Appendix H: Cost-effectiveness analysis

1 Introduction

An economic model was developed to compare the cost-effectiveness of CABG and PCI for patients considered suitable for either revascularisation method (Chapter 12). In our economic literature review we found several studies (Chapter 12) but none of them met the quality and applicability criteria in full. Some{Abizaid, 2001 9151 /id;de Feyter, 2002 39 /id;Eefting, 2003 1030 /id;Legrand, 2004 1001 /id;Weintraub, 1995 350 /id;Weintraub, 2000 9168 /id} were not UK based and therefore only partially applicable. UK-based studies were either cost-consequences analyses{Henderson, 1998 263 /id;Sculpher, 1994 86 /id;Zhang, 2006 532 /id} or cost-utility analysis based on cohort studies{Griffin, 2007 53 /id} with high risk of bias, or had a limited follow-up time{Weintraub, 2004 114 /id}.

The GDG considered it was necessary to build a model to formally evaluate the uncertain trade-offs between clinical outcomes and costs of the two revascularisation strategies.

2 Methods

2.1 Model overview

A cost-utility analysis was undertaken where costs and quality-adjusted life-years (QALYs) were considered from a UK NHS and personal social services perspective. Both costs and QALYs were discounted at a rate of 3.5% per annum in line with NICE methodological guidance{National Institute for Health and Clinical Excellence, 2009 15955 /id}.

The following general principles were adhered to:

- The GDG was consulted during the construction and interpretation of the model.

- When published data was not available we used expert opinion to populate the model.

- Model assumptions were reported fully and transparently.

- The results were subject to sensitivity analysis and limitations were discussed.

- The model employed a cost-effectiveness threshold of £20,000 per QALY gained.

- The model was peer-reviewed by another health economist at the NCGC.

2.1.1 Comparators

The interventions compared are CABG and PCI (with either drug-eluting stents [DES] or bare-metal stents [BMS] or both). In the original meta-analysis (see review protocol in Appendix C) PCI included coronary balloon angioplasty but we decided to focus the economic analysis on PCI with stents as this is the widely used intervention and it is believed to be more effective than coronary balloon angioplasty. Costs and effectiveness in the model are therefore applicable to CABG and PCI with stents.

2.1.2 Population

We looked for data on patients with single vessel disease and multi-vessel disease separately as interventions might yield different outcomes (e.g. different probability of repeating intervention). We found only scarce data on the single vessel group (small sample sizes) and therefore focused solely on patients with multi-vessel disease.

2.1.3 Time horizon

In the base case analysis we adopted a ten-year time horizon, which was the longest follow-up available from the RCTs. In a sensitivity analysis we extrapolated results up to a life-time horizon assuming the annual probabilities of clinical events are constant from year ten.

2.2 Approach to modelling

2.2.1 Model structure

Given the recurrences of events over time, we decided to build a Markov model with a six-month cycle length as this was deemed the minimum clinically meaningful time interval to detect differences between interventions. All the probabilities, costs and health utilities were converted to reflect the six-month cycle length.

Clinical outcomes considered in the model were mortality, myocardial infarction (MI), further revascularisation procedures, and presence or absence of angina symptoms. Stroke was included in the clinical review; we did not include this outcome in the base case of the model as we observed only a non-significant trend for stroke to be more frequent in the CABG arm and the definition and severity of stroke was not reported in each study.

Both arms of the model have the same structure. In the first cycle (
Figure 1), patients undergo the intervention and in the following six months can experience one of the transitional events considered: MI, revascularisation, or death. In the first two events, a HRQoL decrement is applied to MI and the cost of treating MI or the cost of further revascularisation is added. In case of death, the patient ends up in the dead health state which is associated with no cost and a HRQoL equal to 0. If the patient is still alive at the end of the cycle, they can either still have or not have angina symptoms. The presence of angina symptoms defines the health state of the following cycle ('No angina' or 'Angina').
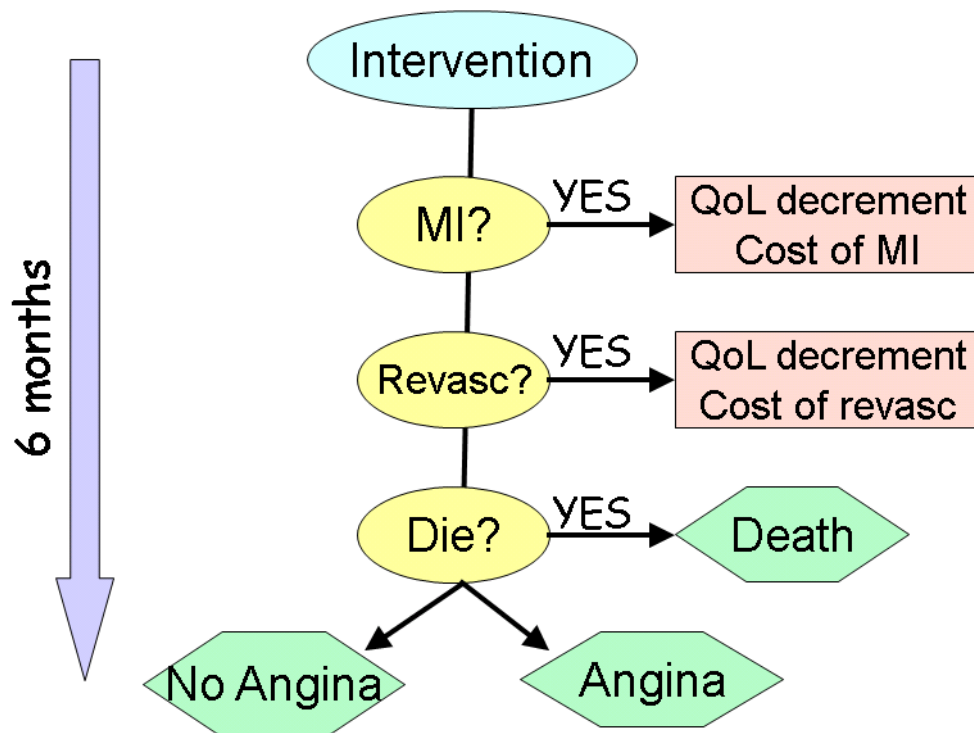
In the following cycles patients re-enter the model and the same transitional events are evaluated with different time-dependent probabilities (see paragraph 2.3.2).
When a patient undergoes a further revascularisation in the base case we have assumed that this is a PCI. We have varied this assumption in a sensitivity analysis using different proportion of CABG and PCI for additional revascularisation.

For each strategy the expected healthcare costs and expected QALYs were calculated by estimating the costs and QALYs for each state and then multiplying them by the proportion of patients who would be in that state as determined by the strategy taken (see 2.4).

2.2.2 Uncertainty

In the **probabilistic analysis** a probability distribution is defined for each model input parameter. When the model is run a value for each input is randomly selected from its respective probability distribution and mean costs and mean QALYs are calculated using these values. The model is run repeatedly – in this case 10,000 times – and results are summarised. Probability distributions in the analysis were based on error estimates from data sources, for example confidence intervals around relative risk estimates.

