



Bioresorbable vascular scaffolds for complex chronic total occlusions[☆]



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ABSTRACT

Purpose: This analysis of a consecutive series of bioresorbable vascular scaffolds (BVS) implanted for complex chronic total occlusions (CTOs) was done to evaluate the potential of this device to avoid a permanent full metal jacket with drug-eluting stents.

Patients: We analyzed 52 young patients (50.8 ± 8.3 years) for the BVS group, and additionally we followed a subgroup of 17 patients where DES were combined with BVS mainly because severe calcification at the lesion site (hybrid group).

Results: BVS were successfully implanted in 69 of 70 patients. An average of 3.17 BVS were used per lesion in the BVS group, with a CTO length of 28 ± 20 mm, and a reference diameter of 2.92 ± 0.34 mm, 69% were J-CTO ≥ 2. The retrograde approach was used in 38%. The device length was 79 ± 25 mm with 3.65 ± 0.34 mm final balloon diameter. In the hybrid group BVS was used to cover the distal segment beyond the actual occlusion predominantly in LAD lesions. Patients were discharged with dual antiplatelet therapy prescribed for 12 months. At 12 months, no patient had died or experienced an acute myocardial infarction. Angiography or MSCT follow-up available in 67% showed no reocclusion within 12 months. The target revascularization was 7% at 12 months. Two patients experienced a late non-acute reocclusion at 17 and 19 months.

Conclusions: The implantation of BVS for long complex CTOs was feasible with no stent thrombosis despite the high complexity of lesions and multiple BVS implanted. The lack of mechanical strength may lead to the need for focal reintervention, but still the long-term burden of full metal jacketed vessels could be avoided.

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1. Introduction

Chronic total occlusions (CTO) are a major subset of coronary lesions, observed in about 16–18% of patients with coronary artery disease [1,2]. The presence of a CTO is the major reason for referring patients to surgery rather than PCI, because of the historically low success rate [3–5]. This has changed considerably over the last decade, with successful recanalization being achieved in similar rates as in non-occlusive complex lesions [6]. Long and multiple stents are often required to cover the CTO lesion and long-term results are threatened by a high restenosis rate and reocclusion rate although drug-eluting stents (DES) improved this situation [7–9]. However, the long-term outcome of vessels with so called full-metal jacket DES treatment is unclear. Even more, there is evidence that this full-metal jacket may

have an adverse influence on lesion recurrence due to a higher likelihood of stent fractures [10–13].

The everolimus-eluting bioresorbable vascular scaffold (BVS) represents a promising new technology with some potential benefits [14]. The term “scaffold” is used to describe a temporary bioresorbable platform, which provides transient vessel support to resist acute recoil, with drug delivery capability, and full resorption and vessel restoration after 3–5 years [15]. Therefore, BVS may restore normal vascular physiology of the treated vessel. Permit vascular remodeling and lead to late lumen enlargement, as well as may liberate jailed side branches and resolve problems of malapposition. The downside specifically in the setting of CTOs would be the lower radial strength which might be not enough to restrain the maximum plaque load in a completely occluded segment [16]. The lack of visibility will also be a problem as often multiple stents are required and need to be carefully positioned with minimum overlap. The latter would be an advantage for the follow-up, as it would make long-term control of vessel patency visible with low-radiation MSCT imaging [17].

Although BVS have become available for several years now, the experience in complex lesions like CTOs was limited to case reports [18–20] and small studies [21–30], mostly limited to CTOs of low complexity. Therefore, the current analysis intended to understand the

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Table 1
Clinical characteristics in patients treated with BVS for a recanalized CTO.

Number of patients	BVS only 52	BVS + DES 17	All 69
Age, years	50.8 ± 8.3	57.2 ± 7.2	52.4 ± 8.4
Male gender [%]	46 [88]	17 [100]	63 [91]
Body mass index [kg/m ²]	27.8 ± 4.5	27.8 ± 2.2	27.8 ± 4.1
Family history [%]	25 [48]	9 [53]	34 [51]
Hypertension [%]	42 [81]	15 [88]	57 [83]
Hypercholesterolemia [%]	39 [75]	12 [71]	51 [74]
History of smoking [%]	40 [77]	13 [76]	53 [77]
Diabetes [%]	4 [8]	5 [29]	9 [13]
Previous MI [%]	21 [40]	9 [53]	30 [43]
Previous MI in territory of CTO [%]	6 [12]	3 [18]	9 [13]
Previous CABG [%]	2 [4]	1 [6]	3 [4]
Previous PCI [%]	27 [52]	9 [53]	36 [52]
CCS (1/2/3/4) [%]	[11/60/27/2]	[12/59/23/6]	[12/59/26/3]
NYHA > 2 [%]	16 [31]	12 [70]	28 [41]
Glomerular filtration rate [ml/min]	104.9 ± 29.5	97.1 ± 24.1	103.0 ± 28.3
Left ventricular ejection fraction > 50% [%]	50 [96]	15 [88]	65 [94]
Number of vessels diseased			
One-vessel disease [%]	22 [42]	5 [30]	27 [39]
Two-vessel disease [%]	16 [31]	6 [35]	22 [32]
Three-vessel disease [%]	14 [27]	6 [35]	20 [29]

