VIA MEDICA

ORIGINAL ARTICLE

Cardiology Journal
2021, Vol. 28, No. 2, 235–243
DOI: 10.5603/CJ.a2019.0111

ISSN 1897–5593
eISSN 1898–018X

Biodegradable polymer-coated thin strut sirolimus--eluting stent versus durable polymer-coated everolimus-eluting stent in the diabetic population

Pawel Gasior[1], Marek Gierlotka[2], Krzysztof Szczurek-Katanski[3], Marcin Osuch[3], Magda Roleder[1], Michal Hawranek[4], Wojciech Wojakowski[1], Lech Polonski[4]

[1]Division of Cardiology and Structural Heart Diseases, Medical University of Silesia, Katowice, Poland
[2]Department of Cardiology, University Hospital, Institute of Medical Sciences, University of Opole, Poland
[3]Scanmed, Gliwice, Poland
[4]3rd Department of Cardiology, School of Medicine with the Division of Dentistry in Zabrze, Medical University of Silesia, Katowice, Silesian Center for Heart Diseases, Zabrze, Poland

Abstract

Background: *The number of patients with diabetes mellitus (DM) presenting with coronary artery disease is increasing and accounts for more than 30% of patients undergoing percutaneous coronary interventions (PCI). The biodegradable polymer drug-eluting stents were developed to improve vascular healing. It was sought herein, to determine 1-year clinical follow-up in patients with DM treated with the thin strut biodegradable polymer-coated sirolimus-eluting stent (BP-SES) versus durable coating everolimus-eluting stent (DP-EES).*

Methods: *Patients were retrospectively analyzed with DM were treated with either a BP-SES (ALEX™, Balton, Poland, n = 670) or a DP-EES (XIENCE™, Abbott, USA, n = 884) with available 1 year clinical follow-up using propensity score matching. Outcomes included target vessel revascularization (TVR) as efficacy outcome and all-cause death, myocardial infarction, and definite/probable stent thrombosis as safety outcomes.*

Results: *After propensity score matching 527 patients treated with BP-SES and 527 patients treated with DP-EES were selected. Procedural and clinical characteristics were similar between both groups. In-hospital mortality was 3.23% in BP-SES vs. 2.09% in DP-EES group (p = 0.25). One-year follow-up demonstrated comparable efficacy outcome TVR (BP-SES 6.64% vs. DP-EES 5.88%; p = 0.611), as well as similar safety outcomes of all-cause death (BP-SES 10.06% vs. DP-EES 7.59%; p = 0.158), myocardial infarction (BP-SES 7.959% vs. DP-EES 6.83%; p = 0.813), and definite/probable stent thrombosis (BP-SES 1.14% vs. DP-EES 0.76%; p = 0.525).*

Conclusions: *The thin-strut biodegradable polymer coated, sirolimus-eluting stent demonstrated comparable clinical outcomes at 1-year after implantation to DP-EES. These data support the relative safety and efficacy of BP-SES in diabetic patients undergoing PCI.* (Cardiol J 2021; 28, 2: 235–243)

Key words: drug-eluting stents, percutaneous coronary intervention, diabetes mellitus

Introduction

The number of patients with diabetes mellitus (DM) presenting with coronary artery disease (CAD) is increasing and accounts for more than 30% of patients undergoing percutaneous coronary interventions (PCI) [1]. The pathophysiology associated with diabetic vasculopathy is multifactorial

Address for correspondence: Paweł Gąsior, MD, PhD, Division of Cardiology and Structural Heart Diseases, Medical University of Silesia, ul. Ziołowa 47, 40–635 Katowice, Poland, tel: +48 600 429 867, e-mail: p.m.gasior@gmail.com

Received: 19.06.2019 Accepted: 5.11.2019

and includes endothelial dysfunction, non-enzymatic glycation end products, circulating free fatty acids, increased systemic inflammation, diabetic autonomic neuropathy, and the vascular effects of hyperinsulinemia [2, 3]. Randomized clinical trials, have demonstrated higher efficacy of coronary artery bypass grafting (CABG) when compared with PCI in DM population especially in patients with multivessel disease and complex coronary anatomy [4]. Nevertheless, advances in the drug eluting stents (DES) technology, have made stents a viable and less invasive alternative therapy when compared to CABG for patients with less complex anatomy. Second-generation DES reduced rates of stent thrombosis (ST) with preserved low restenosis rates when compared to first-generation DES [5–7]. However, very late ST and neoatherosclerosis have been recently observed also with second-generation DES [8–10]. To address the limitations of the durable polymer DES, new platforms that make use of biodegradable polymers have been developed. The safety and effectiveness of biodegradable polymer coated DES (BP-DES) over first-generation DES has been previously demonstrated in reducing the risk of very late ST and restenosis [11–13]. However, patients with DM constitute a challenging subset, with poorer outcomes after PCI in comparison with non-diabetics. These patients often present with unfavorable coronary anatomy with small and diffusely diseased vessels and multi-vessel involvement [14].

