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CONTEMPORARY REVIEW

Acute Myocardial Infarction: Etiologies and Mimickers in Young Patients

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ABSTRACT: Acute myocardial infarction is an important cause of death worldwide. While it often affects patients of older age, acute myocardial infarction is garnering more attention as a significant cause of morbidity and mortality among young patients (<45 years of age). More specifically, there is a focus on recognizing the unique etiologies for myocardial infarction in these younger patients as nonatherosclerotic etiologies occur more frequently in this population. As such, there is a potential for delayed and inaccurate diagnoses and treatments that can carry serious clinical implications. The understanding of acute myocardial infarction manifestations in young patients is evolving, but there remains a significant need for better strategies to rapidly diagnose, risk stratify, and manage such patients. This comprehensive review explores the various etiologies for acute myocardial infarction in young adults and outlines the approach to efficient diagnosis and management for these unique patient phenotypes.

Key Words: acute myocardial infarction ■ atheromatous ■ nonatheromatous ■ young

Acute myocardial infarction (AMI) remains a significant cause of death worldwide.[1] Although the risk of suffering an AMI increases with older age,[2] the incidence of AMI in younger patients (<45 years of age) has progressively increased over time. Previously, there had been little focus on the diagnosis, management, and prevention of AMI in young individuals given the low prevalence of this disease. However, AMI remains an important cause of morbidity and mortality among young individuals globally and studies have shown that the proportion of younger patients with AMI has steadily grown over the years. This has prompted investigations to understand the various etiologies for AMI in the young to optimize prevention and treatment strategies. The current literature notes that premature atherosclerosis with plaque rupture or plaque erosion is the most common etiology, accounting for almost 90% of AMI in young adults.[3] The remaining 10% of cases are secondary to nonplaque etiologies that include spontaneous coronary artery dissection (SCAD), coronary vasospasm, hypercoagulability, coronary embolic phenomena, autoimmune-mediated inflammation, and drug-induced occlusions. Across all these mechanisms for AMI, there are notable lifestyle and potential genetic risk factors that constitute a patient's overall risk profile for AMI. For instance, familial hypercholesterolemia or heavy cigarette smoking can both contribute substantially to premature atherosclerosis. The genetics and lifestyle factors for other more unique etiologies for AMI are not well understood and warrant further investigation. Importantly, given the higher potential for nonatherosclerotic etiologies of AMI in young individuals, there is a potential for delayed diagnosis and treatment that could carry serious clinical implications. Despite a growing understanding of the other nonatherosclerotic mechanisms for myocardial infarction, there is a significant gap in the literature on effective strategies to rapidly diagnose, risk stratify, and manage AMI in younger patients. This review explores the various etiologies for AMI in young adults and outlines the approach to efficient diagnosis and management for the different patient phenotypes.

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Nonstandard Abbreviations and Acronyms

CAV	coronary artery vasculitis
SCAD	spontaneous coronary artery dissection

EPIDEMIOLOGY AND RISK FACTORS

The incidence and mortality of AMI has been declining less among younger individuals as compared with older individuals.[4] The ARIC (Atherosclerosis Risk in Communities) Surveillance study examined trends in hospitalizations for AMI in the United States across a 20-year span (1995 to 2014). Over this time span, ≈30% of total AMI were in patients 35 to 54 years of age. Importantly, the proportion of AMI admissions attributable to young patients increased from 27% in 1995 to 1999 to 32% in 2010 to 2014 (*P* for trend=0.002).[5] The Framingham Heart Study estimated the incidence of AMI over a 10-year follow-up to be 12.9/1000 in men 30 to 34 years of age and 5.2/1000 in women 35 to 44 years of age.[6] In a separate multinational study, the prevalence of AMI among patients <55 years of age was 23%.[7] Additional studies estimate that anywhere from 1% to 10% of all AMIs across various national registries occur in young patients.[5] Within these registries, the most common risk factors were male sex, smoking, hypertension, obesity, family history of premature AMI, and hyperlipidemia.[8] However, the individual risk among patients will vary depending on the mechanism for AMI.

While traditional risk factors such as hypertension, cigarette smoking, obesity, hyperlipidemia, and a family history of coronary artery disease (CAD) have been shown to be prevalent in young adults with AMI, there are also nontraditional risk factors such as HIV, systemic lupus erythematosus, and obstructive sleep apnea relevant to this patient population.[9] In the Veterans With Premature Atherosclerosis (VITAL) registry, recreational substances were independently associated with a higher likelihood of first extremely premature atherosclerotic cardiovascular disease event (<40 years of age).[10] The more nontraditional risk factors are thought to mediate AMI risk through increased systemic inflammation and increased sympathetic activity, oxidative stress, and endothelial dysfunction leading to earlier atherosclerosis.[11–13] Autoimmune diseases are also common causes of accelerated atherosclerosis and AMI in young adults. This is driven by chronic inflammation but may result from secondary factors such as autoimmune-mediated renal disease leading to hyperlipidemia or immunosuppressant-induced hyperglycemia or hyperlipidemia.

