

REVIEW

The role of percutaneous coronary intervention in spontaneous coronary artery dissection: between Scylla and Charybdis

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ABSTRACT

Spontaneous coronary artery dissection (SCAD) is a distinct and increasingly recognized cause of acute coronary syndromes, primarily affecting young and middle-aged women with few cardiovascular risk factors. While SCAD often resolves spontaneously with conservative management, percutaneous coronary intervention (PCI) is sometimes necessary, especially in patients with ongoing ischemia or high-risk anatomical features. This review summarizes the current state of knowledge regarding the interventional approach in SCAD, emphasizing the rationale for conservative treatment, and the indications for and challenges associated with PCI. It also provides practical recommendations, particularly highlighting technical aspects of PCI in SCAD, the critical role of intracoronary imaging, and the modality and timing of post-PCI surveillance.

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KEY WORDS: Spontaneous coronary dissection; Percutaneous coronary intervention; Interventional ultrasonography; Optical coherence tomography.

Natural history of spontaneous coronary dissection

Spontaneous coronary dissection (SCAD) consists of a non-iatrogenic and non-traumatic separation in the layers of the coronary arteries,

generally in their middle and distal segments, of acute onset, which usually generates a compromise of antegrade blood flow. It occurs more frequently in women (9 out of 10 cases) around 50 years of age, with few or no cardiovascular risk factors. It represents 1-4% of all acute coro-

nary syndromes (ACS),^{1,2} commonly presenting with chest pain, myocardial infarction (MI) with or without ST elevation, ventricular arrhythmias, and/or sudden cardiac death.³ In the subgroup of women <50 years, however, SCAD represents up to 35% of ACS.⁴

Conditions associated with this pathology have been previously described, although the causal interaction with these conditions is not fully understood. Hormone fluctuations have been proposed as a precipitating trigger in some cases of SCAD. Pregnancy and delivery represent no more than 10% in any contemporary series,^{5,6} but these patients have more complex anatomical compromises with greater myocardial tissue at risk. Moreover, the previous use of exogenous hormonal therapy has been associated with worse short-term outcomes in SCAD cohorts.⁷ Moreover, a relevant association of SCAD with fibromuscular dysplasia (FMD), with a prevalence ranging from 13% to 37% in different series, has gained researchers' attention.^{3,8} Other associated conditions are autoimmune and connective tissue disorders, which have been considered predisposing and precipitating factors, and can coexist in up to 12% of cases of SCAD.⁹ Hypothyroidism, with a variable prevalence (8-26% of cases), has also been proposed to have a role in SCAD pathophysiology.^{10,11}

The pathophysiology of SCAD is not yet fully understood. It consists of the formation of an intramural false lumen (FL) that may or may not be communicated with the true lumen, depending on the presence of fenestrations. There are two main proposed mechanisms;¹² the "inside-out" mechanism, in which a spontaneous tear of the intimal layer of the endothelium generates an accumulation of blood in the media (fenestrated dissection), and on the other hand, the "outside-in" mechanism secondary to rupture of microvessels (vasa vasorum) within the coronary wall and without the presence of fenestrations (non-fenestrated dissection). However, both explanations could be resulting from the same pathological process: intramural bleeding; and the interaction between FL pressurization and intimal elasticity would determine the presence of fenestrations. Furthermore, analysis with optical coherence tomography (OCT) has allowed us to

understand the relationship between the presence of fenestrations, the pressurization of the FL, and the compression of the true lumen (TL).¹²

SCAD shows a trend of spontaneous healing overtime. The onset of hematoma resorption has been described a few days after the index event, and it is likely that complete resorption requires a few weeks, depending on the volume of the hematoma. It is reported that about 86% of cases of SCAD treated conservatively heal spontaneously and that this percentage can increase to 95% if the control angiography was performed at least 30 days later,¹³ considering as healing criteria the improvement of angiographic stenosis and residual stenosis of less than 50% and thrombolysis in myocardial infarction (TIMI) 3 distal flow. The presence of isolated and circumscribed intramural hematoma with the absence of fenestrations in angiography (types 2A and 3 in Figure 1) is associated with a greater risk of clinical deterioration and the need for early urgent revascularization in the short term.^{14,15} These findings suggest that initially localized lesions may be more prone to progress and cause recurrent ischemia. Indeed, these localized lesions, as well as multivessel involvement and the degree of stenosis in the initial study, have been shown to be predictors of clinical and angiographic worsening.¹⁴

Rationale for a non-interventional approach in SCAD

Conservative treatment in SCAD has been established as the preferred approach for these patients based on observational data. This is reflected by figures reported in modern registries: 78-85% of conservative management is the first choice.^{6,16-18} Despite the absence of randomized data, the rationale for this attitude is essentially based in two notions: 1) the fact of spontaneous healing, additionally supported by the favorable outcomes of conservatively-managed patients in different registries (Table I);^{5,9,11,17,19} 2) the greater risk of iatrogenic injury to the coronary arteries (discussed in a following section) coupled with the failure of percutaneous coronary intervention (PCI), reported in up to 53% of cases.⁵ Saw *et al.*⁶ reported good in-hospital survival and 30-day follow-up (in-hospital mortality in