The way in which distributions are defined reflects the nature of the data, so for example probabilities were given a beta distribution, which is bounded by zero and one – see Table 1. All of the variables that were probabilistic in the model and their distributional parameters are detailed in Table 2.

Table 1: Description of the type and properties of distributions used in the probabilistic sensitivity analysis

Parameter	Type of distribution	Properties of distribution	Parameters for the distribution
Probabilities	Beta	Bounded on 0 – 1 interval. Derived from sample size, number of patients experiencing events.	α = events β = sample size – α
Cost	Gamma	Bounded at 0. Derived from mean and standard error.	α = (mean/SEM)^2 λ = mean/SEM^2
Number of resources used (number of stents)	Triangular	Derived from expert opinion.	Min = minimum value Likeliest = mean Max = maximum value
Utility decrements	Gamma	Bounded at 0. Derived from mean and standard error.	α = (mean/SEM)^2 λ = mean/SEM^2
Relative risk	Lognormal	Bounded at 0. Derived from log (of the RR) and standard error.	μ = ln(RR) SD(μ) = (ln[UpperCI] – ln[lowerCI])/1.96*2

2   SEM=standard error of the mean

3 For simplicity the following variables, were left deterministic (i.e. were not varied in the
4 probabilistic analysis): discount rate and cost-effectiveness threshold (which were deemed to
5 be fixed by NICE) and drug prices.

6 In addition, various **deterministic sensitivity analyses** were undertaken to test the robustness
7 of model assumptions and data sources. In these one or more inputs were changed and the
8 model rerun to see the impact on results.

9

10 *2.3   Model inputs*

11 2.3.1   Summary table of model inputs (details in subsequent
12   sections)

13
14 Table 2 - Summary of parameters used in the model

Description of variable	Point estimate	Probability distribution	Parameters for the probability distribution	Source
a) Probability of events (see 2.3.2)				
Probability of death after CABG – 1 year	2.68%	Beta	α = 63 β = 2288	Systematic review of clinical effectiveness (Appendix K)
Probability of death after CABG – from 1 to 2 years	0.37%	Beta	α = 0.4 β = 1075	See 2.3.2
Probability of death after CABG – from 2 to 3 years	1.97%	Beta	α = 11.6 β = 577	See 2.3.2

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Probability of death after CABG – from 3 to 5 years	4.49%	Beta	α = 34.6 β = 736	See 2.3.2
Probability of death after CABG – from 5 to 10 years	17.79%	Beta	α = 32.9 β = 152	See 2.3.2
Probability of MI after CABG – 1 year	4.44%	Beta	α = 102 β = 2197	Systematic review of clinical effectiveness (Appendix K)
Probability of MI after CABG – from 1 to 2 years	0.72%	Beta	α = 4.2 β = 574	See 2.3.2
Probability of MI after CABG – from 2 to 3 years	0.52%	Beta	α = 3 β = 571	See 2.3.2
Probability of MI after CABG – from 3 to 5 years	3.49%	Beta	α = 26.6 β = 736	See 2.3.2
Probability of MI after CABG – from 5 to 10 years	1.57%	Beta	α = 2.9 β = 182	See 2.3.2
Probability of repeating revascularisation after CABG – 1 year	4.59%	Beta	α = 85 β = 1767	Systematic review of clinical effectiveness (Appendix K)
Probability of repeating revascularisation after CABG – from 1 to 2 years	0.69%	Beta	α = 7.3 β = 1047	See 2.3.2
Probability of repeating revascularisation after CABG – from 2 to 3 years	1.43%	Beta	α = 8.2 β = 565	See 2.3.2
Probability of repeating revascularisation after CABG – from 3 to 5 years	0.87%	Beta	α = 6.6 β = 748	See 2.3.2
Probability of freedom from angina symptoms after CABG – 6 months	85.20%	Beta	α = 121 β = 21	Systematic review of clinical effectiveness (Appendix K)
Probability of freedom from angina symptoms after CABG – 1 year	80.94%	Beta	α = 1168 β = 275	Systematic review of clinical effectiveness (Appendix K)
Probability of freedom from angina symptoms after CABG – 2 years	87.20%	Beta	α = 508 β = 75	Systematic review of clinical effectiveness (Appendix K)

Probability of freedom from angina symptoms after CABG – 3 years	87.20%	Beta	α = 503 β = 74	Systematic review of clinical effectiveness (Appendix K)
Probability of freedom from angina symptoms after CABG – 5 years	78.84%	Beta	α = 637 β = 171	Systematic review of clinical effectiveness (Appendix K)
Probability of freedom from angina symptoms after CABG – 10 years	64.04%	Beta	α = 130 β = 73	Systematic review of clinical effectiveness (Appendix K)
Relative risk of death at 1 year – PCI vs. CABG	1.18	Log-normal	$\mu = 0.166$ $SD(\mu) = 0.168$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of death at 2 years – PCI vs. CABG	1.32	Log-normal	$\mu = 0.278$ $SD(\mu) = 0.238$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of death at 3 years – PCI vs. CABG	0.79	Log-normal	$\mu = -0.236$ $SD(\mu) = 0.278$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of death at 5 years – PCI vs. CABG	1.11	Log-normal	$\mu = 0.104$ $SD(\mu) = 0.154$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of death at 10 years – PCI vs. CABG	0.95	Log-normal	$\mu = -0.051$ $SD(\mu) = 0.173$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of MI at 1 year – PCI vs. CABG	1.20	Log-normal	$\mu = 0.182$ $SD(\mu) = 0.130$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of MI at 2 years – PCI vs. CABG	1.30	Log-normal	$\mu = 0.262$ $SD(\mu) = 0.231$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of MI at 3 years – PCI vs. CABG	1.30	Log-normal	$\mu = 0.262$ $SD(\mu) = 0.220$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of MI at 5 years – PCI vs. CABG	1.36	Log-normal	$\mu = 0.307$ $SD(\mu) = 0.146$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of MI at 10 years – PCI vs. CABG	1.27	Log-normal	$\mu = 0.239$ $SD(\mu) = 0.276$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of repeating revascularisation at 1 year – PCI vs. CABG	3.55	Log-normal	$\mu = 1.267$ $SD(\mu) = 0.117$	Systematic review of clinical effectiveness (Appendix K)

