Review article

The invasive management of angina: issues for consumers and commissioners

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Abstract

Objective – To review, from the purchaser's perspective, the current state of knowledge of techniques for investigation and treating coronary artery disease. The study was based on evidence from past and continuing randomised controlled trials (RCTs).

Criteria for inclusion of reports – Articles listed on Medline (1990-3) with the keywords coronary disease, angina, and unstable angina (combined with surgery, economics, therapy, or drug therapy) and percutaneous transluminal coronary angioplasty (PTCA) and coronary artery bypass grafting (CABG) were included. Articles published before 1990 were obtained from two comprehensive literature reviews published by the Rand organisation in 1991¹² and from the papers obtained using the Medline search. A hand search of relevant journals published between July 1993 and June 1994 was also undertaken. Results from more recently published RCTs are included.

Results – CABG provides improved angina relief compared with drug treatment and may prolong life in patients with more severe illness. PTCA is also better than drug treatment, but less so than CABG, and its cost advantages over CABG decrease with time. Repeat intervention for return of symptoms is more frequently required after PTCA, but increasing numbers of patients are also undergoing second and third repeat CABG for graft occlusion in the years after the original operation. Newer PTCA techniques are not, as yet, fully evaluated. One technique, atherectomy, has been shown to be no more effective, and more expensive, than conventional balloon angioplasty. In the short term intracoronary stents reduce the problems associated with vessel occlusion after PTCA and therefore reduce the need for further intervention. PTCA should not be performed without ready access to cardiothoracic support. There is an increasing trend towards the development of coronary catheterisation units at peripheral sites. This may lead to increasing, inappropriate use of this investigation in suboptimal circumstances.

Conclusions – Ischaemic heart disease is an important cause of morbidity and mortality and invasive management techniques are developing rapidly; some service expansion is occurring without trial evidence. More research is required to determine the optimum balance of PTCA, CABG, and angiography and population requirements for these procedures. In the meantime, in the absence of firm long term evidence of the superior cost effectiveness of PTCA compared with CABG, the rapid expansion of this procedure should be limited. Patients should be fully informed of the benefits and disadvantages of CABG and PTCA, where either procedure is indicated, to enable them to make fully informed choices.

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Ischaemic heart disease (IHD) is the leading cause of death in the United Kingdom and a common cause of morbidity.³⁻⁵ Increasing rates of invasive procedures (coronary artery bypass grafting (CABG) and percutaneous coronary angioplasty (PTCA)) have coincided with a gradual reduction in age adjusted IHD death rates since the 1970s,⁶ although it seems unlikely that these procedures have played more than a minor role in the observed decline.⁷

Treatments for IHD consume 2.5% of NHS expenditure.⁸ If the current (1984) UK target of 300 CABGs per million population per year is met, the annual bill will be in excess of £60M.⁹ This target level has now been met in many areas and various authorities suggest that higher target levels may be appropriate.¹⁰ In addition 8459 PTCA's (costing approximately £3000 each) were performed in the UK in 1990.¹¹

There is striking variation in these intervention rates.¹² The UK Clinical Standards Advisory Committee reported a twofold inter regional variation in NHS CABG rates and a fourfold variation in PTCA. International variations are even more marked.¹¹⁻¹⁵ The CABG rate in the United States was four times that in the UK in 1991, and that for PTCA eight times higher. This variation greatly exceeds the likely variation in disease incidence and thus provides strong presumptive evidence of sig-

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nificant clinical uncertainty, although unmet need may partly account for this. There is currently no clear evidence on the population incidence and prevalence of angina that is unresponsive to maximal medical treatment or the incidence of angiographically proved IHD associated with lesions for which PTCA or CABG are of proven benefit.

