A meta-analysis of the prospective randomised trials of coronary revascularisation before noncardiac vascular surgery with attention to the type of coronary revascularisation performed

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Summary

Prospective randomised trials of coronary revascularisation prior to noncardiac surgery have shown no survival benefit following noncardiac surgery. However, these studies have not differentiated the outcomes associated with coronary artery bypass grafting (CABG) and percutaneous coronary interventions. We performed a meta-analysis of the randomised controlled trials of pre-operative coronary revascularisation for noncardiac surgery, extracting data for 30 day and long term all-cause mortality and myocardial infarction (MI) following revascularisation, according to the type of revascularisation performed. Pre-operative percutaneous coronary intervention was associated with significantly increased 30 day MI and composite death and MI. Pre-operative CABG was associated with a significantly improved long term composite outcome of death and MI compared to percutaneous coronary interventions. The adverse effect of percutaneous coronary interventions on both short and long term outcomes in vascular surgical patients should be taken into consideration when interpreting these trials. CABG may improve long term outcomes in vascular surgical patients. The indications for and timing of CABG in vascular surgical patients needs further research.

Peri-operative myocardial infarction is a major cause of morbidity and mortality in patients undergoing vascular surgery. Although the majority of patients who have died following a peri-operative myocardial infarction have been shown to have significant coronary disease [], the pathophysiology of the fatal event is approximately evenly distributed between oxygen supply-demand imbalance and plaque rupture [1, 2].

Following the observations by Hertzer et al. [3] that severe surgically correctable coronary artery disease was present in 25% of patients presenting for noncardiac vascular surgery, many attempts have been made to define the role of prophylactic pre-operative coronary revascularisation. The initial series of predominantly retrospective studies examining the role of coronary artery bypass grafting (CABG) in reducing cardiac events in high risk patients undergoing vascular surgery showed a potential for reduction of both morbidity and mortality from myocardial events [4–8].

However, the first prospective randomised trial, the Coronary Artery Revascularization Prophylaxis (CARP) study [9], a recent meta-analysis [10] and subsequent publication of the second prospective randomised trial, the Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echo – V (DECREASE-V) pilot study [11], all failed to show survival benefit associated with pre-operative revascularisation.

While the studies of only CABG showed early survival benefit, more recent publications have considered ‘coronary revascularisation’ to include both CABG and percutaneous coronary interventions [12–16] including the two prospective randomised trials [9, 11]. Although no difference in outcome was shown between CABG and percutaneous coronary interventions...
in the early observational studies, this is probably a reflection of the study design and patient selection. Patients were included who had coronary revascularisation either 6 months [16], a median of 29 months [7], and years prior to noncardiac surgery [14, 15]. Because of the long interval prior to noncardiac surgery, it is not surprising that this conclusion was reached.

In contrast to registry observational studies, where the time between percutaneous coronary revascularisation and noncardiac surgery was generally much longer, cohort publications that reported on noncardiac surgery within weeks to 90 days after percutaneous coronary interventions were not associated with a survival benefit [17, 18]. The largest cohort publications have shown that mortality following noncardiac surgery is significantly increased for up to 90 days following insertion of a bare metal stent [19] and may be increased up to a year following insertion of a drug-eluting stent [20].

Of concern is that in the CARP and DECREASE-V trials, patients who underwent percutaneous coronary interventions had their respective subsequent noncardiac surgery at a median of 41 days [9] and 29 days [11] following the percutaneous intervention. Indeed in the CARP study, CABG and percutaneous coronary intervention have been subsequently compared and perioperative myocardial infarction was found to be significantly decreased in the CABG group (p = 0.024) [21].

The aim of this meta-analysis was to analyse the efficacy of coronary revascularisation prior to noncardiac vascular surgery, using data from prospective randomised trials and to present outcomes according to whether the patients had pre-operative percutaneous coronary intervention or CABG, based on the assumption that these different procedures may have influenced the results of the studies and their interpretation.

Methods
We conducted a meta-analysis of the utility of pre-operative coronary revascularisation in preventing early (30 days) and late postoperative mortality and non-fatal MI in patients following vascular surgery. A subgroup analysis was conducted to identify the individual outcomes associated with pre-operative CABG and percutaneous coronary interventions.