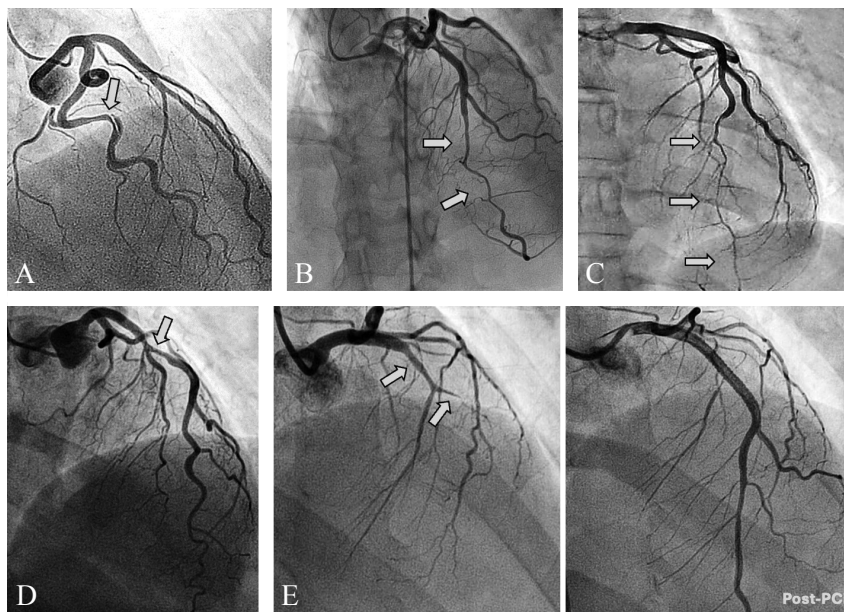


Figure 1.—Angiographic presentations of spontaneous coronary artery dissection (SCAD). A) Angiotype 1, featuring the classical double lumen or luminal flap. B, C) Angiotype 2 with a long, smooth tapering. Subtype 2A shows lumen restoration in the distal segment, while subtype 2B extends to the end of the artery. D) Angiotype 3, characterized by a focal stenosis that is indistinguishable from an atherosclerotic lesion. E) Angiotype 4, characterized by a total occlusion, typically observed distally; the right side shows its post-PCI result.

TABLE I.—In-hospital outcomes of conservative management in SCAD.^{5, 9, 11, 17, 19}

Study	Study type	N. total	N. medical treatment	Unplanned revascularization*	Death*
Tweet <i>et al.</i> , ⁵ 2014	Retrospective and prospective, single-center	189 patients	94 (50%)	8.5%	0%
Combaret <i>et al.</i> , ¹⁷ 2021	Prospective, national	373 patients	314 (84%)	1.9%	0%
Saw <i>et al.</i> , ⁹ 2022	Prospective, national	750 patients	644 (86%)	0.3%	0.2%
Garcia-Guimaraes <i>et al.</i> , ¹¹ 2022	Prospective, national	389 patients	305 (78%)	3.3%	1.3%
Benenati <i>et al.</i> , ¹⁹ 2023	Retrospective and prospective, international	369 patients	240 (65%)	6.7%	0.4%

SCAD: spontaneous coronary artery dissection.
 *Referring to the conservatively managed subgroup only.

0.1%, and mortality post-discharge at 30 days of 0%) despite the fact that the majority of patients (84.3%) underwent conservative management; likewise, in the post-discharge follow-up, recurrent MI and unplanned revascularization were reported in 2.1% and 0.1% of patients, respectively. The Spanish registry,²⁰ which included 318 patients (2015-2019), concluded that conservative management should be the initial choice in patients with SCAD, given the low need for revascularization during hospital admission (3% of patients). Moreover, PCI was associated with an increased risk of in-hospital adverse events in this cohort (adjusted OR 5.97, 95% CI: 1.78-20). In the French DISCO registry,¹⁷ initial conservative management was performed in 84.2%

of patients, with good in-hospital and follow-up outcomes, proving to be safe and without deaths in the one-year follow-up.

In patients managed conservatively, observational data suggest that a ‘less is more’ approach is beneficial in SCAD. Specifically, single antiplatelet therapy (SAPT) appears to be safer than dual antiplatelet therapy (DAPT) in real-world practice, as supported by non-randomized data from the DISCO registry.²¹ Patients who receive stent implantation should continue with DAPT as per general guidelines, while those undergoing PCI without stent implantation may not require DAPT. Based on our recommendation, a duration of one month of DAPT followed by SAPT may be sufficient.

All these contemporary clinical data support the conservative attitude for most patients with SCAD. However, some patients do suffer recurrent events on the days following the acute episode. We should try to identify these patients and demarcate the role of revascularization in the acute setting of SCAD.

The role of percutaneous revascularization in SCAD

PCI is the revascularization modality of choice in SCAD. Although surgical revascularization may be indicated in anatomically complex disease (left main), it does carry several inconveniences: it is not as ready to perform in the acute setting; distinguishing the true lumen to anastomose may be challenging; mid-distal segments are often involved, which are not secured by the bypass graft; spontaneous healing may provoke failure of the graft in the mid-term.^{5, 22}

When considering PCI in SCAD, it is important to determine which patients can benefit most from this option limiting the risk of associated complications. In the Italian-Spanish DISCO registry,¹⁹ the presence of ST elevation MI at presentation, involvement of proximal segments, suboptimal TIMI flow in the culprit vessel, and an increase in the severity of luminal narrowing were predictors of choosing PCI as treatment; but when compared with the medical treatment group, no differences were found in terms of in-hospital and short-term outcomes. Jamil *et al.*,²³ in their meta-analysis with 22 non-randomized observational studies with 1435 patients, there was a comparable risk of in-hospital outcomes when comparing PCI *versus* medical therapy in terms of mortality and MI; likewise, in the follow-up, evaluated with the presence of recurrence of SCAD and heart failure. However, it is important to recognize that this is non-randomized data, and the treatment decision was determined at the discretion of the treating physician.

