and anticoagulation</strong></td>
<td>Ila</td>
<td>B</td>
</tr>
<tr>
<td><strong>Antiarrhythmic drugs should be considered for symptomatic postoperative AF after CABG or PCI in an attempt to restore sinus rhythm.</strong></td>
<td>Ila</td>
<td>C</td>
</tr>
<tr>
<td><strong>Surgical occlusion or exclusion of the LAA may be considered for stroke prevention in patients with AF undergoing CABG surgery</strong></td>
<td>IIb</td>
<td>B</td>
</tr>
</tbody>
</table>

AF = atrial fibrillation; CABG = coronary artery bypass grafting; LAA = left atrial appendage; PCI = percutaneous coronary intervention.

*aClass of recommendation.

*bLevel of evidence.

### 14.3 Gaps in evidence

The duration of anticoagulation and the combination with antiplatelet therapy in patients with new onset AF after PCI or CABG has not been studied sufficiently. Likewise, the role of routine left atrial exclusion at surgery for the prevention of stroke is currently unclear.

### 15. Procedural aspects of coronary artery bypass grafting

CABG remains the most common cardiac surgery procedure, and the techniques have been refined during 50 years of evolution. Perioperative medication and blood management are covered in separate guidelines.

### 15.1 Surgical techniques

#### 15.1.1 Completeness of revascularisation

The current surgical practice is largely based on an anatomical definition of complete revascularisation, and aims to bypass all epicardial vessels with a diameter
exceeding ≥ 1.5 mm and a luminal reduction of ≥ 50% in at least one angiographic view. Depending on the definition of completeness of revascularisation, the outcome after CABG in patients with incomplete revascularisation was either similar or inferior to that of patients with complete revascularisation. Certainly, in some patients with a stenosis in small vessels with little myocardium at risk, complete revascularisation may not be necessary.

FFR-guided surgical revascularisation has been associated with improved graft patency, but more studies are needed to investigate whether it improves clinical outcomes. Further discussion on FFR-guided revascularisation is provided in sections 3.2.1.1 and 5.3.1.1.

15.1.2 Conduit selection
In addition to patient related factors, the outcome following CABG is related to the long-term patency of grafts and therefore is maximized with the use of arterial grafts, specifically the internal mammary artery (IMA). Except in rare circumstances, all patients should receive at least one arterial graft—the LIMA—preferentially to the LAD. Saphenous vein graft (SVG) patency rates for non-LAD targets has been reported to be suboptimal. Bilateral internal mammary artery (BIMA) and radial artery (RA) for non-LAD targets have been shown to provide better patency rates than SVG in particular for the left coronary artery system. A second arterial graft should, therefore, be considered depending on patient’s life expectancy, risk factors for sternal wound complications, coronary anatomy, degree of target vessel stenosis, graft quality and surgical expertise.

The question whether the use of additional arterial grafts can translate into prolonged survival remains debated. Data from non-randomised studies suggest that the use of BIMA over single internal mammary artery (SIMA) use is associated with improved long-term survival, as well as fewer non-fatal events such as MI, recurrent angina, and need for re-operation. However, observational studies are subject to selection bias, despite propensity matching, and the effect of a prolonged survival with additional arterial grafts has not been confirmed in randomized trials.

The ART trial has been designed to answer the question whether BIMA can improve
10-year survival when compared to SIMA. Interim analysis showed no difference at 5 years in the rate of death or the composite of death, myocardial infarction or stroke and 10-year results are warranted to draw final conclusions. Limitations of the ART trial include a high cross over rate from the BIMA arm to the SIMA arm and a high rate of radial artery use in the SIMA arm that may have deluded the benefit of BIMA. The use of BIMA grafting is associated with an increase in sternal dehiscence and increased rate of mediastinitis in obese patients and patients with diabetes. In the ART trial the use of BIMA was associated with a 1.0%-1.5% absolute risk increase in the need for sternal would reconstruction and a subsequent sub-analysis has found that this risk is minimised with skeletonised harvesting. Awaiting the 10-year data of the ART trial, currently, BIMA grafting should be considered in patients with a reasonable life expectancy and a low risk of sternal wound complication.

The radial artery constitutes an alternative as the second arterial graft in patients in whom BIMA grafting is not feasible, patients with a high risk of sternal wound complications, or as third arterial graft. There is a strong, adverse influence on radial artery patency when the native coronary artery stenosis is < 70% and therefore its use should be limited to coronary artery stenosis>70% and ideally >90%. Use of the radial artery as the second conduit of choice has been linked to improved survival in registry studies. Available RCTs testing the radial artery vs saphenous vein graft used angiographic patency as primary endpoint and none was powered to detect difference in clinical outcomes. A recently published patient-level meta-analysis pooling all RCTs comparing radial artery vs saphenous vein graft showed that the use of radial artery was associated with a lower rate of adverse cardiac event at mid-term mainly driven by a significant reduction of need for reintervention and subsequent MI.

15.1.3 Mammary artery harvesting

While the skeletonized technique of harvesting the IMA has a higher theoretical potential for injury, the potential benefits include a longer conduit, more versatility (sequential anastomosis), higher blood flow and fewer wound healing problems. Therefore, in patients at higher risk of sternal wound complications,
skeletonization is recommended.

15.1.4 Radial artery harvesting
RA harvesting is associated with negligible morbidity. Endoscopic radial harvesting is possible but robust evidence concerning its safety and efficacy is scarce. Use of the radial artery after recent coronary angiography with radial access should be discouraged due to potential endothelial damage.

15.1.5 Saphenous vein harvesting
Saphenous vein harvest can be accomplished using open and minimally invasive techniques, which include interrupted incisions and partial or full endoscopic procedures. Endoscopic vein graft harvesting leads to a reduced rate of leg wound complications, but the short- and long-term patency of endoscopically harvested vein grafts, compared with openly harvested grafts, has been challenged. Although there is no unequivocal evidence concerning patency rates, most data from meta-analyses and randomised and non-randomised trials do not demonstrate inferior clinical outcomes with endoscopic vein harvest. If an endoscopic vein graft harvest is performed, it should be undertaken by experienced surgeons or physician assistants with appropriate training and reasonable caseload. If an open technique is used, the ‘no-touch’ technique has shown superior patency rates in multiple randomised trials, with a patency rate >80% after 16 years.

15.1.6 Construction of central anastomosis
A single cross-clamp technique may be preferred to multiple manipulations of the aorta, with the aim of reducing atheroembolic events, but a strict no-touch technique most effectively reduces embolization of atherosclerotic material. In cases of off-pump surgery, devices that allow a clampless procedure may help reduce incidences of cerebral vascular complications.

15.1.7 Intraoperative quality control
Besides continuous ECG monitoring and transoesophageal echocardiography immediately after revascularisation, intraoperative quality control may also include graft flow measurement to confirm or exclude a technical graft problem. Transit-time flow measurement is the most frequently used technique for graft assessment.
and has been able to detect 2–4% of grafts that require revision. In observational studies, the use of intraoperative graft assessment has been shown to reduce the rate of adverse events and graft failure, although interpretation can be challenging in sequential and T-graft configurations.

15.1.8 On-pump and off-pump procedures
Two large, international, randomised trials have shown no difference in 30-day or 1-year clinical outcomes between on- and off-pump surgery, when performed by experienced surgeons. There is also evidence to conclude that, for most patients and surgeons, on-pump surgery provides excellent short- and long-term outcomes. For some surgeons, off-pump surgery is associated with inferior early and late graft patency rates and possibly compromised long-term survival; however, aortic no-touch/clampless off-pump procedures in the hands of highly trained teams appear to be associated with a reduced risk of early morbidity, such as stroke, and fewer transfusions. In the subgroup of patients with end-stage CKD, there is some evidence that off-pump surgery is associated with lower in-hospital mortality and less need for new renal replacement therapy.

15.1.9 Minimally invasive and hybrid procedures
Minimally invasive coronary surgery with LIMA, harvested either directly or under video-assisted vision, may represent an attractive alternative to a sternotomy. It has a similar safety and efficacy profile to conventional on-pump and off-pump procedures, with markedly reduced postoperative length of stay and an early quality-of-life benefit, although spreading of the ribs is associated with increased postoperative pain. It has been shown to be safe and effective in the treatment of proximal LAD stenosis or chronically occluded LAD arteries. Moreover, when compared to PCI in a setting of single vessel proximal LAD disease, minimally invasive coronary surgery was associated with less need for coronary re-intervention. When combined with PCI to non-LAD vessels, it provides the opportunity to perform hybrid coronary revascularisation in selected patients with multivessel disease.

Hybrid revascularisation can be performed consecutively in a hybrid operating room, or sequentially on separate occasions in the conventional surgical and PCI
environments. In a small randomised trial of 200 patients, 1-year and 5-year rates of death, MI, stroke and major bleeding or repeat revascularisation were not significantly different between hybrid revascularisation and CABG. Heart Team discussion and the prospective planning of a joint strategy are critical for the success of a hybrid revascularisation strategy.

15.2 Reporting perioperative outcome
Perioperative reporting of outcome after CABG procedures should be done on a risk-adjusted basis. The early risk period after CABG extends up to 3 months, is multifactorial, and depends on the interface between technical variability and patient comorbidity.

15.3 Gaps in evidence
The role of FFR and iFR in guiding surgical revascularisation needs further investigation whether it improves clinical outcomes. Likewise, there is insufficient data on the impact of intraoperative assessment of graft flow on outcomes.

In view of the limitations of observational studies comparing BIMA with SIMA and the limitations of the ART trial, the ROMA trial is recruiting to answer the question whether the use of additional arterial conduits (either BIMA or RA) translates into superior clinical outcomes when compared to SIMA supplemented by SVG only.

Hybrid procedures, which combine minimally invasive arterial grafting with percutaneous coronary intervention proved feasible and safe. However, multicenter studies are required to prove the efficacy and superiority of this approach in stable, multivessel coronary disease.

**Recommendations on procedural aspects of coronary artery bypass grafting**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Level&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GENERAL CONSIDERATIONS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimization of aortic manipulation is recommended&lt;sup&gt;507, 508, 543, 544&lt;/sup&gt;</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>CT scans of the ascending aorta should be considered in patients</td>
<td>IIA</td>
<td>C</td>
</tr>
<tr>
<td>Requirement</td>
<td>Evidence Code</td>
<td></td>
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<tr>
<td>-----------------------------------------------------------------------------</td>
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<tr>
<td>over 70 years of age and/or with signs of extensive generalized atherosclerosis.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete myocardial revascularisation should be consideredc 128, 129.</td>
<td>Iia B</td>
<td></td>
</tr>
<tr>
<td>Routine intraoperative graft flow measurement should be considered 515, 516.</td>
<td>Iia B</td>
<td></td>
</tr>
<tr>
<td>Prior to aortic manipulation, epi-aortic ultrasound should be considered identify atheromatous plaques and select the optimal surgical strategy</td>
<td>Iia C</td>
<td></td>
</tr>
<tr>
<td><strong>CONDUIT SELECTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arterial grafting with IMA to the LAD system is recommended 452, 453, 545.</td>
<td>I B</td>
<td></td>
</tr>
<tr>
<td>An additional arterial graft should be considered in appropriate patients 546-551 481, 547, 551, 552</td>
<td>Ila B</td>
<td></td>
</tr>
<tr>
<td>Use of the radial artery is recommended over saphenous vein in patients with high-degree stenosisd 481, 548, 549, 553, 554</td>
<td>I B</td>
<td></td>
</tr>
<tr>
<td>BIMA grafting should be considered in patients who do not have a high risk of sternal wound infectiond 546, 547, 550, 551</td>
<td>Ila B</td>
<td></td>
</tr>
<tr>
<td><strong>VESSEL HARVESTING</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skeletonized IMA dissection is recommended in patients with a high risk of sternal wound infectiond 470, 483, 484.</td>
<td>I B</td>
<td></td>
</tr>
<tr>
<td>Endoscopic vein harvesting, if performed by experienced surgeons, should be considered to reduce the incidence of wound complications 489, 492, 493, 499, 555.</td>
<td>Ila A</td>
<td></td>
</tr>
<tr>
<td>No-touch vein harvesting should be considered, when an open technique is used 505, 506, 556, 557.</td>
<td>Ila B</td>
<td></td>
</tr>
<tr>
<td><strong>MINIMALLY INVASIVE TECHNIQUES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off-pump CABG and preferably no-touch techniques on the ascending aorta, by experienced operators, are recommended in patients with significant atherosclerotic aortic disease 507, 508, 543, 558-560</td>
<td>I B</td>
<td></td>
</tr>
<tr>
<td>Off-pump CABG should be considered for subgroups of high-risk patients by experienced off-pump teams 524, 558-561.</td>
<td>Ila B</td>
<td></td>
</tr>
<tr>
<td>Where expertise exists, minimally invasive CABG through limited thoracic access should be considered in patients with isolated LAD</td>
<td>Ila B</td>
<td></td>
</tr>
</tbody>
</table>
lesions or in the context of hybrid revascularisation\textsuperscript{143, 533, 534, 562}.

| Hybrid procedures, defined as consecutive or combined surgical and percutaneous revascularisation, may be considered in specific patient subsets at experienced centres\textsuperscript{562-565}. | Ilb | B |

CABG = coronary artery bypass grafting; CT = computed tomography; IMA = internal mammary artery; BIMA = bilateral internal mammary artery. LAD = left anterior descending coronary artery.