Search strategy and selection criteria
A PubMed Central search was conducted using the terms: ‘preoperative’, ‘randomized’ and ‘coronary revascularization’ with the limit terms including ‘human’, ‘clinical trial’, ‘meta-analysis’ and ‘randomized controlled trial’. It was last updated on 23rd February 2009. The reference lists of reviews and included studies were hand searched for further possible publications not identified in the electronic search. Only prospective randomised trials of pre-operative coronary revascularisation that reported mortality (all-cause and/or cardiac) and nonfatal myocardial infarction in patients undergoing vascular surgery were included. Each author independently screened citations, abstracted data and assessed methodological quality, using a standardised data extraction sheet. Disagreements were resolved through consensus or by contacting the original authors.

Outcomes
We extracted data on 30-day and long term all-cause mortality and nonfatal myocardial infarction. Authors of included studies were contacted to obtain additional data.

Statistical analysis
All statistical analyses were performed using Revman version 4.2.10 software (The Nordic Cochrane Centre, Kobehavn, Denmark). Heterogeneity between studies was assessed using univariate chi-square analysis. Random or fixed effects models were used based on the presence or absence of significant heterogeneity between studies respectively. Pooled dichotomous outcomes were reported as the odds ratio (OR) and the 95% confidence intervals (CI).

Results
Search results
We identified 235 papers, of which 228 were excluded after review of the abstracts. The excluded papers consisted of seven viewpoint papers, 175 cardiac surgical papers, 43 percutaneous coronary stent papers and seven noncardiac surgery papers. Of the seven papers retrieved for detailed assessment, only the CARP trial and DECREASE-V met the inclusion criteria [9, 11]. Two studies were excluded because they were not randomised controlled studies or did not study pre-operative coronary revascularisation [12, 22], and three studies were excluded which reported other outcomes of the CARP trial [21, 23, 24].

Description of the included studies
The study design and characteristics of the two remaining studies are listed in Table 1.

Recruitment criteria
Both studies recruited elective vascular surgical patients scheduled for aortic aneurysm or infra-inguinal surgery. Eligibility for coronary revascularisation in the CARP trial included coronary artery stenosis of ≥70%, with exclusion of patients with left main stem stenosis of ≥50% [9]. In the DECREASE-V study, patients were eligible
Table 1  Characteristics of the two prospective randomised studies IQR or SD.

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<thead>
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<tbody>
<tr>
<td></td>
<td>Inclusion criteria</td>
<td>Exclusion criteria</td>
</tr>
<tr>
<td></td>
<td>≥ 70% stenosis</td>
<td>Extensive myocardial ischaemia</td>
</tr>
<tr>
<td></td>
<td>≥ 50% LMS LVEF&lt; 20% Severe AS</td>
<td>&lt; three risk factors No or limited ischaemia</td>
</tr>
<tr>
<td>Patients screened; n</td>
<td>5859</td>
<td>1880</td>
</tr>
<tr>
<td>Patients investigated; n</td>
<td>1048</td>
<td>329</td>
</tr>
<tr>
<td>Patients recruited; n</td>
<td>510</td>
<td>101</td>
</tr>
<tr>
<td>Age; years</td>
<td>66 ± 11</td>
<td>71 (64–74)</td>
</tr>
<tr>
<td>Prior myocardial infarction; %</td>
<td>43</td>
<td>100</td>
</tr>
<tr>
<td>Diabetes mellitus; %</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>History of CCF; %</td>
<td>12</td>
<td>47</td>
</tr>
</tbody>
</table>

LMS, left main stem; LVEF, left ventricular ejection fraction; AS, aortic stenosis; CCF, congestive cardiac failure; Revasc, revascularised.

for randomisation if they had extensive regional wall motion abnormalities; defined as ≥5 ischaemic segments on a 17 segment dobutamine stress echocardiography or ≥3 ischaemic walls on a six wall stress perfusion scintigraphy [11]. As a result of the inclusion criteria, the patients recruited in the DECREASE-V study had a higher risk profile than those in the CARP trial (Table 1). Sixty-seven percent of the patients in the DECREASE-V study revascularisation group had three-vessel coronary artery disease in contrast to 31% in the CARP trial. In addition, 8% of the revascularised patients in DECREASE-V study had significant left main stem disease [11].

