One year comparison of costs of coronary surgery versus percutaneous coronary intervention in the stent or surgery trial

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Objectives: To compare initial and one year costs of coronary artery bypass grafting (CABG) versus percutaneous coronary intervention (PCI) in the stent or surgery trial.

Design: Prospective, unblinded, randomised trial.

Setting: Multicentre study.

Patients: 988 patients with multivessel disease.

Interventions: CABG and stent assisted PCI.

Main outcome measures: Initial hospitalisation and one year follow up costs.

Results: At one year mortality was 2.5% in the PCI arm and 0.8% in the CABG arm ($p = 0.05$). CABG was no different in the composite of death or Q wave myocardial infarction (6.9% for PCI v 8.1% for CABG, $p = 0.49$). There were more repeat revascularisations with PCI (17.2% v 4.2% for CABG). There was no significant difference in utility between arms at six months or at one year. Quality adjusted life years were similar 0.6938 for PCI v 0.6954 for PCI, $\Delta = 0.00154$, 95% confidence interval (CI) $-0.0242$ to $0.0273$). Initial length of stay was longer with CABG (12.2 v 5.4 days with PCI, $p < 0.0001$) and initial hospitalisation costs were higher (£7321 v £3884 for PCI, $\Delta = £3437$, 95% CI £3040 to £3848). At one year the cost difference narrowed but costs remained higher for CABG (£8905 v £6296 for PCI, $\Delta = £2609$, 95% CI £1769 to £3314).

Conclusions: Over one year, CABG was more expensive and offered greater survival than PCI but little added benefit in terms of quality adjusted life years. The additional cost of CABG can be justified only if it offers continuing benefit at no further increase in cost relative to PCI over several years.
Statistical analyses

Data are expressed as proportions or as mean with 95% confidence interval (CI) for non-normal continuous data. The two randomised arms were compared according to intention to treat. Follow up for mortality and repeat procedures was complete to one year or to the time of death for all patients. Differences in categorical variables were analysed by the χ² test (or Fisher's exact test) and differences in continuous variables were analysed by the Wilcoxon rank sum test. Because the cost data were not normally distributed, a resampling approach (5000 samples) was taken to obtain confidence intervals for the cost differences by using the empirical percentiles of the bootstrap distribution. Missing utility data were estimated by multiple imputation. Quality adjusted life years were calculated as the area under the utility curve from baseline to one year or time of earlier death. Statistical analysis was performed with SAS (SAS Institute, Cary, North Carolina, USA) and S-Plus (MathSoft Inc, Seattle, Washington, USA).

RESULTS

At one year the mortality rate was lower for the surgical group (0.8% vs 2.5%, p = 0.05), but there was no difference in the composite of death plus Q wave myocardial infarction (6.9% for PCI vs 8.1% for CAGB, p = 0.49). Repeat revascularisation was significantly greater in the PCI arm (17.2% vs 4.2%, p < 0.001).

Table 1 shows initial hospitalisation resource utilisation and unit costs. The majority of patients had their initial revascularisation procedure as planned, with a small number of crossovers. Resources are divided into PCI consumables and laboratory time, CAGB, hospital length of stay, and adverse events. Length of stay, calculated as the number of days the patients spent in the intensive care unit, high dependency unit, and general ward, was longer in the CAGB arm. Average postprocedural and total in-hospital stays were 8.7 days and 12.2 days for CAGB and 2.7 days and 5.4 days for PCI. There were also more investigator reported myocardial infarctions in the PCI arm but more bleeding in the CAGB arm. There was no difference in the incidence of stroke. During the initial hospitalisation there were more additional catheterisations and revascularisations in the PCI arm (table 2).

During follow up there were more repeat revascularisation procedures and additional cardiac catheterisations in the PCI arm (table 2). There were also more investigator reported myocardial infarctions during follow up in the PCI arm. There was no difference noted in the incidence of stroke or bleeding. The incidence of other hospitalisations and mean time in rehabilitation was higher in the CAGB arm.

Table 3 summarises rehabilitation and medications. Medications usage and cost, in particular the use of the antithrombotic agents ticlopidine and clopidogrel, as well as oral nitrates and calcium blockers, were greater in the PCI arm.

Table 4 summarises costs. Initial hospitalisation costs were higher in the CAGB arm. These higher initial costs are largely attributable to higher costs associated with the procedure and longer stay in the intensive care unit and wards. Higher initial hospitalisation costs were found for CAGB in each of the major subgroups (according to age, sex, presence of diabetes, presence of an acute coronary syndrome, history of a previous myocardial infarction, and number of diseased coronary vessels) (fig 1). Follow up costs were higher overall for PCI because of higher rehospitalisation and medication costs. Costs for rehabilitation were higher with CAGB. The total cost at one year remained higher with CAGB, both overall and for each of the major subgroups (fig 2).