In the present study, it was sought to determine the 1-year clinical follow-up of patients treated with the thin strut BP-coated sirolimus-eluting stent (BP-SES) versus durable coating everolimus-eluting stent (DP-EES) in an all-comers DM population.

Methods

Study design

The interventional cardiology network registry is a prospective, observational registry which includes all patients treated with PCI in 4 Polish interventional cardiology centers in Poland. A retrospective screening of unselected patients (n = = 21,400) treated with PCI between 2010 and 2016 was undertaken. All consecutive patients included were previously diagnosed with DM who underwent single or multi-vessel revascularization with either BP-SES (ALEX, Balton, Warsaw, Poland) or DP-EES (XIENCE, Abbott Vascular, Santa Clara, CA, USA) during the index procedure following acute coronary syndrome or stable angina presentation. Follow-up data for patients treated in years 2015–2016 is currently not available. Therefore, for final analysis only patients treated between 2010 and 2014 were selected, due to availability of 1-year follow-up data for all the patients. Due to observational nature of the study and lack of any interference in diagnostic and therapeutic decision-making process no permission was required from the Institutional Review Board and Bioethics Committee.

Stent system description

The BP-SES used in this study is a Conformité Européenne (CE)-approved balloon expandable cobalt-chromium stent with a 71 microns strut thickness covered with a biodegradable copolymer of poly-lactic and glycolic acid together with sirolimus. In a previously published study, BP-SES demonstrated comparable safety and efficacy in all-comers and acute myocardial infarction (MI) patient population when compared to the benchmark balloon-expandable cobalt-chromium DP--EES [15, 16]. DP-EES was previously granted the specific indication for DM patients from the Food and Drug Administration of the United States and CE mark from the European Commission. DP-EES has a strut thickness of 81 microns. Everolimus is blended in a non-erodible polymer coated over another non-erodible polymer primer layer.

Study population

The demographic, clinical and angiographic data collected in the course of the index hospitalization were retrieved from a prospectively recorded Institutional Electronic Database. Follow-up data, including exact dates of death, MI and repeat revascularization were obtained from the health insurer (National Health Fund) database. Detailed angiographic data for repeat revascularization were obtained from the medical centers that performed the procedures.

All patients underwent coronary angiography with following or postponed PCI using standard devices. All interventional strategies, including the use of stents, choice of stent type and periprocedural antithrombin and antiplatelet therapy, were at the discretion of the attending physicians. Pharmacological treatments recommended by the European Society of Cardiology were introduced before and after the intervention unless contraindicated.

Ethics approval and consent to participate

Due to the observational nature of this study and lack of any interference in a diagnostic and therapeutic decision-making process no permission

was required from the Institutional Review Board and Bioethics Committee.

Definitions and endpoints

The efficacy outcome was defined as target vessel revascularization (TVR). The safety outcomes included separate endpoints of death, MI, and definite or probable ST. MI was defined as an ischemic event that fulfilled the European Society of Cardiology/American College of Cardiology criteria for MI and was clinically distinct from the index event at the time of first hospitalization [17]. TVR was defined as any repeat percutaneous intervention or surgical bypass of any segment of the target vessel including ischemia-driven and symptomatic-driven intervention. ST was considered as acute (0–24 h), subacute (> 24 h to 30 days) or late (> 31 days) and was defined as either definitive or probable according to the Academic Research Consortium [18].

Statistical analysis

Categorical variables are presented as percentages and were compared using the χ^2 test, whereas continuous variables are displayed as means ± standard deviation and were compared using the Student t-test. A propensity score method was used to match the BP-SES and DP-EES groups for all baseline clinical characteristics and angiographic parameters listed in Tables 1 and 2. The area under curve for logistic model was 0.708 (95% confidence interval 0.686–0.731); $p < 0.0001$. The greedy matching algorithm, available in NCSS, was used with the distance calculation option set to "Mahalanobis Distance within Propensity Score Calipers (no matching outside caliper)" and caliper to 0.2*Sigma. Cumulative event rates in 1-year follow-up were analyzed with the Kaplan-Meier method and compared with the log-rank test. All tests were 2-tailed, and a p-value < 0.05 was considered to indicate statistical significance. Statistics were calculated with STATISTICA 12 (Statsoft, Tulsa, Oklahoma, USA) and NCSS 12 Statistical Software (NCSS, LLC. Kaysville, Utah, USA).

