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Original Research

Three-Year Outcomes After Bifurcation Stenting With Zotarolimus-Eluting Stents: Final Results From the RESOLUTE ONYX Postapproval Study

Matthew J. Price, MD [a,*], Loukas Boutis, MD [b], Ajay J. Kirtane, MD, SM [c], Stanley Chetcuti, MD [d], Petra Poliačiková, MD [e], Joseph Dens, MD [f], Michael Attubato, MD [g], Yale Wang, MD [h], Patrick Hu, MD [i], Douglas Spriggs, MD [j], Joshua Krasnow, MD [k], Yiannis Chatzizisis, MD [l], Adel Aminian, MD [m], Ronald Caputo, MD [n], Alpesh Shah, MD [o], Michelle Dauler, MS [p], Sherif Ibrahim, MD [p], Te-Hsin Lung, PhD [p], Roxana Mehran, MD [q]

[a] *Scripps Clinic, La Jolla, California;* [b] *North Shore University Hospital, Manhasset, New York;* [c] *Columbia University Irving Medical Center/NewYork-Presbyterian Hospital, New York, New York;* [d] *University of Michigan Health System, Ann Arbor, Michigan;* [e] *Stredoslovenský ústav srdcových a cievnych chorôb, Banská Bystrica, Slovakia;* [f] *Ziekenhuis Oost Limburg, Genk, Belgium;* [g] *NYU Langone Medical Center, New York, New York;* [h] *Abbott Northwestern, Minneapolis, Minnesota;* [i] *Riverside Community Hospital, Riverside, California;* [j] *Morton Plant Hospital, Clearwater, Florida;* [k] *Huntsville Hospital, Huntsville, Alabama;* [l] *Nebraska Medical Center, Omaha, Nebraska;* [m] *CHU Charleroi, Charleroi, Belgium;* [n] *St. Joseph's Hospital Health Center, Syracuse, New York;* [o] *Houston Methodist Hospital, Houston, Texas;* [p] *Medtronic, Santa Rosa, California;* [q] *The Zena and Michael A. Wiener Cardiovascular Institute, Icahn School of Medicine at Mount Sinai, New York, New York*

ABSTRACT

Background: Bifurcation represents a challenging lesion subset for percutaneous coronary intervention.

Methods: In this prospective study of the Resolute Onyx zotarolimus-eluting stent (ZES), patients with a single bifurcation target lesion who underwent planned treatment using a provisional stenting technique were enrolled at 25 centers in the United States and Europe. The primary end point was target-vessel failure (TVF) at 1 year, and follow-up was performed through 3 years.

Results: A total of 205 patients were enrolled. Mean age was 66.6 ± 10.7 years, 21.5% of patients were female, and diabetes mellitus was present in 30.2%. A provisional approach with a single stent was performed in 96.6% of patients. The rate of TVF at 1 year was 7.4%, fulfilling the prespecified performance criterion (upper 1-sided 95% CI of 11.1%, compared with the performance goal of 24.5%). At 3-year follow-up, the rate of TVF was 12.1%, the rate of clinically driven target-lesion revascularization was 6.0%, and there were no episodes of stent thrombosis related to the target lesion. Event rates were consistent among the cohort of patients with angiographic core laboratory-confirmed bifurcation lesions.

Conclusions: In this prospective, multicenter study, bifurcation lesion treatment with Resolute Onyx ZES using a planned provisional stent approach was associated with favorable clinical outcomes through 3 years. These results support the longer-term safety and effectiveness of Resolute Onyx ZES to treat bifurcation lesions that are amenable to a planned provisional stenting technique.

Introduction

Bifurcation lesions are frequently encountered during percutaneous coronary intervention (PCI), and they are associated with a higher risk of both early and late major adverse cardiovascular events despite the introduction of drug-eluting stents (DES).[1] Current society guidelines recommend that stent implantation within the main vessel only, followed by provisional balloon angioplasty with or without stenting of the side branch, should be the preferred approach for most bifurcation lesions.[2] Stent design might influence acute and longer-term outcomes of bifurcation stenting. The Resolute Onyx zotarolimus-eluting stent (ZES) consists of a single continuous wire composed of an outer shell of cobalt alloy and an inner core of platinum iridium, formed into an 81.0-μm-thick sinusoidal design.[3,4] This design may facilitate post-dilation within the proximal main vessel and access to opening toward the side branch and, thus, might be a particularly favorable for

Abbreviations: CD-TLR, clinically driven target-lesion revascularization; DES, drug-eluting stent; PCI, percutaneous coronary intervention; TIMI, thrombolysis in myocardial infarction; TLF, target-lesion failure; TLR, target-lesion revascularization; TVF, target-vessel failure; ZES, Resolute Onyx zotarolimus-eluting stent.

