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ORIGINAL STUDIES

Five-year follow-up of patients who underwent everolimus-eluting bioresorbable scaffold implantation

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Abstract

Objectives: The aim of this study was to evaluate very long-term results after unrestricted everolimus-eluting bioresorbable scaffolds (BRS) implantation.

Background: Previous randomized studies mainly included selected patients differing from those seen during daily routine and long-term data from all-comers registries are sparse.

Methods: Consecutive patients undergoing BRS implantation were included in this observational, single center study. Clinical follow-up was conducted up to 5 years. Endpoint of interest was the composite of target lesion failure (TLF), including target-vessel myocardial infarction and target lesion revascularization and cardiac death. Furthermore, ARC-defined scaffold thrombosis (ScT) were assessed.

Results: A total of 176 patients with a median age of 64 (55 – 72) years were analyzed, of which 59.6% presented an acute coronary syndrome. A total of 183 mainly complex lesions (55.8%) were treated. At 5 years, the rate for TLF was 21.6%. Definite or probable ScT rate was 4.1%. The rate of ScT within the first year was 2.8% and afterwards 1.2%. Notably, no ScT was seen later than 2 years.

Conclusions: Although this real-world registry displays high rates of clinical events during long-term follow-up, no ScT was seen after 2 years.

KEYWORDS

ACS/NSTEMI, acute myocardial infarction/STEMI, bioabsorbable devices/polymers, bioabsorbable stent, coronary artery disease, drug-eluting stent

1 | INTRODUCTION

Bioresorbable scaffolds (BRS) were implemented in the treatment of coronary artery disease to improve the long-term outcomes of metallic stents. Remaining metallic stents are associated with chronic inflammation resulting in late adverse events with stent thrombosis being the worst complication.[1–3] Theoretically, BRS provide short- to mid-term scaffolding of the previously stenosed vessel and then completely dissolve. Currently, only few BRS are under investigation since the everolimus-eluting BRS was taken from the market.

Jens Wiebe and Felix J. Hofmann contributed equally to this study and are joint first authors.

TABLE 1 Baseline characteristics

	N = 176 patients
Age	64 (55–72)
Female gender	40 (22.7)
Hypertension	147 (83.5)
Diabetes	52 (29.5)
Insulin dependent	17 (32.7)
Hypercholesterolemia	93 (52.8)
History of smoking	86 (48.8)
Family history of coronary artery disease	42 (23.9)
Previous percutaneous coronary intervention	67 (38.1)
Coronary artery disease	
1-vessel-disease	65 (36.9)
2-vessel-disease	72 (40.9)
3-vessel-disease	39 (22.2)
Clinical presentation	
ST-elevation myocardial infarction	38 (21.6)
Non-ST-elevation myocardial infarction	40 (22.7)
Unstable angina	27 (15.3)
Stable angina	70 (39.8)
Other	1 (0.6)

Note: Data shown as median (interquartile range) or number (percentage).

TABLE 2 Procedural characteristics

	N = 183 lesions
Target vessel	
Left anterior descending	80 (43.7)
Circumflex artery	49 (26.8)
Right coronary artery	54 (29.5)
De novo lesion	173 (94.5)
In-stent-restenosis	10 (5.5)
Thrombotic lesion	33 (18.0)
Chronic total occlusion	11 (6.0)
Bifurcation	15 (8.2)
Complex lesion morphology (B2/C)	102 (55.8)
Reference vessel diameter (mm)	2.9 ± 0.6
Lesion length (mm)	17.0 ± 10.3
BRS per lesion	1.3 ± 0.7
BRS diameter (mm)	3.1 ± 0.4
BRS length per lesion (mm)	26.5 ± 17.7
Intravascular imaging	23 (12.6)
Pre-dilatation	174 (95.1)
Post-dilation	67 (36.6)
Maximum balloon diameter post-dilatation (mm)	3.4 ± 0.5
Maximum post-dilatation pressure (atm)	16.5 ± 4.3
Antiplatelet/anticoagulant therapy at discharge (patient based)	
Aspirin	172 (97.7)
Clopidogrel	72 (40.9)
Ticagrelor	53 (30.1)
Prasugrel	51 (29.0)
Direct oral anticoagulant	14 (8.0)
Vitamin-K-antagonist	13 (7.4)

Note: Data shown as means ± *SD* or number (percentage).
Abbreviation: BRS, bioresorbable scaffold.

