

TECHNICAL ASPECTS OF REVASCULARIZATION

Coronary artery by-pass grafting (CABG)

Contemporary CABG procedures carry a **1-2% peri-operative mortality, 0.3-10% risk of myocardial infarction, 2-4% of reoperation for bleeding, 1-4% of wound infection, 0.5-1% renal failure, 1-3% of stroke, and 0.5-3% mediastinitis.**¹⁻³ Five and 10-year survival rates with modern techniques are approximately 80% and 75%.² The beneficial effects of CABG may not last beyond 10 years after surgery, presumably due to the limited longevity of used grafts (Table 1). Grafting a coronary artery increases the risk of disease progression 3 to 6 times, especially in the right coronary artery.⁴ Isolated elevations in cTnT ≥ 7 upper reference limit (URL) and/or cTnI ≥ 20 URL in the 48-h post-operative period may indicate the presence of prognostically significant peri-operative myocardial injury, and should prompt clinical evaluation to exclude Type 5 MI. Where ECG/angiography/imaging evidence of MI is available, lower levels of biomarker elevation (cTn $\times 10$ URL) should be considered for diagnosing prognostically significant myocardial injury, as per the Universal MI definition.⁵ However, the clinically significant cut-offs for enzyme rise are not established,⁶ and isolated biomarker release is not a feasible means of detecting prognostically relevant myocardial injury after surgery.⁷

Type of grafts

Saphenous vein grafts (SVGs) remain the most frequently used conduits in CABG. Despite advances in surgical techniques and pharmacotherapy, SVG failure rates remain high, often leading to repeat coronary revascularization (Table 1).⁸ At 12-18 months after CABG, 17-25% of **vein grafts** have failed, and 34% of patients had at least one failed graft,^{9, 10} while at 10 years only about half of saphenous vein grafts are patent, and of those only half are free of angiographic arteriosclerosis.¹¹ The **no-touch SVG harvesting** technique (minimal graft manipulation with preservation of vasa vasorum and nerves) theoretically reduces the risk of SVG failure,⁸ but its superiority to conventional harvesting is not established.¹² Intermediate (30%–60%) SVG stenoses often progress rapidly. Stenting of intermediate SVG stenoses failed to improve outcomes; hence, treatment focuses on strict control of coronary artery disease risk factors. Perioperative aspirin and high-intensity statin administration are the cornerstones of secondary prevention after CABG. Redo CABG is associated with higher perioperative mortality compared with percutaneous coronary intervention (PCI); hence, the latter is preferred for most patients requiring repeat revascularization after CABG.⁸ SVG PCI is limited by high rates of no-reflow and a high incidence of restenosis during follow-up.

Embololic protection devices reduce no-reflow and should be used when feasible.⁸

Aortocoronary **saphenous vein graft aneurysms** occur with an approximate incidence of 0.07% as a late complication of CABG, but this is probably an underestimation. They are associated with significant morbidity and mortality since they grow with time and percutaneous or surgical management is recommended.¹³

The use of the **left internal thoracic artery (LITA)** to the LAD is superior to venous grafts (SVG) and the right internal thoracic artery is preferable to the radial to the best recipient vessel after the LAD (Table 2).^{11, 14} **Bilateral internal thoracic artery grafting** is theoretically superior to single LITA, but this was not verified by the three RCTS published so far.¹⁵ The largest of them, the ART randomized trial, demonstrated similar clinical outcomes for single and bilateral internal thoracic artery use at 1 year, but bilateral grafts were associated with a small absolute increase (1.3%) in the need for sternal wound reconstruction.¹⁶ At 10 years, there was no significant between-group difference in the rate of death from any cause in the intention-to-treat analysis.¹⁷ In retrospective analyses, bilateral internal thoracic artery grafting was associated with a reduced risk of repeat revascularization and an improvement in long-term survival compared to use of a single LITA.¹⁸ The use of bilateral internal thoracic arteries is therefore promising, but the right internal thoracic artery may be associated with an increased risk of sternal wound infection compared to the radial artery without a clear benefit.¹⁹ “Skeletonization” of ITA grafts is associated with a lower rate of sternal wound complications,²⁰ endoscopic harvesting is associated with reduced SVG patency, and no-touch technique of SVG harvesting that reduces endothelial injury has shown superior long-term patency when compared with conventional harvesting.²¹ A difference in these surgical techniques may not become evident until 10 years, during which time >95% of ITAs remain patent, in contrast to only 32-71% of saphenous veins. LITA failure is associated with intermediate LAD stenosis without functional evidence of ischaemia, due to competitive flow, and grafting should be avoided in this setting.²² Anterior ischemia in the presence of a patent anastomosed LITA may suggest subclavian steal syndrome, ie proximal subclavian stenosis.²³

Multiple arterial grafts result in a lower rate of cardiac events compared to vein grafts.²⁴⁻²⁶ **Radial artery** grafts may offer a patency comparable that of LITA when they are used to graft a vessel with >90% stenosis.^{25, 27} In a meta-analysis of 6 RCTs (RADIAL), the use of radial artery grafts for CABG resulted in a lower rate of adverse cardiac events and a higher rate of patency at 5 years of follow-up, compared with the use of saphenous vein grafts.²⁴ The 10-year patency rate of the radial artery is also significantly higher than that of the free RITA and better than that of the SV (RAPCO-RITA RCT).²⁸ The only situation in which a **SVG** may have a better patency than an ITA graft is when used to bypass a moderately stenotic (50-70%) RCA, probably due to less competitive flow.²⁹ If one radial

artery has been used for coronary angiography or intervention, the contralateral one should be used for grafting, or, perhaps, the same one but at least 3 months after the coronary procedure.³⁰ Endoscopic vein graft harvesting is not inferior to open vein graft harvesting when performed by experienced operators (REGROUP trial).³¹

Diabetes does not appear to influence long-term patency of bypass grafts, either arterial or venous.³² Bypassing **intermediate lesions** can result in more rapid progression of native vessel disease as well as accelerated graft failure, and FFR might be useful in identifying significant lesions that deserve bypass grafting.³³ A significant association between preoperative FFR and anastomotic arterial graft function at 6 months in CABG patients has been demonstrated. Arterial grafts to target vessels with FFR <0.78 had extremely high patency rate at 6 months.³⁴

Off-pump beating heart bypass surgery

A reduced risk of stroke with off-pump beating heart bypass surgery (OPCAB), that was suggested by a meta-analysis,³⁵ has not been verified in the largest randomized trials so far. In RCTs, similar³⁶⁻³⁸ or even worse outcomes (ROOBY trial)^{39, 40} with OPCAB have been reported, and the issue of less effective revascularization with this approach has been raised with a resultant worse long-term survival compared to on-pump surgery.⁴¹⁻⁴³ Among patients with left main disease treated with CABG in the EXCEL trial, off-pump surgery was also associated with an increased risk of 3-year all-cause death compared with on-pump surgery.⁴⁴ Off-pump surgery may be protective against new-onset ventricular arrhythmias,⁴⁵ and reduces stroke when completely avoiding aortic manipulation by a no-touch, total arterial off-pump CABG.⁴⁶ In the elderly no difference between the two modalities has been detected, but incomplete revascularization, irrespective of the type, was associated with worse survival.⁴⁷ Dual antiplatelet therapy is recommended for off-pump CABG.⁸

Minimally invasive and robotic CABG

These mainly involve harvesting of a LIMA and off-pump anastomosis to LAD, and are currently under investigation.²

Shockwave therapy

Shockwave therapy has been shown to induce angiogenesis in the hibernating myocardium and trigger myocardial regeneration effects.⁴⁸ Direct cardiac shockwave therapy, in addition to coronary bypass surgery has been shown to improve LVEF and physical capacity in patients with ischaemic heart failure.⁴⁹

Other issues

The European System for Cardiac Operative Risk Evaluation, **logistic EuroSCORE and EuroSCORE II** (www.euroscore.org) and the **Society of Thoracic Surgeons STS score** (<http://riskcalc.sts.org>) that is probably more accurate in high risk patients (ACC/AHA SCAI 2021 GL on revascularization I B-NR), are useful guides for

calculation of the intraoperative risk. Additional risk factors not quantified by the STS score are cirrhosis, frailty and malnutrition.⁵⁰ The prevalence of **severe carotid disease** (> 80% stenosis of the internal carotid artery) among patients undergoing **coronary artery bypass grafting is 6-12%,⁵¹ but the optimum management of concomitant** carotid disease of this population remains controversial. Observational studies have suggested that a combined endarterectomy and CABG or staged carotid stenting followed by CABG is superior to staged endarterectomy followed by CABG at a later stage,^{52, 53} but in the first RCT on the subject, although underpowered, no benefit of simultaneous CABG and carotid endarterectomy was seen.⁵⁴ In the ESC 2024 GL on aortic and peripheral diseases, carotid endarterectomy in general is now considered in stenosis > 70% (I A) or 50%(IIa A) in asymptomatic patients, and 60% (IIa B) in asymptomatic patients not at high surgical risk.⁵⁵

In a pooled analysis of four large CABG trials, in the first 5 years after surgery, **women** were found to have worse cardiac and cerebrovascular outcomes than men. The difference in outcomes between the sexes was not evident after 75 years of age and was significantly affected by preoperative LVEF, but not by variations in the surgical technique used.⁵⁶

