ORIGINAL ARTICLE

Complete or Culprit-Only PCI in Older Patients with Myocardial Infarction

S. Biscaglia, V. Guiducci, J. Escaned, R. Moreno, V. Lanzilotti, A. Santarelli, E. Cerrato, G. Sacchetta, A. Jurado-Roman, A. Menozzi, I. Amat Santos, J.L. Díez Gil, M. Ruozzi, M. Barbierato, L. Fileti, A. Picchi, V. Lodolini, G. Biondi-Zoccai, E. Maietti,* R. Pavasini, P. Cimaglia, C. Tumscitz, A. Erriquez, C. Penzo, I. Colaiori, G. Pignatelli, G. Casella, G. Iannopollo, M. Menozzi, F. Varbella, G. Caretta, D. Dudek, E. Barbato, M. Tebaldi, and G. Campo, for the FIRE Trial Investigators†

ABSTRACT

BACKGROUND

The benefit of complete revascularization in older patients (≥75 years of age) with myocardial infarction and multivessel disease remains unclear.

METHODS

In this multicenter, randomized trial, we assigned older patients with myocardial infarction and multivessel disease who were undergoing percutaneous coronary intervention (PCI) of the culprit lesion to receive either physiology-guided complete revascularization of nonculprit lesions or to receive no further revascularization. Functionally significant nonculprit lesions were identified either by pressure wire or angiography. The primary outcome was a composite of death, myocardial infarction, stroke, or any revascularization at 1 year. The key secondary outcome was a composite of cardiovascular death or myocardial infarction. Safety was assessed as a composite of contrast-associated acute kidney injury, stroke, or bleeding.

RESULTS

A total of 1445 patients underwent randomization (720 to receive complete revascularization and 725 to receive culprit-only revascularization). The median age of the patients was 80 years (interquartile range, 77 to 84); 528 patients (36.5%) were women, and 509 (35.2%) were admitted for ST-segment elevation myocardial infarction. A primary-outcome event occurred in 113 patients (15.7%) in the complete-revascularization group and in 152 patients (21.0%) in the culprit-only group (hazard ratio, 0.73; 95% confidence interval [CI], 0.57 to 0.93; P=0.01). Cardiovascular death or myocardial infarction occurred in 64 patients (8.9%) in the complete-revascularization group and in 98 patients (13.5%) in the culprit-only group (hazard ratio, 0.64; 95% CI, 0.47 to 0.88). The safety outcome did not appear to differ between the groups (22.5% vs. 20.4%; P=0.37).

CONCLUSIONS

Among patients who were 75 years of age or older with myocardial infarction and multivessel disease, those who underwent physiology-guided complete revascularization had a lower risk of a composite of death, myocardial infarction, stroke, or ischemia-driven revascularization at 1 year than those who received culprit-lesion–only PCI. (Funded by Consorzio Futuro in Ricerca and others; FIRE ClinicalTrials.gov number, NCT03772743.)

The authors' full names, academic degrees, and affiliations are listed in the Appendix. Dr. Biscaglia can be contacted at bscsmn@unife.it or at the Cardiology Unit, Azienda Ospedaliera Universitaria S. Anna, Via Aldo Moro 8, 44124 Cona, Italy.

*Deceased.

†A list of the FIRE trial investigators is provided in the Supplementary Appendix, available at NEJM.org.

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An increasing proportion of older patients (≥75 years of age) are being admitted to hospitals with myocardial infarction. Although increasing age is a known predictor of a poor outcome after myocardial infarction, patients in this older age group are often excluded or underrepresented in clinical trials, and many are treated conservatively or suboptimally.[1,2] Clinicians often face challenges in medical and procedural treatment of older patients with myocardial infarction because of a lack of robust evidence in this age group, concerns about complications, perceptions of poor outcomes, and low success rates.[3,4]

One such challenge is the decision regarding whether to pursue complete coronary-artery revascularization by treating nonculprit lesions with percutaneous coronary intervention (PCI).[5,6] Although the benefits of complete revascularization are well established in younger patients with myocardial infarction who have multivessel coronary artery disease,[7,8] such benefits in older patients with myocardial infarction who are at higher risk for complications are uncertain.[9,10] To address this knowledge gap, we conducted a multicenter, randomized trial involving older patients with myocardial infarction and multivessel disease to investigate whether complete revascularization that is performed on the basis of coronary physiology is superior to culprit-only PCI.

Methods

Trial Design and Oversight

The Functional Assessment in Elderly MI Patients with Multivessel Disease (FIRE) trial was an investigator-initiated, multicenter, prospective, superiority, randomized trial that was designed to evaluate a strategy of physiology-guided complete myocardial revascularization as compared with a culprit-only strategy in older patients (≥75 years of age) who had either ST-segment elevation myocardial infarction (STEMI) or non–ST-segment elevation myocardial infarction (NSTEMI) and multivessel disease. The executive committee was responsible for the protocol design and for the conduct and oversight of the trial. The protocol (available with the full text of this article at NEJM.org) was approved by the institutional review board at each participating center.