However, the most data is available for this BRS, which is made from poly-L-lactic acid and which dissolves within 3–4 years.[4] Theoretically, advantages of BRS over might become apparent after this period.

Findings from several randomized-controlled trials are available, comparing this BRS with DES. After 1 year of follow-up, clinical results were comparable between both devices besides a slightly higher incidence of scaffold thrombosis.[5] These scaffold thrombosis cases were supposed to be associated with the implantation technique.[6,7] Surprisingly, the scaffold thrombosis rate further increased disproportionately in comparison to DES after 3 years of follow-up.[8]

Nevertheless, outcomes data beyond 3 years of follow-up is sparse. Additionally, patients treated in the context of randomized studies were highly selected and differ significantly from patients treated in daily routine. To compensate this lack of knowledge, this study evaluates long-term outcomes after percutaneous coronary intervention with BRS implantation during clinical practice.

2 | METHODS

2.1 | Study design and patient selection

Consecutive patients with coronary artery disease undergoing BRS implantation were included in this observational, single center study at the University Hospital of Giessen, Germany. The present analysis includes only patients which were at least available for the 5 year follow-up. This study was approved by the ethics board of Justus-Liebig University of Giessen, Germany (AZ:246/12). The investigation adheres to the principles outlined in the Declaration of Helsinki. Further details of the study were published previously.[9]

2.2 | Study procedure and medication

The device used in this study was a poly-L-lactic acid-based BRS (Absorb BVS, Abbott Vascular, Santa Clara, CA). Its strut thickness is approximately 157 μm and the BRS is coated with a 1:1 ratio of poly-D-L-lactic acid and the anti-proliferative drug everolimus. To facilitate imaging two radiopaque markers are located at both ends. Implantation was primarily performed via radial access. Intravascular imaging including optical coherence tomography and intravascular ultrasound was used to assist the implantation according to the physician's discretion. Pre-dilation was mandatory and the decision to perform post-dilatation was finally left to the implanting physician. Peri-procedural intravenous aspirin and body-weight adjusted unfractionated heparin were administered. According to the patient's clinical presentation and current guidelines, post-procedural

dual antiplatelet therapy of aspirin and a P2Y12 inhibitor was prescribed for at least 12 months, after initial application of a loading dose of the P2Y12 inhibitor. In patients with concomitant oral anticoagulation, the combination of antiplatelet and oral anticoagulant therapy was prescribed according to current recommendations. In those patients, aspirin was usually discontinued 12 months after PCI. Testing for clopidogrel resistance was not performed routinely.

TABLE 3 Clinical outcome at 5-years

	5-years
Major adverse cardiac events (composite of all-cause death, myocardial infarction, target lesion revascularization)	31.0
Target lesion failure (composite of cardiac death, target-vessel myocardial infarction, target lesion revascularization)	21.6
Myocardial infarction	12.5
Target-vessel myocardial infarction	7.5
Target lesion revascularization	11.4
Scaffold thrombosis (definite or probable)	4.1
All-cause death	16.1
Cardiac death	8.2

Note: Data shown as percentage by Kaplan Meier estimates.

2.3 | Follow-up and endpoints

In-hospital testing included the acquisition of the patient's medical history and medication, physical examination, 12-lead electrocardiography, echocardiography and laboratory testing. Clinical follow-up was conducted via standardized telephone interviews or office visits at 1, 6, and 12 months and thereafter yearly up to 5 years. Data collection was performed by specialized personnel and entered into a data base. All data was verified by the investigator. Endpoints of interest were major adverse cardiac events (MACE), a composite endpoint of all-cause death, target lesion revascularization (TLR), and myocardial infarction (MI). The composite endpoint of target lesion failure (TLF) consists of cardiac death, target vessel myocardial infarction (TV-MI), and TLR. Additionally, the individual components of the composite endpoints as well as scaffold thrombosis according to Academic Research Consortium criteria were assessed.[10]