Results

Baseline demographic characteristics

A total of 670 BP-SES and 884 DP-EES patients were found to be eligible for matching. Patients in BP-SES group were older than in DP-EES group (respectively: 68.78 ± 9.14 vs. 67.75 ± 9.60; $p = 0.031$). Previous MI and PCI procedures were less common in the BP-SES group when compared to DP-EES (respectively: 31.34% vs. 37.22%; $p = 0.016$, 22.69% vs. 30.20%; $p < 0.001$). Cardiogenic shock at admission occurred more often in BP-SES than in DP-EES group (respectively: 3.28% vs. 1.36%; $p = 0.010$)

Following propensity score analysis and matching, 527 pairs were selected for further analysis with a mean age of 68.41 ± 9.13 years in BP-SES group and 68.21 ± 9.34 in DP-EES group. There were no relevant differences found in baseline characteristics following matching. The proportions of patients with ST-segment elevation MI (BP-SES 10.63% vs. DP-EES 10.63%) and non-ST segment elevation MI (BP-SES 30.17% vs. DP-EES 28.08%) unstable (BP-SES 38.9% vs. DP-EES 37.57%) and stable angina (BP-SES 24.29% vs. DP-EES 23.52%) were comparable between matched groups. An overview of the unmatched and matched baseline characteristics is presented in Table 1.

Patients angiographic and procedural characteristics

Before propensity score matching, there were significant differences between BP-SES and DP--EES in angiographic and procedural characteristics. Left main CAD occurred less frequently in the BP--SES group when compared to the DP-SES group. The rate of multi-vessel PCI was lower in BP-DES compared to DP-EES. The proportion of direct stenting rate was similar in both studied groups. Also, number of stents implanted per patient was similar between the groups.

After propensity score matching angiographic and procedural characteristics such as a multivessel CAD, left main CAD and targeted vessels were comparable between studied groups. There was no difference in single-vessel intervention rates. There was no difference in the number and length of stents implanted per patient. Angiographic and procedural characteristics, before and after propensity score matching, are summarized in Table 2.

Clinical outcomes in matched cohorts

In-hospital (BP-SES 3.23% vs. DP-EES 2.09%; $p = 0.250$) and 30-day mortality (BP-SES 4.55% vs. DP-EES 2.47%; $p = 0.066$) was comparable in the matched groups. The efficacy outcome of TVR rates at 12 months did not differ significantly between BP-SES and DP-EES (respectively: 6.64% vs. 5.88%; $p = 0.611$). There was also no difference in safety endpoints between the matched groups regarding death, MI, and definite/probable ST (Fig. 1).

Table 1. Baseline characteristics.

	Unmatched			Matched		
	BP-SES (n = 670)	DP-EES (n = 884)	P	BP-SES (n = 527)	DP-EES (n = 527)	P
Age [years]	68.78 ± 9.14	67.75 ± 9.60	0.031	68.41 ± 9.13	68.21 ± 9.34	0.711
Female	49.10%	45.02%	0.110	47.06%	48.96%	0.538
Previous MI	31.34%	37.22%	0.016	32.26%	34.91%	0.361
Previous PCI	22.69%	30.20%	0.001	24.67%	26.19%	0.571
Previous bypass surgery	10.30%	10.86%	0.722	10.06%	10.82%	0.687
Previous stroke	5.82%	4.86%	0.403	4.93%	4.93%	1.000
Hypertension	90.15%	89.48%	0.666	89.94%	89.75%	0.919
Hypercholesterolemia	40.60%	42.76%	0.392	40.04%	42.31%	0.453
Smoking	14.33%	11.65%	0.118	13.28%	13.09%	0.927
Obesity	45.97%	44.34%	0.523	45.73%	45.35%	0.902
Chronic heart failure	26.42%	26.58%	0.942	26.38%	27.51%	0.677
Chronic renal failure	13.58%	14.14%	0.753	12.71%	12.33%	0.852
Cardiogenic shock	3.28%	1.36%	0.010	2.09%	1.71%	0.652
Indication for procedure:						
STEMI	11.04%	9.05%	0.192	10.63%	10.63%	1.000
NSTEMI	29.10%	11.04%	0.156	28.08%	30.17%	0.456
Unstable angina	37.46%	37.22	0.921	38.90%	37.57%	0.657
Stable CAD	23.30%	24.03%	0.738	24.29%	23.52%	0.773

MI — myocardial infarction; PCI — percutaneous coronary intervention; STEMI — ST-segment elevation myocardial infarction; NSTEMI — non-ST-segment elevation myocardial infarction; CAD — coronary artery disease

Table 2. Angiographic and procedural characteristics.