Guidelines on the appropriate use of CABG, PTCA and angiography have been produced by, among others, the British Cardiac Society and the American College of Cardiology and American Heart Association (ACC/AHA).^{16 17} One UK audit that compared practice with guidelines has indicated that 21% of angiographies and 16% of CABGs may be inappropriate.¹⁸ Studies from the United States suggest that PTCA, judged against consensus criteria, is particularly prone to inappropriate use.^{19–21}

The goal of rational purchasing is impeded by a number of factors. The first is the emergence of new, largely unevaluated interventions, which include vibrational coronary angioplasty,²² the use of lasers,²³ and rotablaters.²⁴ Results from randomised trials of atherectomy and stenting have recently been published.^{25–28} Even PTCA, although widely adopted, has not until recently been comprehensively evaluated in randomised studies, although several are now in progress and interim results have been published.^{29–33} Secondly, the experimental evidence comparing CABG with medical treatment dates from 1970s,^{34–36} since when there have been changes in both surgical techniques (such as use of internal mammary artery grafts) and medical treatments (routine use of aspirin and calcium antagonists). The participants in these trials were largely men aged less than 65, thus restricting the extrapolation of the results to women and older age groups. Lastly, most trials published have failed to incorporate rigorous health economic components.

Against this backdrop this review has three main objectives: to summarise current research of effectiveness and cost effectiveness; highlight gaps in the research record; and address specific issues surrounding the performance of coronary angiography and PTCA in units without cardiac surgical standby.

Effectiveness of CABG and PTCA

CABG and PTCA are mainly undertaken in the UK for the treatment of stable and unstable angina. An increasing proportion are repeat procedures.^{37–39} The cornerstone of acute infarct management is thrombolytic therapy. Although PTCA is being increasingly used in the USA in the acute phase, any slight advantage^{40–42} is arguably outweighed by the cost of making it available in all units.⁴³ IHD patients may sensibly be subdivided according to the type and severity of symptoms, ejection fraction, and the site and number of coronary arteries involved. The four coronary arteries whose occlusion may be identified angiographically are the right coronary, the left main, and its two branches the circumflex and

left anterior descending arteries. Randomised controlled trial evidence comparing medical, surgical, and PTCA treatments *for each subgroup* is not available.

CABG

Randomised controlled trials in the 1970s showed that overall in stable angina, CABG provides symptomatic relief in 49% of patients at one year, compared with 15% of those treated medically.² At five years these differences narrow to 36% and 21% respectively and there is little difference at 10 years. In certain subgroups (those with left main coronary artery disease; those with reduced ejection fraction and two or three vessel disease; left anterior descending artery disease if part of two or three vessel involvement) life expectancy is also improved. A recent overview of trials randomising patients to CABG or medical management showed significant overall reductions in mortality at five and 10 years in those treated surgically (10.2% *v* 15.8% mortality at five years; 26.4% *v* 30.5% at 10 years). Although in some subgroups of patients no significant effect on mortality was observed. Differences in symptom relief and mortality between medically and surgically treated groups diminish gradually with time. Some of this convergence is because a considerable proportion of those randomised to medical treatment subsequently underwent CABG for symptomatic control and graft occlusion occurred in others randomised to surgery. CABG does not reduce the subsequent incidence of acute myocardial infarction or enable more patients to return to work.^{2 34–36 44–57}

In unstable angina, CABG provides improved symptom relief and improved survival to those with three vessel disease and those with low ejection fractions (<0.5) regardless of vessel involvement.^{58–63}

PTCA

PTCA requires a shorter hospital stay than CABG and permits more rapid convalescence.¹⁰ In some centres it is being conducted on an outpatient basis in selected patients.⁶⁴ Complications include an in hospital mortality of 0.4% and requirement for emergency CABG in 2–4%.¹ Ninety per cent of lesions are successfully dilated but 20–40% re-occlude by one year. These complications are more common with particular anatomical lesions and in patients with unstable angina, multivessel disease, or where operators are less experienced.^{65–69}

In a comparison of PTCA and medical treatment for angina patients with single vessel disease (ACME study),⁷⁰ 64% in the PTCA group and 46% in the medical group were angina free at six months (*p*<0.01). Exercise treadmill time was significantly greater in the PTCA arm. Sixteen of 105 patients in the PTCA arm required repeat PTCA, and seven required CABG. In the medically treated arm, 11 subsequently underwent PTCA. There was one death in the medical treatment arm of the

trial. The conclusion was drawn that, for single vessel coronary artery disease, PTCA offered earlier and more complete relief of angina and improved exercise tolerance, but at the cost of a higher subsequent invasive intervention rate. A second trial of PTCA versus medical treatment (RITA II), incorporating a health economic evaluation, is currently underway.

