Spontaneous Coronary Artery Dissection
Revascularization Versus Conservative Therapy

Marysia S. Tweet, MD; Mackram F. Eleid, MD; Patricia J.M. Best, MD; Ryan J. Lennon, MS; Amir Lerman, MD; Charanjit S. Rihal, MD, MBA; David R. Holmes Jr, MD; Sharonne N. Hayes, MD; Rajiv Gulati, MD, PhD

Background—Spontaneous coronary artery dissection (SCAD) is a nonatherosclerotic acute coronary syndrome for which optimal management remains undefined.

Methods and Results—We performed a retrospective study of 189 patients presenting with a first SCAD episode. We evaluated outcomes according to initial management: (1) revascularization versus conservative therapy and (2) percutaneous coronary intervention (PCI) versus conservative therapy stratified by vessel flow at presentation. Demographics were similar in revascularization versus conservative (mean age, 44±9 years; women 92% both groups), but vessel occlusion was more frequent in revascularization (44/95 versus 18/94). There was 1 in-hospital death (revascularization) and 1 late death (conservative). Procedural failure rate was 53% in those managed with PCI. In the subgroup of patients presenting with preserved vessel flow, rates of PCI failure were similarly high (50%), and 6 (13%) required emergency coronary artery bypass grafting. In the conservative group, 85 of 94 (90%) had an uneventful in-hospital course, but 9 (10%) experienced early SCAD progression requiring revascularization. Kaplan–Meier estimated 5-year rates of target vessel revascularization and recurrent SCAD were no different in revascularization versus conservative therapy (30% versus 19%; P=0.06 and 23% versus 31%; P=0.7).

Conclusions—PCI for SCAD is associated with high rates of technical failure even in those presenting with preserved vessel flow and does not protect against target vessel revascularization or recurrent SCAD. A strategy of conservative management with prolonged observation may be preferable. **(*Circ Cardiovasc Interv*. 2014;7:777-786.)**

Key Words: acute coronary syndrome ■ coronary artery dissection, spontaneous ■ percutaneous coronary interventions

Spontaneous coronary artery dissection (SCAD) is a nonatherosclerotic acute coronary event of uncertain cause, typically affecting young otherwise healthy women, and likely under-recognized as a cause of sudden death and myocardial infarction.[1,2] The pathophysiology involves dissection and hematoma formation within the vessel media, causing luminal compression and obstruction. Intimal dissection itself is not universal. Angiography may, therefore, indicate luminal narrowing alone because of intramural hematoma, which could be misinterpreted as atherosclerotic plaque[3] or coronary vasospasm.

Half of all acute SCAD syndromes present with ST-segment–elevation myocardial infarction[4] with the remainder presenting as non–ST-segment–elevation myocardial infarction or sudden cardiac death. American College of Cardiology/American Heart Association guidelines for the acute management of both ST-segment–elevation myocardial infarction and acute coronary syndromes (ACS) stress the importance of early percutaneous intervention of culprit vessels. These recommendations for ACS are based on evidence from multiple large randomized studies, which were composed primarily of patients with atherothrombotic coronary disease.[5–7] SCAD, however, is a distinct, nonatherosclerotic entity, and it remains unknown whether the same guideline recommendations are appropriate in this population.

Clinicians confronted with decision making on the acute management of SCAD face conflicting data[4,8–10] and as such treatment continues to be empirical. Some have suggested favorable outcomes with invasive management.[9,10] However, other small SCAD series have shown that in selected patients, conservative management can be associated with late angiographic healing of dissection.[4,8,11] More so, we previously observed an unexpected elevated risk of technical complications in patients with SCAD treated acutely with percutaneous coronary intervention (PCI).[4] Limitations of previous SCAD series include (1) relatively small sample size; (2) no outcomes comparison based on initial treatment (revascularization

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From the Divisions of Cardiovascular Diseases (M.S.T., M.F.E., P.J.M.B., A.L., C.S.R., D.R.H., S.N.H., R.G.) and Biomedical Statistics and Informatics (R.J.L.), Mayo Clinic, Rochester, MN.

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Correspondence to Rajiv Gulati, MD, PhD, Mayo Clinic, 200 First St SW, Rochester, MN 55905. E-mail gulati.rajiv@mayo.edu

WHAT IS KNOWN

- Spontaneous coronary artery dissection is a cause of acute coronary syndrome for which optimal management remains uncertain.

WHAT THE STUDY ADDS

- Percutaneous coronary intervention for spontaneous coronary artery dissection is associated with high complication rates and emergency coronary artery bypass surgery even in those presenting with preserved vessel flow.
- Coronary artery bypass grafting for selected patients confers excellent early outcomes.
- Revascularization does not reduce the risk of long-term target vessel revascularization or recurrent spontaneous coronary artery dissection.
- Despite conservative management being associated with favorable in-hospital outcomes in the majority, an important minority develop clinically significant, early extension of dissection.

versus conservative therapy); (3) lack of stratification by vessel flow at presentation—it being difficult to make a case for a conservative approach in the setting of acute major coronary occlusion. Accordingly, to help inform clinical decision making, we performed a retrospective, comparative treatment study in a large series of SCAD. We evaluated early and late outcomes in patients presenting with a first episode of SCAD (n=189), managed with either revascularization or conservative therapy. In addition, we compared outcomes of PCI versus conservative therapy for SCAD, stratified by vessel flow at presentation.

Methods

Patient Population

The study was approved by the Mayo Foundation Institutional Review Board. Only patients who had provided authorization for the use of their records for research were included as required by Minnesota state statute. We identified patients with confirmed SCAD all of whom were seen at Mayo Clinic between 1984 and 2014 (n=189). This included those who received initial care at a referring institution. SCAD was defined as a clinical ACS together with typical diagnostic features (intimal dissection and intramural hematoma) identified by angiography and intravascular imaging and complete absence of atherosclerosis. Intimal tear was defined as the presence of a radiolucent plane, with or without contrast staining. Intramural hematoma was identified by an abrupt vessel tapering in concordance with recent proposed classification.[12] Patients with iatrogenic coronary artery trauma or atherosclerotic dissection were excluded. There was complete concordance between ≥2 independent cardiologists experienced in the angiographic diagnosis of SCAD. Follow-up comprised scheduled (routine or otherwise) review in the Mayo SCAD Clinic as described elsewhere,[13] review with primary cardiologist and telephone calls as part of the Mayo SCAD Registry.

Variables and Definitions

Demographics, clinical presentation, coronary distribution, treatment modality, early and late outcomes were determined via medical records, angiographic review, and follow-up.

