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CME

Coronary Obstruction Following Transcatheter Aortic Valve Implantation

A Systematic Review

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CME Objective for This Article: At the completion of this article, the learner should be able to discuss:

1. incidence and factors associated with coronary obstruction following TAVI;
2. clinical presentation of coronary obstruction following TAVI; and
3. results associated with the treatment of coronary obstruction following TAVI.

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Coronary Obstruction Following Transcatheter Aortic Valve Implantation

A Systematic Review

Objectives This study sought to evaluate, through a systematic review of the published data, the main baseline characteristics, management, and clinical outcomes of patients suffering coronary obstruction as a complication of transcatheter aortic valve implantation (TAVI).

Background Very few data exist on coronary obstruction after TAVI.

Methods Studies published between 2002 and 2012, with regard to coronary obstruction as a complication of TAVI, were identified with a systematic electronic search. Only the studies reporting data on the main baseline and procedural characteristics, management of the complication, and clinical outcomes were analyzed.

Results A total of 18 publications describing 24 patients were identified. Most (83%) patients were women, with a mean age of 83 ± 7 years and a mean logistic European System for Cardiac Operative Risk Evaluation score of 25.1 ± 12.0%. Mean left coronary artery (LCA) ostium height and aortic root width were 10.3 ± 1.6 mm and 27.8 ± 2.8 mm, respectively. Most patients (88%) had received a balloon-expandable valve, and coronary obstruction occurred more frequently in the LCA (88%). Percutaneous coronary intervention was attempted in 23 cases (95.8%) and was successful in all but 2 patients (91.3%). At 30-day follow-up, there were no cases of stent thrombosis or repeat revascularization, and the mortality rate was 8.3%.

Conclusions Reported cases of coronary obstruction after TAVI occurred more frequently in women, in patients receiving a balloon-expandable valve, and the LCA was the most commonly involved artery. Percutaneous coronary intervention was a feasible and successful treatment in most cases. Continuous efforts should be made to identify the factors associated with this life-threatening complication to implement the appropriate measures for its prevention. (J Am Coll Cardiol Intv 2013;6:452–61)

Transcatheter aortic valve implantation (TAVI) has emerged as an alternative to surgical aortic valve replacement in those patients considered at very high or prohibitive risk for surgery (1). Despite its more widespread adoption as a treatment option and the increasing experience of the centers, TAVI is still associated with complications, such as vascular/bleeding and cerebrovascular events, conduction abnormalities requiring permanent pacemaker implantation, and significant residual aortic regurgitation (1). The relatively high rate of such complications has made possible an accurate evaluation of their predictive factors and clinical consequences, and this does indeed represent a first step in the way of implementing appropriate preventive measures and treatment. Nonetheless, TAVI has also been associated with very rare but life-threatening complications, such as coronary ostia obstruction. Specific clinical data on this important complication—apart from some reports on its incidence (usually <1%) in some TAVI series (2–8)—have been scarce and restricted to case reports and small case series, precluding any appropriate evaluation of the baseline characteristics of patients suffering this complication as well as its management and clinical impact. The objective of the present study was to provide further insight into the baseline characteristics, management, and clinical outcomes of patients with coronary obstruction as a complication of TAVI through a systematic review of all the studies on TAVI and coronary obstruction published thus far.

Methods

All relevant papers published in English about TAVI and coronary obstruction published between December 2002 and July 2012 were systematically searched in BioMedCentral, Google Scholar, and PubMed. The following query terms were used: aortic stenosis, transcatheter aortic valve implantation, transcatheter aortic valve replacement, transcatheter heart valve, heart valve prosthesis implantation, coronary stenosis, coronary occlusion, and coronary obstruction. Further studies

Abbreviations and Acronyms

CABG = coronary artery bypass graft

CAD = coronary artery disease

CT = computed tomography

LCA = left coronary artery

PCI = percutaneous coronary intervention

TAVI = transcatheter aortic valve implantation

were sought by means of a manual search of secondary sources, including references from primary papers (backward snowballing) and contacts with international experts.

Citations were first screened at the title/abstract level by 2 independent reviewers (HBR, LNF) and retrieved as complete manuscripts if potentially pertinent. Divergences were resolved after consensus, to gather all the pertinent case reports and case series concerning coronary obstruction in TAVI. Published papers that included only the incidence of the complication without any case description were excluded from this analysis.