CABG VERSUS PTCA (FOR SUMMARY OF RECENT TRIALS SEE APPENDIX A)

A number of randomised controlled trials are currently examining the relative effectiveness of CABG and PTCA⁷¹ (Appendix A). Recruitment is complete in all of them but follow up is continuing. RITA is a UK based randomised controlled trial and involves 1011 patients with one, two, or three vessel disease.²⁹ At 2.5 years there was no significant difference between the two groups' mortality or mortality and acute myocardial infarction combined. Sixteen (3.1%) patients in the PTCA arm and 18 (3.6%) in the CABG arm of the trial had died. CABG offered significantly better angina relief at six months (89% CABG group symptom free *versus* 68% in PTCA group) and at two years (78% *versus* 69%). In addition, 38% of those in the PTCA group had either had an acute myocardial infarction, died, or required revascularisation compared with only 11% in the CABG group ($p < 0.001$).

In EAST, the other large randomised trial which has reported medium term (three years) results, 392 patients were randomised to CABG or PTCA.³³ There was no difference in mortality or the combined outcome of death, acute myocardial infarction, or the presence of large filling defects on thallium scans at three years between CABG and PTCA. Angina, however, was significantly more improved in those who underwent CABG (88% *v* 80% angina free), although there was no difference in exercise tolerance. Three times more of those treated with PTCA subsequently required repeat revascularisation.

Three other randomised trials have reported outcomes one to two years after randomisation.³⁰⁻³² In GABI the combination of death or acute myocardial infarction occurred more frequently in the CABG arm of the trial (13.6% *v* 6% $p = 0.017$). However, four of the nine deaths in the CABG patients occurred before surgery. Forty four per cent of the PTCA patients required repeat revascularisation compared with only 6% of those treated with CABG.³¹ The other two trials showed no significant differences in mortality between CABG and PTCA. They too showed that re-intervention was required considerably more frequently in those treated with PTCA. Better symptomatic relief was achieved by CABG.³⁰⁻³²

A number of observational studies have also provided evidence on this matter. They have failed to show any difference in medium and long term survival between the two treatment categories although symptomatic improvement is more likely with CABG and the need for further intervention is considerably reduced. These advantages of CABG are at the price of a

longer stay in hospital and longer postoperative recovery.⁷²⁻⁷⁸

No randomised controlled trial to date has contained three arms - CABG, PTCA, or medical treatment. Wong *et al*, using data available up to 1989, constructed a decision analysis model comparing the relative benefits, costs, and outcomes of these therapies in patients with different disease severity.⁷⁹ They conclude that "revascularisation is not indicated unless severe symptoms, other markers of ischaemia, or severe multivessel disease are present."

NEWER ANGIOPLASTY TECHNIQUES

Difficulties dilating some obstructive lesions have led to the development of new devices which are both expensive and generally unevaluated.²²⁻²⁴ An exception is coronary atherectomy which has been evaluated in two randomised controlled trials - the coronary angioplasty versus atherectomy trial (CAVEAT) and the Canadian coronary atherectomy trial (CCAT).^{27 28 80} In both, the comparison was between one angioplasty technique and another. While hospital costs for atherectomy were significantly greater (\$11 904 *versus* \$10 637 for angioplasty), there was little difference in six month, event free survival between the two. Twelve month follow up results from CAVEAT show increased mortality in those undergoing atherectomy. Eleven (2.2%) receiving atherectomy died compared with only 3 (0.6%) of those randomised to PTCA ($p = 0.035$).^{80a}

Intracoronary stents (synthetic devices designed to maintain vessel patency) have been developed^{25 26 81-83} to address the problem of restenosis after PTCA.¹ Two randomised controlled trials have examined their effectiveness compared with traditional PTCA.^{25 26} Both trials showed that in the short term (six and seven months' follow up) patients treated with stents required fewer repeat procedures (PTCA or CABG) and clinical outcomes were similar. Length of hospital stay was, however, twice as long and complication rates were higher in those treated with stents. Compared with PTCA for single vessel disease, stenting has an estimated incremental cost effectiveness ratio of \$23 600 per quality adjusted life year, although this varies with different patient groups.⁸⁴ The long term costs, benefits, and risks of these devices are therefore uncertain and in one trial there was a suggestion that the difference between the two treatments diminished towards the end of the follow up period.²⁵

