Complete Revascularization

Coronary Artery Bypass Graft Surgery Versus Percutaneous Coronary Intervention

Andrew T.L. Ong, MBBS, FRACP; Patrick W. Serruys, MD, PhD

The concept of complete revascularization arose from the early studies on coronary artery bypass grafting (CABG) surgery whereby some publications demonstrated that patients who were completely revascularized enjoyed a mortality benefit over those who were incompletely revascularized, thus setting the standard for the field of CABG. Over the past 3 decades, CABG has evolved from saphenous vein grafting to more frequent use of arterial grafting, better perioperative management, development of a less invasive approach, and off-pump surgery as a genuine option. The development of percutaneous coronary interventions (PCIs) for the treatment of coronary stenosis has developed out of the treatment of single-vessel disease to become an alternative to CABG in the treatment of multivessel disease. PCI has progressed from balloon angioplasty to coronary stents, and now drug-eluting stents, with the simultaneous development of new devices to treat chronic total occlusions (CTOs). For both groups of patients treated by either CAGB or PCI, there is recognition that aggressive pharmacological secondary-prevention therapies such as statins and antiplatelet agents are beneficial and are now commonly used.

Despite the mantra of complete revascularization, none of the current guidelines set out by the American or European cardiology societies formally discuss the issue in detail. Although this topic has been addressed separately within each revascularization strategy, to date there has been only 1 report from a randomized trial that compared the end point of complete revascularization between CABG and PCI. This review will therefore address the issue separately for CABG and for PCI and finally provide a comparison of the 2 strategies.

Definition of Complete Revascularization

There is no universal definition for what is meant by "complete" revascularization (Table 1). Different studies employ different definitions, and for that reason, comparisons between studies must be interpreted with caution. For example, revascularization may be declared complete if all stenotic vessels are revascularized, irrespective of size (anatomic revascularization) and territory supplied; others impose minimum diameter criteria; yet others differentiate between main vessels and branch vessels. Second, a functional classification may be used, whereby revascularization is declared complete if all ischemic myocardial territories are reperfused; areas of old infarction with no viable myocardium are not required to be reperfused. Another method that may be used is to count the number of vessels with stenoses and then to count the number of distal anastomoses (an equal number would be declared a complete revascularization). Finally, a scoring system can be used whereby stenoses in different vessels assume different weightings; the overall extent of disease, and its treatment, is then a continuous variable.

Studies that have examined the extent of revascularization in CABG patients usually rely on the surgical report, because routine angiographic restudy in patients immediately after CABG is not commonly performed. PCI studies, on the other hand, have the option of utilizing either operator reports or, more objectively, independent ascertainment of the procedural angiographic results themselves to visually and accurately determine the adequacy of revascularization. Completeness of revascularization is therefore based on the immediate procedural outcome. Failure after an initial successful attempt at revascularization (eg, graft failure with CABG, restenosis with PCI) is not measured directly but is included as part of the end point of repeat revascularization.

CABG Surgery

Since the beginning of the revascularization era, no specific CABG study has been performed with the primary end point of complete revascularization as an outcome. The need to completely revascularize the coronary tree has been stated to be a tenet, even a truism. The following studies on the extent of surgical revascularization are post hoc analyses of major studies and are described in order to obtain an understanding of the literature.

First, in a seminal publication from the Coronary Artery Surgery Study (CASS) Registry, 3372 patients with 3-vessel disease (including left main disease) who underwent isolated first-time CABG between July 1974 and June 1979 were analyzed with a mean follow-up of 4.9 years. The extent of revascularization for this study was defined by the number of the 3 major vessels (or their branches) that received a bypass...
TABLE 1. Different Definitions of Complete Revascularization as Found in the Literature

