

Coronary artery bypass grafting

Synonyms: bypass grafting, triple bypass, quadruple bypass

What is coronary artery bypass grafting?

This is one of two coronary revascularisation techniques currently used in the treatment of coronary artery disease, the other being [percutaneous coronary intervention \(PCI\)](#). The patient will already have had a clinical diagnosis of coronary heart disease (CHD), confirmed by coronary angiography to delineate the obstruction.

If PCI is feasible, it may be performed at the time of coronary angiography (ad hoc PCI). Coronary artery bypass grafting (CABG - pronounced 'cabbage') may be performed as a primary procedure, after failed PCI, or as a repeat procedure.

See also the articles on [Stable Angina](#), [Acute Myocardial Infarction](#) and [Acute Coronary Syndrome](#).

Benefits of treatment

The main purpose of revascularisation is to relieve the symptoms of stable angina and both CABG and PCI are effective.

In the SYNTAX (**SY**Nergy between PCI with **TAX**us and cardiac surgery) study, CABG was compared with PCI, confirming that CABG is superior to PCI in patients with stable, complex coronary artery disease with a reduction in major adverse outcomes with CABG. ^[1]

The patients in this study had left main coronary artery disease, triple vessel disease or both. The researchers augmented the SYNTAX score (a combination of clinical and anatomical features) to include additional prognostic variables, including gender, age and comorbidities, to decide which patients should be offered CABG.

The use of the improved SYNTAX score II helped to choose those patients most likely to benefit from CABG. [2]

Coronary artery bypass grafting is often delayed after acute myocardial infarction to avoid an increase in postoperative morbidity and mortality. Studies have found no statistically significant difference between timing cohorts (less than 24 hours, and 24 hours or more) for mortality or major adverse cardiovascular and cerebrovascular event readmissions. [3]

Choice of revascularisation procedure [4]

The choice of CABG or PCI depends on the distribution of the coronary artery disease, comorbidities and patient preference. Any patient with left main vessel or complex three-vessel disease or with other relevant clinical factors should be the subject of a multidisciplinary team meeting, to discuss the risks and benefits of the revascularisation techniques in their individual case, followed by an explanation and discussion with the patient. [5]

Both CABG and PCI are reasonable options for patients with advanced coronary artery disease. Current evidence dictates that despite advances in stent technology, patients with diabetes are better served with CABG surgery than PCI. In left main stem disease, multivessel coronary artery disease, or patients with left ventricular dysfunction, CABG surgery should be favoured in patients with complex coronary lesions and anatomy and PCI in less complicated coronary disease or deemed a high surgical risk. [6]

A systematic review of CABG versus PCI concluded that: [6]

- Patients with significant left main disease, multivessel disease or left ventricular (LV) dysfunction, if the severity is deemed to be more complex (SYNTAX >22) benefit from CABG, due to lower cardiac events with CABG surgery.
- Patients with less complex disease (SYNTAX <22) and/or the patient is a higher surgical risk benefit from PCI.
- Patients with diabetes, irrespective of the severity of their coronary anatomy, benefit from CABG, due to improved long-term survival and lower major adverse cardiac and cerebrovascular events.
- The incidence of revascularisation after PCI is higher than after CABG.

- The incidence of stroke is higher after CABG surgery than after PCI.

A meta-analysis of studies comparing patients with multi-vessel coronary disease who underwent CABG versus PCI (6,055 participants) demonstrated unequivocal benefit of CABG in long-term mortality and myocardial infarctions, regardless of whether or not the participants had diabetes.^[7]

It is recommended that no more than two weeks should elapse between diagnostic catheterisation and revascularisation (CABG or PCI) in patients with severe symptoms or high-risk anatomy. In all other patients, with stable coronary artery disease but in whom the symptoms aren't satisfactorily controlled with medical treatment, it is desirable to perform revascularisation within six weeks.^[4]

Non-ST-segment elevation acute coronary syndrome (NSTEMI-ACS)

There is no randomised comparison of percutaneous coronary intervention vs. CABG in the specific setting of **NSTEMI-ACS**. The currently available evidence indirectly suggests that the criteria applied to patients with stable coronary artery disease to guide the choice of revascularisation modality should be applied to stabilised patients with NSTEMI-ACS.