The identification of potential predictors of early events helps depict a patient profile of high risk, which may merit closer surveillance and/or lower threshold for intervention. Some factors have already been spotted in observational cohorts: the presence of intramural hematoma,

particularly angiotypes 2A and 37,^{14, 16} (Figure 1), multivessel involvement¹⁴ and pregnancy-associated SCAD (OR=4.56, 95% CI: 1.94-10.62, P=0.02).⁶ Furthermore, dual antiplatelet therapy has been related to a higher frequency of major adverse cardiac events (MACE) in both short-term and follow-up compared to simple antiplatelet therapy.^{11, 21} As discussed earlier, PCI has also been associated with worse outcomes in the Spanish registry.¹⁶

Current recommendations on the management of SCAD are based on observational data and expert consensus. The European working group on SCAD²⁴ recommends medical treatment as the first choice in clinically stable patients with preserved antegrade coronary flow. The working group of the American Heart Association²⁵ considers that in clinically stable patients without high-risk anatomy, medical treatment should be the first choice; likewise, surgical revascularization could be considered in clinically stable patients with involvement of the left main coronary artery or dissection that involves the proximal segments of two vessels; and finally, PCI could be considered in patients with hemodynamic instability, or in active or ongoing ischemia. Last but not least, the guidelines for acute coronary syndromes issued in 2023 by the European Society of Cardiology included a formal recommendation stating the criteria for performing PCI in SCAD: PCI is recommended only for patients with symptoms and signs of ongoing myocardial ischemia, a large area of myocardium in jeopardy, and reduced antegrade flow (recommendation class I, level of evidence C).²⁶ We proposed an algorithm for the management of SCAD in the acute setting in a previous article (Figure 2) which is still in line with current thoughts and official recommendations.

Risk of technical failure and complications

Although a conservative approach is generally recommended in SCAD, high-risk presentations may require PCI as mentioned in the previous section.²⁶ Whether attempted initially or to rescue failure of conservative management, the technique results complex and represents a clini-

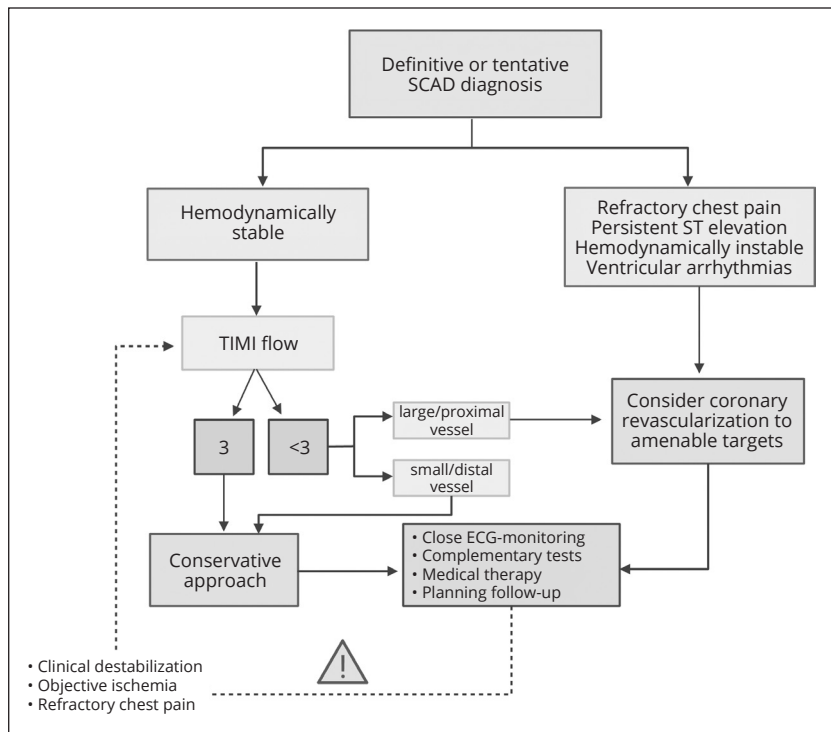


Figure 2.—Proposed algorithm for acute management of spontaneous coronary artery dissection (SCAD).

TABLE II.—Rate of procedural success (complete and partial), treatment adopted (stent implantation and cutting balloon use) and clinical outcomes of PCI in SCAD, as reported in the current literature.^{4, 5, 9, 16, 19, 22, 27-31}

Study	N. (% of PCI)	Cutting balloon	Stent implantation	PCI success	Death	MACE
Buja <i>et al.</i> , ²⁸ 2013	17 (45%)	NA	100.0%	100%	5.0%*	10.0%*
Tweet <i>et al.</i> , ⁵ 2014	89 (47%)	NA	NA	70%	1.1%*	NA
Lettieri <i>et al.</i> , ²² 2015	51 (42%)	NA	86.3%	73%	3.8%*	16.1%*
Nakashima <i>et al.</i> , ⁴ 2016	35 (56%)	NA	68.0%	92%	NA	NA
Conrotto <i>et al.</i> , ²⁷ 2017	238 (100%)	NA	96.0%	78%	10.3%	23.7%
Lobo <i>et al.</i> , ²⁹ 2019	33 (62%)	NA	81.1%	91%	2.7%*	NA
Garcia-Guimaraes <i>et al.</i> , ¹⁶ 2021	70 (22%)	3.0%	63%	81%	NA	NA
Hassan <i>et al.</i> , ³⁰ 2021	75 (19%)	1.3%	73.3	72%	0.0%	24.0%
McAlister <i>et al.</i> , ³¹ 2021	14 (12%)	NA	NA	64%	NA	29.0%
Saw <i>et al.</i> , ⁹ 2022	106 (14.1%)	4.9%	65.0%	70%	0.9%	10.4%
Benenati <i>et al.</i> , ¹⁹ 2023	129 (35%)	3.0%	78.0%	77%	0.7%	13.9%

NA: not available; PCI: percutaneous coronary intervention; SCAD: spontaneous coronary artery dissection; MACE: major adverse cardiac events.