Choice of the graft conduit and peri-operative medication are presented in Table 3. Evidence to support the Society of Thoracic Surgeons quality measure requiring **β -blocker** administration within 24 hours before CABG is uncertain in β -blocker-naïve patients.⁵⁷ Perioperatively, β -blockers are useful for the prevention of AF after CABG, especially when initiated ≤ 72 hours postoperatively in high-risk patients (age >75 years, history of AF, longer aortic cross-clamp duration).⁵⁷ The use of **calcium channel blockers** for the first postoperative year, with dihydropyridines (eg, amlodipine or nifedipine) preferred over nondihydro-pyridines (eg, diltiazem or verapamil), may help limit radial artery graft spasm. duration).⁵⁷ Low-dose **aspirin** initiated within 6 hours after CABG and continued indefinitely improves graft patency and reduces future cardiovascular events.⁵⁷ In patients with ACS undergoing CABG, **DAPT** for 1 year is associated with a lower risk of death and cardiac events.^{57, 58} DAPT decreases graft rate but at the expense of an increased risk of bleeding.⁵⁹ However, dual antiplatelet therapy may not be overall superior to aspirin alone in stable patients undergoing CABG,^{60, 61} even after an acute coronary syndrome.⁶² Aspirin and ticagrelor may result in increased SVG patency at one year compared to aspirin alone,⁶³ but in the benefit of dual therapy was not confirmed in a subsequent RCT.⁶⁴ The combination of rivaroxaban 2.5 mg twice daily plus aspirin may reduce MACE.⁶⁵ Thus, the choice of antithrombotic therapy should be individualized, based on ischaemic and bleeding risks, and regularly reassessed.⁵⁸

Sexual activity is allowed 6-8 weeks after CABG or non-coronary open heart surgery (IIa-C).⁶⁶

Percutaneous coronary intervention (PCI)

The **in-hospital mortality** of PCI is estimated approximately **1%**, whereas **periprocedural infarction** (defined as increase in biomarkers >3 times the 99th percentile upper reference limit) is **15%**, **ischemic stroke 0.1%**, and **emergency CABG** is required in **0.1-0.4%** of patients.⁶⁷⁻⁶⁹ In the National Cardiovascular Data Registry report, PCI in-hospital mortality was 1.27%, ranging from 0.65% in elective PCI to 4.81% in ST-segment elevation myocardial infarction patients.⁶⁹ More recent data indicate a mortality of 1.08% and an inverse relationship between complications and operator and institutional volume.⁶⁷ In nonagenarians, however, a 10.6% 30-day mortality following PCI has been reported.⁷⁰ Older age, extreme body mass indexes, multivessel disease, a lower ejection fraction, unstable hemodynamic state or shock, several comorbidities (cerebrovascular disease, peripheral vascular disease, congestive heart failure, chronic obstructive pulmonary disease, diabetes mellitus, and renal failure), and a history of coronary artery bypass graft surgery are risk factors that increase mortality.⁷¹

General recommendations on PCI are presented in Tables 4 and 5.

Types of stents

Bare-metal stents (**BMS**) is superior to balloon, and drug-eluting stents (**DES**) is superior to BMS by decreasing target lesion revascularization.^{72, 73} However, drug-coated balloons are superior to BMS in patients at bleeding risk.⁷⁴ There has been evidence from a meta-analysis that second-generation DES may also decrease mortality or the risk of MI compared to BMS,⁷⁵ but this was not confirmed in the NORSTENT trial,⁷⁶ or another individual patient data meta-analysis.⁷³ Early stent thrombosis (within the first 20 days) with second generation DES is <1% and thereafter 0.2-0.4% per year.⁷⁷ Uncovered struts and underexpansion are usually found in acute/subacute stent thrombosis, and neoatherosclerosis and uncovered struts in late/very late stent thrombosis.⁷⁸ There is evidence for a safety advantage of 2nd generation drug-eluting stents, such as everolimus-eluting, and biolimus-eluting stents, as compared with early generation DES, as detected in long-term (>1 year) follow-up,⁷⁹ especially in diabetics.

80

Ultrathin-strut DES (<70 μm) also reduce the risk of target lesion failure (defined as a composite of cardiac death, target-vessel myocardial infarction or clinically driven target lesion revascularization), compared with conventional 2nd-generation thin-strut DES, with similar risks myocardial infarction, cardiac death, and all-cause mortality.⁸¹

DES with a **biodegradable polymer** and thin struts thickness (<81 μm) are theoretically attractive but they have not resulted in reduced stent thrombosis or MI compared to thin-strut everolimus- or zotarolimus-eluting conventional stents (81 and 91 μm ,

respectively),^{82, 83} but this finding is not universal.⁸⁴ In patients at high risk for bleeding, a **polymer-free** umirolimus-coated stent has been found superior to a bare metal stent, with a 1-month course of dual antiplatelet therapy.⁸⁵ However, in subsequent trials, the value of polymer-free drug-coated stents compared to polymer-based or biodegradable stents zotarolimus-eluting stents was not established.⁸⁶⁻⁸⁸

The permanent presence of a metallic foreign body within the artery following stenting may cause vascular inflammation, restenosis, thrombosis, and neoatherosclerosis, and impair the physiological vasomotor function of the vessel and future potential of grafting the stented segment. **Bioresorbable** scaffolds have the potential to overcome these limitations and are under trial.^{89, 90} However, there has been evidence of increased stent thrombosis with a 1st generation thick-strut (150 µm poly-L-lactic acid-PLLA) bioresorbable, everolimus-eluting stent (Absorb BVS), with reported rates of 0.9% to 3% in 6 months to three years follow-up (ABSORB II, ABSORB Japan, ABSORB China, ABSORB III, EVERBIO II, AIDA, and TROFI II trials).⁹¹ These unfavorable results were also observed at 5-years follow-up despite the improved implantation technique, with 3% greater absolute rate of target lesion failure.⁹² Meta-analyses of these studies has confirmed a 2.4% stent thrombosis vs 0.6% with everolimus-eluting stents over 3 years.^{93, 94} Other bioabsorbable stents are also in study, but no data refute their inferiority compared to conventional DES.⁹⁵

The safety of drug-eluting stents in those with **nickel allergy**, as well as the safety of **MRI** is now established.⁹⁶

Duration of dual antiplatelet therapy

Duration of dual antiplatelet therapy depends on several factors and is still controversial (Tables 4 and 5, and Figures 1 and 2). Continuation of dual antiplatelet therapy beyond one year has not been found beneficial in randomized trials on both stable and unstable patients treated with 1st and 2nd generation DES. Treatment with dual antiplatelet therapy beyond 1 year after drug-eluting stent implantation reduces myocardial infarction and stent thrombosis, but at the expense of more bleeding events.⁹⁷ Thus, it may be associated with increased mortality because of an increased risk of non-cardiovascular mortality not offset by a reduction in cardiac mortality.⁹⁸ With 2nd generation DES even 1-3 months of dual antiplatelet therapy may reduce bleeding without affecting major cardiac events compared to 12-24 months therapy in both stable patients and after an ACS. In several RCTs (such as SMART-CHOICE, TWILIGHT-HBR, STOPDAPT-2, GLOBAL LEADERS, TICO, HOST-EXAM, T-PASS, A-CLOSE, and others) discontinuation of aspirin with continued P2Y₁₂ inhibitor monotherapy has been found to reduce the risk of bleeding without increasing major adverse cardiovascular events when stopped 1 month or 3 months (when clopidogrel is used) after PCI, in both stable patients and after an acute coronary syndrome.⁹⁹⁻¹⁰¹ DAPT-based de-escalation in certain patients is associated with both decreased ischaemic and

bleeding endpoints.¹⁰² In patients requiring infinite antiplatelet therapy, clopidogrel appears superior to aspirin alone,^{103, 104} but this has also been controversial.^{105, 106}

These findings cannot be generalized, and it should be noted that most of these studies had a mean duration of follow-up of one year. In an analysis of the DAPT study (30% of patients with stable CAD), patients who discontinued thienopyridine, either 12 months or 30 months after a percutaneous coronary intervention, were at an increased risk of an MI in the subsequent months mainly unrelated to stent thrombosis.¹⁰⁷ The optimum duration of dual antiplatelet therapy after stenting should be individualized, depending on condition treated, age of the patient, and comorbidities such as renal failure or history of prior myocardial infarction that affect the relative risk of adverse cardiac event and haemorrhage, while the type of stent used is not important with the new generation DES.¹⁰⁸⁻¹¹⁰ In patients with stable ischemic heart disease, the ACC/AHA/SCAI 2021 GL on revascularization recommend that, after consideration of recurrent ischemia and bleeding risks, select patients may safely transition to P2Y₁₂ inhibitor monotherapy and stop aspirin after 1 to 3 months of dual antiplatelet therapy.⁵⁰ The DAPT score may also be used in this respect (see Chapter 28).^{111, 112} In most patients, administration of DAPT for as long as 12 months may be not justified.⁹⁸ However, extended (12 months) DAPT duration may be beneficial following complex PCI procedures in high risk patients, following, especially, acute coronary syndromes.¹¹³ In diabetics, 12 months DAPT is most probably indicated after an acute coronary syndrome and PCI.¹¹⁴ In patients with AF and oral anticoagulation undergoing PCI, single anti-platelet therapy was not inferior to ≥ 2 months dual anti-platelet therapy followed by single therapy thereafter.¹¹⁵ Individualized duration of DAPT is recommended in patients with cancer with stable CAD, following revascularization, based upon thrombotic/ischaemic and bleeding risk, type and stage of cancer, and current cancer treatment (ESC 2022 GL on cardio-oncology, I C).¹¹⁶ In patients ≥ 75 years old, DAPT is generally discouraged beyond 12 months.¹¹⁷ Thus, the optimum duration of triple therapy after stenting may differ on the basis of individual patient characteristics (and especially HAS-BLED score), stent, and drug characteristics (see also Chapter on ACS).^{110, 118, 119} In stable patients with AF, monotherapy with a Xa inhibitor is appropriate one year after PCI.¹²⁰ Recommendations are provided in Chapter 28.

Patients on oral anticoagulants

Coronary angiography or PCI can be performed in patients on oral anticoagulation (warfarin or NOAC) and with additional anticoagulation, preferably through a radial access. For elective PCI, there is no need of additional anticoagulation if the INR is >2.5 .¹²¹ In patients with stable CAD, no antiplatelet may be needed in addition to oral anticoagulation one year after stenting, but the issue is still controversial.¹²² The management of patients on oral anticoagulants who are subjected to PCI is presented in Table 6 and also discussed in the Chapters on ACS and AF.