The nonprofit organization Consorzio Futuro in Ricerca served as the trial sponsor and received unrestricted funding from Sahajanand Medical Technologies, Medis Medical Imaging Systems, Eukon, Siemens Healthineers, General Electric Healthcare, and Insight Lifetech. The companies that provided funds had no involvement in the trial design; in the collection, analysis, or interpretation of the data; or in the writing of the manuscript.

The authors attest to the accuracy and completeness of the data and adherence of the trial to the protocol. A data and safety monitoring committee provided oversight and assessed the safety profile of the trial. Independent contract research organizations were responsible for site monitoring and data collection (see the Supplementary Appendix, available at NEJM.org).

Patients

Patients were eligible for inclusion in the trial if they were at least 75 years of age, had been admitted to the hospital with either STEMI or NSTEMI, had undergone successful PCI of the culprit lesion, and had multivessel disease with at least one lesion in a nonculprit coronary artery that had a minimum vessel diameter of 2.5 mm and a visually estimated diameter stenosis of 50 to 99%. Exclusion criteria included an inability to identify a clear culprit lesion (on the basis of clinical history, electrocardiography, echocardiography, and angiography), localization of the nonculprit lesion in the left main coronary artery, planned or previous surgical revascularization, or life expectancy of less than 1 year. Detailed lists of inclusion and exclusion criteria have been published previously[11] and are provided in the Supplementary Appendix. All the patients provided written informed consent to participate in the trial.

Randomization

After successful treatment of the culprit lesion, the patients underwent randomization either immediately or within 48 hours. With the use of a central randomization system, patients were assigned in a 1:1 ratio to receive either physiology-guided complete revascularization or culprit-only revascularization. Randomization was concealed with the use of a Web-based system (Integrated Clinical Trial Environment, AdvicePharma), and treatment assignment was determined by a computer-generated randomization list stratified according to center, sex, and clinical presentation with STEMI or NSTEMI.

TREATMENTS AND FOLLOW-UP

Patients who had been randomly assigned to receive physiology-guided complete revascularization underwent PCI of all functionally significant nonculprit lesions.[11] Both physiological assessment and PCI of nonculprit lesions were allowed during either the index intervention or in a staged procedure within the index hospitalization.

Physiological assessment was conducted by means of wire-based methods (hyperemic or nonhyperemic) and angiography-based (quantitative flow ratio) measurements (Medis QFR, Medis Medical Imaging Systems).[11] A functionally significant nonculprit lesion was defined as a lesion with a hyperemic, nonhyperemic, or angiography-based threshold ratio of 0.80, 0.89, and 0.80 or less, respectively. Patients who had been randomly assigned to undergo culprit-only revascularization did not undergo any physiological assessment or revascularization of nonculprit lesions.[11]

The use of sirolimus-eluting, biodegradable polymer, ultrathin stents (Supraflex Cruz, Sahajanand Medical Technologies) was strongly suggested.[11] Guideline-based medical therapy was indicated for both treatment groups. Dual antiplatelet therapy for a minimum of 1 year was recommended, except for patients at high risk for bleeding.[11] Follow-up visits occurred at 1 month and 12 months and were then scheduled annually for up to 5 years after randomization.

OUTCOMES

The primary outcome was a composite of death, myocardial infarction, stroke, or ischemia-driven coronary revascularization occurring within 1 year after randomization.[11] A key secondary outcome was a composite of cardiovascular death or myocardial infarction at 1 year. Other secondary outcomes were the individual components of the primary outcome.[11]

The safety outcome was a composite of contrast-associated acute kidney injury, stroke, or bleeding defined as type 3, 4, or 5 by the Bleeding Academic Research Consortium (BARC) at 1 year.[11] Outcome events were adjudicated according to definitions of the Academic Research Consortium and BARC consensus documents.[12,13] A detailed description of outcome definitions is provided in the Supplementary Appendix. All events were reported by investigators and analyzed and adjudicated by an independent clinical evaluation committee whose members were unaware of group assignments.

STATISTICAL ANALYSIS

We assumed that a primary-outcome event would occur in 15% of the patients in the culprit-only group, with an anticipated relative risk reduction of at least 30% in the complete-revascularization group.[11] On the basis of these assumptions, we determined that the enrollment of 1358 patients would provide the trial with 80% power to show the superiority of complete revascularization over culprit-only revascularization at an alpha level of 5%. All hypothesis tests were two-sided, and a P value of less than 0.05 was considered to indicate statistical significance. To account for an anticipated 2% attrition, the final sample size was increased to 1385.[11] All the analyses were performed on an intention-to-treat basis.[11]

The two treatment groups were compared for baseline characteristics to ensure that the randomization process had minimized any differences between groups. Time-to-event plots were constructed for clinical events. A primary event was defined as the first occurrence of any outcome in the composite. Cox proportional-hazard models were fitted to estimate hazard ratios with 95% confidence intervals for treatment comparisons with respect to the primary outcome and the overall risk of death. Estimates and confidence intervals for the outcomes that included cardiovascular death were adjusted for the competing risk of noncardiovascular death. Other secondary and safety outcomes were adjusted for the competing risk of death.[14] The widths of the confidence intervals have not been adjusted for multiplicity, so the confidence intervals should not be used for hypothesis testing. The expected amount of missing data was minimal, and no imputation of missing values was performed for the outcomes. However, imputation of missing values with the use of multiple imputation techniques could be performed in case of any missing data for covariates (e.g., baseline characteristics and laboratory results).