CTO = chronic total coronary occlusion; CABG = coronary artery bypass grafting; CCS = Canadian Cardiovascular Society angina score; MI = myocardial infarction; NYHA = New York Heart Association; PCI = percutaneous coronary intervention; numbers are patients [percentage]; values are mean values ± SD or %.

potential of BVS in patients with complex occlusion with the need for complex procedures such as reverse CART, and the coverage of long stented segments.

2. Methods

2.1. Objective

Patients with a CTO were evaluated to be candidates for receiving BVS instead of a gold standard DES after successful recanalization of the occlusion. The cost of a BVS is multiples of a regular DES, and therefore criteria were based on potential benefit of this new treatment modality such as young age and absence of severe general coronary artery atherosclerosis. Technical criteria were absence of severe calcification and adequate vessel diameter to accommodate the limited diameter range of available Absorb scaffolds (2.5–3.5 mm).

2.2. Patients and procedure

This is an anonymized data analysis of a consecutive series of all patients, who received a BVS for a CTO. The first patient receiving a BVS for a CTO procedure was done in October 2012, the next patient was done only after confirmation of a promising midterm result in July 2013. The patients were explicitly informed that this new therapy concept may bear some potentials but may also require reinterventions in case of loss of radial strength. Due to the intended limitation to young patients < 60 years, and a careful selection of patients, the further enrolment in this patient cohort was slow until the availability of BVS at the end of 2016. In all 69 patients received BVS during this time period, during which a total of 987 patients were treated successfully for a CTO. To limit procedural variability only one operator performed these procedures.

The procedure was indicated on the basis of clinical symptoms in this typical subset of patients with stable angina. Contemporary technique was applied to open the coronary occlusion including all available modalities, specifically the retrograde transcollateral approach [31]. The decision to use a BVS instead of a conventional DES was based on the angiographic appearance with focus on the degree of calcification after the

balloon dilatation of the recanalized vessel. IVUS was used to confirm the feasibility for a BVS implantation mainly based on the vessel diameter and the sonographic appearance of calcification (circumferential rather than intra plaque).

2.3. The hybrid group

In 17 of 69 patients we combined a DES (Xience, Abbott Vascular) with BVS. The strategy was to cover severely calcified lesions with a DES and add BVS to cover the peripheral segment if it was diffusely diseased. This was required in seven patients. In seven patients a DES was required due to unavailable BVS sizes to accommodate for the required vessel diameter of a larger than 4 mm ostium or a smaller than 2.5 mm peripheral segment. In three cases angiography and IVUS showed a severe recoil within the BVS even after repeated high-pressure dilatation which was then covered by a 4 mm Xience of appropriate length. All these patients were summarized in the hybrid group.

2.4. Procedural approach

The lesion was prepared in all cases either based on angiographic assessment, but in 78% on IVUS assessment, with predilatation balloon sizes appropriate to the planned BVS diameter. The implantation of the BVS was done according to the specific recommendations of Abbott Vascular. All BVS were postdilated with a noncompliant balloon .5 mm bigger in diameter than the implanted BVS. In all but 3 patients, more than one BVS was implanted. The connection site between two BVS was controlled with the help of careful angiographic analysis using stent enhancement algorithms of a Siemens Artis-Zee biplane angiographic system.

All patients were monitored in-hospital for 48 h after the procedure, with daily measurement of renal function and cardiac enzymes (troponin T and creatinine kinase). No patient with need for triple therapy because of atrial fibrillation was included. Each patient received clopidogrel 600 mg loading at least 4 h before BVS implantation and was kept on dual antiplatelet therapy for 12 months.

2.5. Follow-up

All patients were followed clinically at least for 12 months. A follow-up angiography was not mandatory, as this was a clinical cohort observation, but they were advised to undergo a follow-up angiography

Table 2
Procedural characteristics in patients treated with BVS for a recanalized CTO.