Keywords: bifurcation; drug-eluting stent; percutaneous coronary intervention; zotarolimus.

* Corresponding author: price.matthew@scrippshealth.org (M.J. Price).

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bifurcation stenting.[5] There are a paucity of data regarding the clinical outcomes of bifurcation PCI with specific DES because target lesions involving a bifurcation have generally been excluded from FDA registration trials of coronary stents. Observational, postmarket registries can inform the clinical safety and effectiveness of particular DES for this lesion subset. We therefore conducted a prospective, multicenter, international, observational study to evaluate clinical outcomes of bifurcation PCI using this third-generation DES.

Methods

Study design

The RESOLUTE ONYX Postapproval Study is a single-arm, open-label, multicenter study for patients with ischemic heart disease attributable to stenotic coronary artery lesions amenable to treatment with Resolute Onyx ZES. The study was conducted in the United States and Europe. Three patient cohorts were prospectively defined by the study protocol: primary, extra-large vessel, and bifurcation. This analysis focused on the RESOLUTE ONYX bifurcation cohort, which prospectively enrolled patients with bifurcation lesions suitable for treatment with a provisional stenting approach.

All patients provided written informed consent. An external, independent clinical events committee (MedStar Health Research Institute) adjudicated all safety and effectiveness end points. An independent angiographic core laboratory (Beth Israel Deaconess Medical Center) evaluated all baseline and event-related angiograms. Study monitors verified patient data employing a risk-based monitoring strategy and ensured compliance with the study protocol. The study adhered to the Declaration of Helsinki and was approved by the institutional review board or ethics committee at each center. The study is registered at ClinicalTrials.gov as NCT03584464.

Patient eligibility

Patients were eligible to be enrolled if there was 1 de novo target lesion involving a bifurcation within a native coronary artery that was amenable to treatment with Resolute Onyx ZES using a provisional stenting technique. The main branch reference vessel diameter (RVD) was required to be $\geq$2.25 to 5.0 mm, the side branch RVD of $\geq$2.0 mm, target-lesion length of $\leq$35.0 mm, stenosis of $\geq$50% and $<$100%, and target-vessel thrombolysis in myocardial infarction (TIMI) flow of $\geq$2, all according to the visual estimate of the operator. Key exclusion criteria included unprotected left main disease, planned PCI of 3-vessel disease, planned 2-stent technique for treatment of a bifurcation, and more than 1 target lesion involving a bifurcation. Patients could have a second target lesion treated if that lesion did not involve a bifurcation. Complete inclusion and exclusion criteria are listed in Supplemental Table S1.

Study procedures

The recommended treatment technique was the provisional approach, wherein coronary guide wires are introduced into both the main vessel and side branch, a Resolute Onyx ZES is implanted in the main vessel, and then, proximal optimization technique is performed. Balloon dilation and/or implantation of a second stent within the side branch was performed according to operator discretion; the protocol stated that stenting of the side branch was warranted if there was threatened vessel closure, TIMI flow of $<$3, dissection type B or worse, residual stenosis of $>$80%, or abnormal assessment by fractional flow reserve ($\leq$0.80) or instantaneous wave-free ratio ($\leq$0.89), if performed. Postdilation of the stent(s) and final kissing balloon inflation were performed at operator discretion.

Study end points

The primary end point was target-vessel failure (TVF), defined as cardiac death, target-vessel myocardial infarction according to the third Universal Definition of Myocardial Infarction,[6] or clinically driven target-vessel revascularization. Secondary end points included the components of TVF and clinically driven target-lesion revascularization (CD-TLR), target-lesion failure (TLF, defined as cardiac death, target-vessel myocardial infarction, or target-lesion revascularization [TLR]), death, major adverse cardiovascular events (defined as death, myocardial infarction [Q wave and non–Q wave], emergent coronary artery bypass surgery, or CD-TLR by percutaneous or surgical methods), and definite/probable stent thrombosis according to the Academic Research Consortium definition.[7] Lesion success was defined as the attainment of $<$30% residual stenosis by quantitative coronary angiography (QCA) (or $<$20% by visual assessment) and TIMI grade 3 flow after the procedure using any percutaneous method. Device success was defined as the attainment of $<$30% residual stenosis by QCA (or $<$20% by visual assessment) and TIMI grade 3 flow after the procedure, using the assigned device only. Procedure success was defined as the attainment of $<$30% residual stenosis by QCA (or $<$20% by visual assessment) and TIMI grade 3 flow after the procedure without the occurrence of major adverse cardiovascular events during the hospital stay. The angiographic core laboratory reviewed all baseline angiograms and categorized the bifurcations according to the Medina classification.[8] A post hoc analysis was performed among the cohort of patients with bifurcation lesions confirmed by the angiographic core laboratory. Clinical follow-up occurred at discharge, 30 days, 6 months, and 1, 2, and 3 years. The primary analysis was at 1-year follow-up, and follow-up to 3 years presented in this study.