<table>
<thead>
<tr>
<th>Revascularization Definition</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete anatomic revascularization</td>
<td>All stenotic vessels are revascularized, irrespective of size and territory supplied.</td>
</tr>
<tr>
<td>Unconditional</td>
<td>All stenotic vessels greater than a defined diameter are revascularized, OR</td>
</tr>
<tr>
<td>Conditional</td>
<td>All stenotic main-branch vessels are revascularized.</td>
</tr>
<tr>
<td>Complete functional revascularization</td>
<td>All ischemic myocardial territories are reperfused; areas of old infarction with no viable myocardium are not required to be reperfused.</td>
</tr>
<tr>
<td>Complete numeric revascularization</td>
<td>The number of stenotic vessels must equal the number of distal anastomoses applied.</td>
</tr>
<tr>
<td>Complete revascularization by a predetermined scoring cutoff value</td>
<td>Scoring of stenoses in different vessels at different locations (weightings may be used). The overall extent of disease is a continuous variable, the treatment is another variable, and the posttreatment score determines completeness of revascularization.</td>
</tr>
<tr>
<td>Anatomic</td>
<td>Irrespective of viable myocardium</td>
</tr>
<tr>
<td>Functional</td>
<td>Jeopardy score: The postrevascularization score is calculated on the basis of the amount of remaining myocardium at risk.</td>
</tr>
</tbody>
</table>

An average of 3.2 distal anastomoses were performed. Grafts were placed to the left anterior descending artery in 98%. In this study, only 16% of patients received an internal mammary artery conduit, as was the usual practice then. Patients with severe angina (Canadian Cardiovascular Society class III or IV) in whom more complete revascularization was performed (defined as bypassing 3 or more vessels versus 1 or 2) enjoyed improved survival (relative risk [RR] 0.75, 95% confidence interval [CI] 0.59 to 0.94, P=0.01) and event-free survival (RR 0.87, 95% CI 0.78 to 0.96, P=0.01) independently of any baseline differences. These patients were also more likely to be asymptomatic or to have less severe angina that those with incomplete revascularization. Subset analysis revealed a significant survival benefit in patients with significant left ventricular dysfunction (ie, ejection fraction <0.35) with 3 or more vessels bypassed compared with those with 2 (P=0.04).

A criticism of the method described above was that it did not take into account the relative role of each coronary artery in supplying the left ventricle and therefore the effect of coronary stenosis in the particular vessel(s). To address this criticism, a novel functional scoring system that incorporated the amount of myocardium supplied by a particular vessel was developed by Leaman et al and published in Circulation in 1981.12 Two hundred patients were studied by coronary angiography before CABG and at 1 year after surgery and scored on the basis of their coronary anatomy. Angina class and left ventricular function were also recorded. In the group studied, the severity of coronary artery disease (as measured by this score) did not statistically correlate with the frequency of angina. Postoperatively, no relationship between the frequency of angina and the completeness of revascularization could be determined. The principles of this scoring system have been used in the development of the SYNTAX score, an anatomic scoring system created for the SYnergy between Percutaneous Coronary Intervention with TAXus and Cardiac Surgery (SYNTAX) Study that eventually may be used as a tool to predict outcomes.13,14

The Bypass Angioplasty Revascularization Investigation (BARI) study compared the outcomes of patients with multivessel coronary artery disease treated with percutaneous transluminal coronary angioplasty (PTCA) versus CABG and enrolled patients from August 1988 to 1991 in either a randomized arm or in a registry arm (due to the patient or physician preference for the type of treatment). Patients had to be suitable for both PTCA and CABG, and left main stenosis was an exclusion criteria. Approximately two thirds of patients had 3-vessel disease. In total, 1526 patients (901 in the randomized arm and 625 in the registry arm) underwent CABG, and 1507 were analyzed in a post hoc report with a mean follow-up of 7.1 years.11 In this study, the authors attempted to establish different definitions and then apply them to the available results to derive the most appropriate definition of extent of revascularization. They came up with 4 different definitions: (1) Traditional—all coronary arteries with at least 1 significant lesion received a graft. (2) Functional—all diseased “primary” coronary segments were bypassed, with a unique algorithm developed for this definition (primary segments were defined on the basis of the BARI system of dividing the coronary arteries into 29 segments; for example, the main body of the right coronary has 2 segments, and there are additional primary segments based on the anatomy of the branches, including the acute marginal, posterior descending, and up to 3 posterolateral branches). (3) Patients were grouped according to whether or not the number of distal anastomoses was less, equal to, or more than the number of diseased coronary segments. (4) Patients were grouped by whether they had 2 or more grafts to both the left anterior descending coronary artery and to a non-left anterior descending coronary artery system, or whether no system had multiple grafts. The authors found that by either the traditional or functional definition, complete revascularization conferred no independent advantage, but the risk estimates on late mortality were in the direction that favored complete revascularization.