Number of patients	BVS only 52	BVS + DES 17	All 69
Target vessel of the lesion			
Left anterior descending artery [%]	11 [21]	14 [82]	25 [36]
Left circumflex artery [%]	4 [8]	0	4 [6]
Right coronary artery [%]	37 [71]	3 [18]	40 [58]
In-stent occlusion [%]	1 [2]	1 [6]	2 [3]
Duration of CTO (months) [%]	21 ± 33	22 ± 36	21 ± 34
Lesion length [mm]	27.5 ± 20.3	22.2 ± 11.6	25.6 ± 17.7
Previous CTO attempts [%]	30 [58]	8 [47]	38 [55]
J-CTO Score	2.21 ± 1.21	2.82 ± 1.19	2.36 ± 1.22
Retrograde approach [%]	20 [38]	5 [29]	25 [36]
IVUS use [%]	43 [83]	11 [64]	54 [78]
No. of BVS	3.17 ± 1.00	1.35 ± 0.49	2.72 ± 1.20
BVS stent length [mm]	79 ± 25	34 ± 16	68 ± 31
No. of DESS	0.23 ± 0.47	1.88 ± 1.22	0.64 ± 1.01
DES stent length [mm]	3.7 ± 8.3	45 ± 23	14 ± 22
Duration of procedure [min]	122 ± 42	125 ± 46	123 ± 42
Total fluoroscopic time [min]	35.2 ± 18.6	37.8 ± 18.8	35.8 ± 18.5
Contrast volume [ml]	219 ± 101	216 ± 54	218 ± 92
Air Kerma [mGy]	2146 ± 1325	2287 ± 1091	2180 ± 1267

CTO = chronic total coronary occlusion; IVUS = intravascular ultrasound. Numbers are patients [percentage]; values are mean values ± SD or %.

Table 3

In-hospital and long-term outcome in patients with successful recanalization of a CTO receiving a BVS or hybrid treatment with DES and BVS.

	BVS	BVS + DES
Number of patients	52	17
Periprocedural MACE	0	0
Minor complications		
Troponin increase > 10 ULN [%]	1 [2]	0
CK increase > 3 ULN [%]	1 [2]	0
Contrast induced nephropathy [%]	1 [2]	0
Major bleeding (Hg drop ≥ 3 g/dl) [%]	6 [12]	2 [6]
MACE at 12 months-follow-up		
Death [%]	0	0
Nonfatal myocardial infarction [%]	0	0
Coronary reocclusion [%]	0	0
Clinically driven target vessel revascularization [%]	1 [2]	0
Target vessel revascularization at 12 months [%]	5 [10]	0
Further events beyond 12 months		
Late reocclusion [%]	2 [4]	0

Number of patients and percentage. Abbreviations: MACE = major cardiovascular adverse event; ULN = upper limit of normal.

between 6 and 12 months, specifically when they felt recurrence of symptoms. A follow-up angiography was available in 44 of 69 patients (64%), in another 2 patients (3%) a computer tomographic angiography was done.

2.6. Statistics

Data are presented as absolute numbers and percentages, or median and quartiles (25%–75%). Categorical variables were generally compared by Pearson chi-square test, but for infrequent events Fisher's exact test was used. Continuous variables were compared by Mann-

Whitney-Wilcoxon rank-sum test. All statistical comparisons were two-tailed, and *P* values ≤ 0.05 were considered statistically significant. All analyses were performed using NCSS 10 (NCSS LLC, Kaysville, Utah, U.S. A.).

3. Results

3.1. Clinical and angiographic characteristics of patients receiving BVS for CTOs

The patients receiving a BVS were young and predominantly male and only 8% were diabetic (Table 1). As compared to those who received BVS in addition to a DES, BVS only was used predominantly in the right coronary artery where extensive metal caging would interfere with the natural mobility of this artery. On the other hand the hybrid approach was used more often in the left anterior descending coronary artery where the BVS was used to extend the stented area to the mid and distal LAD to avoid a full metal jacket and leave segments metal-free which might serve for a future bypass anastomoses.

IVUS was used to determine whether BVS implantation was feasible, the major criteria being the size of the vessel except in 14% of patients with shorter occlusions. In the hybrid approach where an additional one or two BVS were added distal to a DES this was done without IVUS in 36% but finishing with a non-compliant balloon in the distal vessel 0.5 mm larger than the BVS was always done.

In 38% of procedures a retrograde approach was used in the BVS group, and the reverse CART (controlled antegrade and retrograde tracking) procedure was used in all of these. This involved often a short segment of subintimal wire passage within the lesion segment, which was then covered by the BVS (Table 2).

