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Effects of Coronary Artery Revascularization with a Polymer-Free Biolimus A9–Coated BioFreedom Stent Versus Bypass Surgery before Noncardiac Surgery

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Purpose: The present study aimed to evaluate the efficacy and safety of polymer-free drug-coated BioFreedom stent implantation in comparison to coronary artery bypass graft (CABG) before major noncardiac surgery.

Materials and Methods: In a multicenter registry, 55 patients required revascularization before major noncardiac surgery that should not be delayed >6 months. Of them, 27 underwent BioFreedom stent implantation and 28 underwent CABG. Primary outcomes included rate of noncardiac surgery, time from revascularization to noncardiac surgery, and occurrence of composite outcomes (all-cause death, myocardial infarction, stent thrombosis, stroke, repeat revascularization, or major bleeding).

Results: The rate of major noncardiac surgery was significantly higher in the BioFreedom group (92.6%) than in the CABG group (64.3%; p=0.027). Time from revascularization to noncardiac surgery was significantly shorter in the BioFreedom group (38.0 days) than in the CABG group (73.0 days; p=0.042). During the hospitalization for revascularization period, the occurrence of primary outcomes did not differ between the groups. However, the BioFreedom group showed a shorter hospitalization period and lower total treatment cost than the CABG group. During the hospital stay for noncardiac surgery, the occurrence of composite outcome was not significantly different between groups (4% vs. 0%; p>0.999): stroke occurred in only 1 case, and there were no cases of death or stent thrombosis in the BioFreedom group.

Conclusion: This study demonstrated that BioFreedom stenting as a revascularization strategy before major noncardiac surgery might be feasible and safe in selected patients with less severe coronary artery diseases.

Key Words: Percutaneous coronary intervention, drug-coated stent, coronary artery bypass, preoperative care

INTRODUCTION

In patients with coronary artery diseases in which prompt coronary revascularization is required before a major noncardiac surgery, current guidelines recommend the use of balloon angioplasty, bare-metal stent (BMS) implantation, or coronary artery bypass graft (CABG), although the expanded use thereof in real-world practice is challenging due to their own various limitations.[1,2] In the case of preoperative CABG, it is often a burden to patients to undergo two consecutive major surgeries (CABG and planned major noncardiac surgery) in a short period of time. This burden can be even greater in cases

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in which urgent surgery is needed, such as cancer. With drug-eluting stents (DES), elective surgery is recommended to be delayed for >6 months upon their implantation. Polymer- and carrier-free Biolimus A9–coated stent (BioFreedom, Biosensors Interventional Technologies, Singapore) implantation with 1-month dual antiplatelet therapy (DAPT) was recently reported to be safe and effective for patients with a high risk of bleeding.[1-4] Because of a need for a shorter DAPT duration, its application before noncardiac surgery could be possible, although no data are available to demonstrate this.[3,4] Therefore, we sought to evaluate the outcomes after percutaneous coronary intervention (PCI) with BioFreedom stent implantation for patients requiring coronary revascularization before a major noncardiac surgery, compared with CABG, a standard treatment strategy, before noncardiac surgery.

MATERIALS AND METHODS

This multicenter study was conducted using data from the Korean Multicenter Angioplasty Team registry.[5,6] The study protocol followed the Declaration of Helsinki, and was approved by the Institutional Review Boards of the participating hospitals (IRB No. 4-2015-1094). All study subjects provided informed consent for their participation in the study. Patients who met all of the following criteria were finally analyzed: 1) candidate for intermediate- to high-risk noncardiac surgery; 2) candidate for noncardiac surgery deemed impossible to delay for >3–6 months by noncardiac surgeons; 3) completion of coronary evaluation as recommended in current guidelines;[1,7] and 4) patients requiring revascularization before noncardiac surgery due to the presence of acute coronary syndrome or stable angina with reduced left ventricular ejection fraction <45%, proven ischemia, unstabilized chest pain, or left main artery involvement, based on the recommendations of current guidelines.[1,7] Patients who did not meet these criteria or those with coronary disease unsuitable for both CABG and PCI were excluded. Between January 2016 and March 2017, a total of 8173 patients consulted the cardiology division for a preoperative cardiovascular evaluation before a major noncardiac surgery, and 55 eligible patients required coronary revascularization before noncardiac surgery, including 27 who underwent BioFreedom stent implantation (BioFreedom group) and 28 who underwent bypass surgery (CABG group) upon discussion among a multidisciplinary heart team, noncardiac surgery department, patients, and family members. There was no BMS implantation or plain old balloon angioplasty case during the study period. Details on the flow of the study are provided in Fig. 1.