Gathered data included baseline clinical, echocardiographic, and computed tomography (CT) characteristics. The CT variables included data on left coronary artery (LCA) ostium height from aortic annulus, severity and distribution of valve calcification, and aortic root and annulus diameters. Procedural data on the type and size of the transcatheter valve, approach, and clinical presentation and management of coronary obstruction were recorded. Finally, data on in-hospital or 30-day mortality and clinical status at follow-up, including the need for repeat revascularization, were also gathered.

Categorical variables were reported as n (%), and continuous variables were reported as mean ± SD. Group comparisons were performed with the chi-square test for categorical variables and Student *t* test adjusted for multiple comparisons (Bonferroni method) for continuous variables. The results were considered significant with p values <0.05. All analyses were conducted with the statistical package SAS (version 9.3, SAS Institute, Inc., Cary, North Carolina).

Results

Between January 2002 and May 2012, 19 publications describing a total of 27 patients who had experienced coronary obstruction related to a TAVI procedure were identified (9–27). All studies referred to single case reports or small series, with a maximum of 5 reported cases of coronary obstruction. Three cases with previous surgical aortic valve prosthesis ("valve-in-valve" procedure) were excluded from this

Table 1. Individual Data on Baseline Clinical and Procedural Characteristics

Patient# (Ref#)	Age	Sex	Previous CABG	Logistic EuroSCORE (%)	Mean Aortic Gradient (mm Hg)	Aortic Annulus (mm)	Aortic Root (mm)	LCA Height (mm)	Approach	Valve Type	Valve (mm)
1 (9)	85	F	No	13.3	88	22.0	—	9.1	TA	SAPIEN	26
2 (10)	87	—	No	—	—	—	—	—	TF	SAPIEN	—
3 (11)	85	F	No	18.0	45	—	—	—	TF	SAPIEN	23
4 (12)	81	F	No	21.0	—	—	—	>12	TA	SAPIEN	26
5 (12)	85	F	No	23.8	—	—	—	>12	TF	SAPIEN XT	23
6 (12)	80	M	No	31.0	—	—	—	>12	TA	SAPIEN XT	29
7 (13)	86	F	No	24.3	51	22.4	31.3	9.7	TF	SAPIEN	26
8 (13)	78	F	Yes	51.5	46	19.3	27.8	10.3	TA	SAPIEN	23
9 (13)	80	F	No	25.3	58	20.9	26.4	9.0	TA	SAPIEN	23
10 (13)	88	F	No	22.0	55	18.0	26.2	11.0	TA	SAPIEN	23
11 (13)	82	M	No	20.7	43	22.1	33.0	9.0	TA	SAPIEN	23
12 (14)	86	M	No	—	—	—	—	—	TF	SAPIEN	23
13 (15)	87	F	No	—	60	20.0	—	—	TF	SAPIEN	23
14 (16)	87	F	No	—	70	20.0	—	—	TA	SAPIEN	23
15 (17)	58	F	No	—	57	—	—	—	TF	SAPIEN	26
16 (18)	86	F	No	—	—	—	—	—	TF	SAPIEN	23
17 (19)	82	F	No	—	—	—	—	7.0	TF	SAPIEN	23
18 (20)	68	F	No	8.8	46	21.6	26.4	—	TA	SAPIEN	26
19 (21)	86	F	No	31.2	55	—	—	10.2	TF	SAPIEN	23
20 (22)	76	F	No	9.1	90	24.0	—	—	TF	SAPIEN XT	26
21 (23)	86	F	No	—	68	—	—	—	TF	SAPIEN XT	23
22 (24)	86	F	No	45.0	—	20.0	27.0	11.0	TF	CoreValve	26
23 (25)	89	F	No	25.3	65	20.0	—	12.0	TF	CoreValve	26
24 (26)	87	M	No	—	—	—	—	—	TF	CoreValve	29

SAPEIN and CoreValve (Medtronic, Minneapolis, Minnesota).

CABG = coronary artery bypass graft; CAD = previous coronary artery disease; EuroSCORE = European System for Cardiac Operative Risk Evaluation; LCA = left coronary artery; TA = transapical; TF = transfemoral.

analysis (24,27), leading to a final study population of 24 patients. The main baseline clinical characteristics were available in all patients. The CT data on left main ostium height and annulus and aortic root measurements were reported in 13, 12, and 8 patients, respectively. No data were reported on the severity and distribution of valve calcification. Procedural and clinical data on the clinical presentation, diagnosis, and management of the coronary obstruction were available in all patients. All studies reported data on in-hospital outcomes, 12 studies (including 16 patients) reported data on 30-day outcomes, and 11 studies (including 14 patients) reported data at follow-up.

