Original Research

Left Main Protection During Transcatheter Aortic Valve Replacement With a Balloon-Expandable Valve

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A B S T R A C T

Background: Coronary obstruction during transcatheter aortic valve replacement (TAVR) is a rare, yet life-threatening, complication. The routine use of left main (LM) protection with or without stent placement in high-risk patients remains controversial. The aim of this study was to evaluate the outcomes of LM protection during TAVR and identify anatomic factors associated with need for stent placement.

Methods: We retrospectively reviewed all TAVR cases (native and valve-in-valve) performed in our institution between 2014 and 2019 and identified patients who underwent LM protection with a coronary wire, balloon, and/or stent during the procedure. We compared the pre-TAVR computed tomography aortic root characteristics, procedural data, short-, and long-term outcomes among the patients who eventually received an LM stent and those who did not.

Results: Among 1925 TAVR patients, 41 (2.1%) underwent LM protection, and 10 of them (25%) had eventually a stent placed in the LM for threatened obstruction after valve deployment. In the native TAVR group (*n* = 35), 8 patients underwent LM stenting. A larger TAVR prosthesis, larger annular circumference (83.8 vs 76.1 mm; *P* = .038), lower ratio of sinotubular junction diameter to prosthesis size (1.02 vs 1.11; *P* = .032), and longer left coronary cusp (15.1 vs 13.9 mm; *P* = .18) were associated with higher incidence of LM stenting. In the valve-in-valve TAVR group (*n* = 6), 5 patients had a valve-to-coronary distance of less than 4 mm, and 2 of them received an LM stent. Both stent and nonstent groups had excellent outcomes with no major adverse cardiovascular events or coronary obstruction at 30 days. After a median follow-up of 351 days, 4 patients died (9.7%) (1 in the stent and 3 in the nonstent group), without any cases of late coronary obstruction or percutaneous coronary intervention in either group.

Conclusions: LM protection with a coronary guidewire, balloon, or stent is a safe and effective method of coronary protection during TAVR in appropriately selected high-risk patients. Annular circumference, prosthesis size, left coronary cusp length, LM ostial height, and ratio of sinotubular junction to prosthesis size are important predictors of stent deployment.

Introduction

Transcatheter aortic valve replacement (TAVR) is a safe, effective, and less invasive approach for the treatment of severe aortic stenosis (AS) across all surgical risk categories.[1-5] Nevertheless, it is important that operators are mindful of potential procedural complications, including obstruction of the coronary ostia by the aortic valve (AV) leaflets during transcatheter valve expansion. While rare and difficult to predict, coronary obstruction, with left main (LM) obstruction accounting for the vast majority of the cases, is associated with significant increase in short- and long-term mortality.[6-9]

Risk factors for LM obstruction include ostial height <11 mm, sinus of Valsalva diameter <30 mm, left coronary cusp (LCC) length more than LM ostial height, and valve-in-valve (ViV) TAVR, especially with valve-
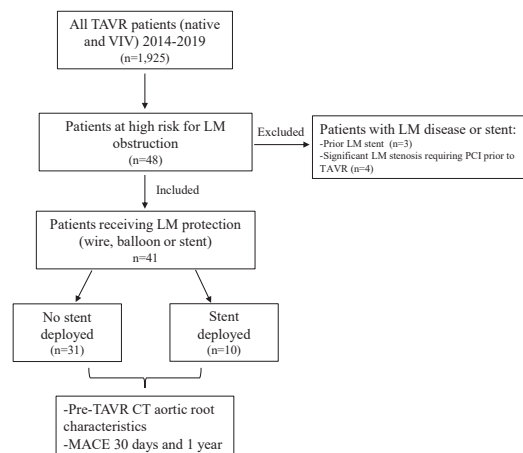
Figure 1. Study design.

to-coronary (VTC) distance <4 mm.[10-16] Pre-emptive LM wiring with or without stent placement has been utilized for coronary protection in high-risk cases.[8,10,11] The BASILICA procedure (bioprosthetic aortic scallop intentional laceration to prevent iatrogenic coronary artery obstruction) has emerged as a novel technique for coronary protection during native and ViV TAVR; however, its use may be limited to experienced centers and operators.[12,13]

Data on LM protection strategies and outcomes are relatively limited. With this study, we aimed to (1) identify anatomic characteristics associated with stent placement for threatened LM obstruction, (2) assess the outcomes of LM protection during TAVR, and (3) compare the different LM protection methods (stent, balloon, or wire alone).

Methods

Study population

We retrospectively reviewed all TAVR cases performed in our institution between 2014 and 2019 to identify patients who received LM protection based on high-risk aortic root characteristics on pre-TAVR computed tomography (CT). The CT was reviewed by the interventionalist performing the procedure as well as imaging specialists. The operators used the following criteria to identify high-risk patients for LMT obstruction: LMT ostial height from the annulus <11 mm, long LCC relative to LMT ostial height (and especially severely calcified leaflets), sinus of Valsalva <30 mm, and VTC distance <4 mm for patients undergoing ViV TAVR. Furthermore, a virtual valve was positioned in the aortic root with the use of the embedded geometry software feature, and the size/position of the prosthesis were assessed in relation to the sinotubular junction (STJ), sinuses of Valsalva, and coronary ostia, with measurement of VTC distance for ViV TAVR cases. The choice of LMT protection strategy (wire, balloon, and/or stent) was based on operator's clinical judgment on case-by-case basis. Patients with severe native AS or degenerated surgical bioprosthesis were included, while patients with pre-existing LM stent or angiographically significant LM stenosis who underwent percutaneous intervention prior to TAVR were excluded. The study population was divided into 2 groups: those who underwent LM stent deployment and those who did not (Figure 1). Patients were additionally stratified in subgroups based on the type of protection initially used (unexpanded stent or balloon or wire alone). The study received approval from the Cleveland Clinic Institutional Review Board.