Between 1997 and 1998, the multicenter Arterial Revascularization Therapies Study (ARTS) trial enrolled patients with multivessel disease who could be potentially completely and equivalently revascularized.4 In total, 1205 patients were randomized to either PCI with stenting or CABG. Left main coronary stenosis was excluded, and 30% of the population had 3-vessel disease. In this contemporary study, 93% of
patients received at least an arterial graft. All angiograms were reviewed centrally, and all lesions with a >50% diameter in a segment with a reference diameter of ≥1.50 mm were scored as potentially amenable to treatment. An anatomic definition was used: if all such segments were treated according to the case report form, they were classified as a complete revascularization. In a post hoc analysis from the trial, complete revascularization was not associated with a difference in mortality or in major adverse cerebral or cardiac events (MACCE) compared with patients with incomplete revascularization at 1 year (Table 2; Figure). The respective freedom from MACCE was 89.9% versus 87.8%.

More recently, a single-center retrospective analysis of 1034 patients who underwent first-time CABG with a mean follow-up of 3.3 years was performed. The authors chose a functional classification, with complete revascularization defined as the placement of at least 1 bypass graft distal to a >50% narrowing in each diseased territory. This “real-world” cohort had a mean age of 68 years and included both on- and off-pump CABG, with the choice of technique left to the individual operator’s preference. The most common reasons recorded for incomplete surgical revascularization were that the arteries were too small, that they were severely diseased, or both. In this study, compared with completely revascularized patients, incomplete revascularization was associated with a 5-year unadjusted increased overall mortality rate (47.4% versus 17.6%, respectively, P<0.001) and cardiac mortality rate (25.5% versus 6.9%, P<0.001). After adjustment for predictors of death, incomplete revascularization remained an independent risk factor for death (hazard ratio [HR] 1.85, 95% CI 1.03 to 3.34, P=0.04 for all-cause death, and HR 1.73, 95% CI 1.18 to 2.55, P=0.006 for cardiac death only).

Controversies

There have been other reports in the literature on completeness of revascularization in the CABG population, but in general incompletely revascularized patients tended to be sicker, and outcomes were usually not adjusted to reflect this bias. Second, the development of hybrid or integrated coronary revascularization in the 1990s to treat multivessel disease by combining percutaneous techniques with minimal-access coronary surgery through a minithoracotomy has been unsuccessful owing to the increased need for repeat revascularization in these patients, driven by incomplete revascularization and in-stent restenosis. Finally, off-pump CABG has been shown to be a successful alternative to conventional or on-pump CABG, with randomized trials demonstrating that, in the hands of experienced operators, off-pump CABG surgery results in a degree of revascularization that is comparable to on-pump surgery.

Percutaneous Coronary Intervention

Early in the balloon angioplasty era, according to a report of the 1985 to 1986 National Heart, Lung, and Blood Institute PTCA registry, complete revascularization was attempted and achieved in 57% and 46% of patients with 2- and 3-vessel coronary artery disease, respectively. The majority of lesions not amenable to PTCA were total occlusions, and the success rate for attempted occlusions was 54%. In the long-term (9-year) follow-up study from the same registry, the authors report that compared with patients who were completely revascularized, patients who were incompletely revascularized (whether intended, attempted, or not achieved) had no different risks of dying, myocardial infarction, or repeat revascularization by PTCA or CABG after adjustment for baseline characteristics. Incomplete revascularization, however, remained a significant risk factor for subsequent CABG by 9-year follow-up, and incompletely revascularized patients showed a strong trend toward more recurrent angina at long-term follow-up, but this risk became weaker after adjustment.