Technical Issues

General recommendations are provided in Tables 6-8.

Femoral and radial approach

Femoral artery **pseudoaneurysms** following PCI through the **femoral** artery constitute the most common femoral access complication following angiography, with an incidence ranging from 0.2% to 8%.¹²³ For small, stable pseudoaneurysms (<2 cm), observation with weekly duplex ultrasound until thrombosis occurs is appropriate. Ultrasound-guided compression should be considered if a pseudoaneurysm is >2 cm, has a short (<4 mm) neck width, is enlarging, is associated with significant pain, or occurs within 7 days of femoral access, or if continued anticoagulation is required. Compression is applied with the ultrasound probe in 10-minute cycles; an average of 37 minutes is required to achieve thrombosis. Patient discomfort may limit the procedure, and most patients require analgesia. The patient lies flat for 2-4 hours following compression. Repeat duplex ultrasound should be performed in 24-48 hours to verify that the pseudoaneurysm has not reopened. The success rate is 63-88%. Ultrasound-guided thrombin injection is preferred for larger aneurysms. Dilute thrombin is slowly injected into the pseudoaneurysm under duplex imaging and observed for thrombosis. Following successful thrombosis, the patient remains on bedrest for ≤12 hours. The procedural success rate is 93-97%, and the most common complication is distal embolization (0.5%).¹²⁴ Surgical repair may be necessary for pseudoaneurysms that are rapidly expanding, infected, or associated with skin necrosis or compressive symptoms such as ischemia or neuropathy.¹²³ Closure devices may decrease complications and short-term mortality even after elective intervention via femoral access.^{125, 126} In patients undergoing PCI, bleeding is associated with increased in-hospital mortality that is highest with non-access site bleeding.¹²⁷ Pseudoaneurysm is the most common femoral access complication following angiography; incidence ranges from 0.2% to 8%.

The **radial** access offers less vascular and bleeding complication rates, as well as lower mortality in patients with anemia, but at increased fluoroscopy times at the initial steps of the learning curve.¹²⁸⁻¹³⁰ The use of a narrow J tipped, 1.5mm hydrophilic guidewire ('Baby J') has been shown to improved technical success.¹³¹ Transradial catheterization and intervention may be performed regardless of the results of the Allen or Barbeau tests and in those with prior mastectomy.⁹⁶ The risk of artery occlusion with modern techniques ranges from 2.5 to 3.5%, but is usually asymptomatic.¹³² The risk of peri-procedural stroke may be increased with right but not left radial access.^{133, 134} An extensive series from Japan has actually argued in favour of a reduced risk of stroke with radial (right or left) compared to femoral access intervention.¹³⁵ It probably preferable to avoid using the radial artery for at least 3 months after transradial access and to assess patency and flow characteristics with Doppler before use as a conduit.^{30, 96, 136} A hemostasis duration of 2 hours offers the best

balance for efficacy (prevention of radial artery occlusion) and safety (prevention of access site hematoma/rebleeding).¹³⁷

In-stent restenosis

In a patient-level pooled analysis of RCTs, the 1-year rates of ischemia-driven target lesion revascularization (TLR) were 14.7%, 4.9%, and 2.5% with BMS, early-generation DES, and new-generation DES, respectively. Conversely, from 1 to 5 years, the respective cumulative rates of ischemia-driven TLR were 6.1%, 5.9%, and 4.4%.¹³⁸ Despite the substantial improvements in DES technologies, ISR and the need for target lesion revascularization still occur at a rate of 1%-2% per year with contemporary DES platforms.¹³⁹ The treatment of in-stent restenosis is challenging; high-pressure balloon pre-dilatation followed by drug-coated balloons may be used, but everolimus-eluting DES is the best options for DES restenosis.¹³⁹⁻¹⁴⁴ Interestingly, although restenosis is an independent predictor of long-term survival in patients undergoing coronary stenting, revascularization has not been found to offer any advantage on survival.¹⁴⁵ New ischemic perfusion defects (usually silent) are expected in 23% of patients and 40% of them are due to disease progression not related to stents.¹⁴⁶

Coronary bifurcations

The MEDINA classification is now the preferred classification scheme.¹⁴⁷ In coronary bifurcations, stenting of both the main vessel and side branch in bifurcation lesions may increase myocardial infarction and stent thrombosis risk compared with stenting of the main vessel only.^{148 149} A two-stents strategy may be adopted with large (≥ 2.5 mm diameter) side branches.^{150 151} For left main stem lesions, a stepwise provisional rather than systematic dual stenting appears to be preferable with lower target lesion revascularization (EBC MAIN RCT).¹⁵²

Chronic total occlusions

Outcomes of chronic total occlusion (CTO) intervention have improved because of advancements in equipment and techniques. Antegrade wiring, antegrade dissection and reentry, and the retrograde approach are all complementary and necessary crossing strategies.^{153, 154} However, despite initial evidence from registries,^{155 156} observational and randomized trials have failed to demonstrate improved LV function or improved cardiovascular outcomes following successful recanalization of native, chronic total occlusions.¹⁵⁷⁻¹⁶⁰ In the ISCHEMIA trial, the risks and benefits of invasive compared with conservative were similar among patients with and without CCTA-determined CTOs (more frequent procedural MI, less frequent spontaneous MI, and significantly improved angina and dyspnea-related quality of life). In an observational comparison, successful CTO revascularization was associated with a high probability of lower cardiovascular death or MI (driven by lower MI).¹⁶¹

Results on angina relief and QoL have been rather controversial. The EUROCTO RCT showed improved symptom relief and quality of life after PCI as compared with medical,¹⁶² whereas the DECISION-CTO RCT showed no difference,¹⁵⁹ although a meta-analysis of the two trials showed an improvement in QoL.¹⁶² In the recent ORBITA-CTO RCT in patients with symptomatic single-vessel CTO, PCI for CTO improved angina beyond placebo.¹⁶³ However, with just 50 patients, this trial was relatively small, all patients were treated in specialized centers by experienced operators, and patients with the most complex CTO features were also excluded from the study. Thus, until robust evidence emerges, attempting to treat a CTO is neither safer nor more effective than medical therapy alone for reducing CV death or MI, and that an invasive strategy for true CTOs remains an antianginal procedure.¹⁶⁴

Complex calcified lesions

Various techniques including cutting balloon, rotational atherectomy, lithotripsy balloon and orbital atherectomy are now available for crossable lesions. However, in the ECLIPSE RCT, routine treatment with orbital atherectomy before stenting did not increase minimal stent area or reduce the rate of target vessel failure at 1 year compared with a balloon angioplasty-based approach.¹⁶⁵ If the wire cannot cross the lesion, crossing with a microcatheter or laser may be tried.¹⁶⁶

Small vessels

Coronary arteries with a diameter <3 mm are prone to higher rates of restenosis and stent thrombosis.^{167, 168} Ultra-thin-strut stents,¹⁶⁹ and drug-coated balloons may be useful in this setting.^{144, 170}

Saphenous vein grafts

PCI for SVG accounts for more than 5% of all procedures.¹⁷¹ It is limited by a risk of distal embolization and higher rates of repeat revascularization compared with redo CABG. DES do not provide superior patency than bare-metal stents for treatment of SVG lesions at 5 years, and their superiority even at 12 months is controversial.^{172, 173} In patients with prior CABG presenting with graft failure, current guidelines recommend PCI of the bypassed native coronary artery. However, in PROCTOR RCT, SVG PCI was associated with improved 1-year clinical outcomes compared with native vessel PCI (80% of them CTOs).¹⁷⁴

Chronic kidney disease

In patients with chronic kidney disease DES are preferred.¹⁷⁵ **Contrast-induced nephropathy** is associated with a worse outcome, but the incidence is low (1.2%) and the incidence of sustained renal injury even lower.¹⁷⁶ Caution is needed in patients with creatinine ≥ 2 mg/dL or an eGFR < 30 mL/min/1.73m², and hydration with sodium chloride to maintain a urine output > 150 mL/h is probably the only protective measure with the strongest evidence. Assuming optimal contrast media administration, no prophylaxis is necessary for patients

with eGFR >30 mL/min/1.73 m².¹⁷⁷ Adjunctive pharmacotherapy, such as acetylcysteine or sodium bicarbonate, have not been demonstrated to effectively prevent or treat contrast-induced nephropathy.^{178, 179} Statins are protective, and statin loading with atorvastatin 80 mg within 24 hour preprocedure,¹⁸⁰ or rosuvastatin (40-10 mg)^{181, 182} should be given in statin-naïve patients. In addition, inorganic nitrate in the form of potassium nitrate capsules (KNO₃: 6 mmol each giving 12 mmol in total equivalent to 744 mg of nitrate) once daily for a total of 5 days with the first dose taken prior to coronary angiography has been shown to improve kidney function in patients at risk (NITRATE-CIN RCT).¹⁸³ More importantly, the smallest amount of contrast should be used (<350 mL), and an isosmolar contrast (290 mOsm/kg) is indicated for high-risk patients, whereas low-osmolar agents (700-850 mOsm/kg) are reasonable in moderate-risk patients. Recommendations are provided in Table 7, and Figure 3.

Elderly

Coronary artery disease is a major cause of morbidity and mortality in patients ≥80 years of age and PCI, when feasible, is more attractive than CABG in this setting.¹⁸⁴ A patient-centered approach, taking into account health status, functional ability and frailty, cognitive skills, and patient preferences is essential when considering revascularization for older adults with CAD.