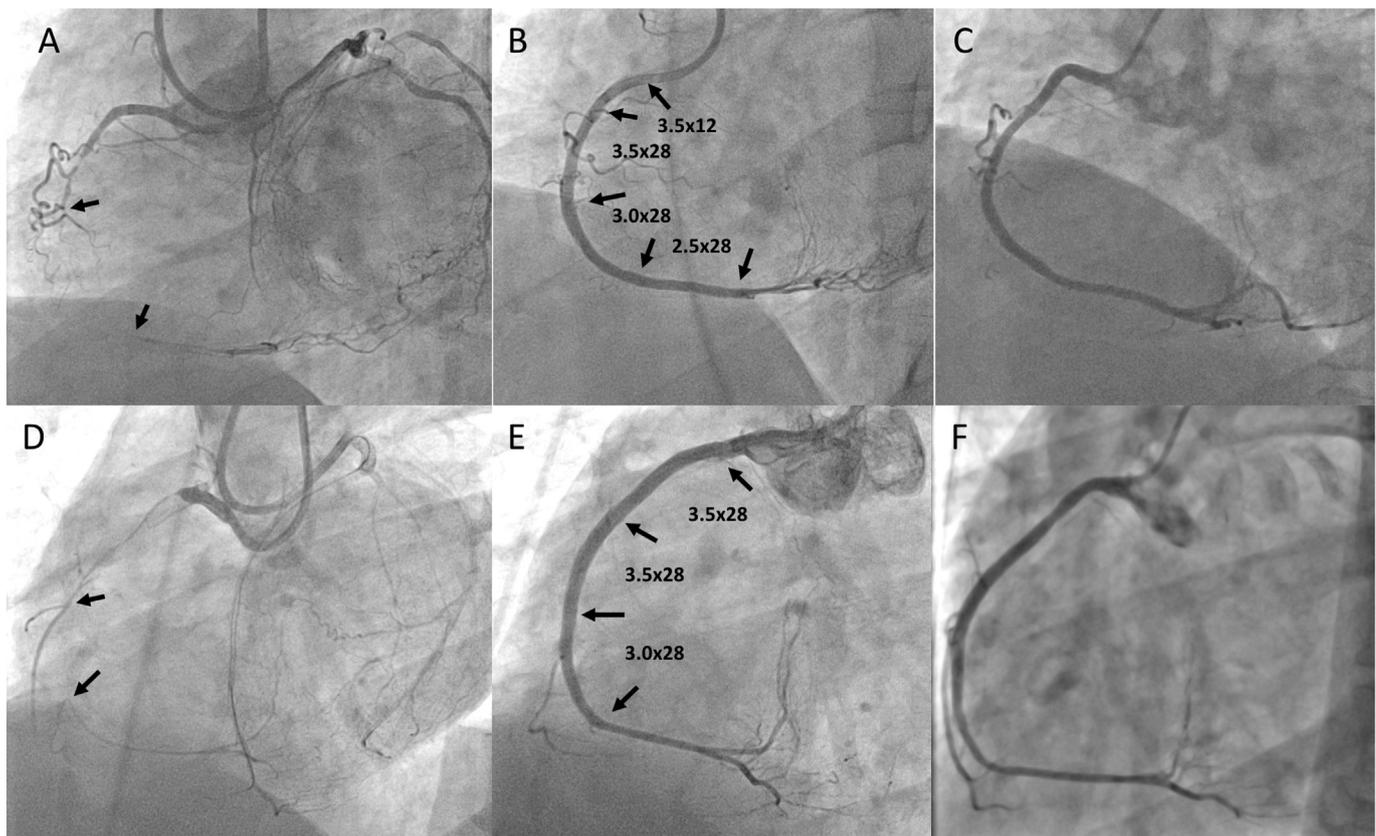


Fig. 1. A: Long RCA occlusion (J-CTO score 4) in a 50 year old male. B: In a retrograde reverse CART procedure (duration 99 min, fluoro time 29 min) after predilatation four BVS were implanted. C: At nine months follow-up no restenosis was detected, notice the positive remodeling in the branches beyond the crux cordis. There is no clinical event at four years after PCI. D: Long RCA occlusion (J-CTO score 3) in a 41 year old male. E: In a retrograde reverse CART procedure (duration 134 min, fluoro time 34 min) after predilatation three BVS were implanted. F: At eight months follow-up no restenosis was detected. No clinical events were reported two years after PCI.