The genetics behind AMI are complex but can be simplified into patterns of monogenic versus polygenic expression. Monogenic diseases associated with early AMI include familial hypercholesterolemia, homocystinuria, antiphospholipid syndrome, fibromuscular dysplasia, and other rare syndromes.[14] There are more complex genes with variable expressivity and interactions with other genes and risk factors that are less well understood and not fully identified. However, the advent of polygenic risk scores may facilitate the identification of patients at risk for AMI at an early age. A polygenic risk score is calculated from a set of independent risk variants associated with a specific disease that is based on current evidence from genome-wide association studies. A few studies have developed and studied polygenic risk scores for AMI and found higher scores to be significantly associated with early AMI.[15,16] There is even evidence to suggest using polygenic risk scores earlier in a patient's life may prove to be more accurate as a risk stratification tool.[17] However, there is still a lack of data with regards to clinical applicability for patients.

AMI in Young Versus Old Adults

When comparing AMI in young and old patients, there are several key differences worth noting. Namely, studies have found young adults who experience AMI are more likely to have significant underlying single-vessel coronary disease, more modifiable risk factors (ie, obesity, smoking, substance use), and a lower long-term all-cause and cardiovascular mortality rate.[18–21] One study even noted younger AMI patients more often have a significant family history of premature CAD compared with older adults.[22] Interestingly, young patients were more likely to receive guideline-proven therapies and have better in-hospital mortality. In addition, the etiology for AMI in older patients is more commonly atheromatous, whereas younger patients may have both atheromatous and nonatheromatous causes for their AMI. These differences are summarized in Table 1.

ETIOLOGIES OF MYOCARDIAL INFARCTION IN YOUNG PATIENTS

The following sections will discuss 3 distinct categories for AMI in young patients. Figure 1 demonstrates the diverse pathophysiology of AMI in young adults, and Table 2 summarizes the risk factors and treatment strategies for these subtypes.

ATHEROMATOUS AMI

Traditional Type 1 Myocardial Infarction (Due to Plaque Rupture)

Atherosclerosis is the most common cause of AMI even in young patients. Atherosclerotic plaque rupture

Table 1. Comparison of Acute Myocardial Infarction Risk Factors and Outcomes: Younger Versus Older Adults

	Comparison between younger and older adults
Modifiable risk factors for CAD	Younger adults>older adults
Traditional risk factors for CAD	Older adults>younger adults
Single-vessel CAD	Younger adults>older adults
Cardiovascular and all-cause mortality	Older adults>younger adults
Nonatheromatous AMI	Older adults>younger adults
Family history of premature coronary disease	Younger adults>older adults
In-hospital mortality	Older adults>younger adults
Guideline-proven therapies	Younger adults>older adults

AMI indicates acute myocardial infarction; and CAD, coronary artery disease.

or erosion leads to an inflammatory cascade of monocytes and macrophages, thrombus formation, and platelet activation and aggregation. Atherosclerosis in younger patients likely has the same pathophysiological process as is seen in older patients. Young patients are at risk for premature atherosclerosis by means of the traditional risk factors for CAD such as smoking, diabetes, hypertension, and hyperlipidemia. For example, several studies have noted higher rates of cigarette smoking among younger patients with CAD as compared with older patients.[23–25] There is also increased evidence to suggest e-cigarette use, which is predominantly more frequent among younger patients,[26] leads to plaque formation[27] and is associated with an increased risk of AMI.[28] At the same time, atherosclerotic MI in younger populations has been more frequently associated with nontraditional cardiovascular risk factors than AMI in older patients. Some of these nontraditional risk factors span a range of autoimmune, inflammatory, genetic, and acquired diseases that confer a risk for accelerated atherosclerosis. These diseases include but are not limited to HIV, systemic lupus erythematosus, inflammatory bowel disease, rheumatoid arthritis, psoriasis, homocystinuria, polycystic ovarian syndrome, and obstructive sleep apnea.[9,29–32]

NONATHEROMATOUS MI

Coronary Vasospasm

Coronary vasospasm is a rare but important cause of AMI in young patients and a subcategory of myocardial infarction with nonobstructive coronary arteries. This syndrome refers to a transient process characterized by sudden onset chest pain secondary to epicardial coronary artery spasm which usually leads to transient myocardial ischemia, with chest pain and ECG changes.[33] Persistent and refractory vasospasm is what ultimately leads to myocardial necrosis and AMI. Although the prevalence of coronary spasm is unknown,[34] it predominantly affects younger patients with similar incidence in

