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# Comparison of Stenting Versus Bypass Surgery According to the Completeness of Revascularization in Severe Coronary Artery Disease

## Patient-Level Pooled Analysis of the SYNTAX, PRECOMBAT, and BEST Trials

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## ABSTRACT

**OBJECTIVES** The aim of this study was to compare long-term survival between patients with severe coronary artery disease undergoing coronary artery bypass grafting (CABG) and those undergoing percutaneous coronary intervention (PCI) achieving complete revascularization (CR) or incomplete revascularization.

**BACKGROUND** The importance of CR in decision making regarding revascularization strategy in patients with severe coronary artery disease is unknown.

**METHODS** Data were pooled from the SYNTAX (Synergy Between PCI With Taxus and Cardiac Surgery), PRECOMBAT (Premier of Randomized Comparison of Bypass Surgery Versus Angioplasty Using Sirolimus-Eluting Stent in Patients With Left Main Coronary Artery Disease), and BEST (Randomized Comparison of Coronary Artery Bypass Surgery and Everolimus-Eluting Stent Implantation in the Treatment of Patients With Multivessel Coronary Artery Disease) trials. The primary outcome was death from any cause and was compared in an as-treated analysis.

**RESULTS** The rate of CR was 61.7% (57.2% with PCI and 66.8% with CABG). During a median 4.9-year follow-up period (interquartile range: 4.5 to 5.0 years), compared with patients undergoing CABG with CR, those undergoing PCI with incomplete revascularization had a higher risk for death from any cause (adjusted hazard ratio [aHR]: 1.43; 95% confidence interval [CI]: 1.03 to 2.00; $p = 0.036$) and the composite of death, myocardial infarction, and stroke (aHR: 1.48; 95% CI: 1.14 to 1.92; $p = 0.003$). However, there was no significant difference between patients undergoing CABG with CR and those undergoing PCI with CR regarding the risk for death from any cause (aHR: 1.16; 95% CI: 0.83 to 1.63; $p = 0.39$) and the composite of death, myocardial infarction, and stroke (aHR: 1.14; 95% CI: 0.87 to 1.48; $p = 0.35$). Subgroup analysis of multivessel coronary disease, high SYNTAX score (>32), and diabetes showed consistent findings.

**CONCLUSIONS** For the treatment of left main or multivessel coronary artery disease, PCI resulting in CR was associated with a similar long-term survival rate to CABG resulting in CR. Therefore, the ability to achieve CR should enter into the decision algorithm for choice of revascularization strategy. (J Am Coll Cardiol Intv 2017;10:1415–24)


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**ABBREVIATIONS AND ACRONYMS**

**CABG** = coronary artery bypass grafting

**CR** = complete revascularization

**IR** = incomplete revascularization

**MI** = myocardial infarction

**PCI** = percutaneous coronary intervention

Coronary artery bypass grafting (CABG) offers a better survival rate compared with percutaneous coronary intervention (PCI) in patients with severe coronary artery disease (1), multivessel disease (2,3), and diabetes (4). Therefore, CABG has been considered the standard revascularization strategy in the treatment of severe coronary artery disease (5,6). However, previous studies were limited by the high prevalence of incomplete revascularization (IR). Although randomized trials intended to enroll patients with anatomy amenable to both CABG and PCI by protocol, a significant proportion of patients did not achieve complete revascularization (CR), particularly in patients undergoing PCI. IR has been known to have a negative impact on outcomes (7–9). In addition, a recent study demonstrated that inferior outcomes of PCI compared with CABG were observed only in patients with IR, whereas patients achieving CR showed similar outcomes between PCI and CABG, suggesting the importance of the completeness of revascularization in decision making regarding revascularization strategy in patients with multivessel coronary artery diseases (10).

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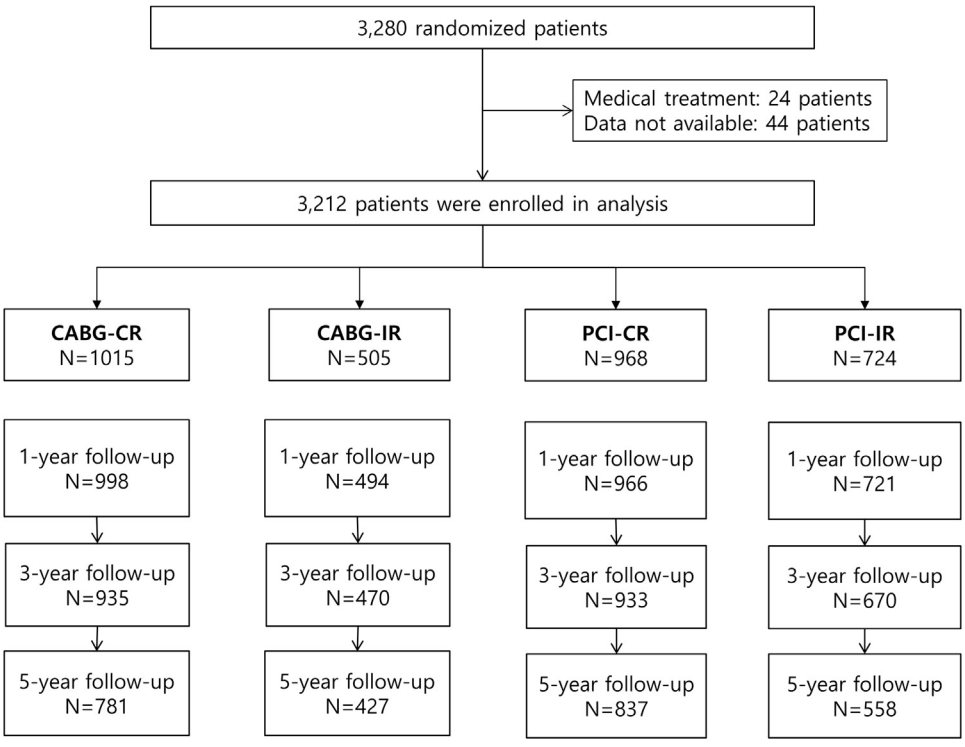
In the present study, we hypothesized that when severe coronary artery disease was completely revascularized by either revascularization strategy, PCI and CABG would show similar long-term survival. Based on a patient-level pooled database from 3 randomized trials enrolling patients with left main and multivessel disease, we compared CABG versus PCI with drug-eluting stent implantation according to the completeness of revascularization with respect to long-term survival.