	Unmatched			Matched		
	BP-SES (n = 670)	DP-EES (n = 884)	P	BP-SES (n = 527)	DP-EES (n = 527)	P
Multi-vessel CAD	66.87%	70.14%	0.169	66.22%	67.36%	0.695
LM CAD	4.03%	7.13%	0.001	3.98%	3.98%	1.000
Target vessel:						
LM	1.04%	5.88%	< 0.001	1.33%	0.57%	0.204
LAD	38.66%	51.36%	< 0.001	42.31%	44.40%	0.494
Cx	23.88%	12.56%	< 0.001	19.76%	21.26%	0.490
RCA	32.24%	26.92%	0.022	32.26%	29.79%	0.387
Bypass	4.18%	3.28%	0.351	4.36%	3.98%	0.758
Single vessel PCI	85.67%	77.04%	< 0.001	85.01%	85.39%	0.543
Bifurcation PCI	6.72%	17.53%	< 0.001	7.40%	7.21%	0.906
Stents used per patient	1.45 ± 0.82	1.46 ± 0.75	0.847	1.42 ± 0.77	1.41 ± 0.73	0.890
Total length of stents	26.39 ± 16.94	30.61 ± 17.67	< 0.001	26.85 ± 16.75	26.84 ± 15.28	0.991
Maximal implantation pressure	14.67 ± 2.23	14.64 ± 2.79	0.854	14.68 ± 2.24	14.64 ± 2.72	0.823
Direct stent implantation	40.00%	35.52%	0.071	37.76%	38.33%	0.849
Post dilatation	22.54%	23.08%	0.802	21.82%	18.79%	0.221
Thrombectomy	4.18%	3.96%	0.828	3.23%	4.36%	0.333
Procedural glycoprotein IIb/IIIa inhibitor	5.07%	5.54%	0.684	4.36%	4.36%	1.000

CAD — coronary artery disease; LM — left main; LAD — left anterior descending; Cx — circumflex; RCA — right coronary artery; PCI — percutaneous coronary intervention

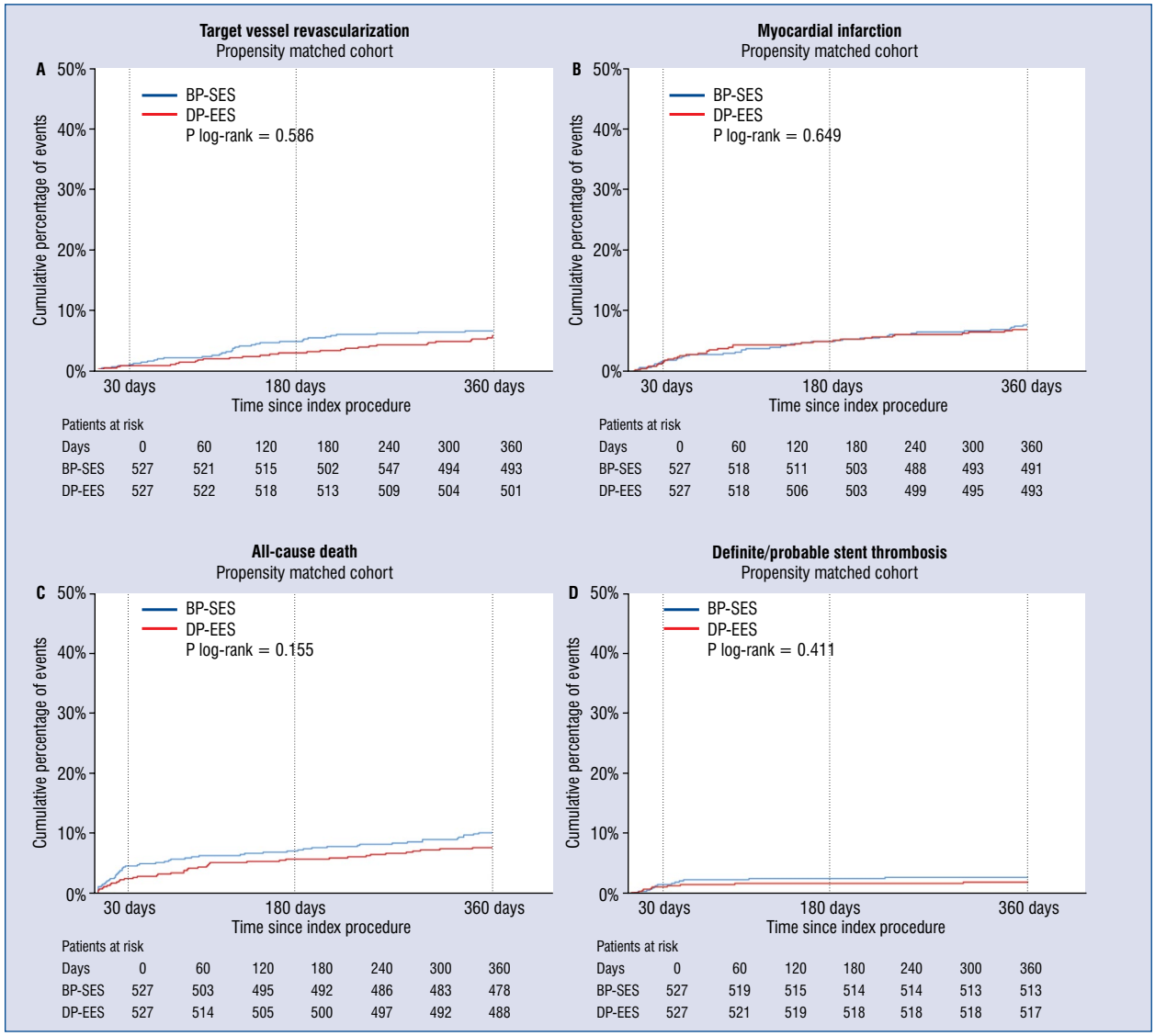

Figure 1. One-year Kaplan-Meier events rates. Kaplan-Meier curves show the cumulative incidence of target vessel revascularization (**A**); myocardial infarction (**B**); all-cause death (**C**); and definite/probable stent thrombosis (**D**).