2.4 | Statistics

The statistical analysis was performed by SPSS Statistics (SPSS Statistics 24, IBM Deutschland GmbH, Ehningen, Germany). Categorical variables are expressed as numbers and percentages and compared by

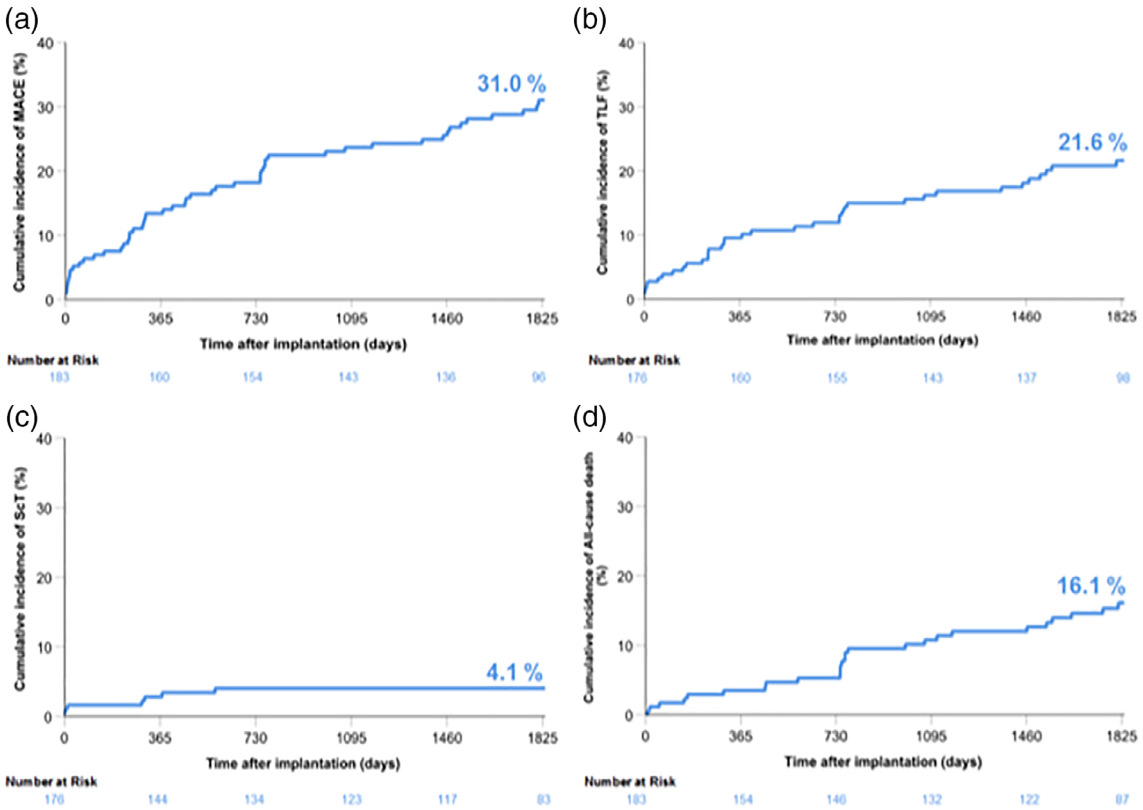

FIGURE 1 Kaplan–Meier event curves for clinical outcomes. This figure shows the Kaplan–Meier event rates for (a) major adverse cardiac events (MACE), including all-cause death, target lesion revascularization, and myocardial infarction; (b) target lesion failure (TLF), composite of cardiac death target lesion revascularization and target-vessel myocardial infarction; (c) definite or probable scaffold thrombosis (ST); and (d) all-cause death [Color figure can be viewed at wileyonlinelibrary.com]