## METHODS

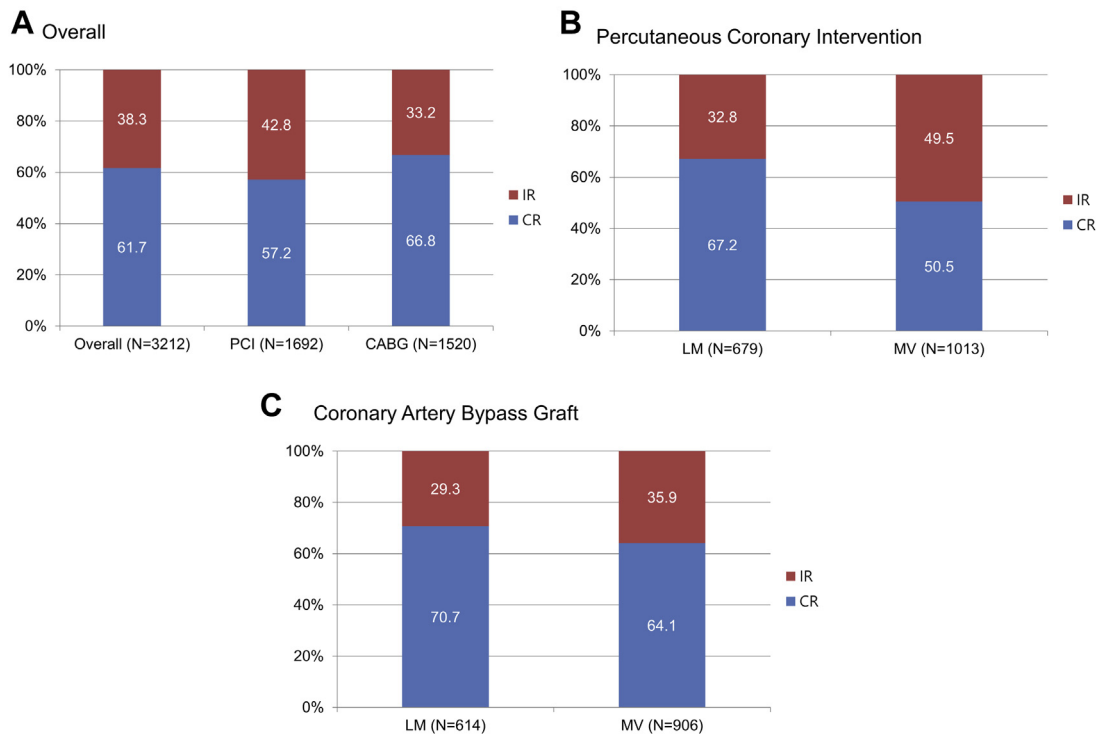
**STUDY PATIENTS.** The study designs, detailed entry criteria, and outcomes of individual trials have been described previously (11–13). In brief, these trials were multicenter and multinational; SYNTAX (Synergy Between PCI With Taxus and Cardiac Surgery)

**FIGURE 1 Study Flow**




CABG = coronary artery bypass grafting; CR = complete revascularization; IR = incomplete revascularization; PCI = percutaneous coronary intervention.

**FIGURE 2** **Proportion of Completeness of Revascularization**




CABG = coronary artery bypass grafting; CR = complete revascularization; IR = incomplete revascularization; LM = left main coronary artery disease; MV = multivessel disease; PCI = percutaneous coronary intervention.

recruited patients from Europe and the United States, PRECOMBAT (Premier of Randomized Comparison of Bypass Surgery Versus Angioplasty Using Sirolimus-Eluting Stent in Patients With Left Main Coronary Artery Disease) recruited patients from South Korea, and BEST (Randomized Comparison of Coronary Artery Bypass Surgery and Everolimus-Eluting Stent Implantation in the Treatment of Patients With Multivessel Coronary Artery Disease) recruited patients from Asia. The SYNTAX trial included 1,800 patients with 3-vessel or left main coronary artery disease. The PRECOMBAT trial included 600 patients with left main coronary artery disease. The BEST trial included 880 patients with 2- or 3-vessel CAD. Patients eligible for both CABG and PCI were randomized to treatment with either strategy. PCI was performed using paclitaxel-eluting stents in the SYNTAX trial, sirolimus-eluting stents in the PRECOMBAT trial, and everolimus-eluting stents in the BEST trial.

**COMPLETENESS OF REVASCULARIZATION.** Completeness of revascularization was prospectively determined after the revascularization procedure by the operator (14). CR is defined as the treatment of any lesions with more than 50% diameter stenosis in vessels ≥1.5 mm in the SYNTAX trial (11), ≥2.0 mm in the BEST trial (13), and ≥2.5 mm in the PRECOMBAT trial (12), as estimated on the diagnostic angiogram.