All study patients remained on DAPT, consisting of aspirin 100 mg and clopidogrel 75 mg, until 5–7 days before noncardiac surgery. The timing of noncardiac surgery was finally decided based on the multidisciplinary discussion of the heart team, including primary attending physicians, cardiac surgeons, and noncardiac surgery department members, who considered the patients' opinions and medical conditions.

The primary outcomes were as follows: 1) rate of noncardiac surgeries finally performed and 2) composite of major clinical adverse events, including all-cause death, myocardial infarction (MI), stent thrombosis, stroke, repeat revascularization, or major bleeding during hospitalization for noncardiac surgery.

The secondary outcomes were as follows: 1) the time from coronary revascularization to noncardiac surgery; 2) time from index coronary angiography to revascularization; 3) a composite of major clinical adverse events during hospitalization for revascularization and during the total study period, from the initial angiography to the last hospital visit; 4) major or minor bleeding; and 5) total hospitalization costs for revascularization and noncardiac surgery.

Clinical events were defined by the Academic Research Consortium.[8,9] All deaths were considered to be of cardiac origin unless a definite noncardiac cause was established. MI was defined as an elevation of creatine kinase-MB above the upper normal limit (UNL) or a troponin T/I level >99th percentile of the UNL with concomitant ischemic symptoms or electrocar-

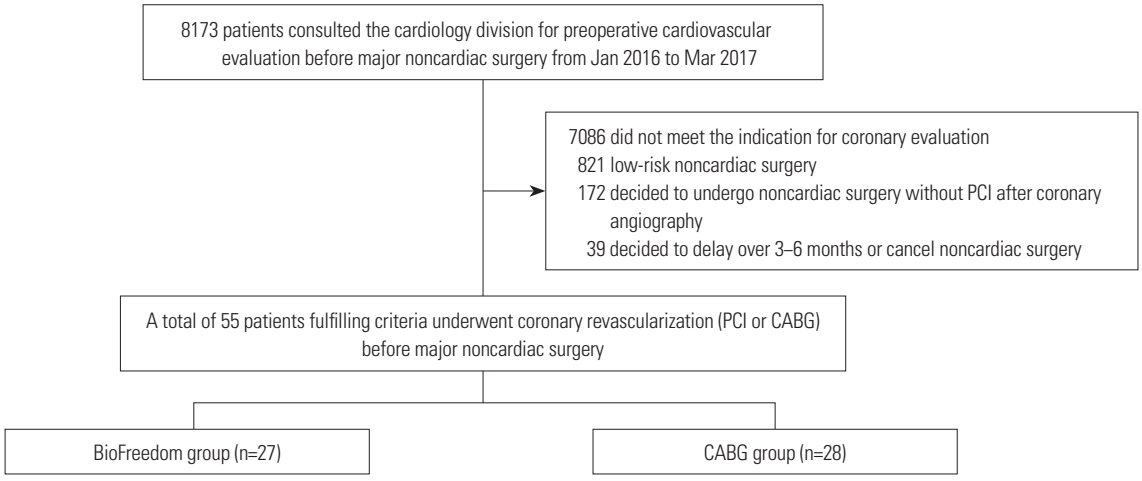

Fig. 1. Study flow. PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft.

diographic findings indicative of ischemia unrelated to an interventional procedure. Cardiac enzymes were measured during revascularization, and perioperative hospitalization and peak levels were analyzed. Stent thrombosis was defined as definite or probable stent thrombosis. Stroke event was defined as an acute neurological deficit of vascular etiology lasting >24 h.[10] Bleeding was classified by Thrombolysis in Myocardial Infarction risk score.[11] The planned surgeries were classified according to their clinical urgency into urgent (category 1: admission within 30 days desirable), semi-urgent (category 2: admission within 90 days desirable), and indolent (category 3: admission at some time in the future acceptable).[12] To assess cardiac operative risk, the European system for cardiac operative risk evaluation (EuroSCORE) II was obtained.[13] Coronary lesion complexity was expressed as Synergy between PCI with Taxus and Cardiac Surgery (SYNTAX) score,[14] for which an analysis was performed at an independent core laboratory (Cardiovascular Research Center, Seoul, Korea). Hospitalization cost was assessed as total uninsured medical expenses.