There was a significant advantage to CAGB over PCI in life years gained (0.9943 v 0.9805, Δ = 0.0138, 95% CI 0.0012 to 0.0268), with the difference in mean life years between groups translating into 13 hours, favouring CAGB. The cost per life year gained for CAGB compared with PCI in the first year is £189 982 (95% CI £75 654 to £1 064 986).

DISCUSSION

CAGB offered significantly lower mortality and less angina at one year but the increase in quality adjusted life years compared with PCI was negligible and came at a considerable increase in cost, at least in the first year. Greater follow up costs associated with PCI were not enough to make up for the higher initial hospitalisation costs with CAGB. Exploratory subgroup analyses suggest that these differences are consistent for all the obvious subgroups.
The mortality results, with CABG being significantly better than PCI, probably reflect the play of chance. In the ARTS trial, the one year mortality rate for both PCI and CABG was the same as the PCI mortality in the present trial. In contrast, ERACI II showed a significant survival benefit for stenting. This considerable uncertainty about what the real difference is in mortality and in utility between CABG and PCI makes problematic a formal estimate of a one year time horizon, as well as long term incremental cost effectiveness analysis. The in-trial mortality advantage for CABG would result in a favourable incremental cost effectiveness ratio in cost per life year saved extended long term. However, whether this result may be considered meaningful depends entirely on the

Table 1 Average resource use per patient, unit cost, and average cost per patient during initial hospitalisation by treatment group

| Resource                  | PCI (n = 488) | CABG (n = 500) | Unit costs (£) | Average cost (£) |
|---------------------------|--------------|---------------|---------------|-----------------|
| Consumables for PCI       |              |               |               |                 |
| Laboratory time (min)     | 96.09        | 1.68          | 1.62          | 155.7           | 2.7             |
| Amount of contrast used (ml) | 380.82     | 7.06          | 0.15          | 57.1            | 1.1             |
| Number of guide catheters used | 2.05        | 0.04          | 36.62         | 74.9            | 1.5             |
| Number of guidewires used | 2.03         | 0.04          | 54.38         | 110.2           | 2.0             |
| Number of balloons used   | 2.43         | 0.04          | 186.00        | 360.7           | 7.1             |
| Number of IVUS catheters used | 0.05        | 0             | 495.00        | 23.3            | 0               |
| Number of stents used     | 2.57         | 0.04          | 553.00        | 142.0           | 24.3            |
| Abciximab (vial)          | 0.246        | 0             | 280.00        | 68.9            | 0               |
| Tirofiban (vial)          | 0.025        | 0             | 146.11        | 3.6             | 0               |
| Number of AngioSeal devices used | 0.02        | 0             | 72            | 1.6             | 0               |
| Number of IABP procedures | 0.01         | 0             | 445           | 4.6             | 0               |
| Number of Rotabulators used | 0.01        | 0             | 1007.73       | 12.4            | 0               |
| Number of Rotoblator 1.25 and 1.75 | 0.004 | 0 | 1451.61 | 5.9 | 0 |
| CABG (excluding length of hospital stay) | 0.014 | 0.97 | 3403.14 | 48.8 | 3314.7 |
| Hospitalisation length of stay (days) |            |               |               |                 |
| Intensive care unit       | 0.34         | 1.84          | 976.62/day    | 330.1           | 1796.4          |
| High dependency unit      | 0.61         | 0.92          | 557.12/day    | 342.3           | 510.9           |
| General ward              | 4.50         | 9.49          | 169.49/day    | 762.6           | 1608.5          |
| Adverse events (excluding length of hospital stay) |        |               |               |                 |
| Non-fatal myocardial infarction† | 0.039 | 0.016 | 885.00 | 0 | 0 |
| Stroke                    | 0.01         | 0.01          | 153.86        | 0.9             | 0.3             |
| Bleeding at vascular puncture site from cardiovascular procedure | 0.006 | 0.002 | 153.86 | 0.9 | 0.3 |
| Bleed at gastrointestinal site | 0.002 | 0.004 | 517.00 | 1.1 | 2.1 |
| Bleeding after surgery or other procedure | 0.002 | 0.026 | 1673.74 | 3.4 | 43.5 |

*Resource use presented only for initial hospitalisation; same unit costs used for repeat revascularisation.
†Additional costs included only for myocardial infarctions not associated with a revascularisation procedure.
CABG, coronary artery bypass grafting; IABP, intra-aortic balloon pump; IVUS, intravascular ultrasound; PCI, percutaneous coronary intervention.