Procedural technique

If the patient was deemed to be at high risk of LMT obstruction during TAVR based on the criteria mentioned above, a left coronary

guiding catheter was advanced in the aortic root, and a coronary guidewire was inserted through the LMT in the left anterior descending artery. In the majority of the cases, a guide catheter extension was also used due to its lower profile and crossability. Based on operator's judgment, a balloon or a stent was then advanced through the LM into the left anterior descending. Then the guiding catheter was withdrawn into the proximal ascending aorta, and the balloon-expandable TAVR prosthesis was deployed in the usual fashion. Postdeployment aortography was performed through a pigtail catheter for the assessment of paravalvular regurgitation and coronary flow. If there was evidence of encroachment of the LMT ostium by the displaced LCC and reduced flow into the left system, the operator would proceed with stent deployment into the LMT (Central Illustration).

Variables, endpoints, and definitions

Baseline patient and procedural characteristics were obtained from the electronic medical record. Pre-TAVR CT analysis was performed by cardiac imaging specialists and interventionalists for the measurement of aortic root characteristics. For the native TAVR group, measurements included LM and right coronary artery (RCA) ostial height, aortic annulus circumference, cross-sectional area and diameter, sinus of Valsalva and STJ diameter, STJ height, LCC length, effective LCC height, and native AV leaflet calcifications. For the ViV group, the LM ostial height, STJ and sinus of Valsalva size, and VTC distance were measured. The primary endpoint was the composite of all-cause mortality, myocardial infarction, pacemaker implantation, conversion to open heart surgery, and stroke at 30 days and 1 year. Secondary endpoints included coronary obstruction up to 48 hours after TAVR, acute kidney injury at 30 days, and percutaneous coronary intervention at 1 year.

Statistical analysis

Categorical variables were compared using Fisher exact test and presented as numbers and percentages. Continuous variables were compared using *t* test or the Mann-Whitney *U* test and presented as mean ± standard deviation or median (interquartile range). Univariate logistic regression analysis was also performed in order to determine factors

Table 1. Baseline characteristics.

Variable	No stent deployed (n = 31)	Stent deployed (n = 10)	P value
Age, y	76.1 ± 10.4	72.8 ± 7.5	.36
Body mass index, kg/m²	31.0 ± 8.5	32.6 ± 5.0	.57
Female sex	20 (64.5)	4 (40.0)	.27
African American	3 (9.7)	2 (20.0)	.22
Caucasian	25 (80.7)	8 (80.0)	
Asian	1 (3.2)	0	
Diabetes	14 (45.2)	6 (60.00)	.48
Hyperlipidemia	26 (83.9)	10 (100)	.31
Hypertension	29 (93.5)	10 (100)	>.99
Chronic lung disease	17 (54.8)	4 (40)	.48
Peripheral vascular disease	8 (25.8)	2 (20)	>.99
History of CVA	3 (9.7)	1 (10)	>.99
Atrial fibrillation	8 (25.8)	1 (10)	.41
Prior CABG	2 (6.5)	5 (50)	.006
Prior PCI	6 (19.4)	0	.30
Prior AVR	4 (12.9)	2 (20)	.622
Hemoglobin, g/dL	12.0 ± 1.68	13.3 ± 2.4	.067
Platelets, K/μL	205 ± 75	223 ± 48	.47
Creatinine, mg/dL	1.10 ± 0.38	2.32 ± 2.79	.02
STS score	5.55 ± 2.93	4.35 ± 2.60	.31

Values are mean ± standard deviation or n (%). CABG, coronary artery bypass graft; CVA, cerebrovascular accident; PCI, percutaneous intervention; STS, Society of Thoracic Surgery.

Table 2. Procedural characteristics (native TAVR).

	No stent deployed (n = 27)	Stent deployed (n = 8)	P value
General anesthesia	5 (18.5)	2 (25.0)	.64
Sentinel device used	18 (66.7)	6 (75.0)	1.00
Sapien S3 size			
20 mm	6 (22.2)	1 (12.5)	.028
23 mm	13 (48.1)	1 (12.5)	
26 mm	3 (11.1)	1 (12.5)	
29 mm	5 (18.5)	5 (62.5)	

Values are n (%). TAVR, transcatheter aortic valve replacement.

predictive of stent deployment. *P* value less than .05 was considered statistically significant. Kaplan-Meier curves were used to assess long-term major adverse cardiovascular events. All statistical analyses were conducted using IBM SPSS Statistics, version 26 (IBM Corp) and Stata/SE 14.0 (StataCorp).