All-cause mortality at 1 year was similar in both groups (BP-SES 10.06% vs. DP-EES 7.59%; p = 0.158). MI rates were comparable in both groups (BP-SES 7.59% vs. DP-EES 6.83%; p = 0.633). The cumulative rates of definite/probable ST were relatively low with no significant difference between the matched groups (BP-SES 2.66% vs. DP-SES 1.90%; p = 0.408). Also, there was no difference in acute (BP-SES 0.00% vs. DP-SES 0.19%; p = 0.317), subacute (BP-SES 1.52% vs. DP-SES 0.95%; p = = 0.402) and late (BP-SES 1.14% vs. DP-SES 0.76%; p = 0.525) definite/probable ST. In summary, no significant differences were found in terms of clinical outcomes after 1 year. Detailed follow-up results are presented in Table 3.

Discussion

The present study describes a direct comparison of the clinical outcomes of thin strut biodegradable polymer coated sirolimus-eluting stent against benchmark non-erodible polymer coated everolimus-eluting stent in the DM patients. The major finding of this investigation in a propensity-matched cohort is comparable 1-year clinical outcomes for the BP-SES when compared with DP-EES, with reasonable event rates, demonstrating similar safety and efficacy of the devices in the DM patient population.

Coronary artery disease remains the most important cause of morbidity and mortality among

Table 3. Clinical outcomes at 30 days, 6 months, and 12 months in a propensity matched cohort.

	BP-SES (n = 527)	DP-EES (n = 527)	P
30 days			
Target vessel revascularization	6 (1.14%)	5 (0.95%)	0.762
Myocardial infarction	9 (1.71%)	9 (1.71%)	1.000
All cause death	24 (4.55%)	13 (2.47%)	0.066
6 months			
Target vessel revascularization	26 (4.93%)	16 (3.04%)	0.115
Myocardial infarction	26 (4.93%)	26 (4.93%)	1.000
All cause death	37 (7.02%)	30 (5.69%)	0.377
12 months			
Target vessel revascularization	35 (6.64%)	31 (5.88%)	0.611
Myocardial infarction	40 (7.59%)	36 (6.83%)	0.633
All cause death (n)	53 (10.06%)	40 (7.59%)	0.158
Definite/probable stent thrombosis			
Acute (0–1 days)	0 (0.00%)	1 (0.19%)	0.317
Subacute (2–30 days)	8 (1.52%)	5 (0.95%)	0.402
Late (31–365 days)	6 (1.14%)	4 (0.76%)	0.525

patients with DM. It is estimated that ≈75% of patients with diabetes will die from cardiovascular causes [19]. DM patients often present with unfavorable coronary anatomy with small and diffusely diseased vessels and multi-vessel involvement when compared to non-diabetics [14]. Hyperglycemia and associated metabolic disarrangements enhance the development, progression, and instability of atherosclerotic plaque [2]. The diabetic vasculopathy pathophysiology is multifactorial and includes vascular effects of hyperinsulinemia, non-enzymatic glycation end products, endothelial dysfunction, circulating free fatty acids, diabetic autonomic neuropathy, and increased systemic inflammation [2]. Despite similar initial angioplasty success rates, DM patients have higher restenosis rates and worse long-term outcomes. Also, in a DM population, acute coronary syndrome is more frequent and has a higher risk of complications [20]. Although DES implantation reduces neointimal hyperplasia and TVR rates in these patients, diabetes remains a risk factor for restenosis and adverse events after PCI [21, 22]. The increase in oxidative and inflammatory mediators in diabetic patients promotes atherosclerosis [19]. Rapamycin and its analogs (like sirolimus and everolimus) are mTOR complex inhibitor agents. In animal models, the enhancement of the extracellular signal response kinase (ERK) pathway produces a relative resistance to mTOR inhibitors. Therefore, the demonstration of an enhanced activity of the ERK pathway in diabetic vasculature provides an alternative pathway, not affected by limus analogues, for proliferation of vascular smooth muscle cells. This potentially explains the reduction in the long-term effectivity of limus eluting stents in DM [23].