Table 2 Initial and follow up resource utilisation

| Event                      | PCI (n = 488) | CABG (n = 500) | p Value |
|----------------------------|--------------|---------------|---------|
| Initial hospitalisation     |              |               |         |
| Revascularisation as planned | 480 (98.4%) | 487 (97.4%)   | 0.30    |
| Crossover revascularisation| 7 (1.4%)     | 11 (2.2%)     | 0.37    |
| Additional catheterisation | 5 (1.0%)     | 0 (0%)        | 0.029   |
| Additional CABG            | 6 (1.2%)     | 4 (0.8%)      | 0.542   |
| Additional PCI             | 6 (1.2%)     | 0 (0.0%)      | 0.014   |
| Rehospitalisation†         |              |               |         |
| Repeat PCI                 | 56           | 18            | <0.0001 |
| Repeat CABG                | 32           | 1             | <0.0001 |
| Cardiac catheterisation only | 62         | 11            | <0.0001 |
| Myocardial infarction      | 11           | 3             | 0.028   |
| Stroke                     | 4            | 3             | 0.72    |
| Bleeding                   | 0            | 1             | 1.0000  |
| Other reasons for hospitalisation† | 64 | 131 | <0.0001 |
| Mean time in rehabilitation (days) | 0.85 | 2.36 | <0.0001 |
| 95% confidence interval    | 0.42 to 1.44 | 1.78 to 3.01  |         |

*Total number of events.
†Other reasons (frequency) are as follows. For PCI arm: chest pain—cardiac (20), gastrointestinal (7), chest pain—non-cardiac (6), other—specify (6), genitourinary/gynaecological (4), vascular—other (4), haematological/lymphatic (2), musculoskeletal (2), respiratory (2), transient ischaemic attack (2), unable to classify (2), cancelled procedure (1), cardiac—other (1), cardiac arrhythmias—supraventricular/atrial fibrillation/atrial flutter (1), cardiac failure (1), ear, nose, throat (1), effusion—pleural (1), ophthalmological (1). For CABG arm: cardiac arrhythmias—supraventricular/atrial fibrillation/atrial flutter (13), chest pain—cardiac (12), respiratory (12), chest pain—non-cardiac (10), effusion—pleural (10), other—specify (10), gastrointestinal (8), musculoskeletal (8), genitourinary/gynaecological (7), cardiac—other (5), vascular—other (3), cardiac arrhythmias—complete heart block/bradycardia (4), surgical wound—infected of sternum (4), unable to classify (4), ear, nose, throat (3), neurological (3), surgical wound—infected of other site (3), vascular—deep vein thrombosis/pulmonary embolism (3), surgical wound—unstable sternum (2), cancelled procedure (1), cardiac arrhythmias—ventricular tachycardia/ventricular fibrillation/arrest (1), cardiac failure (1), dermatological (1), transient ischaemic attack (1).
The generalisability of the mortality data in this trial, which favoured CABG.

Other randomised trials comparing PCI with CABG have been carried out during the past 15 years. In the RITA-1 (randomised intervention treatment of angina) trial, 1011 patients with coronary artery disease (45% single vessel, 55% multivessel) were randomly assigned between May 1988 and November 1991 to an initial strategy of PTCA or CABG.11 4 No difference was noted in the incidence of death or the composite of death plus myocardial infarction. There were more repeat interventions and a greater degree of angina in the PTCA group. Total health care costs over five years, derived by similar methods to those used for SoS, were not significantly different between groups (mean difference £426, 95% CI £383 to £1235, p = 0.30).14 BARI (bypass angioplasty revascularisation investigation) and EAST (Emory angioplasty versus surgery trial) compared state of the art PTCA with CABG from the late 1980s.23 In each of these studies there was similar survival in both arms but more revascularisations with PTCA. While both studies reported higher costs initially with CABG, this cost difference narrowed over five years in BARI and over eight years in EAST.12 16 Both PTCA (or PCI) and CABG have changed dramatically since the time of those trials, especially with the introduction of coronary stents30 31 and minimally invasive or off pump CABG.32 Costs, on an inflation adjusted basis, have fallen, at least in one study from the USA, for both forms of coronary revascularisation.33 34 The older trials that compared