Relative risk of repeating revascularisation at 2 years – PCI vs. CABG	4.42	Log-normal	$\mu = 1.486$ $SD(\mu) = 0.139$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of repeating revascularisation at 3 years – PCI vs. CABG	4.03	Log-normal	$\mu = 1.393$ $SD(\mu) = 0.167$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of repeating revascularisation at 5 years – PCI vs. CABG	4.15	Log-normal	$\mu = 1.423$ $SD(\mu) = 0.135$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of freedom from angina symptoms at 6 months – PCI vs. CABG	1.01	Log-normal	$\mu = 0.010$ $SD(\mu) = 0.048$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of freedom from angina symptoms at 1 year – PCI vs. CABG	0.87	Log-normal	$\mu = -0.139$ $SD(\mu) = 0.020$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of angina symptoms at 2 years – PCI vs. CABG	0.92	Log-normal	$\mu = -0.083$ $SD(\mu) = 0.025$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of angina symptoms at 3 years – PCI vs. CABG	0.94	Log-normal	$\mu = -0.062$ $SD(\mu) = 0.025$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of angina symptoms at 5 years – PCI vs. CABG	0.92	Log-normal	$\mu = -0.083$ $SD(\mu) = 0.027$	Systematic review of clinical effectiveness (Appendix K)
Relative risk of angina symptoms at 10 years – PCI vs. CABG	0.91	Log-normal	$\mu = -0.094$ $SD(\mu) = 0.081$	Systematic review of clinical effectiveness (Appendix K)
b) Quality of life values (see 2.3.3)				
Utility of No Angina	0.87	Beta	$\alpha = 348$ $\beta = 52$	Melsop 2003{Melsop, 2003 8989 /id}
Utility decrement of Angina vs. No angina	-0.167	Gamma	$\alpha = 2.678$ $\lambda = 16.04$	See 2.3.3
Utility decrement after MI	-0.24	Gamma	$\alpha = 177.78$ $\lambda = 740.74$	See 2.3.3
Utility decrement of CABG vs. PCI	-0.06	Gamma	$\alpha = 39.81$ $\lambda = 663.46$	See 2.3.3
c) Costs (see 2.3.4)				

Cost of CABG procedure	£7,959	Gamma	α = 13.04 λ = 0.0016	NHS Reference Costs 2008-09, Elective Inpatient CABG 1st time{Department of Health, 10 A.D. 15958 /id}
Cost of PCI procedure	£2,610	Gamma	α = 2.64 λ = 0.0010	NHS Reference Costs 2008-09, Elective Inpatient PCI 0 – 2 stents{Department of Health, 10 A.D. 15958 /id}
Cost of each stent	£300	Gamma	α = 15.19 λ = 0.0506	Experts opinion
Number of stents used	4	Triangular	Min = 2 Likeliest = 4 Max = 6	Experts opinion
Cost of Clopidogrel treatment over 12 months	£436	None		BNF 59{Royal Pharmaceutical Society of Great Britain, 2010 15947 /id}
Cost of Rehab	£550	Gamma	α = 15.19 λ = 0.0276	Bethell 2007{Bethell, 2009 162 /id}
Cost of angiography	£841	Gamma	α = 11.66 λ = 0.0139	2008-09 NHS Ref costs: Day cases, HRG EA41Z - Other Non-Complex Cardiac Surgery + Catheterisation{Department of Health, 10 A.D. 15958 /id}
Cost of MPS with SPECT	£293	Gamma	α = 15.19 λ = 0.0518	Chest Pain guideline{National Clinical Guideline Centre for Acute and Chronic Conditions, 2010 15959 /id}
Cost of medications over 6 months	£61.37	None		See 2.3.4.2
Cost of treatment of MI	£1,783	Gamma	α = 15.19 λ = 0.00852	Acute Coronary Syndromes Guideline{National Clinical Guideline Centre for Acute and Chronic Conditions, 2010 15960 /id}

Cost of referral	£112	Gamma	α = 15.19 λ = 0.1356	2008-09 NHS Reference Costs-Consultant Led: Follow up Attendance Non-Admitted Face to Face - Cardiology{Department of Health, 10 A.D. 15958 /id}
d) Other parameters and assumption				
Discount rate (cost and QALYs)	3.5%	none		NICE reference case

2.3.2   Baseline event rates and relative treatment effects

CABG was used as the baseline arm of the model. Data on event rates in this arm were derived from the systematic review of clinical effectiveness (Appendix K). Events in the model were total MI (both fatal and non-fatal), repeat revascularisation, and death. Only studies of CABG versus PCI with stents were included and the probabilities of events for each available time point (1 year, 3 years, 5 years, and 10 years) were calculated as:

$$P = r/n$$

Where r is the number of events in the CABG arm and n is the total number of patients randomised to CABG.

Probabilities of events at year 1 were taken directly from the meta-analysis for that time point. Probabilities at subsequent time points were calculated as follows:

$$p_{t2-t1} = \frac{p_{t2} - p_{t1}}{1 - p_{t1}}$$

Where

p_{t2-t1} is the probability of an event between an initial time t1 and a subsequent time t2

p_{t1} is the total probability of events at the initial time t1

and p_{t2} is the total probability of events at the subsequent time t2.

Among the patients alive at follow-up, the proportions of those who had angina symptoms were obtained from those studies reporting the number or proportion of patients with angina or no angina. In some papers results were expressed as mean CCS score (e.g. Buszman et al. (2008){Buszman, 2008 9132 /id}) and were excluded. If papers reported the number of patients in each CCS scores we combined CCS 0 + I to represent the 'No Angina' state, and II + III + IV to represent the 'Angina' state. The overall proportion of patients with or without angina at a time-point is used in the model to determine the angina/no angina health state for the whole cohort reaching the end nodes. We assumed that the proportion in each cycle was the same as the proportion at the following available time point. For example, in cycles 6 to 9

1 (corresponding to 3.5. up to 5 years) 78.84% of patients who are still alive have no angina in
2 the CABG arm; this figure corresponds to the probability of being angina-free at 5 years.

3 Table 3 summarises the clinical effectiveness data used in the model.

4 Table 3 - Summary of estimates of effectiveness used in the base case model

Parameter	Time point	Probability at time x – CABG arm	Probability from time (x-n) to time x	RR PCI vs. CABG	Source
Death (all)	1 year	2.68%	-	1.18	Sigwart et al. 2002{Sigwart, 2002 3794 /id}, Eefting et al. (2003){Eefting, 2003 1030 /id}, Serruys et al. (2001){Serruys, 2001 3726 /id}, Buszman et al. (2008){Buszman, 2008 9132 /id}, Serruys et al. (2009){Serruvs, 2009 3717 /id}, Hueb et al. (2004){Hueb, 2004 4637 /id}
	2 years	2.71%	0.37%	1.32	Unger et al. (2003){Unger, 2003 1120 /id}, Booth et al. (2008){Booth, 2008 267 /id}
	3 years	4.63%	1.97%	0.79	Serruys et al. (2005){Serruys, 2005 9140 /id}
	5 years	8.91%	4.49%	1.11	Serruys et al. (2005){Serruys, 2005 9140 /id}, Hueb et al. (2007){Hueb, 2007 2913 /id}
	10 years	25.12%	17.79%	0.95	Hueb et al. (2010){Hueb, 2010 15922 /id}
MI (all)	1 year	4.44%	-	1.20	Sigwart et al. 2002{Sigwart, 2002 3794 /id}, Eefting et al. (2003){Eefting, 2003 1030 /id}, Serruys et al. (2001){Serruys, 2001 3726 /id}, Serruys et al. (2009){Serruvs, 2009 3717 /id}, Hueb et al. (2004){Hueb, 2004 4637 /id}