\textsuperscript{a}Class of recommendation.

\textsuperscript{b}Level of evidence.

\textsuperscript{c}Definitions of complete revascularisation are provided in section 5.3.1.3.

\textsuperscript{d}Patients with diabetes mellitus, chronic pulmonary obstructive disease, previous mediastinal radiation, and obesity, particularly when multiple of these are present.

16. Procedural aspects of percutaneous coronary intervention

16.1 Percutaneous coronary intervention devices

16.1.1 Balloon angioplasty

Plain balloon angioplasty has been superseded in the treatment of \textit{de novo} coronary lesions after demonstration of the superiority of stenting in terms of requirement for repeat revascularisation.\textsuperscript{566} Balloon angioplasty might be considered for the treatment of selected patients in whom implantation of stents is not technically feasible, or in a vessel that is considered too small to be stented. Balloon angioplasty is no longer preferred to stenting with DES for patients who require urgent non-cardiac surgery as short duration DAPT may be reasonable with both strategies.\textsuperscript{567, 568}

16.1.2 Choice of coronary stents

Stenting with BMS results in approximately 30\% lower rate of restenosis in comparison with plain balloon angioplasty.\textsuperscript{566} Although many efforts have been made to further reduce restenosis by modification of stent design and materials, reducing the thickness of stent struts has been the only proven modification capable of a reduction in restenosis of BMS.\textsuperscript{569, 570}

A major reduction in the risk of restenosis has been achieved with DES technology. Early-generation DES released sirolimus\textsuperscript{571} or paclitaxel\textsuperscript{572} from a permanent
polymer matrix coating on a relatively thick strut (120–140 µm) stainless steel backbone. These devices reduced angiographic and clinical restenosis by approximately 50–70%, but increased the risk of very late stent thrombosis compared with BMS.\textsuperscript{336, 573}

Early-generation DES have now been supplanted by new-generation DES. These stents represented an iterative development of early generation technology, including polymers with enhanced biocompatibility (permanent or biodegradable), exclusively sirolimus-analogue active drugs, and stent backbones with thin struts (50–100 µm) composed of stainless steel, cobalt chromium or platinum chromium.\textsuperscript{574-579} New-generation DES have higher efficacy and safety in comparison with both early generation DES and BMS.\textsuperscript{336, 573, 580} Although stenting with new-generation DES confers a similar risk of death or MI at mid- to long-term follow-up in comparison with BMS,\textsuperscript{581} the risk of subacute and late stent thrombosis is significantly lower.\textsuperscript{581, 582} Moreover, the risk of very late stent thrombosis is at least comparable to that of BMS and lower than that of early generation DES.\textsuperscript{336, 573, 581, 582} These observations were conformed in a recent trial enrolling patients aged 75 years or older and demonstrating superior outcomes (composite of all-cause mortality, myocardial infarction, stroke, or ischaemia-driven target lesion revascularisation) with DES as compared with BMS with similar duration of intended DAPT (1 month or 6 month) in both treatment arms.\textsuperscript{583} Similarly, there is no clear evidence of a difference between DES and BMS in the risk of stent thrombosis following unplanned disruption of DAPT.\textsuperscript{567} Accordingly, new-generation DES should be preferred to BMS for routine use.

A large number of new-generation DES have received approval for use and CE mark in Europe.\textsuperscript{580} \textbf{Supplementary Table 6} displays a list of new-generation DES with the CE mark, supported by evidence from large-scale clinical trials powered for clinical primary endpoints.

Biodegradable polymer and polymer-free DES offer the potential to reduce late adverse events after PCI by eliminating inflammatory reactions to permanent polymer coatings. A number of large-scale trials showed comparable efficacy and safety compared with permanent polymer stents.\textsuperscript{577, 578, 584-592} However, at the moment,
there is no evidence of differential efficacy with new generation biodegradable polymer in comparison with new generation permanent polymer DES in large-scale randomised trials with follow-up out to 5 years.593-596

Regarding polymer-free DES, two large-scale trials with different devices showed comparable results with new generation DES and superior results to BMS.166, 579 Long-term follow-up from randomised trials vs. new generation permanent polymer DES is only available for a single device and shows comparable outcomes between the devices.593

The high clinical efficacy and safety of new-generation DES support their preferred use in patients with an indication for PCI, including patients with diabetes, CKD, multivessel and left main stem (LMS) disease, AMI, vein grafts, restenotic lesions, and chronic total occlusions. New-generation DES should therefore be considered as the default stent type for PCI regardless of clinical presentation, lesion subtype, concomitant therapies or comorbidities.

16.1.3 Bioresorbable scaffolds
Completely bioresorbable scaffolds (BRS), which degrade to predominantly inert end products after fulfilling their scaffold function in the lesion site of the coronary vessel, have been developed with the goal of reducing or eliminating stent-related adverse events at long-term follow-up. Current scaffold platforms to have reached clinical testing are based on two different technologies: bioresorbable, polymer-based scaffolds (resorption up to 3–4 years) and resorbable, metallic (magnesium) scaffolds (resorption up to 1 year).597 Although a number of devices have received approval for use in Europe (see Supplementary Table 7), randomised trial data are available only with the Absorb bioresorbable vascular scaffold (Absorb BVS, Abbott Vascular).

The safety and efficacy profile of Absorb BVS has been compared with contemporary DES in several trials. Findings of these trials as well as meta-analyses consistently indicate inferior efficacy and safety of Absorb BVS as compared with contemporary DES during long-term follow-up. Specifically, the Absorb BVS is associated with a significantly increased risk of target-lesion revascularisation and device thrombosis, with numbers needed to harm of 40–60.598, 599 Of note, commercial use of Absorb
BVS was stopped in 2017 (for additional details see web addenda).

Available evidence on the magnesium scaffold is limited to small observational studies. Initial results appear encouraging, but further evaluation is needed. Therefore, the Task Force endorses the recommendation of the recent ESC/EAPCI document on bioresorbable scaffolds that any BRS should not be used outside well-controlled clinical studies. In patients who have been treated with BRS prolonged duration DAPT out to 3 years or longer may be considered.

16.1.4 Drug-coated balloons
The rationale for using DCB is based on the concept that with highly lipophilic drugs even short contact times between the balloon surface and the vessel wall are sufficient for effective drug delivery. There are various types of DCB approved for use in Europe and their main characteristics are listed in Supplementary Table 8. Although specifically designed comparative randomised trials are lacking, a class effect for all drug-coated balloons cannot be assumed. Randomised trial data supporting the use of DCB angioplasty are limited to the treatment of in-stent restenosis (see Chapter 13.4). In terms of the use of DCB angioplasty for de novo disease, a number of small randomised trials have been reported with somewhat conflicting results. At present, there are no convincing data to support the use of DCB angioplasty for this indication.

16.1.5 Devices for lesion preparation
Lesion preparation is critical for successful PCI. In addition to plain balloon angioplasty (with standard or non-compliant balloons), cutting or scoring balloon angioplasty or rotational atherectomy may be required in selected lesions—particularly those with heavy calcification—in order to adequately dilate lesions prior to stent implantation. However, studies investigating the systematic use of these adjunctive technologies such as rotational atherectomy have failed to show clear clinical benefit.

16.2 Invasive imaging tools for procedural guidance
16.2.1 Intravascular ultrasound
The majority of existing clinical trial data relates to the use of IVUS guidance during
PCI. In the BMS era several RCTs addressed the potential of IVUS in reducing restenosis and adverse events after stenting, with somewhat conflicting results. Findings from one meta-analysis of randomised trials suggested better outcomes with IVUS guidance in terms of acute procedural results and reduced angiographic restenosis, repeat revascularisation and MACE, with no effect on death and MI.\textsuperscript{605, 606} In the DES era, meta-analysis of randomised and observational studies also suggests better clinical outcomes with IVUS-guided vs. angiography-guided PCI.\textsuperscript{607}\textsuperscript{608} However, the contribution of findings from observational studies must be weighed against the likelihood of considerable residual confounding due to treatment selection bias. Similarly, findings of improved outcome in patients undergoing LM stem PCI with IVUS-guided PCI vs. angiography-guided PCI from a propensity-score matched analysis must be interpreted cautiously.\textsuperscript{35} In cases of stent failure, including restenosis and stent thrombosis, the use of IVUS should be considered in order to identify and correct underlying mechanical factors (see Chapter 13).\textsuperscript{385}

**16.2.2 Optical coherence tomography**

A number of studies have assessed OCT imaging for PCI guidance. Two observational studies show that OCT imaging changes operator behaviour but its impact on clinical outcomes is unclear.\textsuperscript{609, 610} Indeed OCT is more accurate than angiography or IVUS in detecting subtle morphological details including malapposition, residual thrombus, plaque prolapse, and residual dissections, although many of these additional findings may have a benign course.\textsuperscript{611, 612} A single randomised trial compared OCT with IVUS and coronary angiography and showed that OCT-guided PCI was safe and resulted in similar minimum stent area to that of IVUS-guided PCI.\textsuperscript{613} However, OCT-guidance was not superior to either IVUS or angiography alone. An additional randomised trial that enrolled patients with NSTE-ACS compared OCT-guided PCI with angiography-guided PCI and found no signal of impact on clinical outcomes.\textsuperscript{614}

A number of observational studies have shown that OCT is feasible and safe in the assessment of stent failure due to thrombosis and may yield information that may be clinically useful.\textsuperscript{385, 386, 615, 616} Likewise, in cases of in-stent restenosis, intrastent
neointimal tissue may be characterized by OCT, enabling for example the detection of neoatherosclerosis.\textsuperscript{385, 617, 618} In cases of stent failure, the use of OCT should be considered in order to identify and correct underlying mechanical factors (see Chapter 13).

16.3 Specific lesion subsets

16.3.1 Bifurcation stenosis

A number of RCTs have investigated the optimal intervention strategy in patients with bifurcation lesions and showed no benefit for the systematic two-stent approach vs. main branch only stenting with provisional stenting of the side branch in terms of clinical outcomes.\textsuperscript{619} A recent pooled analysis of two RCTs showed lower 5-year survival in patients randomised to a systematic two-stent approach.\textsuperscript{620} In addition, procedure time, contrast volume, radiation exposure, and cost are higher with a two-stent approach.\textsuperscript{620} The EBC TWO (European Bifurcation Coronary TWO) trial found no difference between a provisional T-stent strategy and a systematic two-stent strategy (culotte technique) in terms of the composite endpoint of death, MI, and TVR at 12 months among 200 patients with large calibre true bifurcation lesions (side branch diameter $\geq 2.5$ mm) and significant ostial disease length ($\geq 5$ mm).\textsuperscript{621} Thus, main branch only stenting with provisional stenting of the side branch should be the preferred approach for most bifurcation lesions. Exceptions to this rule, where upfront side branch stenting may be preferable, include the presence of a large side branch ($\geq 2.75$ mm) with a long ostial side branch lesion ($> 5$mm) or anticipated difficulty in accessing an important side branch after main branch stenting, and true distal LM bifurcations. Recently, a multicentre trial conducted in China directly compared a double-kissing crush 2-stent strategy with provisional stenting of the main branch in 482 patients with distal LM bifurcation disease. Double-kissing crush resulted in a lower risk of the primary endpoint target-lesion failure at 1 year as compared with provisional stenting.\textsuperscript{622}

When a two-stent strategy is necessary, it is debated which two-stent technique should be preferred. The three most widely-used contemporary two-stent techniques are culotte, crush (classic or double-kissing crush), and T and protrusion (TAP).\textsuperscript{623, 624, 625, 626} Several RCTs compared these techniques. In non-LM bifurcation lesions, there is no compelling evidence that one technique is superior to the others in terms
of major clinical endpoints. In LM true bifurcation lesions, double-kissing crush has the most favourable outcome data.

Final 'kissing' balloon dilation is generally recommended when two stents are eventually required, with no advantage from final kissing with the one-stent technique. Several stents, designed specifically for treatment of bifurcation lesions, have undergone extensive evaluation with promising angiographic and clinical results, though RCTs against current recommended therapy are limited. Further technical details in relation to bifurcation PCI are described in the consensus document of the European Bifurcation Club.

16.3.2 Chronic total coronary occlusion

Dedicated RCTs examining outcomes of patients with chronic total occlusion (CTO) allocated to revascularisation or conservative therapy are lacking. One recent trial randomised patients with STEMI and CTO in a non-culprit vessel to CTO-PCI vs. conservative therapy and found no difference in the primary endpoint of LVEF and LV end-diastolic volume at 4 months. A systematic review of 25 observational studies showed that at median follow-up of 3 years, successful CTO-PCI was associated with improved clinical outcomes in comparison with failed revascularisation, including overall survival, angina burden and requirement for bypass surgery. Broadly speaking, treatment of CTOs may be considered analogous to the treatment of non-CTO lesions (see recommendations in chapter 5). In cases of regional wall motion abnormalities in the territory of the CTO, objective evidence of viability should be sought. The decision to attempt CTO-PCI should be considered against the risk of greater contrast volume, longer fluoroscopy time and higher MACE rates in comparison with non-CTO PCI patients. Ad hoc PCI is generally not recommended for CTOs, although it may be necessary in selected cases (e.g. acute bypass graft failure not amenable to recanalization of the bypass graft).