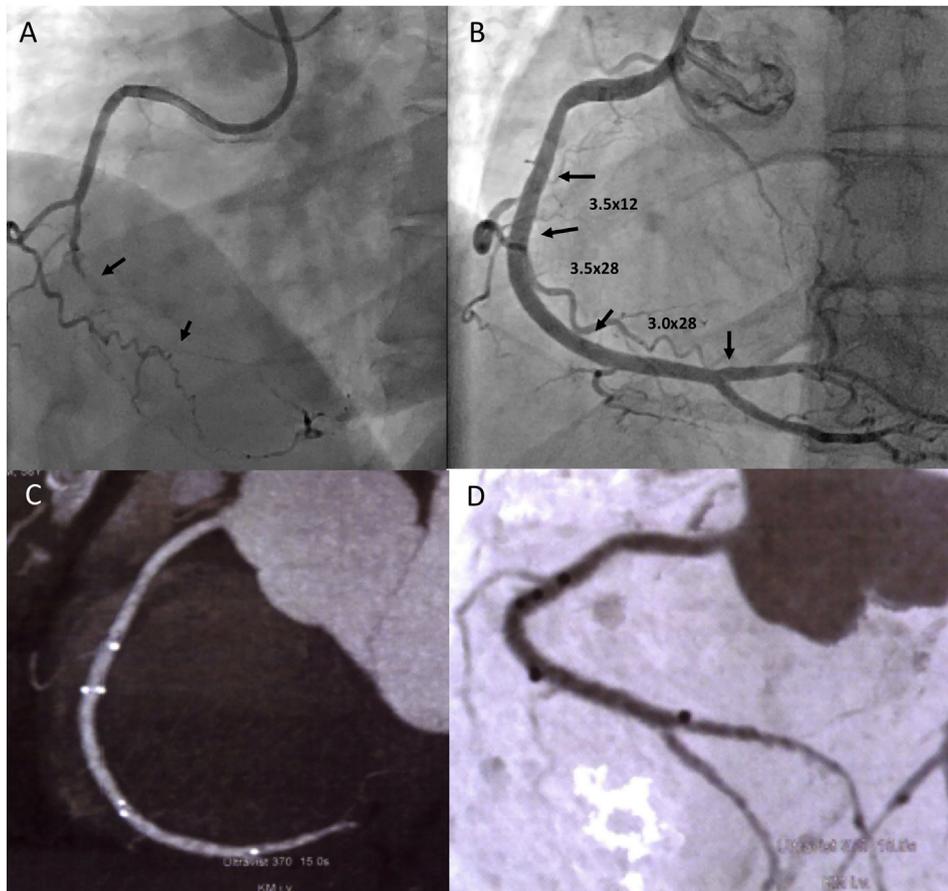


Fig. 2. A: Long RCA occlusion (J-CTO score 2) in a 58 year old male. B: In an antegrade wire based approach (duration 93 min, fluoro time 21 min) after predilatation three BVS were implanted. C and D: At twelve months follow-up the patient underwent a CT angiography. No restenosis was detected. No clinical event was reported at four years after PCI.

3.2. Procedural outcomes of PCI

Only after a successful balloon dilatation, BVS were planned to be used, therefore TIMI 3 flow was already confirmed before the BVS placement. BVS could be delivered in all but one patient, who is not included in the analysis. This patient had severe calcification finally covered by a DES delivered through a guide-extension device. In all patients reported here, the delivery of the BVS was done after sufficient lesion preparation based on non-compliant balloon angioplasty. Patients who would need rotational atherectomy were not deemed suitable for BVS.

The procedural events are summarized in Table 3. There were 15 patients (22%) of all patients with a slight increase of troponine T by more than ten times the ULN, but only one with >70, and only this one patient with a CK increase above three times ULN. One patient had a transient increase of creatinine qualifying as contrast induced nephropathy, and seven patients had a asymptomatic drop of hemoglobin ≥ 3 g/dl, but none needed blood transfusion. All patients were discharged 48 h after the procedure on aspirin and clopidogrel.

3.3. Long-term outcome in patients with a CTO treated with BVS

In all patients, but specifically in those receiving more than one BVS we advised a follow-up angiography, which was done in the referring hospital or in our own institution in 65% patients in the BVS group, and in 59% of patients in the hybrid group (Fig. 1). Two patients in the BVS group elected to have a CT-angiography as follow-up (Fig. 2).

No patient had a reocclusion at the time of the first follow-up angiography seven months after the procedure. One patient had improved, but ongoing symptoms, in whom a residual lesion within the BVS was

treated by a Xience stent. Four other patients had no symptoms, but IVUS on follow-up revealed a considerable recoil within an area of massive plaque load especially with lack of remodeling, and therefore three received a Xience stent, in one patient another BVS with good immediate result was implanted (Fig. 3).

There were two patients in whom the initial angiographic follow-up showed a patent artery with TIMI 3 flow without clinical symptoms. Both had long diffuse occlusions and extensive disease at the outset, and therefore no further intervention was done at follow-up as they were asymptomatic. However, as the angiographic result was not reassuring, we scheduled an additional follow-up which revealed then late reocclusion in both at 16 and 17 months after PCI (Fig. 4). One could be reopened with Xience stent coverage, the other was failed even with a retrograde approach.

Notably, none of the hybrid patients showed any restenosis at follow-up, neither within the DES segment of the original CTO body, nor in the BVS used to cover the distal disease. There was also a patient with an in-stent CTO in both groups each with uneventful follow-up.

4. Discussion

At the time of this report, the BVS used in this study is no longer available due to doubts in long-term safety of BVS related to the longer follow-up of larger trials [32]. Despite that, there are several reports that showed the feasibility of BVS use in CTOs [21–30]. Our series adds to this perception of a feasible option for revascularization in a subset of rather young patients with long and complex CTO lesions successfully treated with modern recanalization technique including a high fraction of the retrograde approach.