*Including a few patients who underwent CABG as modality of revascularization.

cal challenge, often yielding suboptimal results (Table II).^{4, 5, 9, 16, 19, 22, 27-33} Despite the lack of an optimal standardized approach, the primary goal of PCI in SCAD is to restore myocardial perfusion and alleviate ischemia.

As a difference with the setting of conventional atherosclerotic disease, defining PCI success in SCAD is not straightforward, prompting the

need of consensus in using appropriate metrics to define success in this context. For instance, Tweet *et al.* proposed a SCAD-specific definition of success, encompassing improvement in baseline TIMI grade 0 to 1 flow (≥ 1 grade improvement) or maintenance or improvement of TIMI grade 2 to 3 flow.⁵ Of note, there is currently no consensus agreement regarding the definition of

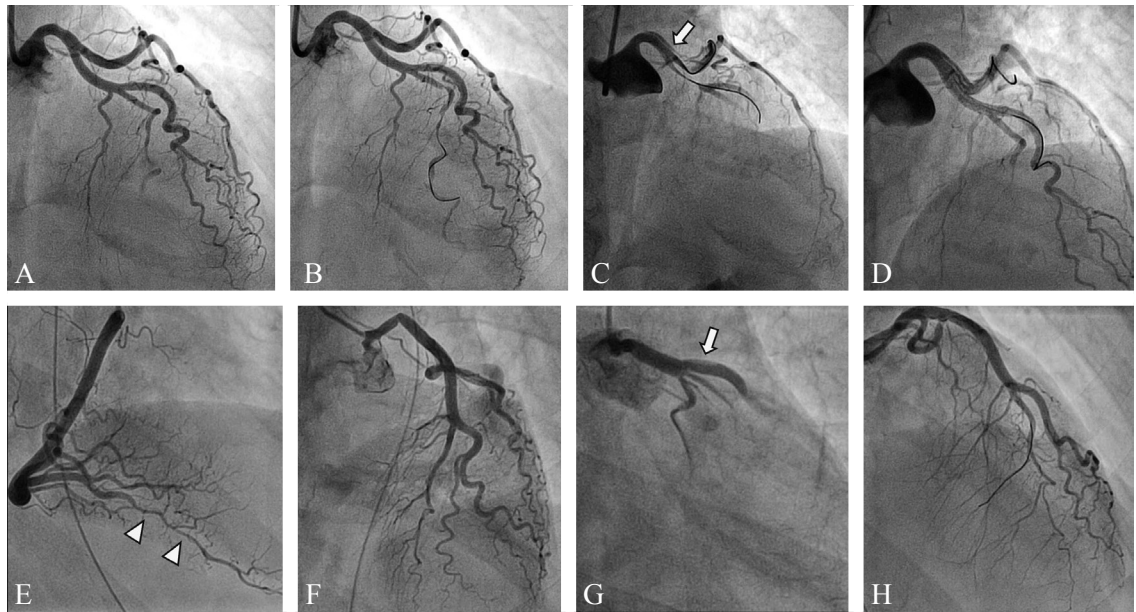


Figure 3.—Case examples of iatrogenic coronary artery dissection (ICAD) in patients with a spontaneous coronary artery dissection. Case 1: ST-elevation myocardial infarction (STEMI) due to acute occlusion (TIMI 0) in the mid-left anterior descending artery (LAD), indicative of spontaneous coronary artery dissection type 4 (SCAD, A). Subsequent advancement of a work-horse guidewire partially restored flow (TIMI 2, B). However, catheter manipulations induced a iatrogenic coronary artery dissection (ICAD) involving the left main stem (arrow) causing occlusion of the LAD and extending to the circumflex artery (LCx, C). A long drug-eluting stent was implanted from the mid-LAD extending into the left main, achieving final TIMI 3 flow in the diagonal branch and LCx, but with persistent occlusion in the mid-LAD (D). Case 2: E shows a SCAD type 2a of the distal posterior descending artery (arrowheads). First injections of the left coronary artery showed kinking of the mid left main due to the catheter (F); During the third injection, an acute occlusion of the LAD (arrow) occurred due to ICAD (G). The procedure ended with a provisional stenting of the LMS, resulting in a good final angiographic result (H).

PCI success in SCAD, but it seems reasonable to aim toward improvement in flow rather than treating vessel stenosis and restoring vessel architecture.

SCAD affects coronary arteries with underlying arteriopathy and inherent architectural weakness, rendering them susceptible to iatrogenic dissections during PCI procedures³ (Figure 3). An incidence of catheter-induced iatrogenic dissections of 4.7% during acute SCAD management has been documented in the Vancouver registry³⁴ and confirmed by Fahey *et al.*, which reported the same digit (4.7%) in a retrospective analysis of 85 SCAD cases.³⁵ These figures represent a more than ten-fold increased risk compared to non-SCAD patients, whose reported incidence is less than 0.2%,³⁶ and especially dangerous in cases of catheter-related dissections involving the ostial right coronary artery or left-main.