| Table 3 | Average resource use for rehabilitation and outpatient medication use during one year follow up by treatment group |
|---------|---------------------------------------------------------------------------------------------------------------|
| Resource | Average resource use (days) | Costs (£) |
|         | PCI (n = 488) | CABG (n = 500) | Unit costs (£/day) | PCI (n = 488) | CABG (n = 500) |
|         |               |               |                   |               |               |
| Rehabilitation | | | | | |
| Other hospital for rehabilitation or further treatment | 0.819 | 2.321 | 175 | 143.3 | 406.1 |
| Residential or nursing home care on a temporary basis | 0.029 | 0.042 | 53.97 | 1.5 | 2.3 |
| Medication | | | | | |
| Antiplatelet | | | | | |
| Aspirin | 347.72 | 332.08 | 0.05 | 17.40 | 16.60 |
| Ticlopidine | 81.72 | 20.13 | 3.34 | 272.94 | 67.23 |
| Other (clopidogrel) | 20.86 | 3.79 | 0.59 | 12.31 | 2.24 |
| Other (dipyridamole) | 0.02 | 7.02 | 0.11 | 0.02 | 0.77 |
| Anticoagulants | | | | | |
| Warfarin | 4.18 | 11.34 | 0.11 | 0.46 | 1.25 |
| Heparin | 0 | 1.84 | 3.44 | 0 | 6.33 |
| Low molecular weight heparin (dalteparin sodium) | 4.78 | 2.42 | 11.30 | 54.01 | 27.35 |
| Antianginal agents | | | | | |
| β Blockers (atenolol) | 215.30 | 178.24 | 0.03 | 6.46 | 5.35 |
| Calcium channel antagonists (diltiazem) | 132.65 | 75.76 | 0.30 | 39.80 | 22.73 |
| Nitrates (sodium nitroprusside) | 151.20 | 53.75 | 0.40 | 60.48 | 21.50 |
| Potassium channel activators (nicorandil) | 9.93 | 1.39 | 0.26 | 2.58 | 0.36 |
| Lipid lowering agents | | | | | |
| Fibrates (bezafibrate) | 23.94 | 19.57 | 0.20 | 4.79 | 3.91 |
| HMG-CoA reductase inhibitors (simvastatin) | 231.41 | 194.02 | 1.06 | 245.29 | 205.66 |
| Other (nicotinic acid) | 1.16 | 0 | 1.11 | 1.29 | 0 |
| Other cardiac treatment | | | | | |
| ACE inhibitor (lisinopril) | 113.52 | 89.59 | 0.65 | 73.79 | 58.23 |
| Diuretics (furosemide) | 56.56 | 93.19 | 0.08 | 4.52 | 7.46 |
| Digoxin | 6.61 | 15.13 | 0.02 | 0.13 | 0.30 |
| Antiarrhythmic (amiodarone) | 6.62 | 12.24 | 0.23 | 1.52 | 2.82 |
| Antiarrhythmic (propafenone) | 0.42 | 1.88 | 0.71 | 0.30 | 1.33 |
| Antiarrhythmic—β blocker (nadolol hydrochloride) | 0.79 | 0 | 0.18 | 0.14 | 0.18 |
| Antiarrhythmic—calcium channel antagonist (verapamil) | 0.65 | 0 | 0.30 | 0.20 | 0 |
| Other cardiac agents | | | | | |
| Antihypertensive (clonidine hydrochloride) | 0.31 | 0 | 0.17 | 0.05 | 0 |
| β Adrenergic receptor blocker (labetalol) | 3.63 | 0 | 0.63 | 2.29 | 0.55 |
| β Adrenergic receptor blocker (indoramin) | 0.04 | 0.15 | 0.40 | 0 | 0.06 |
| Angiotensin II antagonist (candesartan cilexetil) | 2.54 | 2.06 | 0.53 | 1.35 | 1.09 |
| Angiotensin II antagonist (irbesartan) | 0.36 | 1.04 | 0.59 | 0.21 | 0.61 |
| Angiotensin II antagonist (lisinopril) | 2.34 | 1.69 | 0.62 | 1.45 | 1.05 |
| Angiotensin II antagonist (valsartan) | 0.72 | 0 | 0.56 | 0.40 | 0 |
| ACE, angiotensin converting enzyme; HMG-CoA, hydroxymethyl glutaryl coenzyme A.