We used 2 definitions of PCI success. (1) Conventional success: <30% residual stenosis after stent placement, including nonstented segment of dissection or <50% residual stenosis for angioplasty.[14] (2) SCAD-specific definition of success: improvement in baseline Thrombolysis in Myocardial Infarction (TIMI) grade 0 to 1 flow (≥1 grade improvement) or maintenance/improvement of TIMI grade 2 to 3 flow. Detailed angiographic features including American College of Cardiology classification,[15] lesion location, lesion length, vessel stenosis, reference vessel diameter, number of stents, stented length, residual stenosis, presence of an angiographic dissection plane, intramural hematoma, and intracoronary thrombosis were also assessed. Progressed SCAD was defined as clinically significant ischemia and angiographic extension of the initial SCAD lesion occurring within 2 weeks of the index event. Recurrent SCAD was defined as a clinical ACS distinct from the index event with an angiographic dissection plane and intramural hematoma or dissection on intravascular ultrasound or optical coherence tomography. Target vessel revascularization (TVR) was defined as PCI or coronary artery bypass grafting (CABG) to the index SCAD vessel at follow-up.

Statistical Analysis

We evaluated early and late outcomes in 2 treatment groups: (1) revascularization by CABG or PCI (revascularization) and (2) conservative therapy (conservative). Moreover, we further analyzed 4 SCAD groups according to presenting vessel flow: (1) vessel occlusion (TIMI 0–1) treated with PCI (n=41); (2) vessel occlusion treated conservatively (n=15); (3) preserved vessel flow (TIMI 2–3) treated with PCI (n=46); preserved vessel flow treated conservatively (n=77). Continuous data were summarized as mean (SD), and comparisons were performed with Student *t* test. Discrete variables were expressed as frequencies or percentages, and comparisons were performed by Fisher exact test. Kaplan–Meier methods and log-rank tests were used to estimate survival curves for follow-up events. For angiographic data, when patients had multiple lesions, the value of the lesion with the worst (ie, highest risk) characteristic was summarized. We conducted unadjusted models to assess associations between angiographic features and PCI success. We constructed a propensity score for conservative treatment using logistic regression. Five strata with similar propensity scores were created and strata-adjusted associations between treatment, early and long-term outcomes were estimated. More details on the propensity score analysis are available in the Data Supplement. Statistical analysis was performed with JMP version 9.0.0 and SAS 9.3 (both from SAS Institute, Inc, Cary, NC). A 2-sided value of $P<0.05$ was considered statistically significant.

Results

Clinical Characteristics

Mean age of the SCAD population was 44±9 years, and 92% were women with low rates of atherosclerotic risk factors (Table 1). Clinical characteristics of revascularization versus conservative, including peripartum and fibromuscular disease status, were similar. Those treated with initial revascularization more frequently presented with ST-segment–elevation myocardial infarction compared with those managed conservatively (51% versus 23%; $P=0.0002$) with higher rates of vessel occlusion (48% versus 19%; $P<0.0001$), larger diameter vessels (2.8 versus 2.6 mm; $P=0.011$), and higher mean lesion stenosis (90% versus 75%; $P<0.0001$). Rates of angiographic intracoronary thrombus were low in both groups. Analysis according to presenting TIMI flow demonstrated similar findings (Table 2). The small percentage of occluded vessels selected for conservative management tended to be distal, small caliber vessels.

Table 1. Baseline Data With Comparison According to Treatment Strategy: Revasc by Coronary Artery Bypass Grafting or Percutaneous Coronary Intervention vs Con Therapy

	All (n=189)*	Revasc (n=95)	Con (n=94)	*P* Value (Revasc vs Con)
Clinical characteristics				
Age, y ±SD	44±9	44±9	44±9	0.76
Women, %	92	92	92	>0.99
White, %	95	96	94	0.53
BMI, kg/m^2 ±SD	26±6	26±6	26±5	0.76
Hyperlipidemia, %	31	32	30	0.87
Hypertension, %	22	22	22	>0.99
Diabetes mellitus, %	2	1	3	0.62
Smoking, %	15	14	16	0.69
Postpartum, %	15	17	13	0.54
FMD, n†	61	28	33	0.63
Clinical presentation,%				
STEMI‡	37	51	23	0.0002
VT/VF	10	13	7	0.33
Initial LVEF %, mean±SD§	52±12	50±12	54±11	0.04
Coronary territory, %				
LM	4	6	1	0.12
LAD	61	65	57	0.30
Ramus	4	3	4	0.72
Left circumflex	25	26	25	0.87
RCA	25	23	28	0.51
Multivessel	15	16	15	>0.99
Dissection origin, %‖				0.50
Ostial	2	3	1	
Proximal	17	19	15	
Mid	54	57	52	
Distal	27	22	33	
Presenting TIMI flow, %				<0.0001
0–1	32	48	17	
2–3	68	52	83	
ACC classification, %				0.68
A	0	0	0	
B	17	15	18	
C	84	85	82	
Mean lesion stenosis,% ±SD	83±19	90±14	75±21	<0.0001
Mean lesion length, mm ±SD	48±31	48±30	48±32	0.99
Mean reference vessel diameter, mm ±SD	2.7±0.6	2.8±0.6	2.6±0.6	0.011
Intramural hematoma, %	86	86	85	>0.99
Intimal dissection plane, %	76	84	68	0.027
Angiographic thrombus, %	0	0	0	0.62
IVUS/OCT, %	13	18	9	0.08

ACC indicates American College of Cardiology; BMI, body mass index; Con, conservatively managed SCAD; FMD, fibromuscular dysplasia; IVUS, intravascular ultrasound; LAD, left anterior descending; LM, left main artery; LVEF, left ventricular ejection fraction; OCT, optical coherence tomography; PCI, percutaneous coronary intervention; Revasc, percutaneous coronary intervention or coronary artery bypass grafting as index treatment; RCA, right coronary artery; STEMI, ST-segment–elevation myocardial infarction; TIMI, Thrombolysis in Myocardial Infarction; and VT/VF, ventricular tachycardia or fibrillation requiring cardioversion/defibrillation.

*Eight received fibrinolytics in Revasc; 6 received fibrinolytics in Con.

†In total, 113 underwent imaging for FMD.

‡One patient had stable angina and ischemia on a stress test prompting her angiogram and diagnosis. All others who did not present with STEMI had non–STEMI.

§Event LVEF was available in 141.

‖Those 26 with an incomplete set of initial angiographic images were not included in the detailed angiographic analysis. Analysis was performed on the primary spontaneous coronary artery dissection (SCAD) vessel; separate analyses of those with multivessel SCAD did not reveal any added differences.