Cost effectiveness of invasive procedures

The most serious current drawback is the lack of a completed randomised controlled trial comparing the cost effectiveness of PTCA and CABG. Economic analyses from RITA after two years of follow up have recently been published;⁸⁵ longer term follow up results will not be available for several years. Other, less robust economic analyses - mainly from the United States - have focused on hospital charges rather than actual economic costs.⁸⁶

CABG
The CASS study in the 1970s⁸⁷ indicated that in stable angina total *inpatient costs* in the first year were \$3432 for medical therapy and \$11 100 for CABG. Both direct (mainly hospital charges and professional fees), and indirect costs (loss in productive capability as measured by loss of income) were measured. CABG is, however, likely to have lower follow up costs. On the effectiveness side of the equation, although long term survival was similar, CABG patients experienced less angina and, by inference, had a better quality of life (see above). A simple expression of cost effectiveness from these data is not, however, possible. Other data have suggested greater cost differences in the first six months after initial angiographic investigation (medical treatment \$5705; CABG \$27 862 (1977 prices)).⁸⁸

PTCA
The ACME trial – the only completed randomised controlled trial directly comparing medical therapy and PTCA⁷⁰ – concluded that PTCA offers more relief of angina for one-vessel disease but at a higher cost. Formal cost effectiveness ratios were not derived, however. PTCA costs over one year have been reported elsewhere to be five times greater (13 625 Dfl *v* 2770 Dfl) than those of medical treatment but the cost differences diminish with time.⁸⁹ Hospital costs for atherectomy are greater than those for PTCA (see above).²⁷ The cost differential between PTCA and stenting is even greater (\$5396 versus \$7878).

CABG VERSUS PTCA
Analysis of health service costs after two years follow up in the RITA trial show the mean cost of PTCA to be £6916 (SE £235) and for CABG is £8739 (SE £212) in the London centres (difference £1823 (£1202 to 2404)). The cost difference was smaller (£1050 (SE £621 to 1279) in the centres outside London.⁸⁵ Whether these differences in costs translate into differences in cost effectiveness and whether these differences diminish with longer

periods of follow up remains to be seen. In ERACI, hospital costs after one year for those treated with CABG were 1.9 times greater than for PTCA.³⁰ Economic evaluation from EAST will be published soon. Otherwise only observational data are currently available, which may be invalidated by important case-mix differences. Initial costs of CABG are 1.6 to 2.9 times those of PTCA, although after one year this diminishes to between 1.2 and 1.8, and after five to 10 years there is relatively little difference (PTCA \$26 916; CABG \$32 465 at five years in one study).^{79 89 97} PTCA, on the other hand, provides poorer symptomatic relief and reintervention rates are higher (see above).

QUALITY ADJUSTED LIFE YEARS (QALYS)
Cost effectiveness comparisons between invasive cardiological interventions and other competing claims for NHS resources are hampered if a common measure of benefit is not used. The quality adjusted life year (QALY) is widely known as a generic measure for such purposes (see table 1). Unfortunately many cost per QALY figures are based upon *estimates* of effectiveness rather than robust data from randomised controlled trials and incorporate average rather than marginal figures.^{98 99} The survival advantage offered by CABG in those with left main vessel disease is, however, clearly reflected in this table as is the lack of evidence of enhanced survival in those with single vessel disease.¹⁰⁰

Service delivery issues: PTCA, angiography, and the need for surgical standby

The main immediate risks of PTCA are acute vessel occlusion, coronary artery rupture, and distal embolisation. In this event three options are available. No action may be taken and the patient may sustain an acute myocardial infarction which is managed in the usual way. Alternatively, redilation or placing of a stent may be attempted. Finally, if the patient is fit and other approaches fail, emergency CABG may be undertaken. It is vital to consider the cost effectiveness of maintaining a cardiac surgical team on constant standby to cover this last eventuality and, further, to assess whether PTCA can safely be performed on sites without surgical back up.¹⁰¹⁻¹⁰⁵ In some centres, surgical back up is provided at units geographically separate from the centre where PTCA is performed. One estimate of the cost of on site surgical standby is \$100 000 per patient requiring emergency CABG (using a 2% rate of emergency CABG for PTCA).¹⁰² The opportunity cost is clearly great.