Recent developments in catheter and wire technology and increasing operator expertise with both antegrade and retrograde approaches as well as wire escalation and dissection/re-entry techniques have translated into increasing success rates of CTO-PCI with low rates of MACE. Success rates are strongly dependent on
operator skills, depending on experience with specific procedural techniques, and the availability of dedicated equipment, and vary from 60–70% to > 90%.\textsuperscript{634-636}

\textbf{16.3.3 Ostial lesions}

In ostial coronary lesions, additional judgement and caution is essential before proceeding to PCI. In particular, a catheter-induced coronary spasm must be rigorously excluded. Lesion assessment with IVUS may be helpful, particularly in LM ostial stenosis. FFR measurement may also be valuable in the assessment of ostial lesions of borderline significance,\textsuperscript{637} taking special care to avoid a wedge position of the guiding catheter and using i.v., rather than intracoronary, adenosine. When performing intervention, due to interaction between the guide catheter and the proximal stent edge, the risk of longitudinal stent deformation must be considered\textsuperscript{638} and avoided with careful catheter manipulation. The accurate positioning of the stent, precisely in the coronary ostium, may be technically challenging and some specialized techniques that may help to achieve the optimal stent placement have been described.\textsuperscript{639, 640}

\textbf{16.4 Vascular access}

A number of RCTs have compared radial access with femoral access for diagnostic angiography and PCI. The two largest were RIVAL (Radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes) and Minimizing Adverse Haemorrhagic Events by Transradial access Site and Systemic Implementation of AngioX (MATRIX).\textsuperscript{165, 641} In the RIVAL trial, which enrolled 7021 patients, the primary outcome of death, MI, stroke, or non-CABG-related major bleeding at 30 days occurred at a similar rate in radial vs. femoral access (HR 0.92, 95% CI 0.72 to 1.17; \(P = 0.50\)).\textsuperscript{641} In the MATRIX trial, 8404 ACS patients were randomly allocated to radial or femoral access.\textsuperscript{165} In terms of the first co-primary endpoint of 30-day MACE, there was no significant difference between radial access and femoral access (RR 0.85, 95% CI 0.74 to 0.99; two-sided \(P = 0.031\); non-significant at a pre-specified alpha of 0.025). The second co-primary outcome of 30-day net adverse clinical events (MACE or non-CABG BARC (Bleeding Academic Research Consortium) major bleeding) was significantly lower with radial access (RR 0.83, 95% CI 0.73 to 0.96; \(P = 0.009\)). Major BARC 3 or 5 bleeding was significantly reduced in the radial group (1.6% vs. 2.3%; RR 0.67, 95% CI 0.49 to
0.92; \( P = 0.013 \) and radial access was associated with a lower risk of all-cause mortality (1.6% vs. 2.2%; RR 0.72, 95% CI 0.53 to 0.99; \( P = 0.045 \)). However, the benefit of radial over femoral access depends upon the operator’s expertise in the radial technique.\(^{642}\)

Treatment of restenotic and saphenous vein graft lesions are discussed in **Chapter 13.3**.

### Recommendations on choice of stent and access site

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class(^a)</th>
<th>Level(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DES are recommended over BMS for any PCI irrespective of: clinical presentation</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>lesion type</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>planned non-cardiac surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>anticipated duration of DAPT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>concomitant anticoagulant therapy (^{100, 580, 643, 644})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radial access is recommended as the standard approach, unless there are overriding procedural considerations (^{165, 641, 645})</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>BRS are currently not recommended for clinical use outside clinical studies (^{646-654})</td>
<td>III</td>
<td>C</td>
</tr>
</tbody>
</table>

BMS = bare-metal stents; BRS = bioresorbable scaffolds; DES = drug-eluting stents; DAPT = dual antiplatelet therapy; PCI = percutaneous coronary intervention.

\(^a\)Class of recommendation.

\(^b\)Level of evidence.
### Recommendations on intravascular imaging for procedural optimisation

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Level&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVUS or OCT should be considered in selected patients to optimise stent implantation&lt;sup&gt;605, 614, 655-657&lt;/sup&gt;.</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>IVUS should be considered to optimise treatment of unprotected left main lesions&lt;sup&gt;35&lt;/sup&gt;.</td>
<td>IIa</td>
<td>B</td>
</tr>
</tbody>
</table>

IVUS = intravascular ultrasound; OCT = optical coherence tomography.

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence.

### Recommendations on specific lesion subsets

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Level&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stent implantation in the main vessel only, followed by provisional balloon angioplasty with or without stenting of the side branch, is recommended for PCI of bifurcation lesions&lt;sup&gt;658-662&lt;/sup&gt;.</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Percutaneous revascularisation of CTOs should be considered in patients with angina resistant to medical therapy or with a large area of documented ischaemia in the territory of the occluded vessel&lt;sup&gt;663-667&lt;/sup&gt;.</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>In true bifurcation lesions of the left main, double-kissing crush technique may be preferred over provisional T-stenting&lt;sup&gt;622&lt;/sup&gt;.</td>
<td>IIb</td>
<td>B</td>
</tr>
</tbody>
</table>

CTO = chronic total occlusion; PCI = percutaneous coronary intervention.

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence.

### 17. Antithrombotic treatments

Antithrombotic treatment is mandatory in CAD patients undergoing myocardial revascularisation. Its choice, the combination, the time point of initiation and the treatment duration depend on the patient’s characteristics, co-morbidities, the clinical setting (elective revascularisation vs. ACS), and the mode (PCI vs. CABG) of revascularisation. Both ischaemic and bleeding events significantly influence the outcome of CAD patients and their overall mortality risk during and after myocardial revascularisation.<sup>668</sup> Thus, the choice of treatment should reflect ischemic and bleeding risk. The recommended drugs (<strong>Figure 8</strong>) and doses (<strong>Table 7</strong>) for
Anticoagulant and antiplatelet drugs used in conjunction with myocardial revascularisation are summarized below.

**Figure 8**: Antithrombotic treatment for myocardial revascularisation and its pharmacological targets. The figure illustrates anticoagulant and antiplatelet drugs being used during and after myocardial revascularisation (PCI or CABG). Drugs with oral administration are shown in black letters and drugs with preferred parenteral administration in red. ADP=adenosine diphosphate, ASA=acetylsalicylic acid, DAPT=dual antiplatelet treatment, FXa= Factor Xa, GP=glycoprotein, TxA2= Thromboxan A2, UFH= unfractionated heparin.
Table 7 Doses of antiplatelet and anticoagulant drugs used during and after myocardial revascularisation

<table>
<thead>
<tr>
<th>Antiplatelet drugs</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspirin</td>
<td>Loading dose of 150–300 mg orally or of 75–150 mg i.v. if oral ingestion is not possible, followed by a maintenance dose of 75–100 mg/day</td>
</tr>
<tr>
<td>Clopidogrel</td>
<td>Loading dose of 600 mg orally, followed by a maintenance dose of 75 mg/day</td>
</tr>
<tr>
<td>Prasugrel</td>
<td>Loading dose of 60 mg orally, followed by a maintenance dose of 10 mg/day In patients with body weight &lt;60 kg, a maintenance dose of 5 mg is recommended. In patients &gt;75 years, prasugrel is generally not recommended, but a dose of 5 mg should be used if treatment is deemed necessary</td>
</tr>
<tr>
<td>Ticagrelor</td>
<td>Loading dose of 180 mg orally, followed by a maintenance dose of 90 mg b.i.d</td>
</tr>
<tr>
<td>Abciximab</td>
<td>Bolus of 0.25 mg/kg i.v. and 0.125 μg/kg/min infusion (maximum 10 μg/min) for 12 h</td>
</tr>
<tr>
<td>Eptifibatide</td>
<td>Double bolus of 180 μg/kg i.v. (given at a 10-min interval) followed by an infusion of 2.0 μg/kg/min for up to 18 h</td>
</tr>
<tr>
<td>Tirofiban</td>
<td>Bolus of 25 μg/kg over 3 min i.v., followed by a an infusion of 0.15 μg/kg/min for up to 18 h</td>
</tr>
<tr>
<td>Cangrelor</td>
<td>Bolus of 30 μg/kg i.v. followed by 4 μg/kg/min infusion for at least 2 hours or duration of procedure, whichever is longer.</td>
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<table>
<thead>
<tr>
<th>Anticoagulant drugs for PCI</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfractionated heparin (UFH)</td>
<td>70–100 U/kg i.v. bolus when no GP IIb/IIIa inhibitor is planned 50–70 U/kg i.v. bolus with GP IIb/IIIa inhibitors</td>
</tr>
<tr>
<td>Enoxaparin</td>
<td>0.5 mg/kg i.v. bolus</td>
</tr>
<tr>
<td>Bivalirudin</td>
<td>0.75 mg/kg i.v. bolus followed by i.v infusion of 1.75 mg/kg/h for up to 4 h after the procedure as clinically warranted</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oral anticoagulant drugs (concomitant treatment after PCI)</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin K Antagonists (e.g. warfarin, phenprocoumon)</td>
<td>Dosing is based on INR value and the respective clinical indication</td>
</tr>
<tr>
<td>Apixaban</td>
<td>Maintenance doses of 5 and 2.5 mg b.i.d.</td>
</tr>
<tr>
<td>Dabigatran</td>
<td>Maintenance doses of 150 and 110 mg b.i.d.</td>
</tr>
<tr>
<td>Edoxaban</td>
<td>Maintenance dose of 60 and 30 mg/d</td>
</tr>
<tr>
<td>Rivaroxaban</td>
<td>Maintenance doses of 20 and 15 mg/d and 2.5 mg b.i.d (vascular dose)</td>
</tr>
</tbody>
</table>

17.1 Percutaneous coronary intervention in stable coronary artery disease
17.1.1 Choice of treatment and pretreatment
DAPT consisting of aspirin and a P2Y₁₂ receptor inhibitor represents the cornerstone of treatment in patients undergoing elective PCI. The P2Y₁₂ receptor inhibitor
clopidogrel is recommended for elective stenting procedures. For a routine clopidogrel pretreatment (administration of the drug when the coronary anatomy is unknown), there is no compelling evidence for a significant clinical benefit in stable CAD patients. Thus, pretreatment may only be an option in selected patients with high probability for PCI or before staged PCI procedures. Figures 8 and 9 summarize the commonly used antiplatelet and anticoagulant drugs in stable CAD patients undergoing PCI.

17.1.2 Peri-interventional treatment
While aspirin and clopidogrel are indicated for elective stenting procedures, prasugrel or ticagrelor may only be considered in selected patients for specific high-risk situations of elective stenting (e.g. complex PCI procedures such as LM stenting, CTO procedures) or in patients with a history of stent thrombosis on clopidogrel treatment.

In parallel to antiplatelet treatment, the use of anticoagulants is standard of care during elective PCI to inhibit thrombin generation and activity. Different agents including unfractionated heparin (UFH) and bivalirudin have been evaluated for their use in clinical practice. The Randomised Evaluation in PCI Linking Angiomax to Reduced Clinical Events (REPLACE)-2 trial demonstrated that the outcome with bivalirudin and provisional glycoprotein (GP) IIb/IIIa blockade is similar to that of UFH plus planned GP IIb/IIIa inhibition during elective PCI. The ISAR-REACT (Intracoronary Stenting and Antithrombotic Regimen Rapid Early Action for Coronary Treatment) 3 trial also showed a similar outcome for bivalirudin vs. UFH treatment. In ISAR REACT 3A, evaluating a lower dose of 100 U/kg UFH, this lower dose showed net clinical benefit compared to the historical control cohort and this benefit was mostly driven by a reduction in bleeding events. In view of the primary endpoint results of the randomised controlled trials and in view of a trend towards a lower risk of MI, UFH remains the standard anticoagulant for elective PCI. Based on the results of the Safety and Efficacy of Intravenous Enoxaparin in Elective Percutaneous Coronary Intervention Randomised Evaluation (STEEPLE) trial, enoxaparin should be considered as an alternative anticoagulant drug.
Drugs for parenteral antiplatelet treatment include cangrelor and GP IIb/IIIa inhibitors. Cangrelor is a direct reversible, short-acting P2Y\textsubscript{12} inhibitor that has been evaluated during PCI for SCAD and ACS in clinical trials comparing cangrelor with clopidogrel, administered before PCI (CHAMPION (Cangrelor versus Standard Therapy to Achieve Optimal Management of Platelet Inhibition) PCI) or after PCI (CHAMPION PLATFORM and CHAMPION PHOENIX).\textsuperscript{677} A meta-analysis showed a benefit with respect to major ischaemic endpoints that is counter-balanced by an increase in relevant bleeding.\textsuperscript{677} Moreover, the benefit of cangrelor with respect to ischaemic endpoints was attenuated in CHAMPION PCI with upfront administration of clopidogrel. Nevertheless, due to its proven efficacy in preventing intra-procedural and post-procedural stent thrombosis in P2Y\textsubscript{12}-inhibitor naïve patients, cangrelor may be considered in P2Y\textsubscript{12} naïve patients undergoing PCI.

Available GP IIb/IIIa inhibitors include abciximab, eptifibatide and tirofiban. In a setting of elective PCI, clinical trials did not demonstrate an additional benefit of GP IIb/IIIa inhibitor administration in stable CAD patients in a setting of DAPT treatment that includes loading with clopidogrel.\textsuperscript{678, 679} A meta-analysis on this topic revealed no mortality benefit of GP IIb/IIIa treatment and while non-fatal MIs were reduced, (minor) bleeding events were significantly higher when utilizing these agents.\textsuperscript{680} Thus, GP IIb/IIIa inhibitors may only be considered in specific ‘bail-out’ situations including high intra-procedural thrombus burden, slow flow or no-flow with closure of the stented coronary vessel.