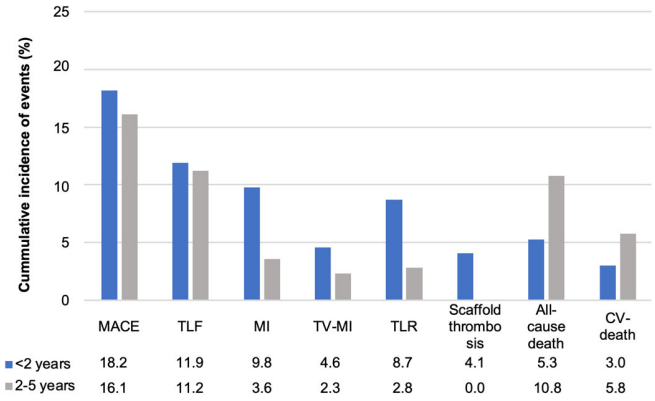

FIGURE 2 Landmark analysis of clinical outcomes. This figure shows the Kaplan–Meier event rates in landmark analysis for major adverse cardiac events (MACE), including all-cause death, target lesion revascularization (TLR), and myocardial infarction (MI); target lesion failure (TLF), composite of cardiac death (CV-death), target lesion revascularization (TLR), and target-vessel myocardial infarction (TV-MI); definite or probable scaffold thrombosis [Color figure can be viewed at wileyonlinelibrary.com]

the chi-square test, continuous variables are displayed as means with standard deviation or median with interquartile range and compared by the students-*t*-test. Survival and event rates were calculated by using Kaplan–Meier-estimation and rates were compared using the log-rank test. All tests were two-tailed and a p value <.05 was considered to indicate statistical significance. To report events in the long-term period, a landmark analysis was performed at 2 years. A subgroup analysis was performed to assess the optimal implantation strategy, which was defined as any pre-dilation, sizing with a reference vessel diameter ± 0.25 mm to scaffold diameter, and post-dilation with a balloon to scaffold ratio of ≥1:1 and ≤1,5:1 at >12 atm ("PSP-technique").[6]

3 | RESULTS

3.1 | Baseline and procedural characteristics

A total of 176 consecutive patients were available for analysis. The median age was 64 (55–72) years, 22.7% of the patients were female and 29.5% suffered from diabetes. At baseline 59.6% of the patients presented with an acute coronary syndrome. Further patient characteristics are provided in Table 1. In 61.9% radial access was the predominant vessel access. In the majority of cases de novo lesions were treated (94.5%). Of all treated lesions, 8.2% were bifurcation lesions, 18.0% were thrombotic, and 6.0% were chronic total occlusions. According to the AHA/ACC classification, 55.8% of the lesions were considered to be complex (B2/C). The mean reference vessel diameter was 2.9 ± 0.6 mm. The left anterior descending coronary artery was the main target lesion in 43.7%. In 99.1% of lesions, the BRS implantation was successful with a total of 241 BRS being implanted in 183 lesions. In two lesions BRS were not implanted due to delivery failure. The mean BRS length per lesion was 26.5 ± 17.7 mm. Pre-dilation was performed in 95.1% and post-dilation in 36.6%, respectively. Intracoronary imaging using optical coherence tomography or intravascular imaging was performed in 12.6%. At discharge 97.7% of the patients received aspirin and additional clopidogrel, ticagrelor, or prasugrel was prescribed in 40.9%, 30.1%, and 29.0%, respectively. 15.4% were on anticoagulant therapy. An overview of lesion and procedural characteristics is displayed in Table 2.

TABLE 4 Clinical outcomes for non-PSP versus PSP at 5-years

	Non-PSP (n = 149)	PSP (n = 27)	p-value (log-rank)
Major adverse cardiac events (composite of all-cause death, myocardial infarction, target lesion revascularization)	32.3	23.4	.46
Target lesion failure (composite of cardiac death, target-vessel myocardial infarction, target lesion revascularization)	23.8	7.6	.11
Myocardial infarction	13.3	7.4	.55
Target-vessel myocardial infarction	8.1	3.7	.54
Target lesion revascularization	12.0	7.9	.63
Scaffold thrombosis (definite or probable)	4.1	3.7	.99
All-cause death	16.9	11.9	.51
Cardiac death	10.2	0.0	.10

Notes: Data shown as percentage by Kaplan Meier estimates; PSP = "PSP-technique," including pre-dilation, sizing with a reference vessel diameter ± 0.25 mm to scaffold diameter, and post-dilation with a balloon to scaffold ratio of ≥1:1 and ≤ 1,5:1 at >12 atm.

