Coronary artery bypass surgery

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Abstract

For over four decades, coronary artery surgery has been shown to relieve angina and extend life expectancy in patients with severe coronary artery disease. Pioneered in the 1960s, it has grown to become the most commonly performed and most intensively studied surgical procedure in the world, and remains the gold standard method for coronary revascularization, especially in patients with the most severe disease. Although increasingly challenged by percutaneous techniques using stents, the last decade has witnessed a significant reduction in surgical mortality (currently less than 1% in elective patients) and morbidity despite being applied in an increasingly older and sicker population. The use of arterial grafts, especially the left internal mammary artery, has resulted in significant improvements in long-term patency and clinical outcome. More recent technical advances include beating heart (off-pump) surgery and minimally invasive techniques.

Keywords Conduits; coronary artery bypass; ischaemic heart disease; off-pump; revascularization

Coronary artery disease (CAD) represents a major health burden in the Western world. It accounts for around 95,000 deaths in the UK each year, making it the most common cause of death (one in five men and one in seven women die as a consequence of CAD). Around 2.1 million men and 1.3 million women (3.4 million adults) in the UK have suffered angina and/or a heart attack. Worldwide, cardiovascular disease results in over 19 million deaths and CAD accounts for the majority.

Over 110,000 revascularization procedures (>85,000 percutaneous and >28,000 coronary artery bypass grafting [CABG] procedures) were performed in the UK in 2010. Revascularization (either surgical or percutaneous) improves symptoms and quality of life in patients with CAD but only surgical revascularization has been shown to also improve life expectancy.

Coronary artery bypass grafting

CABG is the most common surgical procedure performed on the heart, with over half a million operations performed every year worldwide. For the last three decades, CABG has remained the 'gold standard' treatment for patients with multivessel CAD and is the most extensively studied surgical procedure with follow-up data extending to several decades. It is highly effective in relieving the symptoms of ischaemic heart disease and improves life expectancy in certain anatomical subsets; these benefits are magnified in patients with more severe disease and those with impaired left ventricular function. Furthermore, CABG is a remarkably safe therapy. Improvements in medical, anaesthetic and surgical management have ensured static mortality rates over the last decade despite increasing application to an ageing and sicker patient population. Relief from angina and improved quality of life are achieved in the majority of patients but the main long-term drawback is vein graft failure leading to recurrent angina, myocardial infarction and death. The annual attrition rate of vein grafts is about 2–4%, leading to recurrent angina in 20% of patients at 5 years and 40% at 10 years. However, the widespread use of arterial grafting, antiplatelet agents and statins is likely to improve graft longevity and subsequent outcome.

Indications

Randomized trials performed in the 1970s confirmed the superiority of CABG over medical therapy with respect to relief from angina and improved quality of life in symptomatic patients. The main trials included: the Coronary Artery Surgery Study (CASS), the Veteran's Administration Coronary Artery Bypass Trial, and the European Coronary Artery Bypass Trial. These studies served to define the population subsets most likely to derive prognostic benefit from surgery. A landmark meta-analysis confirmed the benefits of CABG, especially in high-risk patients.[1,2] The clinical indications for CABG are listed in Table 1.[3]

Risk assessment

Several systems of stratification can be used to estimate the risk associated with cardiac surgery. Risk stratification defines the ability to predict outcomes from a given intervention by arranging patients according to the severity of their illness. Thus, outcomes from surgery may be compared to those predicted by risk models. Risk stratification also serves to estimate the risks of surgery in individual patients, allowing careful comparison with the potential or perceived benefits. The most commonly used risk stratification systems include:

- **Parsonnet** – this model was originally developed in the USA in 1985. Recent advances in clinical practice mean that this now overestimates the risk of mortality associated with cardiac surgery, and it is rarely used.
- **EuroSCORE** – developed in Europe and previously widely used in the UK, this is a better predictor of risk than Parsonnet and readily used at the patient's bedside (Table 2). However, it consistently overestimates risk and a modified, updated version (EuroSCORE II) is now available (www.euroscore.org).
- **Society of Thoracic Surgeons (STS) risk calculator** – used in the USA, this extensive system provides measures of both mortality and morbidity (riskcalc.sts.org).

