Title

One-Year Outcomes of Orbital Atherectomy of Long, Diffusely Calcified Coronary Artery Lesions.

Journal

Journal of Invasive Cardiology, 30(6)

ISSN

1042-3931

Authors

Lee, Michael S
Shlofmitz, Evan
Lluri, Gentian
et al.

Publication Date

2018-06-01

Peer reviewed

One-Year Outcomes of Orbital Atherectomy of Long, Diffusely Calcified Coronary Artery Lesions

Michael S. Lee, MD[1]; Evan Shlofmitz, DO[2]; Gentian Lluri, MD, PhD[1]; Kyung Woo Park, MD, PhD[3]; John Hollowed, MD[2]; Richard Shlofmitz, MD[4]

ABSTRACT: Objectives. The aim of this study was to determine the clinical outcomes of patients with long, diffusely calcified coronary artery lesions who underwent orbital atherectomy. **Background.** The presence of severe coronary artery calcification increases the complexity of percutaneous coronary intervention. Orbital atherectomy of long, diffusely calcified lesions may increase the risk of periprocedural angiographic complications. Furthermore, the rate of ischemic complications, including target-vessel revascularization (TVR), in these long, calcified lesions is historically high. **Methods.** In this retrospective multicenter registry, which included 458 real-world patients who underwent orbital atherectomy, a total of 154 patients (33.6%) required a total stent length of ≥50 mm (long-stent group). The primary endpoint was the 1-year major adverse cardiac and cerebrovascular event (MACCE) rate, defined as the composite of death, myocardial infarction, TVR, and stroke. **Results.** The long stent group had a higher rate of perforation (1.9% vs 0.0%; *P*=.01) and dissection (2.6% vs 0.0%; *P*<.01). The primary endpoint was similar in the long and short groups (14.2% vs 11.5%, respectively; *P*=.40), as were the 1-year rates of death (2.6% vs 4.6%, respectively; *P*=.30), myocardial infarction (1.9% vs 1.6%, respectively; *P*=.80), TVR (9.7% vs 6.3%, respectively; *P*=.18), and stroke (1.3% vs 1.3%, respectively; *P*>.90). The stent thrombosis rate was similar in both groups (1.3% vs 1.3%; *P*>.90). **Conclusions.** Despite the higher angiographic complication rates, orbital atherectomy of long, diffusely calcified lesions was associated with acceptable rates of ischemic complications in this challenging lesion subset at 1-year follow-up.

J INVASIVE CARDIOL 2018;30(6):230-233.
KEY WORDS: coronary calcium, orbital atherectomy

Percutaneous coronary intervention (PCI) of heavily calcified coronary artery lesions is technically challenging due to difficulty in stent delivery and achieving optimal stent expansion.[1] In addition to the lower procedural success rates, it is associated with higher rates of ischemic complications including death, myocardial infarction (MI), target-vessel revascularization (TVR), and stent thrombosis.[2,3]

In the ORBIT II trial, patients with heavily calcified coronary artery lesions who underwent orbital atherectomy (Cardiovascular Systems, Inc [CSI]) had low rates of ischemic complications at 30 days and 3 years.[4,5] However, patients with long target lesion length (>40 mm) were excluded from the trial. Long lesions, which suggest a more aggressive and extensive form of atherosclerosis, are commonly excluded from clinical trials because they are associated with worse clinical outcomes. Long lesion length is an independent predictor of worse clinical outcomes including TVR.[6-11]

The outcomes of orbital atherectomy in long, diffusely calcified coronary artery lesions are unknown. In this retrospective analysis, we present the safety and efficacy of orbital atherectomy in long, diffusely calcified lesions.

Methods

Study population. This multicenter registry included 458 real-world patients who underwent orbital atherectomy between October 2013 and December 2015 at three centers (UCLA Medical Center in Los Angeles, California, St. Francis Hospital in Roslyn, New York, and Northwell Health in Manhasset, New York). *Severe coronary artery calcification* was defined as the fluoroscopic presence of radiopacities involving the vessel wall, or ≥270° calcification present on intravascular imaging. The long-stent group (≥50 mm) comprised 154 patients and the short-stent group (<50 mm) comprised 304 patients. The institutional review board at each site approved the review of the data.