Individual-patients data analysis from the BEST, PRECOMBAT, and SYNTAX studies compared the outcome of CABG with that of percutaneous coronary intervention in 1246 patients with stabilised NSTEMI-ACS and multivessel or left main stem disease.

The 5 year incidence of the primary outcome (death, MI, or stroke) was significantly lower with CABG than with percutaneous coronary intervention. The findings of this meta-analysis were consistent with the main findings of the studies included, thus supporting the concept that the principles of stable coronary artery disease should apply to stabilised patients with NSTEMI-ACS as well.

For complex cases, Heart Team discussion and use of the SYNTAX score are recommended, given its ability to predict death, MI, and revascularisation in patients with non-ST-segment elevation acute coronary syndrome and multivessel disease undergoing percutaneous coronary intervention. In patients with multivessel disease and diabetes in particular, recent evidence suggests a greater benefit of CABG vs. percutaneous coronary intervention.

How common is coronary artery bypass grafting? (Epidemiology)^[8]

Internationally there is considerable geographical variation in terms of numbers of revascularisation procedures and the proportion that are surgical.

In England there is a 13-fold difference in the ratio of elective PCI to CABG, which is not explained by overall procedure volume or deprivation.^[9]

Surgical technique^[4]

- The operation is usually performed through a mid-sternal incision.
- Veins may be harvested from the saphenous vein in the legs but arteries are also used and these give better long-term outcomes, particularly the internal mammary artery.
- The most commonly used arteries are the internal thoracic (internal mammary) but the gastro-epiploic also avoids the need for a proximal anastomosis, although it is currently rarely used.
- Endoscopic vein harvesting^[10] and radial artery harvesting are an alternative to open harvesting and are being used increasingly, although there is no unequivocal evidence of beneficial long-term patency.
- Bilateral internal mammary artery grafting is associated with improved long-term survival and non-fatal events. There is a small increased risk of sternal dehiscence and mediastinitis, especially in the obese and people with diabetes, when the radial artery is recommended as the second arterial graft.
- Over 75% of patients have at least three grafts and at least one is usually an artery.

- It is possible to use a smaller incision in a technique called minimally invasive direct coronary artery bypass (MIDCAB) with a more lateral approach:
 - In minimal access surgery, a small incision is made directly over the artery to be bypassed.
 - MIDCAB should be considered in patients with isolated left arterial disease.
 - Minimally invasive procedures are still being evaluated and are not yet available routinely.^[11]
- Operating without cardioplegia (off-pump CABG) is possible, the rationale being that much of the morbidity related to CABG is caused by the cardiopulmonary bypass, in particular the risk of stroke:^[12]
 - Large RCTs have not shown any difference in 30-day or 1-year clinical outcomes between on-pump and off-pump CABG.^[13]
 - Outcomes may depend on the expertise of the surgical team.
 - There may be a subgroup of patients with end-stage chronic kidney disease who might benefit from off-pump CABG; they appear to benefit from lower in-hospital mortality and fewer new renal replacements with off-pump compared with on-pump CABG.
 - On-pump CABG remains the standard surgical procedure.
- Most surgeons prefer cardioplegia with cardiopulmonary bypass.

Outcomes

- CABG significantly improves symptoms of angina, quality of life and exercise capacity; it reduces the need for anti-anginal therapy compared with medical treatment.^[14]
- 10-year cumulative survival rates are in the order of 77% decreasing to 15% at 30 years. In the same centre, 94% of patients needed repeat intervention.^[15]
- At 10 years the benefit of CABG over medical therapy is lost in those who had only saphenous vein grafts but after arterial grafts, it remains.