Higher adverse events rate etiology in DM patients seems to be multifactorial and due to patient-related and stent-related causes [24]. In the present study, propensity matched analysis was performed, therefore most of the patients related variables were controlled and equally distributed. Regarding the possible stent-related causes there are different characteristics of tested devices that could impact outcomes between BP-SES and DP-EES, such as the thinner strut thickness (71 μm vs. 81 μm), the presence of biodegradable polymer, and the limus analogue used (sirolimus vs. everolimus). Although polymer provides a reservoir for programmed drug release, it has no function when drug release is completed, and it may affect late and very late safety and efficacy of DES. In fact, durable polymers may be associated with inflammation, neoatherosclerosis and incomplete stent endothelialization which may contribute to the risk of adverse events also observed with new durable polymers DES [25, 26]. However, recent reports demonstrated similar clinical outcomes after implantation of BP-DES when compared to second generation durable polymer coated

stents despite their theoretical advantages. In a large meta-analysis, treatment with BP-DES significantly reduced late lumen loss and late stent thrombosis rates, without clear benefits on harder endpoints compared to durable polymer DP-DES [27]. Herein, it was speculated that, in the pro-inflammatory milieu typical of DM patients, the presence of biodegradable polymer and thinner struts could be important factors that could affect long-term outcomes after BP-SES implantation when compared to DP-EES [28].

A previously published study demonstrated favorable safety and efficacy of DP-EES in a diabetic population [29]. Clinical events in the present study was numerically higher in the BP-SES group when compared to the DP-EES group, however the differences were not statically significant. Therefore, BP-SES demonstrated no-inferior outcomes to DP-EES in a diabetic population. There was no significant difference in TVR rates between the BP--SES and DP-EES groups (respectively: 6.64% vs. 5.88%; p = 0.611). The current study also showed that treatment with BP-SES was not associated with significantly increased mortality (respectively: 10.06% vs. 7.59%; p = 0.158) and MI rates (respectively: 7.59% vs. 6.83%; p = 0.634) when compared to DP-EES. Furthermore, no significant differences were found in terms of definite and probable stent thrombosis (BP-SES 2.66% vs. DP-SES 1.90%; p = 0.408). The 12-month rates of ST found in this study are slightly higher than in randomized trials comparing biodegradable and durable polymer coated DES. However, it needs to be emphasized that the mentioned difference is probably attributed exclusively to a diabetic population and a high proportion of patients with acute coronary syndromes which are included in present study [30].

It has been previously postulated that longer follow-up is required to demonstrate risk reduction of adverse events in favor of BP-DES compared with DP-DES [31]. For example, 5-year results in the LEADERS trial showed BP-DES was associated with a significant reduction in very late, (> 1 year), definite stent thrombosis [32]. Therefore, follow-up beyond 1 year is required to clarify the potential benefit of BP-SES over DP-EES on clinical outcomes in the DM population.

Taking into consideration the above observations, in a propensity-matched cohort, the opinion reached was that BP-SES included in the present study displays a similar efficacy profile as benchmark DP-EES, without compromising safety, which is of utmost importance among DM patients treated in routine clinical practice.

Limitations of the study

First, the current study is limited by its observational nature and patients were not enrolled in a randomized fashion. Thus, any findings should be confirmed by prospective and sufficiently powered clinical trials. Nevertheless, more challenging patients are often excluded from randomized controlled trials. For such reasons, observational studies can be used as complementary forms of research in real-world populations [33]. An attempted to minimize the selection bias on whether to implant BP-SES or DP-EES by using a propensity score matching for a wide range of variables was undertaken. However, not all differences between the groups could be addressed. For example, matching by coronary lesion complexity according to the American College of Cardiology/American Heart Association classification was not performed.

Second, no routine angiographic surveillance was scheduled, and thus no conclusions regarding potential restenosis could be made. Also, no intravascular imaging data was collected. Adequate DAPT is one of the most important factors preventing stent thrombosis. However, data on antiplatelet drug compliance during follow-up was not available.

Third, only patients treated between 2010 and 2014 were evaluated due to lack of currently available follow-up for 546 patients treated in the years 2015–2016.

Fourth, optimal medical therapy could have impacted clinical outcomes, especially in terms of ST and cardiac death, but unfortunately no specific analysis was performed because data from therapy at follow-up was not available.

Finally, the present study is limited to 1 year of follow-up, while theoretical differential clinical outcomes between the compared technologies might have been observed during long-term follow-up.

Conclusions

This is the first competitive evaluation of BP-SES vs. DP-EES in DM population. It provides evidence for the safety and efficacy of BP-SES. The 12-month outcomes for BP-SES were similar to DP-EES. These findings should be verified in a prospective, randomized trial.

Conflict of interest: None declared

References

1. Centers for Disease Control and Prevention. National Diabetes Statistics Report: Estimates of Diabetes and Its Burden in the