	2 years	5.12%	0.73%	1.30	Unger et al. (2003){Unger, 2003 1120 /id}, Booth et al. (2008){Booth, 2008 267 /id}
	3 years	5.62%	0.52%	1.30	Serruys et al. (2005){Serruys, 2005 9140 /id}
	5 years	8.91%	3.49%	1.36	Serruys et al. (2005){Serruys, 2005 9140 /id}, Hueb et al. (2007){Hueb, 2007 2913 /id}
	10 years	10.34%	1.57%	1.27	Hueb et al. (2010){Hueb, 2010 15922 /id}
Repeat revascularisation	1 year	4.59%	-	3.55	Eefting et al. (2003){Eefting, 2003 1030 /id}, Serruys et al. (2001){Serruys, 2001 3726 /id}, Buszman et al. (2008){Buszman, 2008 9132 /id}, Serruys et al. (2009){Serruvs, 2009 3717 /id}, Hueb et al. (2004){Hueb, 2004 4637 /id}
	2 years	5.70%	0.69%	4.42	Unger et al. (2003){Unger, 2003 1120 /id}, Booth et al. (2008){Booth, 2008 267 /id}
	3 years	6.61%	1.43%	4.03	Serruys et al. (2005){Serruys, 2005 9140 /id}
	5 years	7.43%	0.87%	4.15	Serruys et al. (2005){Serruys, 2005 9140 /id}, Hueb et al. (2007){Hueb, 2007 2913 /id}
Patients free of angina	6 months	85.20%	-	1.01	Eefting et al. (2003){Eefting, 2003 1030 /id}
	1 year	80.94%	-	0.87	Sigwart et al. 2002{Sigwart, 2002 3794 /id}, Eefting et al. (2003){Eefting, 2003 1030 /id}, Serruys et al. (2001){Serruys, 2001 3726 /id}, Hueb et al. (2004){Hueb, 2004 4637 /id}

2 years	87.20%		0.92	Unger et al. (2003){Unger, 2003 1120 /id}
3 years	87.20%	-	0.94	Legrand et al. (2004){Legrand, 2004 1001 /id}
5 years	78.84%	-	0.92	Serruys et al. (2005){Serruys, 2005 9140 /id}, Hueb et al. (2007){Hueb, 2007 2913 /id}
10 years	64.04%	-	0.91	Hueb et al. (2010){Hueb, 2010 15922 /id}

1 * Data not used in the model as inconsistent with the trend.
2
3 Probability of death at 6 years was available from the study by Booth et al. (2008){Booth,
4 2008 267 /id}; however these data showed some inconsistencies when compared to the meta-
5 analysis of all the studies at previous time points (i.e. lower mortality rate compared to
6 previous year) and we decided not to use it in the model. The same decision was made for the
7 repeat revascularisation at 10 years from Hueb et al. (2010){Hueb, 2010 15922 /id}, where
8 the overall proportion of patients experiencing a repeat revascularisation was lower than that
9 at 5 years as defined by the meta-analysis, which included the 5-year follow-up of the same
10 study{Hueb, 2007 2913 /id}.
11

12 2.3.3   Utilities

13 For economic evaluation, a specific measure of HRQoL known as utility is required to calculate
14 QALYs. Utilities indicate the preference for health states on a scale from 0 (death) to 1
15 (perfect health). The NICE reference case specifies that the preferred way for this to be
16 assessed is by the EQ-5D instrument.
17
18 Utilities were attached to the health states in the model (angina, no angina, death) and
19 decrements in HRQoL (disutilities) were calculated for the transitional events in the model (MI
20 and initial revascularisation, in a sensitivity analysis also repeat revascularisation).
21
22 A systematic search identified few studies with de novo utility measures. We selected only
23 those studies reporting utility values separately in patients with and without symptoms of
24 angina. Serruys et al. (2001){Serruys, 2001 3726 /id} reported EQ-5D scores in a
25 randomised trial of PCI versus CABG, but did not report EQ-5D scores separately for patients
26 with or without angina. We therefore decided to use the utilities from another RCT{Melsop,
27 2003 8989 /id} on patients with multivessel coronary artery disease and angina or
28 documented ischemia. In this study time trade-off scores in 400 patients with angina and in 58
29 patients without angina were obtained through telephone interviews in the USA. Scores in
30 patients free of angina were significantly higher than scores in patients with angina (p<0.01).
31 Disutility of CABG was calculated as a differential from the PCI intervention based on the
32 study by Serruys et al. (2001){Serruys, 2001 3726 /id}. In this RCT, one month after the
33 intervention patients in the surgery group had a EQ-5D score of 0.78 (SD ±0.17) compared
34 to 0.84 (SD ±0.16) in patients one month after PCI. We assumed the difference in utility lasts
35 only for one month as data up to this point was available. The total QALY loss is calculated as
36 follows:
37
38 QALY loss = (uPCI − uCABG)/(12 months) = (0.84 − 0.86)/12 = 0.005

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Where

uPCI is the EQ-5D score in the PCI group one month after the intervention

and uCABG is the EQ-5D score in the CABG group one month after the intervention.

However in a study by Scuffham et al. (2006){Scuffham, 2006 9238 /id}, the recovery time after CABG was considered to be 2.5 months. Compared to this study, we have underestimated the decrement in HRQoL after surgery.

To estimate the disutility after a MI, we used the value reported in the HTA by Ward et al. (2007){Ward, 2004 9021 /id}; this was obtained from personal communication with the author of a RCT{Goodacre, 2004 103 /id}. In this study{Goodacre, 2004 103 /id} EQ-5D questionnaires were administered to patients with chest pain for whom a record of diagnosis including MI was available. The EQ-5D scores for patients with MI was 0.760 (uMI); as 1 was the utility representing perfect health (uPH), the disutility due to MI (disMI) corresponds to:

$$disMI = -(uPH - uMI) = -(1-0.760) = -0.24$$

This figure was divided by 2 to reflect the six-month cycle length.

Utilities used in the base case analysis are reported in Table 4.

Table 4 - Utility values used in the model

Parameter	Base case value	Source
Utility no angina	0.87 (SE 0.0435)	Melsop 2003{Melsop, 2003 8989 /id}
Utility angina	0.703 (SE 0.0923)	Melsop 2003{Melsop, 2003 8989 /id}
Immediate disutility CABG (QALYs lost)	-0.005	Calculated from Serruys2001{Serruys, 2001 3726 /id}
Immediate disutility MI (QALYs lost)	-0.24	Calculated from Ward2007{Ward, 2004 9021 /id}

While in the base case the disutility from CABG was estimated as a differential from PCI and no disutility was attached to PCI, in a sensitivity analysis we have calculated the disutility from both PCI and CABG as differentials from the No Angina state. In this way we incorporated an estimate of the disutility associated with the repeat PCI during follow-up (see 3.2).
In another study identified in our search{Shrive, 2007 9345 /id}, EQ-5D scores were calculated for patients in the procedure subgroups: event free, repeat PCI, repeat CABG. In a sensitivity analysis we used the differential utility between the event free group (0.85) and the repeat PCI group (0.77) to estimate the disutility associated with the repeat revascularisation, assuming it lasts for one month. Results are reported in 3.2.