Ensuring guidewires advance through the true lumen can be challenging and may end up

worsening vessel obstruction by deviating the intima-medial flap or by extending the dissection. Hematoma propagation frequently requires several stents for long affected segments or extending distally to small vessels, which may not be amenable to revascularization.^{5, 37} SCAD frequently affects distal coronary segments that may be unsuitable for stent implantation. Tortuosity, which is frequently present, adds another layer of complexity to PCI in this context. Intramural hematoma resorption over time can lead to late stent malapposition, potentially increasing the risk of stent thrombosis.^{25, 38, 39} Mori *et al.* have depicted these challenges and complications from a pathological standpoint, reporting two cases where PCI was unsuccessful due to stent placement in the false lumen or under-expanded stents with dissection propagation.⁴⁰

Technical complexities during treatment translate into more adverse cardiac events in the acute phase and follow-up. In a Mayo Clinic series,

13% of SCAD patients undergoing PCI required emergency coronary artery bypass grafting, and 4% needed additional PCI, with one fatality reported.⁵ Kotecha *et al.* observed that SCAD-PCI is associated with longer stent lengths and higher complication rates (total 38.6%, being serious in 13%).⁴¹ In a multicenter registry, PCI success rates were modest, being completely successful in 29.1% and partially successful in 40.8%. Authors reported a significantly higher major adverse cardiovascular event rates during hospitalization (26.4% *versus* 3.4%, $P < 0.001$) and at 3 years follow-up (33.0% *versus* 10.9% ($P < 0.001$)) compared to non-PCI-treated patients.⁹

Technical aspects of PCI in SCAD

Table III summarizes key tips and tricks for PCI in the setting of SCAD. Given the propensity for iatrogenic damage, PCI in SCAD demands a meticulous approach when indicated (Figure 3). Careful catheter manipulation and coronary engagement along with gentle and minimal amount of contrast injections are essential to prevent iatrogenic dissection or propagation. Radial access, while advantageous in PCI for atherosclerotic causes, may result in noncoaxial engagement at the coronary ostium, necessitating deep catheter engagement and more aggressive manipulation in SCAD patients. Therefore, a low threshold for femoral access is often recommended.³ Notably, in the Vancouver General Hospital SCAD registry, a higher proportion of iatrogenic dissections occurred with radial artery access compared to non-iatrogenic cases (50% vs. 16.4%, $P = 0.009$).³⁴

Vessel wiring deserves special caution in SCAD. Initially, a low threshold for wiring side branches is warranted, given the high risk of propagation to other segments and vessels. To differentiate between false or true lumen, the use of non-hydrophilic wires to enhance tactile feedback and minimize dissection risks may be helpful. The SUOH 03 guidewire (Asahi, Japan) has unique features, including the lowest tip load in the coronary wire catalog (0.3 grams), hydrophilic coating, and high torque control. In a multicenter registry of wiring coronary dissections (including SCAD and non-SCAD etiologies), this wire achieved 64% success in the first pass and 92% overall.⁴² Careful manipulation watching for visual feedback (tip curling usually related to subintimal space versus straight tip progression), use of microcatheters (same reference), and intracoronary imaging confirmation of the wire position might help in successfully wiring the true lumen.

In cases of impaired vessel flow (TIMI 0), a non-hydrophilic wire with a small-size balloon can be used to restore circulation.^{3, 43} Balloon-only angioplasty may initially restore flow, particularly in focal and distal lesions. However, given the dynamic behavior of SCAD, the result may not be durable. Moreover, any dilatation does carry a risk of dissection propagation (“toothpasting” effect), especially in focal compressing hematoma.³ Lettieri *et al.* reported 7 of 51 patients with SCAD treated with PCI received balloon-only angioplasty, though they did not report the specific outcome for this group of patients.²²

The use of cutting or scoring balloons to fe-

TABLE III.—*Tips and tricks for SCAD PCI indication.*

General considerations	
<ul style="list-style-type: none"> • Extreme care of the catheter manipulation and intubation • Low threshold to convert to femoral access • Low-pressure contrast injection 	
Technical considerations for PCI	
Seek	Avoid
<ul style="list-style-type: none"> • Restore or improve flow • Relieve ischemia • Minimum or no stenting: balloon-only PCI and cutting/scoring balloons to decompress hematoma • Use of intracoronary imaging guidance 	<ul style="list-style-type: none"> • High support catheters • Aggressive dilatations • Treating all “significant” stenosis • Upfront use of polymeric wires
<p>OCT: optical coherence tomography; IVUS: intravascular ultrasound; PCI: percutaneous coronary intervention; SCAD: spontaneous coronary artery dissection.</p>	

nestrate intimo-medial flaps and decompress intramural hematomas has been proposed as an attractive option for treating this entity. It might be a reasonable strategy for cases with hemodynamic compromise if a rapid improvement in coronary flow is required. Motreff *et al.* reported 11 SCAD patients in whom flow was restored using scoring or cutting balloon angioplasty, showing favorable long-term clinical outcomes.⁴⁴ Bastante *et al.* reported a series of three consecutive patients treated with coronary fenestration, achieving excellent initial results and mid-term clinical outcomes. However, optical coherence tomography at 6-month follow-up revealed localized residual dissection and diffuse intimal thickening in the treated segment, indicating abnormal vascular healing.⁴⁵ Although these favorable outcomes have also been confirmed by additional few isolated published cases,⁴⁶⁻⁴⁸ such evidence is susceptible to selection and publication bias.

Additionally, the use of an aspiration catheter to manually aspirate the hematoma and subsequently reduce compression of the true lumen has been recently described.⁴⁹

Stenting in SCAD aims to relieve critical stenosis and restore vessel patency rather than completely covering the diseased segment. Vessel sizing (preferably guided with ICI) is sometimes imprecise and hard to demarcate, especially in cases involving compressing hematomas or significant false lumens.³ Undersized stents may increase the risk of in-stent restenosis and stent thrombosis once the hematoma has reabsorbed, while oversized stents may cause an extension of the dissection.⁵⁰ Rather long or several overlapped stents have been used for focal dissections to prevent lesion propagation in either direction.⁵¹ For more extensive dissections, sequential stenting of the distal segment first, followed by the proximal edge, and then the middle portion of the dissection has also been proposed to avoid propagation of the dissection.^{38, 51, 52} Non-high-pressure dilatations may also help preventing hematoma propagation.