Categorical variables are expressed as numbers and percentages, and were compared using the chi-square test or Fisher's exact test. Continuous variables are expressed as a mean±standard deviation, and were compared with analysis of variance. Logistic regression analysis was performed to assess the major determinants of PCI versus CABG as the revascularization strategy. Variables with p values <0.1 in univariate analysis, revised cardiac risk index, which may be an important factor in the decision to perform cardiac surgery, and SYNTAX score were entered in the multivariable model as covariates. We evaluated clinical composite outcomes as time to first event analyses. Hazard ratios (HRs) with 95% confidence intervals (CIs) were determined, and the cumulative event rates were compared with Kaplan-Meier and Cox proportional hazard models with treatment strategy as fixed-effect factors. HRs, 95% CIs, and two-sided p values were calculated using Cox models. All statistical analyses were performed using R software, version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria). p values <0.05 were considered statistically significant.

RESULTS

Baseline characteristics are shown in Table 1. Compared with the CABG group, the BioFreedom group had a lower incidence of history of PCI, a lower proportion of three-vessel disease and chronic total occlusion (CTO), and a lower SYNTAX score. The types of planned noncardiac surgeries did not differ significantly between the two groups.

In the multivariate analysis for the determinants of PCI versus CABG, history of PCI [odds ratio (OR)=65.99; 95% CI=2.52–13645.94; p=0.042], CTO (OR=7.82; 95% CI=1.15–70.52; p=0.044), and a higher SYNTAX score (OR=1.19; 95% CI=1.02–1.45; p=0.043) were significant factors that favored CABG, while history of stroke (OR=0.01; 95% CI=0.00–0.45; p=0.048) was a significant determinant of PCI (Fig. 2).

A detailed explanation of the revascularization procedures performed in both groups is provided in Table 2. The time from initial coronary angiography to revascularization was shorter in the BioFreedom group than in the CABG group (p <0.001).

Table 1. Baseline Characteristics

Variables	BioFreedom (n=27)	CABG (n=28)	*p* value
Age (yr)	71.5±7.4	69.7±6.8	0.341
Male	19 (70.4)	24 (85.7)	0.293
Hypertension	18 (66.7)	19 (67.9)	>0.999
Diabetes mellitus	9 (33.3)	14 (50.0)	0.327
Chronic kidney disease	5 (18.5)	8 (28.6)	0.576
Chronic obstructive lung disease	1 (3.7)	4 (14.3)	0.370
Current smoker	11 (40.7)	7 (25.0)	0.339
Previous percutaneous coronary intervention	1 (3.7)	8 (28.6)	0.033
Previous ischemic stroke	5 (18.5)	1 (3.6)	0.179
Revised cardiac risk index			0.090
1	15 (55.6)	8 (28.6)	
2	9 (33.3)	12 (42.8)	
≥3	3 (11.1)	8 (28.6)	
EuroSCORE II (%)	1.2±0.5	1.2±0.5	0.749
Left ventricular ejection fraction (%)	62.3±11.6	54.5±12.9	0.023
Clinical presentation			0.914
Stable angina	10 (37.0)	11 (39.3)	
Unstable angina	13 (48.1)	12 (42.9)	
Acute myocardial infarction	4 (14.8)	5 (17.9)	
No. of diseased vessels			0.024
1	10 (37.0)	5 (17.9)	
2	11 (40.7)	6 (21.4)	
3	6 (22.3)	17 (60.7)	
Treated vessel, left anterior descending	24 (88.9)	27 (96.4)	0.577
Left main involvement	9 (33.3)	11 (39.3)	0.858
Chronic total occlusion	3 (11.1)	19 (67.9)	<0.001
Bifurcation	6 (22.2)	9 (32.1)	0.601
SYNTAX score	14.7±5.8	23.2±9.2	<0.001
0–22	25 (92.6)	16 (57.1)	0.008
23–32	2 (7.4)	7 (25.0)	
≥33	0 (0)	5 (17.9)	
Details of the planned noncardiac surgery			
Classification by urgency			0.275
Urgent	20 (74.1)	21 (75.0)	
Semi-urgent	5 (18.5)	2 (7.1)	
Indolent	2 (7.4)	5 (17.9)	
Cancer surgery	16 (59.3)	18 (64.3)	0.916

CABG, coronary artery bypass graft; SYNTAX, Synergy between PCI with Taxus and Cardiac Surgery.
Values are presented as a n (%) or mean±standard deviation.