Device description. The coronary orbital atherectomy device changes lesion compliance to facilitate stent expansion with an eccentrically mounted 1.25 mm crown that is coated with 30 micron diamonds. The crown rotates on a 0.014″ ViperWire (CSI) and orbits bidirectionally while expanding laterally with centrifugal force. The ViperSlide lubricant (CSI) infuses through the drive shaft to cool the temperature while reducing the friction during device activation and advancement. The crown flexes away from soft tissue to minimize the damage to the media of the vessel wall.

Procedure and adjunctive pharmacotherapy. Standard techniques were used for PCI. All patients underwent initial atherectomy at low speed (80,000 rpm). High-speed atherectomy (120,000 rpm) was performed at the operator's discretion if the reference vessel diameter was ≥3 mm. The operator advanced the crown at 1 mm/second and limited each pass to 20 seconds. The operator had the discretion to choose the stent type, antithrombotic and antiplatelet regimen, hemodynamic support device, and intravascular imaging.

Table 1. Baseline characteristics.

	Long (≥50 mm) (n = 154)	Short (<50 mm) (n = 304)	*P*-Value
Age (years)	74.6 ± 9.5	72.0 ± 10.7	.04
Male	114 (74.0%)	200 (65.8%)	<.01
Diabetes mellitus	69 (44.8%)	126 (41.4%)	.20
Hypertension	103 (66.9%)	266 (87.5%)	<.01
Hypercholesterolemia	124 (80.5%)	240 (67.1%)	<.01
Smoking (current)	12 (7.8%)	9 (3.0%)	.10
Chronic kidney disease	31 (20.1%)	57 (18.8%)	.70
Ejection fraction (%)	50.6 ± 12.8	52.6 ± 10.5	.20
History of myocardial infarction	26 (16.9%)	45 (14.8%)	.50
Previous PCI	55 (35.7%)	108 (35.5%)	.90
Previous coronary artery bypass grafting	28 (18.2%)	49 (16.1%)	.50
Clinical presentation			.03
Elective	23 (14.9%)	66 (21.7%)	
Acute coronary syndrome	131 (85.1%)	238 (78.3%)	

Data provided as number (%) or mean ± standard deviation.
PCI = percutaneous coronary intervention.

Table 2. Angiographic and procedural characteristics.

	Long (≥50 mm) (n = 154)	Short (<50 mm) (n = 304)	*P*-Value
Total stents/case (n)	3.2 ± 1.2	1.5 ± 0.7	<.01
Total stent length (mm)	71.4 ± 21.8	29.7 ± 11.0	<.01
Maximum inflation pressure (atm)	17.0 ± 4.5	16.1 ± 3.9	.07
Total passes (n)	4.8 ± 3.3	3.8 ± 2.3	.03
Total volume of contrast used (mL)	221.9 ± 107.4	170.2 ± 77.1	<.01
Total fluoroscopy time (min)	27.2 ± 16.7	19.1 ± 17.6	<.01
Heparin	118 (76.7%)	238 (78.3%)	.70
Glycoprotein IIb/IIIa inhibitor	11 (7.1%)	3 (1.0%)	<.01
Temporary pacemaker	12 (7.8%)	15 (4.9%)	.20
Intravascular imaging	35 (22.7%)	76 (25.0%)	.40
Hemodynamic support device	18 (11.7%)	6 (2.0%)	<.01
Intraaortic balloon pump	10 (6.5%)	4 (1.3%)	
Impella	7 (4.5%)	2 (0.7%)	
ECMO	1 (0.6%)	0 (0.0%)	

Data provided as number (%) or mean ± standard deviation.
ECMO = extracorporeal membrane oxygenation.