Table 2. Baseline Data With Comparison According to Treatment Strategy, Stratified by Vessel Flow

		PCI		Con		*P* Value	*P* Value
	CABG (n=6)	Vessel Occlusion (n=41)	Preserved Flow (n=46)	Vessel Occlusion (n=15)	Preserved Flow (n=77)	Vessel Occlusion (PCI vs Con)	Preserved Flow (PCI vs Con)
Clinical characteristics							
Age, y ±SD	40±11	44±9	44±10	46±8	44±9	0.49	>0.99
Women, %	67	95	93	100	90	>0.99	0.53
White, %	67	100	96	100	93	>0.99	0.71
BMI, kg/m^2 ±SD	23±3	25±5	27±7	24±4	27±5	0.37	0.81
Hyperlipidemia, %	17	37	28	27	29	0.54	>0.99
Hypertension, %	0	22	26	13	25	0.71	>0.99
Diabetes mellitus, %	0	0	2	0	4	>0.99	>0.99
Smoking, %	50	5	13	7	18	>0.99	0.61
Postpartum, %	33	10	22	7	14	>0.99	0.33
FMD, n*	1	11	16	6	25	0.50	0.68
Clinical presentation, %†							
STEMI†	50	63	41	20	23	0.006	0.04
VT/VF	17	15	11	0	9	0.18	0.76
Initial LVEF %, mean±SD‡	46±14	47±12	52±12	55±8	53±11	0.03	0.7
Coronary territory, %							
LM	33	5	4	0	1	>0.99	0.56
LAD	67	63	70	60	58	>0.99	0.25
Ramus	0	5	2	7	4	>0.99	>0.99
Left circumflex	50	20	28	20	25	>0.99	0.68
RCA	33	22	22	13	30	0.71	0.40
Multivessel	50	10	17	7	16	>0.99	0.80
Dissection origin, %§						0.10	0.79
Ostial	0	6	0	0	1		
Proximal	33	17	19	0	18		
Mid	67	50	62	40	54		
Distal	0	28	19	60	27		
Presenting TIMI flow, %							
0–1	67	100	NA	100	NA	NA	NA
2–3	33	NA	100	NA	100	NA	NA
ACC classification, %						>0.99	0.50
A	0	0	0	0	0	...	...
B	0	0	29	0	22	...	...
C	100	100	71	100	78	...	...
Mean lesion stenosis, % ±SD	93±6	98±8	83±15	94±10	71±20	0.09	<0.002
Mean lesion length, mm ±SD	47±31	56±30	41±29	46±18	48±34	0.25	0.27
Mean reference vessel diameter, mm ±SD	3.3±0.6	2.8±0.6	2.8±0.5	2.5±0.4	2.6±0.6	0.11	0.10
Intramural hematoma, %	67	94	81	87	85	0.57	0.60
Intimal dissection plane, %	100	86	81	73	67	0.42	0.13
IVUS/OCT, %	0	10	26	0	10	0.56	0.04

ACC indicates American College of Cardiology; BMI, body mass index; CABG, coronary artery bypass grafting; Con, conservatively managed SCAD; FMD, fibromuscular dysplasia; IVUS, intravascular ultrasound; LAD, left anterior descending; LM, left main artery; LVEF, left ventricular ejection fraction; OCT, optical coherence tomography; RCA, right coronary artery; STEMI, ST-segment–elevation myocardial infarction; TIMI, Thrombolysis in Myocardial Infarction; and VT/VF, ventricular tachycardia or fibrillation requiring cardioversion/defibrillation.

*In total, 113 underwent imaging for FMD.

†One patient had stable angina and ischemia on a stress test prompting her angiogram and diagnosis. All others who did not present with STEMI presented with non–STEMI.

‡Event LVEF was available in 141.

§Those 26 with an incomplete set of initial angiographic images were not included in the detailed angiographic analysis. Analysis was performed on the primary spontaneous coronary artery dissection (SCAD) vessel; separate analyses of those with multivessel SCAD did not reveal any added differences.

Early Procedural and Clinical Outcomes

Among both revascularization and conservative groups, in-hospital mortality was low (Table 3). There was 1 in-hospital death in the revascularization group because of multiorgan failure after bailout CABG for unsuccessful PCI. Compared with conservative therapy, those treated with revascularization had markedly elevated risk of requiring emergency CABG (13% versus 2%; odds ratio, 6.65; 95% confidence interval, 1.45–30.6; *P*=0.015) primarily because of PCI failure. After adjusting for baseline differences, the association was nonsignificant (odds ratio, 6.87; 95% CI, 0.87–53.9; *P*=0.067; Table I in the Data Supplement) although the nonsignificance seems to reflect the reduced statistical power because of adjustment (widening confidence intervals), rather than adjusting the odds ratio substantially downward.

By conventional criteria for PCI success/failure (residual stenosis), PCI failure occurred in 53% overall. Using SCAD-specific criteria (flow-based), failure rate was 30%. Rates of PCI failure and requirement for emergency CABG were similar regardless of vessel patency at presentation (Table 4). Reasons for technical failure in the PCI group with preserved vessel flow (23/46) were failure to cross the vessel with a wire or device because of wire entry into a false lumen (7/23), final loss of flow after stent placement (8/23; Figure 1), and residual stenosis >30% (8/23; Figure 2). There were no angiographic predictors of PCI success (neither conventional nor SCAD specific) by unadjusted analyses.

There were no early deaths among the conservatively managed patients. The majority of the conservative group had an unremarkable in-hospital course; however, 9 of 94 (10%) experienced recurrent chest pain, ischemia, and angiographic findings of SCAD progression, occurring at a mean of 4 days (2–7 days) of initial presentation (Figure 3). Eight of these were revascularized by either PCI (unsuccessful in 2/6) or CABG (successful in both).

Of the 6 patients who received CABG as the initial treatment, in-hospital survival was 100%. Twenty patients with SCAD underwent CABG at some point during the initial hospitalization. Of the 34 intended bypass targets, only 2 could not be bypassed because of extent of dissection, and these were secondary vessels (Table 5).