Statistical analysis

The primary end point of TVF at 1 year in the intention-to-treat population was compared with a performance goal of 24.5%. A binomial exact method was used to calculate a 1-sided upper bound of the 95% CI of the observed 12-month TVF rate. If the upper limit of the 95% CI was $<$24.5%, the primary end point was considered met. This performance goal was derived based on the assumption that the weighted average of 1-year outcomes in patients in the bifurcation cohort after DES implantation was 16.3%,[9,10] and the performance goal was set at 50% above the expected rate. Assuming 10% of patients would be lost to follow-up and a 1-sided 0.05 level of significance, a sample size of 200 patients was required to yield $>$85% power to reject the null hypothesis at a 1-sided 0.05 level of significance.

The intention-to-treat population was the primary analysis population. A post hoc analysis was performed in the cohort with angiographic core laboratory-confirmed bifurcation lesions.

Continuous variables are presented as mean $\pm$ SD or median and interquartile range, and categorical variables are presented as counts and percentages. Clinical outcomes are presented as observed rates and as estimates using the Kaplan-Meier method. All analyses were performed using SAS version 9.4.

Results

Baseline clinical and lesion characteristics

Patient flow through the study is shown in Figure 1. A total of 205 patients with 267 lesions were enrolled at 21 centers in the United States and 4 centers in Europe. Baseline characteristics of the study population are listed in Table 1. The mean age of the cohort was 66.6 $\pm$ 10.7 years, 21.5% of patients were female, and 30.2%

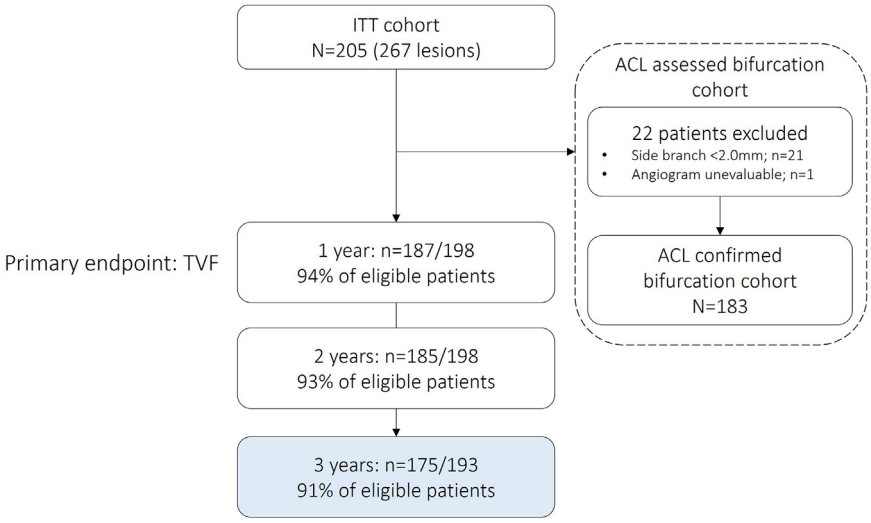


Figure 1.
Patient flow. ACL, angiographic core laboratory; ITT, intention to treat; TVF, target-vessel failure.

presented with diabetes mellitus. The indication for the index revascularization was acute coronary syndrome in 47% of patients. One or more non-bifurcation lesions were treated in addition to a bifurcation lesion in 27.3% of cases. Lesion characteristics are listed in Table 2. Target lesions were complex (95.9% class B2/C) and 33.5% had moderate/severe calcification. Follow-up compliance at 30 days, 6 months, and 1, 2, and 3 years was 89.8%, 91.6%, 94.4%, 93.4%, and 90.7%. At 1-year, 2-year, and 3-year follow-up, 86.4%, 59.2%, and 51.3% were being treated with dual antiplatelet therapy (DAPT), respectively.

Procedural characteristics

Radial access was used in 61.9% of cases. Including non-bifurcation lesions, an average of 1.3 ± 0.6 lesions were treated, and 1.6 ± 0.9 stents were used per patient. Atherectomy was performed in 17 of 209 lesions (8.2%). Resolute Onyx ZES was implanted in all cases. There were no perforations or residual dissections, and final TIMI 3 flow was present in 99.6%. Lesion success was 98.9%, device success 97.3%, and procedure success 96.6%.

Table 1. Baseline patient characteristics of the intention-to-treat cohort.