**DATA COLLECTION.** The principal investigators in each trial (S.-J.P., P.W.S.) programmed a protocol with the pre-specified outcomes and a common set of baseline variables. Individual patient data from each trial were sent to the coordinating board of Asan Medical Center in Seoul, Korea, and merged for analysis. The pooled database was checked for completeness and consistency by investigators at the Asan Medical Center. A committee blinded to randomization adjudicated all clinical endpoints of each study. Unless specified, previously reported definitions from each study were used for variables. In addition, the definition of the CR was followed by the definition of the individual studies as described previously.

**STUDY OUTCOMES.** The primary outcome was death from any cause. The secondary outcomes were a

**TABLE 1 Baseline Characteristics**

| | CABG CR (n = 1,015) | CABG IR (n = 505) | PCI CR (n = 968) | PCI IR (n = 724) | p Value |
|---|---|---|---|---|---|
| Age (yrs) | 64.0 ± 9.7 | 65.0 ± 9.7 | 63.9 ± 9.70 | 65.1 ± 9.70 | 0.023 |
| Male | 793 (78.1%) | 389 (77.0%) | 714 (73.8%) | 541 (74.7%) | 0.11 |
| Body mass index (kg/m$^2$) | 26.5 ± 4.2 | 26.7 ± 3.9 | 26.5 ± 4.4 | 26.5 ± 4.4 | 0.81 |
| Current smoker | 781 (77.2%) | 395 (78.5%) | 210 (21.7%) | 146 (20.2%) | 0.62 |
| Diabetes | | | | | |
| Any | 306 (30.1%) | 172 (34.1%) | 298 (30.8%) | 259 (35.8%) | 0.049 |
| Requiring insulin | 66 (6.5%) | 47 (9.3%) | 53 (5.5%) | 67 (9.3%) | 0.005 |
| Hypercholesterolemia | 642 (63.5%) | 333 (66.6%) | 589 (60.9%) | 493 (68.6%) | 0.007 |
| Hypertension | 623 (61.4%) | 324 (64.2%) | 620 (64.0%) | 489 (67.5%) | 0.073 |
| Clinical presentation | | | | | 0.27 |
| Stable angina | 671 (66.1%) | 311 (61.6%) | 628 (64.9%) | 482 (66.6%) | |
| Acute coronary syndrome | 344 (33.9%) | 194 (38.4%) | 340 (35.1%) | 242 (33.4%) | |
| Previous myocardial infarction | 196 (19.5%) | 131 (26.0%) | 178 (18.6%) | 149 (20.6%) | 0.006 |
| Peripheral vascular disease | 64 (6.3%) | 45 (8.9%) | 58 (6.0%) | 54 (7.5%) | 0.15 |
| CKD (eGFR <60 ml/min) | 13 (1.3%) | 9 (1.8%) | 11 (1.1%) | 8 (1.1%) | 0.72 |
| Left ventricular ejection fraction (%) | 59.6 ± 11.1 | 58.7 ± 10.7 | 59.5 ± 12.5 | 58.5 ± 11.3 | 0.25 |
| Diseased vessels | | | | | <0.001 |
| 2-vessel | 69 (6.8%) | 19 (3.8%) | 105 (10.8%) | 32 (4.4%) | |
| 3-vessel | 512 (50.4%) | 306 (60.6%) | 407 (42.0%) | 469 (64.8%) | |
| Left main | | | | | |
| Isolated | 65 (6.4%) | 3 (0.6%) | 80 (8.3%) | 0 | |
| Plus 1-vessel | 102 (10.0%) | 11 (2.2%) | 113 (11.7%) | 13 (1.8%) | |
| Plus 2-vessel | 144 (14.%) | 46 (9.1%) | 151 (15.6%) | 67 (9.3%) | |
| Plus 3-vessel | 123 (12.1%) | 120 (23.8%) | 112 (11.6%) | 143 (19.8%) | |
| EuroSCORE | 3.3 ± 2.3 | 3.6 ± 2.7 | 3.3 ± 2.4 | 3.4 ± 2.4 | 0.012 |
| SYNTAX score | | | | | |
| Mean | 26.6 ± 10.4 | 29.8 ± 10.7 | 24.5 ± 9.8 | 28.9 ± 10.5 | <0.001 |
| Tertiles | | | | | <0.001 |
| High (≥33) | 265 (26.7%) | 178 (36.0%) | 181 (18.9%) | 232 (32.3%) | |
| Intermediate (23–32) | 348 (35.1%) | 193 (39.1%) | 336 (35.0%) | 270 (37.6%) | |
| Low (≤22) | 379 (38.2%) | 123 (24.9%) | 443 (46.1%) | 217 (30.2%) | |

Values are mean ± SD or n (%).

CABG = coronary artery bypass surgery; CKD = chronic kidney disease; CR = complete revascularization; eGFR = estimated glomerular filtration rate; EuroSCORE = European System for Cardiac Operative Risk Evaluation; IR = incomplete revascularization; PCI = percutaneous coronary intervention; SYNTAX = Synergy Between PCI With Taxus and Cardiac Surgery.

composite of death, myocardial infarction (MI), or stroke; cardiac death; MI; stroke; and any repeat revascularization. Previously reported definitions from each study were used for individual clinical outcomes (11–13).

**STATISTICAL ANALYSIS.** All analyses were performed according to the as-treated principle. Data are summarized for the patient groups as n (%) for categorical variables and as mean ± SD for continuous variables. Differences in the parameters between the groups were compared using the Student *t* test or analysis of variance for continuous variables, and the chi-square test for categorical variables.