Algorithm for antithrombotic drugs in patients undergoing percutaneous coronary intervention is shown in Figure 9.

17.1.3 Post-interventional and maintenance treatment
Following elective stenting, DAPT consisting of clopidogrel in addition to aspirin is generally recommended for 6 months, irrespective of the stent type. In specific clinical scenarios, this standard DAPT duration can be shortened (< 6 months) or extended (> 6–12 months). For a more detailed description of the pertinent clinical trials in the field of DAPT duration we may refer to the 2017 ESC Focused Update on Dual Antiplatelet Therapy in Coronary Artery Disease\textsuperscript{681}. Following DAPT, a life-long single antiplatelet therapy (usually with aspirin) is recommended and patients should
be advised not to prematurely discontinue oral antiplatelet therapy after stenting due to the risks of stent thrombosis and recurrent MI. Recently, the value of a vascular dose of rivaroxaban in conjunction with aspirin was demonstrated in the large-scale Rivaroxaban for the Prevention of Major Cardiovascular Events in Coronary or Peripheral Artery Disease (COMPASS trial). However, its utilization in stable CAD patients is a matter of secondary prevention and is not linked to myocardial revascularisation procedures.

**Figure 9. Algorithm for antithrombotic drugs in patients undergoing percutaneous coronary intervention.** High bleeding risk is considered as an increased risk of spontaneous bleeding during DAPT (e.g. PRECISE-DAPT score > 25). Colour-coding refers to the ESC Classes of Recommendations (green = Class I; yellow = IIa; orange = Class IIb).

1. After PCI with DCB 6 months DAPT should be considered (Class IIa)
2. Clopidogrel if patient is not eligible for a treatment with prasugrel or ticagrelor; or in a setting of DAPT de-escalation (class IIb)
3. Clopidogrel or prasugrel if patient is not eligible for a treatment with ticagrelor
4. Pretreatment before PCI (or at the latest at the time of PCI); Clopidogrel if potent P2Y12 inhibitors are contraindicated or not available
(For scores see Supplementary Table 4)

**Recommendations for antithrombotic treatment in stable coronary artery disease patients undergoing percutaneous coronary intervention**

<table>
<thead>
<tr>
<th>Recommendations for PCI</th>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment and antiplatelet therapy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment with 600 mg clopidogrel is recommended in elective PCI patients once the coronary anatomy is known and a decision is made to proceed with PCI</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Pre-treatment with clopidogrel may be considered if the probability of PCI is high.</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>In patients on a maintenance dose of 75 mg clopidogrel, a new loading dose of 600 mg may be considered once the indication for PCI is confirmed.</td>
<td>IIb</td>
<td>C</td>
</tr>
</tbody>
</table>

**Peri-interventional treatment**

| Aspirin is indicated before elective stenting | I | A |
| An oral loading dose of aspirin (150–300 mg p.o. or 75–250 mg i.v.) is recommended if the patient is not pretreated. | I | C |
| Clopidogrel (600 mg loading dose, 75 mg daily maintenance dose) is recommended for elective stenting | I | A |
| Glycoprotein IIb/IIIa antagonists should be considered only for bail-out. | IIa | C |
| Prasugrel or ticagrelor may be considered in specific high-risk situations of elective stenting (e.g. history of stent thrombosis, left main stenting). | IIb | C |
| Unfractionated heparin is indicated as the standard anticoagulant (70–100 U/kg) | I | B |
| Bivalirudin (0.75 mg/kg bolus, followed by 1.75 mg/kg/h for up to 4 hours after the procedure) is indicated in the case of heparin-induced thrombocytopenia. | I | C |
| Enoxaparin (i.v. 0.5 mg/kg) should be considered as an alternative agent | IIa | B |
| Cangrelor may be considered in P2Y₁₂ inhibitor naïve patients undergoing PCI | IIb | A |

**Post-interventional and maintenance treatment**

| Life-long single antiplatelet therapy, usually aspirin, is recommended | I | A |
| Instruction of patients about the importance of complying with antiplatelet therapy is recommended. | I | C |
| In patients with SCAD treated with coronary stent implantation, DAPT consisting of clopidogrel in addition to aspirin is generally recommended for 6 months, irrespective of the stent type | I | A |
| In patients with SCAD treated with BRS, DAPT should be considered for at least 12 months and up to the presumed full absorption of the BRS based on an individual assessment of bleeding and ischaemic risk. | IIa | C |
| In patients with SCAD treated with DCB, DAPT should be considered for 6 months | IIa | B |
| In patients with SCAD considered at high bleeding risk (e.g. PRECISE-DAPT ≥ 25), DAPT should be considered for 3 months | IIa | A |
In patients with SCAD who have tolerated DAPT without a bleeding complication and who are at low bleeding risk but high thrombotic risk, continuation of DAPT with clopidogrel for > 6 months and up to 30 months may be considered.\textsuperscript{702-704}

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>In patients with SCAD in whom 3-month DAPT poses safety concerns, DAPT may be considered for 1 month.</td>
<td>C</td>
</tr>
</tbody>
</table>

BRS = bioresorbable scaffold; CAD = coronary artery disease; DAPT = dual antiplatelet therapy; DCB = drug-coated balloon; DES = drug-eluting stent; i.v. = intravenous; MI = myocardial infarction; PCI = percutaneous coronary intervention; PRECISE-DAPT = PREdicting bleeding Complications In patients undergoing Stent implantation and subsequent Dual Anti Platelet Therapy; SCAD = stable coronary artery disease.

\textsuperscript{a}Class of recommendation.
\textsuperscript{b}Level of evidence.
\textsuperscript{c}These recommendations refer to stents which are supported by large-scale randomised trials with clinical endpoint evaluation leading to unconditional CE mark
\textsuperscript{d}The evidence supporting this recommendation comes from two studies where zotarolimus-eluting Endeavour stent has been investigated in conjunction with a 3-month DAPT regimen.

17.2 Non-ST-segment elevation acute coronary syndrome
Activation of blood platelets and the coagulation cascade plays a key role in the initial phase and evolution of an ACS. Hence, sufficient platelet inhibition and anticoagulation is essential during ACS and especially in ACS patients undergoing PCI.

17.2.1 Choice of treatment and pretreatment
For NSTE-ACS patients, DAPT including aspirin and a potent P2Y\textsubscript{12} receptor inhibitor (prasugrel or ticagrelor) is recommended (see web addenda).\textsuperscript{705 706} Clopidogrel should only be used when prasugrel or ticagrelor are not available or are contraindicated. Based on the results of the ACCOAST (Comparison of Prasugrel at the Time of Percutaneous Coronary Intervention or as Pretreatment at the Time of Diagnosis in Patients with Non-ST Elevation Myocardial Infarction) trial\textsuperscript{158}, it is not recommended to administer prasugrel in patients in whom coronary anatomy is not known. Nevertheless, pretreatment with ticagrelor was part of the Study of Platelet Inhibition and Patient Outcomes (PLATO) and was associated with an early benefit over clopidogrel.\textsuperscript{706} For these reasons, pretreatment with ticagrelor can be used,
although there is no direct evidence from head-to-head comparison between pretreatment strategies.

17.2.2 Peri-interventional treatment
Anticoagulation is recommended for all patients in addition to antiplatelet therapy during PCI for NSTE-ACS. In general, a crossover between anticoagulants should be avoided (especially between UFH and low-molecular-weight heparin (LMWH)), with the exception of adding UFH to fondaparinux when a patient proceeds to PCI. The respective agents should be discontinued after PCI except for specific clinical settings such as the presence of an LV aneurysm with thrombus or AF requiring anticoagulation.

A number of trials have compared bivalirudin with UFH in ACS patients undergoing PCI (see web addenda). Some of these trials pursued a balanced use of adjunctive GP IIb/IIIa inhibitors with both bivalirudin and heparin, whereas others, predominantly the older ones, had selective use of GP IIb/IIIa inhibitors in the heparin arm. These trials have been reviewed extensively in a number of meta-analyses. The more recent meta-analysis that also included MATRIX (Minimizing Adverse Haemorrhagic Events by Transradial Access Site and Systemic Implementation of AngioX) but not VALIDATE-SWEDEHEART (Bivalirudin versus Heparin in ST-Segment and Non–ST-Segment Elevation Myocardial Infarction in Patients on Modern Antiplatelet Therapy on the Swedish Web-system for Enhancement and Development of Evidence-based care in Heart disease Evaluated According to Recommended Therapies) showed no significant benefit of bivalirudin as compared with UFH with respect to death, MACE and MI. Nevertheless, bivalirudin was associated with a significant increase in the risk of stent thrombosis and a significant decrease in the risk of bleeding. The reduction of bleeding risk was, however, linked to unbalanced use of GPI predominantly with UFH. Recently, VALIDATE-SWEDEHEART study compared UFH vs. bivalirudin in a background of radial access and limited use of GP IIb/IIIa inhibitors. The study demonstrated similar risk patterns for both ischemia and bleeding when comparing the two drugs. Of note, while prior studies reported a reduced bleeding risk with bivalirudin vs. UFH, this was not confirmed in VALIDATE-SWEDEHEART and in a contemporary setting of preferred radial access and selective use of GPIIb/IIIa inhibitors. In summary and
based on the above-mentioned trials, UFH is primarily recommended as an anticoagulant for PCI. Due to its short half-life and favorable results in some of the studies, bivalirudin may be considered as an alternative to UFH in selected cases.

Patients may undergo cardiac catheterization after a conservative treatment phase and these patients are commonly treated with fondaparinux during the conservative treatment phase. This regimen is based on the Optimal Antiplatelet Strategy for Interventions (OASIS)-5 trial. Of note, catheter thrombus formation was an issue with fondaparinux and therefore full-dose UFH must be added to prevent thrombus formation when the patient proceeds to PCI. Enoxaparin should be considered as anticoagulant for PCI in patients pretreated with subcutaneous enoxaparin. A benefit of enoxaparin over UFH to reduce mortality and bleeding complications was recently reported in a meta-analysis including NSTE-ACS patients. Yet, this meta-analysis did not include a dedicated randomised study in NSTE-ACS and was largely based on non-randomised comparisons.

Most of the trials evaluating GP IIb/IIIa inhibitors in PCI-treated patients predated the era of routine oral DAPT treatment. These early trials demonstrated a reduction in the incidence of ischaemic events in favor of GP IIb/IIIa treatment in combination with UFH compared with UFH alone, primarily through a reduction in MI. However, coronary angiography and PCI were delayed as compared to what is recommended now and a consistent major bleeding risk was observed. Overall, there is no compelling evidence for an additional benefit of routine upstream use of GP IIb/IIIa inhibitors in NSTE-ACS patients scheduled for coronary angiography and receiving DAPT treatment. Especially in a setting of potent platelet inhibition with ticagrelor or prasugrel, where randomised data on GP IIb/IIIa use is limited, routine use of these agents cannot be recommended. Nevertheless, it should be considered bail-out situations or thrombotic complications and may be used for high-risk PCI in patients without pretreatment with P2Y$_{12}$ inhibitors. Available evidence on cangrelor suggests that the potential benefit is independent of the clinical presentation. Thus, similar as to stable CAD patients, cangrelor may be considered in specific settings in P2Y$_{12}$-naïve patients undergoing PCI.
### 17.2.3 Post-interventional and maintenance treatment

Following PCI for NSTE-ACS, DAPT consisting of a P2Y$_{12}$ receptor inhibitor in addition to aspirin is generally recommended for 12 months, irrespective of the stent type. Recently, the SMART-DATE (Smart Angioplasty Research Team-safety of 6-month duration of Dual Antiplatelet Therapy after percutaneous coronary intervention in patients with acute coronary syndromes) prospective multicentre Randomised trial supported this notion in the setting of contemporary interventional practice. The study randomly assigned 2712 patients undergoing PCI for NSTE-ACS or STEMI to either the 6-month DAPT or 12-month or longer DAPT. Although the primary endpoint, a composite of all-cause death, myocardial infarction, or stroke, did not confirm the benefit of prolonged DAPT over 6-month DAPT (cumulative event rate 4.7% vs 4.2%; absolute risk difference 0.5%; upper limit of one-sided 95% CI 1.8%; p$_{\text{non-inferiority}}$=0.03 with a predefined non-inferiority margin of 2.0%), myocardial infarction occurred more frequently in the 6-month DAPT group than in prolonged DAPT group (1.8% vs 0.8%; p=0.02). The rate of BARC type 2-5 bleeding was not significantly affected by prolonged DAPT (HR 0.69 [95% CI 0.45-1.05]; p=0.09). The authors concluded that the increased risk of myocardial infarction with 6-month DAPT and the wide non-inferiority margin prevented concluding that short-term DAPT was safe in this setting and suggested that prolonged DAPT should remain the standard of care in patients with acute coronary syndrome without excessive risk of bleeding.\textsuperscript{718}

In specific clinical scenarios, this standard DAPT duration can be shortened (< 12 months) or extended (> 12 months). Further on, switching and especially a de-escalation of DAPT (switch from potent P2Y$_{12}$ inhibitors to clopidogrel) was subject to a number of randomised clinical trials\textsuperscript{719,720}. Triggers for DAPT de-escalation include clinical (bleeding events or presumed high bleeding risk) and socio-economic factors\textsuperscript{719}. Based on recent results from the randomised TROPICAL-ACS trial\textsuperscript{720} (Testing responsiveness to platelet inhibition on chronic antiplatelet treatment for acute coronary syndromes), an approach of DAPT de-escalation guided by platelet function testing may be considered in ACS patients (NSTE-ACS and STEMI) as an alternative to 12 months potent platelet inhibition and especially for patients deemed unsuitable for maintained potent platelet inhibition. For a more detailed description of the pertinent clinical trials in the field of DAPT duration and switching antiplatelet drugs we may refer to the International Expert Consensus document on Switching
Platelet P2Y12 Receptor-Inhibiting Therapies and the 2017 ESC Focused Update on Dual Antiplatelet Therapy in Coronary Artery Disease. Following DAPT, a lifelong single antiplatelet therapy (usually with aspirin) is recommended and patients should be advised not to prematurely discontinue oral antiplatelet therapy after stenting.