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The BioFreedom group had fewer revascularized vessels ($p<0.001$) and a lower complete revascularization rate ($p=0.025$) than the CABG group. While there were no significant inter-group differences in clinical events (Table 2), the BioFreedom group demonstrated fewer bleeding complications (0% vs. 17.8%; $p=0.067$) and less frequent transfusions than the CABG group. Regarding medical expenses for revascularization, the BioFreedom group had a shorter mean hospital stay and lower overall cost than the CABG group ($p<0.001$).

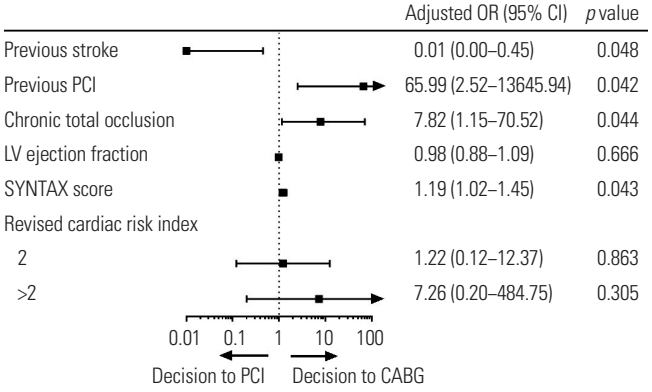

Fig. 2. Independent determinants of PCI vs. CABG. PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; LV, left ventricular; SYNTAX, Synergy between PCI with Taxus and Cardiac Surgery; OR, odds ratio; CI, confidence interval.

After coronary revascularization, the rate of noncardiac surgery was significantly higher in the BioFreedom group (92.6%) than in the CABG group (64.3%; $p=0.027$). Among the patients who planned to have urgent (category 1) surgery, all patients in the BioFreedom group underwent noncardiac surgery after coronary revascularization; six patients in the CABG group (100% vs. 71.4%; $p=0.032$) did not undergo surgery after coronary revascularization because of patient refusal (Table 3, Fig, 3). Time from revascularization to noncardiac surgery was significantly shorter in the BioFreedom group than in the CABG group (38.0 days vs. 73.0 days; $p=0.042$). Total time from diagnostic coronary angiography to noncardiac surgery was also significantly shorter in the BioFreedom group than in the

Table 2. Revascularization Strategy and In-Hospital Outcomes

Variables	BioFreedom (n=27)	CABG (n=28)	*p* value
Time from initial coronary angiogram to revascularization (days)	0 [0–0]	5.5 [2.0–17.5]	<0.001
Revascularization			
No. of vessel revascularized	1.3±0.5	2.3±0.8	<0.001
Total number of stents	1.3±0.5		
Stent diameter (mm)	3.0±0.3		
Stent length (mm)	23.6±7.2		
No. of grafted vessels		2.6±1.2	
Use of left internal thoracic artery		28 (100.0)	
Off-pump surgery		28 (100.0)	
Minimal invasive direct coronary bypass		3 (15.8)	
Complete revascularization	16 (59.3)	25 (89.3)	0.025
In-hospital outcomes			
Day of hospitalization	1 [1–2]	9 [8–12]	<0.001
Complications			
All-cause death	0 (0)	0 (0)	>0.999
Myocardial infarction	0 (0)	0 (0)	>0.999
CK-MB elevation >3×UNL	2 (7.4)	2 (7.1)	>0.999
Repeat revascularization	0 (0)	0 (0)	>0.999
Stroke	0 (0)	0 (0)	>0.999
Any bleeding	0 (0)	5 (17.8)	0.067
Major	0 (0)	3 (10.7)	0.248
Minor	0 (0)	2 (7.1)	0.488
Transfusion	2 (7.4)	9 (32.1)	0.051
Hospitalization cost (United States dollar)	6510 [5779–7759]	26168 [24237–28734]	<0.001
Discharge medication			
Dual antiplatelet therapy	27 (100.0)	28 (100.0)	0.893
Statins	27 (100.0)	28 (100.0)	0.893
Beta blockers	22 (81.5)	25 (89.3)	0.661
Angiotensin converting enzyme or angiotensin receptor blockers	13 (48.1)	10 (35.7)	0.509