Baseline characteristic	N = 205
Age, y	66.6 ± 10.7
Female sex	21.5 (44/205)
Body mass index, kg/m^2	29.4 ± 5.7
Race[a]	
White	82.4 (159/193)
Black or African American	5.7 (11/193)
Asian	4.1 (8/193)
Other	7.8 (15/193)
Ethnicity[a]	
Hispanic/Latino	6.2 (12/194)
Diabetes mellitus	30.2 (62/205)
Hyperlipidemia	74.1 (152/205)
Hypertension	77.1 (158/205)
Current smoker	14.1 (29/205)
Previous myocardial infarction	19.5 (40/205)
Previous percutaneous coronary intervention	35.1 (72/205)
Previous CABG	9.3 (19/205)
Stroke or transient ischemic attack	7.3 (15/205)
Chronic obstructive pulmonary disease	10.2 (21/205)
Multivessel disease	38.0 (78/205)
Clinical evidence	
Silent ischemia	14.2 (27/190)
Stable angina	36.3 (69/190)
Acute coronary syndrome	47.4 (90/190)
STEMI, within 72 h	3.7 (7/190)
Non-STEMI, within 72 h	3.7 (7/190)
Unstable angina	36.8 (70/190)

Values are mean ± SD or % (n/N).
CABG, coronary artery bypass graft; STEMI, ST-elevation myocardial infarction.
[a] Race and ethnicity were not reported by patients in countries where prohibited by law.

Table 2. Procedural and lesion characteristics in the intention-to-treat cohort.

Characteristic	N = 205 patients/ N = 267 lesions
Vascular access	
Femoral	37.7 (81/215)
Radial	61.9 (133/215)
Brachial	0.5 (1/215)
Total procedure time, min	50.9 ± 31.3
Total fluoroscopy time, min	19.6 ± 14.5
Lesions treated/patient	1.3 ± 0.6
Stents implanted/patient	1.6 ± 0.9
Total stent length/patient, mm	36.3 ± 22.0
B2/C lesion class	95.9 (256/267)
Moderate/severe calcification	33.5 (89/266)
No. of stents implanted per subject (Overall)	1.6 ± 0.9
No. of stents implanted per subject (in bifurcation lesion [site])	1.2 ± 0.6
Lesion success[a]	98.9 (261/264)
Device success[b]	97.3 (257/264)
Procedure success[c]	96.6 (196/203)

Values are mean ± SD or % (n/N).
[a] The attainment of <30% residual stenosis by quantitative coronary angiography (QCA; or <20% by visual assessment) and thrombolysis in myocardial infarction (TIMI) flow 3 after the procedure, using any percutaneous method. [b] The attainment of <30% residual stenosis by QCA (or <20% by visual assessment) and TIMI flow 3 after the procedure, using the assigned device only. [c] The attainment of <30% residual stenosis by QCA (or <20% by visual assessment) and TIMI flow 3 after the procedure, using any percutaneous method without the occurrence of major adverse cardiac events during the hospital stay.

Clinical outcomes

The primary end point of the study, the rate of TVF at 1 year, was 7.4%, fulfilling the prespecified performance criterion (upper 1-sided 95% confidence interval of 11.1%, compared with the performance goal of 24.5%). The 1-year rate of TLF was 6.9%, target-vessel MI was 2.9%, CD-TLR was 3.4%, and cardiac death was 1.5%.

Clinical outcomes over complete follow-up are shown in Figure 2 and Central Illustration. The rate of TVF at 2 years was 9.4% and at 3 years 12.1%; the rate of TLF at 2 years was 8.4% and at 3 years 10.1%; the rates of target-vessel MI at 2 and 3 years were both 4.0%; and the rate of CD-TLR at 2 years was 5.0% and at 3 years 6.0%. There were no differences in the 3-year rate of TVF stratified by diabetic status (difference between patients with diabetes and those without diabetes, −4.6%; 95% CI, −13.8% to 4.6%; $P = .47$) or sex (difference between male and female patients, −2.0%; 95% CI, −13.3% to 9.3%; $P = .79$). There were no episodes of acute, early, late, or very late stent thrombosis related to a target lesion over follow-up.