The main clinical, echocardiographic, CT, and procedural characteristics of the patients are shown in Tables 1 (individual data) and 2 (mean data). Mean age of the study population was 83 ± 7 years, and most patients were women (83.3%). The main baseline characteristics of the study population compared with those reported in the largest TAVI registries (3,4,6–8,28–31) (pooled data) and the PARTNER (Placement of Aortic Transcatheter Valve) trial (5,32) are shown in Figure 1. The CT data revealed a mean LCA ostia height of 10.3 ± 1.6 mm and aortic root width of 27.8 ± 2.8 mm. The mean values of LCA height and aortic root diameter compared with the values obtained in a previous population of patients with and without aortic stenosis (33,34) as well as that of patients referred for TAVI (35) are shown in Figure 2. A balloon-expandable Edwards valve (Edwards Lifesciences, Irvine, California) was used in most (87.5%) cases.

Table 2. Baseline Clinical, Echocardiographic, CT, and Procedural Characteristics of the Study Population (N = 24)

Clinical variables	
Age, yrs	82.5 ± 7.0
Female	20 (83.3%)
NYHA	
I–II	18.2%
III–IV	81.8%
Previous CABG	1 (4.2%)
Logistic EuroSCORE (%)	25.1 ± 12.0
Echocardiographic and CT data	
Mean aortic gradient, mm Hg	59.8 ± 14.5
Indexed aortic valve area, cm^2/m^2	0.43 ± 0.09
Aortic annulus, mm	20.8 ± 1.6
Left main height, mm	10.3 ± 1.6
Aortic root width, mm	27.8 ± 2.8
Procedural data	
Approach	
TF	15 (62.5%)
TA	9 (37.5%)
Valve type	
SAPIEN and SAPIEN XT	21 (87.5%)
23 mm	13 (54.2%)
26 mm	6 (25.0%)
29 mm	1 (4.2%)
Unknown	1 (4.2%)
CoreValve	3 (12.5%)
26 mm	2 (8.3%)
29 mm	1 (4.2%)
Ratio valve/annulus	1.19 ± 0.07

Values are mean ± SD or n (%).

NYHA = New York Heart Association functional classification; PCI = percutaneous coronary intervention; other abbreviations as in Table 1.

The main data on clinical presentation and management of coronary obstruction are shown in Tables 3 (individual data) and 4 (mean data). Most (87.5%) cases presented with persistent severe hypotension. Onset of symptoms occurred immediately after valve implantation in 20 patients (83.3%), within the first few hours after the procedure in 2 patients (8.3%), and within the first 2 days after the procedure in another 2 patients (8.3%). Coronary obstruction occurred more frequently in the LCA (83.3%), and the diagnosis was made by coronary angiography in all patients but 1 (post-mortem). Coronary obstruction was related to the displacement of a calcified native aortic valve leaflet toward the coronary ostium in all patients, except for 1 patient with aortic valve cusp shearing and migration into the LCA.

Percutaneous coronary intervention (PCI) was attempted in 23 patients (95.8%) and was successful in all but 2 (91.3%). At least 1 stent was implanted at the coronary ostia in 20 patients. Significant compression of the stent requiring the implantation of a second stent occurred in 3 patients, whereas conversion to open heart surgery was required in 2 patients. The 2 unsuccessful PCI cases consisted of a failure to cross the obstruction with the coronary wire, requiring emergency coronary artery bypass graft (CABG), and a failure to re-establish coronary flow despite successful stent implantation, leading to continuous cardiogenic shock and death.

Hospital mortality rate was 8.3%, and all patients who had successful PCI survived and were discharged from the hospital at a mean of 7 ± 4 days after the intervention, with no cases of stent thrombosis or repeat revascularization. Data at follow-up (mean of 10 ± 6 months) were available in 14 patients, and all of them were alive and in New York Heart Association functional class I or II at that time. One patient needed repeat revascularization due to stent restenosis at 4-month follow-up.

Discussion

The main findings of this systematic review of the published data on symptomatic coronary obstruction after TAVI showed that this complication occurred more frequently in women and in patients with no prior CABG. In these cases, the mean height of the LCA ostium was approximately 10 mm (range 7 to >12 mm), and the mean diameter of the aortic root was approximately 28 mm (range 26 to 33 mm). Also, the vast majority of reported cases of coronary ob-