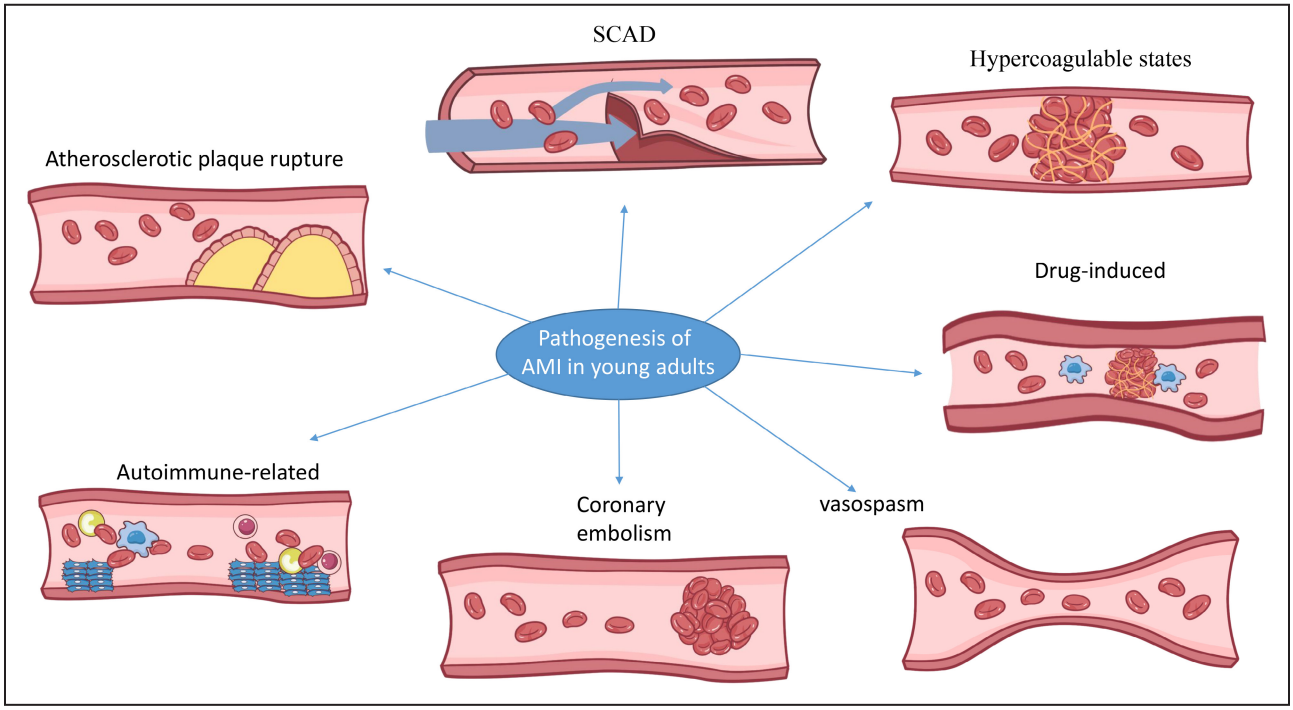

Figure 1. Pathogenetic phenotypes of acute myocardial infarction in young adults.
AMI indicates acute myocardial infarction; and SCAD, spontaneous coronary artery dissection.

Table 2. Risk Factors and Management for AMI Phenotypes in Young Adults

	Risk factors	Treatment
Type 1 plaque rupture	Smoking	β-Blocker and ACE-I in LV systolic dysfunction
	Dyslipidemia	Statins
	Diabetes	
	Hypertension	
	Obesity	
	Sedentary lifestyle	
Embolism	Atrial fibrillation	Thrombectomy
	Prosthetic heart valve thrombosis	
	Atrial myxoma	
	Paradoxical embolism	
	LV thrombus	
	Tumor	
	Nonbacterial thrombotic endocarditis	
	Amyloid	
	Aortic valve calcification	
	Leiomyosarcoma	
	Abdominal aortic atheroma or thrombus papillary fibroelastoma	
Drug-induced	Cocaine	Oxygen
	Amphetamine, ecstasy, and LSD	Aspirin
	Heroin	Nitrates
		Benzodiazepines
		β-blocker (avoid in acute phase)
Hypercoagulable states	Factor V Leiden mutation	Consider long-term anticoagulation after consultation with hematology
	Contraceptive use	
	Nephrotic syndrome	
	Malignancy	
	Other Inherited coagulopathies	
	Cocaine use	
Vasospasm	Cigarette smoking	Smoking cessation
	Cocaine use	ASA at least 1 year
		(DAPT individually)
		Calcium channel blockers
		β-Blockers and ACEI in LV systolic dysfunction
		Statin if indicated for primary prevention of atherosclerosis
SCAD	Female sex	ASA at least 1 year
	Young age	(DAPT individually)
	Extreme emotional stress	β-Blockers and ACEI in LV systolic dysfunction
	Exertion	Statin if clinically indicated
	Pregnancy	
	Fibromuscular dysplasia	
Autoimmune-related	No well-established evidence	Treat underlying conditions
Coronary artery vasculitis	No well-established evidence	Treat underlying conditions