A number of observational studies have examined the effect of delays in intervention on both short and long term outcomes of patients undergoing PTCA.^{106 110} There has been no study with random allocation to PTCA with or without surgical standby. A few case series suggest that, in some instances, immediate access to CABG may have been life saving.¹¹¹

Table 1 Cost/quality adjusted life year (QALY) of competing treatments (adapted from Maynard 1991¹²⁴)

Treatment	Cost/QALY (£, Aug 1990)
Cholesterol testing and diet therapy only (all adults aged 40–69)	220
Advice from GP to stop smoking	270
Neurosurgical intervention for subarachnoid haemorrhage	490
Antihypertensive treatment to prevent stroke (aged 45–64)	940
Hip replacement	1180
CABG (left main vessel disease, severe angina)	2090
Kidney transplant	4710
Breast cancer screening	5780
Heart transplantation	7840
Cholesterol testing and treatment of all adults aged 25–39	14 150
CABG (1 vessel disease, moderate angina)	18 830
Continuous ambulatory peritoneal dialysis	19 870
Erythropoietin treatment for anaemia in dialysis patients (assuming 10% reduction in mortality)	54 380

CABG = coronary artery bypass graft.

Table 2 Advantages and disadvantages of high and low throughput cardiac catheterisation facilities

Low turnover, district based cardiac catheterisation facilities, surgical standby rare	High turnover, cardiac catheterisation facilities based at tertiary centre, with surgical standby
<p><i>Advantages</i></p> <ol style="list-style-type: none">1 Improved access for patient2 Familiar surroundings for patient3 Full investigation and work up by local cardiologist4 Improved job satisfaction for cardiologist5 Shorter waiting list <p><i>Disadvantages</i></p> <ol style="list-style-type: none">1 Reduced operator experience and possible increased complication rates and training costs2 Distant from surgical support in the event of complications3 High cost of keeping equipment up to date4 Need to send films to cardiothoracic surgeon to review5 If accepted that PTCA cannot be undertaken without surgical cover, lose opportunity to undertake synchronous PTCA6 Tendency to supply led rather than demand led angiography¹²⁶	<p><i>Advantages</i></p> <ol style="list-style-type: none">1 Safer for patient with rapid access to emergency surgery2 Possibility of synchronous angiography and PTCA3 Cardiothoracic surgeon on site to review angiograms4 Possible economies of scale and the production of consistent high quality films with most up to date equipment. <p><i>Disadvantages</i></p> <ol style="list-style-type: none">1 Less familiar surrounds for patient and increased anxiety2 Reduced capacity to communicate with referring cardiologist/physician3 Time wasted on routine procedures which could be spent on complex interventions

PTCA=percutaneous transluminal coronary angioplasty; CABG= coronary artery bypass graft.

With modern techniques and devices (stents, perfusion balloons, intra-aortic balloon pumps), however, events for which emergency surgery is deemed necessary are rare.¹¹² Attempts have been made to screen patients into those at low or high risk for complications for which emergency CABG would be necessary.^{106 107} Between 9% and 46% of those undergoing emergency CABG after PTCA had evidence of acute myocardial infarction despite surgical intervention.^{2 113} Surgery may, however, have limited the size of the infarct sustained.

The confusing variation in expert opinion is encapsulated in a number of guideline statements. The British Cardiac Society in 1991 recommended that “*in carefully selected patients it is ethical to attempt PTCA in the absence of immediate surgical standby*”.¹⁶ In 1992 the British Cardiovascular Intervention Working Party concluded that “*on-site surgery is the strongly preferred option*”.¹¹² However, they felt that PTCA can be safely performed without on site cover provided reliable transfer arrangements exist. By contrast in the United States the 1988 ACC/AHA guidelines recommend that “An experienced cardiovascular surgical team should be available within the institution for emergency surgery for all angioplasty procedures”, a view shared by the International Society and Federation of Cardiology.¹⁷ The recent introduction of stenting has now led to a reduction in the need for emergency surgery.

Clearly a balance must be drawn between possible symptomatic improvements gained by making PTCA more accessible at units distant from surgical cover and the safety of undertaking PTCA in such settings. The evidence to approach this more rationally is simply not available at present and constitutes an important area for further work. A pragmatic approach adopted in some localities¹⁰⁸ has been to permit PTCA within a travelling time area equivalent to that required for a surgical team to prepare.