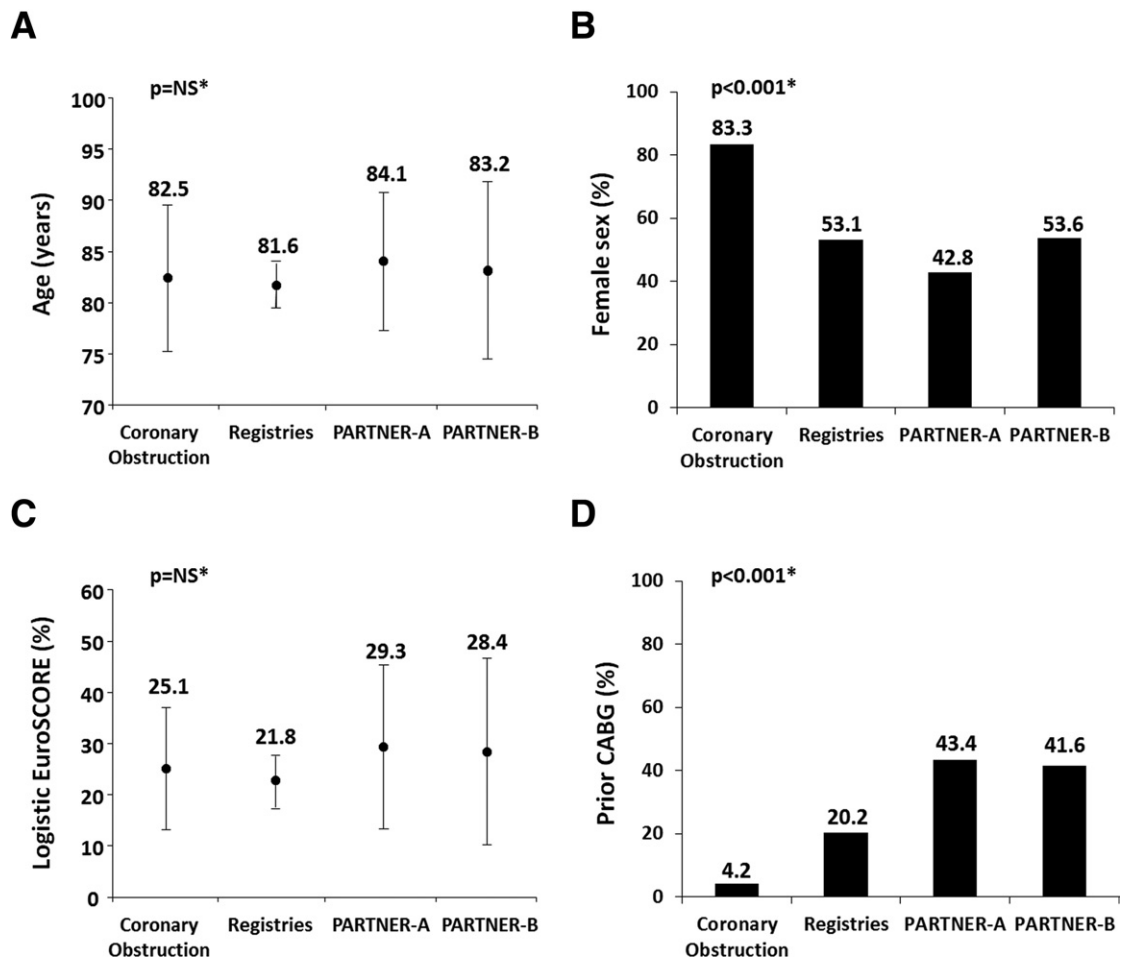

Figure 1. Main Baseline Clinical Characteristics

Main baseline characteristics of the study population compared with the largest transcatheter aortic valve implantation registries (3,4,6–8,28–31) (pooled data) and the PARTNER (Placement of Aortic Transcatheter Valve) trials (5,32), including mean age **(A)**, female sex **(B)**, logistic European System for Cardiac Operative Risk Evaluation (EuroSCORE) **(C)**, and prior coronary artery bypass graft (CABG) **(D)**. *Coronary obstruction versus other groups.

struction post-TAVI occurred in patients who had received a balloon-expandable valve. Clinical presentation included: persistent severe hypotension, ST-segment changes, and ventricular arrhythmias, all of which occurred immediately after valve implantation in most cases. An LCA ostia obstruction was more frequent than RCA obstruction, and most patients were treated with PCI, which was successful in approximately 90% of them. However, conversion to open heart surgery and mechanical hemodynamic support were required in approximately 8% and 25% of PCI attempts, respectively. Importantly, significant compression of the implanted stent was observed in 13% of the cases, requiring the implantation of a second stent in all of them. There were no cases of acute stent thrombosis or repeat revascularization, and the in-hospital mortality rate for the entire study population was 8.3% (0% in those patients with a successful PCI).