3.2 | Clinical outcomes

The median follow-up period was 1830 days (1,537 – 1,924). At 5 years, the rates for MACE and TLF were 31.0% and 21.6%. TLF was mainly derived by TLR, which was noted in 11.4%. Probable or definite ScT occurred in 4.1%, and definite ScT rate was 3.4%. Of the 6 definite ScT, three occurred within 30 days of the BRS implantation, two between 30 days and 1 year, one later than 1 year and no ScT was found later than 2 years. Four patients (66.6%) had discontinued DAPT at the time of ScT and two of these patients (both with subacute ScT) due to non-compliance. All patients presented an acute MI at the time of ScT. Further details of patients with ScT are provided in the Supporting Information. All-cause mortality was 16.1% and the rate for cardiac death was 8.2% at 5 years (Table 3). Kaplan–Meier event curves are shown in Figure 1. When comparing clinical outcomes of non-complex (A/B1) and complex (B2/C) lesions treated

with BRS, a higher rate of TLR (5.7% vs. 16.2%; p = .039) was observed. A total of 161 Patients were available for landmark analysis after 2 years. The rates for MACE and TLF were 16.1% and 11.2%. Definite ScT rate was 0.0%, all-cause mortality was 10.8% whereas cardiac mortality was 5.8%, respectively (Figure 2).

3.3 | PSP subgroup analysis

A total of 27 patients were treated according to the PSP technique. Besides family history of coronary artery disease, no statistically relevant differences were found between the groups regarding the baseline characteristics (Supporting Information). The event rates were consistently numerically higher in the group without PSP regarding MACE (32.3% vs. 23.4%; p = .46), TLF (23.8% vs. 7.6%; p = .11) and TLR (12.0% vs. 7.9%; p = .63), whereas definite ScT were comparable in both groups (3.4% vs. 3.7%; p = .87). An overview of the clinical outcomes according to the PSP strategy can be found in Table 4.

4 | DISCUSSION

The present study evaluates long-term outcomes up to 5 years in 176 patients, who underwent BRS implantation during daily clinical practice. The main findings of this study are:

1. Rates of clinical events, especially the incidence of ScT, were high. In this registry, ScT rate was mainly driven by events within the first year of implantation.
2. No ScT was seen later than 2 years, possibly confirming the concept of BRS.
3. Overall, the rates of post-dilatation and PSP-technique was low, which displays the initial implantation strategy in the early phase of BRS use.
4. According to the landmark analysis, a clustering of events was noted within 2 years after BRS implantation, mainly driven by a high rate of TLR.

Presently, the longest follow-up from a prospective study is from the non-randomized ABSORB Cohort B trial. Briefly, a total of 101 patients with stable coronary artery disease and mostly simple and short lesions were enrolled. After 5 years of clinical follow-up, the TLR rate was 11.0% and during that period there was no evidence of ScT. Furthermore, the angiographic surveillance at 5 years showed satisfactory results with an overall late luminal loss of 0.26 ± 0.42 mm.[11] Furthermore, a large-scale study of 812 patients with predominately stable coronary artery disease and non-complex lesions reports 3-year rates for MACE, TLR, and ScT of 9.2%, 3.1%, and 2.2%, respectively.[12] Besides, randomized-controlled trials with long-term follow-up comparing BRS and DES are available. In the ABSORB II study, 501 patients were randomly assigned in a 2:1 ration to be treated with either BRS or DES.[13] After 4 years of follow-up, the composite endpoint of TLF occurred in 11.5% and was higher than in the DES group (6.0%, p = .063), whereas TLR rates were 8.3% vs. 5.3% (p = .25). However, the scaffold thrombosis was 3.0%, which was significantly higher than in the DES group (p = .035).[14] The ABSORB III study is the largest randomized study with 5-year data.[15] In this trial, a total of 2008 patients were enrolled, which were allocated to be treated with BRS or a DES in a 2:1 distribution. The primary endpoint of TLF occurred in 17.5% of the BRS group and 15.2% of the DES group (p = .07). TLF was mostly driven by TV-MI (10.4% in BRS vs. 7.5% in DES; p = .04) as well as ScT (2.5% in BRS vs. 1.1% in DES; p = .03).[15] In comparison to DES, the observed event rates in this registry on BRS were higher. For example, the EVOLVE study included 1,684 patients, which were treated with 2 different types of new-generation DES (biodegradable polymer DES vs. durable polymer DES) and the 5-year rates for TLR (5.2% vs. 6.7%) and TLF (14.2% vs. 14.3%) were comparable between both groups.[16] Interestingly, the 5-year TLR rate in non-complex lesions in the present study (5.7%) was lower than the overall TLR rates in the previously described studies.