Table 3. Early and 5-Year Outcomes With Comparison According to Treatment Strategy: Revasc by CABG or PCI vs Con therapy

	All (n=189)	Revasc (n=95)	Con (n=94)	*P* Value (Revasc vs Con)
Early outcomes, %				
Death	0.5	1	0	>0.99
Urgent/emergent CABG*	7	13	2	0.01
Progression Rx PCI	6	4†	7†	0.37
Progression Rx consv	1	0	2	0.25
PCI procedural outcomes				
% Conventional PCI failure (residual stenosis ≥30%)	...	53	NA	NA
% SCAD-specific PCI failure	...	30	NA	NA
Mean no. of stents, n ±SD	...	2.4±1.4	NA	NA
Mean stented length, mm ±SD	...	44±29	NA	NA
Mean residual stenosis, % ±SD	...	51±40	NA	NA
Five-year outcomes (median, F-U, 2.3 y; Q1–Q3, 0.7–5.6), n (Kaplan–Meier % estimates)				
Death	2 (2)	1 (1)	1 (4)	0.92
Recurrent SCAD	29 (27)	14 (23)	15 (31)	0.70
Heart failure	13 (13)	7 (12)	6 (16)	0.47
Target vessel revascularization	38 (25)	24 (30)	14 (19)	0.06
F-U LVEF %, mean±SD‡	57±10	55±11	58±9	0.09

CABG indicates coronary artery bypass grafting; Con, conservatively managed SCAD; F-U, follow-up; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; Revasc, PCI or CABG as index treatment; Rx, treatment; and SCAD, spontaneous coronary artery dissection.

*Excludes index CABG treatment (n=6).

†Two unsuccessful PCIs in each group.

‡F-U LVEF available in 161, median 3.8 y (Q1–Q3, 1–8).

Late Clinical and Angiographic Outcomes

Rates of long-term mortality were low (1/94 conservative versus 0/95 revascularization); median follow-up was 2.3 years (Q1–Q3, 0.7–5.6) with 1 patient lost to follow-up. The single death was unrelated to SCAD. Kaplan–Meier estimated rate of TVR at 5 years was no different in revascularization versus conservative (30% versus 19%; *P*=0.06) or preserved vessel flow treated with PCI versus preserved vessel flow-conservative (31% versus 22%; *P*=0.20; Figure 4A and 4B). Substrates for TVR were in-stent restenosis (23/44), persistent dissection (14/44), persistent dissection and occluded graft (1/44), diseased graft with ligated native vessel (1/44), and new SCAD in same vessel (5/44). Among those initially treated with PCI, there were no angiographic predictors of subsequent TVR. In conservative, 59 of 95 patients underwent repeat angiography in follow-up. Clinical indications included recurrent SCAD, chest pain (frequently atypical), MI, and surveillance angiography. Of these, 43 (73%) demonstrated angiographic healing (median, 2.4 years; Q1–Q3, 0.9–6.2).

The Kaplan–Meier estimated rate of recurrent SCAD was 27% at 5 years in the overall population. The risk of SCAD recurrence did not differ between those who had been managed with revascularization or conservatively at their first episode (Figure 4C and 4D). The majority of recurrent SCAD events occurred in de novo coronary territories (revascularization 15/20 [75%] versus conservative 17/19 [90%]; *P*=0.24).

There was no difference in Kaplan–Meier rates of myocardial infarction among revascularization versus conservative at 5 years (Figure 5). The majority of MIs in both groups were because of recurrent SCAD (14/16 versus 15/21; *P*=0.42). Other reasons for MI included in-stent stenosis, persistent SCAD, and iatrogenic dissection. In this regard, a total of 11 patients with SCAD had an iatrogenic coronary dissection at some point during their medical care. Notably in the conservative group, there was no late progression to clinically significant occlusion of the initial SCAD lesion.

Those who underwent CABG at their initial event were not protected against recurrent SCAD (1/20) or TVR (6/20). A total of 11 of 20 patients with CABG underwent follow-up angiography (median, 3.5 years; Q1–Q3, 0.7–3.7); of these, only 5 of 16 of grafts were patent.

Table 4. Early and 5-Year Outcomes With Comparison According to Treatment Strategy, Stratified by Vessel Flow

		PCI		Con		*P* Value Vessel Occlusion (PCI vs Con)	*P* Value Preserved Flow (PCI vs Con)
	CABG (n=6)	Vessel Occlusion (n=41)	Preserved Flow (n=46)	Vessel Occlusion (n=15)	Preserved Flow (n=77)		
Early outcomes,%							
Death	0	2	0	0	0	>0.99	>0.99
Urgent/emergent CABG	NA	15	13	0	3	0.18	0.05
Progression Rx PCI	0	2	6*	0	8*	>0.99	0.74
Progression Rx consv	0	0	7	0	3	>0.99	0.53
PCI procedural outcomes							
% Conventional PCI failure (residual stenosis ≥30%)	NA	54	50	NA	NA	NA	NA
% SCAD-specific PCI failure	NA	30	35	NA	NA	NA	NA
Mean no. of stents, n ±SD	NA	2±0.8	2.7±1.6	NA	NA	NA	NA
Mean stented length, mm ±SD	NA	41±21	46±33	NA	NA	NA	NA
Mean residual stenosis, % ±SD	NA	52±40	42±41	NA	NA	NA	NA
Five-year outcomes (median F-U, 2.3 y; Q1–Q3, 0.7–5.6), n (Kaplan–Meier % estimates)							
Death	0	1 (2)	0	0	1 (5)	0.55	0.34
Recurrent SCAD	0	5 (25)	8 (24)	1 (13)	13 (35)	0.20	0.68
Heart failure	1 (17)	3 (19)	3 (9)	1 (14)	5 (17)	0.46	0.63
Target vessel revascularization	2 (38)	9 (24)	12 (31)	0	13 (22)	0.05	0.20
F-U LVEF %, mean±SD†	46±10	57±9	55±12	59±5	58±9	0.44	0.15

CABG indicates coronary artery bypass grafting; Con, conservatively managed SCAD; F-U, follow-up; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; Rx, treatment; and SCAD, spontaneous coronary artery dissection.

*Two unsuccessful PCIs in each group.

†F-U LVEF available in 161, median 3.8 y (Q1–Q3, 1–8).

Discussion

The principal findings of this study are the following:

1. PCI for SCAD is associated with high rates of complications and emergency CABG, even in those presenting with preserved vessel flow.
2. CABG for selected patients with SCAD confers excellent early outcomes.
3. Conservative therapy for SCAD is associated with favorable in-hospital outcomes. However, an important minority experience clinically relevant progression of dissection within 7 days of presentation.
4. Revascularization does not reduce risk of long-term TVR or recurrent SCAD, underscoring the need for close follow-up and development of novel treatment approaches.