ACE-I indicates angiotensin converting enzyme-inhibitor; ASA, aspirin; DAPT, dual antiplatelet therapy; LSD, lysergic acid diethylamide; LV, left ventricle; and SCAD, spontaneous coronary artery dissection.

men and women.[33] The pathophysiology of coronary vasospasm is multifactorial and is hypothesized to be secondary to autonomic overstimulation, endothelial dysfunction, oxidative stress, and smooth muscle hypercontractility.[35] Clues to consider vasospastic angina include a prior history of repetitive nonexertional chest

pain, ST-elevation in contiguous leads on the presenting ECG, and nonobstructive coronary arteries on angiography. A detailed history of recreational and prescribed drugs that might induce coronary vasospasm may provide additional evidence to support this diagnosis. The definitive assessment for coronary artery vasospasm involves coronary angiography with provocative testing using ergonovine (acts on serotonergic receptors on smooth muscle) or acetylcholine (acts on muscarinic receptors on smooth muscle and the endothelium).[35] A positive provocation test is defined as coronary luminal narrowing of 50%, 70%, 75%, or 90% with accompanying symptoms and ECG changes.[34] The single most important evidence-based therapy for improving prognosis in vasospasm is smoking cessation, if applicable.[36] After this, the primary strategy includes avoidance of vasospasm-precipitating medications and medical therapy with calcium channel blockers and nitrates.[36] Despite adequate treatment, vasospasm may recur in up to 4% to 19% of patients.[37] The overall clinical prognosis is generally favorable if patients are treated with appropriate medical therapies and modifiable risk factors (ie, medications and recreational substance use) are properly addressed.

Spontaneous Coronary Artery Dissection

SCAD refers to a nontraumatic and noniatrogenic separation of the layers of the coronary arterial wall in the absence of atherosclerosis.[38] This can then progress to myocardial injury with coronary obstruction from the intimal tear or formation of an intramural hematoma. In the general population, it is an uncommon cause of AMI and its true incidence remains unclear, but studies estimate that it could account for roughly 1% to 4% of all AMI cases.[38] SCAD is more common in young women, accounting for almost 35% of acute coronary syndrome cases in females younger than age 50 years.[39] The diagnosis is generally made on angiography which can demonstrate multiple radiolucent lines, contrast staining, false lumen appearance, and late contrast clearing.[40] In some situations, angiography may not clearly depict findings to support coronary artery dissection. SCAD is subcategorized into 3 main types (I, II, III).[41] Type I SCAD is characterized by multiple lumens with a longitudinal filling defect and contrast staining of the arterial wall. Type II SCAD typically involves diffuse smooth tubular lesions with no visible dissection plane. Meanwhile, Type III often has multiple focal tubular lesions that can closely mimic atherosclerosis. Findings that may be suggestive of focal type III SCAD (versus focal atherosclerosis) include the presence of severely tortuous vessels that are otherwise devoid of obstruction. Although the use of intravascular imaging such as optical coherence tomography or intravascular ultrasound can better characterize dissection, it can promote propagation of the dissection flap if the wire traverses the false lumen. Moreover, the need for contrast injection with optimal coherence tomography can worsen dissection by extending the false lumen and for this reason, these tools should be used cautiously and only in situations when the diagnosis is uncertain.

Evidence-based treatment and management of SCAD is challenging because of limited data to guide therapy. There is a spectrum of treatment options for SCAD with the majority of patients treated with conservative medical management, and the remaining patients treated with percutaneous coronary intervention (PCI), or coronary artery bypass grafting. The choice and intensity of treatment needs to be based on clinical presentation and overall stability. For those patients who are medically managed, the primary goal is to relieve symptoms and prevent complications and recurrence of SCAD.[42] Although there are no randomized trials evaluating medical management specific to SCAD, there are significant factors worth considering in pharmacologic therapy. For instance, patients with SCAD and left ventricular dysfunction should still be treated with guideline-directed medical therapy.[43,44] In the absence of heart failure, beta-blockers may still be considered as there is some evidence of reduction of SCAD recurrence.[45] Hypertension has also been associated with SCAD recurrence so optimal blood pressure control is also warranted.[45] Systemic anticoagulation is controversial in these patients, but the general approach is to discontinue such therapies unless there exists a separate indication for anticoagulation.[44] As for antiplatelet therapy, the consensus is to follow standard acute coronary syndrome guidelines in patients post-PCI but for medically managed SCAD, there is more uncertainty. Cerrato et al discovered that medically managed with dual antiplatelet therapy had higher rates of 1-year adverse cardiovascular outcomes as compared with single antiplatelet therapy.[46] The consensus now is to prescribe dual antiplatelet therapy for up to 4 weeks followed by aspirin monotherapy for 12 months.[47] In patients with localized SCAD involving a branch vessel that supplies a small territory, a conservative approach may be preferred as the vast majority of SCAD lesions heal without intervention.[44] Additional research on medical management of SCAD is warranted but there is an ongoing randomized control trial aiming to identify the differences between the use or not of beta-blockers and the use of a 1-month versus 12-month dual antiplatelet regimen.[48]

