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# Bypass surgery versus PCI for multivessel coronary artery disease: Competing or complimentary strategies?

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**Coronary artery bypass graft surgery (CABG), in comparison to medical therapy, reduces mortality in patients with high-risk coronary anatomy and/or ventricular dysfunction. Percutaneous coronary angioplasty relieves angina and is the preferred treatment for most single-vessel disease. Recent therapeutic advances (eg, coronary stenting, antiplatelet agents) have expanded the targets for percutaneous coronary intervention (PCI). A subgroup of patients with multivessel disease are candidates for revascularization with either CABG or percutaneous coronary angioplasty. This issue of *Cardiology Rounds* reviews the merits of each approach and outlines a practical management strategy.**

## Coronary artery bypass graft surgery (CABG)

Since its introduction in the 1960s, CABG has been recognized as an excellent treatment for angina. CABG reduces mortality in patients with high-risk coronary anatomy, including left main stenosis, three-vessel disease with involvement of the proximal left anterior descending artery, and multivessel disease with left ventricular dysfunction, even in the absence of angina.[1-4] The extent of ischemia, rather than simply the severity of symptoms, has become paramount in the decision to revascularize. A demonstration of dysfunctional, but viable, myocardium provides further impetus for revascularization since this tissue may be salvaged when blood flow is restored.[5]

Improved outcomes after CABG have resulted from advances in the techniques of surgical revascularization (including use of internal thoracic artery grafts) and in perioperative care.[6] Despite the success and growth of CABG, the search continues for alternatives that avoid the morbidity of a sternotomy and aortic cross-clamping, the neurocognitive sequelae of a cardiopulmonary bypass,[7] and the high cost of surgical intensive care.

## PCI versus CABG: the pre-stent era

PCI includes percutaneous transluminal coronary angioplasty (PTCA), coronary stenting, and other specialized techniques. Trials comparing PTCA with medical therapy for single-vessel disease have demonstrated superiority in the relief of angina, but a neutral effect on mortality.[8,9]

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Angioplasty versus CABG for revascularization of multivessel disease has been studied extensively.[10-16] The largest trial in the pre-stent era was the Bypass Angioplasty Revascularization Investigation (BARI),[17] in which 1829 patients with multivessel disease – equally amenable to angioplasty or CABG – were randomized to one or the other modality. Over 5.4 years of follow-up, an initial strategy of angioplasty was equivalent to CABG with respect to survival (86.3% versus 89.3%, $P = 0.19$) and rate of Q-wave myocardial infarction (MI, 78.7% versus 80.4%, $P = 0.45$), but resulted in less morbidity and shorter initial hospitalization. However, revascularization was less complete after angioplasty and reintervention was required more often. The BARI results are consistent with those of earlier trials: over 1 to 5 years of follow-up, an initial strategy of angioplasty appears to be comparable to CABG with respect to survival and recurrent MI, but results in poorer control of angina, higher rates of hospitalization, and a greater need for repeat revascularization.[18]

## PCI versus CABG : the stent era

The introduction of stents in the early 1990s improved patient outcomes and revolutionized PCI.[19] In a study of the Dynamic Registry, 857 patients who met the criteria for BARI and received contemporary PCI were compared retrospectively with a cohort of 904 patients who had undergone balloon angioplasty in BARI itself. Compared with BARI, the Registry patients had:

- fewer lesions attempted (1.5 versus 2.6)
- more use of intracoronary stents and glycoprotein IIb/IIIa inhibitors
- higher rates of angiographic success (91% versus 72%)
- less abrupt closure (1.5% versus 9.5%)
- less urgent CABG (1.9% versus 10.2%)
- less MI (0.8% versus 2.1%)
- less need for subsequent revascularization,
- but, no mortality difference at 1 year.[20]

Several randomized trials have compared multivessel PCI and stenting with CABG.