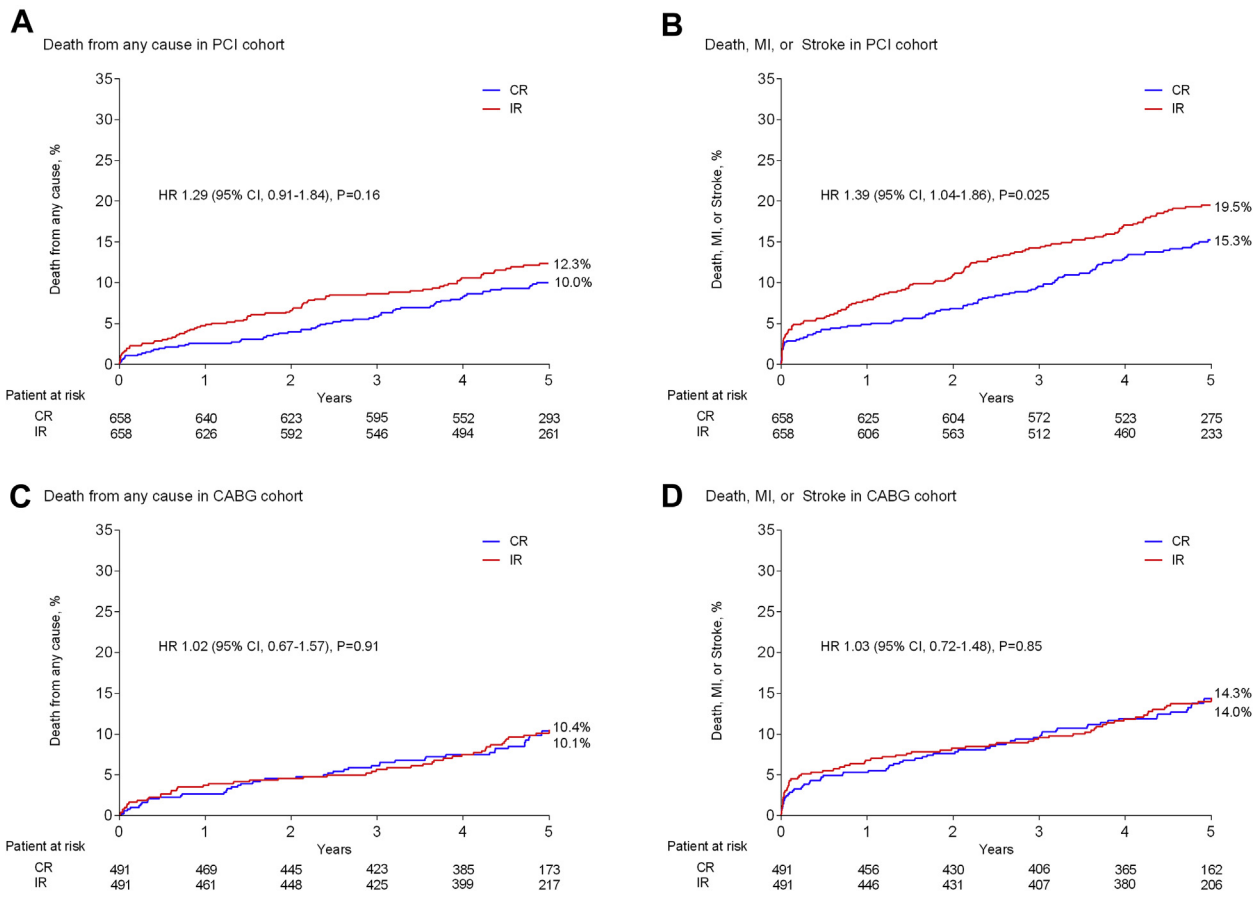
Time-to-event outcomes were displayed using Kaplan-Meier methodology, compared using the log-rank test in the overall cohort. To adjust for any potential confounders, propensity score matching analysis was performed using the logistic regression model. We tested all available variables that could be of potential relevance. Matching was performed with a 1:1 matching protocol using the nearest neighbor matching algorithm, with a caliper width equal to 0.2 of the SD of the propensity score. Stratified Cox proportional hazard models were used to assess the hazard ratio of the IR group compared with the CR group among the matched PCI and CABG populations. In addition, multivariate Cox proportional hazards models were used to compare the outcomes of the CABG CR group with the CABG IR, PCI CR, and PCI IR groups. The proportional hazards assumption regarding treatment assignment was confirmed using the Schoenfeld residuals test; no relevant violations of the assumption were found. Analyses were carried out by an independent statistician who was unaware

**TABLE 2 Procedural Characteristics**

| | Overall | | | Left Main | | | Multivessel | | |
|---|---|---|---|---|---|---|---|---|---|
| | CR | IR | p Value | CR | IR | p Value | CR | IR | p Value |
| PCI | | | | | | | | | |
| SYNTAX score | 24.5 ± 9.8 | 28.9 ± 10.5 | <0.001 | 24.6 ± 11.2 | 31.7 ± 12.8 | <0.001 | 24.5 ± 8.5 | 27.6 ± 9.1 | <0.001 |
| Stent number | 4.0 ± 2.2 | 3.7 ± 1.9 | 0.015 | 3.0 ± 2.0 | 3.4 ± 1.9 | 0.024 | 4.8 ± 2.0 | 3.9 ± 1.9 | <0.001 |
| Stent length (mm) | 84.0 ± 48.6 | 77.4 ± 38.8 | 0.002 | 63.0 ± 43.7 | 67.3 ± 39.0 | 0.21 | 102.7 ± 44.9 | 81.9 ± 37.9 | <0.001 |
| CABG | | | | | | | | | |
| SYNTAX score | 26.6 ± 10.4 | 29.8 ± 10.7 | <0.001 | 27.1 ± 12.1 | 32.1 ± 11.2 | <0.001 | 26.3 ± 9.0 | 28.6 ± 10.2 | 0.001 |
| Off-pump surgery | 36.2% | 34.0% | 0.43 | 34.5% | 42.1% | 0.08 | 37.5% | 29.5% | 0.016 |
| Total graft number | 2.9 ± 0.8 | 2.6 ± 0.7 | <0.001 | 2.7 ± 0.8 | 2.6 ± 0.8 | 0.09 | 3.1 ± 0.8 | 2.6 ± 0.6 | <0.001 |
| Arterial graft | 1.7 ± 0.9 | 1.6 ± 0.7 | 0.01 | 1.6 ± 0.8 | 1.7 ± 0.8 | 0.32 | 1.8 ± 0.9 | 1.5 ± 0.7 | <0.001 |
| Vein graft | 1.2 ± 0.9 | 1.0 ± 0.9 | <0.001 | 1.1 ± 0.9 | 0.9 ± 0.9 | 0.018 | 1.4 ± 0.9 | 1.1 ± 0.8 | <0.001 |
| Use of IMA graft | 98.8% | 98.2% | 0.36 | 97.9% | 95.0% | 0.07 | 99.5% | 100% | 0.56 |