Additional details about the statistical analysis are provided in the trial protocol document. All the analyses were performed with the use of R statistical software (Foundation for Statistical Computing).

RESULTS

PATIENTS

From July 18, 2019, to October 25, 2021, a total of 1898 patients at 34 sites in Italy, Spain, and Poland were screened for the trial (Fig. S1 in the Supplementary Appendix). Of these patients, 1445 were randomly assigned to receive either physiology-guided complete revascularization (720 patients) or culprit-only revascularization (725 patients). Randomization occurred at the time of the index procedure in 877 patients (60.7%) and within 48 hours after the index procedure in 568 patients (39.3%).

The characteristics of the patients at baseline and procedural data are provided in Table 1 and Table 2, respectively. Details regarding the representativeness of the patient sample with respect to race, ethnic background, age, and sex of the broader population affected by myocardial infarction are provided in Table S1. The median age of the patients was 80 years (interquartile range, 77 to 84), 528 patients (36.5%) were women, and 509 (35.2%) were admitted for STEMI. The assigned treatment was performed in 693 patients (96.2%) in the complete-revascularization group and in 706 patients (97.4%) in the culprit-only group (Fig. S1). In the complete-revascularization group, physiological assessment of at least one nonculprit vessel was performed in 700 patients (97.2%); this assessment identified 357 patients (49.6%) with at least one functionally significant nonculprit vessel. Revascularization of at least one nonculprit vessel was performed in 361 patients (50.1%); of these patients, 346 had a functionally significant nonculprit vessel, 4 had a negative physiological assessment, and 11 did not receive physiological assessment before PCI. A detailed description of the physiology-guided management according to patient and according to nonculprit vessel is shown in Figure S2. The median length of hospital stay was 5 days (interquartile range, 4 to 8) and appeared to be longer in the complete-revascularization group than in the culprit-only group (6 days [interquartile range, 4 to 8] and 5 days [interquartile range, 3 to 7], respectively) (Table 1).

PRIMARY OUTCOME

One-year follow-up data were complete for 1444 of 1445 patients (99.9%) (Fig. S1). A primary-outcome event occurred in 113 patients (15.7%) in the complete-revascularization group and in 152 patients (21.0%) in the culprit-only group (hazard ratio, 0.73; 95% confidence interval [CI], 0.57 to 0.93; P=0.01) (Table 3 and Fig. 1A). The number needed to treat to prevent the occurrence of one primary-outcome event was 19 patients.

SECONDARY OUTCOMES

Secondary outcomes are summarized in Table 3. The incidence of the composite outcome consisting of cardiovascular death or myocardial infarction appeared to be lower in the complete-revascularization group (hazard ratio, 0.64; 95% CI, 0.47 to 0.88) (Fig. 1B). The number needed to treat to prevent cardiovascular death or myocardial infarction from occurring in 1 patient was 22 patients.

With the exception of stroke, the incidence of the individual components of the primary outcome appeared to be lower in the complete-revascularization group, including death from any cause (hazard ratio, 0.70; 95% CI, 0.51 to 0.96) (Figs. S3 through S6); the number needed to treat to prevent one death from occurring was 27 patients. Subgroup analyses showed that the effect of complete revascularization on the primary outcome appeared to be consistent across prespecified subgroups (Fig. 2).

SAFETY

There was no apparent difference between the two treatment groups in the incidence of the composite safety outcome consisting of contrast-associated acute kidney injury, stroke, or bleeding (as defined as BARC type 3, 4, or 5), with 22.5% in the complete-revascularization group and 20.4% in the culprit-only group (hazard ratio, 1.11; 95% CI, 0.89 to 1.37; P=0.37) (Table 3).

DISCUSSION

In the FIRE trial, we evaluated the efficacy of physiology-guided complete revascularization as compared with a strategy of culprit-only PCI in patients who were at least 75 years of age with myocardial infarction and multivessel disease. Results showed that physiology-guided complete revascularization resulted in a 27% lower relative risk of a composite of death, myocardial infarction, stroke, or ischemia-driven revascularization than culprit-only revascularization. The benefit was driven by a reduction in each indi-