TABLE 2. Ranked MACCE at 1 Year, in Worst Order, in the ARTS Trial, Stratified According to Extent of Revascularization and Treatment Strategy

<table>
<thead>
<tr>
<th>Event</th>
<th>Complete (n=477)</th>
<th>Incomplete (n=90)</th>
<th>P Within CABG</th>
<th>Complete (n=406)</th>
<th>Incomplete (n=170)</th>
<th>P Within PCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>2.5</td>
<td>4.4</td>
<td>NS</td>
<td>1.7</td>
<td>3.5</td>
<td>NS</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
<td>1.9</td>
<td>0</td>
<td>NS</td>
<td>1.7</td>
<td>1.2</td>
<td>NS</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>3.4</td>
<td>4.4</td>
<td>NS</td>
<td>4.9</td>
<td>5.9</td>
<td>NS</td>
</tr>
<tr>
<td>(Repeat) CABG</td>
<td>0.2</td>
<td>1.1</td>
<td>NS</td>
<td>2.0</td>
<td>10.0</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>(Repeat) PCI</td>
<td>2.1</td>
<td>2.2</td>
<td>NS</td>
<td>13.1</td>
<td>10.0</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Any MACCE</td>
<td>11.1</td>
<td>12.8</td>
<td>NS</td>
<td>23.4</td>
<td>30.6</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

NS indicates not significant. Values are percentages.

Kaplan-Meier curve showing survival free of MACCE at 1 year from the ARTS trial, stratified by treatment and completeness of revascularization. Reprinted from van den Brand et al with permission from the American College of Cardiology Foundation. CVA indicates cerebrovascular accident; MI, myocardial infarction.
After this, investigators from the multivessel BARI trial, which enrolled patients from 1988 to 1991, reported 5-year outcomes of patients treated with PTCA in both the randomized and preference registry arms.24 Similar to the National Heart, Lung, and Blood Institute registry, the adjusted RRs for death, cardiac death, and death or Q-wave myocardial infarction were not different in incompletely revascularized versus completely revascularized patients. As with the previous study, an excess risk of subsequent CABG was seen in the former group.

In the more recent ARTS randomized trial, which mandated equivalence of completeness of revascularization, true anatomic completeness of revascularization, as ascertained by experienced independent observers on review of films after completion of the PCI, occurred in 70.5% of patients, a rate higher than that in previous studies.9 As with previous studies, patients who could not be completely revascularized had a significantly greater number of diseased segments and vessels. Incompletely revascularized patients also had a 3.6-fold higher incidence of total occlusions than completely revascularized patients (19.4% versus 5.4%, P<0.001). In this study, as with previous studies, stented patients who were incompletely revascularized had a higher requirement for subsequent CABG in the first year of follow-up (10% versus 2% in those who were completely revascularized, P<0.05), which resulted in a lower overall MACCE-free rate (69.4% versus 76.6%, P<0.05; Table 2; Figure).

In the most recent publication on this topic, the investigators of the Alberta Provincial Project for Outcomes Assessment in Coronary Heart Disease (APPROACH) reported on 1308 patients completely revascularized after PCI compared with 648 patients with incomplete revascularization after PCI.25 Completeness of revascularization was determined using the Duke jeopardy score, a score developed and validated to describe the extent of coronary disease based on the amount of myocardium at risk. Independent predictors of incomplete revascularization were the presence of a total occlusion, a higher pre-PCI Duke jeopardy score, age >65 years, and renal failure. The authors then used a propensity score to correct for the differing baseline characteristics between the 2 populations and concluded that, with a median follow-up of 3.0±1.8 years, complete multivessel PCI was associated with a reduced need for future PCI, a trend toward better survival, and no difference in repeat PCI.

