Will coronary artery surgery disappear in 10 years' time?

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Over the past 20 years, percutaneous coronary intervention has progressively developed and matured, and many patients with severe coronary artery disease can now be revascularized non-surgically. So are the days of coronary artery bypass graft surgery numbered?

Coronary artery bypass graft (CABG) surgery has been a valuable means of achieving myocardial revascularization in patients with severe coronary artery disease since its introduction into clinical practice in 1967 (Favalaro, 1968). During this time, there have been great developments in technique, e.g. use of arterial conduits, which have improved long-term outcomes. More recently, there have been other major advances in treatment of coronary artery disease. New and improved pharmacological agents and the development of percutaneous coronary intervention (PCI) have enabled greater numbers of patients with uncontrolled angina and acute myocardial infarction (MI) to be treated more effectively (Gruentzig, 1978). Nevertheless, the numbers of patients undergoing CABG has remained high both nationally and internationally, with 180 000 and 28 000 cases being performed in the USA and UK respectively in 1997 (Society of Cardiothoracic Surgeons of Great Britain and Ireland, 2001; Society of Thoracic Surgeons, 2001).

CABG and PCI have been regarded as complementary. Single vessel and single lesion cases are predominantly selected for PCI, while CABG is recommended for those with more extensive disease. Over the last decade, technological improvements in PCI, particularly the emergence of intracoronary stents, has led to its wider application in selected patients with multivessel disease. Consequently, the cardiac surgeon's case mix has changed dramatically. Surgeons are now generally referred the patient with chronic total occlusions, left main stem stenoses, complex coronary artery lesions, diffuse multivessel disease (especially in those with impaired left ventricular function), those who have previously undergone CABG procedures and those patients thought for other reasons to be unsuitable for PCI.

So is this situation likely to continue or will PCI or some other technology make CABG 'a thing of the past' in 10 years' time? In short, it is unlikely that CABG will not be necessary in the next decade. We will probably see a reduction in certain cases referred for surgery, but the extent is very dependent upon developments in the available current technology used in PCI, the introduction of new devices for overcoming presently impossible anatomical challenges and the emergence of randomized clinical trials demonstrating that both short- and long-term benefits of PCI are equivalent to or better than CABG for specific clinical subgroups. Even so, there are situations where CABG will continue to be the treatment of choice. Moreover, as cardiologists continue to investigate an ever increasingly aged population, advanced coronary disease is more frequently being revealed which is beyond the capabilities of PCI. Complex cases are likely to need multiple PCI technologies or synergistic techniques which will significantly increase procedural duration and cost, and it is unlikely that sufficient resources and technical skills will be available to make CABG an unrealistic alternative.

CASES WHICH WILL CONTINUE TO REQUIRE CABG

These patients (*Table 1*) include those with significant coronary artery lesion(s) who require cardiac surgery for some other condition, e.g. valvular disease, aortic dissection or aneurysm repair, or constrictive pericarditis, who will continue to require concomitant CABG unless PCI and a 'hybrid' procedure is deemed more appropriate.

Patients requiring cardiac surgery to deal with mechanical complications of acute MI, e.g. severe mitral regurgitation, large ventricular septal defect or cardiac rupture, will continue to require surgical intervention. Certain clinical and anatomical

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problems currently make PCI impossible, and it seems likely that any developments will overcome these problems within the foreseeable future. These include patients with occluded saphenous vein grafts (SVG) (or arterial grafts); severe, diffuse and extensively calcified coronary arteries and those with tortuous, diffusely diseased old SVGs where 'filter devices' are unlikely to prevent important distal embolization and MI.

Severe obstructive peripheral vascular disease, unfolding and tortuosity of the aorta and marked dilatation of the aortic root can frequently make it impossible to access the coronary ostia with a guiding catheter, leaving CABG as the only option for revascularization. Similarly, severe tortuosity of the coronary artery itself, especially when the lesion is close to the bend or if the vessel is also calcified, may make it impossible to reach or cross the lesion with a guidewire, balloon or stent.

Distal left main coronary artery lesions which involve the origins of the left anterior descending (LAD), left circumflex (LCX) and large intermediate arteries will remain problematic and unpredictable after PCI, and CABG will continue to be the preferred option in all except those where cardiac surgery is contraindicated.