CABG, coronary artery bypass graft; CK-MB, creatine kinase-myocardial band; UNL, upper normal limit.
Values are presented as a n (%), mean±standard deviation, or median [interquartile range].

CABG group (40.0 days vs. 93.0 days; $p<0.001$) (Table 3, Fig. 3). The rate of noncardiac surgery performed after revascularization within 2 months was significantly higher in the BioFreedom group than in the CABG group. Despite a shorter duration of DAPT after PCI and the need for the maintenance of antiplatelet drug therapy during surgery, the BioFreedom group had only one perioperative major adverse event (ischemic stroke), which did not differ significantly from the CABG group (4% vs. 0%; $p>0.999$) (Table 3). Hospitalization periods and costs were similar between the two groups. However, the BioFreedom group had lower overall hospital costs, covering both coronary revascularization and noncardiac surgery. A representative case from the BioFreedom group is shown in Supplementary Fig. 1 (only online).

There was no significant difference in the composite of major clinical events between the BioFreedom and CABG groups

Table 3. Execution, Delay, and Outcomes of Noncardiac Surgery

Variables	BioFreedom (n=27)	CABG (n=28)	*p* value
Patients with noncardiac surgery finally performed	25 (92.6)	18 (64.3)	0.027
Rates of noncardiac surgery finally performed according to the types of surgery			
Urgent	20/20 (100.0)*	15/21 (71.4)*	0.032
Semi-urgent	4/5 (80.0)*	2/2 (100.0)*	>0.999
Indolent	1/2 (50.0)*	1/5 (20.0)*	>0.999
Cancer surgery	16/16 (100.0)*	14/18 (77.8)*	0.140
Reasons for cancellation of noncardiac surgery (n)	2	10	
Patient refusal after revascularization	1	6	
Change of treatment strategy	1	2	
Intracranial hemorrhage	0	2	
Time from revascularization to noncardiac surgery (days)	38.0 [35.0–46.0]	73.0 [35.0–94.0]	0.042
Urgent surgery	38.5 [35.5–50.5]	77.0 [35.0–102.0]	0.083
Cancer surgery	39.5 [35.5–50.5]	79.5 [47.0–116.0]	0.021
Total time from diagnostic coronary angiography to noncardiac surgery (days)	40.0 [37.0–50.0]	93.0 [60.0–137.0]	<0.001
Urgent surgery	40.5 [38.0–53.5]	89.0 [59.0–139.5]	0.002
Cancer surgery	41.0 [39.0–53.5]	97.5 [61.0–142.0]	0.002
Performing noncardiac surgery after revascularization			
Within 1 month	4 (16.0)	3 (16.7)	>0.999
Within 2 months	22 (88.0)	8 (44.4)	0.006
Antiplatelet therapy			
Duration of dual antiplatelet therapy before surgery (days)	31.5±9.4	57.5±47.0	0.027
Maintenance of mono-antiplatelet drug during surgery	24 (96.0)	5 (27.8)	<0.001
Perioperative clinical adverse events			
Composite of major adverse events	1 (4.0)	0 (0)	>0.999
All-cause death	0 (0)	0 (0)	>0.999
MI or stent thrombosis	0 (0)	0 (0)	>0.999
Stroke	1 (4.0)	0 (0)	>0.999
Major bleeding	0 (0)	0 (0)	>0.999
Post-operation cardiac enzyme analysis			
Peak CK-MB values (ng/mL)	3.2±2.6	1.9±1.4	0.115
Peak troponin T values (pg/mL)	14±8	28±32	0.191
CK-MB elevation >UNL×3	0 (0)	0 (0)	>0.999
Troponin T elevation >UNL	5 (35.7)	9 (75.0)	0.108
Other outcomes			
Minor bleeding	0 (0)	4 (22.2)	0.052
Transfusion	4 (16.0)	5 (27.8)	0.578
Hospitalization period (days)	16.0±25.3	15.1±22.3	0.906
Hospitalization cost (United States dollar)	9318 [5112–11981]	10983 [9608–13580]	0.305
Total cost from revascularization to noncardiac surgery (United States dollar)	15347 [12436–18520]	36710 [31995–43000]	<0.001

CABG, coronary artery bypass graft; MI, myocardial infarction; CK-MB, creatine kinase-myocardial band; UNL, upper normal limit.
Values are presented as a n (%), mean±standard deviation, or median [interquartile range].
*Rates according to the types of noncardiac surgery.