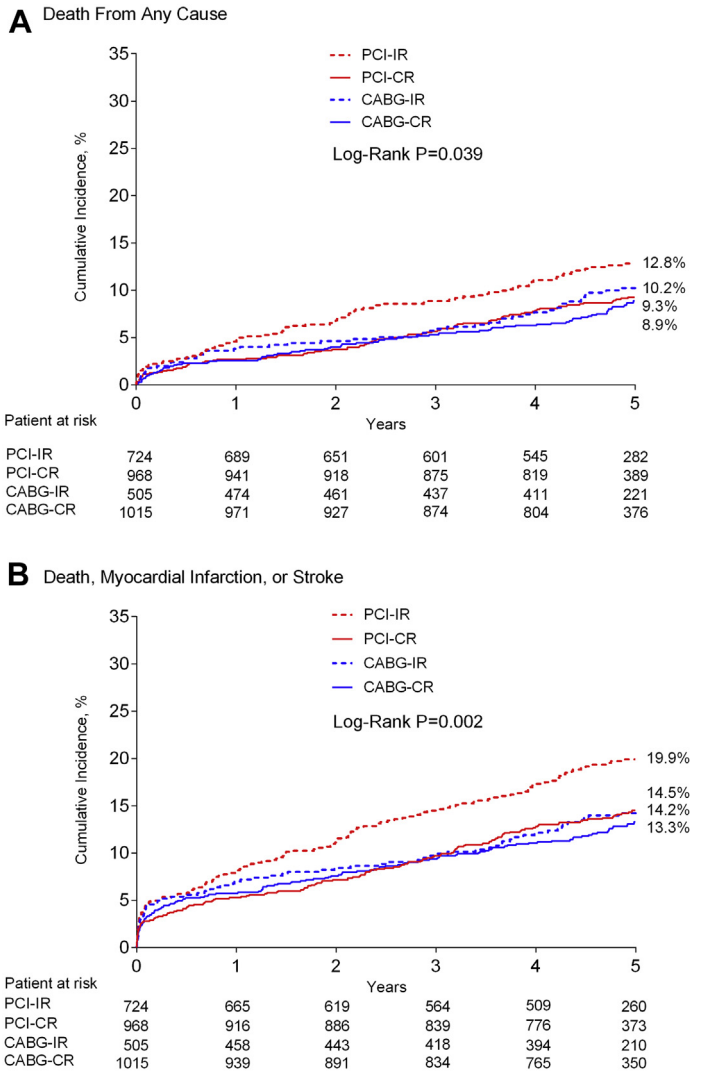
Values are mean ± SD or %.
IMA = internal mammary artery; other abbreviations as in Table 1.

**FIGURE 3 Long-Term Clinical Outcomes Between Complete and Incomplete Revascularization in Patients Undergoing Percutaneous Coronary Intervention and Coronary Artery Bypass Grafting in Propensity Score–Matched Cohort**




CABG = coronary artery bypass grafting; CI = confidence interval; CR = complete revascularization; HR = hazard ratio; IR = incomplete revascularization; MI = myocardial infarction; PCI = percutaneous coronary intervention.

**FIGURE 4 Kaplan-Meier Curve for Death From Any Cause and the Composite of Death From Any Cause, Myocardial Infarction, or Stroke**




CABG = coronary artery bypass grafting; CR = complete revascularization; IR = incomplete revascularization; PCI = percutaneous coronary intervention.

of treatment assignment. All data analysis was performed using SPSS version 2.10 (SPSS, Chicago, Illinois). All reported p values are 2-sided, and p values <0.05 were considered to indicate statistical significance.

## RESULTS

**BASELINE CHARACTERISTICS.** A total of 3,280 patients were enrolled in 3 randomized trials. Excluding patients with medical treatment only (n = 24) or with missing data on the completeness of revascularization (n = 44), 3,212 patients were analyzed: 1,520 patients undergoing CABG and 1,692 patients undergoing PCI (Figure 1). Overall, 61.7% achieved CR, and patients undergoing CABG more frequently achieved CR than those undergoing PCI. In addition, patients with left main coronary artery disease had a higher prevalence of CR than those with multivessel coronary disease (Figure 2). Compared with patients with PCI with CR, patients with PCI with IR were older, more often had insulin-treated diabetes and hypercholesterolemia, less often had left main coronary artery disease, and had lower SYNTAX scores (Table 1). In the PCI group, CR patients required more stents and longer stents. In the CABG group, CR patients required more grafts (Table 2).

**PRIMARY OUTCOMES.** The median length of follow-up after randomization was 4.9 years (interquartile range: 4.5 to 5.0 years), and 81.5% of patients completed 5-year follow-up for clinical outcomes. At long-term follow-up, death from any cause had occurred in 306 patients (9.5%), and cardiac death had occurred in 182 patients (5.7%).