Treatment of Culprit Lesion Versus Total Revascularization

In the only study that has randomized patients with multivessel disease to either PCI limited to the culprit vessel or PCI of all vessels with ≥50% stenosis, 219 patients were randomized and followed up for 5 years.26 Identification of the culprit vessel was determined by 2 independent interventional cardiologists on the basis of the clinical evidence available with PCI for an acute myocardial infarction, an exclusion criterion. This study demonstrated that at long-term follow-up of 4.6 years, although target-lesion revascularization rates were similar in the completely revascularized group and the culprit vessel–treated group (17.3% versus 12.0%, P=0.3), the overall need for repeat PCI was significantly lower (21.2% versus 31.2%, P=0.06) in the completely revascularized group. Overall long-term MACCE rates were similar between groups (34.6% versus 40.4% respectively, P=0.4), as were estimated costs (P=0.8). Despite a relatively low usage of stents (only 55% of the cohort was initially treated with stents), this study suggests that the treatment of other non–culprit lesions at the index procedure (ie, complete revascularization) is linked to a lower need for repeat PCI at long-term follow-up.

The significant difference between this and the other previously described trials was that patients in this trial were actively randomized to treatment groups, and patients here were intentionally left untreated, if randomized to the culprit-vessel treatment arm alone. This is in contrast to the previous trials, in which patients were incompletely revascularized owing to a “failure” of initial revascularization (intended or otherwise) and thus were highly selected and underwent CABG as the second option for revascularization, which was classified as a subsequent CABG. Thus, from a societal perspective, although estimated costs were similar for the two procedures, complete revascularization resulted in less need for a repeat intervention later.

New Developments With PCI: Overcoming CTOs

With the percutaneous approach, the presence of CTOs remains the biggest and most important obstacle and technical challenge to achieving complete revascularization. CTOs occur relatively frequently, appearing in up to 20% of patients undergoing diagnostic coronary angiography. Furthermore, CTOs make up 10% of PCIs in the contemporary practice of a tertiary referral catheterization laboratory.27 Historically, the success rate of crossing CTOs percutaneously approximates 60% with conventional techniques. This success rate is dependent on operator experience, the number of attempts performed, anatomic considerations, and the choice of devices available.

To overcome this major limitation, new devices and adjunctive methods have been developed to improve the success rate. Multislice computed tomography coronary angiography has provided additional information such as occlusion length and degree of calcification, features that predict procedural success and that are often underestimated by conventional coronary angiography.28 In the only randomized trial of a device, the TOTAL trial (Total Occlusion Trial with Angioplasty by using Laser guidewire), laser-tipped guidewires were no better than conventional wires.29 Local delivery of thrombolytic therapy to the site of occlusion via a specialized catheter to facilitate wire crossing was recently reported, with promising results.30 Japanese device makers have led the development of specialized guidewires to allow the development of a systematic approach. New devices in development include a blunt dissection catheter,31 a helical screwlike-tipped microcatheter,32 and a specific system that uses optical coherence reflectometry together with radiofrequency ablation. Optical coherence reflectometry is used to direct the tip of a guidewire in a coaxial plane within the lumen, and radiofrequency ablation delivered at the tip is used to enhance forward wire passage. Two separate registries of this latter device have reported successful recanaliza-
...stenting Versus Coronary Bypass Surgery in ERACI-2 (Argentine Randomized Study: Coronary Angioplasty Compared with bare-metal stents (Table 3).27,36–38 Sustained reduction in restenosis rates, need for reintervention all with angiographic follow-up, convincingly demonstrate a...patients with CTOs by reducing restenosis compared with bare-metal stenting. Although no randomized study on CTOs...in drug-eluting stents has been shown to improve the midterm outcomes of patients for whom conventional wire techniques had failed previously.33,34 Finally, a technique used in peripheral angioplasty has been newly introduced in which a subintimal dissection plane or false lumen is deliberately created parallel to the true lumen that contains the CTO.35 Under the direct vision of an intravascular ultrasound catheter placed in the false lumen, a guidewire is advanced from the false lumen into the true lumen distal to the occlusion site, bypassing the occlusion, and the newly created track is then stented with drug-eluting stents.

**Drug-Eluting Stents**

After successful recanalization, the placement of drug-eluting stents has been shown to improve the midterm outcomes of patients with CTOs by reducing restenosis compared with bare-metal stenting. Although no randomized study on CTOs in drug-eluting stents has been published to date, 3 registries, all with angiographic follow-up, convincingly demonstrate a sustained reduction in restenosis rates, need for reintervention, and occurrence of MACCE with drug-eluting stents compared with bare-metal stents (Table 3).