US and European professional society guidelines advocate early percutaneous revascularization for patients with ACSs, based on data from multiple large-scale randomized studies.[16–18] These studies were composed primarily of

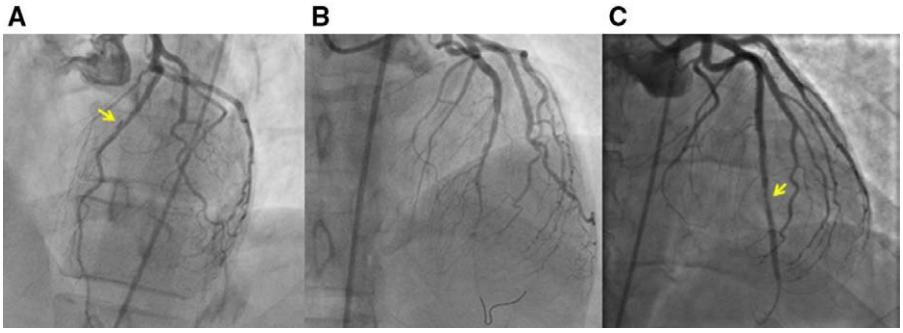

Figure 1. Unsuccessful percutaneous coronary intervention (PCI) because of loss of flow. A 33–year-old woman presenting with non–ST-segment–elevation myocardial infarction and left anterior descending (LAD) spontaneous coronary artery dissection (SCAD) with Thrombolysis in Myocardial Infarction 3 flow. The dissection extended during PCI with final loss of flow. In the subsequent 4 years, she has undergone >10 angiograms with multiple PCIs to the LAD and septal perforator because of recurrent pain and stent restenosis. **A**, SCAD (arrow) of the mid-LAD artery in a stable patient. **B**, Unsuccessful PCI with dissection extension and final loss of distal flow. **C**, Recurrent in-stent restenosis (arrow) at 4 years after multiple target vessel revascularizations.

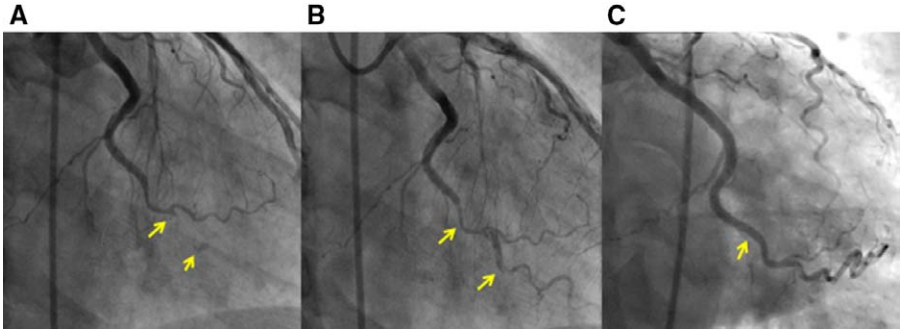

Figure 2. Example of revascularization defined as unsuccessful by conventional definition (severe residual stenosis) but successful by spontaneous coronary artery dissection (SCAD)–specific definition (improved vessel flow). A 43-year-old woman presenting with non–ST-segment–elevation myocardial infarction and occluded second obtuse marginal who received percutaneous transluminal coronary angioplasty with residual stenosis >50% but Thrombolysis in Myocardial Infarction (TIMI) 2 final vessel flow. Follow-up angiogram 2 months later demonstrated complete vessel healing. **A**, Occlusive SCAD of the second obtuse marginal (arrow). **B**, Unsuccessful percutaneous transluminal coronary angioplasty (PTCA) by conventional definition (severe residual stenosis). Successful PTCA by SCAD-specific definition (improved vessel flow). **C**,Vessel healing at 2.3 months.

patients with atherosclerotic coronary artery disease, who derived benefit from intervention by the trapping of plaque and thrombus material behind a stent scaffold in addition to restoration of flow. In this regard, the conventional definition of a successful procedure is the absence of residual stenosis after PCI, conferring lower risks of both acute closure and long-term TVR. SCAD, however, is a distinct entity for which current guidelines do not differentiate a management approach. Luminal obstruction from SCAD is caused by compression caused by hematoma within the vessel media or by separation of the intima from the media and not by atherosclerotic plaque. The combination of a unique disease process (often with diffuse, long lesions) and unpredictable response to conventional dilation argues for a novel definition of success when PCI is performed for SCAD rather than atherosclerotic disease. Moreover, unlike atherosclerosis, the natural history of residual stenosis caused by SCAD is frequently vessel healing, as the current study emphasizes.

Because of the low prevalence of SCAD, a randomized trial comparing treatment strategies in this population is unlikely. Moreover, there is a paucity of retrospective comparative data to help guide management. In a retrospective review of the literature, Shamloo et al[9] concluded short- and long-term outcomes to be more favorable in patients treated with an invasive rather than conservative approach at initial presentation. However, major limitations of this study were selection bias, publication bias, and nonuniform follow-up inherent with data being primarily compiled from published case reports. Although a recent single-center study also suggested favorable outcomes for PCI in SCAD,[10] our earlier observations suggested poor outcomes with PCI.[4] The current study addressed limitations of previous SCAD analyses by including a larger sample size and incorporating stratification by baseline vessel flow at presentation.

The current study indicates that the risk of emergency CABG is disturbingly high among patients with SCAD treated with PCI, including those with normal flow. In contrast, conservative management was associated with favorable outcomes. This underscores the importance of careful consideration of indications that may warrant an invasive strategy. In our experience, pain is frequent in SCAD, even

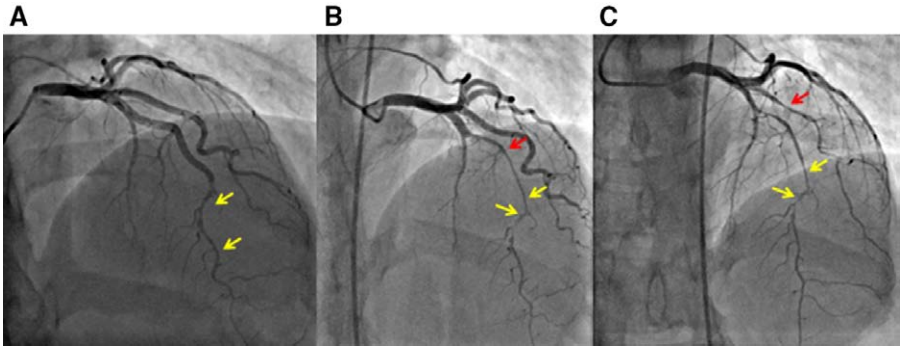

Figure 3. Progression of a conservatively managed dissection. A 32-year-old woman presenting with non–ST-segment–elevation myocardial infarction and left anterior descending (LAD) spontaneous coronary artery dissection (SCAD) managed conservatively (yellow arrows; **A**). Three days later, she had recurrent chest pain with repeat angiogram showing dissection progression. Again, she was conservatively managed but the next day had recurrent chest pain, progressed SCAD and ST-elevation during angiography so underwent emergent bypass surgery. The surgeon noted an edematous, dark cord along the LAD and diagonal. The vessels were thin and shredded; only the LAD could be bypassed. **B**, Upstream hematoma propagation (red arrow) managed conservatively on day 3. **C**, Further hematoma progression to the diagonal (red arrow) wityh subsequent emergent coronary artery bypass grafting on day 4.