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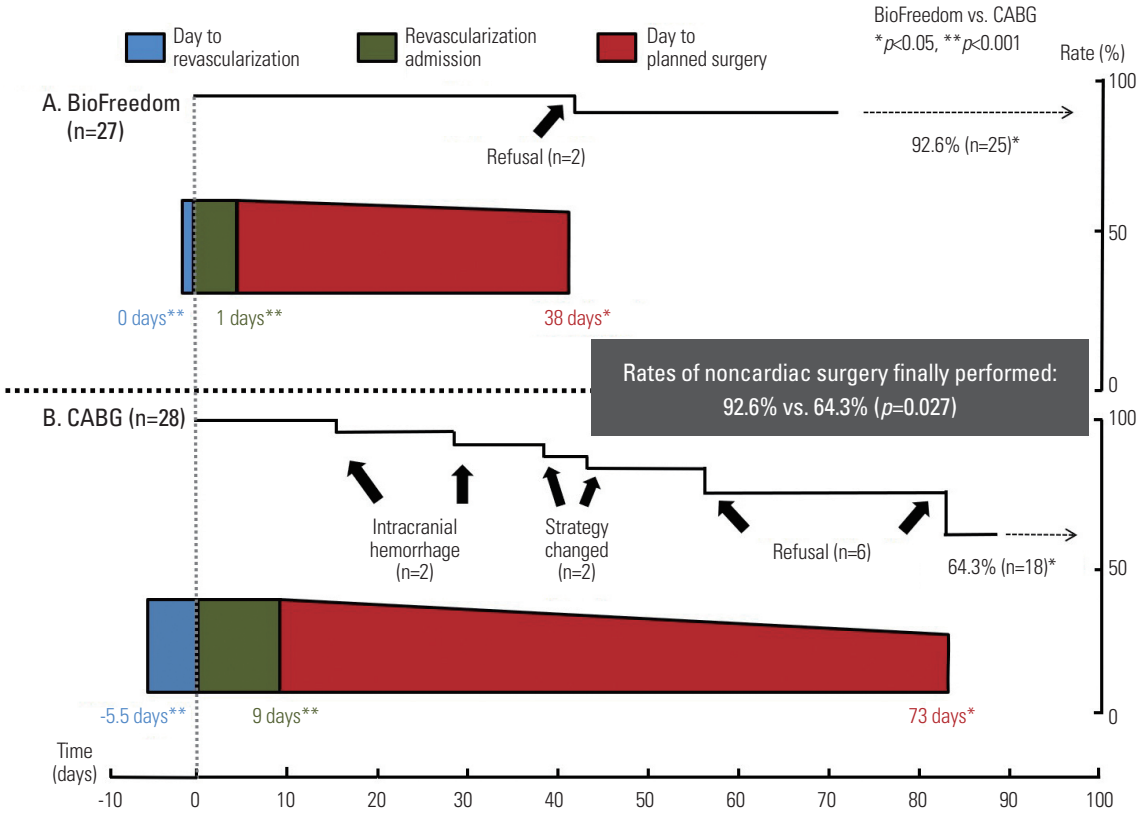

Fig. 3. Comparison of various time intervals and rates of noncardiac surgery performed between the BioFreedom group (A) and the coronary artery bypass graft (CABG) group (B). The curves indicate the rates of noncardiac surgery finally performed and the reasons for cancellation (black arrows) in either group.

(Table 4). However, bleeding occurred less frequently in the BioFreedom group than in the CABG group (p=0.038). A similar trend was identified among those patients who underwent noncardiac surgery.