In contrast, a patient with shock because of SCAD involving the left main or proximal left anterior descending artery may require immediate intervention and possibly hemodynamic support if needed. The choice of coronary artery bypass grafting versus PCI

must be individualized in these patients depending on the availability of immediate cardiac surgery, the extent of coronary dissection, and hemodynamic stability. While a conservative strategy is recommended for patients with SCAD, if a patient has ongoing ischemia, left main artery dissection, refractory arrhythmia, or hemodynamic instability, urgent intervention with PCI or coronary artery bypass grafting should be considered.[44] However, PCI for SCAD is associated with an increased risk of complications and technical failure. Some of these risks include iatrogenic dissections and extension of dissection. Conversely, coronary artery bypass grafting is more appropriate for left main and proximal dissections, PCI complications, or ongoing ischemia.[44] However, there is a risk for venous and arterial conduit failure given the frequent healing of the native SCAD vessels resulting in competitive flow and graft occlusion. A scientific statement from the American Heart Association on the management of SCAD therefore recommends revascularization only in selected cases (Figure 2).[44] Following treatment of SCAD, patients are recommended to have close follow-ups with their cardiologists and encouraged to partake in cardiac rehabilitation. All patients with SCAD should be considered for additional testing for conditions often associated with SCAD such as fibromuscular dysplasia, Ehlers-Danlos Syndrome, or Marfan Syndrome.

Drug Use

An important risk factor for AMI in young adults is illicit drug abuse, which is associated with a poor prognosis.[49] For this reason, a detailed history of illicit drug use is a necessary part of assessment of a young individual with an AMI. The most implicated substances are stimulants such as cocaine, amphetamines, and 3,4-methylenedioxymethamphetamine (MDMA, ecstasy). Mechanisms that lead to cardiac complications with these drugs typically involve vessel damage, prothrombotic effects and direct myocardial injury.[50] In contrast, cocaine may increase myocardial oxygen demand because of increase in blood pressure and heart rate, while also promoting platelet activation[51] or coronary vasospasm,[52] resulting in acute myocardial ischemia. The exact pathophysiological mechanism of AMI following amphetamine use is not well understood but likely because of a combination of coronary vasospasm, intracoronary thrombus formation, and increased myocardial oxygen demand.[53] Management of AMI secondary to amphetamine and cocaine abuse is not clearly defined but includes calcium channel blockers for treatment of suspected coronary vasospasm or