Time to noncardiac surgery
The time from randomisation to noncardiac surgery was significantly increased in the group randomised to coronary revascularisation in the CARP trial (median 54 vs 18 days, p < 0.001) [9]. However, there was no difference in the time to noncardiac surgery between the patients who had pre-operative CABG or percutaneous coronary intervention. Non-cardiac surgery followed at 50 (interquartile range (IQR) [35–75]) days after CABG and 42 (IQR [22–62]) days after percutaneous coronary intervention in the CARP trial [21] and 29 (range [13–65]) days and 31 (range [19–39]) following CABG and percutaneous coronary intervention respectively in the DECREASE-V study [11].

Characteristics of percutaneous coronary interventions
The treatment group allocations and outcomes are shown in Table 2. In the CARP trial, 90% of the patients who had percutaneous coronary interventions received bare metal stents and none had drug-eluting stents (McFalls, personal communication). In the DECREASE-V study, 30 patients had drug-eluting stents and two patients had bare metal stents [11]. In the DECREASE-V study, antiplatelet therapy (aspirin and clopidogrel) was continued in the peri-operative period [11].

Reported outcomes
In the CARP study, at 2.7 years after vascular surgery, there was no significant difference in mortality between

Table 2  Number of patients randomised, treatment allocation and outcomes [9, 11].

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>Revasc Control</td>
<td>Revasc Control</td>
<td>CABG PCI</td>
<td>CABG PCI</td>
</tr>
<tr>
<td>Number recruited</td>
<td>258 252</td>
<td>49 52</td>
<td>99 141</td>
<td>17 32</td>
</tr>
<tr>
<td>Pre-noncardiac surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>10 1</td>
<td>2 0</td>
<td>2 2</td>
<td>2 0</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>14 0</td>
<td>1 0</td>
<td>7 7</td>
<td>0 1</td>
</tr>
<tr>
<td>Vascular surgery</td>
<td>225 237</td>
<td>46 52</td>
<td>91 131</td>
<td>15 31</td>
</tr>
<tr>
<td>Post-noncardiac surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-day death</td>
<td>7 8</td>
<td>9 6</td>
<td>2 5</td>
<td>2 7</td>
</tr>
<tr>
<td>30-day myocardial infarction</td>
<td>19 20</td>
<td>16 16</td>
<td>6 22</td>
<td>5 11</td>
</tr>
<tr>
<td>Late death*</td>
<td>70 67</td>
<td>11 12</td>
<td>15 28</td>
<td>3 8</td>
</tr>
<tr>
<td>Late myocardial infarction*</td>
<td>37 27</td>
<td>17 19</td>
<td>9 31</td>
<td>6 11</td>
</tr>
</tbody>
</table>

*Includes 30-day outcomes, but not pre-noncardiac surgery outcomes.

Revasc, revascularisation; CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention.
the revascularised and non revascularised groups [relative risk (RR) 0.98, 95% CI 0.7–1.37, p = 0.92] [9]. Similarly, despite the higher risk profile of the patients in the DECREASE-V study, revascularization did not improve 30-day (OR 1.4, 95% CI 0.7–2.8, p = 0.3) or 1 year (OR 1.2, 95% CI 0.7–2.3, p = 0.48) composite outcomes of all-cause death or myocardial infarction [11].

**Meta-analysis results**

Having applied the statistical analyses detailed above, the following results were found. Pre-operative coronary revascularisation was associated with significantly increased 30-day mortality, and the 30-day and late composite outcomes of death and nonfatal myocardial infarction. Thirty-day nonfatal myocardial infarction showed a trend to a worse outcome (Table 3).

When percutaneous coronary interventions and CABG were separated, percutaneous coronary intervention was associated with a trend to increased 30-day mortality, and significantly increased 30-day nonfatal myocardial infarction and composite outcomes. Percutaneous coronary intervention was associated with a trend to a worse long term composite outcome (Figs 1–4).

CABG was associated with a trend to a worse outcome for all 30-day events, and a trend to a better late composite outcome (Figs 5–8).

When comparing CABG and percutaneous coronary intervention, CABG had a trend to less deleterious effects on the composite outcome of death and nonfatal myocardial infarction at 30 days when compared with percutaneous coronary intervention, which was subsequently statistically significant for the late composite outcome (Figs 9, 10).

**Table 3** Meta-analysis of all-cause mortality and nonfatal myocardial infarction reported in the prospective randomised trials of pre-operative coronary revascularisation [9, 11].