A similar debate surrounds the performance of diagnostic angiography.^{11 114} A recent review for the North Western Regional Health Authority concluded that “*local catheter laboratory initiatives in district general hospitals should be discouraged on the grounds of possible litigation in the absence of on-site surgery, service standard*

erosion and sub-optimal use of an expensive facility”.¹¹⁵ Several case series report anecdotal benefits from on site surgical back-up.^{111 116} The UK confidential enquiry into cardiac catheterisation complications reported a mortality rate of 0.12% and 0.08% of subjects underwent emergency CABG.¹¹⁷

The development of new, non-invasive means of delineating coronary artery disease may in due course make these arguments of historic interest.¹¹⁸ In the meantime coronary angiography is increasingly being performed in district hospitals, and increasingly on a day case basis.^{10 119 120} The report of the Cardiac Speciality Service Review Group¹²¹ expected that district hospitals in the Thames health regions would in the near future be performing 30% of all angiographies. Strong positive relationships between outcomes and throughput were found consistently in an American literature review.¹²² Optimal outcome requires several hundred cardiac catheterisations per year. It has been recommended in fact that tertiary centres should undertake 1500–2850 catheter investigations per year, and secondary centres 800–1400.¹²¹

The two broadly competing approaches – either a small number of high volume cardiac catheterisation laboratories with on site surgical standby or a larger number of lower volume centres largely without on site standby – carry distinctive advantages and disadvantages from the patients’, professionals’, and overall NHS perspective (see table 2).

Summary and conclusions

Management strategies for the invasive management of IHD are developing rapidly and a number of important randomised controlled trials have provided only interim results.¹²³ Some of the newer angioplasty techniques are being assessed in randomised controlled trials,^{25–28} but so rapid are developments that it is unlikely that the results from these trials will be applicable to the technologies in use when they are reported. All summaries of existing evidence are necessarily interim. It is important that purchasers should not purchase new technologies unless they form part of a randomised evaluation.

PTCA and CABG offer improved relief over medical treatment for the distress, though not necessarily the disability, caused by angina. PTCA does not offer improved survival or symptom relief over CABG. Short term costs of PTCA are lower, although it has not been shown to be more cost effective than CABG. Use of these procedures should be concentrated upon the more severe grades of angina unrelieved by optimum drug treatment. Within these grades there are those, who can only be identified by angiographic delineation of vessel involvement, upon whom CABG confers improved survival. Use of PTCA and CABG will therefore depend partly upon whether the primary target is improved survival or relief of distress. The "preferred outcome" for angina patients needs to be more clearly defined. Choices need to be made and a balance struck between the goals of reduced premature mortality, reduced frequency of pain and distress from angina, the probability of further intervention, and the ability to return to work. Patients should be informed of the relative benefits and disadvantages of CABG and PTCA, where either procedure is indicated, to enable them to make fully informed choices.

Under certain circumstances it seems likely that the advantages to patients of decentralised coronary angiography and PTCA services are outweighed by their disadvantages in terms of reduced quality and safety. These circum-

stances occur either when surgical support is beyond a reasonable distance or when only low throughput is possible. It is unlikely that operators in a district based service with a throughput below several hundred cases would be able to maintain satisfactory levels of expertise and familiarity with changing equipment. Professional bodies have produced a series of guidelines on this matter and these should generally be adhered to.

Further research is required in a number of areas. These include a pressing need for a pragmatic randomised controlled trial comparing patients with similar angina scores randomised either to receive early angiography and subsequent interventions or be managed expectantly. Further randomised controlled trials are also required to compare CABG and modern medical management of angina in those for whom CABG has not already been shown to prolong life. Finally, angiographic investigation should not be made more widely available until the indications for further intervention have been agreed and the necessary capacity to perform CABGs established.

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Appendix

(A) Randomised controlled trials (RCT) comparing percutaneous transluminal coronary angioplasty (PTCA) with coronary artery bypass graft (CABG) published since 1992