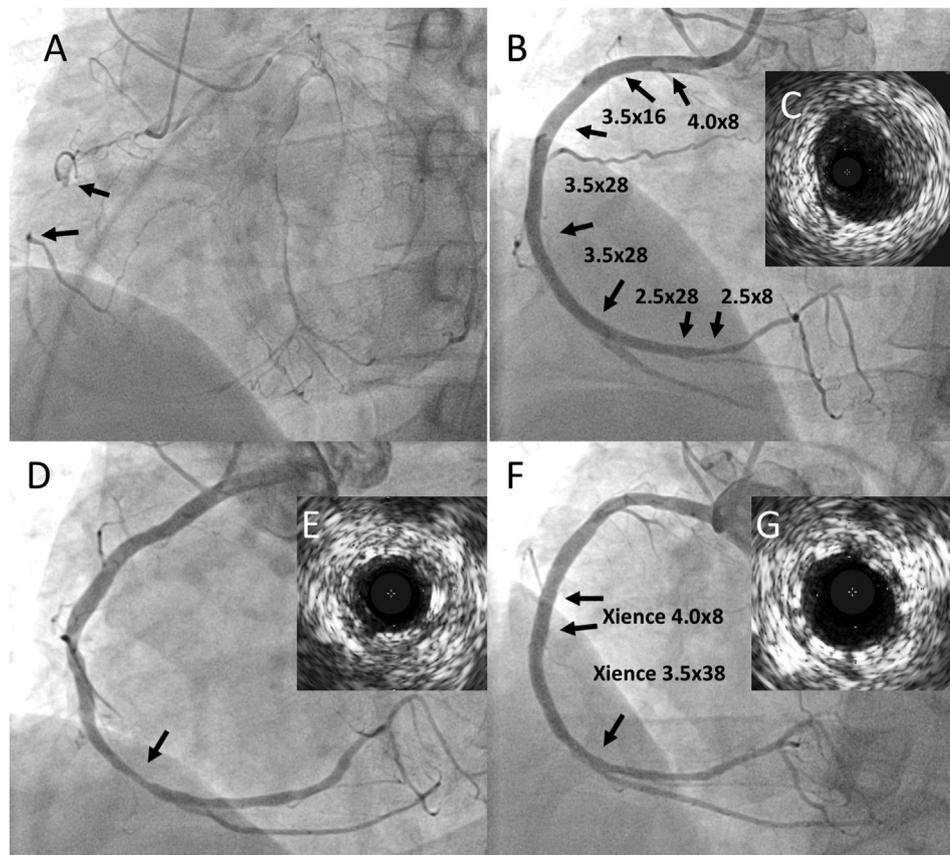


Fig. 3. A: RCA occlusion (J-CTO score 3) in a 43 year old male with diffuse atherosclerosis of the whole target artery. B: In a retrograde reverse CART procedure (duration 150 min, fluoro time 45 min) after predilatation five BVS were implanted with a short 2.5 × 8 distal because of an edge stenosis. C: IVUS showed residual plaque at the RCA ostium with a diameter beyond 3.5 mm, which lead to an additional Xience 4 × 8 mm stent to be implanted there. D: At 13 months follow-up a loss of lumen diameter upto a 50% restenosis was detected. E: IVUS revealed a negative remodeling with a lumen narrowing. F: A long 3.5 × 38 mm Xience drug-eluting stent was implanted in the area of the negative remodeling with an additional 4 × 8 mm immediately proximal. G: IVUS after the Xience stent at the same location as E.

The rationale of using BVS for coronary lesions is to restore the anatomic integrity and vascular function without a permanent implant [33]. The restoration should not be anticipated in heavily calcified lesions, where a permanent restraining force by metallic implants maybe the only way to keep the artery open. We therefore did not plan to include severely calcified lesions after extensive lesion preparation including rotational atherectomy.

When we use BVS in such a challenging lesion subset, we must follow the prescribed rules of implantation stringently to avoid early complications that were experienced in some of the registries (GHOST) [34]. The relevance of the proper deployment technique had been highlighted by subanalysis from several trials [35,36]. The lesion preparation is one of the issues for a successful BVS deployment.

Our results combine two possible approaches to use BVS in CTOs in a younger than usual population with less calcified atherosclerosis. First, we wanted to restore coronary anatomy to a severely diseased occluded artery without permanent residual material, second, we wanted to avoid extensive full metal jackets beyond the actual calcified occlusive site by using BVS for the necessary stent extension distal to the actual lesion site. The latter was predominantly the case in LAD lesions, whereas the former approach was predominantly used in the RCA which is the leading vessel location for CTOs.

4.1. Long-term follow-up and comparison to published data

There are several studies presented in the subset of CTOs that report the feasibility of deploying BVS, but the major issue is the long-term patency. What needs to be avoided primarily is a reocclusion which was observed after the first-generation DES in the PRISON II trial [37].

Second generation everolimus-eluting DES achieved a much lower reocclusion rate [38,39], but it is important to assure patency by other means than just clinical follow-up especially in CTO patients.