Table 1. Characteristics of the Patients at Baseline.*

Characteristic	Culprit-Only Revascularization (N = 725)	Complete Revascularization (N = 720)
Median age (IQR) — yr	80 (77–84)	81 (77–84)
Female sex — no. (%)	265 (36.6)	263 (36.5)
Coexisting illness — no. (%)		
Hypertension	592 (81.7)	593 (82.4)
Dyslipidemia	375 (51.7)	384 (53.3)
Diabetes	233 (32.1)	230 (31.9)
Current smoker	62 (8.6)	61 (8.5)
Previous myocardial infarction	116 (16.0)	104 (14.4)
Previous percutaneous coronary intervention	136 (18.8)	121 (16.8)
Atrial fibrillation	109 (15.0)	91 (12.6)
Estimated glomerular filtration rate of <60 ml/min†	332 (45.8)	330 (45.8)
Peripheral artery disease	127 (17.5)	122 (16.9)
Stroke	63 (8.7)	56 (7.8)
Clinical presentation — no. (%)		
ST-segment elevation myocardial infarction	256 (35.3)	253 (35.1)
Non–ST-segment elevation myocardial infarction	469 (64.7)	467 (64.9)
Killip class ≥II‡	208 (28.7)	204 (28.3)
Left ventricular ejection fraction — %	49.0±10.9	49.4±10.5
Median length of hospital stay (IQR) — days	5 (3–7)	6 (4–8)
Medication at discharge — no. (%)		
Aspirin	683 (94.2)	692 (96.1)
Clopidogrel	358 (49.4)	371 (51.5)
Ticagrelor	337 (46.5)	326 (45.3)
Prasugrel	16 (2.2)	16 (2.2)
Vitamin K antagonist	36 (5.0)	27 (3.8)
Non–vitamin K antagonist oral anticoagulant	129 (17.8)	137 (19.0)
Angiotensin-converting–enzyme inhibitor or angiotensin-receptor blocker	552 (76.1)	556 (77.2)
Beta-blocker	541 (74.6)	556 (77.2)
Statin	661 (91.2)	680 (94.4)

* Plus–minus values are means ±SD. IQR denotes interquartile range.
† The estimated glomerular filtration rate was calculated by means of the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula.
‡ Killip class II indicates findings consistent with mild-to-moderate heart failure, class III the presence of overt pulmonary edema, and class IV the presence of cardiogenic shock.

vidual component of the composite outcome, with the exception of stroke. In addition, physiology-guided complete revascularization was associated with a 36% relative reduction in the composite outcome consisting of cardiovascular death or myocardial infarction.

The daily treatment of older patients with myocardial infarction is becoming increasingly challenging from therapeutic, organizational, and economic perspectives.[6,15,16] The debate concerns the resource-intensive nature of invasive procedures and hospitalizations, along with the lack of strong evidence from randomized trials to support such treatment in this patient population.[6] Studies have

Table 2. Procedural Characteristics.*

Characteristic	Culprit-Only Revascularization (N=725)	Complete Revascularization (N=720)
Procedure		
Total performed — no.	725	961
Index — no.		
All	725	720
With PCI of nonculprit vessels	19†	232
Staged — no.		
All	—	241
With PCI of nonculprit vessels	—	129
Interval between index and staged procedure (IQR) — days	—	3 (2–4)
Radial access — no./total no. of procedures (%)	672/725 (92.7)	911/961 (94.8)
Culprit vessel — no. (%)		
Left main coronary artery	41 (5.7)	35 (4.9)
Left anterior descending artery	330 (45.5)	329 (45.7)
Circumflex artery	133 (18.3)	136 (18.9)
Right coronary artery	209 (28.8)	204 (28.3)
Ramus intermedius artery	12 (1.7)	16 (2.2)
Number of nonculprit vessels per patient — no. (%)		
1	510 (70.3)	503 (69.9)
≥2	215 (29.7)	217 (30.1)
Location of nonculprit vessel — no./total no. (%)		
Left anterior descending artery	291/951 (30.6)	296/948 (31.2)
Circumflex artery	319/951 (33.5)	308/948 (32.5)
Right coronary artery	320/951 (33.6)	310/948 (32.7)
Ramus intermedius artery	21/951 (2.2)	34/948 (3.6)
Reference vessel diameter (IQR) — mm	3.0 (2.5–3.0)	3.0 (2.5–3.0)
Stenosis		
Diameter (IQR) — (%)	70 (60–80)	70 (60–80)
Percent diameter — no./total no. of nonculprit vessels (%)		
50–69%	401/951 (42.2)	390/948 (41.1)
70–89%	378/951 (39.7)	380/948 (40.1)
90–99%	172/951 (18.1)	178/948 (18.8)
Physiological assessment — no./total no. of nonculprit vessels (%)	—	909/948 (95.9)
Type of physiological assessment — no./total no. of nonculprit vessels tested (%)		
Wire-based hyperemic index	—	451/909 (49.6)
Wire-based nonhyperemic index	—	138/909 (15.2)
Angiography-based index	—	320/909 (35.2)
Functionally significant nonculprit vessels — no./total no. of nonculprit vessels (%)	—	425/948 (44.8)
Nonculprit vessel treated with PCI — no./total no. of nonculprit vessels (%)	—	431/948 (45.5)

* Because of rounding, the percentages may not total 100. PCI denotes percutaneous coronary intervention.
† These revascularizations were protocol violations. Details regarding these procedures are provided in Figure S1 in the Supplementary Appendix.