Core laboratory-confirmed bifurcation lesion analysis

The angiographic core laboratory confirmed the presence of a bifurcation target lesion in 183 patients. In these patients, 209 target lesions (including non-bifurcation lesions) were treated. Among the 22 patients (10.7%) who did not meet bifurcation criteria, 21 patients showed a side branch diameter of ≤1.5 mm, and in 1 patient, the angiogram was unavailable. The mean patient age among the confirmed bifurcation group was 66.5 ± 10.9 years, 20.2% were female, and diabetes mellitus was present in 28.4%. The baseline characteristics of this cohort (Supplemental Table S2) were comparable with that of the full cohort. The bifurcation target lesion involved the left anterior descending artery in 55.0% of patients, the left circumflex artery in 25.8% of patients, the right coronary artery in 16.7% of patients, and the left main coronary artery in 2.4% of patients. The mean lesion length within the main vessel was 17.7 ± 10.2 mm, the mean RVD of the main vessel was 2.7 ± 0.5 mm, and the mean diameter stenosis was 65.3 ± 12.6%. The mean RVD of the side branch was 2.0 ± 0.5 mm (Table 3). The angiographic core laboratory classified 68 lesions in 62 patients (34%) as true (ie, with a >50% stenosis of both the main vessel and side branch—Medina classification 1,1,1; 1,0,1; or 0,1,1), whereas 132 lesions in 119 patients (65%) were nontrue bifurcation lesions. Among the true bifurcations, the mean side branch stenosis was 61.0% ± 23.2%, whereas among the nontrue bifurcations, the mean side branch stenosis was 8.6 ± 15.7%. A single stent was implanted within the bifurcation in 96.2% of patients, whereas in 3.4%, a stent was subsequently implanted within the side branch. A final kissing balloon inflation was performed in 18.2% of procedures. At 3-year follow-up, the rate of TVF was 13.0%, the rate of TLF was 10.7%, and the rate of clinically driven TLR was 6.2%. There were no statistically significant differences in the rates of clinical outcomes according to the presence or absence of a true bifurcation (Supplemental Table S3).

Discussion

Bifurcation lesions are commonly encountered during PCI and increase procedural complexity regarding requiring a more demanding technical approach and being associated with increased early-term and long-term adverse clinical outcomes. In general, baseline lesion characteristics dictate the choice of technique—that is, provisional stenting of the side branch versus upfront use of 2 stents—whereas clinical outcomes are likely influenced by both the technique that is applied and the type of stent that is implanted. In this prospective study, we evaluated the safety and clinical effectiveness of the Resolute Onyx ZES in patients who underwent bifurcation lesion PCI with a planned provisional stenting approach. Our main findings are that over 3 years of follow-up, the Resolute Onyx ZES was safe, with no episodes of stent thrombosis associated with a target lesion, and was associated with low rates of adverse clinical events, with only 6% of patients requiring clinically driven TLR. These favorable clinical outcomes support the longer-term safety and effectiveness of the Resolute Onyx ZES in this complex lesion subset and further reinforce provisional stenting of the side branch as the preferred technique to treat bifurcation lesions with suitable anatomic characteristics.

The optimal stent technique to treat a bifurcation lesion has been a topic of intense debate. The most appropriate PCI strategy is dictated