Abrupt vessel closure as a result of coronary artery dissection or thrombosis which causes dramatic haemodynamic collapse is now rare, but if this arises and cannot be rectified by prompt PCI, it will probably only be rescued by emergency CABG and circulatory support. The increase in elective stenting has been responsible for the diminishing frequency of this complication, but it is unlikely to disappear completely.

Finally, an accumulation of adverse features for PCI in a single patient, e.g. tortuosity, calcification, chronic total occlusion and multivessel disease with a bifurcation lesion, would persuade most interventionists to refer such a case for CABG. Although staged procedures could conceivably be performed in these difficult situations, most interventionists accept that a good CABG procedure would be just as (if not more) simple and effective for the patient and interventionist.

TABLE 1.
Cases which will still require coronary artery bypass grafts

Patients requiring concomitant myocardial revascularization at time of other open heart surgery, e.g. valve replacement, aortic dissection or aneurysm repair, left ventricular aneurysm resection	
Patients requiring surgery for post-myocardial infarction ventricular septal defect or mitral regurgitation	
Cases impossible for PCI	Occluded saphenous vein grafts and native coronary arteries
	Tortuous, severely diseased saphenous vein grafts
	Diffuse, severe calcific coronary disease
	Distal left main stem trifurcation stenosis
	Adverse coronary anatomy, e.g. severe tortuosity
	Multiple adverse features for PCI in a single patient
	Severe peripheral vascular disease making access impossible
Abrupt vessel closure after PCI complication associated with haemodynamic collapse which cannot be rescued by catheter-based techniques	

PCI = percutaneous coronary intervention

TABLE 2.
Cases which will require coronary artery bypass grafts less frequently

Complications of percutaneous transluminal coronary angioplasty
Complex lesion morphology
Multivessel disease
Left main stem stenosis
Acute coronary syndromes including acute myocardial infarction

CASES WHICH WILL PROBABLY REQUIRE CABG LESS FREQUENTLY

These are listed in *Table 2*. With the introduction of machine-crimped, low-profile, flexible coronary artery stents, complications of percutaneous transluminal coronary angioplasty (PTCA) can usually be treated successfully without having to resort to emergency CABG. Data from the British Cardiovascular Intervention Society (2000) have confirmed that the increased use of elective stenting has reduced acute complication rates and need for emergency CABG (*Figure 1*). In particular, complex lesions which are prone to a higher risk of complications after PTCA, e.g. bulky, ulcerated or eccentric lesions, lesions on bends and at bifurcation points, are now frequently and confidently treated by PTCA and stent implantation. Whether debulking of specific lesions before stent implantation will improve outcomes remains to be seen (Goldberg and Aji, 1998; Moussa et al, 1998).

Patients with multivessel disease will also be more often treated by PCI than by CABG, especially with the advent of drug-coated or drug-eluting stents that limit the fibrointimal hyperplasia currently responsible for 'in-stent restenosis' and the need for subsequent repeat procedures (Gunn and Cumberland, 1999). Such devices will make stenting of some left main coronary artery lesions (ostial or body) less unpredictable than at present, and PCI will no longer be a contraindication.

Patients with acute coronary syndromes including MI, those who have been treated with glycoprotein IIb/IIIa inhibitors or thrombolytic agents and those who are haemodynamically unstable post-MI are likely to have a lower morbidity and

mortality when treated with PCI than with CABG. Surgery will generally be reserved for those in whom PCI is not technically possible and for those unusual cases with complications after PCI which cannot be rectified by catheter-based techniques.

CASES WHICH MAY BE MORE APPROPRIATE FOR PCI IN THE FUTURE

These are listed in *Table 3*. Certain patients are currently considered poor cases for PCI and referred for CABG. However, technological developments may change these situations. For example, chronic total coronary artery occlusions, especially long occlusions, are not infrequently impossible to cross, and all but the more experienced interventionist will refer such patients for CABG. However, with further developments in guidewire design and other devices for safely seeking a passage through such a lesion, more of these difficult lesions may become more susceptible to PCI.