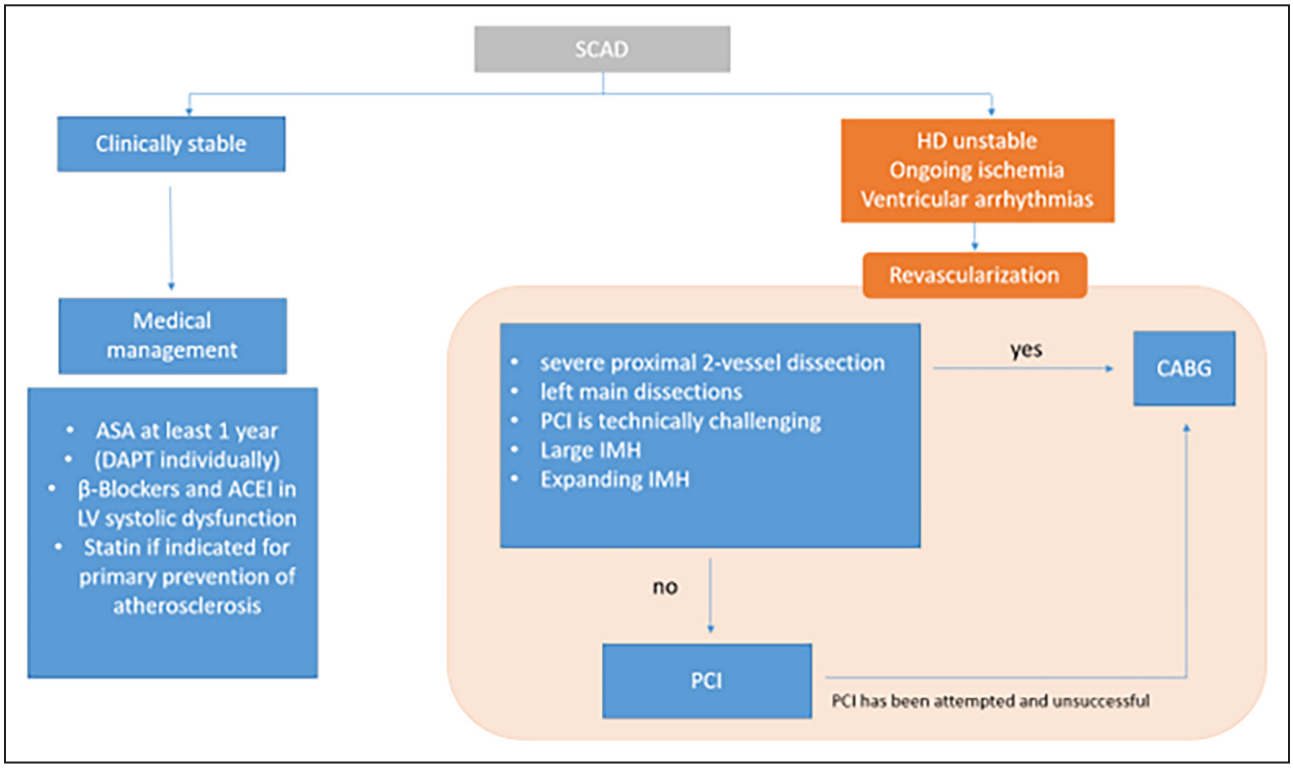

Figure 2. An approach to manage spontaneous coronary artery dissection.
ASA indicates aspirin; CABG, coronary artery bypass graft; DAPT, dual antiplatelet therapy; IMH, intramural hematoma; LV, left ventricle; PCI, percutaneous coronary intervention; and SCAD, spontaneous coronary artery dissection.

thrombolytics/anticoagulants for coronary thrombi.[53] Selective beta-1 adrenergic receptor blockade is generally avoided until the absence of illicit drug use is confirmed as it may exacerbate coronary vasospasm via unopposed alpha adrenergic agonism. The incidence of cocaine-induced AMI has been reported as high as 25% among AMI patients aged 18 to 45 years, particularly in those with other cardiac risk factors.[51] When there is clear thrombus, plaque disruption, or occlusive disease the treatment of ST-segment–elevation myocardial infarction in patients with recent substance use within 6 hours of onset of chest pain follows standard protocol with immediate PCI or thrombolytic therapy if PCI is not available.[51,54,55]

Coronary Artery Vasculitis

Though coronary artery vasculitis (CAV) is an uncommon cause of AMI in young adults, it can be life-threatening. Because CAV often occurs in the context of underlying autoimmune disease, it is important to assess for the presence of extracardiac vasculitis, unusual rash, or other findings suggestive of autoimmune disorders. This may include laboratory inflammatory markers such as erythrocyte sedimentation rate, C-reactive protein, antinuclear antibody, and complements (C3 or C4). The clinical presentation and management of CAV will vary depending on the underlying pathophysiology. The overproduction of proinflammatory cytokines is thought to be related to the pathogenesis of vasculitis processes, leading to inflammatory changes in the smooth muscle walls of the coronary arteries.[56,57] CAV may be seen in various diseases such as Kawasaki disease, Takayasu arteritis, polyarteritis nodosa, and giant cell arteritis. Each CAV syndrome has its classic features of noncoronary vasculitis. For example, patients with Takayasu arteritis often have upper limb arteritis and claudication, while patients with giant cell arteritis are often associated with carotid vasculitis causing headaches, jaw claudication, and acute vision loss. In contrast, patients with polyarteritis nodosa often have mesenteric and peripheral arteritis associated with abdominal pain, livedo reticularis, or peripheral neuropathy. The management of CAV is primarily based on treating the underlying autoimmune disease process to mitigate the degree of cardiac involvement.

THROMBOEMBOLIC AMI

Hypercoagulable States

Hypercoagulability refers to a state wherein the coagulation cascade is abnormally functioning and prone to thrombus formation.[58] Several hypercoagulable disorders have been studied and noted to be associated with AMI in young adults. Specifically, these include antiphospholipid syndrome and nephrotic syndrome.