Study reference, duration and setting	Design	Main findings	Comment
RITA ²⁹ 2.5 year follow up, UK	(a) RCT n=1011 (b) Mean age 57; 19% women (c) 1, 2, or 3 vessel disease in patients in whom revascularisation achievable by either procedure (d) 59% grade III or IV angina; 45% single vessel disease (e) Stable and unstable angina, 7% had no angina	(a) Mortality similar in CABG 18 (3.6%) and PTCA 16 (3.1%). Mortality and AMI: CABG 43 (8.6%) PTCA 50 (9.8%) (b) Required revascularisation, died or had MI: CABG 11%; PTCA 38% p<0.001 (c) Angina at 2 years: CABG 22%; PTCA 31%. p<0.007 (d) No difference in employment status, breathlessness, physical activity at 2 years	(a) CABG performed sooner than under typical NHS conditions. (b) Only 3% of all patients undergoing angiography eligible
EAST ³³ Emory angioplasty versus surgery trial 3 year follow up, USA	(a) Single centre RCT n=392. 26% women; mean age 62 (b) 80% angina grade III/IV; 60% 2 vessel, 40% 3 vessel disease. 72% with a greater than 50% stenosis of the left anterior descending artery (c) Enrolment ended 1990	(a) Mortality at 3 years: CABG 6.2%; PTCA 7.1% (b) Death, Q wave AMI, or large filling defect on thallium scan: CABG 27.3% PTCA 28.8% (NS) (c) Required repeat revascularisation at 3 years: CABG 13% required PTCA, 1% required repeat CABG; PTCA 22% required CABG, 41% required repeat PTCA (p<0.001) (d) Angina at 3 years: CABG 12% PTCA 20% (p=0.04). Taking of antianginal drugs CABG 51%; PTCA 66% (p=0.005) (e) No difference in exercise capacity or employment status	(a) 16.5% of patients screened were eligible; only half of these patients agreed to participate in the trial
ERACI ³⁰ 1 year follow up, Argentina	(a) RCT n=127 (b) Multiple vessel disease (70% + obstruction in more than one major artery) suitable for either CABG or PTCA (c) 85% male; mean age 58 years (d) Stable and unstable (83%) angina	(a) No difference in mortality at 1 year (CABG = 3; PTCA=3) or periprocedural MI (b) 1 year freedom from cardiac events: CABG 83.5%; PTCA 63.7% p<0.005	(a) Small numbers (b) Unstable angina significantly more frequent in CABG group at entry (c) 40% of patients with indications for revascularisation fulfilled entry criteria. Of these 42% were randomised
BARI ¹²⁵ United States and Canada	(a) RCT n=2400 to be enrolled from 1988. (b) Multiple vessel disease in whom either procedure could be applied (c) 60% + stenosis of two or more vessels (d) No asymptomatic patients	No findings reported at time of writing.	

GABI ³¹ 1 year follow up, German angioplasty bypass investigation	(a) 8 centre RCT n=359. Mean age 58; 21% women (b) Symptomatic (<or=grade II angina) multi-vessel disease in which either procedure technically feasible (c) 44% patients 2 vessel disease; 56% 3 vessel disease (d) Median delay between randomisation and treatment PTCA 19 days; CABG 53 days	(a) Mortality at 12 months: CABG 5.1%; PTCA 2.2% (NS). Mortality and AMI at 12 months CABG 13.6%; PTCA 6.0% (p=0.017) (b) Required repeat revascularisation at 1 year: CABG 6%; PTCA 44% (p<0.001) (c) Angina at 1 year: CABG 26%; PTCA 29% (NS); Significantly more PTCA patients required antianginal medication (88% v 78% p=0.04) (d) No difference in capacity to exercise	(a) Enrolment to the study terminated early because the primary clinical endpoint (freedom from angina) showed no difference between the groups at 1 year (b) Four of the deaths in the CABG arm of the trial occurred before surgery (c) Only 4% of patients screened were eligible for inclusion in the trial (d) Significantly more patients in the CABG arm had their LAD artery revascularised
Goy et al 1994 ³² 2 year follow up, Switzerland	(a) RCT n=134 (b) Mean age 54 (CABG); 57 (PTCA 20% women) (c) Stable angina associated with isolated proximal left anterior descending artery stenosis (50% stenosis) (d) 78% grade III or IV angina	(a) Mortality at 1 year CABG 1 (1.5%) and PTCA 0 (0%) (b) Required revascularisation or had AMI: CABG 8%; PTCA 37% p<0.01 (c) Angina at 2 years: CABG 11%; PTCA 23% (NS) (d) At 2 years PTCA patients took significantly more anti anginal drugs	(a) Small numbers (b) 9% of patients randomised to CABG underwent PTCA rather than CABG (c) Only 8% of patients with single vessel disease were eligible
CABRI ⁷¹	RCT multiple vessel disease	No results available at time of writing	

AMI=acute myocardial infarction.