DISCUSSION

This is the first study to compare overall outcomes between BioFreedom stent implantation and CABG among real-world patients requiring coronary revascularization before noncardiac surgery. This study demonstrated that BioFreedom stent implantation with a minimal DAPT duration was associated with a higher proceeding rate of planned noncardiac surgery, with a shorter delay, than CABG. The composite clinical outcomes were not significantly different between the BioFreedom and CABG groups during hospital stay for revascularization and noncardiac surgery. However, because BioFreedom stent implantation was performed in selected patients at a lower surgical risk than those who underwent CABG, it cannot be generalized to other patient populations.

For patients with coronary artery diseases requiring coronary revascularization before major noncardiac surgery, current guidelines recommend balloon angioplasty, BMS implantation, or CABG. Although balloon angioplasty or BMS implantation did not raise concerns related to DAPT discontinuation, such treatment is available for simple lesions only and cannot be applied for multi-vessel and complex lesions, which were more frequently observed on coronary angiogram. CABG has been recommended as the initial standard strategy for the highest-risk patients with complex lesions before noncardiac surgery that should not be delayed.[1,7,14] However, its use could pose disadvantages for high-risk patients, and may be difficult to apply universally for patients with simple lesions. In addition, because two major operations, CABG and noncardiac surgery, should be consecutively performed, some patients could abandon the noncardiac surgery after CABG. In this study, the CABG group showed a significantly higher rate of cancellation of noncardiac surgery than the BioFreedom group (35.7% vs. 7.4%, respectively; p=0.027), mainly due to patient refusal (60%). Even in cancer surgery, 22.2% of patients in the CABG group did not undergo their planned surgery. For similar reasons, the proportion of patients who underwent noncardiac surgery after CABG within 2 months was also lower than that of those who underwent the PCI strategy (44.4% vs. 88.0%, respectively; p=0.006). On the contrary, DES, which has shown efficacy and safety even in high-risk patients and complex lesions, could be suggested as the initial revascularization strategy before noncardiac surgery. However, because DES could introduce concerns of stent thrombosis in surgeries that should not be

Table 4. Comparison of Clinical Outcomes between the BioFreedom and CABG Group (Overall and Surgery-Performed Patients)

Clinical outcomes	BioFreedom (n=27)	CABG (n=28)	HR (95% CI)	*p* value
Overall populations				
Follow-up duration	201.0 [141.5–376.0]	315.0 [212.0–408.5]	-	0.117
Composite of major clinical adverse events (%/year)	1 (3.8)	3 (15.7)	0.34 (0.04–3.30)	0.332
Individual events				
All-cause death	0 (0)	0 (0)	-	>0.999
MI or stent thrombosis	0 (0)	0 (0)	-	>0.999
Stroke	1 (3.8)	0 (0)	-	0.200
Repeat revascularization	0 (0)	0 (0)	-	>0.999
Any bleeding	2 (10.9)	9 (47.2)	0.23 (0.05–1.06)	0.038
Major bleeding	0 (0)	3 (15.7)	-	0.085
Minor bleeding	2 (10.9)	6 (31.5)	0.34 (0.07–1.71)	0.173
Clinical outcomes	**BioFreedom (n=25)**	**CABG (n=18)**	**HR (95% CI)**	***p* value**
Patients performing noncardiac surgery				
Follow-up duration	201.0 [153.0–375.0]	336.5 [238.0–409.0]	-	0.046
Composite of major clinical adverse events (%/year)	1 (4.0)	1 (8.0)	0.72 (0.04–11.5)	0.815
Individual events				
All-cause death	0 (0)	0 (0)	-	>0.999
MI or stent thrombosis	0 (0)	0 (0)	-	>0.999
Stroke	1 (4.0)	0 (0)	-	0.266
Repeat revascularization	0 (0)	0 (0)	-	>0.999
Any bleeding	2 (11.9)	7 (56.0)	0.23 (0.05–1.10)	0.045
Major bleeding	0 (0)	1 (8.0)	-	0.238
Minor bleeding	2 (11.9)	6 (48.0)	0.27 (0.05–1.36)	0.090

CABG, coronary artery bypass graft; HR, hazard ratio; CI, confidence interval; MI, myocardial infarction.
Values are presented as a n (events per 100-person-year), mean±standard deviation, or median [interquartile range].