Results

During the study period, 41 of 1925 (2.13%) patients undergoing TAVR in our institution were deemed to be at high risk of LM obstruction and received protection with a coronary guidewire, unexpanded balloon, and/or stent. A stent was eventually deployed across the LM ostium in 10 (24.4%) patients.

Baseline characteristics

The mean age of the patients was 75.2 years, and 64.5% were female. Thirty-five of the 41 patients had native AS, and the remaining 6 had a degenerated surgical bioprosthesis (3 St. Jude Trifecta, 2 Carpentier-Edwards, and 1 Edwards Perimount). The baseline characteristics were similar between the stent and nonstent groups, except for higher serum creatinine (2.24 vs 1.05 mg/dL; *P* = .010) and more common history of coronary artery bypass grafting (50% vs 6.5%; *P* = .006) in the stent group. The baseline characteristics are reported in detail in Table 1.

Procedural characteristics

All patients received the Edwards Sapien 3 valve. Eight of 35 (22.8%) native TAVR and 2/6 (33.3%) ViV patients had a stent deployed in the LM. From the 2 patients in the ViV group who underwent LM stent placement, 1 had a degenerated 27-mm St. Jude Trifecta valve, and the

other had a degenerated 21-mm Carpentier-Edwards valve. The procedure was performed under general anesthesia in 8/41 patients (19.5%), and a cerebral embolic protection device was used in 28/41 patients (68.2%). Sixty percent of the patients in the stent group received S3 valves 26 mm or larger, while 74.2% of the patients in the nonstent group received S3 valves 23 mm or smaller. Details about the S3 prostheses used in the stent and nonstent groups are provided in Table 2 and Figure 2. For the 6 ViV patients, details about the degenerated surgical valve and S3 valve size are reported in Table 3.

CT variables

Native TAVR

The pre-TAVR CT variables for the native TAVR patients are presented in Table 4. The stent group was found to have significantly larger aortic annulus circumference (83.8 vs 76.1 mm; *P* = .038) with a smaller ratio of STJ diameter to prosthesis size (1.02 vs 1.11; *P* = .032). Furthermore, there was a trend for longer LCC (15.06 vs 13.85 mm; *P* = .18) and larger LCC length minus ostial height difference (3.57 vs 2.98 mm; *P* = .53) in the stent group. The LM ostial height (11.48 vs 10.87 mm; *P* = .54), RCA ostial height (14.05 vs 13.56 mm; *P* = .61), STJ diameter (27.1 vs 26.3 mm; *P* = .53), and STJ height (17.2 vs 16.6 mm, *P* = .53) were similar between the 2 groups. CT images of a patient with long LCC and relatively small STJ who ultimately required stent placement due to threatened LMT obstruction after valve deployment are shown in Figure 3.

On univariate analysis (Table 5), patients with LCC length ≥16.5 mm were nearly 8 times more likely to undergo LM stent placement (odds ratio [OR], 7.80; confidence interval [CI], 1.59-38.11; *P* = .01). Patients with sinus of Valsalva diameter <31 mm were 7 times more likely to undergo stent placement (OR, 7.12; CI, 1.17-43.14; *P* = .03). Aortic annulus diameter ≥25 mm (OR, 7.12; CI, 1.17-43.13; *P* = .03), perimeter ≥82 mm, and area ≥5.0 cm^2 (OR, 8.57; CI, 1.39-52.74; *P* = .02) were associated with higher occurrence of LM stenting. The severity, size, and location (base or tip of the leaflet or both) of AV calcifications were similar between the 2 groups and were not associated with increased risk for LM obstruction or stent placement (Supplemental Table S1).

ViV TAVR

The majority (5/6) of the patients in the ViV TAVR group had a VTC distance of less than 4 mm, and 4/6 had a sinus of Valsalva diameter of less than 30 mm. The 2 patients from the ViV group who underwent LM stent placement for threatened obstruction had a low LM ostial height (≤10 mm), narrow sinus of Valsalva (<30 mm), and VTC distance <4
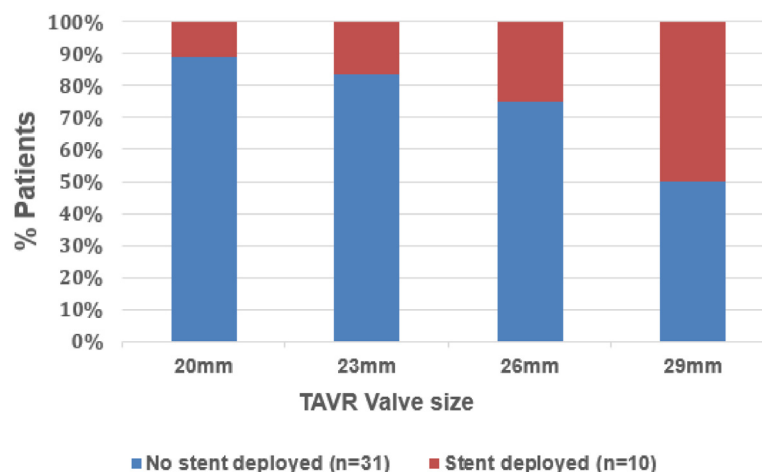

Figure 2. Sapien 3 valve size distribution in the stent and nonstent groups. Implantation of larger prostheses was associated with higher incidence of LM stenting.