IVUS and OCT

Intracoronary imaging may be necessary for the detection of vulnerable plaques that may constitute an indication for PCI.¹⁸⁵ Intravascular ultrasound (IVUS) should be considered to assess the severity of unprotected left main lesions (ESC/EACTS 2018 GL on revascularization, IIa-B),¹⁸⁶ The value of optical coherence tomography (OCT) is rather debatable in this respect,¹⁸⁷⁻¹⁸⁹ but OCT seems to be useful for PCI of bifurcations,¹⁹⁰ and for calcified lesions.¹⁹¹ In the RENOVATE-COMPLEX-PCI RCT, intravascular imaging-guided PCI with either IVUS or OCT led to a lower risk of composite of cardiac death, MI, or TLR than angiography-guided PCI of complex lesions.¹⁹² and in a subsequent meta-analysis IVUS-guided PCI was associated with a reduction in ischemia-driven target lesion revascularization.¹⁹³ IVUS was also superior to angiography in complex coronary bifurcation lesions treated with the 2-stent DK crush technique (DKCRUSH VIII RCT),¹⁹² and an updated meta-analysis suggested reductions in the rates of cardiac and all-cause mortality after imaging-guided left-main PCI.¹⁹⁴ However, in the ORBITA and IVUS-CHIP RCTs in main stem or complex lesions unprotected left main coronary artery disease, IVUS-guided PCI has showed no additional benefit over angiography-guided PCI.^{195, 196}

For **FFR** and **iFR** see the Chapter on Stable CAD.

Other issues

There has been some evidence that concomitant **balloon counterpulsation** may improve long-term outcomes in high-risk patients undergoing PCI.^{197, 198} PCI should be performed by operators with a **workload** of at least 75 cases per year in an institution performing more than 400 and certainly not less than 200 cases per year. However, although operator volume may not be associated with mortality following PCI,¹⁹⁹ and operator volume is not associated with long-term outcomes among patients surviving the index hospitalization.²⁰⁰

The treatment of symptomatic **myocardial bridge** refractory to beta blockers remains a clinical challenge. PCI has been associated with reports of stent fracture, stent thrombosis, and perforation during stent deployment, and CABG may be preferable. However, these concerns may be reliably mitigated using second-generation DES, accurate stent sizing aided by detailed intravascular imaging, and preferential use of high radial strength platforms.²⁰¹ Restenosis still likely occurs more frequently with PCI for myocardial bridge than for atherosclerotic lesions, and in this case CABG is indicated. Furthermore, the mechanisms underlying myocardial bridging are multifactorial, and most patients should be treated conservatively as they are asymptomatic. For those with persistent symptoms despite tailored medical therapy, surgical myotomy or CABG may be considered in preference to intervention, but these approaches carry procedural risks and lack robust comparative data.²⁰²

Recommendations for assessment and life-style changes after revascularization are provided in Table 8.

On-site **surgical back-up** is no more mandatory for elective PCI, provided there have been plans for rapid transport to a cardiac surgery operating room in a nearby hospital (Table 9).^{203, 204} Rates of in-hospital mortality and emergency CABG for primary and nonprimary PCI appear similar at centers with and without on-site surgery (CPORT and MASS COMM trials and VA CART Program).^{205 206} No further monitoring is needed after non-urgent PCI,²⁰⁷ and same day discharge following PCI is safe in low-risk patients.²⁰⁸

Recent evidence also suggest a shorter **nothing by- mouth** time before the cardiac catheterization procedure, continuation of medications (except for perhaps *ACE inhibitors*/ARBs in those with eGFR <60 mL/min) previously recommended to hold before the procedure (such as **metformin** in patients with no or mild renal impairment), avoidance of the use of **opiates** as part of the sedation cocktail in young patients (but potential use in the elderly in the place of benzodiazepines), and not requiring **allergy prophylaxis** in those with shellfish allergy.⁹⁶ **Iodine** is present throughout the body (eg, thyroid hormones, amino acids) and therefore cannot be an allergen. **Women** have worst outcomes than men.²⁰⁹

Hybrid Coronary Revascularization

Hybrid coronary revascularization (defined as the planned combination of LIMA-to-LAD artery grafting and DES of ≥ 1 non-LAD coronary arteries) is reasonable in patients with heavily calcified proximal aorta or poor target vessels for CABG (but amenable to PCI) or unfavorable LAD artery for PCI (i.e., excessive vessel tortuosity or chronic total occlusion). It can also be considered as an alternative to multivessel PCI or CABG in an attempt to improve the overall risk–benefit ratio of the procedures.²¹⁰ Available evidence is limited,²¹¹ but in one randomized comparison, hybrid coronary revascularization had similar 5-year all-cause mortality when compared with conventional coronary bypass grafting (POL-MIDES trial).²¹²

References

1. Hillis LD, et al. 2011 ACCF/AHA Guideline for Coronary Artery Bypass Graft Surgery: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2011;124:e652-735.
2. Head SJ and al. e. Current Practice of State-of-the-Art Surgical Coronary Revascularization. *Circulation*. 2017.
3. Gaudino M, et al. Considerations on the Management of Acute Postoperative Ischemia After Cardiac Surgery: A Scientific Statement From the American Heart Association. *Circulation*. 2023;148:442-454.
4. Kroncke GM, et al. Five-year changes in coronary arteries of medical and surgical patients of the Veterans Administration Randomized Study of Bypass Surgery. *Circulation*. 1988;78:1144-50.
5. Thielmann M, et al. ESC Joint Working Groups on Cardiovascular Surgery and the Cellular Biology of the Heart Position Paper: Perioperative myocardial injury and infarction in patients undergoing coronary artery bypass graft surgery. *Eur Heart J*. 2017;38:2392-2407.
6. Omran H, et al. High-sensitivity cardiac troponin I after coronary artery bypass grafting for post-operative decision-making. *Eur Heart J*. 2022;43:2388-2403.
7. Polzl L, et al. Impact of myocardial injury after coronary artery bypass grafting on long-term prognosis. *Eur Heart J*. 2022;43:2407-2417.
8. Xenogiannis I, et al. Saphenous Vein Graft Failure: From Pathophysiology to Prevention and Treatment Strategies. *Circulation*. 2021;144:728-745.
9. Hess CN, et al. Saphenous vein graft failure after coronary artery bypass surgery: insights from PREVENT IV. *Circulation*. 2014;130:1445-51.
10. Gaudino M, et al. Graft Failure After Coronary Artery Bypass Grafting and Its Association With Patient Characteristics and Clinical Events: A Pooled Individual Patient Data Analysis of Clinical Trials With Imaging Follow-Up. *Circulation*. 2023;148:1305-1315.
11. Sabik JF, 3rd, et al. Comparison of saphenous vein and internal thoracic artery graft patency by coronary system. *The Annals of thoracic surgery*. 2005;79:544-51; discussion 544-51.
12. Thelin S, et al. No-touch vein grafts in coronary artery bypass surgery: a registry-based randomized clinical trial. *Eur Heart J*. 2025;46:1720-1729.
13. Vinciguerra M and al. e. Management of Patients With Aortocoronary Saphenous Vein Graft Aneurysms. *JACC*. 2021.
14. Ruttman E, et al. Second internal thoracic artery versus radial artery in coronary artery bypass grafting: a long-term, propensity score-matched follow-up study. *Circulation*. 2011;124:1321-9.
15. Gaudino M and al. e. Continuing Conundrum of Multiple Arterial Conduits for Coronary Artery Bypass Grafting. *Circulation*. 2018.
16. Taggart DP, et al. Randomized trial to compare bilateral vs. single internal mammary coronary artery bypass grafting: 1-year results of the Arterial Revascularisation Trial (ART). *Eur Heart J*. 2010;31:2470-81.
17. Taggart DP, et al. Bilateral versus Single Internal-Thoracic-Artery Grafts at 10 Years. *N Engl J Med*. 2019;380:437-446.
18. Samadashvili Z and al. e. Multiple Versus Single Arterial Coronary Bypass Graft Surgery for Multivessel Disease. *JACC*. 2019.
19. Goldstone AB, et al. Second Arterial versus Venous Conduits for Multi-Vessel Coronary Artery Bypass Surgery in California. *Circulation*. 2017.
20. Sakic A, et al. Simple adaptations of surgical technique to critically reduce the risk of postoperative sternal complications in patients receiving bilateral internal thoracic arteries. *Interact Cardiovasc Thorac Surg*. 2013;17:378-82.