**CABG Surgery Versus PCI**

In the stent era, the 3 largest randomized trials comparing CABG surgery to PCI for multivessel disease were performed in the late 1990s.4,39,40 The largest trial, the ARTS trial, mandated that equivalent revascularization was mandatory.4 On the other hand, the Stent or Surgery trial encouraged but did not mandate equivalent revascularization,39 whereas ERACI-2 (Argentine Randomized Study: Coronary Angioplasty With Stenting Versus Coronary Bypass Surgery in Patients With Multiple-Vessel Disease) mandated complete functional revascularization.40 Of the 3 trials, only the ARTS trial has published the 1-year outcomes of patients who were completely or incompletely revascularized.9 In that study, despite the potential for equivalent revascularization, complete revascularization was more frequently achieved in CABG-treated patients (84.1%) than in stented patients (70.5%, P<0.001; Table 2). Although no differences in mortality or the combined end point of death/stroke/myocardial infarction were seen in the comparison of the 4 groups, overall MACCE rates were significantly higher in the incompletely revascularized stented group, driven by an increased need for CABG within the first year of follow-up (Figure).

**Advantages and Disadvantages of Each Approach**

The advantages of PCI are obvious. It is performed under local anesthetic, postprocedural morbidity is minimal, and patients endure a short hospital stay. With the use of drug-eluting stents, long, diffuse stenoses can be treated effectively. Despite all the technology that has been described, however, it remains restricted by the inability to overcome total occlusions, and success rates vary, as described above. Symptomatic failures will eventually require CABG. CABG surgery has the clear advantage of overcoming chronic occlusions, and necessitating fewer repeated revascularizations, but it is associated with a not-insubstantial postoperative morbidity, longer period of hospitalization, and a slower return to normal activities. Multiple long and diseased coronary segments may be a challenge, with multiple grafts required in small vessels, and longer surgical procedures are associated with higher morbidity.

**TABLE 3. Summary of Studies Comparing Drug-Eluting Stents With Bare-Metal Stents for Treatment of CTOs**

<table>
<thead>
<tr>
<th>Composition of Groups</th>
<th>Consecutive Cohort</th>
<th>Historical Control</th>
<th>Consecutive Cohort</th>
<th>Matched Control</th>
<th>Consecutive Cohort</th>
<th>Historical Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stent type</td>
<td>SES</td>
<td>BMS</td>
<td>SES</td>
<td>BMS</td>
<td>SES</td>
<td>BMS</td>
</tr>
<tr>
<td>Patients, n</td>
<td>56</td>
<td>28</td>
<td>48</td>
<td>48</td>
<td>122</td>
<td>259</td>
</tr>
<tr>
<td>Diabetes, %</td>
<td>14</td>
<td>7</td>
<td>33</td>
<td>29</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>Prior MI</td>
<td>55</td>
<td>46</td>
<td>42</td>
<td>47</td>
<td>55</td>
<td>63</td>
</tr>
<tr>
<td>Minimum duration of CTO</td>
<td>1 mo</td>
<td>1 mo</td>
<td>2 wk</td>
<td>2 wk</td>
<td>3 mo</td>
<td>3 mo</td>
</tr>
<tr>
<td>Occlusion &gt;3 mo, %</td>
<td>NA</td>
<td>NA</td>
<td>73</td>
<td>65</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>CTO length, mm</td>
<td>11.3</td>
<td>12.7</td>
<td>18±13</td>
<td>16±12</td>
<td>10.4±10.2</td>
<td>9.6±6.9</td>
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<tr>
<td>Reference diameter, mm</td>
<td>2.35±0.46</td>
<td>2.37±0.50</td>
<td>2.65±0.65</td>
<td>2.57±0.47</td>
<td>3.05±0.44</td>
<td>3.05±0.55</td>
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<tr>
<td>Postprocedure MLD, mm</td>
<td>2.06±0.48</td>
<td>2.18±0.49</td>
<td>2.26±0.36</td>
<td>2.16±0.60</td>
<td>2.67±0.49</td>
<td>2.69±0.53</td>
</tr>
<tr>
<td>Late loss, mm</td>
<td>0.13±0.46</td>
<td>…</td>
<td>0.19±0.62</td>
<td>1.21±0.70</td>
<td>0.28±0.56</td>
<td>1.04±0.87</td>
</tr>
<tr>
<td>Binary restenosis rate, %</td>
<td>9.1</td>
<td>…</td>
<td>8.3</td>
<td>51.1</td>
<td>9.2</td>
<td>33.3</td>
</tr>
<tr>
<td>Reocclusion, %</td>
<td>1.8</td>
<td>…</td>
<td>2.1</td>
<td>23.4</td>
<td>2.5</td>
<td>6.6</td>
</tr>
<tr>
<td>Stent thrombosis within 1 mo, %</td>
<td>1.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>TLR, %</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>7.4</td>
<td>26.3</td>
</tr>
<tr>
<td>MACCE, %</td>
<td>3.6*</td>
<td>17.9*</td>
<td>12.4*</td>
<td>47.9*</td>
<td>16.4†</td>
<td>35.1†</td>
</tr>
</tbody>
</table>