Table 3. Valve-in-valve TAVR characteristics.[a]

	Surgical valve type	Surgical valve size, mm	S3 size, mm	Stent deployed	LM height, mm	STJ size, mm	VTC, mm	Sinus diameter minus valve size, mm	Sinus size, mm
1	St. Jude Trifecta	27	23	Yes	10.0	29	3.25	4.5	27.5
2	Carpentier Edwards	21	23	Yes	9.0	28	3.68	7.0	30.0
3	St. Jude Trifecta	23	23	No	8.5	28	3.10	6.0	29.0
4	St. Jude Trifecta	23	23	No	13.0	31.5	4.30	10.0	33.0
5	Carpentier Edwards	21	20	No	13.0	23	3.80	3.0	27.0
6	Carpentier Edwards	19	20	No	11.0	28	3.85	5.0	25.0

LM, left main; STJ, sinotubular junction; TAVR, transcatheter aortic valve replacement; VTC, virtual distance valve-to-coronary artery.
[a] All ViV patients received Edwards Sapien S3 valve.

mm. The CT-derived aortic root measurements for the 6 ViV TAVR patients are presented in detail in Table 3.

Clinical outcomes

The median follow-up duration was 351 days. Among the 41 patients who received LM protection, there were no cases of coronary obstruction within the first 48 hours after TAVR. The incidence of all-cause death, myocardial infarction, pacemaker implantation, conversion to open heart surgery, stroke, and acute kidney injury was 0% at 30 days. The 1-year outcomes were also similar between the stent and nonstent groups (Figure 4). On long-term follow-up, there was 1 death in the stent group 431 days after TAVR (prosthetic valve endocarditis/abscess) and 3 deaths in the nonstent group 32, 572, and 589 days after TAVR (aspiration pneumonia in the setting of chronic obstructive pulmonary disease, hypertensive emergency, and pneumonia/septic shock, respectively). There were no cases of late coronary obstruction or catheter-based coronary interventions in either group after 1 year.

Subgroup analysis based on type of LMT protection

Among the 35 native TAVR patients undergoing LM protection, 2 (4.9%) had protection with wire alone, 14 (34.1%) with unexpanded

Table 4. Pre-TAVR CT aortic root variables (native TAVR).

	No stent deployed (n = 27)	Stent deployed (n = 8)	P value
LM ostial height, mm	10.87 ± 2.6	11.48 ± 2.01	.54
RCA ostial height, mm	13.56 ± 2.50	14.05 ± 1.81	.61
Aortic annulus perimeter, mm	76.1 ± 9.0	83.9 ± 8.8	.038
Aortic annulus area, cm^2	4.34 ± 1.02	5.07 ± 0.91	.081
Aortic annulus diameter, mm	23.8 ± 2.8	25.7 ± 2.4	.095
Left coronary sinus diameter, mm	29.4 ± 4.0	31.4 ± 3.6	.22
STJ diameter, mm	26.3 ± 3.3	27.1 ± 2.2	.53
LCC length, mm	13.85 ± 2.15	15.06 ± 2.40	.18
LCC length/LM ostial height ratio	1.33 ± 0.32	1.32 ± 0.15	.85
LCC length minus LM ostial height, mm	2.98 ± 2.52	3.57 ± 1.23	.53
STJ height, mm	16.63 ± 1.90	17.16 ± 2.68	.53
LCC effective height, mm	9.83 ± 1.58	9.53 ± 3.15	.71
Sinus diameter minus valve size, mm	5.55 ± 2.52	4.68 ± 1.57	.37
STJ diameter to prosthesis size ratio	1.11 ± 0.097	1.02 ± 0.098	.032