Coronary obstruction after TAVI was first described in the first TAVI experimental porcine model (36), and this potential complication was subsequently confirmed by other authors in different experimental models (37). The occurrence of coronary obstruction after TAVI in humans was first described in 2006 (10), and its reported incidence has usually been <1%, ranging from 0% to 4.1% in contemporary series (10,13,38–40). The rates of coronary obstruction in recent TAVI registries and in the PARTNER trial are summarized in Table 5.

Factors associated with coronary obstruction after TAVI. The most frequent mechanism associated with coronary obstruction after TAVI has been the displacement of the calcified native cusp over the coronary ostium, and this has also been confirmed by the present review of the published data. In fact, no cases of coronary obstruction related to the struts of

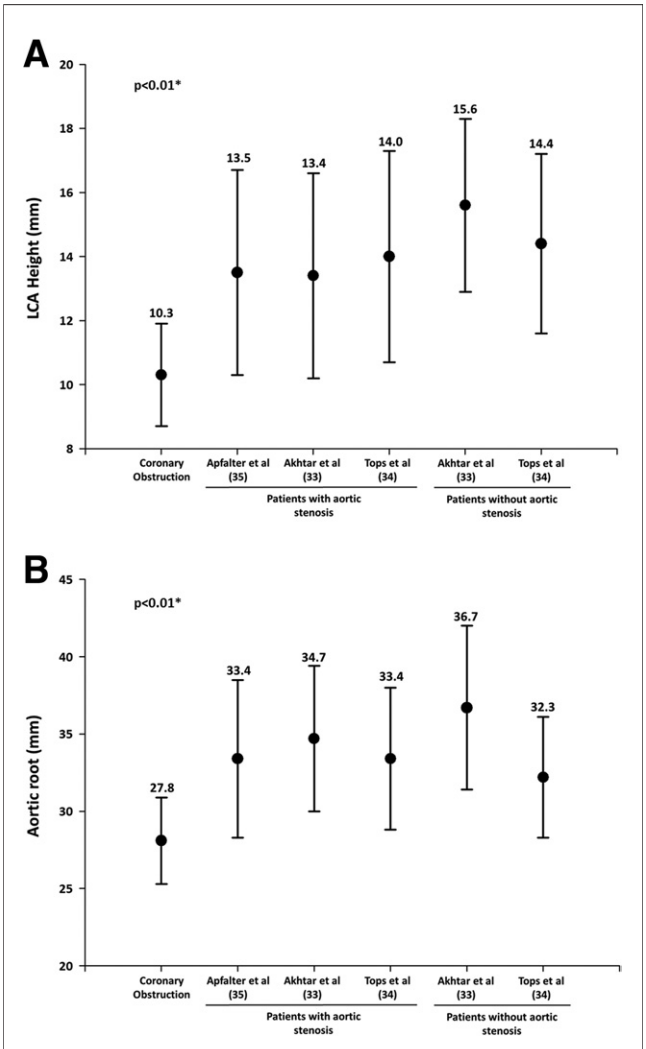

Figure 2. Computed Tomography Data

Mean values of the left coronary artery (LCA) height **(A)** and aortic root diameter **(B)** of patients with coronary obstruction after transcatheter aortic valve implantation compared with the values obtained from previous computed tomography studies, including patients with and without aortic stenosis (33–35). *Coronary obstruction versus other groups.

the transcatheter valve frame or to the cuff/leaflets of the transcatheter valve itself have been reported to date. Although the final mechanism leading to coronary obstruction after TAVI is well understood, the risk factors that predispose a patient to its occurrence remain largely unknown. A low position of the coronary ostia with respect to the aortic annulus has been highlighted as one of the most important factors contributing to this complication, and it has been suggested that a coronary ostia height cutoff ≤10 mm increases the risk of coronary obstruction during TAVI (41,42). In a recent post-mortem study, including 51 normal hearts, the mean LCA height, as determined by the LCA distance to the bottom of the corresponding sinus, was 12.6 ± 2.6 mm (43). In another study that evaluated the aortic root with multislice CT in 169 patients with and without aortic stenosis, the mean distance from the basal attachment point of the aortic valve leaflets to the ostium of the LCA was 14.4 ± 2.9 mm, with no differences between patients with and without aortic stenosis (34). Akhtar et al. (33) found that aortic stenosis was associated with a shorter distance from the aortic valve annulus to the LCA ostium (13.4 ± 3.2 mm vs. 15.6 ± 2.7 mm; p = 0.01). The present study showed that the mean height of the LCA ostium in the reported cases of coronary obstruction after TAVI was 10.3 mm (range 7 to >12 mm), a mean value that seems to be significantly lower (2 to 5 mm) compared with that reported in prior pathological and CT studies in patients with and without aortic stenosis (Fig. 2). However, this mean coronary ostium height value was higher than the previously suggested 10-mm "safety" cutoff, and indeed, approximately 60% of the cases with coronary obstruction after TAVI had a coronary ostia height >10 mm. This suggests that factors other than a short-distance between the aortic annulus and coronary ostia might also be involved in the occurrence of this complication.