In the crude cohort, although CR was associated with lower mortality and a lower rate of death, MI, or stroke compared with IR in the PCI group, there was no statistical difference between CR and IR in the CABG group (Online Figure 1). In the propensity score-matched cohort, CR was associated with a lower risk for death, MI, or stroke compared with IR in the PCI group, and there was no statistical difference between CR and IR in the CABG group (Figure 3, Online Tables 1 and 2).

In addition, compared with patients undergoing CABG who achieved CR, those undergoing PCI who achieved IR had a higher risk for death from any cause and for cardiac death. However, there was no significant difference between patients undergoing CABG and PCI with CR regarding the risk for death from any cause and for cardiac death. Even after adjustment, consistent findings were observed (Figure 4, Table 3).

**SECONDARY OUTCOMES.** MI, stroke, and any repeat revascularization occurred in 158 patients (4.9%), 76 patients (2.4%), and 462 patients (14.4%), respectively. The composite of death from any cause, MI, and stroke was significantly more common in patients undergoing PCI with IR, as opposed to those undergoing PCI with CR, compared with those undergoing CABG (Figure 4). Compared with patients undergoing CABG, those undergoing PCI with both CR and IR had a higher risk for MI and any repeat revascularization. The risk for stroke was not different (Table 3).

**TABLE 3 Clinical Outcomes in Overall Cohort**

| | Crude Incidence | | | | | Adjusted Hazard Ratio* (95% Confidence Interval) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CABG CR (n = 1,015) | CABG IR (n = 505) | PCI CR (n = 968) | PCI IR (n = 724) | p Value | CABG CR (n = 1,015) | CABG IR (n = 505) | PCI CR (n = 968) | PCI IR (n = 724) | p Value |
| Death from any cause | 84 (8.3%) | 49 (9.7%) | 86 (8.9%) | 87 (12.0%) | 0.057 | 1.00 (reference) | 1.03 (0.69–1.52) | 1.16 (0.83–1.63) | 1.43 (1.03–2.00) | 0.15 |
| Cardiac death | 43 (4.2%) | 28 (5.5%) | 55 (5.7%) | 56 (7.7%) | 0.021 | 1.00 (reference) | 1.10 (0.63–1.92) | 1.51 (0.94–2.42) | 1.91 (1.21–3.04) | 0.023 |
| Myocardial infarction | 30 (3.0%) | 17 (3.4%) | 51 (5.3%) | 60 (8.3%) | <0.001 | 1.00 (reference) | 0.93 (0.49–1.79) | 1.97 (1.22–3.17) | 2.83 (1.79–4.49) | <0.001 |
| Death from any cause, myocardial infarction | 109 (10.7%) | 60 (11.9%) | 119 (12.3%) | 126 (17.4%) | <0.001 | 1.00 (reference) | 0.98 (0.69–1.39) | 1.24 (0.93–1.65) | 1.67 (1.26–2.21) | 0.001 |
| Stroke | 24 (2.4%) | 15 (3.0%) | 19 (2.0%) | 18 (2.5%) | 0.68 | 1.00 (reference) | 1.10 (0.56–2.15) | 0.69 (0.36–1.31) | 0.94 (0.51–1.74) | 0.60 |
| Death from any cause, myocardial infarction, or stroke | 128 (12.6%) | 69 (13.7%) | 135 (13.9%) | 136 (18.8%) | 0.003 | 1.00 (reference) | 0.94 (0.68–1.29) | 1.14 (0.87–1.48) | 1.48 (1.14–1.92) | 0.006 |
| Any repeat revascularization | 83 (8.2%) | 56 (11.1%) | 154 (15.9%) | 169 (23.3%) | <0.001 | 1.00 (reference) | 1.48 (1.04–2.11) | 1.76 (1.31–2.36) | 3.14 (2.37–4.16) | <0.001 |
| Death from any cause, myocardial infarction, stroke, or any repeat revascularization | 195 (19.2%) | 111 (22.0%) | 248 (25.6%) | 247 (34.1%) | <0.001 | 1.00 (reference) | 1.12 (0.87–1.44) | 1.28 (1.04–1.58) | 1.94 (1.58–2.37) | <0.001 |

Values are n (%). *Adjustment variables included age, sex, body mass index, current smoking, diabetes, hypercholesterolemia, hypertension, clinical presentation, previous myocardial infarction, previous PCI, previous stroke, chronic lung disease, peripheral vascular disease, chronic kidney disease, left main disease, European System for Cardiac Operative Risk Evaluation score, and SYNTAX (Synergy Between PCI With Taxus and Cardiac Surgery) score.

Abbreviations as in Table 1.

**SUBGROUP ANALYSIS.** Subgroup analysis showed consistent results with primary findings. Even in patients with high SYNTAX scores (>32), diabetes, and multivessel disease, those undergoing PCI who achieved CR had a similar risk for death from any cause to those undergoing CABG. However, patients undergoing PCI who achieved IR had a higher risk for long-term mortality (**Figure 5, Table 4**).