Values are mean ± standard deviation. CT, computed tomography; LCC, left coronary cusp; LM, left main; RCA, right coronary artery; STJ, sinotubular junction; TAVR, transcatheter aortic valve replacement.
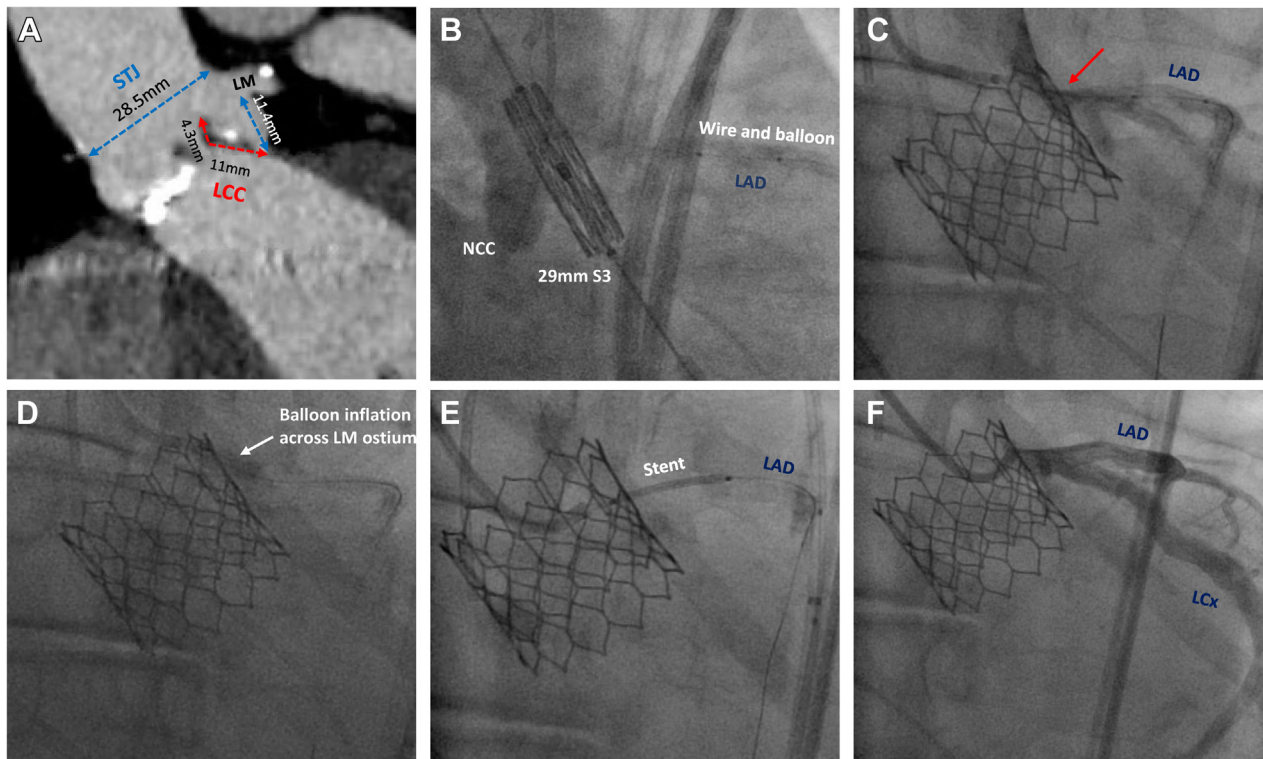
balloon, and 19 (46.3%) with unexpanded stent (Figure 5). None of the patients who received LM protection with wire alone required stent placement. Three of 14 patients (21.4%) in the balloon protection group underwent balloon inflation in the sinus, between the LM ostium and the displaced LCC, and 1 of them had a stent deployed in the LM. In these cases, the displaced LCC appeared to compromise blood flow to the LM ostium based on post-valve deployment angiography and intravascular ultrasound (IVUS) assessment. In the stent protection group, 7/19 patients (36.8%) had eventually a stent deployed across the LMT ostium due to threatened LMT obstruction (encroachment of the LMT ostium by the LCC, decreased flow in the LM on postdeployment aortography). Subgroup analysis (protection with stent vs balloon vs wire) of CT variables in the native TAVR patients is shown in Supplemental Table S2.

Among the 6 ViV patients, 4 were protected with an unexpanded stent, and 2 with an unexpanded balloon (50%). A total of 2 (33.3%) ViV patients finally had a stent deployed in the LM for threatened obstruction (Figure 5).

IVUS was used in borderline cases (10/35 patients of the native TAVR group and 2 patients of the ViV group) where the aortogram after valve deployment suggested encroachment (or close proximity) of the LMT ostium by the displaced LCC without clear compromise of blood flow (Figure 6).

Discussion

Main findings

This is the largest single-center study investigating the outcomes and anatomic factors associated with stent placement for threatened LM obstruction during TAVR. The main findings of our study are as follows: (1) Only 2.1% of patients undergoing TAVR were deemed to be at high risk of LMT obstruction, and 25% of them ultimately underwent LM stent deployment (about 0.5% of the total TAVR cohort); (2) anatomic predictors of stent placement in native TAVR patients include LCC length ≥16.5 mm, larger aortic annulus size (diameter ≥25 mm, perimeter ≥82 mm, area ≥5.0 cm^2), and lower ratio of STJ diameter to prosthesis size (1.02); and (3) 30-day and 1-year outcomes were favorable in both stent and nonstent groups (see Central Illustration).

Clinical implications

This study demonstrates that LM protection with a coronary wire, balloon, and/or unexpanded stent is a safe and effective strategy of preventing coronary obstruction during TAVR in high-risk patients. Although pre-TAVR CT analysis is crucial for the identification of high-risk anatomic features, coronary obstruction is difficult to accurately predict. This is reflected in previous studies, where the majority of the patients who were considered to be at high risk did not ultimately experience coronary obstruction during TAVR.[8,17] Although the majority

Figure 3. Case of threatened left main (LM) obstruction after valve deployment treated successfully with stent placement. (**A**) Pre-transcatheter aortic valve replacement (TAVR) computed tomography (CT) showing left coronary cusp (LCC) length greater than LM ostial height and a relatively small sinotubular junction (STJ). (**B**) LM protection with coronary wire and unexpanded balloon in the left anterior descending (LAD). (**C**) Angiogram after valve deployment with impaired flow in the left system caused by the displaced LCC (red arrow). The S3 valve occupies the entire STJ. (**D**) Balloon inflation in the area between the valve stent and LM ostium. (**E**) A drug-eluting stent was deployed coaxially in the LM through the S3 valve frame. (**F**) Final angiography after LM stenting with Thrombolysis in Myocardial Infarction (TIMI) 3 flow in the left system.