2.3.4 Resource use and cost

Costs are associated either with initial strategy (CABG or PCI), health states ('angina' or 'no angina'), or transitional events (MI, revascularisation, and development of angina).

2.3.4.1 Cost of initial strategy

The cost of the initial strategy is used in the first cycle of the model (cycle 0). Cost components are described in Table 5 and comprise the cost of initial procedure, necessary medical therapy following PCI, cost of medical treatment as for the 'no angina' state (see 2.3.4.2) and

rehabilitation. In a study by Bethell et al. (2007){Bethell, 2009 162 /id} a different proportion of patients have rehabilitation after CABG compared to PCI. However in the model we assume everyone undergoes rehabilitation regardless of their initial intervention.

	CABG	PCI	Source
Cost of initial procedure - CABG	£7,959	-	NHS Reference Costs 2008-09, Elective Inpatient CABG 1st time{Department of Health, 10 A.D. 15958 /id}
Cost of initial procedure - PCI	-	£2,610	NHS Reference Costs 2008-09, Elective Inpatient PCI 0 – 2 stents Or PCI 3 or more stents (EA49Z){Department of Health, 10 A.D. 15958 /id}
Cost of additional stents	-	4 * £300	Experts opinion
Treatment with Clopidogrel for 12 months*	-	12*£36.35	BNF 59{Royal Pharmaceutical Society of Great Britain, 2010 15947 /id}
Medical treatment (no Angina)	£43	£42.55	BNF 59{Royal Pharmaceutical Society of Great Britain, 2010 15947 /id}
Rehabilitation	£550	£550	Bethell et al. (2007){Bethell, 2009 162 /id}
TOTAL	**£8,552**	**£4,839**	

* the total 12 month cost of the treatment was added to the first 6-month cycle

In the NHS reference costs{Department of Health, 10 A.D. 15958 /id}, the cost of PCI procedure includes the cost of 0 to 2 stents. In our model, patients had multi-vessel disease and would have more than two stents. We asked the experts of our GDG to estimate the average number of stents required in this intervention for the included population (4 stents). We could not find the cost of stents from publicly available sources therefore the GDG experts provided us with this estimate as well (£300 each).

In the review of the economic literature we found a study{Weintraub, 2004 114 /id} comparing the one-year costs of PCI and CABG in patients enrolled in the SoS trial, which was included in our review of clinical effectiveness (see Appendix E and Appendix G). In this study the cost of the initial procedure including hospitalisation and ward costs was higher in the CABG group compared to the PCI group (£7,321 vs. £3,884; p<0.05). These figures are very similar to the initial cost calculated in our model.

2.3.4.2 Cost of health states

The possible health states in which a patient could be in the model are 'angina', 'no angina' and 'death'. We collected information on the resources used while in these states from the GDG experts (data on medications use from a GP practice) which were supported by the estimates of medications used in patients randomised to optimal medical treatment in the

1 COURAGE trial{Weintraub, 2008 9247 /id}. We estimated the 6-month costs of the defined
2 medical treatment based on national sources of unit costs{Royal Pharmaceutical Society of
3 Great Britain, 2010 15947 /id}.

4 Patients who still have angina symptoms after the intervention are treated medically
5 according to the treatment profile reported in Table 6.
6
7 **Table 6 - Resources and cost of medical treatment in patients with angina**

Class of drug	Name of drug [a]	Proportion of patients treated [b]	Total cost for 6 months [c]
Statins	Simvastatin 40mg 1/day	100%	£9.15
Aspirin	Aspirin 75 mg, 1/day	100%	£6.40
BB and CCB	Bisoprolol 5mg 1/day Amlodipine 10mg 1/day	Total 100% (BB 85%, CCB 15%)	£7.85
Ivabradine	Ivabradine 5mg, 2/day	2%	£5.10
ACE inhibitors and ARB	Ramipril 5mg 1/day Losartan 50mg 1/day	Total 100% (ACE 75%, ARB 25%)	£27.00
Other drugs	Nicorandil 20mg, 2/day	5%	£4.75
Nitrates	Isosorbide mononitrate 20mg, 2/day	16%	£1.14
Total			**£61.39**

8 a) The most commonly used drug within the same class was identified by the GDG experts
9 b) Data from a GP practice (personal communications).
10 c) Source of cost BNF 59{Royal Pharmaceutical Society of Great Britain, 2010 15947 /id}. Cost of drugs was
11 calculated using the lowest cost of non-proprietary medicines. E.g. if capsules were cheaper than tablets then the
12 cost of capsules was used.
13
14 In a sensitivity analysis we have increased the cost of medications in the angina state based on
15 the annual cost reported in the study by Ward et al. (2007){Ward, 2004 9021 /id} which
16 was £171; we added the cost of statins (reported in Table 6) to this figure.

17 In the model, patients with no angina would still be medically treated to prevent
18 cardiovascular events. Drugs used and the computation of their cost are reported in Table 7.

19 **Table 7 - Resources and cost of medical treatment in patients with no angina symptoms**

Class of drug	Name of drug	Proportion of patients	Total cost for 6 months*
Statins	Simvastatin 40mg 1/day	100%	£9.15
Aspirin	Aspirin 75 mg, 1/day	100%	£6.40
ACE inhibitors and ARB	Ramipril 5mg 1/day Losartan 50mg 1/day	Total 100% (ACE 75%, ARB 25%)	£27.00
Total			**£42.55**

20 * Source of cost BNF 59{Royal Pharmaceutical Society of Great Britain, 2010 15947 /id}. Cost of drugs was
21 calculated using the lowest cost of non-proprietary medicines. E.g. if capsules were cheaper than tablets then the
22 cost of capsules was used.
23
24 No costs were associated with the death state.

25 **2.3.4.3 Cost of transitional events**

26 Transitional events in the model were MI, further revascularisation, and the appearance of
27 angina symptoms (event preceding the 'angina' health state).

1   Each of these events is associated with some costs (Table 8).

3   The cost of MI was obtained from the Acute Coronary Syndromes Guideline{National Clinical
4   Guideline Centre for Acute and Chronic Conditions, 2010 15960 /id}, and it incorporates the
5   cost of hospital stay, ambulance and A&E.

7   When a further revascularisation was required according to the clinical probability (2.3.2), this
8   was assumed to be a PCI and its cost as calculated in 2.3.4.1 was used. This assumption was
9   varied in a one-way sensitivity analysis where we increased the proportion of CABG/PCI as
10   revascularisation procedure up to 1. The cost of CABG was used for the selected proportion of
11   patients undergoing this procedure.