Based on the results of the ATLAS-ACS 2–TIMI 51 (Anti-Xa Therapy to Lower cardiovascular events in Addition to Standard therapy in subjects with Acute Coronary Syndrome–Thrombolysis In Myocardial Infarction 51) trial in NSTE-ACS and STEMI patients, a low-dose rivaroxaban may be considered after discontinuation of parenteral anticoagulation for patients with no prior stroke/TIA and at high ischaemic risk as well as low bleeding risk receiving aspirin and clopidogrel. Of note, rivaroxaban was not investigated in a background of potent P2Y12 inhibitors.

**Recommendations for antithrombotic treatment in patients with non-ST-elevation acute coronary syndromes undergoing percutaneous coronary intervention**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pretreatment and antiplatelet therapy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspirin is recommended for all patients without contraindications at an initial oral loading dose of 150–300 mg (or 75–250 mg i.v.), and at a maintenance dose of 75–100 mg daily long-term.</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>A P2Y12 inhibitor is recommended in addition to aspirin, and maintained over 12 months unless there are contraindications such as excessive risk of bleeding Options are:</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>• Prasugrel in P2Y12-inhibitor naïve patients who proceed to PCI (60 mg loading dose, 10 mg daily dose)</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>• Ticagrelor irrespective of the preceding P2Y12-inhibitor regimen (180 mg loading dose, 90 mg b.i.d.)</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>• Clopidogrel (600 mg loading dose, 75 mg daily dose), only when prasugrel or ticagrelor are not available or are contraindicated</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>GP IIb/IIIa antagonists should be considered for bail-out if there is evidence of no-reflow or a thrombotic complication.</td>
<td>Ila</td>
<td>C</td>
</tr>
<tr>
<td>For pretreatment in patients with NSTE-ACS undergoing invasive management, ticagrelor administration (180 mg loading dose, 90 mg b.i.d.), or clopidogrel (600 mg loading dose, 75 mg daily dose) if ticagrelor is not an option, should be considered as soon as the diagnosis is established.</td>
<td>Ila</td>
<td>C</td>
</tr>
<tr>
<td>GP IIb/IIIa antagonist may be considered in P2Y12-inhibitor naïve patients undergoing PCI</td>
<td>IIb</td>
<td>C</td>
</tr>
</tbody>
</table>
Cangrelor may be considered in P2Y\textsubscript{12}-inhibitor naïve patients undergoing PCI\textsuperscript{677}.

<table>
<thead>
<tr>
<th>Pretreatment with GP IIb/IIIa antagonists in patients in whom coronary anatomy is not known is not recommended\textsuperscript{716, 717}</th>
</tr>
</thead>
</table>

| It is not recommended to administer prasugrel in patients in whom coronary anatomy is not known\textsuperscript{158}. |

### Peri-interventional therapy

Anticoagulation is recommended for all patients in addition to antiplatelet therapy\textsuperscript{707, 727}.

<table>
<thead>
<tr>
<th>It is recommended to select anticoagulation according to both ischaemic and bleeding risks, and according to the efficacy–safety profile of the chosen agent.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>UFH is recommended.</th>
</tr>
</thead>
</table>

| In patients on fondaparinux, a single bolus UFH (85 IU/kg, or 60 IU in the case of concomitant use of GP IIb/IIIa receptor inhibitors) is indicated\textsuperscript{728}. |

| Enoxaparin should be considered in patients pretreated with subcutaneous enoxaparin\textsuperscript{894}. |

| Discontinuation of parenteral anticoagulation should be considered immediately after an invasive procedure. |

| Bivalirudin (0.75 mg/kg bolus, followed by 1.75 mg/kg/h for up to 4 hours after the procedure) may be considered as an alternative to UFH\textsuperscript{156, 717, 729}. |

| Crossover of UFH and LMWH is not recommended\textsuperscript{708}. |

\textit{b.i.d.} = twice daily; \textit{GP} = glycoprotein; \textit{LMWH} = low-molecular-weight heparin; \textit{NSTE-ACS} = non-ST-segment elevation acute coronary syndromes; \textit{PCI} = percutaneous coronary intervention; \textit{UFH} = unfractionated heparin.

\textsuperscript{a}Class of recommendation.

\textsuperscript{b}Level of evidence.

### Recommendations for post-interventional and maintenance treatment in patients with non-ST-elevation acute coronary syndromes and ST-elevation myocardial infarction undergoing percutaneous coronary intervention

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class\textsuperscript{a}</th>
<th>Level\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td>In patients with ACS treated with coronary stent implantation, DAPT with a P2Y\textsubscript{12} inhibitor on top of aspirin is recommended for 12 months unless there are contraindications such as excessive risk of bleeding (e.g. PRECISE-DAPT ≥ 25)\textsuperscript{730-732}.</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>In patients with ACS and stent implantation who are at high risk of bleeding (e.g. PRECISE-DAPT ≥ 25), discontinuation of P2Y\textsubscript{12} inhibitor therapy after 6 months should be considered\textsuperscript{733, 734}.</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>In patients with ACS treated with BRS, DAPT should be considered for at least 12 months and up to the presumed full absorption of the BRS based on an individual assessment of bleeding and ischaemic risk.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>De-escalation of P2Y\textsubscript{12} inhibitor treatment (e.g. with a switch from prasugrel or ticagrelor to clopidogrel) guided by platelet function testing may be considered as an alternative DAPT</td>
<td>IIb</td>
<td>B</td>
</tr>
</tbody>
</table>
strategy, especially for ACS patients deemed unsuitable for 12-month potent platelet inhibition\textsuperscript{720}.

| In patients with ACS who have tolerated DAPT without a bleeding complication, continuation of DAPT for longer than 12 months may be considered \textsuperscript{735, 736}. | IIb | A |
| In patients with MI and high ischaemic risk\textsuperscript{c} who have tolerated DAPT without a bleeding complication, ticagrelor 60 mg \textit{b.i.d.} for longer than 12 months on top of aspirin may be preferred over clopidogrel or prasugrel \textsuperscript{737-739}. | IIb | B |
| In ACS patients with no prior stroke/TIA and at high ischaemic risk as well as low bleeding risk receiving aspirin and clopidogrel, low-dose rivaroxaban (2.5 mg \textit{b.i.d.} for approximately 1 year) may be considered after discontinuation of parenteral anticoagulation \textsuperscript{723}. | IIb | B |

ACS = acute coronary syndrome; \textit{b.i.d.} = twice daily; BRS = bioresorbable scaffold; DAPT = dual antiplatelet therapy; MI = myocardial infarction; PCI = percutaneous coronary intervention; PRECISE-DAPT = PREdicting bleeding Complications In patients undergoing Stent implantation and subsEquent Dual Anti Platelet Therapy; TIA = transient ischaemic attack.

\textsuperscript{a}Class of recommendation.

\textsuperscript{b}Level of evidence.

\textsuperscript{c}Defined as at least 50 years of age, and had one of the following additional high-risk features: age of 65 years or older, diabetes mellitus requiring medication, a second prior spontaneous MI, multivessel coronary artery disease, or chronic renal dysfunction, defined as an estimated creatinine clearance < 60 mL/min.

17.3 ST-segment elevation myocardial infarction

17.3.1 Choice of treatment and pretreatment

STEMI patients undergoing primary PCI should receive aspirin and a P2Y\textsubscript{12} receptor inhibitor as soon as the diagnosis of STEMI is established. In line with the treatment recommendations for NSTE-ACS patients, DAPT is the cornerstone of treatment for STEMI patients and includes aspirin and a potent P2Y\textsubscript{12} receptor inhibitor (prasugrel or ticagrelor).\textsuperscript{705, 706} For both antiplatelet drugs, published subgroup analyses on STEMI patients are available (see web addenda). Randomised data on a comparison of ticagrelor vs. prasugrel in STEMI patients are limited, but the recently published randomised PRAGUE-18 (Comparison of Prasugrel and Ticagrelor in the Treatment of Acute Myocardial Infarction) trial\textsuperscript{740} with limited statistical power found similar safety and efficacy profiles of ticagrelor and prasugrel in a setting of primary PCI. When potent P2Y\textsubscript{12} receptor inhibitors are contraindicated or are not available, clopidogrel should be given for primary PCI instead\textsuperscript{726}. The value of pretreatment with
ticagrelor was addressed in the Administration of Ticagrelor in the Cath Lab or in the Ambulance for New ST-Elevation Myocardial Infarction to Open the Coronary Artery (ATLANTIC) trial. No significant differences were observed on the level of the two co-primary surrogate endpoints measured before PCI (thrombolysis in myocardial infarction [TIMI] flow, ST segment resolution). Likewise, the incidence of a combined ischaemic endpoint (death, MI; stroke, stent thrombosis, urgent revascularisation) did not differ between the two treatment arms. Nevertheless, in both TRITON (TRial to Assess Improvement in Therapeutic Outcomes by Optimizing Platelet InhibitioN with Prasugrel–Thrombolysis In Myocardial Infarction) and PLATO pretreatment was part of the therapeutic regimen in STEMI.

17.3.2 Peri-interventional treatment
Immediate and sufficient anticoagulation is mandatory in the setting of primary PCI for STEMI and available options include UFH, bivalirudin and enoxaparin. A number of RCTs compared bivalirudin vs. UFH in different settings and with different utilization of GP IIb/IIIa inhibitors (see web addenda). The primary recommendation of UFH, reserving bivalirudin for selected cases, is essentially the same for primary PCI as for PCI in NSTE-ACS and is based on the same clinical trials (see Chapter 17.2.2).

Enoxaparin was compared with UFH in the randomised open-label Acute STEMI Treated with primary PCI and intravenous enoxaparin Or UFH to Lower ischaemic and bleeding events at short- and Long-term follow-up (ATOLL) trial, and based on the trial results enoxaparin should be considered as an alternative to UFH treatment in STEMI patients.

A number of clinical trials, performed at a time when pretreatment and potent platelet inhibition was not part of routine clinical practice, had documented clinical benefits of GP IIb/IIIa inhibitors as an adjunct to primary PCI performed with UFH. A meta-analysis showed a significant survival benefit especially in high-risk STEMI patients, but also a higher risk of bleeding with GP IIb/IIIa administration. Dedicated trials have investigated the value of upstream treatment in the past. Based upon the available evidence, the routine use of i.v. or intracoronary GP IIb/IIIa inhibitor administration—regardless of whether treatment starts upstream or in the
catheterization laboratory—cannot be recommended. Especially in a setting where potent P2Y\(_{12}\) inhibitors like prasugrel or ticagrelor are used, the value of GP IIb/IIIa inhibitors remains uncertain as these agents exhibit a fast onset of action (usually <1 hour). GP IIb/IIIa inhibitors remain an option as bail-out therapy or in high-risk PCI without pretreatment with P2Y\(_{12}\) inhibitors. Of note, the bail-out scenarios have never been addressed in randomised controlled trials. For reasons discussed above (see Chapters 17.1 and 17.2), cangrelor may be considered in specific settings in P2Y\(_{12}\)-naïve patients undergoing PCI.

### 17.3.3 Post-interventional and maintenance treatment

Following PCI for STEMI, DAPT consisting of a P2Y\(_{12}\) receptor inhibitor in addition to aspirin is generally recommended for 12 months. Recommendations for maintenance DAPT treatment are generally consistent with those for NSTE-ACS patients and are detailed in chapter 17.2.3.