Endpoints. The *primary endpoint* was the 1-year major adverse cardiac and cerebrovascular event (MACCE) rate, defined as the occurrence of death, MI, TVR, and stroke. *Myocardial infarction* was defined as recurrent ischemic symptoms with new ST-segment elevation or re-elevation of cardiac biomarkers >2 times the upper limit of normal. *Target-vessel revascularization* was defined as percutaneous or surgical revascularization of the target vessel. *Stent thrombosis* was defined per the Academic Research Consortium.[12] Baseline patient data and clinical outcomes were obtained from medical records and entered into a dedicated PCI database.

Statistical analysis. Continuous variables are presented as mean ± standard deviation and compared using the Wilcoxon rank-sum test, while categorical variables are presented as percentages and compared using Fisher's exact test. A *P*-value <.05 was considered statistically significant. Statistical analyses were performed using SAS 9.1 (SAS Institute, Inc).

Results

Baseline demographic and procedural characteristics. The long-stent group patients were older and had a higher prevalence of male gender, hypercholesterolemia, and presentation with acute coronary syndrome, but a lower prevalence of hypertension (Table 1). The long-stent group had more stents used per case, longer total stent length, higher number of passes, higher volume of contrast, longer fluoroscopy time, and higher use of glycoprotein IIb/IIIa inhibitor and hemodynamic support device (Table 2).

Procedural results. The long-stent group had higher rates of perforation (1.9% vs 0%; *P*=.01) and dissection (2.6% vs 0%; *P*<.01). The rate of no-reflow was non-significantly higher in the long-stent group (1.9% vs 0.3%; *P*=.08). No stents were lost in either group.

One-year clinical outcomes. The long stent and short-stent groups had similar rates of the primary endpoint of MACCE (14.2% vs 11.5%, respectively; *P*=.40) as well as the individual endpoints of death (2.6% vs 4.6%, respectively; *P*=.30), MI (1.9% vs 1.6%, respectively; *P*=.80), TVR (9.7% vs 6.3%, respectively; *P*=.20), and stroke (1.3% vs 1.3%, respectively; *P*>.90). Stent thrombosis was similar in both groups (1.3% vs 1.3%; *P*>.90).

Discussion

In the only analysis of its kind, the main finding was that the treatment of long diffusely calcified lesions with orbital atherectomy was associated with higher rates of perforation and dissection. However, the primary endpoint as well as the individual endpoints at 1 year were similar in both groups.

The presence of severe coronary artery calcification increases the technical difficulty of PCI. The extent of calcification has been shown to correlate directly with the rate of adverse cardiac events, including death, TVR, and stent thrombosis.[13-22] The orbital atherectomy system has been shown successful for the treatment of calcified coronary lesions.[4,23] However, there

Table 3. Angiographic complications.

	Long (≥50 mm) (n = 154)	Short (<50 mm) (n = 304)	*P*-Value
Perforation	3 (1.9%)	0 (0.0%)	.01
Cardiac tamponade	3 (1.9%)	0 (0.0%)	.01
Dissection	4 (2.6%)	0 (0.0%)	<.01
No reflow	3 (1.9%)	1 (0.3%)	.08
Stent loss	0 (0.0%)	0 (0.0%)	>.90

Data provided as number (%).

Table 4. One-year clinical event rates.

	Long (≥50 mm) (n = 154)	Short (<50 mm) (n = 304)	*P*-Value
MACCE	22 (14.2%)	35 (11.5%)	.40
Death	4 (2.6%)	14 (4.6%)	.30
Myocardial infarction	3 (1.9%)	5 (1.6%)	.80
Target-vessel revascularization	15 (9.7%)	19 (6.3%)	.20
Stroke	2 (1.3%)	4 (1.3%)	>.90
Stent thrombosis	2 (1.3%)	4 (1.3%)	>.90
Emergent coronary artery bypass grafting	0 (0.0%)	1 (0.3%)	>.90

Data provided as number (%).
MACCE = major adverse cardiac and cerebrovascular events.

are no data on the outcomes of orbital atherectomy of long calcified lesions. The mean lesion length in the ORBIT II trial was 18.9 ± 0.4 mm.[4] In the ROTAXUS trial, the mean total stent length in patients who underwent rotational atherectomy was 27.7 ± 12.2 mm.[24]