- Although limited to a 1-year follow-up, the Argentine randomized study, Coronary Angioplasty with Stenting versus Coronary Bypass Surgery in Multivessel Disease (ERACI II),[21] was the first trial to suggest superiority of multivessel PCI over CABG with respect to survival (96.9% versus 92.5%, $P < 0.017$) and freedom from MI (97.7% versus 93.4%, $P < 0.017$). As expected, repeat revascularization was more common after PCI than CABG (16.8% versus 4.8%, $P < 0.002$).
- In contrast, the larger Arterial Revascularization Therapy Study (ARTS[22]) found no significant difference at 1 year between PCI and CABG with respect to survival (97.5% versus 97.2%) or freedom from MI (94.7% versus 96%). Again, repeat revascularization was higher after PCI at 1 year (16.8% versus 3.5%). One explanation for this difference is a higher percentage of unstable patients in ERACI II, a factor related to poorer surgical outcomes. However, retrospective analysis of ARTS with stratification for stable or unstable angina failed to identify higher surgical risks in patients with unstable syndromes.[23]
- The Stent or Surgery (SOS) trial[24] reported even better results with surgery, including lower mortality at 1 year after CABG (0.8%) than after PCI (2.5%). The generalizability of the SOS results is limited by the exceptionally low surgical mortality, as well as a greater number of noncardiovascular deaths in the PCI group.
- Favourable outcomes after surgery were also demonstrated in the Medical, Angioplasty, and Surgery Study (MASS II[25]) that randomized 611 patients with multivessel disease to medical therapy, angioplasty (including stenting in 70% of patients), or CABG. Although there was no mortality difference at 1 year, repeat revascularization was required in 14% of patients after PCI, 8% of patients receiving medication alone, and in no patients after CABG ($P < 0.0005$).

Five-year results from the trials mentioned above are eagerly anticipated. The findings of the major published trials are presented in Table 1.

## Special considerations: Diabetic patients

Among diabetics – a subgroup not specified in the original BARI protocol – survival after angioplasty was significantly lower than after CABG at 5 years (65.5% versus 80.6%, $P = 0.003$) and 7 years (55.7% versus 76.4%, $P = 0.001$), while use of an internal thoracic artery graft was the strongest independent predictor of improved survival.[26] Angiographic evidence of a

**Table 1: Selected trials of PCI versus CABG for multivessel disease**

| Trial | Duration | N | Death (%) | | Stroke (%) | | MI (%) | | Revascularization (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | PCI | CABG | PCI | CABG | PCI | CABG | PCI | CABG |
| BARI[17] | 5.4 years | 1829 | 13.7 | 10.7 | 0.2* | 0.8* | 21.3 | 19.6 | 54 | 8 |
| ERACI II[21] | 18.5 months | 450 | 3.1 | 7.5 | 0.0† | 0.9† | 2.3 | 6.6 | 16.8 | 4.8 |
| ARTS[22] | 12 months | 1205 | 2.5 | 2.8 | 1.5 | 2.0 | 5.3 | 4.0 | 16.8 | 3.5 |

* In-hospital events only
† 30-day events only

myocardium in jeopardy increased in diabetics from 1 to 5 years after angioplasty, but not after CABG,[27] suggesting that among diabetics, CABG provides more durable revascularization.

The ARTS trial echoed these findings in the stent era; diabetic patients treated with PCI had lower event-free survival at 1 year (63.4%) than nondiabetics after PCI (76.2%) or diabetics treated with CABG (84.4%).[28]

However, the BARI registry, which included 2010 patients who were not randomized, demonstrated equivalent mortality in diabetic patients when physicians were allowed to select the mode of revascularization. Angioplasty rather than CABG was chosen as initial revascularization for 65% of registry patients, with no effect on survival after 7 years in either nondiabetic or treated diabetic patients.[29] Furthermore, the Coronary Angioplasty versus Bypass Revascularization Investigation (CABRI) found equivalent mortality in diabetics treated with balloon angioplasty or CABG, although the mortality in both groups was more than double that of nondiabetics.[30] These findings suggest that patient selection and technical factors are key determinants of outcome after revascularization.

The influence of diabetes on revascularization remains the subject of intense study. Trials are underway to determine if tight glycemic control, drug-eluting stents, and antiplatelet agents can improve outcomes after revascularization in this high-risk group.