SES indicates sirolimus-eluting stent; BMS, bare-metal stent; PES, paclitaxel-eluting stent; MI, myocardial infarction; TLR, target-lesion revascularization; and NA, not applicable. Consecutive cohort columns denote the DES groups.

*Clinical follow-up at 12 months.
†Clinical follow-up at 6 months.
Future Developments
With the increased use of arterial grafts and perioperative aspirin in CABG, increased experience with drug-eluting stents and other new devices in interventional cardiology, and widespread adoption of better secondary-prevention measures such as use of statins, the results that have been described previously are important but may not be as pertinent today. The ongoing SYNTAX trial will provide new insights into contemporary practice. As with the ARTS trial, patients must have the potential for complete and equivalent revascularization before they may be considered for enrollment. This study will involve 1500 patients with 3-vessel or left main disease randomized to either CABG or PCI with paclitaxel-eluting stents, with the aim of determining the best method of revascularization.1,13 Surrounding the randomized arm will be 2 preference registry arms: one for CABG and the other for PCI. As an all-comers trial, consecutive patients will be enrolled, and these registries will monitor patients who cannot be treated by either CABG or PCI owing to technical reasons, physician or patient preferences, or comorbidities. In this trial, CTOs are not an exclusion criterion, and the outcomes of their treatment will be specifically monitored throughout the conduct of the trial. Hence, it is expected that with the new devices not previously available at the time of the previous trials (some of which are described in the present report), a substantial proportion of patients enrolled will have CTOs and will be treated by CABG and PCI. Post hoc analyses of this study, examining the completeness of revascularization and success of CTO recanalization, within and between groups, will provide some useful answers to the current practice of revascularization for multivessel disease.

Conclusions
Completeness of revascularization is not a competition between 2 treatment strategies. Rather, it is an important factor in the decision-making process that requires careful thought before a patient is recommended for either treatment option. The goal should always be complete revascularization, because the overall trend supports it, whether the treatment choice is surgery or percutaneous intervention. From a practical treatment point of view, if a patient undergoing PCI for multivessel disease has a CTO, it would be reasonable to first attempt to cross the occlusion before attempting any other lesion. In that way, if the lesion cannot be crossed percutaneously, the patient would then automatically become a surgical candidate, so as to offer optimal revascularization. Additionally, the ARTS trial demonstrated that, in a study in which equivalent revascularization was believed to be achievable in a joint meeting between cardiologists and surgeons before randomization, it was actually achieved more often in the CABG group than in the PCI group. Despite the discrepancy, irrespective of treatment strategy or completeness of revascularization, there was no mortality difference 1 year after the procedure. Finally, with the multitude of new devices and techniques to overcome CTOs, the SYNTAX trial will provide new contemporary data on completeness of revascularization and outcomes in patients randomized to CABG or PCI in complex coronary disease.

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Disclosures
None.

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Andrew T.L. Ong and Patrick W. Serruys

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