Long coronary lesions, generally considered at least >20 mm in length, comprise a significant component of current interventional practice. In our study, over one-third of the patients who underwent orbital atherectomy had diffuse long-segment disease that required ≥50 mm of stent. Therapeutic management of patients with long, diffusely calcified coronary artery lesions is particularly challenging. Historically, these patients were commonly referred for surgical revascularization due to ineffective stent delivery, suboptimal stent expansion, and high restenosis rates. Due to advancements in stent technology and operator skill, PCI has become a viable option in recent years for this complex lesion subset. However, there continues to be a tremendous need for modalities that can modify diffusely calcified plaque prior to stent delivery and optimal stent expansion. Extensive ablation of long lesions can increase the risk of periprocedural complications, including perforation and dissection. Furthermore, distal embolization can lead to microvascular plugging, vasospasm, and platelet aggregation, leading to slow/no-reflow and MI.

This lesion subset creates not only technical difficulties, but is also associated with worse clinical outcomes, including higher target-lesion revascularization rates.[6-11] Those that also require long stent deployment or multiple overlapping stents are associated with a higher risk of in-stent restenosis.[25-27] The increased risk of restenosis within long stents in diffusely diseased vessels has led to operator avoidance of stent placement.[28] This makes utilizing strategies to optimally modify target-vessel lumens prior to stent deployment integral in providing the best chance at long-term angiographic success. Yet, even in the current era, when there are many different modalities to approach long coronary lesions, effective management remains a challenging clinical question.

Various devices are available to treat long complex coronary lesions, each with advantages and disadvantages and variable rates of success. This includes rotational atherectomy and excimer-laser angioplasty, with no clear advantage with one over the other.[13-18] In this analysis, orbital atherectomy of heavily calcified diffuse coronary artery lesions (total stent length ≥50 mm) prior to stenting resulted in higher rates of perforation (1.9% vs 0%; *P*=.01) and dissection (2.6% vs 0%; *P*<.01). These results are not unexpected, given that these patients had more aggressive coronary atherosclerosis and required more extensive atheroablation, therefore increasing risk. There was also a trend toward a higher rate of no-reflow in the long-stent group (1.9% vs 0.3%; *P*=.08). However, despite the higher angiographic complication rates, the primary endpoint and the individual endpoints of death, MI, TVR, and stroke did not significantly differ between the two groups. Another significant finding was that no patient in the short-stent group experienced perforation and dissection, demonstrating the safety and efficacy of orbital atherectomy in the treatment of shorter lesions.

Long, diffusely calcified lesions are commonly thought to be unamenable to PCI due to the difficulty in stent delivery and optimal expansion as well as high rates of in-stent restenosis. The 1-year TVR rate in the long-stent group was numerically higher in our study (9.7%) compared with the patients who underwent orbital atherectomy in the ORBIT II trial (5.9%), which excluded patients with lesions >40 mm.[29] However, the 1-year TVR rate in the long-stent group fared well compared with the 9-month TVR rate of 16.7% in patients who underwent rotational atherectomy in the ROTAXUS trial.[24] No patient in our study experienced stent loss.

There were significant differences in baseline characteristics. The long-stent group was older and had more of males, history of hypercholesterolemia, and patients presenting with acute coronary syndrome. As expected, the long-stent group required a higher number of passes, higher volume of contrast, longer fluoroscopy time, and higher use of glycoprotein IIb/IIIa inhibitor and hemodynamic support device, which highlights the increased technical complexity of the lesion subset.

Study limitations. This was a retrospective analysis with short-term follow-up. Longer-term follow-up is needed to determine the durability of orbital atherectomy. The long-stent

group represented the minority of those in this registry. There were significant differences in baseline and procedural characteristics, which likely led to confounding. Coronary angiography was not reviewed by an angiographic core laboratory. Quantitative coronary analysis was not performed. The incidence of MI was likely under-diagnosed, as cardiac biomarkers were not obtained on all patients post PCI.