In a smaller recent trial, however with long segments covered by BVS of about 70 mm, the 6-month angiographic patency was perfect with no TVR [40], but our own experience shows that longer follow-up is needed. In contrast another study with complete angiographic follow-up reported high TVR in the range of 20%, however, with an extensive follow-up of almost 2 years [28]. In the CTO-ABSORB pilot study the follow-up included CT angiography and extensive imaging at the time of implantation [23]. Even though the MACE rate appeared clinically low, but there were two silent reocclusions amounting to a 6% rate. The complexity in this study was low given the number of required BVS, and a low rate of retrograde approach. In another report of a less complex CTO population the TVR was in the range of 15% including an acute late occlusion [27]. Other reports show lower event rates in less complex CTOs [22,26].

Series of BVS without or with low rate of angiographic follow-up in CTOs are relying on clinical recurrence, which may be misleading due to silent restenosis or reocclusion in the presence of well-developed collaterals [41]. The largest multi-center report of 105 patients is one without systematic angiographic follow-up, and therefore MACE events of 3 to 4% at 6 months are not necessarily reassuring [30]. The same applies to another study in 70 patients with moderate complexity [21], and to another series without any angiographic follow-up of 65 patients with no MACE reported at all [29].

The distinctive feature of our report as compared to the published data is the extensive BVS number and length in the BVS group, the youngest patient population and the highest rate of reverse CART as