The severity of valve calcification and, especially, the presence of bulky calcium nodules on the left or right aortic leaflets have also been suggested as important predictive factors for coronary obstruction after TAVI. However, the degree of valve calcification or the presence of calcium nodules was not described in any of the reports included in the present review, suggesting that this factor was either not evaluated or not considered. Also, a narrow aortic root with shallow sinuses of Valsalva leaving little room to accommodate the calcified native aortic leaflets after valve deployment might also be an important factor associated with coronary obstruction after TAVI. In this series, the mean aortic root diameter was approximately 28 mm, which was lower than the >30-mm diameter reported in previous studies evaluating aortic root geometry (33,35) (Fig. 2). However, most reports included in the present review evaluated the aortic root diameter by echocardiography, and it has been shown that echocardiography tends to underestimate aortic root diameters compared with multislice CT (34,44). Thus, we cannot draw firm conclusions about the role of aortic morphology, and in particular the degree of aortic root effacement, in relation to this complication.

Analysis of the clinical characteristics of the patients who suffered coronary obstruction after TAVI revealed a mean age (82.5 ± 7 years) and risk profile (mean logistic European System for Cardiac Operative Risk Evaluation score: 25.1 ± 12) similar to those reported in most previous TAVI studies (Fig. 1). However, up to 83% of the patients suffering this complication were women, and this is a significantly higher rate in comparison with the approximately 50% prevalence of women in most TAVI studies (Fig. 1). Moreover, it has been shown that women have a

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Table 3. Individual Data on Clinical Presentation and Management of Coronary Obstruction

		Clinical Presentation			Treatment						
Patient# (Ref#)	Coronary Obstruction	Severe Hypotension	ST-Segment Changes	Ventricular Arrhythmias or CPR	PCI	CABG	Successful PCI	Stent Type	Need for Hemodynamic Support	Hospital Stay (days)	In-Hospital Death
1 (9)	Both	Yes	Yes	No	Yes	No	Yes	BMS	No	11	No
2 (10)	LCA	Yes	No	No	No	No	—	—	No	5	Yes
3 (11)	LCA	Yes	Yes	Yes	Yes	No	Yes	DES	No	5	No
4 (12)	LCA	Yes	Yes	Yes	Yes	No	Yes	BMS	Yes	13	No
5 (12)	RCA	Yes	Yes	No	Yes	Yes	No	—	Yes	12	No
6 (12)	RCA	Yes	Yes	Yes	Yes	No	Yes	—	No	14	No
7 (13)	LCA	Yes	Yes	No	Yes	No	Yes	DES	No	4	No
8 (13)	LCA	Yes	No	Yes	Yes	No	No	BMS	Yes	0	Yes
9 (13)	LCA	Yes	No	Yes	Yes	No	Yes	BMS	No	5	No
10 (13)	LCA	Yes	Yes	No	Yes	No	Yes	BMS	No	4	No
11 (13)	LCA	No	No	No	Yes	No	Yes	—	No	3	No
12 (14)	LCA	Yes	No	No	Yes	No	Yes	BMS	No	—	No
13 (15)	LCA	Yes	No	Yes	Yes	No	Yes	BMS	Yes	5	No
14 (16)	LCA	Yes	No	Yes	Yes	No	Yes	BMS	No	5	No
15 (17)	RCA	Yes	Yes	No	Yes	No	Yes	BMS	No	4	No
16 (18)	LCA	Yes	Yes	No	Yes	No	Yes	DES	No	—	No
17 (19)	LCA	Yes	Yes	Yes	Yes	No	Yes	DES	Yes	8	No
18 (20)	LCA	Yes	Yes	No	Yes	No	Yes	BMS	No	5	No
19 (21)	LCA	Yes	No	Yes	Yes	No	Yes	BMS	No	—	No
20 (22)	LCA	Yes	No	Yes	Yes	No	Yes	DES	No	11	No
21 (23)	LCA	Yes	Yes	No	Yes	No	Yes	Both	No	—	No
22 (24)	LCA	No	Yes	No	Yes	No	Yes	BMS	No	—	No
23 (25)	LCA	No	No	No	Yes	No	Yes	BMS	No	—	No
24 (26)	LCA	Yes	No	Yes	Yes	No	Yes	DES	Yes	—	No