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Coronary revascularisation</th>
<th>Control group</th>
<th>Heterogeneity (I² statistic) (%)</th>
<th>Fixed odds ratio (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-day all-cause mortality</td>
<td>28 / 307</td>
<td>15 / 304</td>
<td>0</td>
<td>2.01 (1.04–3.89)</td>
<td>0.04</td>
</tr>
<tr>
<td>30-day nonfatal MI</td>
<td>50 / 307</td>
<td>36 / 304</td>
<td>0</td>
<td>1.52 (0.94–2.44)</td>
<td>0.09</td>
</tr>
<tr>
<td>30-day composite outcome</td>
<td>78 / 307</td>
<td>51 / 304</td>
<td>0</td>
<td>1.84 (1.21–2.80)</td>
<td>0.004</td>
</tr>
<tr>
<td>Late composite outcome</td>
<td>162 / 307</td>
<td>126 / 304</td>
<td>0</td>
<td>1.60 (1.16–2.21)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

MI, myocardial infarction; composite outcome is defined as death and nonfatal MI; CI, confidence interval.

**Figure 1** Comparison of 30-day all-cause mortality following pre-operative coronary revascularisation using percutaneous coronary intervention.

<table>
<thead>
<tr>
<th>Study or sub-category</th>
<th>PCI</th>
<th>Control</th>
<th>OR (fixed) 95% CI</th>
<th>Weight %</th>
<th>OR (fixed) 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>McFalls</td>
<td>7/141</td>
<td>9/252</td>
<td>63.21</td>
<td>100.00</td>
<td>1.41 [0.51, 3.87]</td>
</tr>
<tr>
<td>Poldermans</td>
<td>7/32</td>
<td>6/52</td>
<td>36.79</td>
<td>100.00</td>
<td>2.15 [0.65, 7.09]</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>173</td>
<td>304</td>
<td></td>
<td>100.00</td>
<td>1.68 [0.78, 3.62]</td>
</tr>
</tbody>
</table>

Test for heterogeneity: \( \chi^2 = 0.29, d.f. = 1 (p = 0.60), I^2 = 0\%

Test for overall effect: \( Z = 1.33 (p = 0.18) \)

**Figure 2** Comparison of 30-day nonfatal myocardial infarction following pre-operative coronary revascularisation using percutaneous coronary intervention.

<table>
<thead>
<tr>
<th>Study or sub-category</th>
<th>PCI</th>
<th>Control</th>
<th>OR (random) 95% CI</th>
<th>Weight %</th>
<th>OR (random) 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>McFalls</td>
<td>29/141</td>
<td>21/252</td>
<td>61.50</td>
<td>100.00</td>
<td>2.85 [1.55, 5.22]</td>
</tr>
<tr>
<td>Poldermans</td>
<td>12/32</td>
<td>16/52</td>
<td>38.50</td>
<td>100.00</td>
<td>1.35 [0.53, 3.41]</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>173</td>
<td>304</td>
<td>100.00</td>
<td>100.00</td>
<td>2.14 [1.05, 4.36]</td>
</tr>
</tbody>
</table>

Test for heterogeneity: \( \chi^2 = 1.75, d.f. = 1 (p = 0.19), I^2 = 42.8\%

Test for overall effect: \( Z = 2.09 (p = 0.04) \)
McFalls | 36/141 | 29/252 | OR (fixed) | 69.47 | 2.64 [1.53, 4.53] |
| Poldermans | 19/32 | 22/52 | OR (fixed) | 30.53 | 1.99 [0.81, 4.88] |
| Total (95% CI) | 173 | 304 | OR (fixed) | 100.00 | 2.44 [1.54, 3.82] |

Test for heterogeneity: $\chi^2 = 0.28$, d.f. = 1 (p = 0.60), $I^2 = 0$
Test for overall effect: $Z = 3.77$ (p = 0.0002)

Figure 3 Comparison of 30-day all-cause mortality following pre-operative coronary revascularisation using CABG.