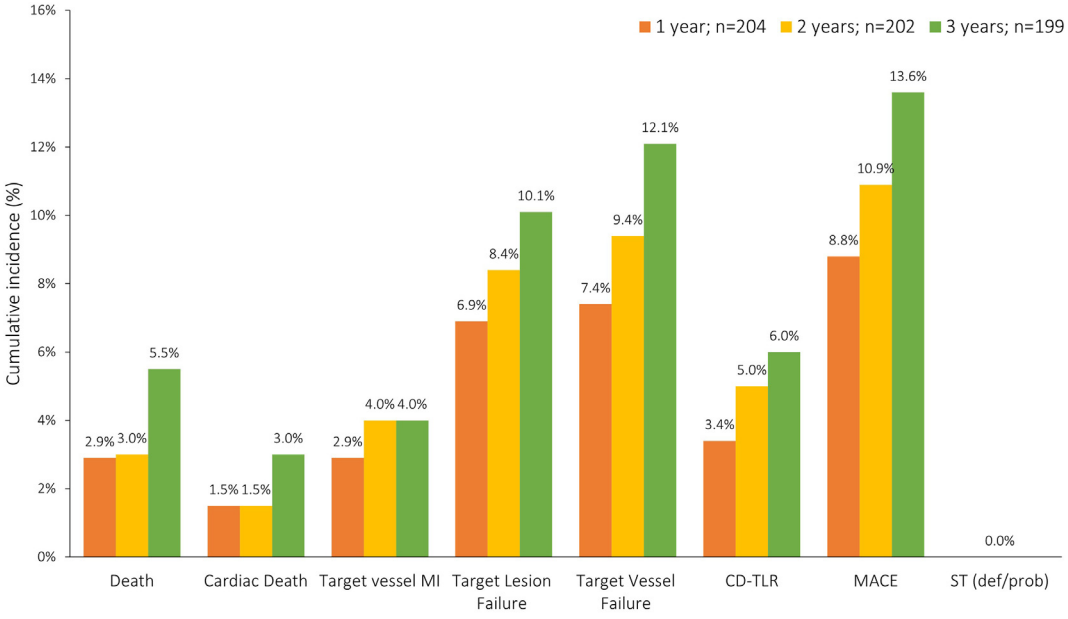
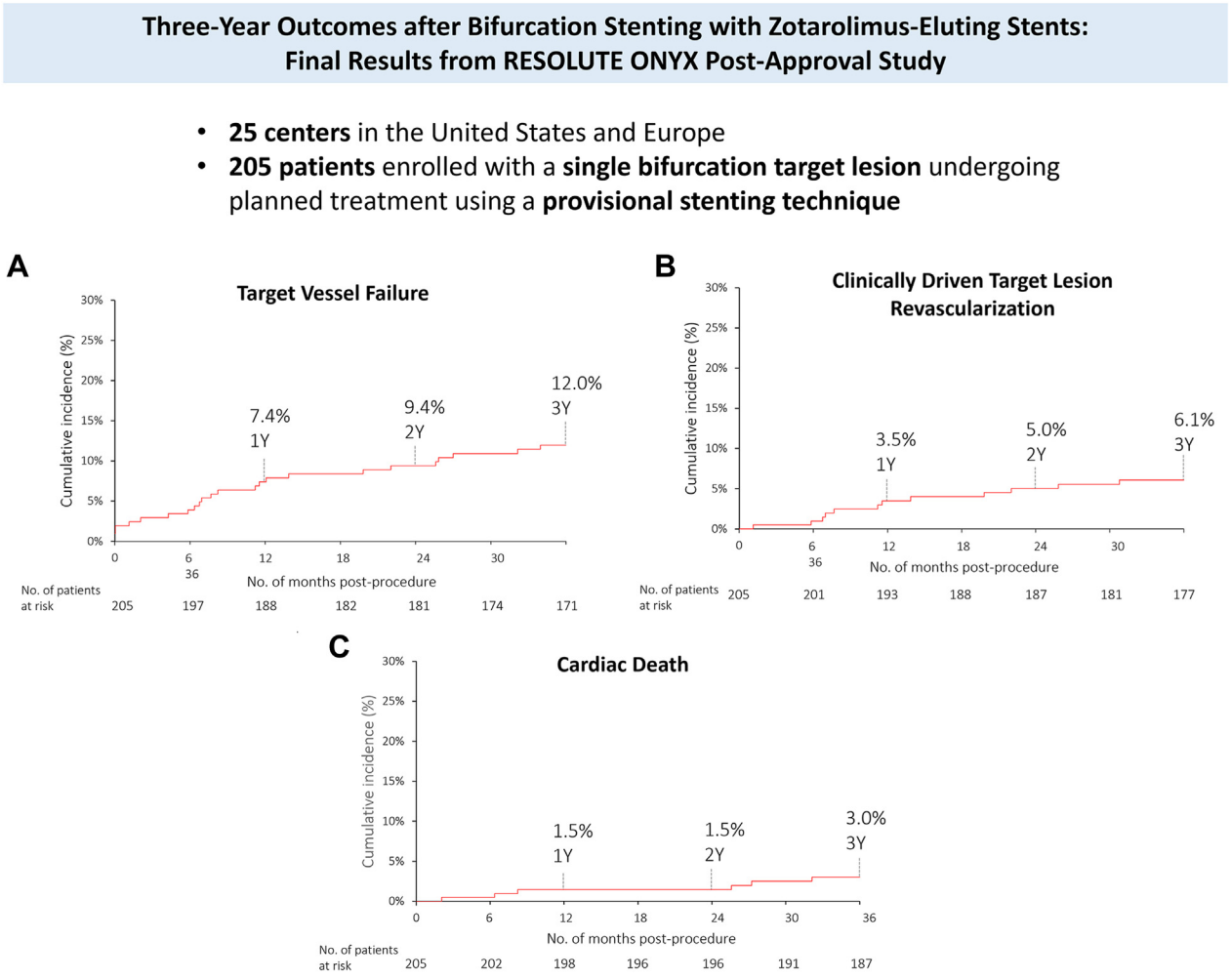


Figure 2.
Observed rates of clinical end points at 1-, 2-, and 3-year follow-up. ST rates refer to those associated with a target lesion. CD-TLR, clinically driven target-lesion revascularization; MACE, major adverse cardiovascular events; MI, myocardial infarction; ST, stent thrombosis; TLF, target-lesion failure; TVF, target-lesion failure; TVR, target-vessel revascularization.



Central Illustration.