13   Patients who transit from the 'no angina' state to the 'angina' state are all assumed to incur the
14   costs of a cardiology outpatient consultation, myocardial perfusion scan with SPECT, and
15   coronary angiography as reported in Table 8.

17   **Table 8 - Cost of transitional events in the model**

Event in the model	Resource	Cost	Source
MI	Hospital stay, ambulance and A&E	£1,783	Acute Coronary Syndromes Guideline{National Clinical Guideline Centre for Acute and Chronic Conditions, 2010 15960 /id}
		TOTAL £1,783	
Further revascularisation	PCI procedure	£2,610	NHS Reference Costs 2008-09, Elective Inpatient PCI 0 – 2 stents Or PCI 3 or more stents (EA49Z){Department of Health, 10 A.D. 15958 /id}
	Stents	4*£300	Experts opinion
		TOTAL £3,810	
Transition to 'angina' state	Referral to cardiologist	£112	NHS Reference Costs 2008-09 - Consultant Led: Follow up Attendance Non-Admitted Face to Face - Cardiology{Department of Health, 10 A.D. 15958 /id}
	Invasive coronary angiography	£841	NHS Reference Costs 2008-09, Day cases, HRG EA41Z - Other Non-Complex Cardiac Surgery + Catheterisation{Department of Health, 10 A.D. 15958 /id}
	Myocardial perfusion scan with SPECT	£293	Chest Pain guideline{National Clinical Guideline Centre for Acute and Chronic Conditions, 2010 15959 /id}
		TOTAL £1,246	

2.4 Computations

The mean cost and effectiveness of the two strategies were calculated using TreeAge Pro 2008. The incremental cost-effectiveness ratio was calculated in Microsoft Office Excel 2007.

2.4.1 Calculating QALYs gained

For each strategy, the expected QALYs in each cycle are calculated as follows:

$$\text{Expected QALYs} = DisU_p + \sum_{j=1}^{19}\sum_{i=1}^{3} U_i P_{ij} + \sum_{j=1}^{19}\sum_{x=1}^{3} DisU_x P_{xj}$$

where

$DisU_p$ = the disutility for the initial intervention p

U_i = the utility score for health state i

P_i = the proportion of patients in health state i

$DisU_x$ = the disutility for event x

P_{xj} = the probability of event x in cycle j

and where intervention p could be either PCI or CABG, health state i could be any of the health states represented by the green boxes in

Figure 1 (death, angina, no angina) and event x could be MI or further revascularisation.

The proportion of patients in each health state depends on the effectiveness of the treatment, in terms of mortality and improvement of symptoms.

QALYs were then discounted to reflect time preference. QALYs during cycle 0 were not discounted. The total discounted QALYs was the sum of the discounted QALYs per cycle.

The overall 10-year expected QALYs are given by the sum of the discounted QALYs calculated for each cycle. The *incremental QALYs gained* associated with a treatment strategy are calculated as the difference between the expected QALYs with that strategy and the expected QALYs with the comparator.

2.4.2 Calculating costs

For each strategy, the expected cost per cohort of patients is calculated as follows:

$$\text{Expected cost} = C_s + \sum_{j=1}^{19}\sum_{i=1}^{3} C_i P_{ij} + \sum_{j=1}^{19}\sum_{x=1}^{3} C_x P_{xj}$$

where

C_s = cost of the initial strategy (PCI or CABG)

1   C_i = cost of health state i

2   P_{ij} = proportion of patients in health state i in cycle j

3   C_x = cost of event x

4   P_{xj} = probability of event x in cycle j

5   and where health state i could be any of the health states represented by the green
6   boxes in

7 Figure 1 (death, angina, no angina), and event x could be any of the events described in
8 Table 8.

9 The proportion of patients in each health state depends on the effectiveness of the treatment,
10 in terms of mortality and improvement of symptoms.

11 Future costs (those occurring after cycle 1) were discounted to reflect time preference.

12 The overall 10-year expected costs are given by the sum of the discounted costs calculated
13 for each cycle. The incremental cost associated with a treatment strategy is calculated as the
14 difference between the expected cost with that strategy and the expected cost with the
15 comparator.

16 **2.4.3 Calculating cost-effectiveness**

17 The widely used cost-effectiveness metric is the incremental cost-effectiveness ratio (ICER). This
18 is calculated by dividing the difference in costs associated with two alternatives by the
19 difference in QALYs. The decision rule then applied is that if the ICER falls below a given cost
20 per QALY threshold then the result is considered to be cost-effective. If both costs are lower
21 and QALYs are higher the option is said to dominate and an ICER is not calculated.

$$ICER = \frac{Costs\ (B) - Costs\ (A)}{QALYs\ (B) - QALYs\ (A)}$$

22

23 Where:

24   Costs/QALYs(X) = total discounted costs/QALYs for option X

25   Option B is cost-effective if: ICER < Threshold

26 It is also possible, for a particular cost-effectiveness threshold, to re-express cost-effectiveness
27 results in term of net benefit (NB). This is calculated by multiplying the total QALYs for a
28 comparator by the threshold cost per QALY value (for example, £20,000) and then
29 subtracting the total costs. The decision rule then applied is that the comparator with the
30 highest NB is the most cost-effective option at the specified threshold. That is the option that
31 provides the highest number of QALYs at an acceptable cost. For ease of computation NB is
32 used to identify the optimal strategy in the probabilistic analysis simulations.

$$Net\ Benefit\ (X) = QALYs\ (X) \times D - Costs\ (X)$$

33

34 Where: Costs/QALYs(X) = total discounted costs/QALYs for option X; D = cost-effectiveness
35 threshold

The probabilistic analysis was run for 10,000 simulations. For each simulation, total discounted costs and total discounted QALYs were calculated for each treatment option. The net benefit was also calculated and the most cost-effective option identified (that is, the one with the highest net benefit), at a threshold of £20,000 per QALY gained.

The results of the probabilistic analysis were summarised in terms of mean discounted costs and QALYs with confidence intervals, where means were the average of the 10,000 simulated estimates and the 95% confidence intervals are the 2.5 and 97.5 percentiles. A cost-effectiveness ratio was calculated from the mean costs and QALYs. The percentage of simulations where each strategy was the most cost-effective gives an indication of the strength of evidence in favour of that strategy being cost-effective.

2.4.4 Interpreting results

Our analysis was built around clinical data and costs for patients with multi-vessel disease who are eligible for both procedures. Consideration will be given to the fact that in patients with single vessel disease PCI is likely to be less costly and have the same effectiveness. In many parameters of our model we have favoured CABG, e.g. we excluded stroke from the outcomes, and we have included RCTs where a mix of stent and non-stent PCI was used (MASS-II trial){Hueb, 2010 15922 /id}.

3 Results

3.1 Base case results

The base case results show that CABG generates more QALYs than PCI over a ten-year period but it generates more costs too (Table 9). The ICER is above what NICE considers to be cost-effective (£20,000/QALY). Therefore PCI is the most cost-effective choice among these two procedures for patients with characteristics similar to the ones enrolled in the trials included in the analysis.