21. Gaudino M, et al. Mechanisms, Consequences, and Prevention of Coronary Graft Failure. *Circulation*. 2017;136:1749-1764.
22. Harskamp RE, et al. Frequency and Predictors of Internal Mammary Artery Graft Failure and Subsequent Clinical Outcomes: Insights From the Project of Ex-vivo Vein Graft Engineering via Transfection (PREVENT) IV Trial. *Circulation*. 2016;133:131-8.
23. Potter BJ and Pinto DS. Subclavian steal syndrome. *Circulation*. 2014;129:2320-3.
24. Gaudino M, et al. Radial-Artery or Saphenous-Vein Grafts in Coronary-Artery Bypass Surgery. *N Engl J Med*. 2018;378:2069-2077.
25. Taggart DP, et al. Associations Between Adding a Radial Artery Graft to Single and Bilateral Internal Thoracic Artery Grafts and Outcomes: Insights From the Arterial Revascularization Trial. *Circulation*. 2017;136:454-463.
26. Pu A and al. e. Long-term Outcomes of Multiple Arterial Coronary Artery Bypass Grafting. A Population-Based Study of Patients in British Columbia, Canada. *JAMA Cardiol*. 2017.
27. Gaudino M, et al. Radial Artery as a Coronary Artery Bypass Conduit: 20-Year Results. *J Am Coll Cardiol*. 2016;68:603-10.
28. Buxton BF, et al. Long-Term Results of the RAPCO Trials. *Circulation*. 2020;142:1330-1338.
29. Adgej J, et al. Significance of Intermediate Values of Fractional Flow Reserve in Patients With Coronary Artery Disease. *Circulation*. 2016;133:502-8.
30. Gaudino M and al. e. The Radial Artery for Percutaneous Coronary Procedures or Surgery? *J Am Coll Cardiol*. 2018.
31. Zenati MA, et al. Randomized Trial of Endoscopic or Open Vein-Graft Harvesting for Coronary-Artery Bypass. *N Engl J Med*. 2019;380:132-141.
32. Raza S, et al. Influence of Diabetes on Long-Term Coronary Artery Bypass Graft Patency. *J Am Coll Cardiol*. 2017;70:515-524.
33. Toth G, et al. Fractional flow reserve-guided versus angiography-guided coronary artery bypass graft surgery. *Circulation*. 2013;128:1405-11.
34. Glineur D, et al. Impact of preoperative fractional flow reserve on arterial bypass graft anastomotic function: the IMPAG trial. *Eur Heart J*. 2019.
35. Afilalo J, et al. Off-pump vs. on-pump coronary artery bypass surgery: an updated meta-analysis and meta-regression of randomized trials. *Eur Heart J*. 2012;33:1257-67.
36. Diegeler A, et al. Off-pump versus on-pump coronary-artery bypass grafting in elderly patients. *N Engl J Med*. 2013;368:1189-98.
37. Lamy A, et al. Five-Year Outcomes after Off-Pump or On-Pump Coronary-Artery Bypass Grafting. *N Engl J Med*. 2016.
38. Forouzannia SM, et al. Early and mid-term outcomes of off-pump versus on-pump coronary artery bypass surgery in patients with triple-vessel coronary artery disease: a randomized controlled trial. *J Cardiothorac Surg*. 2023;18:140.
39. Hattler B, et al. Off-Pump coronary artery bypass surgery is associated with worse arterial and saphenous vein graft patency and less effective revascularization: Results from the Veterans Affairs Randomized On/Off Bypass (ROOBY) trial. *Circulation*. 2012;125:2827-35.
40. Shroyer AL, et al. Five-Year Outcomes after On-Pump and Off-Pump Coronary-Artery Bypass. *N Engl J Med*. 2017;377:623-632.
41. Kim JB, et al. Long-term survival following coronary artery bypass grafting: off-pump versus on-pump strategies. *J Am Coll Cardiol*. 2014;63:2280-8.
42. Smart NA, et al. Long-Term Outcomes of On- Versus Off-Pump Coronary Artery Bypass Grafting. *J Am Coll Cardiol*. 2018;71:983-991.
43. Chikwe J, et al. Long-Term Outcomes After Off-Pump Versus On-Pump Coronary Artery Bypass Grafting by Experienced Surgeons. *J Am Coll Cardiol*. 2018;72:1478-1486.
44. Benedetto U, et al. Off-Pump Versus On-Pump Bypass Surgery for Left Main Coronary Artery Disease. *J Am Coll Cardiol*. 2019;74:729-740.
45. El-Chami MF, et al. Ventricular arrhythmia after cardiac surgery: incidence, predictors, and outcomes. *J Am Coll Cardiol*. 2012;60:2664-71.
46. Zhao DF and al. e. Coronary Artery Bypass Grafting With and Without Manipulation of the Ascending Aorta. A Network Meta-Analysis. *J Am coll Cardiol*. 2017.
47. Diegeler A, et al. Five-Year Outcome After Off-Pump or On-Pump Coronary Artery Bypass Grafting in Elderly Patients. *Circulation*. 2019;139:1865-1871.
48. Shindo T and Shimokawa H. Therapeutic Angiogenesis with Sound Waves. *Ann Vasc Dis*. 2020;13:116-125.
49. Holfeld J and al. e. Cardiac shockwave therapy in addition to coronary bypass surgery improves myocardial function in ischaemic heart failure: the CAST-HF trial *Eur Heart J*. 2024.
50. Lawton JS and al. e. 2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *JACC*. 2021.
51. Schwartz LB, et al. Asymptomatic carotid artery stenosis and stroke in patients undergoing cardiopulmonary bypass. *J Vasc Surg*. 1995;21:146-53.
52. Shishebor MH, et al. A direct comparison of early and late outcomes with three approaches to carotid revascularization and open heart surgery. *J Am Coll Cardiol*. 2013;62:1948-56.

53. Ren S, et al. Long-term outcomes of synchronous carotid endarterectomy and coronary artery bypass grafting versus solely carotid endarterectomy. *Annals of thoracic and cardiovascular surgery : official journal of the Association of Thoracic and Cardiovascular Surgeons of Asia*. 2012;18:228-35.
54. Weimar C, et al. Safety of Simultaneous Coronary Artery Bypass Grafting and Carotid Endarterectomy Versus Isolated Coronary Artery Bypass Grafting: A Randomized Clinical Trial. *Stroke*. 2017;48:2769-2775.
55. Mazzolai L, et al. 2024 ESC Guidelines for the management of peripheral arterial and aortic diseases. *Eur Heart J*. 2024.
56. Gaudino M, et al. Sex differences in outcomes after coronary artery bypass grafting: a pooled analysis of individual patient data. *Eur Heart J*. 2021;43:18-28.
57. Ruel M, et al. Secondary Prevention After Coronary Artery Bypass Graft Surgery: 2026 Update: A Scientific Statement From the American Heart Association. *Circulation*. 2026.
58. Sandner S, et al. Antithrombotic therapy after coronary artery bypass graft surgery: a Clinical Consensus Statement of the ESC Working Group on Cardiovascular Surgery, the ESC Working Group on Cardiovascular Pharmacotherapy, and the European Association for Cardio-Thoracic Surgery (EACTS). *Eur Heart J*. 2026;47:2419-2436.
59. Sandner S, et al. Association of Dual Antiplatelet Therapy With Ticagrelor With Vein Graft Failure After Coronary Artery Bypass Graft Surgery: A Systematic Review and Meta-analysis. *JAMA*. 2022;328:554-562.
60. van Diepen S and al. e. Dual Antiplatelet Therapy Versus Aspirin Monotherapy in Diabetics With Multivessel Disease Undergoing CABG. *FREEDOM Insights. J Am Coll Cardiol*. 2017.
61. Willemsen LM, et al. Effect of Adding Ticagrelor to Standard Aspirin on Saphenous Vein Graft Patency in Patients Undergoing Coronary Artery Bypass Grafting (POPular CABG): A Randomized, Double-Blind, Placebo-Controlled Trial. *Circulation*. 2020;142:1799-1807.
62. Jeppsson A, et al. Ticagrelor and Aspirin or Aspirin Alone after Coronary Surgery for Acute Coronary Syndrome. *N Engl J Med*. 2025;393:2313-2323.
63. Zhao Q and al. e. Effect of Ticagrelor Plus Aspirin, Ticagrelor Alone, or Aspirin Alone on Saphenous Vein Graft Patency 1 Year After Coronary Artery Bypass Grafting. A Randomized Clinical Trial. *JAMA*. 2018.
64. Jeppsson A, et al. Ticagrelor and Aspirin or Aspirin Alone after Coronary Surgery for Acute Coronary Syndrome. *N Engl J Med*. 2025.
65. Lamy A and al. e. Rivaroxaban, Aspirin, or Both to Prevent Early Coronary Bypass Graft Occlusion. The COMPASS-CABG Study. *JACC*. 2019.
66. Steinke EE, et al. Sexual counselling for individuals with cardiovascular disease and their partners: a consensus document from the American Heart Association and the ESC Council on Cardiovascular Nursing and Allied Professions (CCNAP). *Eur Heart J*. 2013;34:3217-35.
67. Badheka AO, et al. Impact of annual operator and institutional volume on percutaneous coronary intervention outcomes: a 5-year United States experience (2005-2009). *Circulation*. 2014;130:1392-406.
68. Kwok CS, et al. Stroke following percutaneous coronary intervention: type-specific incidence, outcomes and determinants seen by the British Cardiovascular Intervention Society 2007-12. *Eur Heart J*. 2015;36:1618-28.
69. Peterson ED, et al. Contemporary mortality risk prediction for percutaneous coronary intervention: results from 588,398 procedures in the National Cardiovascular Data Registry. *J Am Coll Cardiol*. 2010;55:1923-32.
70. Sawant AC, et al. Temporal Trends, Complications, and Predictors of Outcomes Among Nonagenarians Undergoing Percutaneous Coronary Intervention: Insights From the Veterans Affairs Clinical Assessment, Reporting, and Tracking Program. *JACC Cardiovascular interventions*. 2017;10:1295-1303.
71. Wu C, et al. Risk stratification for long-term mortality after percutaneous coronary intervention. *Circulation Cardiovascular interventions*. 2014;7:80-7.
72. Byrne RA, et al. Coronary balloon angioplasty, stents, and scaffolds. *Lancet*. 2017;390:781-792.
73. Piccolo R, et al. Drug-eluting or bare-metal stents for percutaneous coronary intervention: a systematic review and individual patient data meta-analysis of randomised clinical trials. *Lancet*. 2019;393:2503-2510.
74. Rissanen TT and al. e. Drug-coated balloon for treatment of de-novo coronary artery lesions in patients with high bleeding risk (DEBUT): a single-blind, randomised, non-inferiority trial. *The lancet*. 2019.
75. Palmerini T, et al. Long-Term Safety of Drug-Eluting and Bare-Metal Stents: Evidence From a Comprehensive Network Meta-Analysis. *J Am Coll Cardiol*. 2015;65:2496-507.
76. Bonaa KH, et al. Drug-Eluting or Bare-Metal Stents for Coronary Artery Disease. *N Engl J Med*. 2016;375:1242-52.
77. Byrne RA, et al. Stent thrombosis and restenosis: what have we learned and where are we going? The Andreas Gruntzig Lecture ESC 2014. *Eur Heart J*. 2015;36:3320-31.
78. Adriaenssens T, et al. Optical Coherence Tomography Findings in Patients With Coronary Stent Thrombosis: A Report of the PRESTIGE Consortium (Prevention of Late Stent Thrombosis by an Interdisciplinary Global European Effort). *Circulation*. 2017;136:1007-1021.
79. Stefanini GG and Windecker S. Stent performance: never too late to sort it out. *Lancet*. 2014;383:2024-6.
80. Kaul U, et al. Paclitaxel-Eluting versus Everolimus-Eluting Coronary Stents in Diabetes. *N Engl J Med*. 2015;373:1709-19.
81. Madhavan MV, et al. Long-term follow-up after ultrathin vs. conventional 2nd-generation drug-eluting stents: a systematic review and meta-analysis of randomized controlled trials. *Eur Heart J*. 2021;42:2643-2654.