Table 3. Efficacy and Safety Outcomes.*

Outcome	Culprit-Only Revascularization (N=725)	Complete Revascularization (N=720)	Hazard Ratio (95% CI)†	P Value
	number of patients (percent)			
Primary outcome				
Composite of death, myocardial infarction, stroke, or ischemia-driven revascularization	152 (21.0)	113 (15.7)	0.73 (0.57–0.93)	0.01
Key secondary outcomes				
Cardiovascular death or myocardial infarction	98 (13.5)	64 (8.9)	0.64 (0.47–0.88)	
Other secondary outcomes				
Death				
From any cause	93 (12.8)	66 (9.2)	0.70 (0.51–0.96)	
From cardiovascular cause	56 (7.7)	36 (5.0)	0.64 (0.42–0.97)	
Myocardial infarction	51 (7.0)	32 (4.4)	0.62 (0.40–0.97)	
Death or myocardial infarction	133 (18.3)	93 (12.9)	0.68 (0.52–0.88)	
Stroke	7 (1.0)	12 (1.7)	1.73 (0.68–4.40)	
Ischemia-driven coronary revascularization	49 (6.8)	31 (4.3)	0.63 (0.40–0.98)	
Other outcomes				
Noncardiovascular death	37 (5.1)	30 (4.2)	0.82 (0.50–1.32)	
Cerebrovascular accident‡	9 (1.2)	18 (2.5)	2.03 (0.91–4.52)	
Transient ischemic attack	2 (0.3)	6 (0.8)	3.06 (0.62–15.1)	
Stent thrombosis				
Definite	5 (0.7)	6 (0.8)	1.21 (0.37–3.96)	
Probable	3 (0.4)	1 (0.1)	0.34 (0.04–3.22)	
Safety outcome				
Composite of contrast-associated acute kidney injury, stroke, or BARC type 3, 4, or 5 bleeding	148 (20.4)	162 (22.5)	1.11 (0.89–1.37)	0.37
Contrast-associated acute kidney injury	116 (16.0)	129 (17.9)	1.11 (0.87–1.42)	
BARC type 3, 4, or 5 bleeding	36 (5.0)	34 (4.7)	0.95 (0.59–1.53)	

* BARC denotes Bleeding Academic Research Consortium.
† The widths of the confidence intervals have not been adjusted for multiplicity, so the confidence intervals should not be used for hypothesis testing.
‡ Cerebrovascular accident includes stroke and transient ischemic attack.

shown that complete revascularization that is guided by angiography or physiological assessment is superior to the culprit-only strategy in younger and low-risk patients with STEMI.[8,10] This benefit is mainly driven by the reduction of recurrence of myocardial infarction or the need for repeated revascularization.[7,8] However, older patients with myocardial infarction have unique clinical, anatomic, and procedural characteristics that were not captured by these studies, such as the burden of coexisting illnesses, frailty, more complex coronary anatomy, more frequent presentation with NSTEMI, higher risk of complications, and side effects associated with a multidrug treatment regimen. Thus, there is a need for targeted evidence to guide the management and treatment of older patients with myocardial infarction.[3,6]

The FIRE trial addressed the lack of evidence for a revascularization strategy beyond culprit-lesion–only treatment of older patients with myocardial infarction and multivessel disease. The patients who were enrolled in the trial had a median age of 80 years, which is approximately 20 years older than that in earlier pivotal trials in the field.[8] Because patients in this age group have a high incidence of coexisting illnesses such as

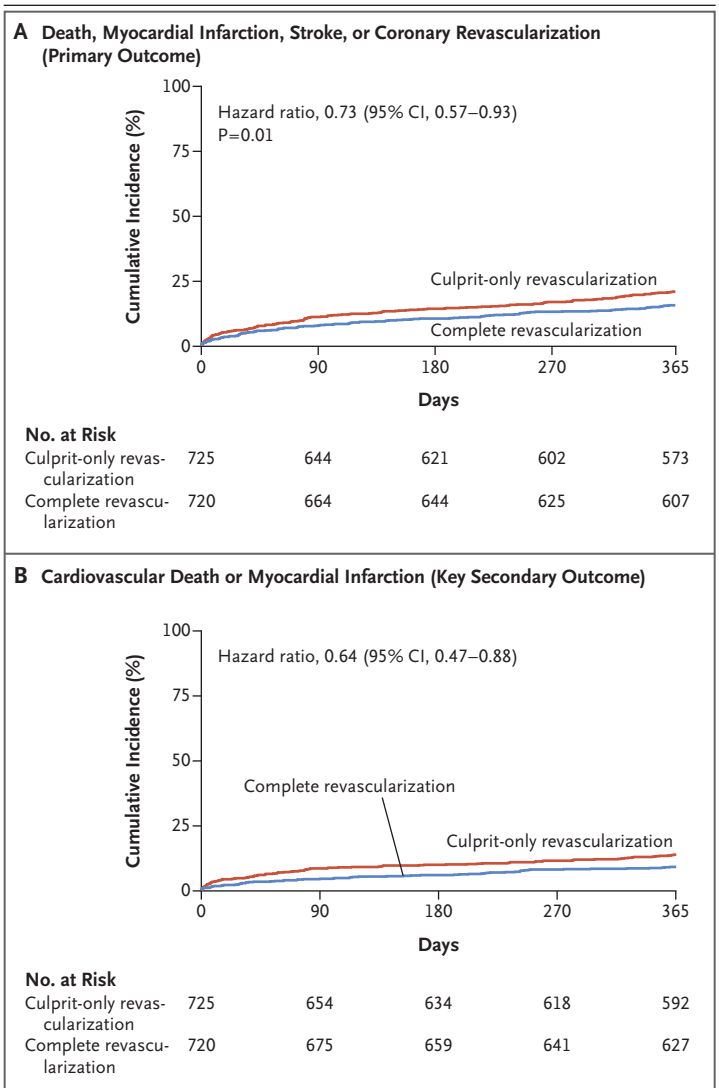

Figure 1. Cumulative Incidence of the Primary and Key Secondary Outcomes.