Different stent platforms have been studied in SCAD. Both drug-eluting and bare-metal were compared in a retrospective study suggesting a trend toward lower MACE rates with drug-elut-

ing stents, mainly driven by target-vessel revascularization (4% vs. 18%, $P=0.08$).²⁷ This study was under-powered and limited by its retrospective nature. Off-label use of polylactic-acid-based bioresorbable scaffolds in this setting was proposed as an appealing alternative to metallic stents for these young and otherwise healthy patients, with favorable long-term results in small series (a total of 40 treated patients adding the two published series, with 1 case of target-lesion failure after a median follow-up longer than 2 years).⁵³⁻⁵⁷ However, the polylactic-acid scaffold was discontinued from the market, and therefore is no longer available as an option. Nevertheless, the concept remains attractive for these patients, and currently available, magnesium based bioresorbable stents, or future improved bioresorbable platforms might be an option in this scenario.⁵⁸

In cases of highly compressive intramural hematomas, a hybrid approach by fenestrating the intima with cutting/scoring balloon prior to stent implantation could be useful to evacuate the contained hematoma and prevent late malapposition after the hematoma is resorbed⁵⁹ (Figure 4). Alternatively, others have proposed stent optimization with postdilatation in a staged procedure allowing hematoma resorption.⁶⁰ In any case, stents should be implanted at nominal pressure at most, with a size guided by intracoronary imaging. Postdilatation in the acute phase is generally discouraged as it increases the risk of propagation.

The role of intracoronary imaging in SCAD

ICI remains the gold standard for diagnostic confirmation of ambiguous lesions (SCAD type 3 and some type 2) and it is therefore essential for guiding management of certain scenarios. The feasibility of ICI is sometimes limited by the common location of SCAD in distal segments of tortuous arteries. When PCI is indicated, it usually corresponds to more amenable locations for the use of ICI (*e.g.*, proximal, wide). In these cases, ICI plays an important role in guiding PCI. First, ICI allows confirmation of wire position in the true lumen, which may not be possible by

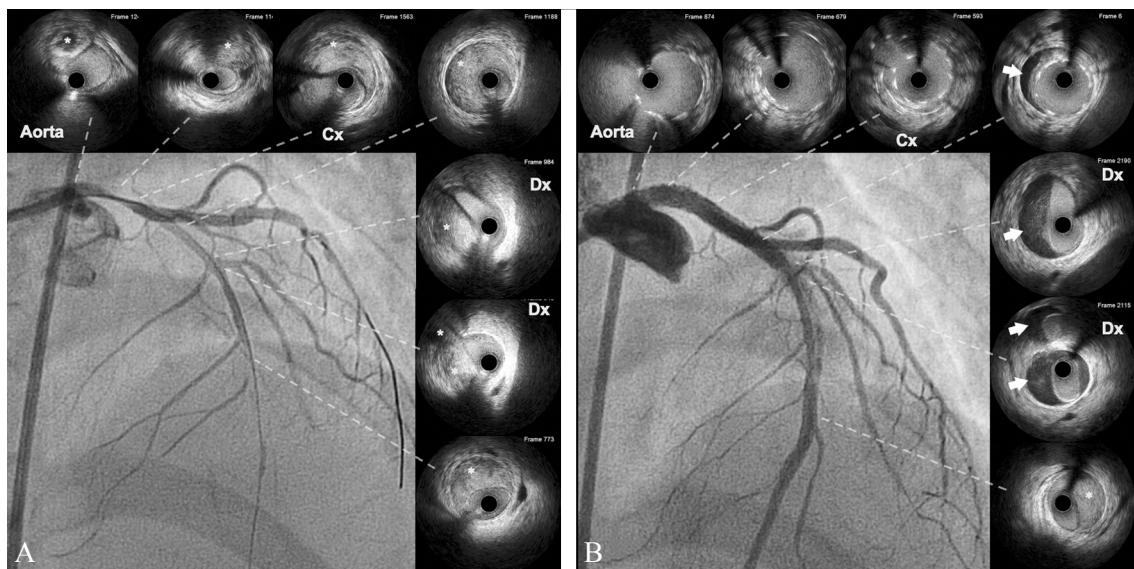


Figure 4.—Intravascular ultrasound guidance for percutaneous coronary intervention in spontaneous coronary artery dissection. A shows an extensive dissection with a compressive intramural hematoma involving the left main stem, the entire left anterior descending artery (LAD), and the ostium of the circumflex artery (Cx). Percutaneous coronary intervention (PCI) was performed under intravascular ultrasound (IVUS) guidance. Intramural hematoma decompression was achieved via fenestration with a cutting balloon, followed by culotte bifurcation stenting of the left-main bifurcation while sparing the mid LAD to prevent hematoma propagation (B).
 *Arrows indicate patent false lumen with contrast filling.

other means. It also reveals vessel dimensions, which may be particularly challenging in the presence of extensive intramural hematoma.^{25, 61} Vessel sizing to guide PCI may not be straightforward in SCAD (Figure 5). External elastic lamina (EEL) is overexpanded in the presence of a pressurised haematoma.¹² The diameter measured for choosing the size of balloons or cutting/scoring balloons should be always smaller than the EEL but slightly larger than the lumen diameter. When stenting is necessary, in an ideal scenario, a distal healthy segment would serve as reference to pick the stent size in a 1:1 relationship. However, very often the disease extends throughout the distal segments. In which case, the stent diameter should be something close to EEL but avoiding 1:1 given the risk of propagating longitudinally. If prior decompression with cutting/scoring balloons does not result, a longer than usual stent length may be chosen to prevent the “toothpasting” effect.