82. von Birgelen C, et al. Very thin strut biodegradable polymer everolimus-eluting and sirolimus-eluting stents versus durable polymer zotarolimus-eluting stents in allcomers with coronary artery disease (BIO-RESORT): a three-arm, randomised, non-inferiority trial. *Lancet*. 2016;388:2607-2617.
83. Pilgrim T, et al. Ultrathin-strut, biodegradable-polymer, sirolimus-eluting stents versus thin-strut, durable-polymer, everolimus-eluting stents for percutaneous coronary revascularisation: 5-year outcomes of the BIOSCIENCE randomised trial. *Lancet*. 2018;392:737-746.
84. Iglesias JF, et al. Biodegradable polymer sirolimus-eluting stents versus durable polymer everolimus-eluting stents in patients with ST-segment elevation myocardial infarction (BIOSTEMI): a single-blind, prospective, randomised superiority trial. *Lancet*. 2019;394:1243-1253.
85. Urban P, et al. Polymer-free Drug-Coated Coronary Stents in Patients at High Bleeding Risk. *N Engl J Med*. 2015;373:2038-47.
86. Windecker S, et al. Polymer-based or Polymer-free Stents in Patients at High Bleeding Risk. *N Engl J Med*. 2020;382:1208-1218.
87. Jensen LO, et al. Randomized Comparison of the Polymer-Free Biolimus-Coated BioFreedom Stent With the Ultrathin Strut Biodegradable Polymer Sirolimus-Eluting Orsiro Stent in an All-Comers Population Treated With Percutaneous Coronary Intervention: The SORT OUT IX Trial. *Circulation*. 2020;141:2052-2063.
88. Kufner S and al. e. 10-Year Outcomes From a Randomized Trial of Polymer-Free Versus Durable Polymer Drug-Eluting Coronary Stents. *JACC*. 2020.
89. Kereiakes DJ, et al. Bioresorbable Vascular Scaffolds for Coronary Revascularization. *Circulation*. 2016;134:168-82.
90. Kereiakes DJ, et al. 3-Year Clinical Outcomes With Everolimus-Eluting Bioresorbable Coronary Scaffolds: The ABSORB III Trial. *J Am Coll Cardiol*. 2017;70:2852-2862.
91. Montone RA and etal. Temporal Trends in Adverse Events After Everolimus-Eluting Bioresorbable Vascular Scaffold Versus Everolimus-Eluting Metallic Stent Implantation. *Circulation*. 2017.
92. Stone GW and al. e. 5-Year Outcomes After Bioresorbable Coronary Scaffolds Implanted With Improved Technique. *JACC*. 2023.
93. 2-year outcomes with the Absorb bioresorbable scaffold for treatment of coronary artery disease: a systematic review and meta-analysis of seven randomised trials with an individual patient data substudy. *The Lancet*. 2017;390:760–772.
94. Ali ZA, et al. Three-Year Outcomes With the Absorb Bioresorbable Scaffold: Individual-Patient-Data Meta-Analysis From the ABSORB Randomized Trials. *Circulation*. 2017.
95. Byrne RA, et al. Report of an ESC-EAPCI Task Force on the evaluation and use of bioresorbable scaffolds for percutaneous coronary intervention: executive summary. *Eur Heart J*. 2017.
96. Bangalore S, et al. Evidence-Based Practices in the Cardiac Catheterization Laboratory: A Scientific Statement From the American Heart Association. *Circulation*. 2021:CIR0000000000000996.
97. Khan SU, et al. Dual Antiplatelet Therapy After Percutaneous Coronary Intervention and Drug-Eluting Stents: A Systematic Review and Network Meta-Analysis. *Circulation*. 2020;142:1425-1436.
98. Valgimigli M, et al. Demystifying the Contemporary Role of 12-Month Dual Antiplatelet Therapy After Acute Coronary Syndrome. *Circulation*. 2024;150:317-335.
99. O'Donoghue ML, et al. The Safety and Efficacy of Aspirin Discontinuation on a Background of a P2Y12 Inhibitor in Patients After Percutaneous Coronary Intervention: A Systematic Review and Meta-Analysis. *Circulation*. 2020;142:538-545.
100. Baber U, et al. Safety and Efficacy of Ticagrelor Monotherapy in Patients With Acute Coronary Syndromes Undergoing Percutaneous Coronary Intervention: An Individual Patient Data Meta-Analysis of TWILIGHT and TICO Randomized Trials. *Circulation*. 2024;149:574-584.
101. Capranzano P, et al. Aspirin-free antiplatelet strategies after percutaneous coronary interventions. *Eur Heart J*. 2024;45:572-585.
102. Kang J, et al. Dual antiplatelet therapy de-escalation in acute coronary syndrome: an individual patient meta-analysis. *Eur Heart J*. 2023;44:1360-1370.
103. Koo BK, et al. Aspirin versus clopidogrel for chronic maintenance monotherapy after percutaneous coronary intervention (HOST-EXAM): an investigator-initiated, prospective, randomised, open-label, multicentre trial. *Lancet*. 2021.
104. Gagnano F, et al. P2Y(12) Inhibitor or Aspirin Monotherapy for Secondary Prevention of Coronary Events. *J Am Coll Cardiol*. 2023;82:89-105.
105. Vranckx P, et al. Ticagrelor plus aspirin for 1 month, followed by ticagrelor monotherapy for 23 months vs aspirin plus clopidogrel or ticagrelor for 12 months, followed by aspirin monotherapy for 12 months after implantation of a drug-eluting stent: a multicentre, open-label, randomised superiority trial. *Lancet*. 2018;392:940-949.
106. Natsuaki M, et al. An Aspirin-Free Versus Dual Antiplatelet Strategy for Coronary Stenting: STOPDAPT-3 Randomized Trial. *Circulation*. 2024;149:585-600.
107. Stefanescu Schmidt AC, et al. Myocardial Infarction Risk after Discontinuation of Thienopyridine Therapy in the Randomized DAPT Study. *Circulation*. 2017.
108. Cuisset T, et al. Update on antithrombotic therapy after percutaneous coronary revascularisation. *Lancet*. 2017;390:810-820.
109. Lee SY, et al. Short-Term Versus Long-Term Dual Antiplatelet Therapy After Drug-Eluting Stent Implantation in Elderly Patients: A Meta-Analysis of Individual Participant Data From 6 Randomized Trials. *JACC Cardiovascular interventions*. 2018.

110. Gorog DA, et al. Antithrombotic therapy for secondary prevention in patients with acute coronary syndromes treated with percutaneous coronary intervention: options for personalization to reduce bleeding or ischaemic risks. A Clinical Consensus Statement of the ESC Working Group on Thrombosis, the Association for Acute CardioVascular Care of the ESC, the European Association of Percutaneous Cardiovascular Interventions of the ESC, and the ESC Working Group on Cardiovascular Pharmacology A Clinical Consensus Statement of the ESC Working Group on Thrombosis, the Association for Acute CardioVascular Care of the ESC, the European Association of Percutaneous Cardiovascular Interventions of the ESC, and the ESC Working Group on Cardiovascular Pharmacology. *EuroIntervention : journal of EuroPCR in collaboration with the Working Group on Interventional Cardiology of the European Society of Cardiology*. 2026;22:e653-e677.
111. Levine GN, et al. 2016 ACC/AHA Guideline Focused Update on Duration of Dual Antiplatelet Therapy in Patients With Coronary Artery Disease: . *Circulation*. 2016;134:e123-55.
112. Yoshikawa Y, et al. Validating Utility of DAPT Score in a Large Pooled Cohort from Three Japanese PCI Studies. *Circulation*. 2017.
113. Hahn JY, et al. 6-month versus 12-month or longer dual antiplatelet therapy after percutaneous coronary intervention in patients with acute coronary syndrome (SMART-DATE): a randomised, open-label, non-inferiority trial. *Lancet*. 2018.
114. Ajjan RA, et al. Antithrombotic therapy in diabetes: which, when, and for how long? *Eur Heart J*. 2021;42:2235-2259.
115. Smits PC, et al. Abbreviated Antiplatelet Therapy in Patients at High Bleeding Risk With or Without Oral Anticoagulant Therapy After Coronary Stenting: An Open-Label, Randomized, Controlled Trial. *Circulation*. 2021;144:1196-1211.
116. Lyon AR, et al. 2022 ESC Guidelines on cardio-oncology developed in collaboration with the European Hematology Association (EHA), the European Society for Therapeutic Radiology and Oncology (ESTRO) and the International Cardio-Oncology Society (IC-OS). *Eur Heart J*. 2022.
117. Andreotti F, et al. Acute, periprocedural and longterm antithrombotic therapy in older adults. *Eur Heart J*. 2023;44:262-279.
118. Angiolillo DJ, et al. Antithrombotic Therapy in Patients With Atrial Fibrillation Treated With Oral Anticoagulation Undergoing Percutaneous Coronary Intervention: A North American Perspective: 2021 Update. *Circulation*. 2021;143:583-596.
119. Kumbhani DJ, et al. Antiplatelet Therapy in the Management of Atherosclerotic Cardiovascular Disease: 2026 ACC Scientific Statement: A Report of the American College of Cardiology. *J Am Coll Cardiol*. 2026.
120. Yasuda S, et al. Antithrombotic Therapy for Atrial Fibrillation with Stable Coronary Disease. *N Engl J Med*. 2019;381:1103-1113.
121. Authors/Task Force m, et al. 2014 ESC/EACTS Guidelines on myocardial revascularization: The Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) Developed with the special contribution of the European Association of Percutaneous Cardiovascular Interventions (EAPCI). *Eur Heart J*. 2014;35:2541-619.
122. Matsumura-Nakano Y, et al. Open-Label Randomized Trial Comparing Oral Anticoagulation With and Without Single Antiplatelet Therapy in Patients With Atrial Fibrillation and Stable Coronary Artery Disease Beyond 1 Year After Coronary Stent Implantation. *Circulation*. 2019;139:604-616.
123. Madia C. Management trends for postcatheterization femoral artery pseudoaneurysms. *JAAPA*. 2019;32:15-18.
124. Dzijan-Horn M, et al. Safety and efficacy of a potential treatment algorithm by using manual compression repair and ultrasound-guided thrombin injection for the management of iatrogenic femoral artery pseudoaneurysm in a large patient cohort. *Circulation Cardiovascular interventions*. 2014;7:207-15.
125. Gurm HS, et al. Comparative safety of vascular closure devices and manual closure among patients having percutaneous coronary intervention. *Ann Intern Med*. 2013;159:660-6.
126. Farooq V, et al. Relationship Between Femoral Vascular Closure Devices and Short-Term Mortality From 271 845 Percutaneous Coronary Intervention Procedures Performed in the United Kingdom Between 2006 and 2011: A Propensity Score-Corrected Analysis From the British Cardiovascular Intervention Society. *Circulation Cardiovascular interventions*. 2016;9.
127. Chhatriwalla AK, et al. Association between bleeding events and in-hospital mortality after percutaneous coronary intervention. *JAMA*. 2013;309:1022-9.
128. Mason PJ and al. e. An Update on Radial Artery Access and Best Practices for Transradial Coronary Angiography and Intervention in Acute Coronary Syndrome. A Scientific Statement From the American Heart Association. *Circulation*. 2018.
129. Amin AP, et al. Transradial Access for High-Risk Percutaneous Coronary Intervention: Implications of the Risk-Treatment Paradox. *Circulation Cardiovascular interventions*. 2021:CIRCINTERVENTIONS120009328.
130. Gargiulo G, et al. Effects on Mortality and Major Bleeding of Radial Versus Femoral Artery Access for Coronary Angiography or Percutaneous Coronary Intervention: Meta-Analysis of Individual Patient Data From 7 Multicenter Randomized Clinical Trials. *Circulation*. 2022;146:1329-1343.
131. Bland AC and al. e. Enhancing Guidewire Efficacy for Trans-radial Access: The EAGER Randomized Controlled Trial. *Circulation*. 2024.
132. Aminian A, et al. Comparison of a new slender 6 Fr sheath with a standard 5 Fr sheath for transradial coronary angiography and intervention: RAP and BEAT (Radial Artery Patency and Bleeding, Efficacy, Adverse