Antiphospholipid syndrome is a systemic autoimmune disease characterized by vascular thromboses, pregnancy morbidity, and persistent elevated serum levels of antiphospholipid antibodies.[59] While AMI is infrequent in this syndrome with a frequency of ≈4%,[60] it can affect patients at a younger age. Antiphospholipid syndrome is believed to raise the risk for AMI by predisposing patients to both acute coronary thrombi as well as rapid development of atherosclerosis.[61] The management of antiphospholipid syndrome is still unclear as most data come from case reports. In cases of acute MI with visible thrombus, aspiration thrombectomy, with or without stenting (depending on the presence of underlying plaque/residual disease) is likely the treatment of choice. However, there is data to suggest that intravenous platelet glycoprotein IIb/IIIa receptor inhibitors may be more effective.[7] Overall, though, these patients can have higher rates of complications such as early failure or recurrent coronary stent thrombosis.[62] Long-term anticoagulant therapy to maintain coronary patency and to prevent acute stent occlusion may also be considered with guidance from hematology specialists. In severe cases of thromboembolism and catastrophic antiphospholipid syndrome, high-dose immunosuppressants, plasmapheresis, and immunoglobulin therapy may be considered.[63] Collectively, data on the optimal treatment strategy for these patients is limited and therapy should be tailored on a patient-to-patient basis.

Nephrotic syndrome refers to a group of conditions in which pathologically increased glomerular permeability results in significant proteinuria.[64] Hypercoagulability in this condition results from the loss of coagulation factors from the coagulation cascade that results in a prothrombotic state.[64] Some examples of factor level changes include increases in factors V, VIII, and X, increased fibrinogen and platelet levels, increased adhesion and aggregation of platelets, decreases in factors IX and XI and decreased activity of anti-thrombin-III and anti-plasmin.[65] Typically nephrotic syndrome is associated with venous thrombi formation but some case reports have now shown an extremely rare association with coronary thromboses as well, resulting in the potential for AMI.[66] Acute coronary thrombosis on angiography in the setting of nephrotic syndrome should raise the suspicion for a nonatherosclerotic cause of AMI. Despite having different mechanisms for hypercoagulability, both nephrotic syndrome and antiphospholipid syndrome associated AMI should be managed similarly with conservative medical treatment including antiplatelet agents, thrombolytics, and consideration of long-term anticoagulation.

Coronary Embolism

AMI from coronary embolism refers to a phenomenon wherein embolic material, eg, thrombus, valvular

material, neoplasm, or infectious material, travels to and obstructs a coronary artery to result in myocardial infarction.[67] There are a variety of mechanisms for coronary embolism that includes direct, paradoxical, and iatrogenic etiologies.[68] Direct coronary embolism refers to thrombus origination from the left atrium, ventricle, or pulmonary veins or infectious or neoplastic emboli production on the mitral or aortic valves. Meanwhile, paradoxical emboli access systemic circulation via passage through a patent foramen ovale or an atrial septal defect. Iatrogenic emboli may be seen during cardiothoracic surgeries, coronary interventions, and valvuloplasties. The incidence of coronary embolism is unknown but is estimated to be anywhere between 0.06% to 3% of all acute coronary syndrome.[67] The incidence in young adults is still unknown but is believed to be higher than previously expected. Within the group of coronary embolism cases, some of the most common subtypes include infective endocarditis, cardiomyopathy, atrial fibrillation, and prosthetic valve thromboses.[68] Of these, infective endocarditis is the most common etiology for coronary embolism. Evidence of obstructive occlusion in a coronary artery without atherosclerosis suggests that the mechanism may be coronary embolism. In some situations, emboli may affect multiple coronary territories. The management of coronary embolism depends on the location of the thrombus (proximal versus distal vessel) as well as the overall thrombus burden. An aspiration thrombectomy can be considered in patients with high thrombus burden in proximal vessels.[68] However, it is worth noting that aspiration thrombectomy may have a slightly increased risk of stroke risk in patients with STEMI.[69] Aspiration thrombectomy may also be unsuccessful at removing the obstructing thrombus, especially if it is lodged in a distal branch. Other therapeutic options may warrant consideration in these situations, including intracoronary thrombolytics, heparin infusion, glycoprotein IIb/IIIa inhibitors, or bivalirudin. Longer-term oral anticoagulation may also be necessary depending on the etiology. Sometimes balloon angioplasty and or stenting may be necessary. However, if the underlying mechanism that led to coronary emboli persists (eg, endocarditis), then the patients may be at risk for recurrent stent thrombosis.