Conclusion

Plaque modification of long, diffusely calcified coronary artery lesions with orbital atherectomy was associated with more angiographic complications, including coronary perforation and dissection. However, the rate of ischemic complications was similar to the short-stent group at 1-year follow. Meticulous technique is required to minimize the risk of procedural complications, particularly in patients with complex coronary anatomy. Orbital atherectomy is safe in patients who require stenting <50 mm in length.

References

1. Lee MS, Shah N. The impact and pathophysiologic consequences of coronary artery calcium deposition in percutaneous coronary interventions. *J Invasive Cardiol.* 2016;28:160-167.
2. Généreux P, Madhavan MV, Mintz GS, et al. Ischemic outcomes after coronary intervention of calcified vessels in acute coronary syndromes. Pooled analysis from the HORIZONS-AMI (Harmonizing Outcomes With Revascularization and Stents in Acute Myocardial Infarction) and ACUITY (Acute Catheterization and Urgent Intervention Triage Strategy) trials. *J Am Coll Cardiol.* 2014;63:1845-1854.
3. Lee MS, Yang T, Lasala J, Cox D. Impact of coronary artery calcification in percutaneous coronary intervention with paclitaxel-eluting stents: two-year clinical outcomes of paclitaxel-eluting stents in patients from the ARRIVE program. *Catheter Cardiovasc Interv.* 2016;88:891-897.
4. Chambers JW, Feldman RL, Himmelstein SI, et al. Pivotal trial to evaluate the safety and efficacy of the orbital atherectomy system in treating de novo, severely calcified coronary lesions (ORBIT II). *JACC Cardiovasc Interv.* 2014;7:510-518.
5. Lee MS, Genereux P, Shlofmitz R, et al. Orbital atherectomy for treating de novo, severely calcified coronary lesions: 3-year results of the pivotal ORBIT II trial. *Cardiovasc Revasc Med.* 2017;18:261-264
6. Kamineni R, Heuser RR. New approaches to long lesions. *J Interv Cardiol.* 2004;17:405-409.
7. Saucedo JF, Kennard ED, Popma JJ, et al. Importance of lesion length on new device angioplasty of native coronary arteries. NACI Investigators. New approaches to coronary interventions. *Catheter Cardiovasc Interv.* 2000;50:19-25.
8. Rensing BR, Hermans WRM, Vos J, et al. Luminal narrowing after percutaneous transluminal coronary angioplasty. A study of clinical, procedural, and lesional factors related to long-term angiographic outcomes. Coronary Artery restenosis Prevention on Repeated Thromboxane Antagonism (CARPORT) study group. *Circulation.* 1993;88:975-985.
9. Vandormael MG, Deligonul U, Kern MJ, et al. Multilesion coronary angioplasty: clinical and angiographic follow up. *J Am Coll Cardiol.* 1987;10:246-252.
10. Bourassa MG, Lesperance J, Eastwood C, et al. Clinical, physiologic, anatomic and procedural factors predictive of restenosis after percutaneous transluminal coronary angioplasty. *J Am Coll Cardiol.* 1991;18:368-376.
11. Kastrati A, Schömig A, Elezi S, et al. Predictive factors of restenosis after coronary stent placement. *J Am Coll Cardiol.* 1997;30:1428-1436.
12. Cutlip DE, Windecker S, Mehran R, et al; Academic Research Consortium. Clinical end points in coronary stent trials: a case for standardized definitions. *Circulation.* 2007;115:2344-2351.
13. Tan K, Sulke N, Taub N, et al. Clinical and lesion morphologic determinants of coronary angioplasty success and complications: Current experience. *J Am Coll Cardiol.* 1995;25:855-865.
14. Teirstein PS, Warth DC, Haq N, et al. High-speed rotational disease. *J Am Coll Cardiol.* 1991;18:1694-1701.
15. Jiang J, Sun Y, Xiang M, et al. Complex coronary lesions and rotational atherectomy: one hospital's experience. *J Zhejiang Univ Sci B.* 2012;13:645-651.