(75%) of the patients in our study did not experience coronary obstruction either, the rate of LM stenting (25%) for threatened obstruction was higher than that in previous studies. This finding could be explained by the higher risk profile of the patients included in our cohort.

Historically, the criteria that have been used for the identification of patients at risk of coronary obstruction vary. Abramowitz et al[8] included low LM ostial height, bulky LCC calcium nodules, significant LM stenosis >50% or prior LM stent, and ViV TAVR for surgical bioprosthesis as risk factors for LM obstruction. Similarly, in the Optimized CathEter vAlvular iNtervention - Transcatheter Aortic Valve Implantation (OCEAN-TAVI) study, coronary ostial height <10 mm, shallow coronary sinus, and bulky leaflet calcifications were used as the main risk factors.[17]

In our study, we found that, in addition to the aforementioned factors, the aortic annulus size, STJ diameter, prosthesis size, and LCC length relative to the LM ostial height can be effectively used for risk stratification, procedural planning, and identification of patients who may eventually require LM stent placement. In patients with low LM ostial height, the LCC length is an important predictor of LM stent placement, as the most common mechanism of obstruction after valve deployment is

the displacement of the native LCC toward the LM ostium compromising blood flow to the coronary.[9] In our study, the LM ostial height was similarly low in the stent and nonstent groups (11.4 vs 11.2 mm), while the LCC was longer in the stent group (15.06 vs 13.85 mm), highlighting the importance of assessing coronary ostial height always in conjunction with aortic leaflet length. The aortic annulus size is another important anatomic factor that determines the size of the TAVR prosthesis. We found that larger annuli, and hence larger prostheses, are associated with higher risk of LM obstruction and stent placement, most likely due to decreased VTC distance and sinus sequestration. Furthermore, a large TAVR prosthesis occupying the STJ area (lower ratio of STJ diameter to prosthesis size) was more frequently associated with stent placement.

These criteria appear to be quite effective in identifying patients at risk of LM obstruction and especially those who may require stent placement, as reflected in the relatively higher incidence of stenting in
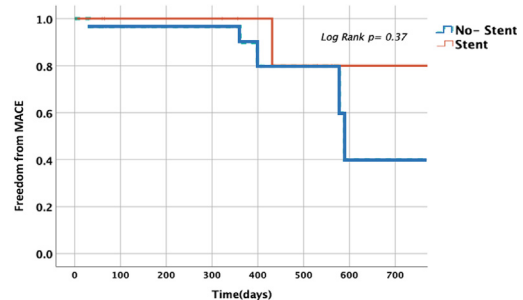
Table 5. Predictors of left main stent placement (native TAVR) univariate analysis.

Variable	Odds ratio (95% CI)	*P* value
Leaflet length ≥16.5 mm	7.80 (1.59-38.11)	.01
CT aortic annulus diameter ≥25 mm	7.12 (1.17-43.14)	.03
CT sinus of valsalva ≥31 mm	7.12 (1.17-43.14)	.03
Aortic annulus perimeter ≥82 mm	8.57 (1.39-52.74)	.02
Aortic annulus area ≥5.0 cm^2	8.57 (1.39-52.74)	.02

CI, confidence interval; CT, computed tomography; TAVR, transcatheter aortic valve replacement.

Figure 4. Kaplan-Meier curve showing freedom from major adverse cardiovascular events in the stent and nonstent groups.
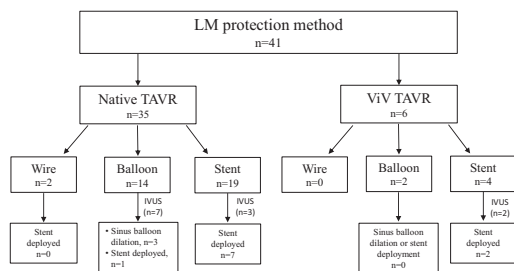
Figure 5. Left main protection methods in native and ViV TAVR groups.

our cohort and the fact that only 1 out of 1925 patients (0.05%) during the 5-year study period required urgent wiring and stent placement for impending LM obstruction after valve deployment. At this point, it is important to emphasize that the CT-derived anatomic measurements represent continuous variables; therefore, applying binary cutoffs to risk stratify patients can be challenging in everyday clinical practice. In that context, a detailed analysis of the pre-TAVR CT on a case-by-case basis, considering all patient and procedure-related factors, is very important for appropriate risk stratification and the decision to proceed with an upfront LMT protection strategy.