McFalls | 68/141 | 95/252 | OR (fixed) | 79.94 | 1.54 [1.01, 2.34] |
| Poldermans | 20/32 | 31/52 | OR (fixed) | 20.06 | 1.13 [0.46, 2.79] |
| Total (95% CI) | 173 | 304 | OR (fixed) | 100.00 | 1.46 [1.00, 2.13] |

Test for heterogeneity: $\chi^2 = 0.37$, d.f. = 1 (p = 0.54), $I^2 = 0$
Test for overall effect: $Z = 1.95$ (p = 0.05)

Figure 4 Comparison of late composite outcome of all-cause mortality and nonfatal myocardial infarction following pre-operative coronary revascularisation using PCI.

McFalls | 4/99 | 9/252 | OR (fixed) | 68.30 | 1.14 [0.34, 3.78] |
| Poldermans | 4/17 | 6/52 | OR (fixed) | 31.70 | 2.36 [0.58, 9.63] |
| Total (95% CI) | 116 | 304 | OR (fixed) | 100.00 | 1.52 [0.62, 3.76] |

Test for heterogeneity: $\chi^2 = 0.60$, d.f. = 1 (p = 0.44), $I^2 = 0$
Test for overall effect: $Z = 1.18$ (p = 0.24)

Figure 5 Comparison of 30-day all-cause mortality following pre-operative coronary revascularisation using PCI.

McFalls | 13/99 | 20/252 | OR (fixed) | 63.78 | 1.75 [0.84, 3.68] |
| Poldermans | 5/17 | 6/52 | OR (fixed) | 36.22 | 0.94 [0.28, 3.11] |
| Total (95% CI) | 116 | 304 | OR (fixed) | 100.00 | 1.46 [0.78, 2.73] |

Test for heterogeneity: $\chi^2 = 0.76$, d.f. = 1 (p = 0.38), $I^2 = 0$
Test for overall effect: $Z = 3.77$ (p = 0.002)

Figure 6 Comparison of 30-day nonfatal myocardial infarction following pre-operative coronary revascularisation using PCI.
Discussion

The reported outcomes of the two landmark prospective randomized controlled studies (CARP and DECREASE-V) [9, 11] stand in contrast to the mainly retrospective observational studies by Landesburg, Hassan, Hertzer, Fleisher and Eagle; as well as older prospective studies by Hertzer and Back, which on the whole showed...
a reduction in late cardiac mortality [3–8, 14, 16, 25]. The overwhelming impression created by these two prospective randomised studies is that revascularisation in high risk patients undergoing vascular surgery is not superior to optimal medical management in reducing the incidence of post operative death or myocardial infarction. As a result of the higher level of evidence weighting assigned to prospective studies these findings have been strongly reflected in the American College of Cardiologists (ACC)/American Heart Association (AHA) recommendations for peri-operative revascularisation in patients undergoing noncardiac surgery [26]. In the light of this meta-analysis, it should be questioned whether the current recommendations accurately reflect the value of prophylactic coronary revascularisation in patients undergoing noncardiac surgery.

Percutaneous coronary intervention
A key aspect to consider is the increasingly prominent and potentially confounding role that percutaneous coronary intervention has come to play in pre-operative coronary revascularisation for noncardiac surgery. The significantly worse 30-day outcomes in comparison to optimal medical therapy (Figs 1–4) and the significantly worse late composite outcome when compared to CABG (Fig. 10) may be a result of both stent associated complications and incomplete revascularisation. As a result of the increasing utilisation of percutaneous coronary intervention in coronary revascularisation we now appreciate how the peri-operative period impacts on stent functioning, aspects of which have been specifically addressed in the ACC/AHA 2007 guidelines for peri-operative cardiovascular evaluation and care for non-cardiac surgery [26].

Newly placed stents are highly thrombogenic, placing patients at risk of acute early and late stent occlusion. The increased incidence of death and nonfatal myocardial infarctions seen in the percutaneous coronary intervention groups may be explained by the non-cardiac surgery taking place during a high risk period for early stent thrombosis (90 days for bare metal stents; 1-year drug-eluting stents) [19, 20]. In the CARP study the average time delay between percutaneous coronary intervention and vascular surgery was 42 days (IQR [22–62]) and in the DECREASE-V study, 31 days (range [19–39]).

The role of antiplatelet therapy in the peri-operative period in patients who have undergone percutaneous coronary intervention, while difficult to quantify, should also be considered. Premature discontinuation, interruption of therapy [20], the use of bridging therapy [27], recommencement dosages and variations in antiplatelet metabolism [28] have been identified as factors in sub-optimal anti-platelet therapy and subsequent stent thrombosis. In the CARP study, the 59 (45%) patients in the percutaneous coronary intervention group who underwent abdominal surgery had their antiplatelet therapy interrupted and no bridging therapy instituted [9, 21]. In the DECREASE-V study patients were continued with antiplatelet therapy in all patients who received percutaneous coronary intervention [11].