Table 9 - Results of base case analysis

Strategy	Cost	Incr Cost	Eff	Incr Eff	ICER
PCI Stents	£10,638		6.1167		
CABG	£13,085	£2,447	6.1992	0.0825	£29,661

Table 10 reports the costs associated with the different types of resources considered in the model.

Table 10 – Cost breakdown – discounted cost per patient in the PCI and CABG strategy

Cost category	PCI	CABG
Procedures (including repeats)	£4,816	£8,221
Drugs	£1,165	£715
Further assessments	£3,895	£3,431
Treating MI	£212	£168
Rehabilitation	£500	£500
TOTAL	£10,638	£13,085

1 Overall CABG decreases those costs which occur later in the model (medication, further
2 assessments, and treatment of MI) but in terms of cost of procedures CABG largely exceeds
3 the cost in the PCI group even when the probability of repeating the procedure (higher in the
4 PCI group) is accounted for.
5
6

7 *3.2   Sensitivity analysis*

8 3.2.1 Deterministic sensitivity analyses

9 The main driver of the results was the high initial cost of the CABG procedure.

10 Since PCI is associated with higher rates of repeat revascularisation, we have explored if
11 results were sensitive to the future costs both by eliminating the discounting for costs and
12 effectiveness (which in the base case favours interventions with low initial costs even if
13 associated with higher future costs) and by changing the assumption around the type of
14 procedure used as a repeat revascularisation (PCI in all the cases in the base case; CABG was
15 possible in the sensitivity analysis).

16 In the base case the initial disutility associated with the CABG intervention was calculated
17 incrementally compared to PCI; in a sensitivity analysis we have incorporated the disutility of
18 repeating PCI by calculating the decrement in HRQoL as a differential from the 'no angina'
19 state. We have also used alternative data on disutilities obtained from a separate
20 study{Shrive, 2007 9345 /id}.

21 Our clinical data were limited to a 10-year period; however we could extrapolate data to a
22 lifetime horizon assuming a constant rate of events except for death which was assumed to be
23 equal to the general population after 10 years from the intervention and therefore did not
24 vary according to the initial intervention.

25 The results of the sensitivity analyses conducted are reported in Table 11.

26 **Table 11 - Results of sensitivity analyses**

Type of sensitivity analysis	Result
No discount rate	ICER CABG vs. PCI = £24,016/QALY
Threshold analysis on proportion of CABG as repeat revascularisation procedure	PCI is the most cost-effective initial strategy if less than 85% of the repeat revascularisation procedures are CABG
Disutilities of PCI and CABG calculated as differential from 'no angina' state	ICER CABG vs. PCI = £28,850/QALY
Threshold analysis on proportion of CABG as repeat revascularisation procedure after disutilities of PCI and CABG were calculated as differential from 'no angina' state	PCI is the most cost-effective initial strategy if less than 83% of the repeat revascularisation procedures are CABG
Disutility of PCI calculated from Shrive et al. (2007){Shrive, 2007 9345 /id}	ICER CABG vs. PCI = £27,070/QALY
Cost of medication in the angina state = £171 per year excluding simvastatin{Ward, 2004 9021 /id}	ICER CABG vs. PCI = £29,354/QALY
Lifetime horizon (mean patient's age = 65)	ICER CABG vs. PCI = £20,050/QALY

27

1 **3.2.2 Probabilistic sensitivity analysis**

2 The results of the PSA show the uncertainty over the base case results (Table 12). In non-linear
3 models, such as Markov models, there is often a difference between the deterministic and
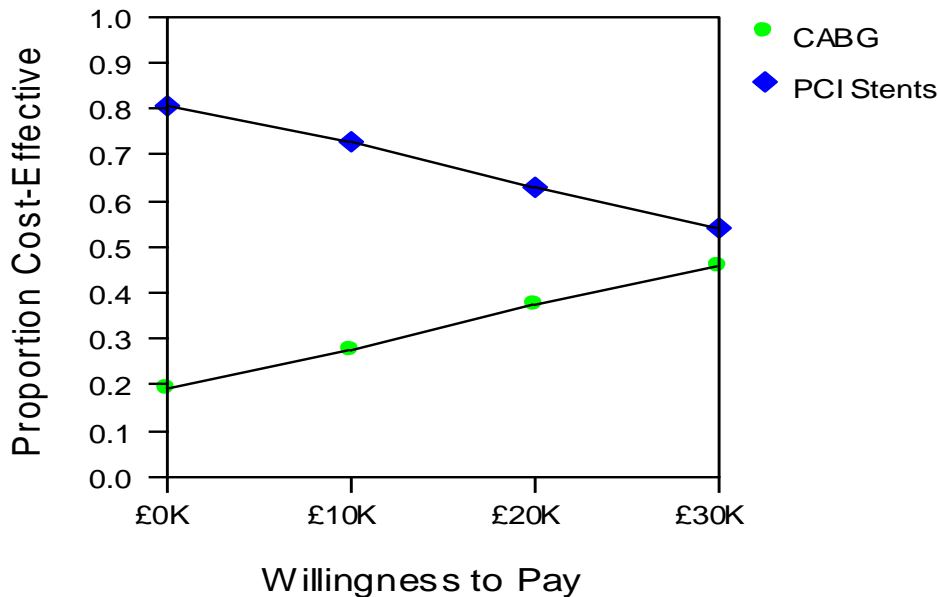4 probabilistic results and in such cases the probabilistic results should take precedence.

5 If we consider a 95% confidence interval the base case results did not reach statistical
6 significance.

7 **Table 12 - Results of PSA - CABG vs. PCI**

Mean cost (£)	Mean QALYs	Mean ICER (£/QALY)	95% CI – lower limit (£/QALY)	95% CI – upper limit (£/QALY)	Probability of being cost-effective at £20,000/QALY
PCI 10,555 CABG 12,982	PCI 6.0857 CABG 6.1551	34,971	CABG dominates	PCI dominates	PCI 63% CABG 37%

8

9 At a willingness to pay of £20,000/QALY PCI has only a 63% probability of being cost-
10 effective; the two interventions have a similar probability (54% and 46% respectively for PCI
11 and CABG) when a £30,000/QALY threshold is adopted (Figure 2).