Table 5. Early and 5-Year Outcomes of Patients With SCAD Treated With In-Hospital CABG

	In-Hospital CABG (n=20)
Early outcomes, n	
Death	1
SCAD vessels not bypassed	2/34
Five-year outcomes, n (Kaplan–Meier % estimates)	
Death	0
Recurrent SCAD	1 (10)
Heart failure	3 (19)
Target vessel revascularization	6 (36)
Graft details	
Left internal mammary artery	9
Saphenous vein	22
Radial artery	1
F-U patent grafts, n (11 angiograms, median F-U, 3.5 y; Q1–Q3, 0.7–3.7)	5/16

CABG indicates coronary artery bypass grafting; F-U, follow-up; and SCAD, spontaneous coronary artery dissection.

when active ischemia has resolved, and may reflect contributing nonischemic mechanisms for pain. A novel observation in the current study is the risk of early extension of dissection in an important minority of conservatively managed patients. More so, even successful stent placement did not fully protect against subsequent extension of dissection in the days after PCI. Collectively, these observations suggest that close inpatient monitoring for a prolonged period should be strongly considered, regardless of initial treatment, a departure from standard practice and ongoing attempts to abbreviate lengths of stay in ACS.

CABG as an index treatment strategy for SCAD was associated with excellent in-hospital outcomes in the present study. Despite concern for inadequacy of distal targets in diffusely dissected vessels, successful graft anastomoses were achieved in every primary vessel and almost all secondary vessels in all patients treated with CABG during index hospitalization (including those initially managed conservatively or with PCI). Acknowledging relatively small sample size and possible selection bias, these data support a low threshold for considering CABG as an initial strategy or failed conservative therapy for SCAD. Collectively, the data presented herein suggest that SCAD-related ACS should prompt a unique and dedicated management algorithm separate from that of patients with typical ACS (Figure 6).

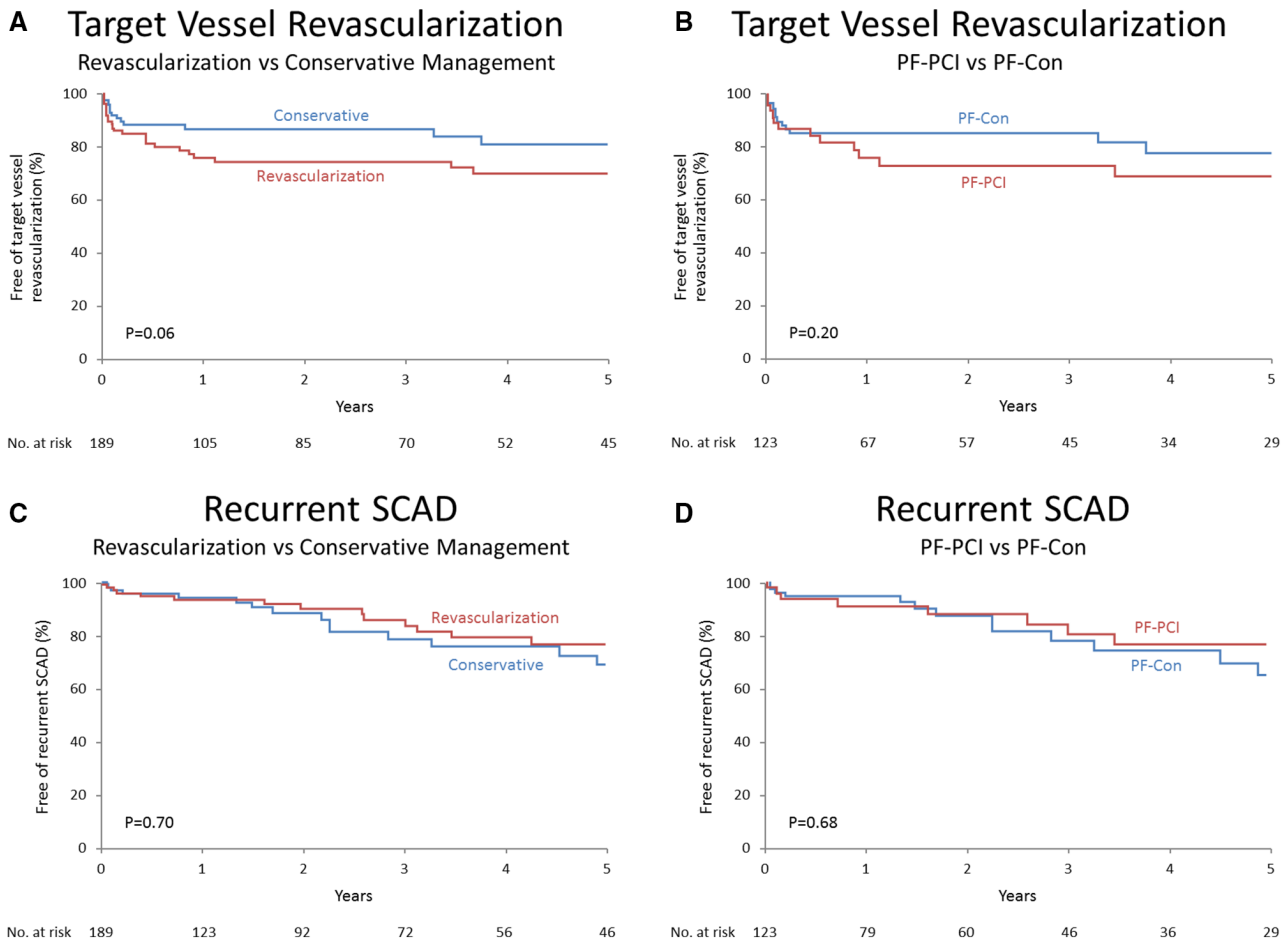

Figure 4. Comparison of long-term outcomes after spontaneous coronary artery dissection (SCAD) according to initial treatment strategy and presenting vessel flow. Kaplan–Meier estimated 5-year rate of target vessel revascularization in percutaneous coronary intervention (PCI) or coronary artery bypass grafting as index treatment (Revasc) vs conservatively managed SCAD (Con); (**A**) and preserved vessel flow (TIMI 2–3) treated with PCI (PF-PCI) vs preserved vessel flow treated conservatively (PF-Con); (**B**) recurrent SCAD in Revasc vs Con (**C**) and PF-PCI vs PF-Con (**D**).