In regard to the outcomes of coronary protection strategies, a multicenter international registry of 236 patients who underwent TAVR with coronary protection reported a 4.3% coronary occlusion rate up to 6 hours after wire removal and higher 3-year cardiac mortality in patients who did not receive stents (15.7% vs 7.8%; $P = .13$) although this finding was not statistically significant.[18] In our study, there was 0% 30-day mortality and lower 1-year mortality rate (10%) in patients who received LM protection, irrespective of stent deployment or not. There were no cases of late coronary obstruction, stent thrombosis, or percutaneous intervention during the first year

after TAVR in either group. These favorable outcomes can be attributed to successful identification of high-risk patients for LM obstruction, appropriate use of angiography and IVUS after valve deployment, stent placement in cases of impending LM obstruction, and the exclusive use of balloon-expandable valves in high-risk cases (lower profile). Careful analysis of aortography after valve deployment for the visualization of a linear filling defect in the native sinus, which represents the displaced LCC between the valve stent frame and LM ostium, and the use of IVUS, when aortography is inconclusive, are very important for the identification of patients with threatened LM obstruction.

In the current era, the BASILICA procedure is an important option for cases of threatened coronary obstruction during TAVR and especially during ViV TAVR. Nevertheless, due to the technical complexity and potential challenges of BASILICA (failure to lacerate the aortic leaflet, asymmetric laceration in the setting of bulky leaflet tip calcification, potential injury to the adjacent anterior mitral valve leaflet, increased stroke risk[19]), the use of traditional protection with a coronary wire, balloon, and/or stent is still an important technique to prevent coronary obstruction.

Study limitations

This is a single-center retrospective study with a relatively limited study population. The identification of patients at high risk of coronary obstruction and the choice of coronary protection strategy were driven by operator preference and clinical judgment. Only cases of LMT protection were included. Based on our clinical experience, the risk of RCA obstruction during TAVR is even lower than that of LMT, likely due to generally higher position of the RCA ostium in relation to the aortic annulus. All patients received Sapien 3 balloon-expandable valves, which is our preferred institutional practice in high-risk cases for coronary
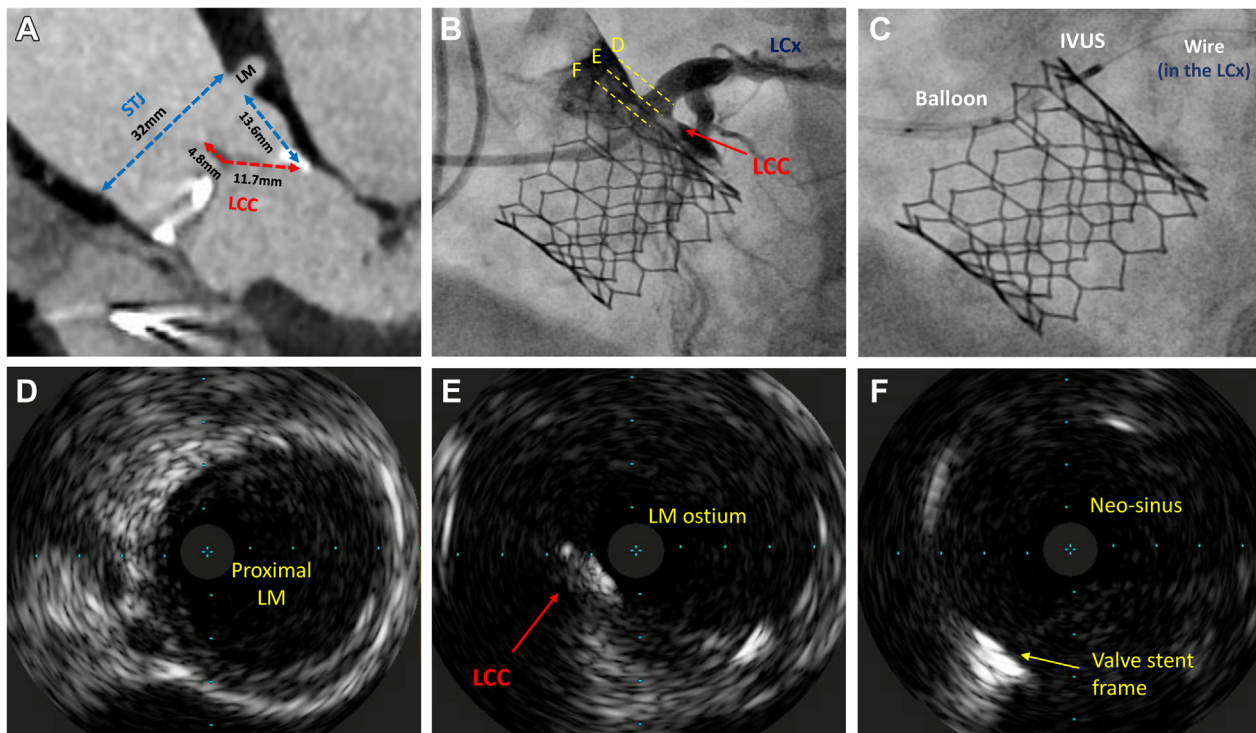