Conduits for CABG

The principle of CABG is to bypass diseased segments of the coronary circulation using arterial and venous conduits – the

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Indications for surgery in ischaemic heart disease

Indications for myocardial revascularization

- Relief of angina (stable or unstable) unresponsive to medical therapy
- Severe symptoms despite optimal medical therapy
- Congestive heart failure complicating acute myocardial ischaemia or severe coronary artery disease
- Cardiogenic shock after myocardial infarction

Anatomic considerations indicating prognostic benefit of CABG

- Left main coronary artery stenosis >50%
- Left main equivalent disease: significant stenosis (>70%) of proximal LAD and proximal circumflex artery
- Three-vessel coronary artery disease with left ventricular dysfunction (left ventricular ejection fraction [LVEF] <50%)
- Two-vessel disease including a proximal LAD stenosis combined with left ventricular dysfunction

Other indications

- Mechanical complications of myocardial infarction including post-infarction ventricular septal defect, mitral regurgitation secondary to papillary muscle dysfunction, and ventricular rupture

Table 1

most frequently used are the left internal mammary artery (LIMA) and the long saphenous vein. Several other options (radial artery, gastroepiploic artery, cephalic vein) have been used with varying results. Performance is judged on the basis of long-term patency and effect on clinical outcome. Patient factors, including coronary anatomy, also play an important part in the decision-making process. Figure 1 shows some of the graft configurations that may be used in CABG.

Left internal mammary artery

Initially used in the early 1970s, popularity of the LIMA conduit has grown remarkably following reports demonstrating superior patency rates (exceeding 90% at 10 years) and patient survival in comparison with saphenous vein grafts. The Cleveland clinic group reported an 11% improvement in 10-year survival in patients receiving LIMA to LAD;[4] this is now the conduit of choice to the diseased LAD and is the standard of care for patients undergoing CABG.

Bilateral internal mammary arteries

The superior performance of the LIMA leads intuitively to the assumption that use of bilateral IMA grafts (BIMA) should maximize benefit. To date, the most powerful supporting evidence comes from a meta-analysis of over 15,000 patients.[5] However, routine use of BIMA should be weighed against potential drawbacks, which include devascularization of the sternum (with resulting increase in the risk of wound complications, especially in obese patients with diabetes mellitus), prolonged operation time and technical challenges associated with its use. The only randomized trial (Arterial Revascularization Trial — ART) comparing the value of BIMA and single IMA has been completed and is due to report long-term outcomes in the near future.[6]

The additive EUROSCORE (www.euroscore.org)

Patient-related factors		**Score**
Age	Per 5 years or part thereof over 60 years	1
Sex	Female	1
Chronic pulmonary disease	Long-term use of bronchodilators or corticosteroids for lung disease	1
Extracardiac arteriopathy	Any one or more of the following: claudication, carotid occlusion or >50% stenosis, previous or planned intervention on the abdominal aorta, limb arteries or carotids	2
Neurological dysfunction	Severely affecting ambulation or day-to-day functioning	2
Previous cardiac surgery	Requiring opening of the pericardium	3
Serum creatinine	>200 mmol/L	2
Active endocarditis	Patient still receiving antibiotic treatment for endocarditis at the time of surgery	3
Critical pre-operative state	Any one or more of the following: ventricular tachycardia or fibrillation or aborted sudden death, pre-operative cardiac massage, pre-operative ventilation before arrival in the anaesthetic room, pre-operative inotropic support, intra-aortic balloon counterpulsation or pre-operative acute renal failure (anuria or oliguria < 10 ml/h)	3
Cardiac-related factors		
Unstable angina	Angina at rest requiring IV nitrates until arrival in the anaesthetic room	2
LV dysfunction	Moderate (LVEF 30–50%)	1
	Poor (LVEF <30%)	3
Recent myocardial infarct	<90 days	2
Pulmonary hypertension	Pulmonary artery systolic pressure >60 mmHg	2
Operation-related factors		
Emergency	Carried out before the beginning of the next working day	2
Other than isolated CABG	Major cardiac procedure other than or in addition to CABG	2
Surgery on the thoracic aorta	Disorder of ascending arch or descending aorta	3
Post-infarct septal rupture		4

Table 2