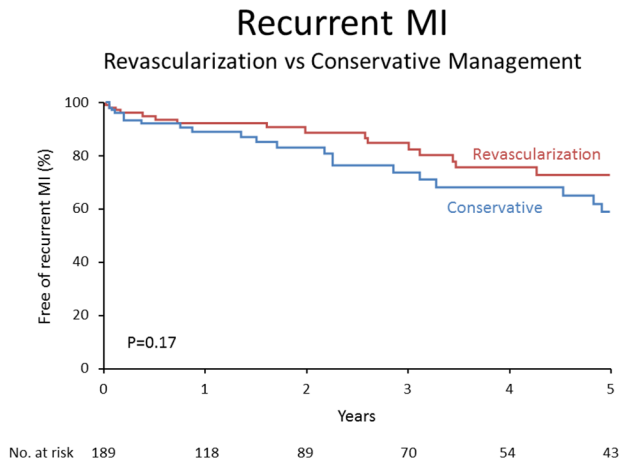

Figure 5. Comparison of long-term rate of recurrent myocardial infarction (MI) after spontaneous coronary artery dissection (SCAD) according to initial treatment strategy. Kaplan–Meier estimated 5-year rate of recurrent MI in revascularization vs conservative management.

Two additional observations are notable. First, late vessel healing occurred in a large proportion of conservatively managed SCAD consistent with previous studies.[4,8,11,19] Second, recurrent SCAD events almost always affected new rather than initially dissected vessels. These findings likely explain why revascularization did not protect against subsequent TVR or recurrent SCAD events. Moreover, the observed natural history of SCAD (healing) almost certainly explains the significant prevalence of late bypass graft occlusion because of competitive filling in healed native vessels.

The current study did not identify any angiographic variable that was predictive of acute success with conventional PCI. As such, innovative invasive treatment strategies might be desirable. In considering development of such approaches, it is important to recognize that the mechanisms of SCAD initiation and propagation are largely undetermined. This is in contrast to, for example, conventional dissection of the aorta. Intimal tear may not be an initiating factor in many cases of SCAD and is frequently absent by imaging.[3] It is possible that the process begins as an intramural hematoma, with an intimal tear occurring secondarily in some (outside-in). Thus, attempted sealing of an intimal tear (even if present), as has been advocated for certain patterns of aortic dissection, may not be beneficial in SCAD. The extent of intramural hematoma is often underappreciated by angiography. Thus, as described in the current study, unanticipated loss of flow after stent placement (because of displacement of hematoma) may occur. Moreover, the presence and underappreciation of the extent intramural hematoma can result in stent undersizing, with the associated long-term risk of late stent malapposition on resorption of hematoma.[20] Novel PCI strategies might include, for example, consideration of cutting balloon angioplasty in attempt to decompress an intramural hematoma. Alternatively, some have advocated optical coherence tomography/intravascular ultrasound guidance to first determine the extent of dissection/hematoma and then to place stents proximally and distally to reduce the risk of dissection propagation. Conceptually, bioabsorbable scaffolds, rather than permanent metallic stents, might be an option to mitigate concerns of late stent malapposition. All such options remain to be tested in the clinical setting.

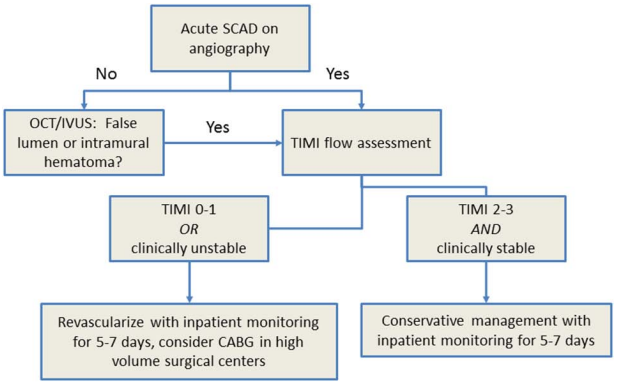

Figure 6. Proposed algorithm for acute management of initial Spontaneous coronary artery dissection (SCAD). CABG indicates coronary artery bypass grafting; IVUS, intravascular ultrasound; and OCT, optical coherence tomography.

Although this is the largest SCAD series reviewing management strategies to date, sample size and the retrospective nature of the analysis remain limiting factors for interpreting and applying our findings to the broader SCAD population. Complication rates may have been overestimated because of referral bias toward complex patients. Despite the fact that acute care was performed by numerous unique healthcare providers at various medical centers, an influence of selection bias in treatment choice and unmeasured confounders cannot be excluded.

By illustrating management challenges, the current study underscores the critical need for accurately ascertaining the pathophysiology and cause of ACS, understanding the coronary architecture of patients at risk for SCAD, determining factors that may provoke an acute dissection and identifying those at highest risk for recurrent clinical events.

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Disclosures

None.

References

1. Desai S, Sheppard MN. Sudden cardiac death: look closely at the coronaries for spontaneous dissection which can be missed. *Am J Forensic Med Pathol*. 2012;33:26–29.
2. Nishiguchi T, Tanaka A, Ozaki Y, Taruya A, Fukuda S, Taguchi H, Iwaguro T, Ueno S, Okumoto Y, Akasaka T. Prevalence of spontaneous coronary artery dissection in patients with acute coronary syndrome [published online ahead of print September 11, 2013]. *Eur Heart J Acute Cardiovasc Care*. doi: 10.1177/2048872613504310.
3. Alfonso F, Paulo M, Gonzalo N, Dutary J, Jimenez-Quevedo P, Lennie V, Escaned J, Bañuelos C, Hernandez R, Macaya C. Diagnosis of spontaneous coronary artery dissection by optical coherence tomography. *J Am Coll Cardiol*. 2012;59:1073–1079.