Cumulativeevent rates after bifurcation lesion PCI with Resolute Onyx DES over 3-year follow-up according to the Kaplan-Meier method. (**A**) Rate of TVF, (**B**) Rate of clinically driven TLR, (**C**) Rate of cardiac death. CD-TLR, clinically driven target lesion revascularization. DES, drug-eluting stent; PCI, percutaneous coronary intervention; TVF, target vessel revascularization.

by several anatomical factors, including but not limited to plaque location and burden, the diameter and angle of the side branch, the bifurcation site, and the presence of more than 2 branches.[11] The 2018 European Society of Cardiology Guidelines on Myocardial Revascularization state that provisional stenting of the side branch should be the preferred approach for most bifurcation lesions, except in cases of a large side branch (≥2.75 mm in diameter) with a long ostial side branch lesion (>5.0 mm in length), anticipated difficulty in accessing an important side branch after stenting of the main vessel, or a true distal left main bifurcation.[2] In this study, patients were eligible to be enrolled if the operator believed the lesion was suitable to be treated with a provisional stent technique. The QCA findings of the angiographic core laboratory-confirmed bifurcation lesions support that provisional stenting was the preferred approach for the lesions that were treated because the target lesion side branches were generally small (mean RVD, 1.99 ± 0.46) and often not severely diseased (true bifurcation lesions according to the Medina classification in 34%).

The excellent acute performance of the Resolute Onyx ZES in this lesion subset is supported by the high rates of procedure success (97%) and the infrequent need for stenting of the side branch (performed in only 3.4%). At 1 year, the rates of CD-TLR and TLF were 3.4% and 6.9%, which are similar to the 1-year rates of these end points in the FDA registration study for the Resolute Onyx ZES (4.0% and 6.7%, respectively), which excluded bifurcation lesions.[4] This suggests that, at least with the stent used in this study, contemporary outcomes for bifurcation lesions believed to be amenable to provisional stenting may be broadly similar to that of non-bifurcation lesions. The Resolute Onyx ZES was also highly effective at longer-term follow-up, with extremely low rates of CD-TLR at 3 years and a numerical increase of only 1% in CD-TLR beyond 2-year follow-up. Importantly, clinical outcomes with Resolute Onyx ZES were not significantly different between patients with and without true bifurcations according to the Medina classification, suggesting consistent efficacy of Resolute Onyx ZES across the spectrum of anatomic complexity of lesions suitable for provisional side branch stenting. However, the number of patients included in the study are too small to draw definitive conclusions, and in an observational registry of patients undergoing PCI with a bioresorbable polymer sirolimus eluting stent, Medina classification–defined true bifurcations were associated with a significantly higher rate of TVF and a numerically higher rate of CD-TLR compared with nontrue bifurcations at 1-year follow-up.[8]

The clinical event rates we observed after planned provisional stenting with the Resolute Onyx ZES are generally lower than that reported in previous studies of bifurcation PCI using other types of DES, although cross-study comparisons are particularly challenging in this context given the influence of lesion characteristics on both the choice of stent technique and outcomes. For example, in a recent meta-analysis of 21 randomized controlled trials, which evaluated clinical outcomes of a variety of bifurcation techniques, the rate of TLR

Table 3. Procedural and lesion characteristics in the cohort with confirmed bifurcations according to the angiographic core laboratory

Lesion characteristics	N = 183 patients/ N = 209 lesions[a]
Medina classification	
True bifurcation	
1,1,1	22.5 (47/209)
0,1,1	6.7 (14/209)
1,0,1	3.3 (7/209)
Other bifurcation	
0,1,0	26.3 (55/209)
1,1,0	23.9 (50/209)
1,0,0	15.3 (32/209)
0,0,1	0.5 (1/209)
Vessel location (lesion level)	
Left anterior descending	55.0 (115/209)
Left circumflex	25.8 (54/209)
Right coronary	16.7 (35/209)
Left main (protected)	2.4 (5/209)
Moderate/severe calcification	35.9 (75/209)
Type C lesion class	100.0 (209/209)
Predilation	16.7 (35/209)
Proximal optimization technique performed	96.2 (176/183)
Stent postdilation	71.8 (150/209)
Final kissing balloon	18.2 (38/209)
Main vessel stenting only	96.6 (198/205)
Side branch (bailout) stenting	3.4 (7/205)
Main vessel	
RVD, mm	2.71 ± 0.47
% Diameter stenosis	65.3 ± 12.6
Lesion length, mm	17.7 ± 10.2
Side branch	
RVD, mm	1.99 ± 0.46
% Diameter stenosis	27.2 ± 31.3

RVD, reference vessel diameter.