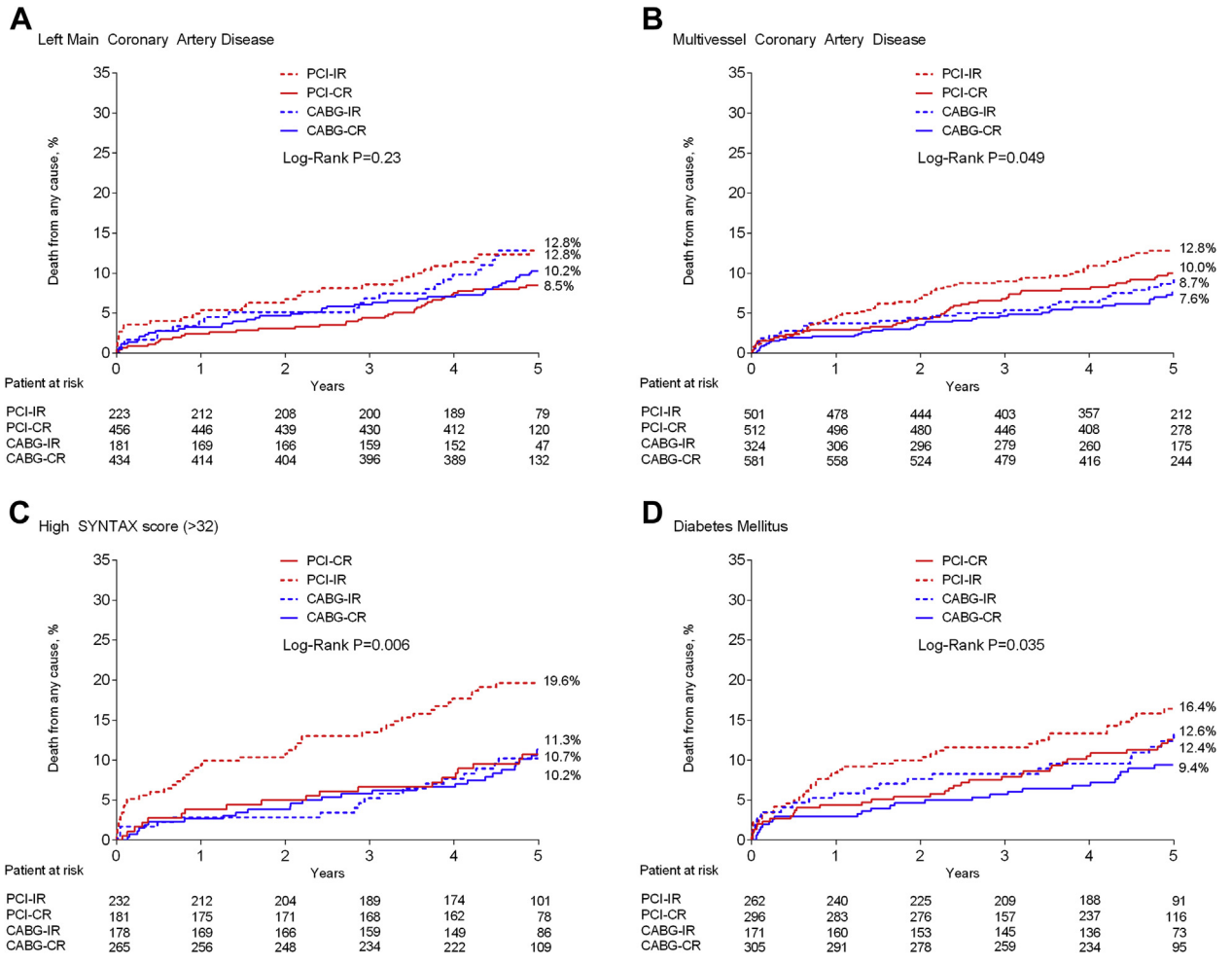
## DISCUSSION

We found that for the treatment of severe coronary artery disease (left main and multivessel disease), PCI resulting in CR was associated with a similar long-term survival rate to CABG resulting in CR, whereas PCI resulting in IR produced a lower survival rate during the 4.9-year follow-up period. These findings were consistent in subgroups with high SYNTAX scores (>32), diabetes, and multivessel disease. Therefore, the ability to achieve CR should enter into the decision algorithm for choice of revascularization strategy.

Previous studies demonstrated that CR conferred a favorable impact on prognosis among patients undergoing PCI with bare-metal stents (8) and drug-eluting stents (9), in acute coronary syndrome (15), and in acute MI (16). In addition, residual coronary stenosis after PCI was a nidus of new events in the future (17). Although another study showed the irrelevance of CR to long-term prognosis after PCI (18), a recent meta-analysis showed that PCI with CR was associated with a reduction in mortality of 27%, in MI of 31%, and in repeat revascularization of 26% compared with PCI with IR in patients with multivessel disease (19). In contrast, as shown in our study, the clinical benefit of CR was less prominent in patients undergoing CABG, as long as the left anterior descending coronary artery was successfully grafted, particularly by using the internal mammary artery (18,20,21). Nevertheless, a meta-analysis showed that CR was associated with a reduction in mortality of 24% compared with IR in patients undergoing CABG (19). Therefore, CR was considered a goal to reach in both PCI and CABG.

This study highlights the comparison of PCI with drug-eluting stents versus CABG according to the completeness of revascularization. Previously, ARTS (Arterial Revascularization Therapies Study) and MASS II (Second Medicine, Angioplasty, or Surgery Study) reported similar mortality between patients undergoing PCI with CR and CABG (22,23). However, those studies used outdated revascularization technology and pharmacological agents and enrolled patients with less complex coronary anatomy compared with contemporary standards. More recently, a New York State registry showed that PCI produced a higher risk for MI than CABG in patients with multivessel disease; this difference in risk was not significant in the subgroup of patients achieving CR (10). Consistently, the present study showed that long-term mortality was similar between patients

**FIGURE 5 Kaplan-Meier Curve of Death From Any Cause According to Subgroups**




CABG = coronary artery bypass grafting; CR = complete revascularization; IR = incomplete revascularization; PCI = percutaneous coronary intervention.

undergoing PCI with CR and CABG, whereas patients undergoing PCI with IR had a higher mortality rate.