Shown is the composite primary outcome consisting of death, myocardial infarction, stroke, or ischemia-driven coronary revascularization (Panel A) and the key secondary outcome, a composite of cardiovascular death or myocardial infarction (Panel B). The widths of the confidence intervals have not been adjusted for multiplicity, so the confidence intervals should not be used for hypothesis testing.

diabetes, peripheral artery disease, and chronic kidney disease, the observed frequency of adverse events was also markedly higher than the frequency in previous trials.[7,8] This increase in adverse events was driven mainly by death and myocardial infarction. Elective invasive coronary procedures are less likely to be performed in older patients than in younger patients. However, in our trial, the risk reduction associated with physiology-guided complete revascularization among older patients was consistent with what has been observed in previous trials.[10] Furthermore, the benefit of complete revascularization was observed to accrue over time with continued divergence of the Kaplan–Meier curves during the first year.

In contrast to previous trials, patients with both STEMI and NSTEMI were enrolled in our trial. In patients with myocardial infarction, the safety of physiology-guided revascularization relies on clearly differentiating the culprit lesion from nonculprit lesions.[11] We found that physiology-guided complete revascularization was feasible and safe in patients with either STEMI or NSTEMI as long as the culprit lesion was clearly identifiable on the basis of electrocardiography, echocardiography, and angiography; this was mandated in the trial protocol.

The rationale behind the use of the coronary physiology in older patients is to decrease the number of interventions by treating only the prognostically determined nonculprit vessels at the time of the culprit-vessel treatment and by minimizing the occurrence of complications that portend a worse prognosis. The potential advantage is not limited to periprocedural complications, such as stroke, contrast-associated acute kidney injury, and periprocedural myocardial infarction. The number of treated vessels and implanted stents is a major driver of a prolonged duration of dual-antiplatelet therapy, which is associated with major bleeding and death in patients at risk for increased bleeding. This category includes patients who are at least 75 years of age, which is one of the minor criteria of the Academic Research Consortium for high bleeding risk. In that regard, it is relevant that 483 nonculprit vessels (50.9%) were not treated with PCI on the basis of physiological measurements that did not indicate the need for revascularization at the time of functional testing. The occurrence of the composite safety outcome consisting of contrast-induced acute kidney injury, stroke, or BARC type 3, 4, or 5 bleeding did not appear to be different between the groups, even though there was a numerical increase in the individual components of the composite safety outcome in the complete-revascularization group.

Our trial has several limitations. Because of the open-label design, knowledge of the angiographic results may have resulted in bias among both patients and physicians toward subsequent