delayed for >3–6 months and require DAPT discontinuation, guidelines do not recommend DES as the first-choice treatment.[1,7] Furthermore, unexpected requests with premature discontinuation of DAPT have been found to be relatively common and continuously proposed during the first year following DES implantation.[15]

The LEADERS FREE (Prospective Randomized Comparison of the BioFreedom Biolimus A9–Coated Stent versus the Gazelle Bare-Metal Stent in Patients at High Bleeding Risk) trial demonstrated that the BioFreedom stent was superior to a BMS with respect to safety and efficacy end points when used with 1 month of DAPT among patients at a high risk for bleeding who underwent PCI.[3] From the outcomes of the LEADERS FREE trial, BioFreedom stent implantation with a 1-month DAPT could be a better alternative revascularization strategy for selective patients with less severe coronary artery lesions before noncardiac surgery than balloon angioplasty or BMS and a comparable strategy to CABG. In the present study, we evaluated the outcomes of BioFreedom stent implantation for selected low-risk patients with less complex lesions requiring coronary revascularization before noncardiac surgery and compared various parameters between PCI with BioFreedom versus CABG. In terms of safety, we found no significant difference in the occurrence of composite clinical outcomes between the BioFreedom and CABG groups during the hospital stay for revascularization and noncardiac surgery. Although the number of patients enrolled was small, no cases of stent thrombosis occurred in the BioFreedom group. In terms of efficacy, the BioFreedom group had a significantly higher proceeding rate of noncardiac surgery, a shorter time from revascularization to noncardiac surgery, a shorter hospital stay, and a lower total cost during revascularization than the CABG group, suggesting that PCI with BioFreedom stents could be comparable to CABG in some ways, but more advantageous in others.

Our findings should be interpreted cautiously. Most patients with CTO or a high SYNTAX score decided to undergo CABG before noncardiac surgery, rather than PCI. Previous studies revealed that CABG may be a better treatment option than PCI in cases of highly complex lesions.[14,16] CABG led to a higher rate of complete revascularization, which may affect long-term clinical outcomes including mortality.[17] While the maintenance of mono-antiplatelet therapy would be surely necessary after BioFreedom stenting with 1-month DAPT, CABG could be suitable in patients planning to undergo surgeries in closed areas, such as intracranial space or the spinal canal, which definitely require antiplatelet discontinuation.[18] Nevertheless, use of the BioFreedom stent may be beneficial in cases of rapidly progressing disease requiring urgent surgery; PCI with BioFreedom stents before noncardiac surgery enables the surgeon to proceed with the preplanned surgery with a high probability

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and shorter delay, which may have clinical implications in preventing the progression of diseases, including cancer. PCI with a BioFreedom stent can be a good option to bring good clinical outcomes for selected patients awaiting noncardiac surgery. Considering the clinical significance and urgency of noncardiac surgery and cardiovascular risk, a multidisciplinary consensus among cardiologists, cardiovascular surgeons, and noncardiac surgeons is important.

This study has some limitations. First, because it was a nonrandomized observational study consisting of a small population, the possibility for actual clinical application in the real world is limited. In addition, the comparison of clinical adverse events between the two groups was underpowered due to small study populations. Furthermore, the SYNTAX scores differed from each group, which might have resulted in selection bias. Second, even though the final decision for coronary revascularization was made following a full discussion of the heart team, surgeon, and patients and family members, there was no systematic uniform selection process. Third, the baseline characteristics of the two groups differed, and there were several determinants for BioFreedom stents or CABG as the revascularization strategy. The patients' clinical conditions, lesion severity and complexity, and surgical urgency affected the decision and there could be unrevealed potential factors. For these reasons, the results of this study do not warrant the universal application of the revascularization strategy instead of CABG and the extended use of BioFreedom stents beyond the stated indications. However, this study implies the safety of PCI with BioFreedom for shorter duration until major noncardiac surgery is performed.

For conclusion, PCI with a BioFreedom stent might be a feasible and safe therapeutic option in selected patients who require preoperative coronary revascularization with less severe coronary artery diseases. We found its use to be associated with a higher rate of undergoing planned surgery with shorter delays and lower hospital costs, compared with CABG, as well as a low incidence of major cardiovascular and bleeding events after noncardiac surgery. However, a larger-scale study is needed to validate our conclusions.

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