13 **Figure 2 - Acceptability curve of PCI and CABG**

14 The uncertainty can also be graphically represented by plotting the results of the incremental
15 analysis for all the 10,000 simulations into a cost-effectiveness plane (Figure 3). Each point
16 represents the ICER of CABG vs. PCI for each simulation. The dotted line represents the
17 £20,000/QALY threshold: the dots below the line indicate a simulation where CABG was cost-

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effective and those above the line where CABG was not cost-effective. The ellipse delimits the 95% confidence area.
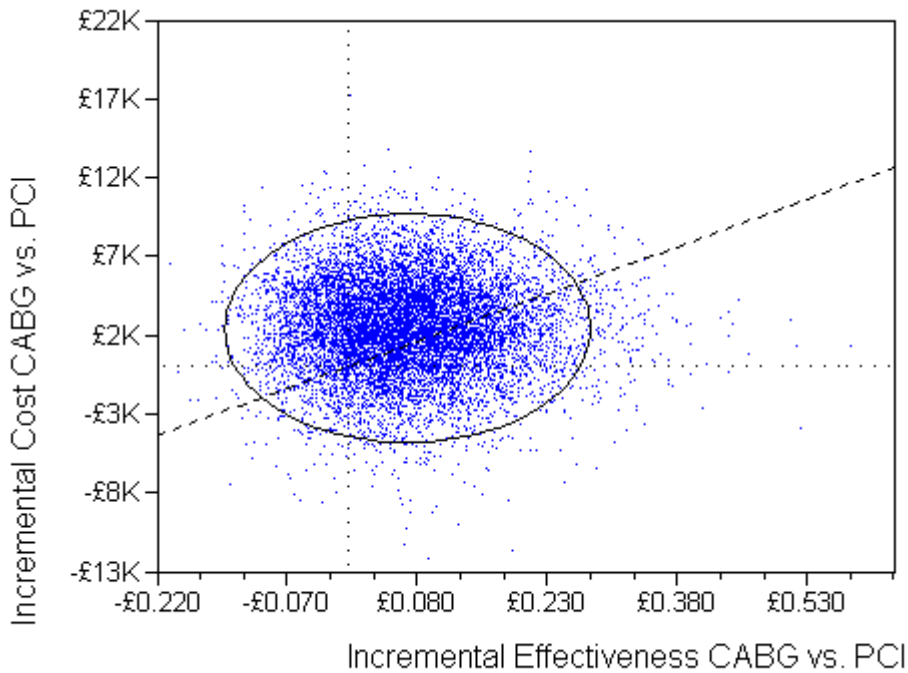
Figure 3 - Incremental cost-effectiveness scatterplot - CABG vs. PCI

4   Discussion

4.1   Summary of results

A new cost-utility analysis was developed which compared CABG and PCI as a revascularisation procedure for patients with angina who are eligible for both. This was based on the RCT data identified in the clinical review; the clinical outcomes incorporated in the model were mortality, myocardial infarction, repeat revascularisation, and presence of angina symptoms. Costs and QALYs were considered from a NHS and personal social services perspective.

We found that CABG was not cost effective when compared to PCI. This conclusion was robust to various deterministic sensitivity analyses; however, when parameters were varied simultaneously in a PSA the results were uncertain.

4.2   Limitations & interpretation

The analysis is based on clinical studies and therefore issues concerning the interpretation of the clinical studies also apply to the interpretation of the economic analysis. One of the main limitations of the model is the possibility that the included population is not representative of the general population of patients with angina. Moreover, the trials in the analysis were conducted over a long time period and the use of different surgical and percutaneous

1 techniques may have influenced the relative risks and benefits of the two revascularisation
2 strategies.

3 The model structure was kept simple and did not incorporate the different mortality rate in
4 patients with MI or angina. This was a pragmatic approach because the trials did not report
5 different mortality rates in people with MI or angina in each arm.

6 We had to disregard some clinical data (i.e. mortality at 6 years from the SoS trial, and
7 repeat revascularisation at 10 years from MASS-II trial) because they were inconsistent with
8 the trend from the meta-analysis of all the studies at previous time points; in fact, the
9 cumulative proportion of patients who were alive in the SoS trial or who had a repeat
10 procedure in the MASS-II trial was smaller than the proportion at the previous time point
11 calculated from the meta-analysis of clinical studies. In the latter example, the meta-analysis
12 at a previous time point included the MASS-II trial as well.

13 HRQoL data were not available from most of the trials; some values were available from the
14 ARTS study{Legrand, 2004 1001 /id}; however, had we used HRQoL outcomes from one trial
15 we would have had to disregard the intermediate clinical outcomes (incidence of MI, angina
16 symptoms) from other trials. In our model we used one estimate of utility attached to the
17 'angina' health state, thus we did not capture the possible impact of differences in symptom
18 severity.

19 We decided not to include stroke in the analysis because of concern about heterogeneity in
20 the definition of stroke across the studies. Furthermore many assumptions on the severity and
21 cost of treatment for stroke would have had to be made. Since the results of the model
22 showed that PCI was more cost-effective and stroke was more frequent in the CABG group
23 (see chapter 12) inclusion of stroke in the model would not have changed the overall result.

24 Furthermore, our analysis has been unfavourable to PCI as we added the cost of additional
25 stents to the basic cost of the procedure, which already included the use of some stents. In
26 addition, for every patient developing angina in any cycle after the initial intervention we
27 included the costs of a referral, myocardial perfusion scan with SPECT, and coronary
28 angiography, and this is likely to overestimate the true requirement for these additional
29 procedures.

30

4.3   Generalisability to other populations / settings

32 Individuals participating in the trials included in the analysis were a highly selected
33 population. The analysis was based on randomised trials of PCI versus CABG and the results
34 only directly apply to patients considered eligible for either revascularisation procedure.

35 A validated risk score for patients with stable angina is not available and therefore a
36 stratified analysis on different baseline risk was not performed as in practice the baseline risk
37 cannot be precisely quantified.

38 Patients in the trials had multi-vessel disease; in single vessel disease the repeat
39 revascularisation rate is generally lower compared to multi-vessel disease and PCI is likely to
40 be an even more cost-effective option for this group of patients.

41

4.4　Comparisons with published studies

All the studies identified in our review (see Chapter 12 and economic evidence tables in Appendix G) consistently reported higher cost of CABG compared to PCI. The difference in costs tends to decrease when a longer follow-up time was considered (e.g. in the ARTS study{Legrand, 2004 1001 /id}, RITA trial{Henderson, 1998 263 /id}). Of the other three cost-utility analyses{Eefting, 2003 1030 /id;Griffin, 2007 53 /id;Weintraub, 2004 114 /id}, two{Eefting, 2003 1030 /id;Weintraub, 2004 114 /id} showed that CABG was not cost-effective but their analysis was limited to a one-year time horizon. The other analysis{Griffin, 2007 53 /id} concluded that CABG was cost-effective in patients suitable for both procedures; however this study was based on non-randomised data and probably most of the PCI procedures were without stents.

Our analysis included the routine use of stent during PCI procedures, and combines short and long follow-up data from a systematic review of RCTs.

4.5　Conclusion= Evidence statement

Our analysis suggests that CABG is effective but not cost-effective compared with PCI for patients eligible for both procedures but there is some uncertainty around this conclusion.

4.6　Implications for future research

Had a validated score for risk stratification for stable angina been available at the time of our analysis we could have identified the most appropriate population for each of the interventions compared. This would mean the resources are distributed more cost-effectively (i.e. offering CABG or PCI only to those patients that would benefit more from the intervention).