Stent malapposition (acute or late due to hematoma reabsorption) and under-sizing are common findings during routine surveillance angiographies or autopsy in SCAD, underscoring the

importance of ICI-guided PCI.^{38, 40} However, the clinical implications of these findings remain uncertain, as an increased incidence of stent thrombosis in SCAD has not been definitively confirmed.

OCT offers superior spatial resolution (10-20 μm) and detailed tissue characterization compared to intravascular ultrasound (IVUS, 150-200 μm up to 40 μm with HD-IVUS).^{25, 62-64} In any case, imaging catheters with low profile and high flexibility are preferred. Both OCT and IVUS have strengths and weaknesses in the SCAD setting. OCT, with its exceptional resolution, provides unparalleled detail in visualizing the true/false lumen, intramural hematoma (Figure 5), intimal tears, and intra-luminal thrombi. In cases of diagnostic uncertainty involving SCAD, OCT offers greater diagnostic clarity than IVUS.^{25, 61, 62} The main disadvantage of OCT is the requirement of washing intracoronary blood out with contrast, which usually implies high-flow injections (risking worsening the dissection by hydraulic damage), and even with that, image quality may not be adequate due to the impairment of the flow caused by the dissection. IVUS provides greater

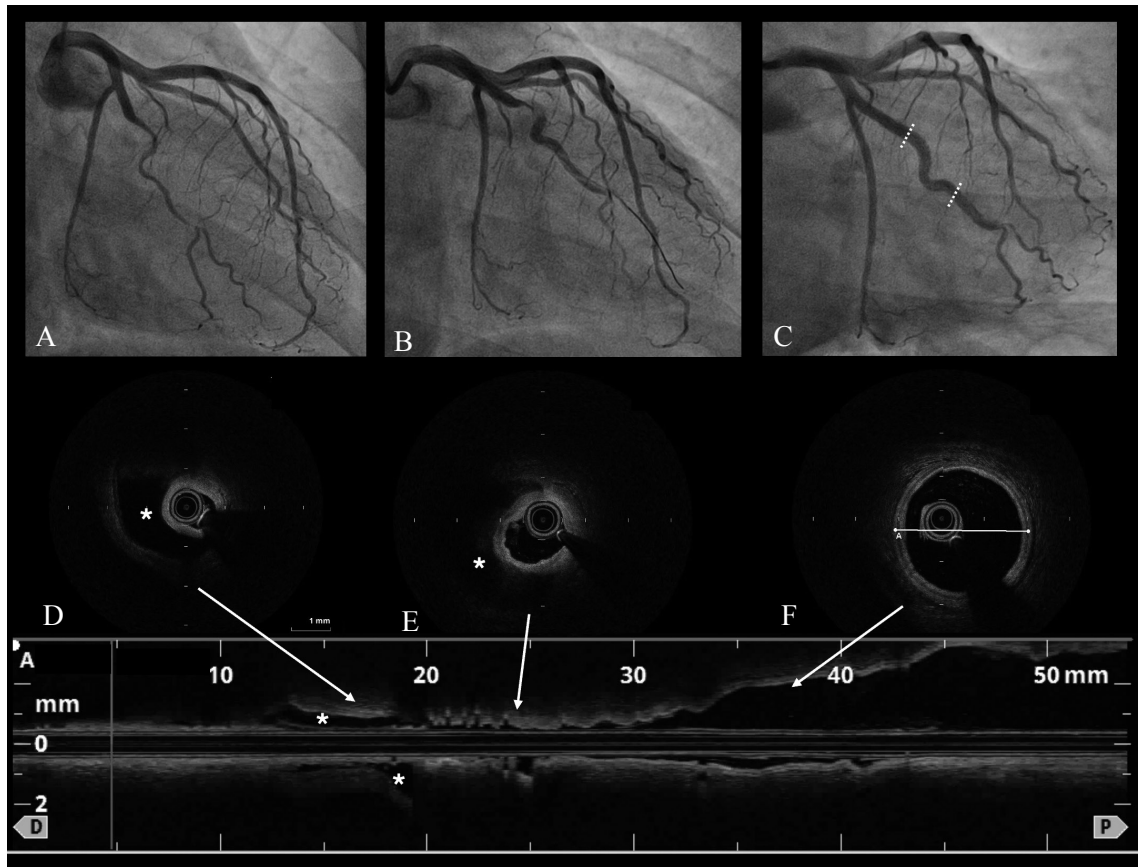


Figure 5.—Intramural hematoma diagnosis and percutaneous coronary intervention guidance using optical coherence tomography in spontaneous coronary artery dissection (SCAD). A shows a severe long stenosis in the first obtuse marginal (OM1) branch, which is angiographically suggestive of a circumscribed intramural hematoma or type 2A SCAD. Following gentle dilation with a small semi-compliant balloon, the intramural hematoma shifted to a spiral-shaped angiographic appearance or type 1 SCAD (B). Intracoronary optical coherence tomography (OCT) confirmed the presence of an intramural hematoma (indicated by the asterisk in D, E, and in the longitudinal view). Due to the presence of a residual severe proximal stenosis, a 3.5 x 16 mm drug-eluting stent was successfully implanted, with sizing based on the proximal reference on OCT, as no healthy distal segment could be visualized (F). The final result showed good distal flow (TIMI 3) and an acceptable angiographic result, with a persisting distal not flow-limiting dissection (C).

penetration depth allowing comprehensive vessel visualization and detailed characterization of the false lumen. IVUS is particularly useful for PCI guidance in scenarios where contrast use is limited or poses risks or where the true lumen is severely distorted and contrast filling is insufficient for OCT imaging.^{25, 61, 65} Additionally, IVUS's deeper imaging penetration is advantageous in proximal vessel dissections, where the false lumen stretches the external elastic lamina, increasing the vessel size (Figure 4).