BMS = bare-metal stent(s); CABG coronary artery bypass graft; CPR = cardiopulmonary resuscitation; DES = drug-eluting stent(s); LCA = left coronary artery; PCI = percutaneous coronary intervention; RCA = right coronary artery.

smaller aortic root (45); this, together with lower coronary ostia height, might partially explain the increased incidence of this complication among women. Also, the rate of prior CABG (4.2%) was much lower than in prior TAVI studies, confirming the "protective effect" of CABG against symptomatic coronary ostia obstruction.

With regard to procedural characteristics, most reported patients who suffered coronary obstruction after TAVI had received a balloon-expandable Edwards valve. Data from previous TAVI registries also showed a slightly higher rate of coronary obstruction after balloon-expandable (>0.4%) versus self-expandable (<0.2%) valve implantation (Table 5) (2–4,6–8). Although the frame characteristics of the transcatheter valves (straight stainless steel or cobalt chromium vs. nitinol) and the mechanisms for valve implantation (balloon-expandable vs. self-expandable) might partially explain these differences, the criteria with regard to minimal sinus of Valsalva diameter and coronary ostia height requirements differ between the 2 transcatheter valves (SAPIEN and CoreValve, Medtronic, Minneapolis, Minnesota), and this might also explain the higher rate of coronary obstruction observed with the Edwards valve system. Whereas no specific formal recommendation for sinus of Valsalva width and coronary ostia height is provided for the implantation of the Edwards valve, a recommendation of a sinus of Valsalva width ≥27 mm (for the 26-mm CoreValve) or ≥28 mm (for the 29-mm CoreValve) mm and a coronary height ≥14 mm is provided by the manufacturer for the implantation of the CoreValve system. These specific recommendations, although probably not followed strictly by all CoreValve implanting centers, might have prevented a significant number of coronary obstructions with the CoreValve system.

Clinical presentation and management of coronary obstruction after TAVI. The vast majority of patients presented with persistent severe hypotension after valve implantation, and approximately 50% and 25% of them also had ST-segment changes (approximately one-half of them with ST-segment elevation) and procedural ventricular arrhythmias, respectively. This clinical presentation could be explained by the fact that approximately 90% of the patients had LCA involvement, thus resulting in significant left ventricular ischemia. Therefore, it is of major clinical importance in the presence of persistent severe hypotension after valve implan-

Table 4. Clinical Presentation and Management of Coronary Obstruction (N = 24)

Obstructed coronary artery	
Left main	20 (83.3%)
Right	3 (12.5%)
Both coronary arteries	1 (4.2%)
Clinical presentation	
Severe maintained hypotension	21 (87.5%)
ST-segment changes	13 (54.2%)
ST-segment elevation	6 (25.0%)
Ventricular arrhythmias	6 (25.0%)
Treatment	
PCI attempted	23 (95.8%)
Successful	21 (91.3%)
Stent successfully implanted	19 (82.6%)
Guide-wire protection only	1 (4.4%)
Catheter manipulation removed the calcium	1 (4.4%)
Unsuccessful	2 (8.7%)
Wire crossing failure	1 (4.4%)
Stent implanted but no flow	1 (4.4%)
Postmortem diagnosis	1 (4.4%)
Type of stent	
BMS only	13 (65.0%)
DES only	6 (30.0%)
Both	1 (5.0%)
Complications	
Need for cardiopulmonary resuscitation	9 (37.5%)
Need for hemodynamic support	6 (25.0%)
Compression requiring 2nd stent	3 (13.4%)
Conversion to open heart surgery	2 (8.3%)
Restenosis	1 (4.2%)
In-hospital death	2 (8.3%)
Hospital stay length, days	7 ± 4

Values are n (%) or mean ± SD.
PCI = percutaneous coronary intervention.

tation, even in the absence of ECG changes, that prompt echocardiography be performed to look for new segmental abnormalities and/or coronary angiography to look for coronary obstruction. Interestingly, both in normal postmortem hearts and in a recent study examining the aortic root with multislice CT, the distance from the LCA ostium to the basal attachment point of the aortic valve leaflet was lower as compared with the right coronary ostium, which might explain why coronary obstruction after TAVI is more frequent on the left side (34,43).