## Limitations of the trials

The trials discussed above provide valuable insights, but have several limitations. Foremost, the patients enrolled were at relatively low risk; ie, the majority had preserved left ventricular systolic function, 2-vessel disease, and few comorbidities. The low ratio of patients screened to patients enrolled further limits generalizability. Finally, the small patient numbers, low event rates, relatively short follow-up, and exclusion of patients with very high-risk coronary anatomy tend to minimize the mortality difference between PCI and CABG. However, retrospective analysis of the BARI trial, in which 40% of patients had 3-vessel disease, demonstrated equivalent survival after angioplasty, even in anatomic subsets associated with improved survival after CABG compared with medical therapy. This suggests that the mortality equivalence between PCI and CABG is not entirely due to patient selection.[31]

## Cost-effectiveness

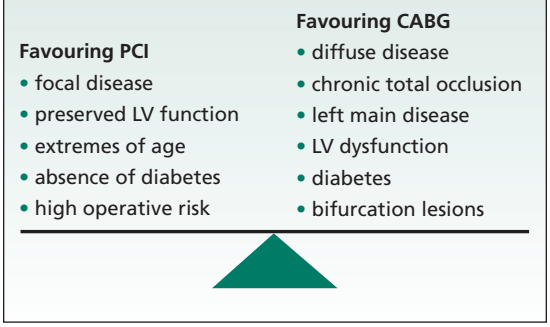
Cost-effectiveness was evaluated in ERACI II[21] and ARTS,[22] among other trials. Although the initial cost of CABG consistently exceeds that of PCI, the high rate of reintervention after PCI erodes the cost differential in ensuing years. There was a cost saving of about $3000 per patient at 1 year after PCI in ARTS, a benefit that extended to diabetic patients despite poorer outcomes.[28] Further studies are under way to compare the long-term cost-effectiveness of each approach.

## Clinical application

Consideration of the following factors is suggested when selecting treatment with PCI or CABG:

- For patients who require revascularization, but have preserved left ventricular function and 2- or 3-vessel

**Figure 1: Factors favouring PCI versus CABG**




disease that is focal in nature, PCI and CABG appear to be equivalent initial strategies with respect to mortality over 5+ years, in the absence of diabetes.

- Patients who prefer a less invasive initial strategy may be best suited for PCI, but they should be made aware that they have a greater chance of requiring repeat revascularization in the future than if they had chosen CABG. In this regard, it is notable that the vast majority of repeat revascularization procedures in the trials were percutaneous, rather than surgical.
- Very young patients may be more suitable for initial PCI, since repeated PCI or eventual CABG may be preferable over repeated CABG.
- The morbidity associated with sternotomy, cardiopulmonary bypass, and aortic cross-clamping argues in favour of PCI for elderly patients, especially those with multiple comorbidities.
- In contrast, CABG should be given first consideration for higher-risk patients with diffuse 3-vessel disease, impaired left ventricular function, chronic total occlusions, or diabetes. These considerations are illustrated in Figure 1.

## The future

Advances in minimally invasive and even robotic cardiovascular surgery have allowed internal mammary graft coronary bypass without sternotomy and cardiopulmonary bypass. Promise has been shown in taking a hybrid approach, combining minimally invasive bypass of the left anterior descending artery with a PCI of the remaining diseased vessels.[32-34] Larger trials with long-term follow-up are needed to determine if this approach has a significant advantage over either multivessel CABG or PCI alone.

Exciting progress with drug-eluting stents[35,36] is likely to dramatically improve outcomes after PCI. If drug-eluting stents fulfill their promise of preventing restenosis, then the principal limitation of PCI will be removed. Multivessel PCI with drug-eluting stent implantation could provide revascularization as durable as CABG, but without the associated morbidity. This hypothesis will be tested in several upcoming clinical trials, including the National Institute of Health-sponsored FREEDOM trial that will compare CABG and PCI with drug-eluting stents for diabetics with multivessel disease.

In summary, the management of multivessel coronary artery disease has benefited from the evolution of complementary, rather than competing, surgical and percutaneous revascularization strategies.

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## Abstracts of Interest

### Computer-enhanced telemanipulation enables a variety of totally endoscopic cardiac procedures.

DOGAN S, AYBEK T, KHAN MF, ET AL. FRANKFURT, GERMANY.