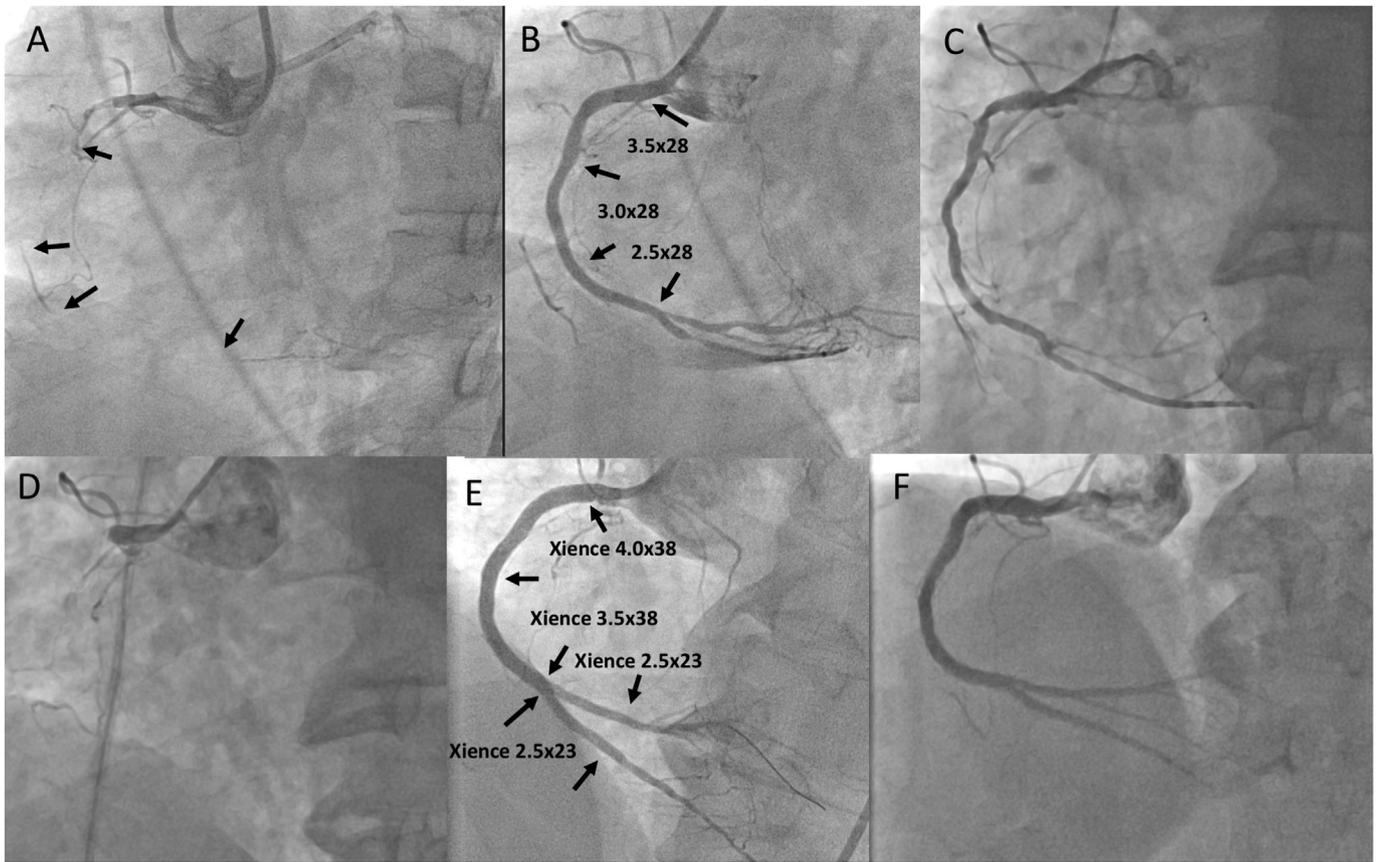


Fig. 4. A: Long RCA double occlusion (J-CTO score 4) in a 42 year old male. B: In a retrograde procedure with successful wire crossing (duration 109 min, fluoro time 33 min) after predilatation three BVS were implanted. The final angiography shows still diffuse disease and stenotic segments beyond the crux cordis which were not treated at that time. C: At eight months follow-up no restenosis was detected within the stented area, but there was a long zone of negative remodeling in the PL system of the RCA but some improvement in the PDA. No PCI was done as there were no clinical symptoms. D: After another nine months follow-up clinical symptoms had recurred, and another angiography revealed now a proximal RCA reocclusion. E: In another retrograde procedure the vessel could be recanalized with four DES including treatment of the distal bifurcation with a V-stent approach. F: A final angiographic follow-up seven months later showed no restenosis and patent distal branches with a <50% stenosis at the origin of the PL branch.

an indicator of lesion complexity required to treat the CTO. The J-CTO score itself of 2.2 does not appear very high as compared to 2.6 in other published studies, the validity of the J-CTO score, however, may be challenged when for a high score a predominant antegrade technique was sufficient for the treatment [23,30].

Nominally the ischemia driven TVR was only 2% and comparable to the above studies, and in many young patients we could achieve the result of restoration of anatomy without a permanent implant. However, on regular IVUS examination we observed a few additional lesions with heavy plaque burden and recoil within the already weakened scaffold which made us act with an additional stent support. This is an anecdotal approach and long-term development may have led to a late positive remodeling. On the other hand, we had the experience in two patients where we did wait on due to the diffuse character of the original atherosclerotic extent and patency at follow-up, which then later at one and a half years resulted in reocclusion. There seem to be lesions which are less responsive to a BVS implantation. The numbers in this series are small, but there were some lesions where the restraining force of a permanent implant appeared necessary. Already at the time of implantation, we had to enforce considerable recoil of the BVS by an additional DES in three patients. Another issue was the restriction of the diameter by the available BVS. Especially in the right coronary artery a larger than 3.5 mm diameter is often necessary to cover the proximal segments, and here we were required to add short DES for the ostium.

We did not perform routine IVUS follow-up, but in those with a relevant lumen loss obvious from the angiography, we used IVUS to examine the segment. It showed that the lesion recurrence was in segments with high plaque load and little positive remodeling, leaving not enough

space for the plaque to be compressed. On the other hand we did not see late malapposition in those with IVUS follow-up due to the fact that the distal BVS lumen size was chosen according to the proximal reference and not the distal reference, which might be misleading given a late positive remodeling typical for CTOs [42,43].

4.2. Late lesion recurrence

We have learned from the ABSORB trials that during longer-term follow-up even late reocclusions or ischemic events may occur [32]. Also, in this study we observed two late occlusions in patients with initial angiographic patency at 16 and 17 months. However, in both patients there was already considerable late loss observed despite absence of symptoms, which was why no early reintervention was done. It appears that the idea of further improvement of the vessel anatomy through late remodeling as observed in serial assessments of the ABSORB I cohort could not be relied on in CTOs with the highest possible plaque load before intervention [17].

From our limited experience in complex CTOs we would not assume that the covering of subintimal tracks which occur in the course of a recanalization procedure was a trigger for late events, but rather the lack of the restraining force of a scaffold in segments with maximum plaque load but lack of positive remodeling. Still the observation of delayed strut coverage in CTOs from OCT examinations [44] and the formation of aneurysms [45] may caution to use BVS in extensive dissections, which are observed when the so called hybrid approach is applied [46].

We included also a series of patients where the BVS was used in a hybrid way together with DES as an additional distal stent in diffusely

diseased segments distal the occlusion site, and in all of them this seemed to have worked out well with no late recurrence. Even the use of BVS or the hybrid approach was feasible in the few in-stent CTOs which were included with good long-term outcome [47]. The rationale in these patients was to avoid additional stent layers and treat the extended lesion beyond the stent with singular layers of BVS or DES.

4.3. Clinical implications

The present report is a prospective analysis from a non-randomized series of successfully opened CTOs in young patients where in order to avoid extensive DES coverage with full metal jacket we elected to use BVS (up to six scaffolds for one lesion). The long-term outcome was favorable even in this cohort of high lesion complexity, similar to previous reports of less complex CTOs, but there remains the caveat of increased recoil in lesions with high plaque load and lack of remodeling, and also the progressive deterioration of the result beyond 6 and 9 months of follow-up.

However, the principle of anatomic restoration occluded vessels without a permanent implant remains a desirable option especially for young patients, and it should be the focus also of future generations of bioresorbable scaffolds to be applicable and effective in CTO lesions [48, 49].

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