| Table 4 | Initial, follow up, and total costs |
|---------|---------------------------------|
|         | PCI (n = 488) | CABG (n = 500) | Δ(CABG–PCI) | 95% CI |
| Initial hospitalisation costs (£) | 3884 | 7321 | 3437 | 3040 to 3848 |
| Procedure costs (£) | 2440 | 3353 | 913 | 804 to 1018 |
| Ward costs (£) | 1435 | 3915 | 2480 | 2105 to 2839 |
| Complication costs (£) | 9 | 51 | 42 | 19 to 69 |
| One year follow up costs (£) | 2412 | 1584 | –828 | –1436 to –332 |
| Rehabilitation costs (£) | 1463 | 721 | –742 | –1263 to –308 |
| Medication costs (£) | 804 | 455 | –349 | –405 to –295 |
| Total one year costs (£) | 6296 | 8905 | 2609 | 1769 to 3314 |
balloon PTCA with CABG are less relevant to the current situation, in which the standard practice of PCI has come to include the use of intracoronary stents and glycoprotein IIb/IIIa inhibitors. The other major multinational trial with an economic analysis besides SoS that has been conducted since the late 1990s, comparing PCI with CABG, is ARTS.8 In ARTS, costs were similar to those in SoS. The in-hospital costs averaged $10,652 (£7,531) with CABG and $6,441 (£4,553) with PCI, a difference of $4,212 (£2,977) (p < 0.001). This difference narrowed due to repeat revascularisation in the PCI arm to a one year cost of $13,638 (£9,638) with CABG and $10,665 (£7,537) with PCI, a difference of $2,973 (£2,101) (p < 0.001).

A potential change in the practice of PCI in the near future may have economic as well as clinical consequences. In early trials, drug eluting stents have been shown to reduce dramatically the restenosis rate after PCI.35 36 If these early results are borne out and restenosis is largely eliminated, then the economic advantage of CABG over PCI during follow up may be attenuated. However, any economic advantage in follow up may not overcome increased initial costs if these new stents are expensive. While this technical advance may shift decision making further towards PCI, its economic consequences remain uncertain.

As important as changes in revascularisation are, medical treatment has also changed, with efforts to control risk factors aggressively, including lipids, blood pressure, diabetes, exercise, diet, and smoking cessation. This will be addressed in detail in the COURAGE (clinical outcomes utilising revascularisation and aggressive drug evaluation) trial that began enrolment in June 1999 and will compare coronary intervention with aggressive medical management versus aggressive medical management alone.37 Changes in medical treatment will also have profound economic consequences with cost of more intense treatment offset by savings from reduced events.

Given the availability of only one year outcomes for all patients in SoS, the conclusions are inherently limited. In addition, CABG is, in the absence of complications, associated with a more difficulty period of recovery. While this was not captured in the utility data, as the first postprocedural measurement was at six months, such a difference is short lived and unlikely to translate into a substantial difference in quality adjusted life years. Both forms of

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**Figure 1** Initial hospitalisation costs for the percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG) arms in major subgroups. ACS, acute coronary syndromes; CI, confidence interval; PMI, previous myocardial infarction.

| Subgroup        | Δ (CABG-PCI) | 95% CI       |
|-----------------|-------------|--------------|
| Overall         | £3,437      | £3,040 to £3,848 |
| Age < 65        | £3,165      | £2,631 to £3,644 |
| Age ≥ 65        | £3,835      | £3,222 to £4,545 |
| Males           | £3,601      | £3,118 to £4,008 |
| Females         | £2,816      | £2,109 to £3,429 |
| Diabetic        | £3,405      | £2,723 to £4,135 |
| Non-diabetic    | £3,444      | £2,971 to £3,909 |
| ACS             | £3,233      | £2,391 to £4,058 |
| Non-ACS         | £3,477      | £3,019 to £3,946 |
| PMI             | £3,435      | £2,900 to £3,965 |
| Non-PMI         | £3,428      | £2,855 to £4,015 |
| 2 vessel        | £3,730      | £3,245 to £4,274 |
| 3 vessel        | £2,953      | £2,205 to £3,581 |
revascularisation appear to be good forms of treatment for angina. While CABG offers better relief of chest pain initially, with time and additional procedures as needed, patients treated with PCI can achieve similar results. For patients equally suitable to either procedure, CABG is initially much more expensive, but this difference may be reduced or disappear over time if additional procedures are performed in the PCI arm. CABG may look more favourable in the longer term, as there will be little reason to expect greater long term induced costs with CABG than with PCI, and over several years patients who have undergone CABG may continue to have less angina. Therefore, the in-trial ratio of cost per life year gained provides a very restricted picture of the relative cost effectiveness of the two procedures: a more meaningful picture requires reliable estimates of long term relative cost and benefit.

The economics of CABG and PCI have changed over the past 10–15 years with technical advances and secular trends. Continuing change in both procedures will lead to an ongoing need for high quality randomised studies measuring clinical and economic outcomes of the two forms of revascularisation, as well as inevitably more speculative modelling of possible longer term costs and effects.

**Figure 2** Total one year costs for the PCI and CABG arms in major subgroups.

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