[a] Three of the 209 lesions assessed by angiography core laboratory were determined to have Medina classification of 0,0,0.

in patients receiving provisional stenting was 9.9% over a median follow-up of 1 year, and stent thrombosis occurred in 1.5%.[12] However, these patients more frequently had larger side branch RVD and greater average side branch percentage of stenoses than the patients enrolled in this study. These differences in lesion characteristics are likely in large part explained by our study protocol, which excluded patients in whom the operator thought an upfront 2-stent strategy was warranted. Similarly, in the DEFINITION II randomized trial, the 1-year and 3-year rates of TLF among patients randomly assigned to provisional stenting with a range of DES types were 11.4% and 16.0%, respectively, [13,14] higher than those observed in the current study (6.9% and 10.1%, respectively). In contradistinction, the rates of adverse clinical events in our study were similar to that of a recent report of the Korean Coronary Bifurcation Stenting registries, in which the 2-year rate of TVF among patients undergoing a single stent strategy in the contemporary era was 6.4%.[15] The technical approach to the provisional stenting in that registry was also comparable with that of our study, with ~20% of patients receiving final kissing balloon dilation (compared with 18.2% in this study).

Continued clinical follow-up beyond 1 year after DES is critical, as late TLR and the occurrence of very late stent thrombosis are well-known phenomena in older-generation DES. This may be particularly problematic in bifurcation lesions, given the risks for stent underexpansion, stent deformation, gross stent malapposition, uncovered struts, and residual disease in this lesion subset. Our study provides novel insights into the longer-term follow-up of the Resolute Onyx ZES in bifurcation lesions because we followed patients through 3 years postprocedure. Stent-related adverse events appeared to plateau beyond 2 years: the major differences in outcomes between 2 and 3 years were driven by cardiac death (from 1.5% to 3.0%), whereas there were no differences in target-vessel related myocardial infarction, no stent thromboses, and little increase in CD-TLR (from 5% to 6%). The prolonged follow-up of our cohort therefore provides 2 key insights: first, there was little attrition in stent-related clinical outcomes with Resolute Onyx beyond 2 years, and second, the risk of very late stent thrombosis remained very low, with no observed episodes of stent thrombosis attributable to the study stent.

Limitations

Study enrollment required that the target lesion was suitable for provisional side branch stenting according to the operator, and therefore, the observed results may not be applicable to bifurcations that require an upfront (preplanned) 2-stent technique. In some cases, the interpretation of what constituted a bifurcation lesion differed between sites and the angiographic core laboratory. However, our study is strengthened by 2 analyses: the primary analysis, which included study-site defined bifurcation lesions, reflects current clinical practice, whereas the additional analysis of core laboratory-confirmed bifurcations provides additional scientific rigor. Some patients received additional stenting of non-bifurcation lesions, which may confound interpretation of the results; however, this again reflects real-world practice. The angiographic core laboratory did not measure lesion length of the side branch, which would have provided additional granularity regarding the anatomic complexity of the treated lesions. The use of intravascular imaging guidance was not formally collected, and therefore, we cannot determine whether intravascular imaging contributed to the observed outcomes. The prolonged use of DAPT in the majority of patients might have contributed to the lack of stent thrombosis events, although abbreviated DAPT appeared safe after PCI with Resolute Onyx ZES for anatomically complex lesions in patients with high-bleeding risk.[16] The proportions of patients with diabetes and female patients in our study population limit our ability to robustly define the influence of these baseline characteristics on clinical outcomes after bifurcation PCI with the Resolute Onyx ZES. Our results apply to the Resolute Onyx ZES and may not apply to other stent platforms.

Conclusions

Bifurcation lesion treatment with Resolute Onyx ZES using a planned provisional stent approach was associated with favorable clinical outcomes through 3 years, with no episodes of stent thrombosis. These results support the longer-term safety and effectiveness of Resolute Onyx ZES to treat bifurcation lesions that are amenable to planned provisional side branch stenting.

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Declaration of competing interest

Matthew Price reports consulting honoraria, speaker's fees, and proctoring fees from Abbott Vascular and Boston Scientific, consulting honoraria from W.L. Gore, Biotronik, and Philips Medical, consulting honoraria and speaker's fees from Medtronic, and consulting honoraria from Shockwave. Joseph Dens receives speaker fees and proctoring fees from Asahi Intec and Boston Scientific and speaker fees from Abbott Vascular, Asahi Intecc, Boston Scientific, Medtronic, and Terumo. Patrick Hu is a proctor and consultant for Abiomed and CSI. Ronald Caputo reports consulting for Cordis and Opsens and equity interest in Transluminal Technologies. Michelle Dauler is an employee of Medtronic. Sherif Ibrahim is an employee of Medtronic. Te-Hsin Lung is an employee

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Ethics statement and patient consent

All patients provided written informed consent. The study adhered to the Declaration of Helsinki and was approved by the institutional review board or ethics committee at each study center.

Supplementary material

To access the supplementary material accompanying this article, visit the online version of the *Journal of the Society for Cardiovascular Angiography & Interventions* at 10.1016/j.jscai.2023.101116.

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