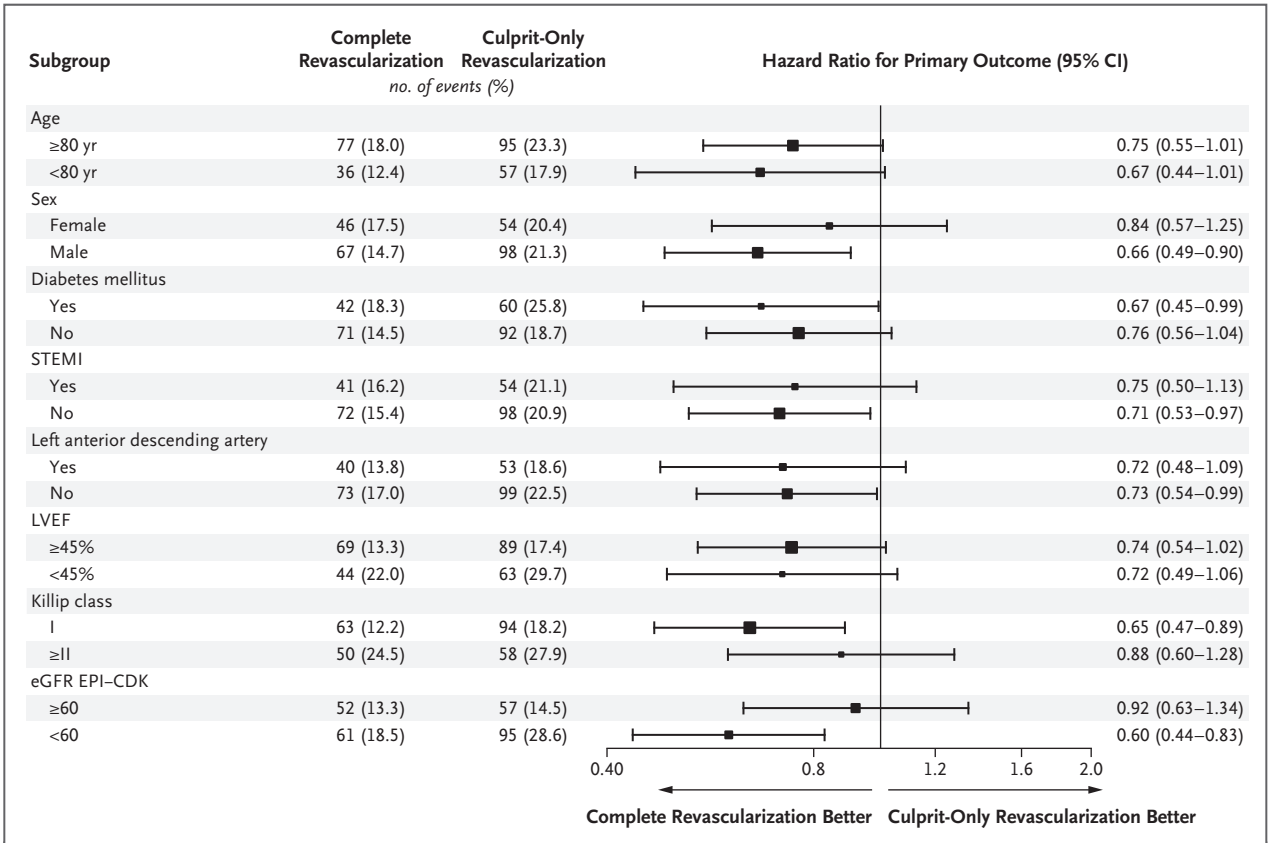

Figure 2. Subgroup Analysis of the Primary Outcome.

Shown are the results of subgroup analyses of the primary outcome, a composite of death, myocardial infarction, stroke, or any revascularization at 1 year. The size of the squares is proportional to the number of patients in each subgroup. The widths of the confidence intervals have not been adjusted for multiplicity and should not be used to evaluate treatment effects. The estimated glomerular filtration rate (eGFR) was calculated with the use of the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula. LVEF denotes left ventricular ejection fraction, and STEMI ST-segment elevation myocardial infarction.

revascularization in the culprit-only treatment group. However, it should be noted that events related to ischemia-driven revascularization represented a small portion of the overall primary-outcome events, whereas hard clinical outcomes (e.g., myocardial infarction and death) accounted for the majority of events. Because complete revascularization was guided by coronary physiological assessment, the transferability of the results to angiography-guided complete revascularization should be considered with caution on the basis of the unique characteristics of the trial population. In addition, revascularization was completed during the index hospitalization and with the implantation of sirolimus-eluting, biodegradable-polymer, ultrathin stents. Therefore, it is not known whether the results of our trial may apply to patients who are receiving different management strategies and stent platforms.

Among patients aged 75 years or older with myocardial infarction and multivessel disease, physiology-guided complete revascularization was associated with a lower occurrence of the composite of death, myocardial infarction, stroke, or ischemia-driven revascularization than culprit-only revascularization.

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

A data sharing statement provided by the authors is available with the full text of this article at NEJM.org.

This article is dedicated to the memory of Dr. Elisa Maietti.

APPENDIX

The authors' full names and academic degrees are as follows: Simone Biscaglia, M.D., Vincenzo Guiducci, M.D., Javier Escaned, M.D., Raul Moreno, M.D., Valerio Lanzilotti, M.D., Andrea Santarelli, M.D., Enrico Cerrato, M.D., Giorgio Sacchetta, M.D., Alfonso Jurado-Roman, M.D., Alberto Menozzi, M.D., Ignacio Amat Santos, M.D., José Luis Díez Gil, M.D., Marco Ruozzi, M.D., Marco Barbierato, M.D., Luca Fileti, M.D., Andrea Picchi, M.D., Veronica Lodolini, B.Sc., Giuseppe Biondi-Zoccai, M.D., Elisa Maietti, Ph.D., Rita Pavasini, M.D., Paolo Cimaglia, M.D., Carlo Tumscitz, M.D., Andrea Erriquez, M.D., Carlo Penzo, M.D., Iginio Colaiori, M.D., Gianluca Pignatelli, M.D., Gianni Casella, M.D., Gianmarco Iannopollo, M.D., Mila Menozzi, M.D., Ferdinando Varbella, M.D., Giorgio Caretta, M.D., Dariusz Dudek, M.D., Emanuele Barbato, M.D., Matteo Tebaldi, M.D., and Gianluca Campo, M.D.