Despite the fact, that randomized-controlled trials represent the gold-standard for the evaluation of a certain treatment strategy, some limitations of available studies comparing BRS and DES apply, most notably that the existing studies share strict in- and exclusion criteria. For example, patients with acute myocardial infarction, impaired ventricular function or on oral anticoagulation were excluded. Furthermore, lesions including a bifurcation, chronic occlusions or long-lesions were excluded as well.[13,17] Patients included in these studies differ from those treated in daily practice and thus, data from all-comers registries with minimal or no in- and exclusion criteria represent an important supplement of knowledge. In the present study, more than half of the patients presented an acute coronary syndrome at admission and there was a substantial proportion of complex lesions. Nevertheless, the event rates are comparable to those of randomized studies mentioned earlier. Reasons are supposed to be related to the implantation technique, lesion selection and to the device itself. While post-dilatation was initially strictly not recommended, data become available to support systematic post-dilatation and recommendations for implantation changed concordantly.[7,18] In a recent study, 1,002 patients underwent BRS implantation according to a pre-specified implantation protocol (including pre-dilation, optimal sizing, and post-dilation with non-compliant balloons). After 2 years of follow-up, the rates for TV-MI, TLR, and ScT were 5.3%, 6.6%, and 1.1%, respectively, with only 1 ScT occurring between 1 and 2 years.[19] In comparison to other studies, these lower event rates underline the importance of a thorough implantation procedure. Additionally, data was published displaying a significant learning-curve within this registry.[20] The implantation was performed predominantly in complex lesions with a high proportion of type B2/C lesions, thrombotic lesions, bifurcations or chronic total occlusions, which are all considered to be "off-label" and complex. Presently, data exist showing a trend towards more non-complex lesions, associated with a better clinical outcome.[21] Worse outcome for complex settings such as bifurcations or ostial lesions have been described as well.[22,23]

Overall, the rate of ScT remains unexpectedly high—consistently to other studies. However, the landmark analysis revealed a clustering

of events in 2 years after BRS implantation, which might be associated with the implantation procedure. It has to be appreciated as well, that no ScT occurred beyond 2 years and thus, the rate of very late ScT in this registry was lower than compared to other studies. Although speculative, a reason for this finding may be, that the mean vessel diameter treated was relatively large (2.9 ± 0.6 mm) and concordantly the mean BRS diameter was also relatively large (3.1 ± 0.4 mm). It is well known, that smaller vessels and smaller BRS are associated with higher rates of ScT and worse clinical outcomes.[7] Besides, the occurrence of very late ScT is currently a well-known adverse event after BRS implantation. In a recent optical coherence tomography investigation, patients who experienced a scaffold thrombosis later than 1 year after implantation were analyzed. Interestingly, scaffold discontinuation was found to be the predominant reason of scaffold thrombosis: it is supposed, that the structural integrity of the BRS gets lost during the degradation process of the BRS resulting in mal-apposed struts, a nidus for thrombus.[24] Furthermore, the BRS itself has shown to be more thrombogenic with the strut thickness playing an important role.[25] Taking the results and especially the increased rates of ScT in current studies into account, the genesis of ScT is multi-factorial and includes suboptimal patient and lesion selection, inappropriate implantation technique, and limitations of the BRS itself. Due to this findings, this type of BRS was removed from the market.