Figure 6. Case of borderline LM obstruction, where IVUS showed adequate distance between LCC and LM ostium. (**A**) Pre-TAVR CT showing normal LM ostial height, long LCC, and normal STJ diameter. (**B**) Angiogram after valve deployment showing the displaced LCC abutting the inferior border of the LM ostium (red arrow) without evidence of LM compromise. (**C**) LM protection with a coronary wire in the LCx, IVUS catheter. (**D**) IVUS at the level of the proximal LM without evidence of significant atherosclerosis. (**E**) IVUS at the level of LM ostium, showing the calcified tip of the LCC abutting the border of the LM ostium at 7 o'clock (red arrow). (**F**) IVUS at the level of left coronary sinus.
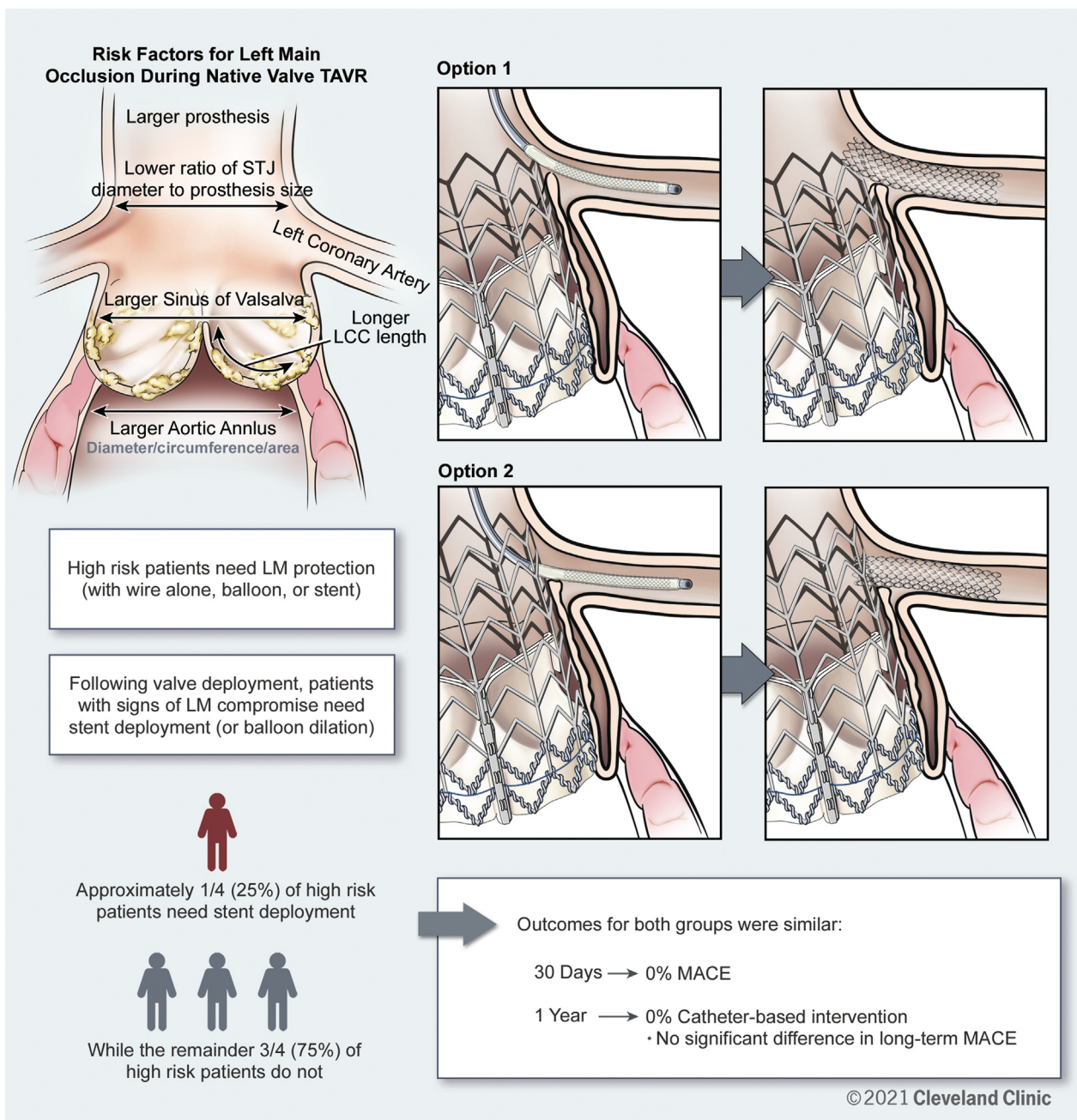
Central Illustration. Left main protection during TAVR. Anatomic risk factors, protection strategies, and outcomes of LMT stenting.

obstruction due to lower profile; hence, no cases of self-expanding valves were included in this study.

Conclusion

LM protection with a wire, unexpanded balloon, and/or stent in patients at risk of coronary obstruction during TAVR, with stent deployment in cases of impending obstruction, is associated with favorable short- and long-term outcomes. Larger aortic annulus and prosthesis, low LM ostial height in conjunction with a relatively long LCC, low ratio of STJ diameter to prosthesis size, and ViV TAVR with a small VTC distance are associated with higher likelihood of LM stent placement. As TAVR expands in low- and intermediate-risk populations, establishment of reliable and reproducible criteria for the identification of patients at risk of coronary obstruction and standardization of coronary protection strategies become increasingly important.

Ethics statement

The research was conducted under the standard ethical guidelines.

Supplementary material

To access the supplementary material accompanying this article, visit the online version of the Journal of the Society for Cardiovascular Angiography & Interventions at https://doi.org/10.1016/j.jscai.2022.100339.

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