The authors' affiliations are as follows: the Cardiology Unit, Azienda Ospedaliero Universitaria di Ferrara, Ferrara (S.B., V. Lodolini, R.P., P.C., C.T., A.E., C.P., G. Campo), the Cardiology Unit, Azienda Unità Sanitaria Locale (USL) IRCCS Reggio Emilia, S. Maria Nuova Hospital, Reggio Emilia (V.G., G.P.), the Cardiology Unit, Ospedale Maggiore (V. Lanzilotti, G. Casella, G.I.), and the Department of Biomedical and Neuromotor Sciences, University of Bologna (E.M.), Bologna, the Cardiovascular Department, Infermi Hospital, Rimini (A.S., M.M.), the Interventional Cardiology Unit, San Luigi Gonzaga University Hospital, Orbassano, and Rivoli Infermi Hospital ASL TO3, Turin (E.C., F.V.), the Cardiology Unit, Umberto I Hospital, ASP Siracusa, Siracusa (G.S.), S.C. Cardiologia, Ospedale Sant'Andrea, ASL5 Liguria, La Spezia (A.M., G. Caretta), the Cardiology Unit, Ospedale Civile di Baggiovara, Baggiovara (M.R.), Interventional Cardiology, Department of Cardio-Thoracic and Vascular Sciences, Ospedale dell'Angelo, Venice (M.B.), the Department of Cardiology, S. Maria delle Croci Hospital, Ravenna (L.F.), the Cardiovascular Department, Azienda USL Toscana Sud-Est, Misericordia Hospital, Grosseto (A.P.), the Department of Medico-Surgical Sciences and Biotechnologies, Sapienza University of Rome (G.B.-Z.), and the Cardiology Unit, Ospedale Santa Maria Goretti, Latina (I.C.), Mediterranea Cardiocentro, Naples (G.B.-Z.), Maria Cecilia Hospital, Cotignola (P.C., D.D.), the Department of Clinical and Molecular Medicine, Sapienza University of Rome, Rome (E.B.), and the Interventional Cardiology Unit, Presidio Ospedaliero San Salvatore di Pesaro, Pesaro (M.T.) — all in Italy; Hospital Clínico San Carlos, Complutense University of Madrid (J.E.), Centro de Investigación Biomédica en Red de Enfermedades Cardiovasculares (CIBERCV), and Instituto de Investigación Hospital La Paz, University Hospital La Paz (R.M., A.J.-R.), Madrid, CIBERCV, Department of Cardiology, Hospital Clínico Universitario, Valladolid (I.A.S.), and CIBERCV, Cardiology Department, H. Universitario y Politécnico La Fe, Valencia (J.L.D.G.) — all in Spain; and the Institute of Cardiology, Jagiellonian University Medical College, Krakow, Poland (D.D.).

REFERENCES

1. Sinclair H, Batty JA, Qiu W, Kunadian V. Engaging older patients in cardiovascular research: observational analysis of the ICON-1 study. Open Heart 2016;3(2):e000436.
2. Veerasamy M, Edwards R, Ford G, et al. Acute coronary syndrome among older patients: a review. Cardiol Rev 2015;23:26-32.
3. Madhavan MV, Gersh BJ, Alexander KP, Granger CB, Stone GW. Coronary artery disease in patients ≥80 years of age. J Am Coll Cardiol 2018;71:2015-40.
4. Biscaglia S, Erriquez A, Serenelli M, et al. Complete versus culprit-only strategy in older MI patients with multivessel disease. Catheter Cardiovasc Interv 2022;99:970-8.
5. Forman DE, Maurer MS, Boyd C, et al. Multimorbidity in older adults with cardiovascular disease. J Am Coll Cardiol 2018;71:2149-61.
6. Rich MW, Chyun DA, Skolnick AH, et al. Knowledge gaps in cardiovascular care of the older adult population: a scientific statement from the American Heart Association, American College of Cardiology, and American Geriatrics Society. J Am Coll Cardiol 2016;67:2419-40.
7. Mehta SR, Wood DA, Storey RF, et al. Complete revascularization with multivessel PCI for myocardial infarction. N Engl J Med 2019;381:1411-21.
8. Pavasini R, Biscaglia S, Barbato E, et al. Complete revascularization reduces cardiovascular death in patients with ST-segment elevation myocardial infarction and multivessel disease: systematic review and meta-analysis of randomized clinical trials. Eur Heart J 2020;41:4103-10.
9. Joshi FR, Lønborg J, Sadjadieh G, et al. The benefit of complete revascularization after primary PCI for STEMI is attenuated by increasing age: results from the DANAMI-3-PRIMULTI randomized study. Catheter Cardiovasc Interv 2021;97(4):E467-E474.
10. Køber L, Engstrøm T. A more COMPLETE picture of revascularization in STEMI. N Engl J Med 2019;381:1472-4.
11. Biscaglia S, Guiducci V, Santarelli A, et al. Physiology-guided revascularization versus optimal medical therapy of nonculprit lesions in elderly patients with myocardial infarction: rationale and design of the FIRE trial. Am Heart J 2020;229:100-9.
12. Garcia-Garcia HM, McFadden EP, Farb A, et al. Standardized end point definitions for coronary intervention trials: the Academic Research Consortium-2 consensus document. Circulation 2018;137:2635-50.
13. Mehran R, Rao SV, Bhatt DL, et al. Standardized bleeding definitions for cardiovascular clinical trials: a consensus report from the Bleeding Academic Research Consortium. Circulation 2011;123:2736-47.
14. Fine JP, Gray RJ. A proportional hazards model for the subdistribution of a competing risk. J Am Stat Assoc 1999;94:496-509.
15. Tsao CW, Aday AW, Almarzooq ZI, et al. Heart disease and stroke statistics — 2023 update: a report from the American Heart Association. Circulation 2023;147(8):e93-e621.
16. Lindstrom M, DeCleene N, Dorsey H, et al. Global burden of cardiovascular diseases and risks collaboration, 1990-2021. J Am Coll Cardiol 2022;80:2372-425.

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