**Recommendations for antithrombotic treatment in ST-elevation myocardial infarction patients undergoing percutaneous coronary intervention**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class*</th>
<th>Levelº</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pretreatment and antiplatelet therapy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspirin is recommended for all patients without contraindications at an initial oral loading dose of 150–300 mg (or 75–250 mg i.v.), and at a maintenance dose of 75–100 mg daily long-term regardless of treatment strategy (^{686, 688, 724}).</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>A potent P2Y12 inhibitor (prasugrel or ticagrelor), or clopidogrel if these are not available or are contraindicated, is recommended before (or at latest at the time of) PCI and maintained over 12 months, unless there are contraindications such as excessive risk of bleeding(^{705, 706, 725, 726, 748, 749}).</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>GP IIb/IIIa inhibitors should be considered for bail-out if there is evidence of no-reflow or a thrombotic complication.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>Cangrelor may be considered in P2Y(_{12})-inhibitor naïve patients undergoing PCI (^{677}).</td>
<td>IIb</td>
<td>A</td>
</tr>
<tr>
<td>GP IIb/IIIa antagonist may be considered in P2Y(_{12})-inhibitor naïve patients undergoing PCI</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td><strong>Peri-interventional therapy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticoagulation is recommended for all patients in addition to antiplatelet therapy during PCI. (^{707, 727})</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Routine use of UFH is recommended.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Routine use of enoxaparin should be considered (^{742}).</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>Routine use of bivalirudin may be considered (^{729, 750, 752}).</td>
<td>IIb</td>
<td>A</td>
</tr>
</tbody>
</table>
17.4 CABG

Antithrombotic treatment before and after CABG is addressed in 2017 ESC Focused Update on Dual Antiplatelet Therapy in Coronary Artery Disease. After reviewing the subsequent literature, the current task force endorses the Recommendations of the Update on DAPT and does not identify the need for any major update. Accordingly, the current recommendation tables are taken from this guideline. For a detailed discussion, we refer to the previous document.

### Dual antiplatelet therapy in patients undergoing cardiac surgery

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class(^a)</th>
<th>Level(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that the heart team estimates the individual bleeding and ischaemic risks and guide the timing of CABG as well as the anti-thrombotic management.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>In patients on aspirin who need to undergo non-emergent cardiac surgery, it is recommended to continue aspirin at a low daily regimen throughout the perioperative period.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>In patients treated with DAPT after coronary stent implantation who subsequently undergo cardiac surgery, it is recommended to resume P2Y(_{12}) inhibitor therapy postoperatively as soon as deemed safe so that DAPT continues until the recommended duration of therapy is completed.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>In patients with ACS (NSTE-ACS or STEMI) treated with DAPT and undergoing CABG and not requiring long-term OAC therapy, resumption of P2Y(_{12}) inhibitor therapy as soon as deemed safe after surgery and continuation up to 12 months is recommended.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>In patients on P2Y(_{12}) inhibitors who need to undergo non-emergent cardiac surgery, it should be considered to postpone surgery for at least 3 days after discontinuation of ticagrelor, at</td>
<td>IIa</td>
<td>B</td>
</tr>
</tbody>
</table>

\(^a\)Class of recommendation.  
\(^b\)Level of evidence.
least 5 days after clopidogrel, and at least 7 days after prasugrel.\textsuperscript{753-755}

In CABG patients with prior MI who are at high risk of severe bleeding (e.g. PRECISE-DAPT ≥25), discontinuation of P2Y\textsubscript{12} inhibitor therapy after 6 months should be considered.

Platelet function testing may be considered to guide decision on timing of cardiac surgery in patients who have recently received P2Y\textsubscript{12} inhibitors.\textsuperscript{186, 756-758}

In patients perceived at high ischaemic risk with prior MI and coronary artery bypass grafting who have tolerated DAPT without a bleeding complication, treatment with DAPT for longer than 12 and up to 36 months may be considered.

ACS = acute coronary syndrome; CABG = coronary artery bypass graft surgery; DAPT = dual antiplatelet therapy; NSTE-ACS = non-ST-elevation acute coronary syndrome; OAC = oral anticoagulant; STEMI = ST-elevation myocardial infarction. PRECISE DAPT = predicting bleeding complications in patients undergoing stent implantation and subsequent dual antiplatelet therapy.

\textsuperscript{a}Class of recommendation.

\textsuperscript{b}Level of evidence.

17.5 Special conditions

17.5.1 Antithrombotic therapy after percutaneous coronary intervention in patients requiring oral anticoagulation

Compared with OAC therapy alone, the addition of DAPT to OAC therapy results in a two- to three-fold increase in bleeding complications suggesting that every effort should be undertaken to avoid bleeding (Table 8).\textsuperscript{759} Assessing the balance of ischaemic and bleeding risks of relatively short (i.e. 6 months or less) triple therapy duration as compared to double therapy consisting of clopidogrel and OAC requires a patient-by-patient decision. Of note, randomised studies evaluating the duration of triple therapy or the benefit of NOAC vs. vitamin K antagonist (VKA) were not adequately powered for assessing ischaemic events and data are lacking on the efficacy of dual therapy in patients at high risk for stroke or recurrent ACS.\textsuperscript{760-763} In the major trials, there was no interaction between the duration of triple therapy and clinical presentation (ACS vs. no ACS). The rate of bleeding events peaked within the first 30 days of initiation of triple therapy and was twice as high when compared with
the rate of acute coronary events including recurrent MI and stent thrombosis. For these reasons, duration of triple therapy should be minimized depending on bleeding and ischaemic risks (see **Tables 8 to 10** for guidance in decision making). In stabilized event-free patients, discontinuation of any antiplatelet agent at 1 year after stenting is encouraged while dual therapy may be continued beyond 1 year according to the stent-driven risk shown in **Table 9**.

Based on the favorable bleeding risk in the large phase 3 studies a NOAC should be preferred over VKA. The PIONEER\textsuperscript{762} (Prevention of bleeding in patients with AF undergoing PCI) trial discussed previously\textsuperscript{681} and the more recent Randomised Evaluation of Dual Antithrombotic Therapy with Dabigatran versus Triple Therapy with Warfarin in Patients with Nonvalvular Atrial Fibrillation Undergoing Percutaneous Coronary Intervention (RE-DUAL)\textsuperscript{763} trial compared a NOAC plus single antiplatelet therapy with triple therapy with VKA plus DAPT and consistently showed significantly lower bleeding risks with the dual antithrombotic regimen. In RE-DUAL both dosing regimens for dabigatran (150 mg and 110 mg b.i.d) vs. warfarin triple therapy were associated with a significant reduction of major or clinically relevant bleeding events. However, as compared with triple therapy an increase in both MI (4.5% vs. 3.0%, \(P = 0.09\)) and ST risk (1.5% vs. 0.8%, \(P = 0.15\)) was reported for the lower dabigatran dose (110 mg b.i.d.), but not for the higher dabigatran dose (150 mg b.i.d.). Although statistical significance was missed, these findings raise concern about the efficacy of the lower dabigatran dose in combination with single antiplatelet therapy in preventing coronary events. Thus, the 150 mg b.i.d. dose of dabigatran is preferred. At present, evidence for a dual treatment approach is available for VKA,\textsuperscript{761} rivaroxaban\textsuperscript{762} and dabigatran\textsuperscript{763}, but none of these studies were powered to assess the efficacy in preventing stent thrombosis or thromboembolic events and only RE-DUAL used a NOAC dose that was previously shown to be effective in the prevention of thromboembolic events. The ongoing AUGUSTUS trial (ClinicalTrials.gov Identifier: NCT02415400) will address the value of apixaban in a similar setting and with and without aspirin. Edoxaban is currently investigated in a setting of triple treatment in the ENTRUST-AF-PCI trial (ClinicalTrials.gov Identifier: NCT02866175).

**Figure 10** illustrates applicable DAPT algorithms in patients with an indication for oral anticoagulation undergoing PCI with the respective classes of recommendations for
the different treatment regimens. For more details on the pertinent studies in the field of triple treatment (DAPT plus OAC) and the associated issues we may refer to and the 2017 ESC Focused Update on Dual Antiplatelet Therapy in Coronary Artery Disease\textsuperscript{681}.

**Table 8 Strategies to avoid bleeding complications in OAC patients**

- Assess ischaemic and bleeding risks using validated risk predictors (e.g. CHA\textsubscript{2}DS\textsubscript{2}-VASc, ABC, HAS-BLED) with a focus on modifiable risk factors.
- Keep triple therapy duration as short as possible; dual therapy after PCI (oral anticoagulant and clopidogrel) to be considered instead of triple therapy.
- One should consider the use of NOAC instead of VKA when NOACs are not contra-indicated.
- Consider a target INR in the lower part of the recommended target range and maximize time in therapeutic range (i.e. > 65%) when VKA is used.
- Clopidogrel is the P2Y\textsubscript{12} inhibitor of choice.
- Use low-dose (≤ 100 mg daily) aspirin.
- Routine use of PPIs.

Adapted from Valgimigli et al.\textsuperscript{409}

ABC = Age, Biomarkers, Clinical history; CHA\textsubscript{2}DS\textsubscript{2}-VASc = Congestive heart failure, Hypertension, Age ≥ 75 years (doubled), Diabetes mellitus, prior Stroke or transient ischaemic attack or thromboembolism (doubled), Vascular disease, Age 65–74 years, Sex category; HAS-BLED = Hypertension, Abnormal renal/liver function, Stroke, Bleeding history or predisposition, Labile INR, Elderly, Drugs/alcohol concomitantly; INR = international normalized ratio; NOAC = non-vitamin K antagonist oral anticoagulant; PPIs = proton pump inhibitors; VKA = vitamin K antagonist.

\textsuperscript{a}Apixaban 5 mg twice daily (\textit{b.i.d.}) or apixaban 2.5 mg \textit{b.i.d.} if at least two of the following: age ≥ 80 years, body weight ≤ 60 kg or serum creatinine level ≥ 1.5 mg/dL (133 μmol/L); dabigatran 110 mg \textit{b.i.d.}; edoxaban 60 mg once daily (\textit{q.d.}) or edoxaban 30 mg \textit{q.d.} if any of the following: creatinine clearance of 30–50 mL/min, body weight ≤ 60 kg, concomitant use of verapamil or quinidine or dronedarone; rivaroxaban 20 mg \textit{q.d.} or rivaroxaban 15 mg \textit{q.d.} if creatinine clearance 30–49 mL/min.

**Table 9 High-risk features for ischaemic events**

- Prior stent thrombosis on adequate antiplatelet therapy
- Stenting of the last remaining patent coronary artery
• Diffuse multivessel disease especially in diabetic patients
• Chronic kidney disease (i.e. creatinine clearance < 60 mL/min)
• At least three stents implanted
• At least three lesions treated
• Bifurcation with two stents implanted
• Total stented length > 60 mm
• Treatment of a chronic total occlusion
• History of STEMI

STEMI = ST-elevation myocardial infarction

Table 10 Unfavourable patient profile for a combination of oral anticoagulant and antiplatelet therapy

- Short life expectancy
- Ongoing malignancy
- Poor expected adherence
- Poor mental status
- End stage renal failure
- Advanced age
- Prior major bleeding/prior haemorrhagic stroke
- Chronic alcohol abuse
- Anaemia
- Clinically significant bleeding on dual antithrombotic therapy

Dual antiplatelet therapy duration in patients with indication for oral anticoagulation

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended to administer periprocedural aspirin and clopidogrel in patients undergoing coronary stent implantation.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>In patients treated with coronary stent implantation, triple therapy with aspirin, clopidogrel and OAC should be considered for 1 month, irrespective of the type of stent used.</td>
<td>Ila</td>
<td>B</td>
</tr>
<tr>
<td>Triple therapy with aspirin, clopidogrel and OAC for longer than 1 month and up to 6 months should be considered in</td>
<td>Ila</td>
<td>B</td>
</tr>
</tbody>
</table>
patients with high ischaemic risk due to ACS or other anatomical/procedural characteristics, which outweigh the bleeding risk.  

Dual therapy with clopidogrel 75 mg/day and OAC should be considered as an alternative to 1-month triple antithrombotic therapy in patients in whom the bleeding risk outweighs the ischaemic risk.  

In patients with an indication for VKA in combination with aspirin and/or clopidogrel, the dose intensity of VKA should be carefully regulated with a target INR in the lower part of the recommended target range and a time in the therapeutic range > 65%.  

In patients with non-valvular AF requiring anticoagulation and antiplatelet treatment, a NOAC should be preferred over VKAs.  

When a NOAC is used in combination with aspirin and/or clopidogrel, the lowest approved dose effective for stroke prevention tested in AF trials should be considered.  

When rivaroxaban is used in combination with aspirin and/or clopidogrel, rivaroxaban 15 mg q.d. may be used instead of rivaroxaban 20 mg q.d.  

When dabigatran is used in combination with aspirin and/or clopidogrel, the dose of 150 mg b.i.d may be preferred over the dose of 110 mg b.i.d.  

The use of ticagrelor or prasugrel is not recommended as part of triple antithrombotic therapy with aspirin and OAC.  

ACS = acute coronary syndrome; AF = atrial fibrillation; b.i.d. = twice daily; INR = international normalized ratio; OAC = oral anticoagulant; NOAC = non-vitamin K oral anticoagulant; q.d. = once daily; VKA = vitamin K antagonist.  

\( ^{a} \)Class of recommendation.  

\( ^{b} \)Level of evidence.  

\( ^{c} \)Apixaban 5mg b.i.d or apixaban 2.5 mg b.i.d. if at least two of the following: age > 80 years, body weight < 60 kg or serum creatinine level > 1.5 mg/dL (133 lmol/L); dabigatran 110 mg or 150 mg b.i.d.; edoxaban 60 mg q.d. or edoxaban 30 mg q.d. if any of the following: CrCl of
30–50 mL/min, body weight <_60 kg, concomitant use of verapamil, quinidine, or dronedarone; rivaroxaban 20 mg q.d. or rivaroxaban 15 mg q.d. if CrCl 30–49 mL/min.