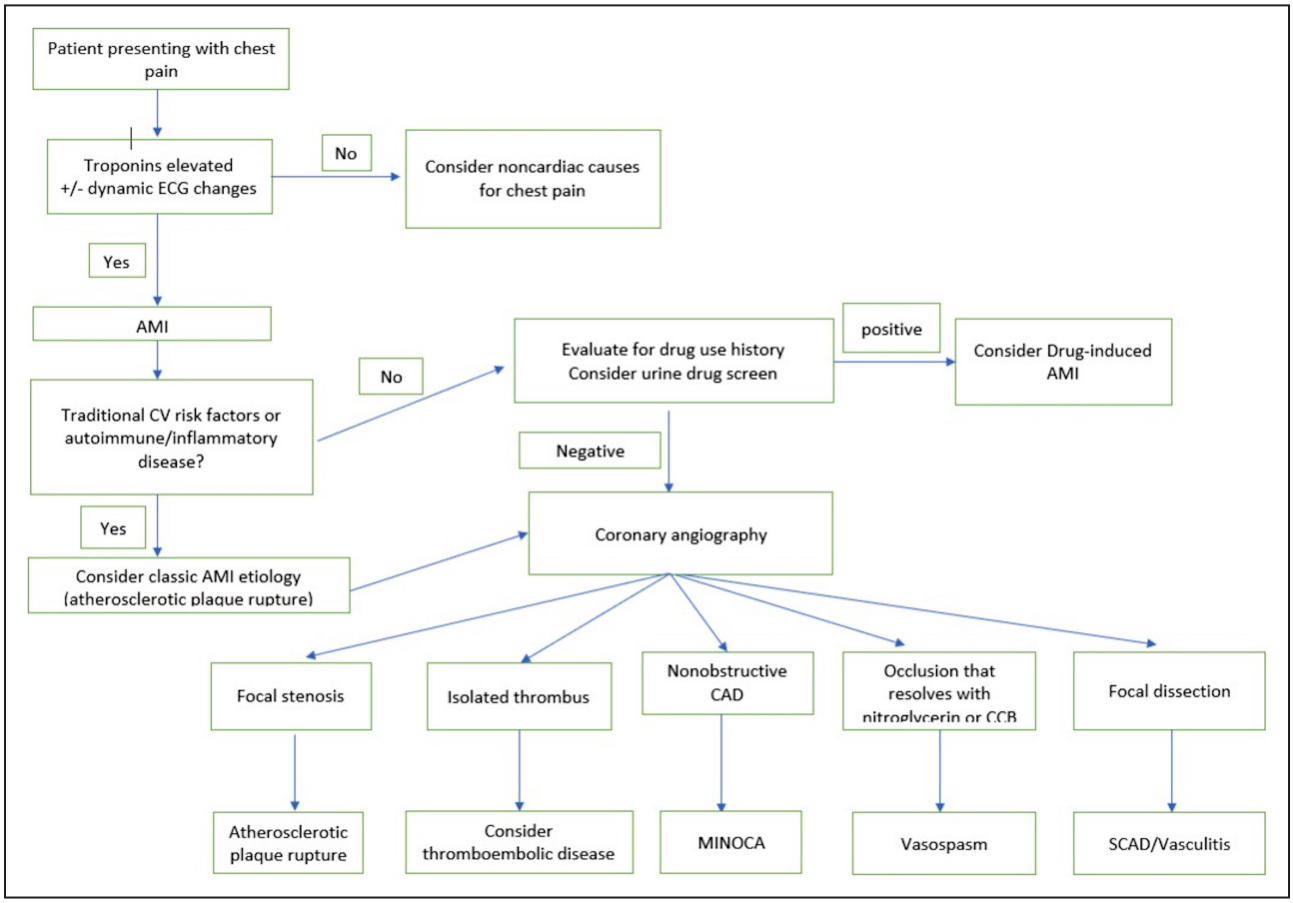

Figure 3. Diagnostic algorithm for evaluation of acute myocardial infarction in young patients.
AMI indicates acute myocardial infarction; CAD, coronary artery disease; CCB, calcium channel blocker; MINOCA, myocardial infarction with nonobstructive coronary arteries; and SCAD, spontaneous coronary artery dissection.

In patients deemed to have coronary thromboembolism, the overall role of longer-term anticoagulation will depend on the clinical context and the underlying cause for embolism.

CLINICAL IMPLICATIONS AND FUTURE DIRECTIONS

The rising incidence of AMI in young patients has garnered significant attention because of the clinical implications that come with incorrect or delayed diagnosis and treatment. As discussed, there are several pathologic causes for AMI in this population that can be categorized into atheromatous, nonatheromatous, and thromboembolic disease processes. It is important that clinicians realize the potential for nonatherosclerotic causes of AMI so that an early diagnosis and etiology-directed therapies can be given. We propose a more standardized approach when evaluating such patients in the hopes of improving diagnosis, treatment, and characterization of such unique AMI phenotypes (Figure 3). Unfortunately, there are no ongoing quality initiatives aimed at addressing the deficiencies in care for young patients with AMI, and future endeavors are needed. In addition, future research should focus on developing risk stratification models for patients with nonatheromatous AMI to guide optimal treatment strategies. While unique etiologies for AMI in young adults warrant recognition, the fact remains that most AMIs are still secondary to atherosclerotic progression and plaque rupture. This only further highlights the need to use more aggressive preventive strategies targeting lifestyle and risk factor modification even earlier in life. With such measures, the hope is to reduce the overall incidence of AMI in the general population and to improve clinical outcomes for those who are affected.

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