- evenT), a randomised multicentre trial. *EuroIntervention : journal of EuroPCR in collaboration with the Working Group on Interventional Cardiology of the European Society of Cardiology*. 2017;13:e549-e556.
133. Porto I, et al. Impact of Access Site on Bleeding and Ischemic Events in Patients With Non-ST-Segment Elevation Myocardial Infarction Treated With Prasugrel: The ACCOAST Access Substudy. *JACC Cardiovascular interventions*. 2016;9:897-907.
 134. Rashid M, et al. Incidence, Determinants, and Outcomes of Left and Right Radial Access Use in Patients Undergoing Percutaneous Coronary Intervention in the United Kingdom: A National Perspective Using the BCIS Dataset. *JACC Cardiovascular interventions*. 2018.
 135. Shoji S, et al. Stroke After Percutaneous Coronary Intervention in the Era of Transradial Intervention. *Circulation Cardiovascular interventions*. 2018;11:e006761.
 136. Mounsey CA, et al. Does Previous Transradial Catheterization Preclude Use of the Radial Artery as a Conduit in Coronary Artery Bypass Surgery? *Circulation*. 2016;134:681-8.
 137. Maqsood MH, et al. Optimal Hemostatic Band Duration After Transradial Angiography or Intervention: Insights From a Mixed Treatment Comparison Meta-Analysis of Randomized Trials. *Circulation Cardiovascular interventions*. 2023;16:e012781.
 138. Moussa ID, et al. Trends and Outcomes of Restenosis After Coronary Stent Implantation in the United States. *J Am Coll Cardiol*. 2020;76:1521-1531.
 139. Giustino G and al. e. Coronary In-Stent Restenosis. *JACC*. 2022.
 140. Siontis GC, et al. Percutaneous coronary interventional strategies for treatment of in-stent restenosis: a network meta-analysis. *Lancet*. 2015;386:655-64.
 141. Moussa ID and al. e. Trends and Outcomes of Restenosis After Coronary Stent Implantation in the United States. *JACC*. 2020.
 142. Giacoppo D, et al. Paclitaxel-coated balloon angioplasty vs. drug-eluting stenting for the treatment of coronary in-stent restenosis: a comprehensive, collaborative, individual patient data meta-analysis of 10 randomized clinical trials (DAEDALUS study). *Eur Heart J*. 2020;41:3715-3728.
 143. Giacoppo D, et al. Coronary artery restenosis treatment with plain balloon, drug-coated balloon, or drug-eluting stent: 10-year outcomes of the ISAR-DESIRE 3 trial. *Eur Heart J*. 2023;44:1343-1357.
 144. Fezzi S, et al. Definitions and standardized endpoints for the use of drug-coated balloon in coronary artery disease: consensus document of the Drug Coated Balloon Academic Research Consortium. *Eur Heart J*. 2025;46:2498-2519.
 145. Cassese S, et al. Prognostic role of restenosis in 10 004 patients undergoing routine control angiography after coronary stenting. *Eur Heart J*. 2015;36:94-9.
 146. Zellweger MJ, et al. Coronary artery disease progression late after successful stent implantation. *J Am Coll Cardiol*. 2012;59:793-9.
 147. Lunardi M, et al. Definitions and Standardized Endpoints for Treatment of Coronary Bifurcations. *J Am Coll Cardiol*. 2022.
 148. Katritsis DG, et al. Double versus single stenting for coronary bifurcation lesions: a meta-analysis. *Circulation Cardiovascular interventions*. 2009;2:409-15.
 149. Behan MW, et al. Coronary bifurcation lesions treated with simple or complex stenting: 5-year survival from patient-level pooled analysis of the Nordic Bifurcation Study and the British Bifurcation Coronary Study. *Eur Heart J*. 2016;37:1923-8.
 150. Hildick-Smith D, et al. The EBC TWO Study (European Bifurcation Coronary TWO): A Randomized Comparison of Provisional T-Stenting Versus a Systematic 2 Stent Culotte Strategy in Large Caliber True Bifurcations. *Circulation Cardiovascular interventions*. 2016;9.
 151. Ferenc M, et al. Culotte stenting vs. TAP stenting for treatment of de-novo coronary bifurcation lesions with the need for side-branch stenting: the Bifurcations Bad Krozingen (BBK) II angiographic trial. *Eur Heart J*. 2016;37:3399-3405.
 152. Arunothayaraj S, et al. Stepwise Provisional Versus Systematic Dual-Stent Strategies for Treatment of True Left Main Coronary Bifurcation Lesions. *Circulation*. 2025;151:612-622.
 153. Brilakis ES, et al. Guiding Principles for Chronic Total Occlusion Percutaneous Coronary Intervention. *Circulation*. 2019;140:420-433.
 154. Tanaka H and al. e. A Novel Algorithm for Treating Chronic Total Coronary Artery Occlusion. 2019.
 155. Hannan EL, et al. Patients With Chronic Total Occlusions Undergoing Percutaneous Coronary Interventions: Characteristics, Success, and Outcomes. *Circulation Cardiovascular interventions*. 2016;9:e003586.
 156. Huqi A, et al. Long-term follow-up of elective chronic total coronary occlusion angioplasty: analysis from the U.K. Central Cardiac Audit Database. *J Am Coll Cardiol*. 2014;64:2707-8.
 157. Lee PH, et al. Successful Recanalization of Native Coronary Chronic Total Occlusion Is Not Associated With Improved Long-Term Survival. *JACC Cardiovascular interventions*. 2016;9:530-8.
 158. Henriques JP, et al. Percutaneous Intervention for Concurrent Chronic Total Occlusions in Patients With STEMI: The EXPLORE Trial. *J Am Coll Cardiol*. 2016;68:1622-1632.
 159. Lee SW, et al. Randomized Trial Evaluating Percutaneous Coronary Intervention for the Treatment of Chronic Total Occlusion. *Circulation*. 2019;139:1674-1683.
 160. Kawashima H and al. e. Mortality 10 Years After Percutaneous or Surgical Revascularization in Patients With Total Coronary Artery Occlusions. *JACC*. 2021.
 161. Bangalore S and al. e. Invasive vs Conservative Management of Patients With Chronic Total Occlusion: Results From the ISCHEMIA Trial. *JACC*. 2025.