Figure 10: Algorithm for dual antiplatelet therapy (DAPT) in patients with an indication for oral anticoagulation undergoing percutaneous coronary intervention (PCI). Colour-coding refers to the number of concomitant antithrombotic medication(s). Triple therapy denotes treatment with DAPT plus oral anticoagulant (OAC). Dual therapy denotes treatment with a single antiplatelet agent (aspirin or clopidogrel) plus OAC.

ABC = age, biomarkers, clinical history; ACS = acute coronary syndrome; mo. = month(s); PCI = percutaneous coronary intervention.

1: Periprocedural administration of aspirin and clopidogrel during PCI is recommended irrespective of the treatment strategy.
2: High ischaemic risk is considered as an acute clinical presentation or anatomical/procedural features which might increase the risk for myocardial infarction.
3: Bleeding risk can be estimated by HAS-BLED or ABC score.

17.5.2 Revascularisation in patients with renal failure
17.5.3 Monitoring of antiplatelet drugs (platelet function testing and genotyping)

See Web Addenda

17.5.4 Surgery in patients on dual antiplatelet therapy

See 2017 ESC Focused Update on Dual Antiplatelet Therapy in Coronary Artery Disease

17.6 Gaps in evidence

- The value of pre-hospital pretreatment with prasugrel in STEMI patients, as well as the safety and efficacy of ticagrelor given at hospital admission in NSTE-ACS patients, has not been addressed in dedicated randomised studies.

- The safety and efficacy of short-term potent antiplatelet treatment with either prasugrel or ticagrelor in stable CAD patients is unknown and subject to ongoing clinical trials (ALPHEUS (Assessment of Loading With the P2Y<sub>12</sub> Inhibitor Ticagrelor or Clopidogrel to Halt Ischemic Events in Patients Undergoing Elective Coronary Stenting) trial: NCT02617290; SASSICAIA (Comparison of Loading Strategies With Antiplatelet Drugs in Patients Undergoing Elective Coronary Intervention) trial: NCT02548611).

- The clinical benefit of a short-term DAPT duration followed by long-term ticagrelor monotherapy (and stopping aspirin) remains unknown. The ongoing GLOBAL LEADERS (Long-term ticagrelor monotherapy versus standard dual antiplatelet therapy followed by aspirin monotherapy in patients undergoing biolimus-eluting stent implantation) and TWILIGHT (Ticagrelor With Aspirin or Alone in High-Risk Patients After Coronary Intervention) trials aim at closing this gap in knowledge (NCT01813435, NCT02270242).

18. Volume–outcome relationship for revascularisation procedures

Operator experience influences outcomes, particularly in critical, complex situations. The greater total experience of an entire hospital team—consisting of supporting members in the operating room or catheterization laboratory and those responsible for postoperative care—results in favorable outcomes.
18.1 Coronary artery bypass grafting

A number of studies have suggested that the CABG volume in a hospital significantly impacts in-hospital mortality, although no consistent cut-offs for volume are used in these studies.\(^764\)\(^765\)\(^766\) This increase in mortality observed in lower volume centres seems to be attributable to so-called “failure to rescue”: although patients operated at low-volume centres are not at particularly higher risk of suffering a major complication, they are more likely to die from such a complication, should it occur.\(^767\) Therefore, consideration should be given to performance of CABG in centres with an annual volume of at least 200 CABG cases. Apart from hospital volume, higher surgeon volume also appears to be inversely related to operative mortality. Birkmeyer and co-authors provided evidence suggesting that both hospital and surgeon have some impact on outcomes.\(^768\)

Several studies suggest that quality measures are more important than volume per se.\(^769\)\(^770\) Missing quality indicators in hospitals strongly predicted mortality, irrespective of surgeon or hospital case volume.\(^771\) Therefore, it is recommended that such quality measures (see as an example Supplementary Table 9) are adopted and reported to facilitate focused quality improvement (see Recommendation Tables).\(^772\)

18.2 Percutaneous coronary intervention

Numerous studies have investigated the relationship between volume of procedures and outcomes of PCI, suggesting a volume–outcome relationship at operator level, as well as at institutional level.\(^764\)\(^773\)-\(^777\) A population-based study from the PCI reporting system of New York indicated that hospital case volumes < 400 PCIs per year and operator case volumes < 75 PCIs per year were associated with impaired outcomes.\(^773\)

Among patients with ACS, particularly STEMI, operator and hospital volume play an important role. A large study in the USA reported that, in a cohort of 36 535 patients undergoing primary PCI, in-hospital mortality was significantly lower in institutions with higher primary PCI volumes (5.7% in hospitals performing >33 primary PCIs/year vs. 7.7% in hospitals performing <12 primary PCIs/year).\(^778\)
Operator volume has also been shown to impact outcomes in LM PCI. A single-centre study of 1948 patients who underwent unprotected LM PCI, performed by 25 operators over a 7-year period, showed reduced 30-day and 3-year mortality for patients who had their PCI performed by a high-volume operator (defined as ≥ 15 LM PCI/year; mean 25/year) vs. a low volume operator (< 15 LM PCI/year). An example of quality measures for PCI is provided in Supplementary Table 10.

18.3 Training in cardiac surgery and interventional cardiology for myocardial revascularisation

A European training programme in interventional cardiology has been proposed by the European Association for Percutaneous Cardiovascular Interventions (EAPCI) in order to ensure high quality of patient care and clinical excellence. The programme should last 1–2 years at high-volume institutions that handle at least 800 PCIs per year and that have established 24-hour/7-day service for the treatment of patients with ACS.

For CABG, no standardized European programme exists at this time. The pace at which proficiency reaches certain acceptable standards, however, differs from trainee to trainee. Therefore, although it is recommended that trainees perform at least 200 CABG procedures under supervision before becoming completely independent, a competency-driven residency programme with regular evaluation of progress is recommended over a volume-driven programme.

Recommendations for operator/institutional volume in myocardial revascularisation

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It should be considered that CABG is performed at institutions with an annual institutional volume of at least 200 CABG cases.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>PCI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It should be considered that PCI for ACS is performed by trained operators with an annual</td>
<td>IIa</td>
<td>C</td>
</tr>
</tbody>
</table>
It should be considered that PCI for SCAD is performed by trained operators with an annual volume of at least 75 procedures at institutions performing at least 200 PCIs per year.

It should be considered that institutions with an annual volume of fewer than 400 PCIs collaborate in networks with higher-volume institutions (more than 400 PCIs per year), with shared written protocols and exchange of operators and support staff.

It should be considered that PCI for LM is performed by trained operators with an annual volume of at least 25 LM PCI cases per year.

It should be considered that non-emergency high-risk PCI procedures, such as for LM disease, single remaining patent coronary artery, and complex chronic total occlusions, are only performed by adequately experienced operators at centres that have access to circulatory support and intensive care treatment.

ACS = acute coronary syndromes; CABG = coronary artery bypass grafting; ESC = European Society of Cardiology; LM = left main; PCI = percutaneous coronary intervention; SCAD = stable coronary artery disease.

aClass of recommendation.

bLevel of evidence

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training in CABG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is recommended that trainees in cardiac surgery and interventional cardiology follow a competency-</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>
driven residency programme with regular evaluation of progression.

It should be considered that trainees in cardiac surgery perform at least 200 CABG procedures under supervision before being independent.

**Training in PCI**

It should be considered that trainees in interventional cardiology perform at least 200 PCI procedures as first operator with one-third of PCI procedures in emergency or ACS patients under supervision before being independent.

It should be considered that trainees in interventional cardiology complete formal training according to a 1–2 year curriculum at institutions with at least 800 PCIs per year and an established 24-hour/7-day service for the treatment of patients with ACS.

ACS = acute coronary syndrome; CABG = coronary artery bypass grafting; PCI = percutaneous coronary intervention.

*a Class of recommendation.

*b Level of evidence.

**Recommendations for outcome registration, monitoring, and benchmarking**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class(^a)</th>
<th>Level(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that specific quality performance measures for CABG are adopted on a national level to allow outcome monitoring and benchmarking.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>It is recommended that national societies establish national databases on CABG practice and outcomes.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>It is recommended to report CABG outcome data by hospital to national databases.</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass grafting;

\(^a\) Class of recommendation.

\(^b\) Level of evidence.
19. Medical therapy, secondary prevention, and strategies for follow-up

Myocardial revascularisation must be accompanied by medical therapy and other secondary prevention strategies for risk factor modification and permanent lifestyle changes. Secondary prevention and cardiac rehabilitation are an integral part of the management after revascularisation because such measures reduce future morbidity and mortality in a cost-effective way and can further improve symptoms. These measures are discussed in detail in the European Guidelines on Cardiovascular Disease Prevention published in 2016.

The need to detect restenosis has been reduced in the DES era. 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. Nevertheless, recurrence of symptoms or ischaemia due to disease progression or restenosis deserve attention.

Strategies for follow-up and management in patients after myocardial revascularisation

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Classa</th>
<th>Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>After CABG or PCI for acute myocardial infarction participation in a cardiac rehabilitation programme is recommended to improve patient outcomes.</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>It is recommended to start and reinforce secondary prevention measures including medical therapy and lifestyle changes after myocardial revascularisation</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>It is recommended to re-evaluate patients after myocardial revascularisation (e.g. at 3 months and thereafter at least on an annual basis) in order to reassess symptoms and adherence with secondary prevention measures and reinforce medical therapy and lifestyle changes when appropriate</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Symptomatic patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary angiography is recommended in patients</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>
An imaging stress test should be considered in patients with prior revascularisation over stress ECG.

### Asymptomatic patients

- **Surveillance by non-invasive imaging based stress testing** may be considered in high-risk patient subsets 6 months after revascularisation.  
  - **IIb**  
  - **C**

- **After high-risk PCI (e.g. unprotected LM stenosis) late (3–12 months) surveillance angiography may be considered, irrespective of symptoms.**  
  - **IIb**  
  - **C**

- **Routine non-invasive imaging based stress testing may be considered 1 year after PCI and > 5 years after CABG.**  
  - **IIb**  
  - **C**

CABG = coronary artery bypass grafting; LM = left main; PCI = percutaneous coronary intervention.

aClass of recommendation.

bLevel of evidence.

cAbsence of intermediate- and high-risk findingsd.

dIntermediate- and high-risk findings at stress imaging are ischaemia at low workload with exercise stress testing, early onset ischaemia with pharmacological stress testing, inducible wall motion abnormality or reversible perfusion defect in ≥10% of LV myocardium

### 19.1 Gaps in evidence

In all studies on the optimal follow-up after PCI, the gain from discovering patients with restenosis is obscured by the high rate of false positive exercise ECG tests indicating ischaemia. Therefore, simple exercise ECG testing is not recommended for follow-up and a non-invasive imaging approach is preferred. Specific studies to clarify which subset of patients benefits more from a specific follow-up approach are missing. More studies are needed to assess the role of CT angiography in patient surveillance after myocardial revascularisation.
20. Key messages

1. Myocardial revascularisation is performed for relief of symptoms of myocardial ischaemia and improvement of prognosis. In SCAD, the prognostic benefit is dependent on the extent of myocardium subject to ischaemia.

2. The prognostic and symptomatic benefit of myocardial revascularisation critically depends on the completeness of revascularisation. Therefore, the ability to achieve complete revascularisation is a key issue when choosing the appropriate treatment strategy.

3. Apart from issues of individual operative risk and technical feasibility, diabetes mellitus and anatomical complexity of CAD determine the relative benefits of PCI and CABG.

4. The SYNTAX score is the recommended tool to gauge the anatomical complexity of coronary disease.

5. In some instances, both PCI and CABG are equally reasonable or sometimes even equally problematic options. This calls for the Heart Team to be consulted to develop individualised treatment concepts with respect for the preferences of the patient informed about early and late outcomes.

6. Timely PCI of the culprit lesion remains the mainstay of treatment of ACS.

7. After PCI of the culprit lesion in ACS, choice of further revascularisation modality should follow the criteria applied to patients with SCAD.

8. Radial access is preferred for any PCI irrespective of clinical presentation, unless there are overriding procedural considerations.

9. DES are recommended for any PCI irrespective of clinical presentation, lesion type, anticipated duration of DAPT or concomitant anticoagulant therapy.

10. Even though 6 months DAPT is generally recommended after PCI in SCAD and 12 months of DAPT after ACS, the type and duration of DAPT should be individualised according to the ischaemic risk and the bleeding risk and appropriately adapted during follow-up. Based on this judgement, treatment durations for DAPT after DES as short as 1 month or as long as life-long may be reasonable.