Difficult bifurcation lesions which involve large side branches exiting the main vessel at awkward angles are frequently a challenge for PCI. PTCA often produces a suboptimal angiographic result and bifurcation stenting is difficult, fraught with hazards and pitfalls, and associated with high restenosis rates. The development of coated or drug-eluting stents, specifically designed to fit particular bifurcation lesions, easy to implant and associated with no restenosis, would make PCI more attractive than CABG and worth the effort. Distal left main coronary artery lesions which involve the origins of the LAD and LCX coronary arteries could also then fall prey to the interventionist rather than the surgeon.

Long lesions, diffuse disease, lesions in small vessels and recurrently restenosing lesions could be satisfactorily dealt with by stenting with devices not associated with thrombosis or restenosis, obviating the need for CABG. Early work with Taxol-coating and rapamycin-eluting stents shows great promise and may herald a new era in coronary intervention (Herdeg and Karsch, 2000). For in-stent restenosis, brachytherapy is being used to prevent recurrent restenosis and the need for CABG (Sheppard and Eisenberg, 2001).

Although heavily calcified coronary arteries make PCI impossible, superficial calcification which may cause balloon resistance can be dealt with by high-speed rotational atherectomy with the Rotablator® (Boston Scientific Ltd, Maple Grove, Minnesota, USA) to enable successful dilatation and stenting to take place. The Cutting Balloon™ (Interventional Technologies Ltd, San Diego, California, USA) can similarly be used for tough, balloon-resistant lesions before stent deployment, and combination of such synergistic techniques are likely to become more widespread among interventionists.

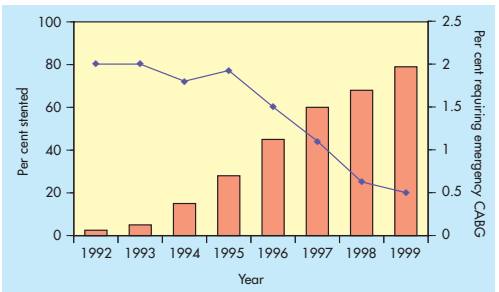

Figure 1. Stenting ■ and the need for emergency coronary artery bypass grafting (CABG) ◆. From British Cardiovascular Intervention Society (2000).

Certain subgroups of patients, such as diabetics, Asians and those with small vessels or multivessel disease and poor left ventricular function, may have better short- and long-term outcomes with PCI than with CABG, with developments such as low-profile, coated or drug-eluting stents being free from the risk of restenosis. Such a strategic change will depend very much on conclusive proof from controlled clinical trials.

DEVELOPMENTS IN CABG

Over the last 24 years since the development of PCI, CABG techniques have further developed in the hope of reducing both early and late morbidity and mortality (Eagle et al, 1999). For example, off-pump surgery seems to significantly reduce the morbidity and cost of CABG, particularly reducing neurological, renal, myocardial, respiratory and haematological complications associated with cardiopulmonary bypass.

Patients who may specifically benefit from surgery off-pump include the elderly, those with atheromatous aortas, significant cerebrovascular disease, impaired renal function and patients undergoing redo surgery, particularly those with patent internal mammary artery (IMA) grafts who can be reoperated on via a left thoracotomy or

TABLE 3.
Cases currently suitable for coronary artery bypass grafts which are likely to be more suitable for percutaneous coronary intervention in the future

Chronic total occlusions
Difficult bifurcation lesions
Distal left main stem lesions
Diffuse disease/multiple sequential lesions
Diseased small coronary arteries
Recurrent restenosis lesions
Diabetics
Multivessel disease and impaired left ventricle

subxiphoid incision. Use of IMA, and probably gastroepiploic and radial arterial grafts seem to improve long-term outcomes compared with SVGs, but artificial grafts which are not prone to late atherosclerosis or thrombosis are still needed.

When it is most suitable, minimally invasive CABG can offer arterial grafting with minimal trauma and a short hospital stay, but it remains to be determined by clinical trials whether techniques such as closed-chest, port-access, video-assisted or robotic CABG procedures offer sufficient advantages to be worth pursuing. Despite these improvements, CABG cannot match the minimally invasive nature of PCI. However, the long-term outcomes of PCI must be comparable to or surpass those of CABG if the former is to replace the latter for any or all subsets of patients with coronary artery disease who require intervention.