Nevertheless, ICI in SCAD carries a particular risk of iatrogenic vessel damage. Major risks include extension of coronary dissection with

wires or imaging catheters, guide-catheter iatrogenic dissection, catheter-induced occlusion of the true lumen in main or side branches, and hydraulic extension with contrast injection for optical coherence tomography.²⁵ In a real-world single-center study of ICI use in SCAD patients from our research group, among 28 patients undergoing ICI, assessment failed in 10.7% (three of 28) of the targeted SCAD lesions and resulted in complications in 21.4% (6 of 28) of cases.⁶⁵ In a multicenter registry, Jackson *et al.* reported complications in five of 63 cases (8%). Among these cases, only one case was managed with stenting, and all patients experienced a good

clinical outcome.¹² However, despite the potential risks, some authors have reported favorable clinical outcomes with imaging-guided PCI in SCAD patients, achieving procedural success rates around 90%, similar to those observed in other ACS etiologies.⁶⁶

Due to the risks involved, the indications of ICI in SCAD should be carefully considered. Current European Society of Cardiology guidelines for acute coronary syndromes recommend the use of ICI when the uncertainty is high enough to justify coronary instrumentation, and even in those cases, anatomic limitations such as small vessel diameter, distal locations and tortuosity may impede reaching the lesion safely.²⁶ Additionally, the guidelines recommend against the use of ICI when the diagnosis of SCAD is sufficiently clear in angiography and there is no indication for PCI.

Post-PCI surveillance imaging

Unlike patients treated with PCI for atherosclerosis, SCAD is known to heal over time, resulting in the resorption of intramural hematoma and restoration of vessel architecture in most patients. This healing process can lead to stent malapposition, particularly if stents were initially undersized during PCI, which may pose an increased risk of stent complications in the long term.^{3, 37} The use of invasive angiography and ICI during follow-up may be warranted in selected cases to optimize the implanted stent.^{38, 67}

The optimal timing for scheduling surveillance imaging studies after SCAD is not well defined, but some authors suggest around 1 month post-PCI.²⁵ However, based on our experience and available data,¹³ the healing process in SCAD may extend beyond 1 month. Therefore, to increase the diagnostic yield and usefulness of surveillance angiography in detecting significant changes and also to minimize the risk of iatrogenic damage, we suggest staging until at least 3 months since the index study. This timeframe can be adjusted based on the size of the hematoma; smaller hematomas may resolve within 4 weeks, whereas larger ones may take several months.³

Regarding the safety of repeated studies, complications occur mainly (or uniquely) during the

acute phase, with little (or no) complications in invasive studies during follow-up. Macaya *et al.* demonstrated that a shorter time from symptom onset to vessel manipulation is associated with a higher occurrence of iatrogenic damage, suggesting a time-dependent risk for complications in SCAD.⁶⁵ These findings are consistent with the study by Prakash *et al.*, where all iatrogenic dissections in SCAD occurred during the acute phase, with no complications observed in follow-up invasive studies.³⁴

Cardiac computed tomography angiography (CCTA) has limitations in the setting of SCAD due to its lower spatial resolution for small vessels, motion artifacts, and uncertain sensitivity and specificity.⁶⁸ However, CCTA may be valuable for noninvasive follow-up of SCAD patients, particularly those initially managed conservatively with dissections in proximal or large-caliber coronary arteries.^{69, 70} Similarly, with regards to patients treated with PCI, CCTA may be useful in monitoring unstented vessels or segments to confirm adequate vessel remodeling and lesion healing.³

Conclusions

In Greek mythology, Scylla and Charybdis were two sea monsters located on opposite sides of the Strait of Messina, between Sicily and Calabria, presenting sailors with a dilemma: avoiding one peril only to face the other. Similarly, the management of patients with SCAD often places cardiologists in a challenging position, requiring a nuanced approach to balance the risks and benefits of conservative management versus interventional procedures.

Conservative treatment remains the mainstay for most patients with SCAD, demonstrating high rates of spontaneous healing and favorable early and long-term outcomes. However, PCI may be necessary in patients with high-risk features or ongoing ischemia, despite its inherent technical challenges and risks. When indicated, PCI requires a meticulous approach, focusing on improving blood flow rather than merely treating vessel stenosis and restoring vessel architecture. Intracoronary imaging plays a crucial role in guiding PCI, although it must be used judicious-

ly to avoid further complications. Finally, post-PCI surveillance is essential to address potential late complications.

Key messages

- Conservative management is preferred in SCAD due to high rates of spontaneous healing and favorable outcomes.
- PCI is recommended for patients presenting with symptoms and signs of ongoing myocardial ischemia, a large area of myocardium in jeopardy, and reduced antegrade flow.
- PCI in SCAD is challenging and associated with technical complexities and higher risks of complications, emphasizing the importance of careful patient selection and procedural planning.

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Conflicts of interest

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Authors' contributions

All authors read and approved the final version of the manuscript. Concept and design: Marco Lombardi, Jorge Chavez-Solsol, Pablo Salinas and Fernando Macaya-Ten. Drafting of the manuscript: Marco Lombardi, Jorge Chavez-Solsol, and Fernando Macaya-Ten. Critical revision of the manuscript for important intellectual content: Enrico Cerrato, Rocco Vergallo, Italo Porto, Ferdinando Varbella, Nieves Gonzalo, Javier Escaned. Administrative, technical, or material support: Marco Lombardi, Jorge Chavez-Solsol, and Fernando Macaya-Ten.

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