4. Tweet MS, Hayes SN, Pitta SR, Simari RD, Lerman A, Lennon RJ, Gersh BJ, Khambatta S, Best PJ, Rihal CS, Gulati R. Clinical features, management, and prognosis of spontaneous coronary artery dissection. *Circulation*. 2012;126:579–588.
5. McNamara RL, Herrin J, Wang Y, Curtis JP, Bradley EH, Magid DJ, Rathore SS, Nallamothu BK, Peterson ED, Blaney ME, Frederick P, Krumholz HM. Impact of delay in door-to-needle time on mortality in patients with ST-segment elevation myocardial infarction. *Am J Cardiol*. 2007;100:1227–1232.
6. Rathore SS, Curtis JP, Chen J, Wang Y, Nallamothu BK, Epstein AJ, Krumholz HM. Association of door-to-balloon time and mortality in patients admitted to hospital with ST-elevation myocardial infarction. *Br Med J*. 2009;338:b1807.
7. De Luca G, Suryapranata H, Ottervanger JP, Antman EM. Time delay to treatment and mortality in primary angioplasty for acute myocardial infarction. *Circulation*. 2004;109:1223–1225.
8. Alfonso F, Paulo M, Lennie V, Dutary J, Bernardo E, Jiménez-Quevedo P, Gonzalo N, Escaned J, Bañuelos C, Pérez-Vizcayno MJ, Hernández R, Macaya C. Spontaneous coronary artery dissection: long-term follow-up of a large series of patients prospectively managed with a "conservative" therapeutic strategy. *JACC Cardiovasc Interv*. 2012;5:1062–1070.
9. Shamloo BK, Chintala RS, Nasur A, Ghazvini M, Shariat P, Diggs JA, Singh SN. Spontaneous coronary artery dissection: aggressive vs. conservative therapy. *J Invasive Cardiol*. 2010;22:222–228.
10. Buja P, Coccato M, Fraccaro C, Tarantini G, Isabella G, Almamary A, Dariol G, Panfili M, Iliceto S, Napodano M. Management and outcome of spontaneous coronary artery dissection: conservative therapy versus revascularization. *Int J Cardiol*. 2013;168:2907–2908.
11. Saw J, Ricci D, Starovoytov A, Fox R, Buller CE. Spontaneous coronary artery dissection: prevalence of predisposing conditions including fibromuscular dysplasia in a tertiary center cohort. *JACC Cardiovasc Interv*. 2013;6:44–52.
12. Saw J. Coronary angiogram classification of spontaneous coronary artery dissection [published online ahead of print November 13, 2013]. *Catheter Cardiovasc Interv*. doi: 10.1002/ccd.25293.
13. Eleid MF, Guddeti RR, Tweet MS, Lerman A, Singh M, Best PJ, Vrtiska TJ, Prasad M, Rihal CS, Hayes SN, Gulati R. Coronary artery tortuosity in spontaneous coronary artery dissection: angiographic characteristics and clinical implications. *Circ Cardiovasc Interv*. 2014;7:656–662.
14. Smith SC Jr, Dove JT, Jacobs AK, Kennedy JW, Kereiakes D, Kern MJ, Kuntz RE, Popma JJ, Schaff HV, Williams DO, Gibbons RJ, Alpert JP, Eagle KA, Faxon DP, Fuster V, Gardner TJ, Gregoratos G, Russell RO, Smith SC Jr; American College of Cardiology/American Heart Association task force on practice guidelines (Committee to revise the 1993 guidelines for percutaneous transluminal coronary angioplasty); Society for Cardiac Angiography and Interventions. ACC/AHA guidelines for percutaneous coronary intervention (revision of the 1993 PTCA guidelines)-executive summary: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (Committee to revise the 1993 guidelines for percutaneous transluminal coronary angioplasty) endorsed by the Society for Cardiac Angiography and Interventions. *Circulation*. 2001;103:3019–3041.
15. Ellis SG, Vandormael MG, Cowley MJ, DiSciascio G, Deligonul U, Topol EJ, Bulle TM. Coronary morphologic and clinical determinants of procedural outcome with angioplasty for multivessel coronary disease. Implications for patient selection. Multivessel Angioplasty Prognosis Study Group. *Circulation*. 1990;82:1193–1202.
16. O'Gara PT, Kushner FG, Ascheim DD, Casey DE Jr, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB, Krumholz HM, Linderbaum JA, Morrow DA, Newby LK, Ornato JP, Ou N, Radford MJ, Tamis-Holland JE, Tommaso JE, Tracy CM, Woo YJ, Zhao DX; CF/AHA Task Force. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2013;127:529–555.
17. Members ATF, Steg PG, James SK, Atar D, Badano LP, Lundqvist CB, Borger MA, Di Mario C, Dickstein K, Ducrocq G, Fernandez-Aviles F, Gershlick AH, Giannuzzi P, Halvorsen S, Huber K, Juni P, Kastrati A, Knuuti J, Lenzen MJ, Mahaffey KW, Valgimigli M, van't Hof A, Widimsky P, Zahger D, Guidelines ECfP, Bax JJ, Baumgartner H, Ceconi C, Dean V, Deaton C, Fagard R, Funck-Brentano C, Hasdai D, Hoes A, Kirchhof P, Kolh P, McDonagh T, Moulin C, Popescu BA, Reiner Ž, Sechtem U, Sirnes PA, Tendera M, Torbicki A, Vahanian A, Windecker S, Reviewers D, Astin F, Åström-Olsson K, Budaj A, Clemmensen P, Collet J-P, Fox KA, Fuat A, Gustiene O, Hamm CW, Kala P, Lancellotti P, Maggioni AP, Merkely B, Neumann F-J, Piepoli MF, Van de Werf F, Verheugt F, Wallentin L. ESC guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. *Eur Heart J*. 2012;33:2569–2619.
18. Hamm CW, Bassand J-P, Agewall S, Bax J, Boersma E, Bueno H, Caso P, Dudek D, Gielen S, Huber K, Ohman M, Petrie MC, Sonntag F, Uva MS, Storey RF, Wijns W, Zahger D, Bax JJ, Auricchio A, Baumgartner H, Ceconi C, Dean V, Deaton C, Fagard R, Funck-Brentano C, Hasdai D, Hoes A, Knuuti J, Kolh P, McDonagh T, Moulin C, Poldermans D, Popescu BA, Reiner Ž, Sechtem U, Sirnes PA, Torbicki A, Vahanian A, Windecker S, Achenbach S, Badimon L, Bertrand M, Bøtker HE, Collet J-P, Crea F, Danchin N, Falk E, Goudevenos J, Gulba D, Hambrecht R, Herrmann J, Kastrati A, Kjeldsen K, Kristensen SD, Lancellotti P, Mehilli J, Merkely B, Montalescot G, Neumann F-J, Neyses L, Perk J, Roffi M, Romeo F, Ruda M, Swahn E, Valgimigli M, Vrints CJ, Widimsky P. ESC guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. *Eur Heart J*. 2011;32:2999–3054.
19. Ito H, Taylor L, Bowman M, Fry ET, Hermiller JB, Van Tassel JW. Presentation and therapy of spontaneous coronary artery dissection and comparisons of postpartum versus nonpostpartum cases. *Am J Cardiol*. 2011;107:1590–1596.
20. Sanchez-Recalde A, Moreno R, Jiménez-Valero S. Stenting of spontaneous intramural coronary haematoma: long-term consequences. *Eur Heart J*. 2008;29:1593.

Spontaneous Coronary Artery Dissection: Revascularization Versus Conservative Therapy

Marysia S. Tweet, Mackram F. Eleid, Patricia J.M. Best, Ryan J. Lennon, Amir Lerman, Charanjit S. Rihal, David R. Holmes, Jr, Sharonne N. Hayes and Rajiv Gulati

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