IMPACT OF NEW RESEARCH ON NUMBERS OF PATIENTS NEEDING CABG

It is extremely unlikely that the next 10 years will see the arrival of any new drug which will reverse the atherosclerotic process, and the introduction of aggressive primary prevention programmes and statins is unlikely to significantly reduce the incidence of coronary artery disease within this time frame. It is also unlikely that techniques for angiogenesis using laser, pharmacological agents or gene therapy will significantly reduce the need for PCI and CABG, although they may prove useful for patients deemed unsuitable for these techniques. However, experimental, clinical, anatomical, biochemical, microbiological, genetic and molecular research will continue to provide a greater understanding of the mechanisms involved in plaque growth, stability and vulnerability and ways of favourably altering the pathological process. If this research is fruitful, future generations will look back with some amusement at the ingenious ways in which cardiologists and surgeons tackled the clinical problem of coronary atherosclerosis, and both PCI and CABG will be truly 'history'.

KEY POINTS

- Percutaneous coronary intervention (PCI) has enabled more patients with angina, acute coronary syndromes and acute myocardial infarction to be treated more effectively than ever before.
- PCI has already affected the sort of cases referred for coronary artery bypass graft (CABG) surgery.
- CABG surgery will continue to be necessary for the foreseeable future.
- PCI will be increasingly preferred over CABG surgery for myocardial revascularization for certain cases.
- PCI may become preferred to CABG surgery for other cases in the future, but this is dependent on advances in the technology currently used in PCI.
- Close working relationships between surgeon and interventionist will ensure optimal treatment for those patients with severe coronary artery disease

CONCLUSIONS

Although PCI has enabled more patients with angina, acute coronary syndromes and acute MI to be more effectively treated than ever before, there are still many problems to be solved before CABG is no longer required. The introduction of 'super stents' which are not prone to acute thrombosis or later restenosis will go a long way to making PCI a real alternative to CABG for a range of patients. More effective devices for dealing with chronic total occlusions and other difficult complex lesion subsets will help further reduce the need for CABG. Repeat CABG or complex PCI techniques may be avoided by the development of artificial surgical conduits for bypass grafting which will not thrombose or develop late atherosclerosis.

CABG is likely to be necessary for a variety of clinical and anatomical reasons for the foreseeable future, and close working relationships between surgeon and interventionist will ensure optimal treatment for patients with severe coronary artery disease. It will take some major advances in the understanding of how atherosclerotic plaques develop, progress and regress and how these processes can be genetically or pharmacologically altered before any significant impact is made on slowing, let alone reversing, growth of this pathology. Perhaps then we will see a reduction in the need for CABG and also PCI. HM

Conflict of interest: none.

British Cardiovascular Intervention Society (2000) BCIS Audit Returns of Interventional Procedures. http://www.bcis.org.uk/audit/oct01.html (accessed 19 November 2001)

Eagle KA, Guyton RA, Davidoff R et al (1999) ACC/AHA guidelines for coronary artery bypass surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol* **34:** 1262–346

Favalaro RG (1968) Saphenous vein autograft replacement of severe segmental coronary artery occlusion: operative technique. *Ann Thorac Surg* **5:** 334–9

Goldberg S, Aji J (1998) Plaque excision combined with stent placement. Can a poor 'finisher' become a good 'starter'? *Circulation* **98:** 1591–3

Gruentzig AR (1978) Transluminal dilatation of coronary artery stenosis. *Lancet* **i:** 263

Gunn J, Cumberland D (1999) Stent coatings and local drug delivery: state of the art. *Eur Heart J* **20**(23): 1693–700

Herdeg C, Karsch KR (2000) Local paclitaxel delivery for the prevention of restenosis: biological effects and efficacy in vivo. *J Am Coll Cardiol* **35**(7): 1969–76

Moussa I, Moses J, Di Mario C et al (1998) Stenting after optimal debulking (SOLD) Registry. Angiographic and clinical outcome. *Circulation* **98:** 1604–9

Sheppard R, Eisenberg MJ (2001) Intracoronary radiotherapy for restenosis. *N Engl J Med* **344**(4): 250–6

Society of Cardiothoracic Surgeons of Great Britain and Ireland (2001) United Kingdom Cardiac Surgical Register 1977–2000. Trends in Surgery for Ischaemic Heart Disease. http://www.ctsnet.org/doc/2102 (accessed 19 November 2001)

Society of Thoracic Surgeons (2001) Annual Trends and Summaries. The Eighth Year 1999. http://www.sts.org (accessed 19 November 2001)