United States, 2014. Atlanta, GA: US Department of Health and Human Services; 2014.
2. Orasanu G, Plutzky J. The pathologic continuum of diabetic vascular disease. J Am Coll Cardiol. 2009; 53(5 Suppl): S35–S42, doi: 10.1016/j.jacc.2008.09.055, indexed in Pubmed: 19179216.
3. Rask-Madsen C, King GL. Mechanisms of Disease: endothelial dysfunction in insulin resistance and diabetes. Nat Clin Pract Endocrinol Metab. 2007; 3(1): 46–56, doi: 10.1038/ncpendmet0366, indexed in Pubmed: 17179929.
4. Farkouh M, Domanski M, Sleeper L, et al. Strategies for Multivessel Revascularization in Patients with Diabetes. N Engl J Med. 2012; 367(25): 2375–2384, doi: 10.1056/nejmoa1211585.
5. Räber L, Magro M, Stefanini GG, et al. Very late coronary stent thrombosis of a newer-generation everolimus-eluting stent compared with early-generation drug-eluting stents: a prospective cohort study. Circulation. 2012; 125(9): 1110–1121, doi: 10.1161/CIRCULATIONAHA.111.058560, indexed in Pubmed: 22302840.
6. Stefanini GG, Windecker S. Stent thrombosis: no longer an issue with newer-generation drug-eluting stents? Circ Cardiovasc Interv. 2012; 5(3): 332–335, doi: 10.1161/CIRCINTERVENTIONS.112.970970, indexed in Pubmed: 22715449.
7. Dores H, Raposo L, Campante Teles R, et al. Stent thrombosis with second- versus first-generation drug-eluting stents in real-world percutaneous coronary intervention: analysis of 3806 consecutive procedures from a large-volume single-center prospective registry. J Invasive Cardiol. 2013; 25(7): 330–336, indexed in Pubmed: 23813060.
8. Naidu SS, Krucoff MW, Rutledge DR, et al. Contemporary incidence and predictors of stent thrombosis and other major adverse cardiac events in the year after XIENCE V implantation: results from the 8,061-patient XIENCE V United States study. JACC Cardiovasc Interv. 2012; 5(6): 626–635, doi: 10.1016/j.jcin.2012.02.014, indexed in Pubmed: 22721657.
9. Nakazawa G, Otsuka F, Nakano M, et al. The pathology of neoatherosclerosis in human coronary implants bare-metal and drug-eluting stents. J Am Coll Cardiol. 2011; 57(11): 1314–1322, doi: 10.1016/j.jacc.2011.01.011, indexed in Pubmed: 21376502.
10. Park SJ, Kang SJ, Virmani R, et al. In-stent neoatherosclerosis: a final common pathway of late stent failure. J Am Coll Cardiol. 2012; 59(23): 2051–2057, doi: 10.1016/j.jacc.2011.10.909, indexed in Pubmed: 22651862.
11. Räber L, Kelbæk H, Ostojic M, et al. Effect of biolimus-eluting stents with biodegradable polymer vs bare-metal stents on cardiovascular events among patients with acute myocardial infarction: the COMFORTABLE AMI randomized trial. JAMA. 2012; 308(8): 777–787, doi: 10.1001/jama.2012.10065, indexed in Pubmed: 22910755.
12. Stefanini GG, Byrne RA, Serruys PW, et al. Biodegradable polymer drug-eluting stents reduce the risk of stent thrombosis at 4 years in patients undergoing percutaneous coronary intervention: a pooled analysis of individual patient data from the ISAR-TEST 3, ISAR-TEST 4, and LEADERS randomized trials. Eur Heart J. 2012; 33(10): 1214–1222, doi: 10.1093/eurheartj/ehs086, indexed in Pubmed: 22447805.
13. Palmerini T, Biondi-Zoccai G, Della Riva D, et al. Clinical outcomes with bioabsorbable polymer- versus durable polymer-based drug-eluting and bare-metal stents: evidence from a comprehensive network meta-analysis. J Am Coll Cardiol. 2014; 63(4): 299–307, doi: 10.1016/j.jacc.2013.09.061, indexed in Pubmed: 24211507.
14. Kip KE, Faxon DP, Detre KM, et al. Coronary angioplasty in diabetic patients. The National Heart, Lung, and Blood Institute Percutaneous Transluminal Coronary Angioplasty Registry. Circulation. 1996; 94(8): 1818–1825, doi: 10.1161/01.cir.94.8.1818, indexed in Pubmed: 8873655.
15. Gasior P, Gierlotka M, Szczurek-Katanski K, et al. Bioresorbable polymer-coated thin strut sirolimus-eluting stent vs durable polymer-coated everolimus-eluting stent in daily clinical practice: Propensity matched one-year results from interventional cardiology network registry. Catheter Cardiovasc Interv. 2019; 93(7): E362–E368, doi: 10.1002/ccd.27919, indexed in Pubmed: 30298545.
16. Gąsior P, Gierlotka M, Szczurek-Katanski K, et al. Safety and efficacy of biodegradable polymer-coated thin strut sirolimus-eluting stent vs. durable polymer-coated everolimus-eluting stent in patients with acute myocardial infarction. Postepy Kardiol Interwencyjnej. 2018; 14(4): 347–355, doi: 10.5114/aic.2018.79194, indexed in Pubmed: 30603024.
17. Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. Eur Heart J. 2012; 33(20): 2551–2567.
18. 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(17): 2344––2351, doi: 10.1161/CIRCULATIONAHA.106.685313, indexed in Pubmed: 17470709.
19. Preis SR, Hwang SJ, Coady S, et al. Trends in all-cause and cardiovascular disease mortality among women and men with and without diabetes mellitus in the Framingham Heart Study, 1950 to 2005. Circulation. 2009; 119(13): 1728–1735, doi: 10.1161/CIRCULATIONAHA.108.829176, indexed in Pubmed: 19307472.
20. Fang J, Alderman MH. Impact of the increasing burden of diabetes on acute myocardial infarction in New York City: 1990-2000. Diabetes. 2006; 55(3): 768–773, doi: 10.2337/diabetes.55.03.06.db05-1196, indexed in Pubmed: 16505241.
21. Flaherty JD, Davidson CJ. Diabetes and coronary revascularization. JAMA. 2005; 293(12): 1501–1508, doi: 10.1001/jama.293.12.1501, indexed in Pubmed: 15784875.
22. Sabaté M, Jiménez-Quevedo P, Angiolillo DJ, et al. Randomized comparison of sirolimus-eluting stent versus standard stent for percutaneous coronary revascularization in diabetic patients: the diabetes and sirolimus-eluting stent (DIABETES) trial. Circulation. 2005; 112(14): 2175–2183, doi: 10.1161/CIRCULATIONAHA.105.562421, indexed in Pubmed: 16203930.
23. Woods TC. Dysregulation of the mammalian target of rapamycin and p27Kip1 promotes intimal hyperplasia in diabetes mellitus. Pharmaceuticals (Basel). 2013; 6(6): 716–727, doi: 10.3390/ph6060716, indexed in Pubmed: 24276258.
24. Dangas GD, Claessen BE, Caixeta A, et al. In-stent restenosis in the drug-eluting stent era. J Am Coll Cardiol. 2010; 56(23): 1897–1907, doi: 10.1016/j.jacc.2010.07.028, indexed in Pubmed: 21109112.
25. Nakazawa G, Nakano M, Otsuka F, et al. Evaluation of polymer-based comparator drug-eluting stents using a rabbit model of iliac artery atherosclerosis. Circ Cardiovasc Interv. 2011; 4(1): 38–46, doi: 10.1161/CIRCINTERVENTIONS.110.957654, indexed in Pubmed: 21205943.
26. Kang SJ, Lee CW, Song H, et al. OCT analysis in patients with very late stent thrombosis. JACC Cardiovasc Imaging. 2013; 6(6): 695–703, doi: 10.1016/j.jcmg.2013.02.006, indexed in Pubmed: 23643282.