162. Werner GS, et al. Quality of Life After Percutaneous Coronary Intervention or Medical Therapy for Chronic Total Coronary Occlusions: EUROCTO and DECISION-CTO Meta-Analysis. *J Am Coll Cardiol*. 2026;88:24-37.
163. Khan S, et al. Randomized, Placebo-Controlled Trial of Chronic Total Occlusion Percutaneous Coronary Intervention in Stable Angina: The ORBITA-CTO Trial. *J Am Coll Cardiol*. 2026;88:4-18.
164. Ali ZA and al. e. Evidence of Benefit for Chronic Total Occlusion Revascularization From ISCHEMIA: New Road or Dead End? *JACC*. 2025.
165. Kirtane AJ, et al. Orbital atherectomy versus balloon angioplasty before drug-eluting stent implantation in severely calcified lesions eligible for both treatment strategies (ECLIPSE): a multicentre, open-label, randomised trial. *Lancet*. 2025;405:1240-1251.
166. Barbato E, et al. Management strategies for heavily calcified coronary stenoses: an EAPCI clinical consensus statement in collaboration with the EURO4C-PCR group. *Eur Heart J*. 2023.
167. Claessen BE, et al. Impact of lesion length and vessel size on clinical outcomes after percutaneous coronary intervention with everolimus- versus paclitaxel-eluting stents pooled analysis from the SPIRIT (Clinical Evaluation of the XIENCE V Everolimus Eluting Coronary Stent System) and COMPARE (Second-generation everolimus-eluting and paclitaxel-eluting stents in real-life practice) Randomized Trials. *JACC Cardiovascular interventions*. 2011;4:1209-15.
168. van der Heijden LC, et al. Small-vessel treatment with contemporary newer-generation drug-eluting coronary stents in all-comers: Insights from 2-year DUTCH PEERS (TWENTE II) randomized trial. *American heart journal*. 2016;176:28-35.
169. Buiten RA, et al. Outcomes in Patients Treated With Thin-Strut, Very Thin-Strut, or Ultrathin-Strut Drug-Eluting Stents in Small Coronary Vessels: A Prespecified Analysis of the Randomized BIO-RESORT Trial. *JAMA cardiology*. 2019;4:659-669.
170. Jeger RV, et al. Long-term efficacy and safety of drug-coated balloons versus drug-eluting stents for small coronary artery disease (BASKET-SMALL 2): 3-year follow-up of a randomised, non-inferiority trial. *Lancet*. 2020.
171. Brilakis ES, et al. Frequency and predictors of drug-eluting stent use in saphenous vein bypass graft percutaneous coronary interventions: a report from the American College of Cardiology National Cardiovascular Data CathPCI registry. *JACC Cardiovascular interventions*. 2010;3:1068-73.
172. Collieran R and al. e. Efficacy Over Time With Drug-Eluting Stents in Saphenous Vein Graft Lesions. *J A Coll Cardiol*. 2018.
173. Brilakis AS and al. e. Drug-eluting stents versus bare-metal stents in saphenous vein grafts: a double-blind, randomised trial. *The Lancet*. 2018.
174. De Winter RW and al. e. PCI of Native Coronary Artery vs Saphenous Vein Graft After Prior Bypass Surgery. *JACC*. 2026.
175. Tomai F, et al. Randomized Comparison of Xience V and Multi-Link Vision Coronary Stents in the Same Multivessel Patient With Chronic Kidney Disease (RENAL-DES) Study. *Circulation*. 2014;129:1104-12.
176. **Weisbord SD** and al. e. Contrast-Associated Acute Kidney Injury and Serious Adverse Outcomes Following Angiography. *JACC*. 2020.
177. Nijssen EC and al. e. Prophylactic hydration to protect renal function from intravascular iodinated contrast material in patients at high risk of contrast-induced nephropathy (AMACING): a prospective, randomised, phase 3, controlled, open-label, non-inferiority trial *The Lancet*. 2017;389:1312-1322.
178. Giacoppo D, et al. Preventive Strategies for Contrast-Induced Acute Kidney Injury in Patients Undergoing Percutaneous Coronary Procedures: Evidence From a Hierarchical Bayesian Network Meta-Analysis of 124 Trials and 28 240 Patients. *Circulation Cardiovascular interventions*. 2017;10.
179. Weisbord SD, et al. Outcomes after Angiography with Sodium Bicarbonate and Acetylcysteine. *N Engl J Med*. 2018;378:603-614.
180. Quintavalle C, et al. Impact of a high loading dose of atorvastatin on contrast-induced acute kidney injury. *Circulation*. 2012;126:3008-16.
181. Leoncini M, et al. Early high-dose rosuvastatin for contrast-induced nephropathy prevention in acute coronary syndrome: Results from the PRATO-ACS Study (Protective Effect of Rosuvastatin and Antiplatelet Therapy On contrast-induced acute kidney injury and myocardial damage in patients with Acute Coronary Syndrome). *J Am Coll Cardiol*. 2014;63:71-9.
182. Han Y, et al. Short-term rosuvastatin therapy for prevention of contrast-induced acute kidney injury in patients with diabetes and chronic kidney disease. *J Am Coll Cardiol*. 2014;63:62-70.
183. Jones DA, et al. Inorganic nitrate benefits contrast-induced nephropathy after coronary angiography for acute coronary syndromes: the NITRATE-CIN trial. *Eur Heart J*. 2024;45:1647-1658.
184. Madhavan MV and al. e. Coronary Artery Disease in Patients ≥ 80 Years of Age. *J Am Coll Cardiol*. 2018.
185. Borovac JA. Percutaneous coronary intervention for non-obstructive vulnerable plaques. *Lancet*. 2024.
186. Neumann FJ, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. *Eur Heart J*. 2018.
187. Lee JM, et al. Intravascular Imaging-Guided or Angiography-Guided Complex PCI. *N Engl J Med*. 2023;388:1668-1679.
188. Ali ZA, et al. Optical Coherence Tomography-Guided versus Angiography-Guided PCI. *N Engl J Med*. 2023;389:1466-1476.

189. Kang DY, et al. Optical Coherence Tomography-Guided or Intravascular Ultrasound-Guided Percutaneous Coronary Intervention: The OCTIVUS Randomized Clinical Trial. *Circulation*. 2023;148:1195-1206.
190. Holm NR, et al. OCT or Angiography Guidance for PCI in Complex Bifurcation Lesions. *N Engl J Med*. 2023;389:1477-1487.
191. Ali ZA, et al. Optical coherence tomography- vs angiography-guided coronary stent implantation in calcified lesions: the ILUMIEN IV trial. *Eur Heart J*. 2025;46:3201-3210.
192. Gao X, et al. IVUS or Angiography Guidance for Percutaneous Coronary Intervention in Complex Coronary Bifurcation Lesions: The DKCRUSH VIII Randomized Clinical Trial. *J Am Coll Cardiol*. 2026;87:2080-2095.
193. Giacoppo D, et al. Coronary Angiography, Intravascular Ultrasound, and Optical Coherence Tomography for Guiding of Percutaneous Coronary Intervention: A Systematic Review and Network Meta-Analysis. *Circulation*. 2024;149:1065-1086.
194. Stone GW, et al. Intravascular imaging-guided coronary drug-eluting stent implantation: an updated network meta-analysis. *Lancet*. 2024;403:824-837.
195. Diletti R, et al. Intravascular Ultrasound-Guided or Angiography-Guided Complex High-Risk PCI. *N Engl J Med*. 2026.
196. Testa L, et al. IVUS-Guided versus Angiography-Guided PCI in Unprotected Left Main Coronary Disease. *N Engl J Med*. 2026.
197. O'Neill WW, et al. A prospective, randomized clinical trial of hemodynamic support with Impella 2.5 versus intra-aortic balloon pump in patients undergoing high-risk percutaneous coronary intervention: the PROTECT II study. *Circulation*. 2012;126:1717-27.
198. Perera D, et al. Long-term mortality data from the balloon pump-assisted coronary intervention study (BCIS-1): a randomized, controlled trial of elective balloon counterpulsation during high-risk percutaneous coronary intervention. *Circulation*. 2013;127:207-12.
199. Hulme W, et al. Operator volume is not associated with mortality following percutaneous coronary intervention: insights from the British Cardiovascular Intervention Society registry. *Eur Heart J*. 2018.
200. Fanaroff AC, et al. Relationship Between Operator Volume and Long-Term Outcomes After Percutaneous Coronary Intervention. *Circulation*. 2019;139:458-472.
201. Sternheim D and al. e. Myocardial Bridging: Diagnosis, Functional Assessment, and Management: JACC State-of-the-Art Review. *JACC*. 2021.
202. Rodriguez BC, et al. Myocardial bridging: a practical guide for clinicians. *Eur Heart J*. 2026;47:5266-5278.
203. Dehmer GJ, et al. SCAI/ACC/AHA Expert Consensus Document: 2014 update on percutaneous coronary intervention without on-site surgical backup. *J Am Coll Cardiol*. 2014;63:2624-41.
204. Lee JM, et al. Percutaneous Coronary Intervention at Centers With and Without On-Site Surgical Backup: An Updated Meta-Analysis of 23 Studies. *Circulation*. 2015;132:388-401.
205. Maddox TM, et al. Patient access and 1-year outcomes of percutaneous coronary intervention facilities with and without on-site cardiothoracic surgery: insights from the Veterans Affairs (VA) Clinical Assessment, Reporting, and Tracking (CART) program. *Circulation*. 2014;130:1383-91.
206. Goel K, et al. Outcomes and Temporal Trends of Inpatient Percutaneous Coronary Intervention at Centers With and Without On-site Cardiac Surgery in the United States. *JAMA cardiology*. 2016.
207. Sandau KE, et al. Update to Practice Standards for Electrocardiographic Monitoring in Hospital Settings: A Scientific Statement From the American Heart Association. *Circulation*. 2017;136:e273-e344.
208. Shroff A, et al. Same-Day Discharge After Percutaneous Coronary Intervention: Current Perspectives and Strategies for Implementation. *JAMA cardiology*. 2016;1:216-23.
209. Manfrini O, et al. Sex and gender differences in coronary pathophysiology and ischaemic heart disease. *Eur Heart J*. 2026;47:2727-2749.
210. Harskamp RE, et al. Practice patterns and clinical outcomes after hybrid coronary revascularization in the United States: an analysis from the society of thoracic surgeons adult cardiac database. *Circulation*. 2014;130:872-9.
211. Puskas JD, et al. Hybrid Coronary Revascularization for the Treatment of Multivessel Coronary Artery Disease: A Multicenter Observational Study. *J Am Coll Cardiol*. 2016;68:356-65.
212. Tajstra M, et al. Hybrid Coronary Revascularization in Selected Patients With Multivessel Disease: 5-Year Clinical Outcomes of the Prospective Randomized Pilot Study. *JACC Cardiovascular interventions*. 2018;11:847-852.