(B) Non-randomised comparisons between percutaneous transluminal coronary angioplasty (PTCA) and coronary artery bypass graft (CABG) published since 1992

Weintraub et al 1993 ⁷² 5 year follow up, United States	(a) Retrospective observational cohort n=454 CABG; 415 PTCA (b) 2 vessel disease undergoing elective CABG or PTCA 1984-5 (c) Mean 50%+stenosis in 2 major coronary vessels	(a) 5 year survival: CABG: 89%; PTCA: 93% NS No difference in risk adjusted survival (b) Additional revascularisation required at 5 years: CABG: 7%; PTCA 43% p<0.0001 (c) Little difference in proportion with angina at 6 years (CABG 28%; PTCA 25%)	(a) Non RCT (b) CABG patients older, with more comorbidities, more severe angina, more occluded vessels and more LMCA narrowing than PTCA group
O'Keefe et al ⁷³ 1993 Mean 3 year follow up, United States	(a) Retrospective observational cohort; n=100 CABG matched for age, sex, ejection fraction with 100 undergoing multivessel PTCA. Interventions undertaken in 1985-88 (b) Multiple vessel disease 50%+stenosis of two or more vessels (c) Ejection fraction≤40% (d) Patients with AMI excluded (e) Mean age 65 years; 78% male	(a) 5 year survival PTCA: 67%; CABG: 76% NS (b) In hospital death or stroke or both: CABG 12%; PTCA 3% (p=0.03) (c) 5 year freedom from disabling angina: CABG 99%; PTCA 89% p=0.01 (d) Hospital length of stay: CABG 12.8 days; PTCA 4.3 days (e) Repeat revascularisation: CABG 0%; PTCA 50% (p<0.001) (f) Early results favour PTCA, late survival favours CABG	(a) Non RCT (b) More severe end of the disease spectrum studied (low ejection fraction; multivessel disease) (c) CABG patients contained more with grade III/IV angina (d) Revascularisation less complete in PTCA group (e) Small proportion of cohort followed up to 5 years
Vacek et al 1992 ⁷⁴ Mean 2 year follow up for PTCA; 2.5 years for CABG, United States	(a) Prospective observational cohort n=152 PTCA; n=134 CABG Operated upon 1986-89 (b) P-tients with multiple vessel disease having either 3+ bypasses or 2+ dilation's to major arteries (c) Mean age 65 years; 77% male	(a) Mortality (2-2.5 years): CABG 14%; PTCA 10% (b) 2 year AMI rate: CABG 2%; PTCA 4% (c) Angina free: CABG 87%; PTCA 78% p<0.02 (d) Repeat angiography: CABG 10%; PTCA 49% (e) In PTCA group 30% required repeat PTCA and 23% required CABG. In CABG 4% had these interventions	(a) Non RCT (b) More severe pathology in CABG group, so would expect bias in favour of PTCA (c) PTCA group constituted only 5% of population undergoing PTCA (Majority had only 1 or minor arteries dilated) (d) Significantly more in CABG group had 3 vessel disease
Hartz et al 1992 ⁷⁵ Max follow up 2 years, United States	(a) Registry study: retrospective observational cohort n=25 423 PTCA; n=71 243 CABG. Small subgroup (n=2931 revascularisations) examined in detail (b) All patients in US undergoing these procedures and billed by Medicare 1985 and random sample of these (c) No patients with cardiac arrest of AMI preprocedure included (d) Risk adjustments for comorbidities, cardiac function, coronary anatomy, severity of angina, sex, age	(a) After eliminating patients admitted with AMI ... Mortality CABG: day 30 5.1%, 1 year 10.8%. PTCA: 30 day 1.9%, 1 year 6.0%; Risk adjusted mortality for CABG vs PTCA 1.72 (0.9 for high risk subgroup) (b) Post procedure mortality much higher than reported in published series	(a) Non RCT (b) Large database study, probably unable to adjust fully for differences between groups. Reflects use of these procedures in practice (c) 3 or 4 vessel disease in 36% CABG groups, 20% of those undergoing PTCA (d) Short term follow up only: may miss any long term benefits/risks

AMI=acute myocardial infarction; LMCA=left main coronary artery.

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