The present study showed that PCI was the preferred strategy for the treatment of coronary obstruction after TAVI. It is noteworthy that PCI was feasible and associated with a 91.3% success rate. Bare-metal stents were used more frequently than drug-eluting stents, and there were no cases of stent thrombosis or need for repeat revascularization during the hospital stay. However, 3 patients (13%) needed a second stent due to significant compression of the first implanted stent unresponsive to balloon post-dilation. Hence, one might argue for the use of stents with higher radial force and routinely perform high-pressure post-dilation with a noncompliant balloon. The reasons for these findings are not yet understood; nonetheless, the struts from the valve frame and most likely external compression from the calcific native valve cusp might play an important role (24,25). Importantly, up to 25% and 8% of the patients required either mechanical hemodynamic support (cardiopulmonary bypass, intra-aortic balloon, tandem heart support) or conversion to open heart surgery, respectively, highlighting the importance of performing these procedures in highly experienced centers with cardiac surgery facilities.

Study limitations. The present study has the limitations inherent to a systematic review that collects only the information described in the publications. Therefore, there might be relevant information omitted in the publications that could shed some more light on this complication. Indeed, imaging data (especially on CT) was not available in all reported cases, and this prevented an appropriate evaluation of the characteristics of the patient determining a higher risk for the occurrence of this complication. In addition, all the papers found in the published data were either case reports or very small series, precluding comparison with the entire TAVI population at risk. Additionally, the reported patients might have tended to pursue a better outcome than those who were not published ("selection bias").

Conclusions

Coronary obstruction remains a rare but potentially life-threatening complication of TAVI. Baseline characteristics from reported cases suggest that this complication occurs more frequently in women with no prior CABG and in patients receiving a balloon-expandable valve. Future studies will have to confirm these data and elucidate whether the potential lower rate of coronary obstruction observed after self-expandable valve implantation is due to a transcatheter valve class effect or to differences between valve types with regard to pre-specified recommendations on coronary ostia height and aortic root dimensions. Also, although the 10-mm "safety cut-off" for coronary ostia height might help to prevent coronary obstruction during TAVI, approximately one-half of the patients who had this complication exhibited a coronary ostia height >10 mm, suggesting both that a higher "safety cut-off" might be required and that factors other than coronary height (dimensions of sinuses of Valsalva and/or severe valve calcification) might probably play an important role in the occurrence of this complication. The results of this study also suggest that the occurrence of persistent severe hypotension, irrespective of the presence or absence of ST-segment changes, immediately after valve implantation requires ruling out this complication. Importantly, PCI was a feasible and effective treatment

Table 5. Data on Coronary Obstruction From Large TAVI Registries and the PARTNER Trial

Study (Ref. #)	n	Valve/Approach	TF	TA	All Procedures	Cases SAPIEN	Cases CoreValve
ADVANCE (3)	996	CoreValve	0.1%	—	0.1%	—	1
Canadian (4)	345	Cribier-Edwards, SAPIEN, SAPIEN XT/49% TF, 51% TA	0.6%	1.1%	0.9%	3	—
FRANCE (2)	244	SAPIEN or CoreValve/66% TF, TS 5%, 29% TA	SAPIEN (2.1%) CoreValve (1.5%)	0%	1.2%	2	1
German (8)	670	SAPIEN or CoreValve/96% TF, 4% TA	—	—	0.1%	—	—
SOURCE (6)	1,038	SAPIEN/45% TF, 55% TA	0.7%	0.5%	0.6%	6	—
PARTNER (5)	348	SAPIEN/70.1% TF, 29.9% TA	0%	0%	0%	—	—
Source XT (7)	2,600	SAPIEN XT/63% TF, 34% TA	0.3%	0.3%	0.3%	8	—
Pooled studies			13/3,726 (0.35%)	8/1,833 (0.44%)	22/6,241 (0.35%)	19	2
SAPIEN					19/4,497 (0.42%)		
CoreValve					2/1,074 (0.19%)		

ADVANCE = Medtronic CoreValve study; FRANCE = FRench Aortic National CoreValve and Edwards registry; PARTNER = Placement of Aortic Transcatheter Valve trial; SOURCE = SAPIEN aortic bioprosthesis European outcome registry; TAVI = transcatheter aortic valve implantation; other abbreviations as in Table 1.

in most cases, although the rates of additional hemodynamic support, conversion to open heart surgery, or stent compression requiring the implantation of a second stent remained important. Future prospective studies, including consecutive series of TAVI patients with this complication, are needed to further evaluate the predictive factors and the most appropriate clinical management of this important complication of TAVI.

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Key Words: aortic stenosis ■ coronary obstruction ■ coronary occlusion ■ coronary stenosis ■ transcatheter aortic valve replacement ■ transcatheter heart valve.

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