4.1 | Limitations

There are several limitations that need to be acknowledged: The decision to use a BRS was driven by the operator's discretion and thus a selection might be possible. This small-sized, non-randomized registry displays real-world data from a single center at the very early time of experience with BRS. Thus it has to be considered, that initially, post-dilatation was not performed systematically due to the recommendations for implantation at this time point. Furthermore, intravascular imaging was not part of the clinical routine during this early phase. Patients with CTO or bifurcation lesions were treated "off-label," which may impact the clinical outcomes. In addition, the total BRS lengths was relatively long, a well know predictor of stent failure as known from DES studies.[26] Results from the subgroup analysis have to be interpreted with caution due to the small number of patients assigned to the PSP group. Routine angiographic or intravascular imaging follow-up data are missing and thus no information on the anti-restenotic performance of BRS, subclinical ScT and their influence on long-term clinical outcomes in this cohort exist. However, the fact that no ScT was found after the probable resorption of BRS further confirms the assumption that the concept of BRS should be further properly researched in the future.

5 | CONCLUSION

In this real-world registry, long-term follow-up after BRS implantation in daily routine showed a relatively high rate of scaffold thrombosis. A clustering of events within the first year was noted, which might be procedure related and thus, a dedicated implantation technique may has an influence of the occurrence of late events, especially since no ScT was seen after 2 years. Nevertheless, further large-scale studies investigating long-term outcomes of patients undergoing optimal BRS implantation in daily routine as well as imaging studies will be needed to completely understand the concept of BRS.

CONFLICT OF INTEREST

Holger Nef received research grants (institutional) and speaker honoraria from Abbott Vascular. All other authors did not report any potential conflict of interest.

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REFERENCES

1. Joner M, Finn AV, Farb A, et al. Pathology of drug-eluting stents in humans: delayed healing and late thrombotic risk. J Am Coll Cardiol. 2006;48:193-202.
2. Stone GW, Ellis SG, Colombo A, et al. Long-term safety and efficacy of paclitaxel-eluting stents final 5-year analysis from the TAXUS clinical trial program. JACC Cardiovasc Interv. 2011;4:530-542.
3. Taniwaki M, Stefanini GG, Silber S, et al. 4-year clinical outcomes and predictors of repeat revascularization in patients treated with new-generation drug-eluting stents: a report from the RESOLUTE all-comers trial (a randomized comparison of a Zotarolimus-eluting stent with an Everolimus-eluting stent for percutaneous coronary intervention). J Am Coll Cardiol. 2014;63:1617-1625.
4. Wiebe J, Nef HM, Hamm CW. Current status of bioresorbable scaffolds in the treatment of coronary artery disease. J Am Coll Cardiol. 2014;64:2541-2551.
5. Cassese S, Byrne RA, Ndrepepa G, et al. Everolimus-eluting bioresorbable vascular scaffolds versus everolimus-eluting metallic stents: a meta-analysis of randomised controlled trials. Lancet. 2016;387:537-544.
6. Ortega-Paz L, Capodanno D, Gori T, et al. Predilation, sizing and post-dilation scoring in patients undergoing everolimus-eluting bioresorbable scaffold implantation for prediction of cardiac adverse events: development and internal validation of the PSP score. EuroIntervention. 2017;12:2110-2117.
7. Puricel S, Cuculi F, Weissner M, et al. Bioresorbable coronary scaffold thrombosis: multicenter comprehensive analysis of clinical presentation, mechanisms, and predictors. J Am Coll Cardiol. 2016;67:921-931.
8. Ali ZA, Gao R, Kimura T, et al. Three-year outcomes with the absorb bioresorbable scaffold: individual-patient-data meta-analysis from the ABSORB randomized trials. Circulation. 2018;137:464-479.
9. Wiebe J, Mollmann H, Most A, et al. Short-term outcome of patients with ST-segment elevation myocardial infarction (STEMI) treated with an everolimus-eluting bioresorbable vascular scaffold. Clin Res Cardiol. 2014;103:141-148.
10. Cutlip DE, Windecker S, Mehran R, et al. Clinical end points in coronary stent trials: a case for standardized definitions. Circulation. 2007;115:2344-2351.