11. Off-pump surgery with no touch aorta for high risk patients should be considered when expertise exists.
12. Multiple arterial grafting should be considered using the radial artery for high-grade stenosis and/or bilateral internal mammary artery grafting for patients who do not have an increased risk of sternal wound infection.
## 21. Evidence-based “To do a and not to do” messages

<table>
<thead>
<tr>
<th>Risk models to assess short- and long-term outcomes after myocardial revascularisation</th>
<th>Class(^a)</th>
<th>Level(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>When evidence of ischaemia is not available, FFR or iFR are recommended to assess the haemodynamic relevance of intermediate-grade stenosis</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>It is recommended to calculate the STS score to assess in-hospital or 30-day mortality, and in-hospital morbidity after CABG.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>In patients with LM or multivessel disease it is recommended to calculate the SYNTAX score to assess the anatomical complexity of CAD and the long-term risk of mortality and morbidity after PCI.</td>
<td>I</td>
<td>B</td>
</tr>
</tbody>
</table>

### Indications for revascularisation in patients with stable angina or silent ischaemia

<table>
<thead>
<tr>
<th>For prognosis</th>
<th>For symptoms</th>
<th>CABG</th>
<th>PCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM disease with stenosis &gt; 50(^c)</td>
<td>Any haemodynamically significant coronary stenosis in the presence of limiting angina or angina equivalent, , with insufficient response to optimized medical therapy</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Any proximal LAD stenosis &gt; 50(^c)</td>
<td></td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Two-vessel or three-vessel disease with stenosis &gt; 50(^c) with impaired LV function (LVEF ≤ 35(^c))</td>
<td></td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Large area of ischaemia detected by functional testing (&gt; 10% LV) or abnormal invasive FFR(^d)</td>
<td></td>
<td>I</td>
<td>B</td>
</tr>
</tbody>
</table>

### Type of revascularisation (CABG or PCI) in patients with SCAD in the absence of diabetes with suitable coronary anatomy for both procedures and low predicted surgical mortality

<table>
<thead>
<tr>
<th>Recommendations according to extent of CAD</th>
<th>CABG</th>
<th>PCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>One vessel CAD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with proximal LAD stenosis</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Two-vessel CAD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with proximal LAD stenosis</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Left main CAD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left main with low SYNTAX score 0–22</td>
<td>I</td>
<td>A</td>
</tr>
</tbody>
</table>
### Invasive evaluation and revascularisation in NSTE-ACS

<table>
<thead>
<tr>
<th>Left main with intermediate SYNTAX score &gt; 22 ≤32</th>
<th>I</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left main with high SYNTAX score &gt;32</td>
<td>I</td>
<td>A</td>
</tr>
</tbody>
</table>

**Urgent** coronary angiography (< 2 hours) is recommended in patients at very high ischaemic risk (Figure 3).

**An early** invasive strategy (< 24 hours) is recommended in patients with at least one high-risk criterion (Figure 3).

An invasive strategy (< 72 hours after first presentation) is indicated in patients with at least one intermediate-risk criterion (Figure 3) or recurrent symptoms.

It is recommended to base the revascularisation strategy (*ad hoc* culprit-lesion PCI/multivessel PCI/CABG) on the **clinical status** and comorbidities as well as the **disease severity**, i.e. distribution and angiographic lesion characteristics (e.g. SYNTAX score), according to the principles for SCAD.

In cardiogenic shock, routine revascularisation of non-IRA lesions is not recommended during primary PCI.

### Primary PCI for myocardial reperfusion in STEMI

#### Indication

Reperfusion therapy is indicated in all patients with time from symptom onset < 12 hours duration and persistent ST-segment elevation.

A primary PCI strategy is recommended over fibrinolysis within indicated timeframes.

#### Logistics

It is recommended that the prehospital management of STEMI patients be based on regional networks designed to deliver reperfusion therapy timely and effectively, and to offer primary PCI to as many patients as possible.

It is recommended that primary PCI-capable centres deliver a 24-hour/7-day service and ensure for primary PCI to be performed as fast as possible.

Patients transferred to a PCI-capable centre for primary PCI should bypass the emergency department and be transferred directly to the catheterization laboratory.
<table>
<thead>
<tr>
<th>Strategy/Technique</th>
<th>Level</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>In cardiogenic shock, routine revascularisation of non-IRA lesions is not recommended during primary PCI.</td>
<td>III</td>
<td>B</td>
</tr>
<tr>
<td>Routine use of thrombus aspiration is not recommended.</td>
<td>III</td>
<td>A</td>
</tr>
<tr>
<td><strong>Recommendations on revascularisations in patients with chronic heart failure and systolic LV dysfunction (ejection fraction ≤ 35%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In patients with severe LV systolic dysfunction and coronary artery disease suitable for intervention, myocardial revascularisation is recommended.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>CABG is recommended as first revascularisation strategy choice in patients with multivessel disease and acceptable surgical risk.</td>
<td>I</td>
<td>B</td>
</tr>
</tbody>
</table>

### Revascularisations in patients with cardiogenic shock

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Level</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency invasive evaluation is indicated in patients with acute heart failure or cardiogenic shock complicating ACS.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Emergency PCI is indicated for patients with cardiogenic shock due to STEMI or NSTE-ACS independent of time delay of symptom onset if coronary anatomy is amenable.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Emergency CABG is recommended for patients with cardiogenic shock if the coronary anatomy is not amenable to PCI.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Routine use of IABP in patients with cardiogenic shock due to ACS is not recommended.</td>
<td>III</td>
<td>B</td>
</tr>
</tbody>
</table>

### Recommendations for revascularisation in patients with diabetes

In patients with stable multivessel CAD and an acceptable surgical risk, CABG is recommended over PCI.                                      | I     | A     |

### Prevention of contrast-induced nephropathy

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Dose</th>
<th>Level</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patients with moderate-to-severe CKD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of low-osmolar or iso-osmolar contrast media is recommended.</td>
<td></td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>It is recommended to minimize volume of contrast media.</td>
<td>total contrast volume/GFR &lt; 3.7.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td><strong>Severe CKD</strong></td>
<td></td>
<td>III</td>
<td>B</td>
</tr>
<tr>
<td>Haemodialysis therapy is not</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
recommended as a preventive measure.

### Preoperative strategies to reduce the incidence of stroke in patients undergoing CABG

In patients undergoing CABG, carotid DUS is recommended in patients with recent (< 6 months) history of stroke/TIA.  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
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<tbody>
<tr>
<td>I</td>
<td>B</td>
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</table>

### Disease progression and late graft failure

Repeat revascularisation is indicated in patients with extensive ischaemia or severe symptoms despite medical therapy.  

<table>
<thead>
<tr>
<th>Recommendation</th>
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<tbody>
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<td>I</td>
<td>B</td>
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</table>

IMA is the conduit of choice for redo CABG in patients in whom the IMA was not used previously.  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>B</td>
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</tbody>
</table>

DES are recommended for the treatment of in-stent restenosis within BMS or DES.  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A</td>
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</tbody>
</table>

Drug-coated balloons are recommended for the treatment of in-stent restenosis within BMS or DES.  

<table>
<thead>
<tr>
<th>Recommendation</th>
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</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A</td>
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</tbody>
</table>

### Prevention of ventricular arrhythmias by revascularisation

A primary PCI strategy is recommended in patients with resuscitated cardiac arrest and an SCG consistent with STEMI.  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
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<tbody>
<tr>
<td>I</td>
<td>B</td>
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</tbody>
</table>

Peri-operative oral beta-blocker therapy is recommended for the prevention of postoperative AF after CABG surgery.  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>B</td>
</tr>
</tbody>
</table>

### Procedural aspects of CABG

Arterial grafting with IMA to the LAD system is recommended.  

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>I</td>
<td>B</td>
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</tbody>
</table>

Use of the radial artery is recommended over saphenous vein in patients with high-degree stenosis.  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A</td>
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</tbody>
</table>

Skeletonized IMA dissection is recommended in patients with high risk of sternal wound infection.  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>B</td>
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</tbody>
</table>

Minimization of aortic manipulation is recommended.  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
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<td>I</td>
<td>B</td>
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</table>

Off-pump CABG should be considered for subgroups of high-risk patients by experienced off-pump teams.  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>B</td>
</tr>
</tbody>
</table>

### Procedural aspects of PCI

DES are recommended over BMS for any PCI irrespective of:  
- clinical presentation  
- lesion type  
- planned non-cardiac surgery  

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A</td>
</tr>
</tbody>
</table>
anticipated duration of DAPT concomitant anticoagulant therapy.

Radial access is recommended as the standard approach, unless there are overriding procedural considerations.  

Stent implantation in the main vessel only, followed by provisional balloon angioplasty with or without stenting of the side branch, is recommended for PCI of bifurcation lesions.

<table>
<thead>
<tr>
<th><strong>Antithrombotic treatment in SCAD patients undergoing PCI</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment with 600 mg clopidogrel is recommended in elective PCI patients once anatomy is known and decision to proceed with PCI.</strong></td>
</tr>
<tr>
<td>Aspirin is indicated before elective stenting.</td>
</tr>
<tr>
<td>Clopidogrel (600 mg loading dose, 75 mg daily maintenance dose) is recommended for elective stenting.</td>
</tr>
<tr>
<td>UFH is indicated as a standard anticoagulant (70–100 U/kg).</td>
</tr>
<tr>
<td>Life-long single antiplatelet therapy, usually aspirin, is recommended.</td>
</tr>
<tr>
<td>In patients with SCAD treated with coronary stent implantation, DAPT consisting of clopidogrel in addition to aspirin is generally recommended for 6 months, irrespective of the stent type.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Antithrombotic treatment in NSTE-ACS patients undergoing PCI</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspirin is recommended for all patients without contraindications at an initial oral loading dose of 150–300 mg (or 75–250 mg i.v.), and at a maintenance dose of 75–100 mg daily long-term regardless of treatment strategy.</td>
</tr>
<tr>
<td>A P2Y\textsubscript{12} inhibitor is recommended in addition to aspirin, and maintained over 12 months unless there are contraindications such as excessive risk of bleeding. Options are:</td>
</tr>
<tr>
<td>• Prasugrel in P2Y\textsubscript{12}-naïve patients who proceed to PCI (60 mg loading dose, 10 mg daily dose)</td>
</tr>
<tr>
<td>• Ticagrelor irrespective of the pretreatment and revascularisation strategy (180 mg loading dose, 90 mg twice daily)</td>
</tr>
<tr>
<td>• Clopidogrel (600 mg loading dose, 75 mg daily dose), only when prasugrel or ticagrelor are not available or are contraindicated.</td>
</tr>
<tr>
<td>Pretreatment with GP IIb/IIIa antagonists in patients in whom coronary anatomy is not known is not recommended.</td>
</tr>
</tbody>
</table>
It is not recommended to administer prasugrel in patients in whom coronary anatomy is not known.

| Peri-interventional anticoagulation is recommended for all patients in addition to antiplatelet therapy. |
|---|---|
| In patients on fondaparinux (2.5 mg daily s.c.), a single bolus UFH (85 IU/kg, or 60 IU in the case of concomitant use of GP IIb/IIIa receptor inhibitors) is indicated. |
| Crossover of UFH and LMWH is not recommended. |
| In patients with ACS treated with coronary stent implantation, DAPT with a P2Y₁₂ inhibitor on top of aspirin is recommended for 12 months unless there are contraindications such as excessive risk of bleeding (e.g. PRECISE-DAPT ≥ 25). |

**Antithrombotic treatment in STEMI patients undergoing PCI**

| Aspirin is recommended for all patients without contraindications at an initial oral loading dose of 150–300 mg (or 75–250 mg i.v.), and at a maintenance dose of 75–100 mg daily long-term regardless of treatment strategy. |
| A potent P2Y₁₂ inhibitor (prasugrel or ticagrelor), or clopidogrel if these are not available or are contraindicated, is recommended before (or at latest at the time of) PCI and maintained over 12 months, unless there are contraindications such as excessive risk of bleeding. |

**Strategies for follow-up and management**

| After CABG or PCI for acute myocardial infarction participation in a cardiac rehabilitation programme is recommended to improve patient outcomes. |
| It is recommended to start and reinforce secondary prevention measures including medical therapy and lifestyle changes after myocardial revascularisation. |

ACS = acute coronary syndrome; BMS = bare metal stent; BRS = bioresorbable scaffolds; CABG = coronary artery bypass grafting; CKD = chronic kidney disease; DAPT = dual antiplatelet therapy; DES = drug eluting stents; DUS = duplex ultrasound; ECG = electrocardiogram; FFR = fractional flow reserve; GFR = glomerular filtration rate; GP = glycoprotein; IABP = intra-aortic balloon pump; iFR = instantaneous wave-free radio; IMA = internal mammary artery; i.v. = intravenous; LAD = left anterior descending; LBBB = left bundle branch block; LM = left main; LMWH = low-molecular-weight heparin; LV = left
ventricular; LVEF = left ventricular ejection fraction; MACCE = major adverse cardiac and cerebrovascular event; NSTE-ACS = non-ST-elevation acute coronary syndrome; PCI = percutaneous coronary intervention; PRECISE-DAPT = PREdicting bleeding Complications In patients undergoing Stent implantation and subsEquent Dual Anti Platelet Therapy; s.c. = subcutaneous; SCAD = stable coronary artery disease; STEMI = ST-elevation myocardial infarction; STS = Society of Thoracic Surgeons; SVG = saphenous vein graft; SYNTAX = Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery; TIA = transient ischaemic attack; UFH = unfractionated heparin.

\(^a\)Class of recommendation.

\(^b\)Level of evidence.

\(^c\)With documented ischaemia or FFR ≤ 0.80, iFR ≤ 0.89 or diameter stenosis ≥ 90%.

\(^d\)Based on clinical judgment and FFR < 0.75

\(^e\)These recommendations refer to stents which are supported by large-scale randomised trials with clinical endpoint evaluation leading to unconditional CE mark (53).
22. References

Please note that in the final version, the references in the main document will be moved en bloc to the supplementary appendix with only references from 2015 on retained (as in the last version). After this round, the medical writer stage is planned. In order to facilitate edits arising from the medical writer, this version contains active citation tags and the full reference list. It is planned to eliminate the tags and finalize the reference list at this stage. We hope this is acceptable.


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