- Survival is improved, with the greatest relative benefit going to those with left main stem (LMS) stenosis of >50%. Patients with angina and triple-vessel disease or two-vessel disease, including proximal LAD stenosis, also survive longer but those with two-vessel disease excluding proximal LAD stenosis or with single-vessel disease, gain no survival advantage.
- Patients with abnormal LV function or strongly positive exercise tests derive greater absolute survival benefit from CABG surgery than from medical therapy.
- Women undergoing both CABG and PCI have greater complications and early mortality compared to men, which is independent of comorbidity and age.^[16] However, despite this, long-term survival does not differ between genders.^[17]

Complications

Chest pain^[18]

Data suggest that almost 10% of patients who undergo coronary artery bypass grafting (CABG) are readmitted to hospital within 30 days of surgery. The causes of **chest pain** after cardiac surgery include infectious, inflammatory and ischaemic.

Pain is often related to mechanical trauma from the sternotomy, in which case it is localised and exacerbated by movement. A palpable click suggests mediastinal instability, which should prompt referral back to the cardiac surgeon.

Pain may be related to wound infection, which also leads to localised pain, along with characteristic signs of infection.

Nerve damage while harvesting the internal mammary artery for grafting purposes may result in neuropathic parasternal hypo- or hyperesthesia.

Pericarditis and myocardial ischaemia must always be considered.

Other complications^[4]

- **Myocardial infarction** occurs in 1-2% with probably rather more cases of diffuse myocardial damage.

- [Acute kidney injury](#).
- Low output states requiring supportive measures.
- Ventricular arrhythmias like [broad complex tachycardias](#).
- [Stroke](#) occurs in 1-2%. Reducing handling of the aorta may reduce cerebral embolism: in patients with significant atherosclerosis of the ascending aorta, off-pump CABG and/or no-touch on-pump techniques are recommended:
 - Pre-operative Doppler ultrasound scanning is recommended in patients with a history of stroke/transient ischaemic attack.
 - In selected patients, carotid artery revascularisation at the same time as CABG may be performed.
- Damage to other organs is rare in elective surgery but the risk increases with bypass time and increasing age.
- Antiplatelet therapy:^[19]
 - Low-dose aspirin should be maintained except in those patients at very high risk of peri-operative bleeding or those who refuse transfusion, in whom it should be stopped three days prior to CABG.
 - Clopidogrel should be stopped five or more days prior to CABG, to avoid bleeding complications that may increase peri-operative mortality. The only exception is if there is uncontrolled ischaemia. Discontinuation does not appear to increase cardiac risk.
 - Prasugrel should be stopped seven days prior to CABG.
 - Ticagrelor should be stopped five days prior to CABG.
 - Bridging therapies, using short-acting antiplatelets or an antiplatelet antagonist, are being explored.

- Cognitive decline following CABG has been reported in various studies. Most changes in cognition are thought to be mild and to reverse within the first few months after surgery. This has been confirmed in a study of 696 patients in whom neurocognitive deficits were identified both at discharge and at three months postoperatively but were not associated with any significant clinical differences in quality of life or patient outcomes. [20]

Follow-up

Attention must be paid to [secondary prevention of CHD](#) and [cardiac rehabilitation](#), including:

- Stopping smoking is essential where relevant.
- Statins should be used to achieve target cholesterol levels. [21]
- Control of blood pressure and diabetes should be optimised.
- Encourage exercise and a healthy diet.

Further reading

- [Ford TJ, Berry C](#); Angina: contemporary diagnosis and management. *Heart*. 2020 Mar;106(5):387–398. doi: 10.1136/heartjnl-2018-314661. Epub 2020 Feb 12.
- [Acute coronary syndromes](#); NICE Guidance (November 2020)
- [Angina](#); NICE CKS, October 2022 (UK access only)
- [Doenst T, Thiele H, Haasenritter J, et al](#); The Treatment of Coronary Artery Disease. *Dtsch Arztebl Int*. 2022 Oct 21;119(42):716–723. doi: 10.3238/arztebl.m2022.0277.

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