With respect to the risk for MI and any repeat revascularization, the PCI group showed a higher risk for events than the CABG group, regardless of achieving CR or IR, which is a well-known limitation of PCI and is considered a trade-off for its lesser invasiveness, although the higher risk for MI or any

**TABLE 4 Risk for Death From Any Cause in Subgroups**

| | Crude Incidence | | | | | Adjusted Hazard Ratio (95% Confidence Interval)* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CABG CR | CABG IR | PCI CR | PCI IR | p Value | CABG CR | CABG IR | PCI CR | PCI IR | p Value |
| Left main disease | 44 (10.1%) | 22 (12.2%) | 38 (8.3%) | 28 (12.6%) | 0.28 | 1.00 (reference) | 1.06 (0.63–1.80) | 0.88 (0.56–1.39) | 1.10 (0.67–1.80) | 0.85 |
| Multivessel disease | 40 (6.9%) | 27 (8.3%) | 48 (9.4%) | 59 (11.8%) | 0.044 | 1.00 (reference) | 1.00 (0.60–1.65) | 1.28 (0.83–1.96) | 1.65 (1.10–2.48) | 0.005 |
| High SYNTAX score | 29 (10.9%) | 17 (9.6%) | 19 (10.5%) | 44 (19.0%) | 0.01 | 1.00 (reference) | 0.83 (0.45–1.53) | 0.93 (0.51–1.72) | 1.68 (1.02–2.76) | 0.032 |
| Diabetes | 28 (9.2%) | 21 (12.3%) | 35 (11.8%) | 40 (15.3%) | 0.17 | 1.00 (reference) | 1.23 (0.68–2.23) | 1.32 (0.79–2.23) | 1.70 (1.02–2.84) | 0.23 |

Values are n (%). *Adjustment variables included age, sex, body mass index, current smoking, diabetes, hypercholesterolemia, hypertension, clinical presentation, previous myocardial infarction, peripheral vascular disease, chronic kidney disease, left main disease, European System for Cardiac Operative Risk Evaluation, and SYNTAX (Synergy Between PCI With Taxus and Cardiac Surgery) score.

Abbreviations as in Table 1.

repeat revascularization did not translate into high mortality in PCI with CR.

This study suggests a number of discussion points. First, despite current clinical recommendations, not all stenoses could be revascularized by either PCI or CABG. In our study, CR was achieved in 62% of the overall population, 57% in the PCI group, and 67% in the CABG group. The rate of CR was lower than in earlier studies (22,23) but was similar to more recently reported ones from contemporary large registries (8,9,18). The ability to achieve CR was not always a matter of choice, because several anatomic situations made it difficult to achieve CR, including chronic total occlusion and multiple lesions for PCI and diffuse disease or a narrowed (≤2 mm) segment distal to the lesion (7). In addition, IR was associated with a greater burden of anatomic coronary complexity and clinical comorbidity. Therefore, the negative impact of IR could be partly understood in this context (14).

Second, this study did not justify the extensive use of stent implantation to achieve CR. The revascularization of coronary stenosis supplying small myocardial territory or coronary stenosis without functional significance (fractional flow reserve >0.80) may not be associated with improvement of outcomes but with stent-related complications (24,25). PCI might be considered the preferred strategy if it is achievable with an appropriate number and length of stents. Otherwise, CABG would be favored.

Third, subgroup analysis showed that patients with high SYNTAX scores, multivessel disease, and diabetes showed comparable long-term mortality when CR was achieved. Based on results from clinical trials, clinical guidelines favor CABG as the primary revascularization strategy in these groups (1,2,4). Therefore, these findings support the notion that the ability to achieve CR should be considered in the decision tree for preferred revascularization strategy in addition to the established anatomic scoring system or specific clinical entities.

**STUDY LIMITATIONS.** First, although this was a pooled analysis of randomized trials, the strategy of CR and IR was not randomized.

Second, the 3 studies had different definitions of reference vessel size in assessing the completeness of revascularization. However, the status of completeness of revascularization of clinically relevant stenoses in large coronary arteries must be captured in any diagnostic criteria.

In addition, a previous study showed that reclassification between CR and IR according to reference vessel size between 1.5 and 2.5 mm was limited (18). Therefore, different definitions of CR in studies may not significantly affect the main findings of the present study.

Fourth, this study was based on selected populations from randomized trials with inclusion and exclusion criteria. Therefore, generalization of our findings should be undertaken with care in real-world practice.

Fifth, the definition of MI is not what is done in standard practice (especially in post-CABG patient) and is not consistent with current MI definitions.

Finally, all studies did not perform functional evaluation. The ongoing FAME 3 (Fractional Flow Reserve Versus Angiography for Multivessel Evaluation) trial will provide insight regarding the comparison between CABG and PCI with functionally CR in multivessel coronary artery disease (26).

## CONCLUSIONS

This pooled analysis of randomized trials comparing CABG and PCI in patients with severe coronary artery disease showed that PCI with CR was associated with similar long-term survival to CABG. Our findings should be confirmed or refuted in future clinical trials.

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## PERSPECTIVES

**WHAT IS KNOWN?** The importance of the CR in decision making regarding revascularization strategy in patients with severe coronary artery disease is unknown.

**WHAT IS NEW?** In this study, patients undergoing PCI achieving CR showed similar long-term survival to those undergoing CABG with CR, whereas PCI with IR produced a lower survival rate. Therefore, the ability to achieve CR should enter into the decision algorithm for choice of revascularization strategy.

**WHAT IS NEXT?** Future clinical trials comparing CABG versus PCI with CR in patients with multivessel coronary artery disease are needed.

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**KEY WORDS** bypass surgery, coronary artery disease, stenting

**APPENDIX** For supplemental tables and figures, please see the online version of this article.