16. Reifart N, Vandormael M , Krajcar M, et al. Randomized comparison of angioplasty of complex coronary lesions at a single center. Excimer laser, rotational atherectomy, and balloon angioplasty comparison (ERBAC) study. *Circulation*. 1997;96:91-98.
17. Hinohara T, Robertson GC, Selmon MR, et al. Restenosis after directional coronary atherectomy. *J Am Coll Cardiol*. 1992;20:623-632.
18. Kornowski R, Bhargava B, Fuchs S, et al. Procedural results and late clinical outcomes after percutaneous interventions using long (> or = 25 mm) versus short (<20 mm) stents. *J Am Coll Cardiol.* 2000;35:612-618.
19. Mintz GS. Intravascular imaging of coronary calcification and its clinical implications. *JACC Cardiovasc Imaging.* 2015;8:461-471.
20. Schlüter M, Cosgrave J, Tübler T, et al. Rotational atherectomy to enable sirolimus-eluting stent implantation in calcified, nondilatable de novo coronary artery lesions. *Vasc Dis Manage.* 2007;4:63-69.
21. Mosseri M, Satler LF, Pichard AD, et al. Impact of vessel calcification on outcomes after coronary stenting. *Cardiovasc Revasc Med.* 2005;6:147-153.
22. Benezet J, Diaz de la Llera LS, Cubero JM, et al. Drug-eluting stents following rotational atherectomy for heavily calcified coronary lesions: long-term clinical outcomes. *J Invasive Cardiol*. 2004;16:493-499.
23. Lee MS, Shlofmitz E, Kaplan B, Alexandru D, Meraj P, Shlofmitz R. Real-world multicenter registry of patients with severe coronary artery calcification undergoing orbital atherectomy. *J Interv Cardiol.* 2016;29:357-362.
24. Abdel-Wahab M, Richardt G, Joachim Büttner H, et al. High-speed rotational atherectomy before paclitaxel-eluting stent implantation in complex calcified coronary lesions: the randomized ROTAXUS (Rotational Atherectomy Prior to Taxus Stent Treatment for Complex Native Coronary Artery Disease) trial. *JACC Cardiovasc Interv.* 2013;6:10-19.
25. Mauri L. Effects of stent length and lesion length on coronary restenosis. *J Am Coll Cardiol*. 2004;93:1340-1346.
26. Kobayashi Y, De Gregorio J, Kobayashi N, et al. Stented segment length as an independent predictor of restenosis. *J Am Coll Cardiol.* 1999;34:651-659.
27. Lemos PA, Hoye A, Goedhart D, et al. Clinical, angiographic, and procedural predictors of angiographic restenosis after sirolimus-eluting stent implantation in complex patients: an evaluation from the Rapamycin-Eluting Stent Evaluated At Rotterdam Cardiology Hospital (RESEARCH) study. *Circulation.* 2004;109:1366-1370.
28. Degertekin M, Arampatzis CA, Lemos PA, et al. Very long sirolimus-eluting stent implantation for de novo coronary lesions. *J Am Coll Cardiol.* 2004;93:826-829.
29. Généreux P, Lee AC, Kim CY, et al. Orbital atherectomy for treating de novo severely calcified coronary narrowing (1-year results from the pivotal ORBIT II Trial). *Am J Cardiol.* 2015;115:1685-1690.

From the [1]Division of Interventional Cardiology, UCLA Medical Center, Los Angeles, California; [2]Division of Interventional Cardiology, Columbia University Medical Center, New York, New York; [3]Department of Internal Medicine, Cardiovascular Center, Seoul National University Medical Center, Seoul, South Korea; and [4]Division of Cardiology, St. Francis Hospital, Roslyn, New York.

Disclosure: The authors have completed and returned the ICMJE Form for Disclosure of Potential Conflicts of Interest. Drs Lee, E. Shlofmitz, and R. Shlofmitz report honoraria from Cardiovascular Systems, Inc. The remaining authors report no conflicts of interest regarding the content herein.

Manuscript submitted January 11, 2018, provisional acceptance given January 22, 2018, final version accepted February 6, 2018.

Address for correspondence: Dr Michael S. Lee, UCLA Medical Center, 100 Medical Plaza, Suite 630, Los Angeles, CA 90095. Email: mslee@mednet.ucla.edu