Another consideration is that besides the potentially dangerous timing of noncardiac surgery following percutaneous coronary intervention, the patients who received coronary stents may have had significantly less coronary protection at the time of vascular surgery in comparison to those patients who had CABG. In the CARP trial, although the patients who had CABG had significantly more diseased coronary vessels than those who had percutaneous coronary intervention, the latter patients had significantly less complete revascularisation [21]. Similarly, in the DECREASE-V pilot study, the only patients who had incomplete revascularisation, had undergone percutaneous coronary intervention and not CABG [11].

CABG
In contrast to percutaneous coronary intervention, CABG has been associated with improved long term survival in patients undergoing noncardiac vascular surgery. Hertzer et al. [4] showed in a prospective cohort of 1000 patients with peripheral vascular disease, that CABG was associated with superior 5-year survival compared to medical management (72% vs 21%, p = 0.0001 respectively). Since then CABG has shown improved outcomes in the majority of early observational studies [8, 16], with an improved long term survival in patients with severe CAD following aortic surgery [4, 16] and peripheral vascular surgery [4]. The trend towards a better long term composite outcome associated with CABG in this meta-analysis is consistent with these earlier observations. It is important to realise that this meta-analysis is however underpowered to adequately address this issue. Using the late composite event rate of the control group (41.1%), to show a 25% reduction in events with a power of 80% and a significance of 0.05 would require 340 subjects per arm. In addition, the duration of follow up in both the CARP and DECREASE-V trials may have been too short for the benefits of CABG to become apparent.

Pre-operative CABG for noncardiac surgery may, however, be associated with an adverse outcome at 30 days following noncardiac surgery (OR 1.58, 95% CI 0.90–2.76, p = 0.95).

The discrepancy in the early and late outcomes associated with pre-operative CABG raises a further issue that needs to be addressed. In patients who meet the inclusion criteria of the two randomised prospective studies [9, 11], should we be considering coronary
revascularisation after successful noncardiac vascular surgery in order to prolong survival? This consideration needs further investigation.

Left main stem stenosis

The findings from the CARP study regarding left main stem pathology should be highlighted. In the 4.6% of patients identified with > 50% left main stem stenosis they found that coronary revascularisation prior to noncardiac surgery significantly improved long term survival (82% vs 52%, p < 0.01) [29]. Left main stem stenosis was found in 8% of the patients randomised to coronary revascularisation in the DECREASE-V [11].

Limitations of subgroup analysis

When considering our findings it is important to keep in mind that neither of these studies was designed to study the superiority of one method of revascularisation over the other. Local investigators could independently choose percutaneous coronary intervention or CABG based on coronary anatomy, perceived benefit relating to possible delay of index surgery [11] and benefit in patients with diabetes and multivessel disease [9]. Thus it is possible that those patients with a more urgent surgical or cardiac indication, and thus possibly higher risk, were assigned to the percutaneous coronary intervention group.

The process of sub-analysis is fraught with potential statistical problems [30]. The dramatic reduction in the power of the study may have led to findings that exist solely due to random error. In addition our subgroup analysis suffers from a loss of intention-to-treat as some patients who were randomised to coronary revascularisation died before the type of coronary intervention to be performed was determined. Thus our results may inflate the potential benefit of CABG on late outcomes. However, it is important to note that the findings of this meta-analysis are consistent with existing data from both the peri-operative and medical literature regarding CABG and percutaneous coronary intervention.

Conclusion

Pre-operative percutaneous coronary intervention for noncardiac vascular surgery is associated with significantly increased early and possibly increased late adverse outcomes. This may have significantly and negatively contributed to the outcome and subsequent interpretation of pre-operative coronary revascularisation studies. Pre-operative CABG is probably associated with a worse early outcome following vascular surgery, although it is possible that long term outcomes are improved. Further research is necessary to define both the indications for and the timing of CABG to improve long term survival in vascular surgical patients.

Acknowledgements

We are grateful to Drs McFalls, Poldermans and Schouten for sharing their data with us.

References