27. Lupi A, Gabrio Secco G, Rognoni A, et al. Meta-analysis of bioabsorbable versus durable polymer drug-eluting stents in 20,005 patients with coronary artery disease: an update. Catheter Cardiovasc Interv. 2014; 83(6): E193–E206, doi: 10.1002/ccd.25416, indexed in Pubmed: 24478247.
28. Endothelial dysfunction in diabetes mellitus. Vasc Health Risk Manag. 2007; 3(6): 853–876.
29. Kaul U, Bhagwat A, Pinto B, et al. Paclitaxel-eluting stents versus everolimus-eluting coronary stents in a diabetic population: two-year follow-up of the TUXEDO-India trial. EuroIntervention. 2017; 13(10): 1194–1201, doi: 10.4244/EIJ-D-17-00333, indexed in Pubmed: 28741578.
30. Christiansen EH, Jensen LO, Thayssen P, et al. Biolimus-eluting biodegradable polymer-coated stent versus durable polymer-coated sirolimus-eluting stent in unselected patients receiving percutaneous coronary intervention (SORT OUT V): a randomised non-inferiority trial. Lancet. 2013; 381(9867): 661–669, doi: 10.1016/S0140-6736(12)61962-X, indexed in Pubmed: 23374649.
31. Stefanini GG, Byrne RA, Serruys PW, et al. Biodegradable polymer drug-eluting stents reduce the risk of stent thrombosis at 4 years in patients undergoing percutaneous coronary intervention: a pooled analysis of individual patient data from the ISAR-TEST 3, ISAR-TEST 4, and LEADERS randomized trials. Eur Heart J. 2012; 33(10): 1214–1222, doi: 10.1093/eurheartj/ehs086, indexed in Pubmed: 22447805.
32. Serruys PW, Farooq V, Kalesan B, et al. Improved safety and reduction in stent thrombosis associated with biodegradable polymer-based biolimus-eluting stents versus durable polymer-based sirolimus-eluting stents in patients with coronary artery disease: final 5-year report of the LEADERS (Limus Eluted From A Durable Versus ERodable Stent Coating) randomized, noninferiority trial. JACC Cardiovasc Interv. 2013; 6(8): 777–789, doi: 10.1016/j.jcin.2013.04.011, indexed in Pubmed: 23968698.
33. Concato J, Shah N, Horwitz RI. Randomized, controlled trials, observational studies, and the hierarchy of research designs. N Engl J Med. 2000; 342(25): 1887–1892, doi: 10.1056/NEJM200006223422507, indexed in Pubmed: 10861325.