11. Serruys PW, Ormiston J, van Geuns RJ, et al. A polylactide bioresorbable scaffold eluting everolimus for treatment of coronary stenosis: 5-year follow-up. J Am Coll Cardiol. 2016;67:766-776.
12. Costa JR Jr, Abizaid A, Whitbourn R, et al. Three-year clinical outcomes of patients treated with everolimus-eluting bioresorbable vascular scaffolds: Final results of the ABSORB EXTEND trial. Catheter Cardiovasc Interv. 2019;93:E1-E7.
13. Serruys PW, Chevalier B, Dudek D, et al. A bioresorbable everolimus-eluting scaffold versus a metallic everolimus-eluting stent for ischaemic heart disease caused by de-novo native coronary artery lesions (ABSORB II): an interim 1-year analysis of clinical and procedural secondary outcomes from a randomised controlled trial. Lancet. 2015;385:43-54.
14. Chevalier B, Cequier A, Dudek D, et al. Four-year follow-up of the randomised comparison between an everolimus-eluting bioresorbable scaffold and an everolimus-eluting metallic stent for the treatment of coronary artery stenosis (ABSORB II trial). EuroIntervention. 2018;13:1561-1564.
15. Kereiakes DJ, Ellis SG, Metzger DC, et al. Clinical outcomes before and after complete Everolimus-eluting bioresorbable scaffold resorption: five-year follow-up from the ABSORB III trial. Circulation. 2019;140:1895-1903.
16. Kereiakes DJ, Windecker S, Jobe RL, et al. Clinical outcomes following implantation of thin-strut, bioabsorbable polymer-coated, Everolimus-Eluting SYNERGY Stents. Circ Cardiovasc Interv. 2019;12:e008152.
17. Ellis SG, Kereiakes DJ, Metzger DC, et al. Everolimus-eluting bioresorbable scaffolds for coronary artery disease. N Engl J Med. 2015;373:1905-1915.
18. Tamburino C, Latib A, van Geuns RJ, et al. Contemporary practice and technical aspects in coronary intervention with bioresorbable scaffolds: a European perspective. EuroIntervention. 2015;11:45-52.
19. De Carlo M, Testa L, Leoncini M, et al. Two-year clinical outcomes of the "Italian diffuse/multivessel disease absorb prospective registry" (IT-DISAPPEARS). Int J Cardiol. 2019;290:21-26.
20. Wiebe J, Liebetrau C, Dorr O, et al. Impact of the learning curve on procedural results and acute outcome after percutaneous coronary interventions with everolimus-eluting bioresorbable scaffolds in an all-comers population. Cardiovasc Revasc Med. 2015;16:455-460.
21. Nef HM, Wiebe J, Kastner J, et al. Everolimus-eluting bioresorbable scaffolds in patients with coronary artery disease: results from the German-Austrian ABSORB RegIstRy (GABI-R). EuroIntervention. 2017;13:1311-1318.
22. Gori T, Wiebe J, Capodanno D, et al. Early and midterm outcomes of bioresorbable vascular scaffolds for ostial coronary lesions: insights from the GHOST-EU registry. EuroIntervention. 2016;12:e550-e556.
23. Wiebe J, Dorr O, Bauer T, et al. Everolimus-eluting bioresorbable scaffold implantation for the treatment of bifurcation lesions—implications from early clinical experience during daily practice. Cardiovasc Revasc Med. 2016;17:313-317.
24. Yamaji K, Ueki Y, Souteyrand G, et al. Mechanisms of very late bioresorbable scaffold thrombosis: the INVEST registry. J Am Coll Cardiol. 2017;70:2330-2344.
25. Koppara T, Cheng Q, Yahagi K, et al. Thrombogenicity and early vascular healing response in metallic biodegradable polymer-based and fully bioabsorbable drug-eluting stents. Circ Cardiovasc Interv. 2015;8:e002427.
26. Cassese S, Byrne RA, Tada T, et al. Incidence and predictors of restenosis after coronary stenting in 10 004 patients with surveillance angiography. Heart. 2014;100:153-159.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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