**BACKGROUND:** Since its introduction in the field of cardiac surgery in 1997, computer-enhanced telemanipulation has been used in a number of different specialized areas. In cardiac surgery, various procedures have been successfully completed in totally endoscopic fashion ever since. Between June 1999 and January 2002, 75 closed-chest cardiac procedures have been performed at our institution using the da Vinci telemanipulation system.

**PATIENTS AND METHODS:** In 42 patients, a single-vessel totally endoscopic coronary artery bypass was performed on the arrested heart (left internal thoracic artery (LITA) to left anterior descending artery (LAD), n = 36; right internal thoracic artery (RITA) to right coronary artery (RCA), n = 6). 12 patients had different types of multivessel revascularization using both internal thoracic arteries. 8 patients underwent LITA-to-LAD grafting on the beating heart. 10 patients underwent closure of an atrial septal defect (9 direct, 1 patch). 3 patients received an epicardial left ventricular pacemaker lead, 2 of which were reoperations.

**RESULTS:** Overall conversion rate to any kind of incision was 25%. The last 26 LITA to LAD patients on the arrested heart had a conversion rate of 4%. There were no mortalities, 3 patients required re-exploration via a median sternotomy, and one patient suffered a hypoxemic brain damage. The first 22 TECAB patients demonstrated excellent graft patency in angiographic control upon discharge. None of the atrial septal defect (ASD) closures showed any residual shunt on the intraoperative transesophageal echocardiogram (TEE). Patients with end-stage heart failure had successful biventricular stimulation.

**CONCLUSION:** Our current experience confirms the feasibility of various totally endoscopic cardiac procedures with good clinical outcomes. After a steep learning curve, the conversion rate could be lowered to an acceptable figure. Some of these procedures at our institution became a reasonable treatment alternative in selected patients. *Thorac Cardiovasc Surg* 2002;50(5):281-6.

### Coronary artery bypass surgery versus percutaneous coronary intervention with stent implantation in patients with multivessel coronary artery disease (the Stent or Surgery trial): a randomised controlled trial.

SOS INVESTIGATORS.

**BACKGROUND:** Results of trials, comparing percutaneous transluminal coronary angioplasty (PTCA) with coronary artery bypass grafting (CABG), indicate that rates of death or myocardial infarction are similar with either treatment strategy. Management with PTCA is, however, associated with an increased requirement for subsequent, additional revascularisation. Coronary stents, used as an adjunct to PTCA, reduce restenosis and the need for repeat revascularisation. The aim of the Stent or Surgery (SoS) trial was to assess the effect of stent-assisted percutaneous coronary intervention (PCI) versus CABG in the management of patients with multivessel disease.

**METHODS:** In 53 centres in Europe and Canada, symptomatic patients with multivessel coronary artery disease were randomised to CABG (n=500) or stent-assisted PCI (n=488). The primary outcome measure was a comparison of the rates of repeat revascularisation. Secondary outcomes included death or Q-wave myocardial infarction and all-cause mortality. Analysis was by intention to treat.

**FINDINGS:** All patients were followed-up for a minimum of 1 year and the results are expressed for the median follow-up of 2 years. 21% (n=101) of patients in the PCI group required additional revascularisation procedures compared with 6% (n=30) in the CABG group (hazard ratio 3.85, 95% CI 2.56-5.79, P<0.0001). The incidence of death or Q-wave myocardial infarction was similar in both groups (PCI 9% [n=46], CABG 10% [n=49]; hazard ratio 0.95, 95% CI 0.63-1.42, P=0.80). There were fewer deaths in the CABG group than in the PCI group (PCI 5% [n=22], CABG 2% [n=8]; hazard ratio 2.91, 95% CI 1.29-6.53, P=0.01).

**INTERPRETATION:** The use of coronary stents has reduced the need for repeat revascularisation when compared with previous studies that used balloon angioplasty, though the rate remains significantly higher than in patients managed with CABG. The apparent reduction in mortality with CABG requires further investigation.

*Lancet* 2002 28;360(9338):965-70.

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